Australian Society for Fish Biology Workshop Proceedings

Towards Sustainability of Data-Limited Multi-Sector Fisheries

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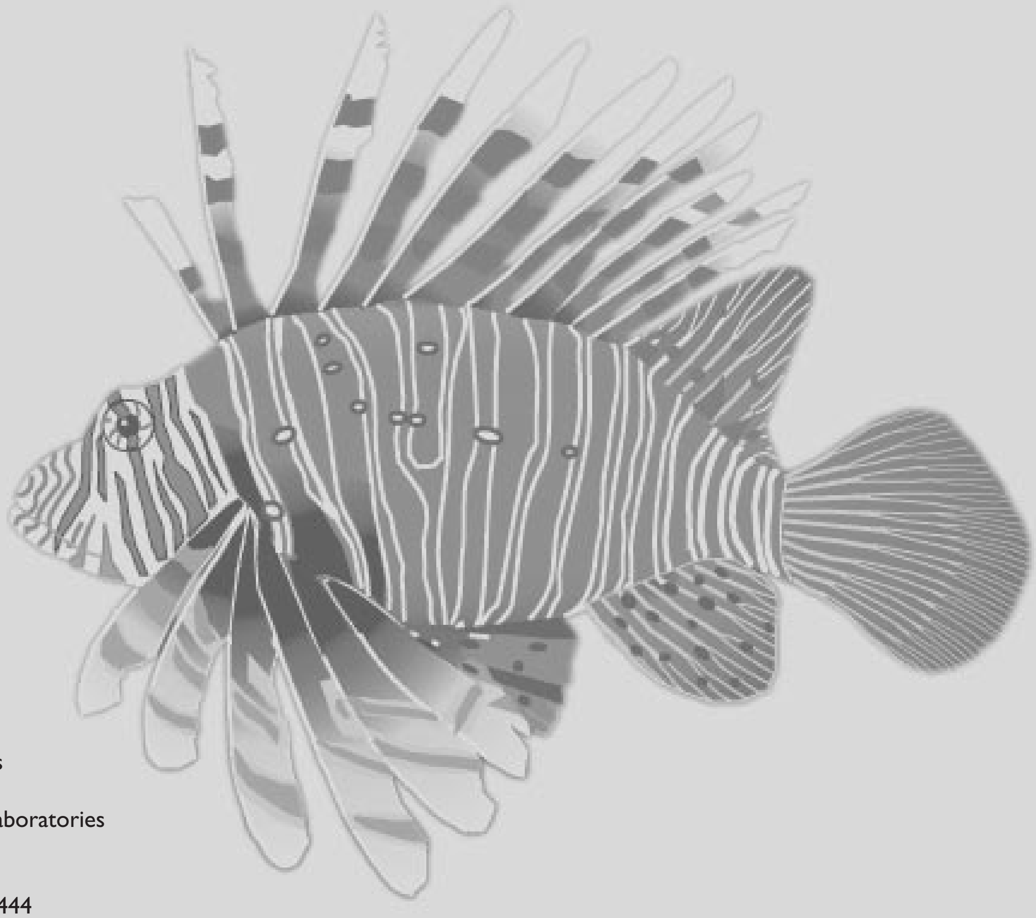
Bunbury, Western Australia 23-24 September 2001

Preferred way to cite this publication:

Newman, S.J., Gaughan, D.J., Jackson, G., Mackie, M.C., Molony, B., St John, J. and Kailola, P. (Eds.). 2003. Towards Sustainability of Data-Limited Multi-Sector Fisheries. Australian Society for Fish Biology Workshop Proceedings, Bunbury, Western Australia 23-24 September 2001. Fisheries Occasional Publications No. 5, June 2003, Department of Fisheries, Perth, Western Australia, 186 pp.



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Published by the Department of Fisheries, Western Australia
Fisheries Occasional Publications No. 5, June 2003
ISSN: 1447 - 2058 ISBN: 1 877098 16 7

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Acknowledgements

Peter Stephenson sought and was granted the funds necessary for this conference and workshop to take place. Danelle Ryan (nee McCoy) undertook the onerous task of conference co-ordinator and did a magnificent job. The organising committee, consisting of Suzy Ayvazian, Daniel Gaughan, Glenn Hyndes, Gary Jackson, Mervi Kangas, Rod Lenanton, Michael Mackie, Brett Molony, Stephen Newman, Gabrielle Nowara, Jill St John, Peter Stephenson and Glen Young, did a tremendous job in assisting in organising the conference and being rapporteurs.

Marie Tassone assisted brilliantly with registrations and the service desk, David van Dordrecht carried out the smooth operation of all computers and projectors for the presentations while Richard Steckis organised and operated the audio-taping used to assist in preparing this document. Also, other staff from the Department of Fisheries, WA and students from various local universities helped as volunteers in the day-to-day activities of the conference. We sincerely thank everyone who gave their time and effort to make the conference a success.

We would like to thank our international guest speakers, Ana Parma and James Ianelli, for their efforts in trying to attend the conference. Their job was made that much harder because of the September 11 incident, resulting in Ana having to travel for a considerable amount of time to arrive at the conference and James not being able to attend due to US Federal Government travel restrictions effective during the conference dates.

In contrast, attendance at the workshop and conference became chaotic as a result of the Ansett collapse just prior to our big event. This made an enormous organisational task much more difficult as well as creating a level of uncertainty that we would not wish on any future organising committee. In the midst of this uncertainty Jim Penn, Director of Research, Department of Fisheries, WA, stepped in to offer the continued support of the Fisheries Research Division for the conference in order to ensure that it still proceeded and was also very successful. As a result of this action, many additional staff were able to attend the conference.

And finally, we would like to say a big thank you to all who attended the conference for making it a very successful and enjoyable event.

Despite our best efforts - firstly encouragement, secondly persistent requests and finally our demands for manuscripts, we must admit failure. Alas, we could not elicit manuscripts in any form from Mark Flanigan (EA) or Roland Griffin (NT Fisheries). We consider this unfortunate for we feel that they both had much to contribute to these proceedings.

The Editorial Team
Stephen J. Newman, Daniel J. Gaughan, Gary Jackson, Michael C. Mackie, Brett Molony, Jill St John and Patricia Kailola.

Sponsors

The Australian Society for Fish Biology would like to acknowledge the generous support of the following organisations for the 2001 Workshop and Conference.

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Foreword

Andrew C. Sanger
President
Australian Society for Fish Biology

The 2001 workshop, entitled 'Towards sustainability of data-limited multi-sector fisheries', continues the series commenced in 1985 by the Australian Society for Fish Biology (ASFB).

As a result of the traumatic domestic and international environment at the time, the workshop was almost declared unsustainable before it even began. Coming only 12 days after the September 11 terrorist attacks on the United States and a few days after the collapse of Ansett Airlines, and the workshop venue being Bunbury (Western Australia), it was an extremely courageous decision by the organisers, with the blessing of the executive, to proceed with the workshop and subsequent conference. As it turned out, fortune favoured the brave, and a successful workshop was delivered.

The workshop series run by the Society has set the benchmark for fisheries research and management meetings in the Australasian region. The workshop topics are chosen for their regional or national significance and address key information gaps in fisheries science. Ongoing support for the series from Society members, other interested individuals and agencies and, most importantly, generous sponsors, attests to the relevance and value of the workshops.

The 2001 workshop tackled a topic of great relevance to Australian fisheries research and management at a time when evidence of sustainability forms an important component of State and Commonwealth statutory approval processes for recreational and commercial fisheries. Providing means by which this evidence can be supplied in data-limited, multi-sector fisheries is a challenge that faces scientists and managers alike. The workshop helped to define the different types of information required, and the many innovative ways in which it can be gathered, measured or estimated. As a result, many people left the workshop armed with a 'grab bag' of ideas, methods and new contacts to help them meet the challenges posed by these fisheries.

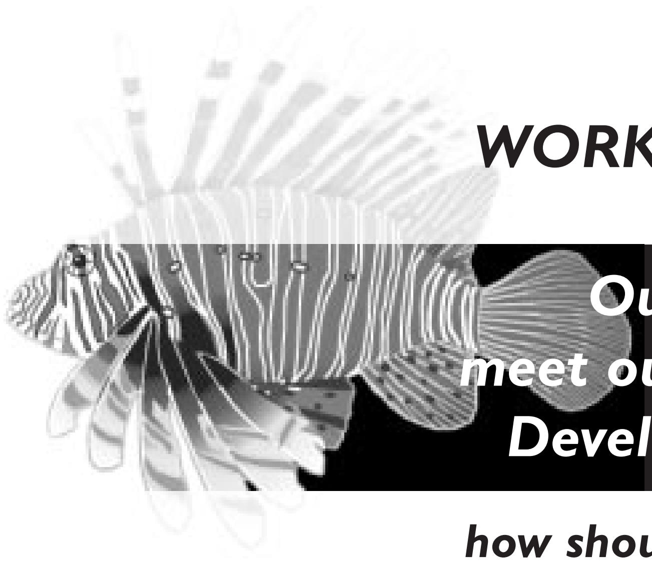
Dr Ana Parma's mammoth trek from South America provided an international perspective to the workshop. Unfortunately, Dr James Ianelli, the second international guest speaker, was unable to travel to Australia from the United States due to travel restrictions on US Federal Government employees post September 11. Likewise, the chaotic domestic travel situation at the time meant that a small number of Australian presenters were unable to attend. Nevertheless, most of the workshop presentations were delivered either by their author or a willing proxy, and the delegates appreciated a full workshop program.

The local organising committee once again did a marvellous job under somewhat trying circumstances, not only in bringing the workshop and conference together, but in coping with last minute changes and logistic problems. Particular thanks are due to Peter Stephenson for bringing this group of people together. Danelle McCoy applied her significant administrative skills to the task of conference co-ordinator, and was able to reassure me about the finances and other concerns when needed.

The Society gratefully acknowledges the support of the sponsors for the workshop. The Department of Fisheries, WA and the Fisheries Research and Development Corporation (FRDC) were the principal sponsors. The ongoing support of FRDC is a testament to the importance of the ASFB workshop series. The contribution of the Department of Fisheries, WA to this workshop was enormous, not only in the financial sense. From the senior level input of Peter Rogers and Jim Penn through to the help from technical staff at the Waterman laboratories, it seemed that the Department of Fisheries, WA was everywhere.

Additional sponsorship was provided by the Centre for Ecosystem Management at Edith Cowan University, Northwest Marine Technology, Floy Tag and Manufacturing Inc., Hallprint Tags, Austral Fisheries, Tenix, the Perth Convention Bureau, and the Aquarium of Western Australia.

Finally, production of these proceedings has been a combined effort by the editorial team, including Steve Newman, Dan Gaughan, Gary Jackson, Jill St John, Mike Mackie, Brett Molony and Trish Kailola.



WORKSHOP INTRODUCTION

Our future responsibilities to meet our Ecologically Sustainable Development (ESD) obligations:

how should we proceed to achieve them?

P. Rogers

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What I want to do is reflect a little on where we have been as fisheries managers and where we need to go from here. And how do you, as biologists and scientists, contribute to the gradual repositioning of fisheries management in Australia and probably the rest of the world.

When I look at where we have been over the last decade or so, I see that there has clearly been substantial debate about the effectiveness of fisheries management. World fisheries at large appear to be failing; and the real challenge is not only in the management of large fisheries, but also in that of the many smaller fisheries, particularly at the national level. Australia has a good reputation for management and that reputation has arisen in part from the contribution that many of you have made over many, many years.

In the last decade we have seen a suite of new legislation that has expanded gradually and positively beyond the focus of commercial fisheries into recreational fisheries. More recently, the debates have been and are progressing on issues such as Aboriginal fishing rights and Native Title. State and national legislation had, by and large, focused on the management of commercial fisheries and the implementation of management arrangements such as licence buy-back, reduction in fishing capacity, effort restrictions, quotas, individually transferable effort allocations (ITEs), and so on. The recognition of the importance of managing recreational fishing, I believe, has only been an issue in the last decade, and certainly much of the debate has focused on equity issues such as appropriate bag limits and legal minimum sizes; but the debate has to shift if sustainability is to be achieved.

Much is also being done in terms of new data requirements. For example, I think we have seen, over the last 12-18 months, the first national survey of significance for the measurement of catch and effort in recreational fishing. The challenge is working out what the results from the survey really mean. Are the broad national figures suitable in dealing with local debates? Possibly not, but they still provide very important positioning data (in terms of the magnitude of the recreational catch and effort relative to other sectors).

In Australia we have been developing management plans for commercial fisheries for some years and I think the first occurred in Western Australia. Since 1963 we have developed 34 or 35 effective management plans in Western Australia, and we probably now have somewhere in the order of a further 10 to 15 to finally complete the number of commercial management packages required.

We have been moving towards a regional planning model in the context of recreational fisheries with the aim of gradually focusing on the whole bioregion. When we come to managing finfish stocks in particular, it is very difficult to deal with a fishery for one stock in isolation from others and increasingly one has to look at the integration of management approaches that cover all of the species in a particular area.

The more recent ESD/sustainability debate has, in fact, refocused our attention on where we need to go in terms of national fisheries management. I am sure many of you are aware that with the introduction of the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC)* legislation at the Commonwealth level, exports will not be permitted from our commercial fisheries unless we can accredit those fisheries in terms of Environment Australia's requirements. [Environment Australia (EA) is the Commonwealth Government department overseeing environmental matters in Australia.] The EA requirements are said to be based on sustainability and on the impact of fisheries on the broader environment, all requirements demanding new information. Within Western Australia that trend has further shifted with the State government putting in place an office for Ecologically Sustainable Development. Having been picked up in other policy platforms at the State level, this step of putting in place an ESD office may subsequently flow through to the national level. Having two overseeing bodies would change the very nature of reporting: not in terms of the fish caught by the commercial fisheries, but increasingly on the interaction of commercial fisheries with recreational fisheries and, more importantly, around the impact of both fisheries on the environment and the ecosystem generally.

If one follows the ESD route, there are a number of reporting requirements that go beyond those of the environment and the ecosystem and extend into economic and social impacts as well as governance issues. State Cabinet in Western Australia has recently approved a shift towards triple bottomline reporting for all departments. For biologists, triple bottomline reporting means that you must not only report on the financial management in terms of running your business, but also on the impact of your business on the environment and the contribution you [your business] is making towards social and economic development within your community. In translating this to fisheries you must ask the question: 'What do we now need to do?' If we take the ESD debate, which also covers a further question of governance, you can see there is a spread of requirements for new information and data that must be developed over the coming decades to meet these challenges.

Triple bottomline reporting is not a new concept. Governments are catching up. If you follow the stock exchange, you will notice that all the big corporations around the world have already adopted some form of triple bottomline reporting: you only need to read BP, or Shell, or Western Mining Corporation reports to get a flavour of what is being intended. I think it is fair to say that these pressures are not only being driven by outside corporate responsibility but also corporate responsibility of governments in the face of this increasingly competitive world and the challenges around management of our natural resources, which go well beyond fisheries.

For those in Western Australia, one can easily recognise the greatest challenge facing this State is not so much our fish stocks but whether our agricultural industries are sustainable. We are looking at a probable 30-40% loss of our arable land in this State through salinity in the next 30-40 years. So it is not surprising that the community, in looking at natural resources, is asking for new reporting requirements which are going to place new challenges on all of us in terms of maintaining fisheries.

I was at a conference in the eastern states recently discussing the question of the management of billfish and tuna around the world. In the wake of the conference, one can only form the opinion that the world has failed. Even the Atlantic, the purported showcase for tuna management, has failed in terms of its responsibility in catch and maintenance delivery of effective management. Virtually every tuna and billfish stock in that part of the world is either collapsing or in major decline. So there is a real challenge in terms of what we must do. I might add that the American environment agencies, because of their concern over the way fisheries are managed, have used their environment legislation to close a significant part of the Hawaiian Tuna Industry. So if we use that as a backdrop, we as fisheries managers, and you as fisheries biologists, really have to meet the challenges of dealing with the future in terms of environment reporting. Otherwise the rest of the community, through legislation such as the EPBC Act, will close down those fisheries for which the community perceives reporting is not up to the mark. This is not an idle threat: it is reality in terms of where management directions are heading.

The Marine Stewardship Council, for those who are familiar with those sort of accreditation systems, is a market manifestation of the same requirement. Increasingly, I think, you will find places like Europe and the Americas (probably not Japan), will be placing greater market emphasis on accredited fisheries management as a basis of marketing strategies for their premium seafood products. So if it is not governments, it may be the markets that will initiate these changes, their initiatives emanating from the commercial edge provided in the market place from addressing community concerns about how our natural resources are managed.

So what does all this mean? It means that we must develop new processes, and later on Rick Fletcher will be explaining the ESD process that has been developed by the Standing Committee for Fisheries and Aquaculture (SCFA) in Australia with input from a number of people including some of you in this room. As a process, I am finding that the outcomes being developed will stand the test of time and it will continue to evolve as the new reporting requirements become more sophisticated and the community comes to better understand the data and what it is saying. I see this as an evolutionary process, not a revolutionary process.

The other challenge is the role of the States and Commonwealth in these issues, and I think that fisheries agencies will need to work more closely with their environmental agencies. Clearly with triple bottomline reporting, the Office of the Auditor General will want an increasing say in the accreditation performance of fisheries agencies in the delivery of their research results and in the management of fisheries. I believe we will move to independent accreditation of our sustainable yield in Western Australia by the Environmental Protection Authority (EPA), and that will form the bottomline requirement in terms of community acceptance with, perhaps, major audits every five years of our fisheries management performance.

Two or three years ago we posed the question: ‘How do we deal with the future?’ How can we solve the problem of increasing populations and technology changes and the issues that flow from it in terms of its impact on exploitation rates and hence the sustainability of fisheries? That debate has now taken place and dealt with the fundamental requirement that if we have to set a yield limit across all user groups, then we have to deal with the question of allocation and reallocation to user groups within the community. If we do not meet that challenge, there is one thing that can be guaranteed – we will lose fisheries. Consequently, we will have to control the total take of all user groups, not just the commercial sector. I think it is fair to say that, in the Australian context, we have focused very much on the exploitation of the commercial fishing sector but not at all on other sectors; and that focus has to change as the population grows.

There are expectations about the outcome of any allocation decision, and in Western Australia we have two inquiries proceeding at the present time. One is under Justice Toohey who is looking into the whole question of allocation and reallocation frameworks between user groups and grappling with issues such as mediation and arbitration and the principles by which access should be allocated. One view, which is in the fisheries literature, prioritises the allocation of access first to the environment in terms of ecosystem requirements, then to recreational fishing, and whatever is left, to the commercial sector. That is a simple solution that occurs by default more than by planning, but is it the right direction for Australia?

One alternative view is that so much of a resource be made available to the recreational community and so much to the commercial sector and that reallocation between these sectors will need to be based on solid principles whether they be market driven or are some sort of measurement of economic worth. If followed, the question is then raised of who pays for any adjustments and whether compensation should occur if rights are transferred from one sector to another. Debate around the nature of property is still not finished in Australia. Some of the law has focused on the questions of commercial fishing rights, but what about the rights of recreational fishers: where do they stand in that debate? Even less has been said on the question of use of fish for the purpose of conservation (no-take uses) and the use of fish by Aboriginal people in terms of meeting their economic development whether it be through aquaculture, commercial fishing or customary fishing (an issue which has not been adequately described in the context of Australian law). There could also be issues around the rights that are attached to offshore waters, intertidal zones, or waters within Aboriginal reserves. I do not believe one should leave those requirements to the courts alone and we are not doing that in Western Australia. Justice Franklin is heading the second inquiry that is trying to address those very difficult issues.

The message is that data collection will move well beyond the requirements of biology and ecology. Hence the challenge lies in the adoption of the right subsets of data and accurate collections of data to help answer the questions that are bound to come.

In summary, we need to find effective arrangements to manage sector allocations. The final outcome I believe is necessary for long-term sustainable resource use in the Australian context is the adoption of effective ESD settings. In some cases it will be for individual species of fisheries; in other cases it will be for groups of fisheries. But it must be effective if we are going to maintain our fish stocks. There has to be an allocation and reallocation framework, whether by mediation or market forces, in order to maintain fisheries. Scientists will not be able to deal with that in isolation and nor will fisheries managers: it will need to involve the community and structures and processes must be placed to enable them to reach consensus decisions – if not on a year-by-year basis then at least on a decade-by-decade basis. To ensure accountability in the data and indicators used, having the performance of agencies assessed is essential whether this be by Environment Australia, or the Auditor General, or the local Environmental Protection Authority (EPA). The value of independent accreditation processes is all-important in de-politicising the process and giving recognition to effective resource management.

You may feel this is all too difficult, but most of your work as biologists and scientists is focused on sustainability in the long term. A sustainable management fisheries framework will, through the ESD and other processes, give you the tools to argue your case much more strongly to resource managers and politicians and hence help to bring them to account in terms of gathering the correct data and management.

The logical end point in all of this sustainable resource management, within the context of temporal and spatial use of fish, is to ultimately embody the major regional plans, where the elements shift from fishery-by-fishery, to a coastal economic resource use of fish stocks. And this again, is evolutionary. I am not convinced that Oceans Policy[1] is heading in the right direction, but it is certainly a direction in the absence of other directions. But if we are serious about our natural resources, then clearly we must have an effective regional marine planning base to help defend the sustainable use of fish and the fish stocks against other perturbations and other resource use needs within the marine environment.

To return to the challenge for you, you need to question: ‘What are the future data requirements?’; ‘How quickly will you need to commence collection?’; and ‘What techniques need to be developed?’ In the final analysis the answers may mean measuring what Aboriginal fishers take, and understanding precisely what the recreational and commercial fisheries take. It is also not just about catch, but the composition of catch. There is no question that as we become more sophisticated and more experienced in our modelling, knowledge and data collection, ecosystem and environmental assessments will improve. For example, in the rock lobster industry, although the collection of puerulus data began in 1969 it was not understood until a decade after it was introduced. Today, using this data alone, we can predict about 95% of the catch variation within that fishery on a four-year forward projection. The challenge for you is to identify required key data sets and have the conviction to start the process.

I must emphasise the urgent need for cost effective recreational fishing data because that area is probably the most under-resourced of all the data sets required. If we had a licensing system, for instance, this could be used as a tool for controls through taxation for finding more cost effective ways of gathering data around the fishery and facilitating the collection of volunteer information, log-book programs and so on. Furthermore, if we are moving to address the issue of resource sharing and managing those shares, we will need to understand the total catches taken and where the shares are becoming disproportionate in terms of what was planned, and finding new management measures to address and readjust catches so it meets the plans the community agrees upon as being a fair and reasonable outcome for all sectors. Otherwise we will not have sustainability. The other interesting challenge is that within most budgets of natural resource management agencies, compliance always costs more than research and cost recovery arrangements are not seen favourably for compliance. The challenge is to get better data around compliance activities and, on a risk assessment basis, how much effort and resources are needed to get the compliance effectiveness we require. The final big challenge in managing costs for recreational fisheries is to find sensible social and economic indicators to address both the triple bottomline reporting requirements and the long-term issues of reallocation as the population increases and resource use priorities change.

[1] Oceans Policy – the Federal Government has set up the National Oceans Office to implement a national oceans policy. For more information visit the National Oceans Office website http://www.oceans.gov.au/oceans.jsp

Workshop Introduction

Discussion, questions and answers

Rapporteurs: Brett Molony and Gabrielle Nowara

Malcolm Haddon (TAFI). “I thought the content of your speech was excellent. I thought the principles were wonderful. I am just wondering about how they could be implemented. I’m not saying it’s too hard, I was just wondering why the sensible social and economic indicators were last. I suppose I always look on management as requiring a set of objectives where you can know what you’re managing towards. So that’s just a comment.

The other one that struck my attention was community ownership or community involvement. What one invariably ends up with, of course, are people who represent groupings and I’ve rarely seen what I would consider adequate representation. In general the democratic view that everyone should join in and make a submission on these things is a fine idea. Do you think that such public submission processes work well when you’re working towards these things or do you think it’s captured by interest groups?”

Peter Rogers. “I guess I’ve been in the business of fisheries management for nearly 30 years and we have used essentially a public process on management change on almost every fishery in WA. Yes, it does work and to a degree you’re right; it is captured by the interest groups, and there’s nothing wrong with that; but they have to participate and you actually have to ask them to join in. One of our failures at the moment is that in the Aboriginal area for instance: whilst they’ve been asked to join, they don’t join because a) they feel uncomfortable, and b) they don’t know enough about what the debate is about. Now that changes with experience and time, and I think you really have to gain community acceptance and gaining community acceptance is broad acceptance by the politicians as well as stakeholder key groups that are there, and if you like, de facto, the politicians are in fact representing the community. You might say that’s a cop-out. It’s not a total cop-out because we went through an exercise on Saturday where we in fact closed an area of Cottesloe Beach not for the purpose of preserving white pointers, but for the purposes of actually preserving a piece of habitat. And the recreational community as represented by the peak body were totally opposed to that coming into place, and yet it went into place because the sheer weight of community ownership of that area just exceeded almost any other force, in terms of what they saw as requirements for their kids, and the protection of that particular reef area to people in that community.

So you do see these weightings shift from time to time and I think you’ll find that as the debate shifts from forests (which it certainly will) to the sea, there is going to be a greater number of people outside the major stakeholder groups that we recognise will want a say and influence how fisheries are managed. If we can demonstrate accountability and performance, I think they’ll leave fisheries alone, because they’ll be satisfied and all most of them are looking for is certainty about the future in terms of natural resource use.”

Murray MacDonald (Fisheries Victoria). “Peter I agree with Malcolm’s assessment. I think you’ve given an excellent description of the issues involved here, with one possible exception and it’s one which I’ve raised on a number of occasions in the past in relation to the national ESD fisheries approach as well. It seems to me that we are looking very carefully at how we can manage fisheries and manage the impact of fishing on habitat and environment in order to demonstrate sustainability in terms of aquatic natural resource management. I'm not sure that we are yet looking at other parts of that equation which are, 'what are the impacts of non-fishing activities on fish resources?' and 'how is that going to affect our ability to demonstrate sustainable management of fisheries and fish resources?'. My question is, is that additional dimension being considered as part of your proposed MOUs between Fisheries and EPA in WA and at a national level? And I guess Rick will probably touch on this later on as well.

How are we going to integrate management of fish resources into management of aquatic natural resources in general, given that there is going to be increasing debates over whether or not looking after these natural resources and the habitats that support them is in fact the way society wants to go; given that there are a whole range of other competing uses and pressures which are going to be placed on aquatic environments and habitats? Perhaps should we not be thinking about how we are going to champion the cause of fish habitats because of their value in producing fish resources to ensure that that is a much broader marine planning process, rather than just focusing on how well we manage fisheries?"

Peter Rogers. "To go back to 'this might not work' [a reference to the Power Point presentation], I think the last point I came to in my summary was the question of marine planning. And I saw that as perhaps the final leverage point that you move to because there is no optimum solution. Certainly there is no easy optimal solution that you can measure because the confounding and competing objectives of so many people can't be put down to a single equation. The way it's been resolved on land is in fact to come up with you liking a planning process where the community has an input but the Government finally makes the decision about where the priority is set. I believe that's where you need to move to in marine resource planning – to deal with the competing requirements. And that includes things like marine parks and habitat protection areas as well as controls on where you can dump pollution and all of those things that have an impact. Unless we move to that final point, then we will fail as we can be so busy protecting the rock lobster that we miss the steel development which wipes out the breeding area of the Abrolhos Islands because someone put a pipeline in the middle of the Abrolhos Islands. Now that might be a ridiculous statement but I think as resource managers one has to look at the whole and not just the parts."

KEYNOTE ADDRESS

Diving for shellfish and data:

incentives for the participation of fishers in the monitoring and management of artisanal fisheries around southern South America

Ana M. Parma, J.M. (Lobo) Orensanz, Inés Elías and Gabriel Jerez

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Abstract

The conventional approach to fisheries management requires reliable estimates of stock size and fishing targets, and strong compliance with fishing regulations. Lack of data and poor enforcement are widespread among small-scale coastal fisheries, especially those that target spatially-structured benthic resources. Spatial heterogeneity in the dynamics of the stock and of the fishing process complicates data collection and assessment and limits the effectiveness of catch and effort controls. Where landing sites are spread out along the coasts, accountability and enforcement are impossible. Overall, the centralised monitoring, assessment and control of these fisheries are unrealistic. It is only through providing the right incentives for the fishers to participate in all stages of management that sustainability is possible. Two co-management initiatives involving commercial diving fisheries in South America illustrate these points. The implementation of territorial use rights in the shellfish fishery of Chile has delegated much of the monitoring and management to the local fishers' organizations, which now find in their own best interest to conserve their resources. In the shellfish diving fishery of northern Argentine Patagonia, a co-management experiment involves fishers, scientists and managers in the development of sustainable management plans.

Introduction

Many artisanal fisheries along the coastal zones of the world rely on a potpourri of spatially-structured stocks associated with the seabed. These fisheries, which support the livelihood of hundreds of thousands of fishers and their families, are often regarded as a nightmare from the viewpoint of stock assessment, and hence unmanageable. One difficulty frequently invoked is the scarcity of data, particularly of the type needed to estimate stock abundance and productivity trends. The cost of collecting these data is prohibitive given the need to capture the spatial heterogeneity of both the resource and the fishing process at a meaningful scale. Yet, would these fisheries be more manageable if those data were available? Not necessarily. Lack of data is just one of the obstacles to the implementation of conventional, assessment-based management approaches in small-scale coastal fisheries. There are other, perhaps more fundamental difficulties, which result from the very nature of the resources and the fishing operations. On the one hand, the spatial structure of the population, the preferential allocation of effort to highest density grounds and the fact that fishing effects are local bring into question the effectiveness of catch and effort controls at the scale of the whole fishery (Orensanz and Jamieson 1998). On the other, the implementation of catch or effort quotas are generally fraught with difficulties: where thousands of fishers land their catch anywhere along the coasts, accountability and enforcement may be simply impossible.

In this paper we argue that (i) centralised monitoring, assessment and control of spatially-structured coastal fisheries is unrealistic, (ii) there is a wealth of empirical information that can be used to develop precautionary management guidelines for such coastal fisheries, and (iii) it is only through providing the right incentives for the fishers to participate in all stages of management (monitoring, analysis of the information, decision-making, and enforcement) that sustainability is achievable. We illustrate these points describing the results of two co-management initiatives involving commercial diving fisheries in South America. These results are the large-scale implementation of territorial use rights (TURFs) in the multi-species shellfish fishery of Chile, and a small test co-management experiment involving a shellfish diving fishery in northern Argentine Patagonia. While still in their infancy, these co-management systems show promise compared to the conventional approaches tried in the past. We discuss their advantages and our caveats, and identify some key problems that need to be addressed in order to consolidate these initiatives.

S-Fisheries: where conventional management approaches do not work

We focus on a particular category of fishery, which can be described by several ‘S’ words:

- *small-scale*, in terms of the size of the fishing units (small boats typically less than 10 metres long), but not necessarily small in terms of the aggregate landings nor of the economic value of the catch;
- targeting *sedentary stocks*, typically structured as ‘metapopulations’, in which subpopulations of relatively sedentary adults are interconnected through larval and/or juvenile dispersal; and
- *spatially-structured*, where the structure of the stock is persistent (relative to pelagic fisheries or fisheries that target more mobile species) and the behaviour of fishers is dominated by spatial heterogeneity.

S-fisheries are very common along coastal zones of the world. Typical examples are diving and trap shellfish fisheries, and hook-and-line reef fin-fisheries. In some cases these fisheries support very lucrative export-oriented industries or touristic/recreational activities[1], while in others the fishery’s significance is not due to its monetary output but to its being a source of labor, often the sole means of support of thousands of fishers and their families.

The limited mobility of the organisms and the heterogeneity of the coastal seascape shape the dynamics of both the stock and the fishing process. Population processes related to growth, reproduction and recruitment are dominated by local effects (both environmental and density-dependent) and tend to vary dramatically over small spatial scales in the order of metres. Fishing tends to effectively remove patches of highest density, modifying the concentration profile of the harvested population in the exploited grounds (Orensanz et al. 1998). The effects of fishing operations are locally persistent, resulting in local depletion of accessible fishing grounds, followed by spatial shifts in effort allocation. In the end, the process can lead to serial depletion of large geographic areas[2]. Because of the small size of the fishing units, port infrastructure requirements are minimal, therefore landing sites tend to be dispersed along the coasts. This non-concentration of landing sites has implications on data collection and enforcement, as discussed later.

[1] Good examples are the geoduck fisheries from Washington and British Columbia (Orensanz et al. 2001) or the artisanal ‘loco’ snail and sea urchin fisheries from Chile (Castilla and Fernández, 1998; Andrew et al., in press).

[2] The Chilean sea urchin fleet moved towards the southernmost regions (XI and XII) following depletion of the grounds in region X (Barahona and Jerez 1998).

S-fisheries are in sharp contrast to the industrial, centralised fisheries after which classical fishery theory was developed (Table 1). The paradigm behind the conventional management approach corresponds to a unitary stock of highly mobile organisms, where population dynamics processes are spatially homogeneous and the local effects of fishing are diluted in a dynamic pool. Fishing mortality can be controlled by placing limits on the total amount of catch that can be taken or the number of units of fishing effort that can be spent on a season. These limits are commonly determined on an annual basis by applying some harvest strategy or control rule (generally defined in terms of target and threshold reference points) applied to best point estimates of stock size or fishing mortality (for example, Figure 1). For this approach to work, stock assessments must be reliable, reference points must be meaningful in terms of the stock and the fishery dynamics, and catch or effort controls must be effectively implemented. This conventional approach is data-thirsty; not many fisheries in the world are able to meet the required information standards.
S-fisheries rarely do.

Dealing with data-poor fisheries

Different approaches have been proposed over the years to deal with data-poor situations. They include:

- *Adjust conventional assessment-driven approaches and work with what you have*

Many methods fall into this category, from the use of rules of thumb to derive fishing mortality reference points (e.g., set fishing mortality equal to natural mortality) to over-simplified methods of stock assessment popularised in the 1980s (Pauly 1983), made available through accessible and user friendly software (Sparre and Venema 1992). Collectively, these methods strive to provide the same management parameters as can be estimated in data-rich situations using conventional analytical assessments based on long-term data series. Short-cuts and simplifying assumptions need to be made to do so (e.g. equilibrium), many of which are often inappropriate, resulting in a degraded product and a dangerous illusion of success.

- *Set conservative fishing targets*

The standard prescription under the Precautionary Approach (Food and Agriculture Organisation 1996) is to acknowledge the uncertainty in the estimates of stock size and reference points and reduce harvest rates appropriately. In some cases, generic rules for adjusting fishing targets as a function of uncertainty have been proposed (e.g. Thompson 1992); in others, precautionary advice is derived from fisheries-specific evaluations of performance of alternative harvesting strategies in simulations considering a wide range of possible scenarios consistent with experience.

- *Use robust strategies that work in the absence of stock-assessments*

Under this category are the use of precautionary size limits to protect reproduction (Myers and Mertz 1998) and the implementation of closed areas to directly limit harvest rates (Lauck et al. 1998, Walters 1998).

The last two prescriptions are not mutually exclusive: both are valuable components of a precautionary approach to management in data-poor situations. Other axes of the management problem, however, are key to the success of any approach (Hilborn et al. 2001, Orensanz et al., in press).

Data poverty generally has some structural correlates

Uncertainty and information quality can be viewed as a continuum ranging from very data-rich situations to total lack of information. In theory, harvest targets could be adjusted along this gradient according to any given degree of risk-aversion. Consideration of other fisheries attributes beyond data availability, however, shows that data-poor cases are not a random set of all fisheries. Rather, data poverty tends to be associated with some structural features of the system, which compound the management problem and require qualitatively different solutions. S-fisheries, in particular, are a case in point. Due to the structural features described in Table 1, S-fisheries tend to be data-poor because:

- catch and effort statistics are difficult or impossible to collect and mis-reporting is commonplace;
- even when catch rate statistics are collected, they are only meaningful locally and not representative of the aggregate abundance; and
- in most cases, total abundance can only be assessed through direct surveys, which are difficult and expensive.

Before we place much weight on the need to collect data we should ask how the data would be used and whether the fisheries would be more manageable if those data were available. Although the answer to these questions is fishery specific, it is generally true that data poverty is symptomatic of more fundamental problems that need to be addressed. The same structural features that explain why S-fisheries are data-poor also result in fisheries that do not fit within the conventional fishery paradigm. In these fisheries:

- the unit-stock concept does not hold: stock dynamics and the fishing process need to be analysed in a spatially-explicit context;
- comprehensive catch or effort controls may not be meaningful; and
- top-down enforcement of catch quotas, effort, or other regulations is often difficult or impossible.

Altogether, this means that centralised monitoring, assessment and control of these fisheries are unrealistic. The only feasible way to obtain the information required to support meaningful management plans at the appropriate spatial scale and to achieve compliance with management regulations is through the cooperation of the fishers. Thus, the key to sustainability is to provide the right incentives for the fishers to participate in all stages of management (monitoring, analysis of the information, decision-making, and enforcement). Excessive focus on data shortage may obscure these more fundamental limitations.

Lessons from S-fisheries in South America

Two co-management initiatives involving commercial diving fisheries in South America illustrate the points discussed above. The first is a large-scale implementation of territorial use rights (TURFs) in the benthic fisheries of Chile (Castilla and Defeo 2001, Castilla and Fernández 1998, Orensanz et al., in press, Stotz 1997); the other is a test co-management experiment involving a small shellfish diving fishery in northern Argentine Patagonia (Figure 2). In both cases, fishers' participation appears to be the only feasible alternative not only to gather the data required to make informed management decisions at the appropriate spatial scale, but also to achieve compliance, driven by self-interest as opposed to top-down enforcement.

1. A mega-experiment with TURFS: benthic fisheries in central and northern Chile

The Chilean shellfish fishery is a large and significant industry, with an aggregate catch in the order of 150,000 tons per year (worth about US$170 million per year) (Castilla et al. 1998, Castilla and Fernández 1998) and enormous social and cultural importance. More than 10,000 commercial divers, based in about 250 fishing communities known as "caletas"[3] (Figure 3) are currently registered with the country's National Fisheries Service (SERNAPESCA). The divers target many species of seaweed and invertebrate, most significant among them 'loco' (*Concholepas concholepas*, a carnivorous snail superficially resembling abalone), sea urchin (*Loxechinus albus*) and key-hole limpets (*Fissurella* spp). Throughout central and northern Chile caletas are spread along approximately 3,000 kilometres of a quasi-linear coastline, spanning over 24 degrees of latitude. Administratively the country is divided into 12 regions (Figure 4, centre), with regions I-IX corresponding roughly to the north-central zone. This zone is the domain where a mega-experiment with TURFs was launched during the 1990s.

Until the late 1980s, fishers harvested overlapping 'historical grounds' in what was essentially an open-access fishery. At about that time, scientists and managers became concerned about the possible overfishing of loco and the fishery was nominally closed for three years (1989-92) (Figure 5, Castilla and Fernández 1998). Fishing never ceased however but became illegal, with disastrous consequences for fishing communities. Economic hardship and social tensions created by the closure motivated the search for management alternatives. The current Fisheries Act, approved by the legislature in 1991, contemplates three regimes for the management of benthic shellfish:

1. **URFs**
2. **Open Access** of historical fishing grounds (outside TURFs) to all artisanal fishers listed in a National Registry compiled by region, and
3. **Total Allowable Catches (TACs) and Individual Quotas (IQ),** the latter granted to all registered divers for resources considered 'fully-exploited'.

In general, artisanal fishers are entitled to operate only in the region where they are registered. The National Registry was closed in 1995, leading *de facto* to a ***limited** entry* system. The Act also contemplates management tactics such as size limits and fishing seasons, and a system of marine reserves.

Interestingly, implementation of the Fisheries Act of 1991 allowed two different management regimes to coexist for the loco fishery. When the fishery was reopened in 1993 loco was considered fully-exploited; therefore, TACs and individual quotas were introduced to limit harvest rates. TACs, however, proved to be unenforceable and the system of tickets used to implement the IQs was ineffective, leading to a black quota market and a distortion of the limited entry program. Hence the system as a whole was considered a failure and was effectively terminated in 2000. Only landings from TURFs have been allowed since then.

Implementation of the TURF system, on the other hand, started in 1996 and gradually increased in importance to absorb the whole fishery, as discussed below. TURFs are granted to officially recognised fishers' organisations, which request them voluntarily. Benthic resources within a TURF are co-managed by the central authority (the Under-Secretary of Fisheries, responsible for fisheries management in the country) and the local fishers' organisation that was granted the TURF, with assistance from a technical consultant

[3] 'Caletas' are sites along the coast which serve as operational bases for local artisanal fleets. In rural areas, caletas are equivalent to fishing villages; in urban areas, fishers and their families are part of larger communities.

hired by the fishers' organisation. The requesting of a TURF is a long and demanding process (Montecinos 2000; Orensanz et al., in press): a detailed base-line survey of the grounds is required, including a map of habitat types and estimates of abundance of all target species. A two-year management plan has to be approved by the central managers and, once a TURF is functioning, annual reports of management performance, including trends in estimated abundance, have to be presented.

So far the TURF system appears to be successful. Overall there is not the sense of crisis that led in the past to drastic policy swings or draconian management measures. On average, the abundance of target species is stable or increasing in the TURFs that have been monitored for the last few years (C. Tapia and J. Garrido, pers. comm.). Marketing style has changed dramatically, from unstructured deals to sales pre-arranged before shellfish are harvested.

Yet there are many problems to be solved. TURFs are taxed on a per-area basis, the rate being the same along the entire coastline. This equal tax encourages requests for small TURFs (Figure 6) and provides an incentive for transporting loco from the open grounds into the TURFs (a practice known as 'apozamiento') that inflates local abundance at the expense of open-access grounds. A more perverse problem is the illusion of self-containment of a TURF (in terms of its sustainability) that often results from the sedentary nature of benthic shellfish. Because local areas are open to recruitment originating in other areas (i.e., each TURF is an open population) the incentives for conserving a reproductive stock within a TURF may be weakened. Mismanagement of one TURF will have consequences for the others and vice versa, even if these effects are not detectable over short temporal scales.

These and other problems were discussed during a workshop conducted in Valparaiso, Chile, in 1999 to evaluate the implementation aspects of the TURF system, then at an early stage of development. The workshop involved representatives of all the sectors that participate in the management system, plus an independent international panel[4]. At the end, the panel produced a consensus report with the following conclusions and recommendations:

1. Coexistence of TURFS and the open access fishery is not viable
   - The system of TURFS should expand to encompass the whole fishery

2. The implementation process is too complex
   - It should be designed so that it can be implemented in hundreds of TURFs
   - It should be understood by the fishers
   - It should not be too costly

3. The data collection system is unnecessarily demanding
   - The information required should be simplified

4. The implementation of the system was judged too 'top-down'
   - Fishers' organisations must be empowered
   - Education is needed so that fishers and managers can participate in management decisions on an equitable basis

[4] The members of the panel were Prof. Loo Botsford (U. of California - Davis), Prof. Ray Hilborn (U. of Washington), Dr. Glen Jamieson (Pacific Biological Station, DFO, Canada), Dr. Jean LeFur (ORSTOM, Montpellier, France), Dr. Robert Pomeroy (World Resources Institute, Washington DC), Dr. Jeremy Prince (Biospherics Inc., Australia), and Prof. Steve Thompson (Pennsylvania State University). A copy of the report is available from the authors upon request.

Guidelines for the implementation of the TURFs have been simplified in recent years and the system keeps expanding at a fast pace. The number of TURFs increased explosively, especially in some regions (Figure 4, Montecinos 2000). By 2001, 264 had been assigned, encompassing 43,200 hectares of seabed; and of those 80 were being implemented. Although the TURFs are generally small (Figure 6) the percentage of the total catches that they contribute increased rapidly over time. A three-year moratorium on fishing in 'historical grounds' was sanctioned in June 2000, putting a *de facto* end to the TAC-based 'benthic regime'. Since then, loco fishing in regions I-IX has been allowed only within the TURFs. In 2000 a controlled ('research') fishery was allowed in regions X-XI, but this did not re-open in 2001.

This loco fishery is an interesting case study in the context of this symposium because knowledge and implementation have provided feedback to each other in many ways. Knowledge about the benthic fisheries of central and northern Chile, and particularly about loco, is exceptional for an S-fishery from the developing world. Three major **paths** to this knowledge can be recognised: scientific knowledge, stock-assessment models based on fishery statistics, and folk knowledge.

PATH 1 corresponds to work conducted by Chilean scientists over the years, including studies on the basic biology of commercial species, experimental work on benthic communities, and experimental and comparative studies on the dynamics of localised harvested populations (Castilla and Defeo 2001). Experimental work conducted in the 1980s elucidated key aspects of the response of benthic communities and stocks to harvesting (Moreno et al. 1984, Castilla 1999). Based on those results, scientists and fishers collaborated in local stock-rebuilding experiments in a few well-organised caletas from central Chile, and these were granted exclusive fishing rights over adjacent sectors of the sea bed between 1987 and 1992. Local abundance was rebuilt after two or three year closures and closely monitored by participating fishers (Castilla 1997, Castilla et al. 1998). It is most remarkable that these studies were a major input for the inception of TURFs in the Fisheries Act of 1991 in what has been called the 'institutionalization of scientific knowledge' (Castilla 1994).

PATH 2 was the dominant input to management after the moratorium on the loco fishery was lifted in 1992 when management was based on TACs and individual quotas. A TAC had to be estimated for each of the 12 administrative regions. This was done using a state-of-the-art statistical catch-at-length stock-assessment model. Path 2 corresponds to the provision and use of information (data + models) in the classical tradition of industrial fisheries assessment and management. Although the model was internally consistent, the full list of problems with assessment, implementation and enforcement that typically afflict S-fisheries worked against the success of the TAC regime (A. Zuleta, pers. comm.). The situation was worst in the central and northern regions, where catch statistics are poorest due to the lack of centralised landing sites. Abundance estimates were meaningless in those areas.

PATH 3 corresponds to folk or empirical fishers' knowledge, a source of information whose significance has been acknowledged only in recent years (Johannes et al. 2000). This information is most often of pure observational nature. Chilean fishers, for example, are knowledgeable about the natural history and distribution of harvested species, as well as about the dynamics of recovery of harvested patches. A program of interviews conducted by the Chilean *Instituto de Fomento Pesquero* (IFOP) to gather empirical information in the sea urchin fishery (regions X-XI; Barahona et al. 2001) has produced very important information, including criteria for the design of reproductive reserves (Orensanz et al., in press). Yet, what is most exceptional in Chile is that many fishers' organisations have attempted manipulative experiments such as self-imposed temporal or spatial closures, removal of alleged predators and competitors ('limpiezas'), transplantation of loco to sites where prey are abundant and protection of the latter, and closure of patches with high density of loco recruits ('maternidades'). Some of these experiments did not produce the expected results: for example, in one case (O. Avilés, pers. comm.) the removal of black sea urchins (*Tetrapygus niger*, a species of no commercial value and a supposed competitor of the commercially valuable white sea urchin, *Loxechinus albus*), resulted in the development of macroalgal beds that smothered benthic communities. Although experiments are not designed according to scientific standards and are often ill-conceived, they are significant because fishers have been willing to invest time and labour in experimental probing, on occasions at substantial spatial scales.

This rich tapestry of knowledge has influenced important elements of the management system and guided their implementation. Paths 1 and 3 paved the way towards the inception of TURFs in the Fisheries Act of 1991, which incorporated inputs from scientists as well as from fishers. The fact that Chile has a very strong tradition in benthic ecology was a major factor in the course taken by the implementation process (Montecinos 2000), as many managers and consultants have been trained in that field. This strong tradition is reflected in the level of ecological detail required by baseline studies, management plans and annual follow-ups, which demand a substantial investment in the acquisition of data that is generally not used for management decisions. The 1999 external panel actually concluded that (1) too much emphasis had been placed on collection of ecological data, (2) information requirements were too complex, and (3) complexity required the hiring of consultants as primary knowledge-providers, which increases implementation costs. Data are being collected faster than they can be analysed by managers. The central administration is bogged down scrutinising individual base-line studies and management plans, and they lack the resources to look at the dynamics of the system as a whole.

Beyond the specific contents of the information assembled, there are indirect positive effects of the influential role of Path 1 in the implementation process, as follows.

- Information requirements have created a sense of institutionality and order in the transition between the 'open access' and the TURF systems.
- Many consultants (e.g. IFOP) have worked very closely with fishers' organisations in the collection of data required for base-line studies, management plans and annual follow-ups. These activities have included the participation of the local fleets in surveys, and the training of monitors within communities. Participation of fishers in monitoring and surveys creates trust in the system, and reduces the costs.
- In a further development, some caletas have retained quasi-resident biologists as regular consultants. These come close to the 'barefoot ecologists' profiled by Prince (in press) as ideal primary producers of information in S-fisheries.

While demanding of ecological information, the implementation of a TURF largely ignored Path 3. Baseline studies, for example, paid no attention to the exploitation history of the area, even though this is a significant piece of information for management, and one on which fishers are generally very knowledgeable. Structured interviews or other forms of gathering empirical knowledge are not a regular part of data acquisition protocols.

The strong tradition in experimental ecology in Chile has created expectations about various forms of experimental and/or adaptive management, particularly considering that the many TURFs along the coast could be managed differently (in a planned way) with a consequent gain in insights about population responses to exploitation. This, however, would apply only to post-dispersal processes, because of the lack of dynamic independence among the TURFs discussed above.

An evaluation of the sustainability of the system at the scale of the whole fishery will require a considerable effort to consolidate the massive amount of information generated into a form that facilitates the analysis. A synthesis above the level of individual TURFs should examine performance in terms of key indicators and consider the different axes of sustainability (Charles 2001): biological (e.g. trends in abundance and recruitment, size compositions), economic (e.g. yields, sales, sale prices, profits), community (e.g. level of organisation, distribution of labour and benefits) and institutional (e.g. participation of fishers in management). Such a synthesis would help to develop criteria for designing suitable harvesting strategies (e.g. harvest rates, size limits) and for coordinating management plans of individual TURFs at a regional scale – a role that would correspond primarily to the central fishery administration responsible for the sustainability of the fishery as a whole.

This overview of data, information and knowledge of Chilean benthic fisheries points to some aspects requiring further attention. They are:

- the need to gather folk knowledge in a systematic way, and the convenience of utilising it;
- the importance of involving fishers in surveys and monitoring; and
- the possible value of promoting 'barefoot ecologists' as primary providers of knowledge in place of external consultants.

More generally, this case illustrates why more information does not necessarily mean better management. This applies both to some of the data currently required by the baseline studies and to the assessment models used as part of the TAC regime. It was not the costly accumulation of information but rather the introduction of appropriate incentives to the fishing communities that created sustainable options for the fishery.

2. *A test co-management initiative in the diving fishery of the San José Gulf in northern Argentine Patagonia*

Small-scale coastal fisheries of Argentine Patagonia are very small due to the large amount of exposed and inhospitable coasts, where artisanal fishing is only possible in a few places. Among these, San José Gulf (Figure 2), a productive semi-closed body with an approximate surface area of 800 km^2, is the most significant. Shellfish and finfish resources currently support an estimated 110 artisanal fishers and their families, many of them organised in a professional association ('Asociación de Pescadores Artesanales de Puerto Madryn', APAPM[5]). A commercial hookah-diving fishery for scallops (*Aequipecten tehuelchus*) developed in the mid 1970s, following the 'boom-and-bust' cycle of a scallop dredge fishery in the adjacent San Matías Gulf (Orensanz et al. 1991). Because of the demonstrated unsustainability of that fishery, dredging was banned in San José Gulf (then designated as a Provincial Marine Park) out of concerns over the negative impact of the gear on the bottom and the potential destruction of habitat considered suitable for settlement of scallop larvae (Orensanz 1986). A hookah diving fishery operated after that, targeting several clam and mussel species in addition to scallops. Fishing units are boats less than 10 metres long equipped with compressors and outboard motors, typically operated by a crew of one deck assistant and two divers. These units are able to land the catch at many locations along unpopulated coastlines (Figure 3b).

[5] For further information see http://www.apamadryn.com.ar

In contrast with the Chilean system, coastal fisheries are under provincial jurisdiction: San José Gulf fisheries are managed by the fishery administration of Chubut Province. Under open access, the artisanal fleet grew to approximately 30 units (60 divers) by 1995.

A weak peso favoured exports and divers responded by taking higher risks to work in deeper waters, thereby lowering the density threshold considered profitable and violating size limit regulations. All existing reproductive refuges disappeared, landings rose to approximately 1,200 tons per annum. The fishery collapsed soon after, and remained closed for three years (Figure 7). Fishing was resumed in 1999 at a rather modest level. However, a crisis in the off-shore industrial hake (*Merluccius hubbsi*) fishery in 2000 cascaded into the coastal zone. Social pressure on the provincial fishery administration to issue new permits mounted as a way of absorbing fishers displaced from the off-shore sector.

This critical scenario led in 2000 to discussions for solutions between the fisheries administration of Chubut Province, artisanal fishers, environmentalists and scientists.

Unlike the case of central and northern Chile (discussed above), the implementation of a TURF system is not an option for this fishery because:

- Fishers generally do not live close to the fishing grounds. Only two permit holders live along the coasts of San José Gulf, where there is a permanent moratorium on the establishment of new human settlements[6]. Most fishers live in Puerto Madryn, about 60 km away from the gulf. Enforcement of territorial rights would therefore be difficult.
- The fishers' organisation is weak, although this is in part a consequence of the historical open nature of the fishery.

Instead, a test co-management experiment was initiated. It emphasises flexibility and allows for input from all the parties, open discussion of options and feedback from short-term learning.

- A technical advisory team was formed with participation of the APAPM, technical staff from the provincial administration and scientists from CENPAT[7].
- Artisanal fishers received an intensive four-month course covering aspects related to the ecology and natural history of target species, conservation and environmental effects of fishing, assessment techniques and management.
- The technical advisory team prepared short-term management guidelines for the scallop fishery and for a newly-developed geoduck (*Panopea abbreviata*) fishery.

Management recommendations for 2001 were relatively straightforward in the case of scallops, because a pre-season survey had indicated very high abundance of pre-recruits (one year old scallops, smaller than the minimum legal size of 60 mm) in several grounds along the coast of the San José Gulf. The technical advisory team considered that protection of this cohort would be enough to guarantee successful reproduction during the upcoming season. Emphasis was thus placed not on the overall TAC but on the protection of sublegal animals, and on the close monitoring of the fishing season.

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6 San José Gulf is part of Península Valdés, designated by UNESCO as Natural World Heritage Area in 1999. The main motivation is that this and neighboring coastal areas are mating/calving grounds for the southern right whale, Eubalaena australis. During the l990s there was friction between fishers and conservationists concerned about interference of fishing with whale behaviour.

7 CENPAT (National Patagonian Center) is a regional research facility that reports to Argentina's National Council for Scientific and Technical Research (CONICET).

In contrast to the scallop, the data available to guide management decisions in the case of geoduck were very scarce. No information about total biomass existed, nor would it be feasible to survey the entire grounds. Instead, information from two sources was used to develop a management plan.

1. Information was borrowed from the North American species (*Panopea abbreviata*), which supports a lucrative fishery in Washington and British Columbia (Orensanz et al. 2001). Due to its very high longevity (maximum recorded age in the order of 160 years) and apparently low productivity only a very small fraction (around 2%) of the biomass is exploited annually. We assumed that the local species would be similarly long-lived with a comparable productivity.
2. Fishers' knowledge about geoduck availability, gathered while they explored potential yields from different grounds, was also utilised.

Although patchy, the information from these sources was sufficient to select a robust harvesting strategy, at least for the short-term. The key elements of the plan were:

- to limit harvest rates by opening up only a small fraction of the overall grounds;
- to rotate fishing areas annually; and
- to assess pre-harvest biomass in the area to be opened and monitor depletion over the fishing season with cooperation from the fishers.

The rotational strategy was proposed by the fishers, as was also the area opened in 2001. The plan was developed within the technical advisory team and after several meetings of the APAPM. Overall, the process resulted in trust between fishers, scientists and technicians from the fishery administration, and all sectors felt that the plan was theirs.

For the longer term, strategic management plans will need to be designed and management procedures fine-tuned. In a most significant development the APAPM petitioned a limited entry program for the diving fishery. In response, the fisheries authority froze the number of permits. During the 2001 season, only 'historical fishers' were allowed to fish scallops (15 diving teams) while about the same number were not given any quota. While still far from a formal limited entry program, these first steps have encouraged a conservative attitude on the part of the permit-holders and have facilitated the collection of detailed catch and effort statistics by fishing ground. At the same time we are developing operating models of the fisheries, which will be used to evaluate alternative regulatory tactics and information needs for implementation.

Discussion

Experience with the cases discussed here, and more generally with small-scale coastal fisheries, has led us to conclude that *the key limitation for management of data-poor fisheries is not lack of data.* S-fisheries are typically data-poor, but this is only one of the difficulties faced by management. More fundamentally, shortage of data commonly comes together with spatial heterogeneity in the dynamics of both the resource and the fishing process, inadequacy of overall catch and effort controls, and unenforceablility of management regulations. In these circumstances, the conventional top-down approach to fisheries management based on TACs or effort quotas determined from analytical stock assessments would fail even if all the standard input data were available.

A qualitatively different approach is needed; one that is based on participation. While solutions will need to take into account the peculiar characteristics of the exploited system in terms of resource dynamics and fleet behaviour, and the geography of fishers' communities, some general prescriptions can be offered to address management of data-poor fisheries.

- *Use empirical information for developing management plans*

Shortage of scientific data may preclude conducting standard analytical stock assessments, but it does not mean absence of information. There is usually a wealth of empirical knowledge that may be gathered, organised and used for the development of management guidelines (Johannes 1998). As discussed by Berkes et al. (2001), the challenge is to find ways of combining information coming from multiple sources into an understandable and communicable form, so that it can be used in support of decision-making. Although the value of empirical information has been appreciated only during the last decade or so, experience is rapidly accumulating (Johannes et al. 2000, Neiss et al. 1999).

- *Fishers themselves can collect the data needed to assess exploited resources*

Fishers can be motivated to get involved in monitoring and data-collection programs once they understand the value of the knowledge that they can contribute. Appreciation of that knowledge by scientists, managers and other stakeholders empowers fishers, fostering their participation in the management process. Simple protocols need to be designed for the regular collection of fishery data (catch, effort, size composition and quality of the catch) at the appropriate spatial scale, a process for gathering and archiving the data, and software to facilitate data visualisation and analysis. Shortcomings of CPUE data to monitor abundance trends are well known (Hilborn and Walters 1992) and should not be overlooked. However, the idea here is to use CPUE as a relative indicator of the local status of the resource in the different grounds, and not necessarily as an index that is proportional to abundance as assumed in conventional assessment models. Also, CPUE is one of the determinants (often the most significant one) of the suitability of locations or grounds as perceived by the fishers. Other determinants of suitability include perceived abundance, exposure, depth, distance to harbour, type of bottom and quality of the shellfish. The costs of collecting scientific data at an appropriate spatial scale, on the other hand, may be prohibitive in S-fisheries.

- *Educate the fishers, and in the process of so doing enlighten the scientists*

Benefits will be maximised if fishers have an adequate understanding of the different elements that support management decisions, from the biology of the resources to the dynamics of the fishing process, to basic concepts about fisheries management and conservation. Investing in education, rather than in expensive scientific surveys, results in broader benefits to the management process and, in the end, a more sustainable monitoring system. It is our experience that scientists are enlightened themselves in the process of educating the fishers.

- *Use the experience gathered with similar systems elsewhere*

Whether informally or using formal approaches for meta-analysis (e.g. Myers et al. 2002), information gathered about related species or fisheries elsewhere should be considered in the development of management plans.

- *Work in association with fishers and other stakeholders including managers and scientists to develop management plans*

The best way to appreciate the value of collecting fishery data, both scientific and empirical data, is to make use of the extended knowledge base in the development of management plans that make sense to all the sectors involved with the fishery: managers, scientists and other stakeholders. It is essential that a participatory and transparent process be established for the analysis of the information and the evaluation of alternative management approaches. To work, management plans do not require a formal stock assessment and estimation of absolute stock abundance. In the absence of analytical assessments, precautionary guidelines can still be developed (Berkes et al. 2001, Mahon 1997). Simple harvest rules can be developed that do not strive for optimality, but may still provide 'pretty good yields' (Hilborn et al. 2002).

- *Promote management systems that provide the right incentives*

In order for the fishers to participate in monitoring and management in an effective way they need to be genuinely interested in the sustainability of the fishery. This will only happen when fishers have secure long-term access rights to the fishery (Orensanz et al., in press). It is only by providing the right incentives that fishers will be motivated to spend the time it takes to participate in resource monitoring, provide unbiased information about stock status, cooperate with enforcement and organise themselves to contribute effectively to management discussions and decision making.

Acknowledgements

Our experience with artisanal fisheries of Chile and Argentina was gathered through close collaboration with fishers, managers and many colleagues and friends on both sides of the Andes. In particular, we want to acknowledge the *Asociación de Pescadores Artesanales de Puerto Madryn* (APAPM) and three regional federations from Chile: FEPAR, Region III, FEPEMACH, Region IV (especially Oscar Avilés), and FEDEPESCA, Region V); the managers and technical staff of the *Dirección General de Pesca y Acuicultura* of Chubut Province, Argentina (Katty Olsen and her team), and of the *Subsecretaría de Pesca de Chile* (the team led by Ricardo Norambuena); and our collaborators in these projects at the *Centro Nacional Patagónico* in Puerto Madryn (Nestor Ciocco, Ana Cinti, Luciana Loto, Bebote Vera, Hormiga Díaz and Bocha Rua) and at the *Instituto de Fomento Pesquero* in Chile (Hernán Miranda, Lucho Ariz, Gladys Jofré, Claudio Romero, Jorge Garrido and Jorge González). Special thanks are due to Alejandro Zuleta for sharing his critical views about the assessment-based approaches implemented for the loco fishery. A Pew Fellows Program in Marine Conservation to Lobo Orensanz provided support for these interactions. Much of our experience with the Chilean system was gathered while participating in a project funded by FONDEF (CONICYT, Chile) and executed by IFOP to collaborate with the three regional fishers' federations in the implementation of 15 TURFs. Finally, our viewpoints were enriched by discussions with many colleagues who participated in the workshop organised by IFOP as part of the FONDEF project. Ana Parma thanks the Australian Society for Fish Biology for the possibility to participate in the conference that motivated this paper.

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Table 1. Contrasts between S-fisheries and the type of fishery addressed by the classical theory. ITQ: individual transferable quota; IVQ: individual vessel quota; IEQ: individual effort quota; CDQ: community development quota.

	S-fisheries	The classical fishery
Nature of the physical world		
	Coastscapes and inshore waters, heterogeneous	Offshore waters, perceived as homogeneous
Target populations		
Stock structure	Metapopulation, composed of heterogeneous subpopulations	Unit stock, spatially homogeneous, dynamic pool
Life style	Sedentary	Mobile
Stock–recruitment	Subpopulations open to recruits originating in other subpopulations; processes involved decoupled by the dispersal phase	Unitary stock–recruitment relationship
Growth and mortality	Spatial gradients (often very steep) within subpopulations	Homogeneous within a stock
Small-scale spatial processes	Spatial location of individuals relative to others is significant[8]	Spatial location of individuals ignored
Fleets and fishing process		
Fishing units	Small-scale, artisanal	Large-scale, industrial
Fishing effects	Locally persistent	'Diluted' in the dynamic pool
Fleet behaviour	Central for the design of spatially explicit management strategies (reserves, rotation, etc.)	Secondary significance, academic interest
Landing sites	Dispersed along the coasts	Consolidated industrial ports
Stock assessment		
Direct estimation of total abundance	Always too costly, often technically unachievable, and in many cases irrelevant	Facilitated by sampling surveys (e.g. hydroacoustics, trawling)
CPUE as an index of abundance	Often useless except at very local scale, yet important in the analysis of the fishing process	Useful, with due caveats
Catch-at-size/age methods	Often useless due to spatial patchiness in age composition and gradients in size-at-age	Usual approach to estimating stock abundance
Mark-recapture methods	Non-mixing of tagged and non-tagged individuals violates basic assumptions	In many cases a reasonable alternative
Aggregate biomass models	N/A	Part of the core theory
Stock–recruitment relation	Pre- and post-dispersal processes decoupled; pattern cannot be captured using an aggregate function	Can be reasonably modeled as an aggregate relationship

[8] This corresponds to concentration, which may affect rates of fertilization, settlement, growth, etc. (Orensanz et al. 1998).

Table 1. continued.

	S-fisheries	The classical fishery
Management options		
Control of catch and effort	Generally N/A, as they require reliable abundance estimates and enforcement	Main option
Spatially explicit strategies	Important options include rotation and closed areas	Often not an option due to individual movements
Manipulation of productivity	Feasible even at the local scale of a TURF: habitat manipulation, control of predators and competitors, thinning and restocking	N/A
Experimental management	Spatially defined treatments and controls possible involving post-dispersal processes	Generally N/A
Access rights	Mostly TURFs; limited entry	Typically based on catch or effort quotas (ITQs, IVQs, IEQs, CDQs).
Conflict with other users or stakeholders	Very common, involving pollution, habitat degradation, recreational/tourism uses, urban development and military use. Conflicts often constrain options	Rare

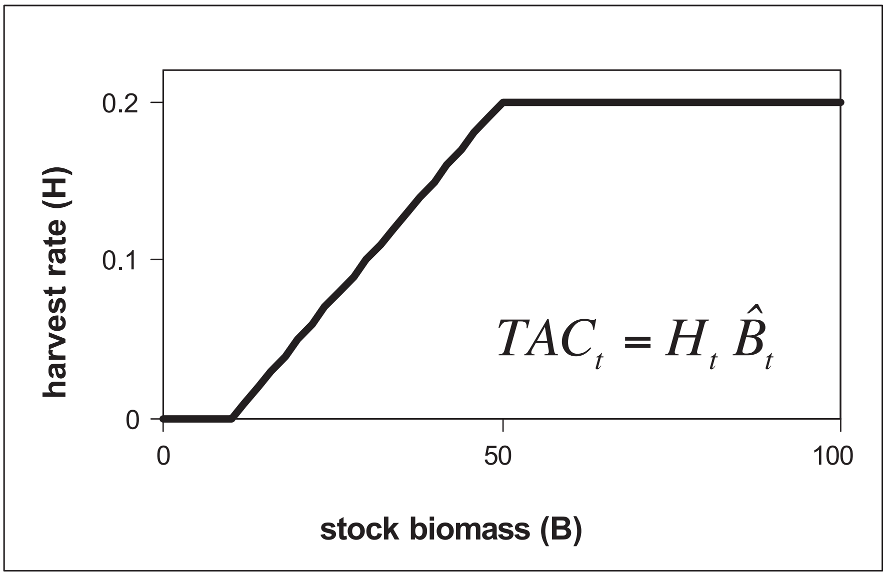

Figure 1. Generic control rule specifying the target harvest fraction in year t, H_t as a function of the estimated stock size $\hat{B}_t$, both used to set the Total Allowable Catch *(TAC)* for that year.

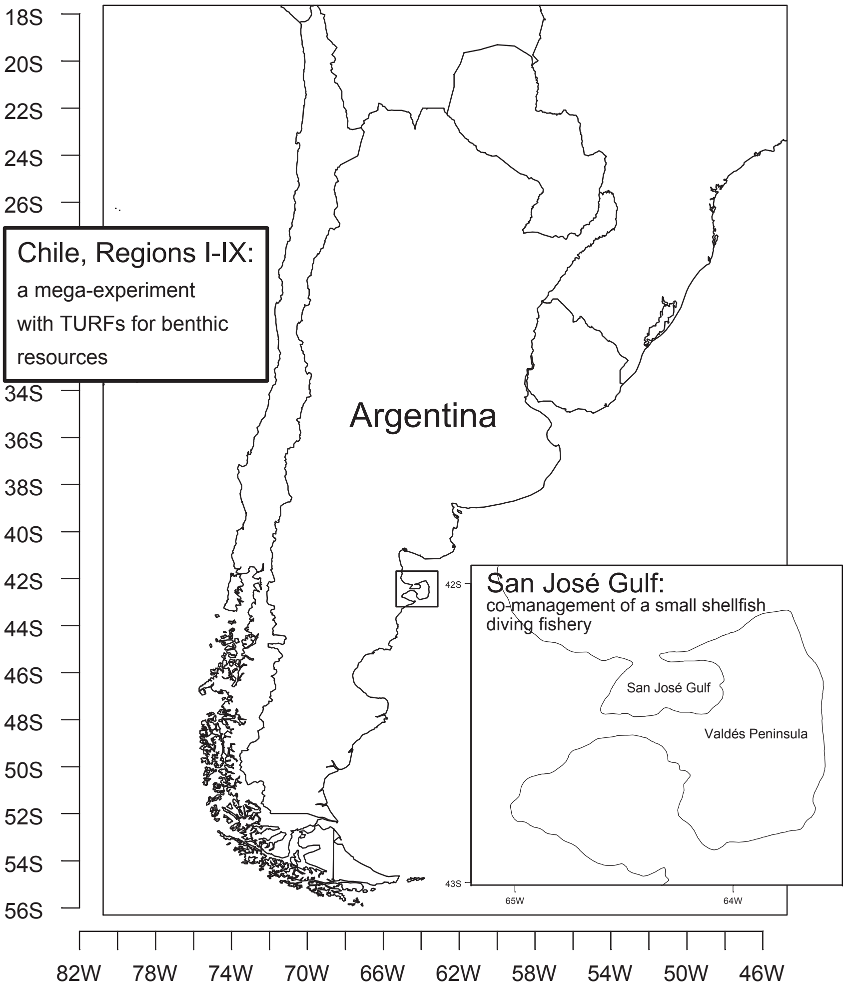

Figure 2. Map of southern South America showing the extensive coastline of Chile, where a mega-experiment on Territorial Use Rights has been launched, and San José Gulf, Argentina, where a test co-managemnt project is being conducted, both involving artisanal shellfish diving fisheries.

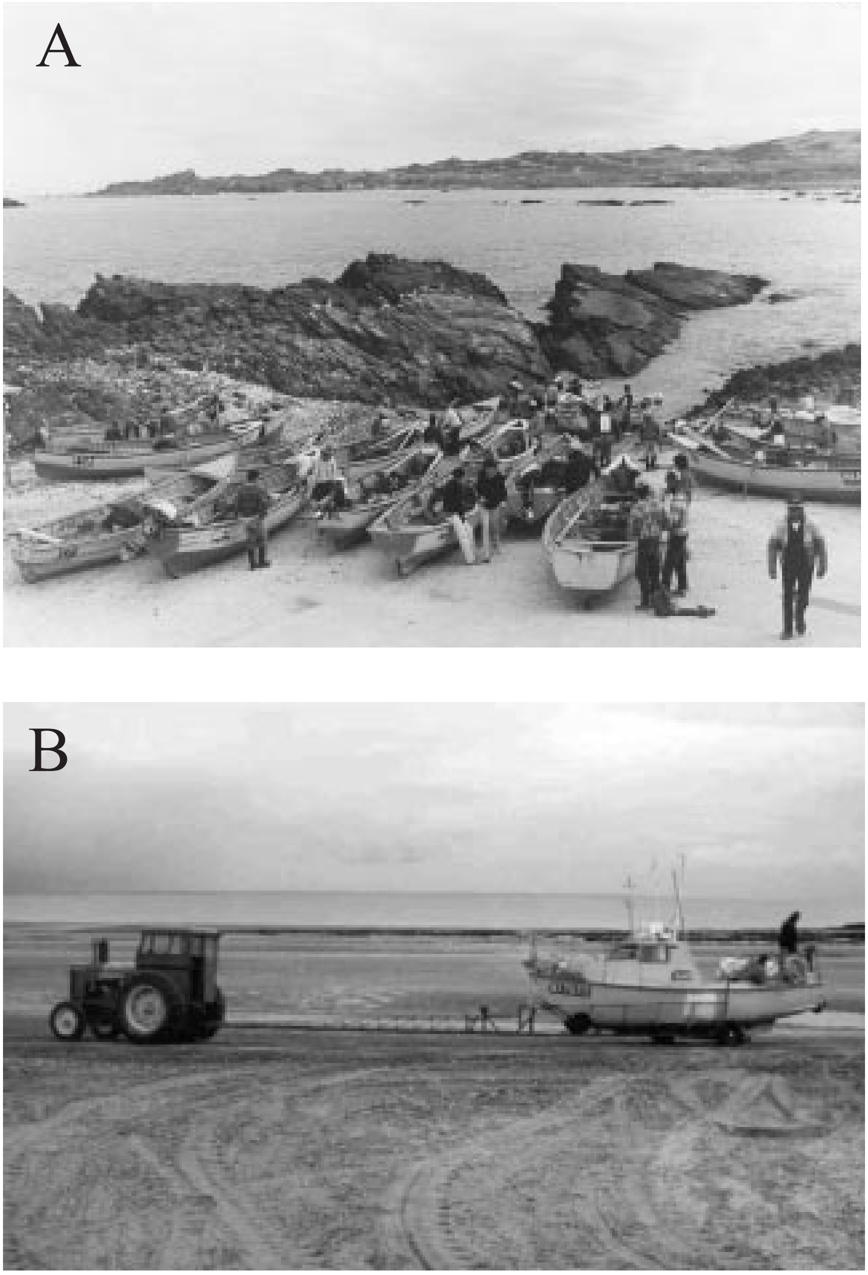

Figure 3. Artisanal fleets can land the catch at many locations along extensive coast lines. (A) Caleta Totoralillo Sur in region IV of central Chile; (B) vessel geared with diving gear, pulled by a tractor in San José Gulf.

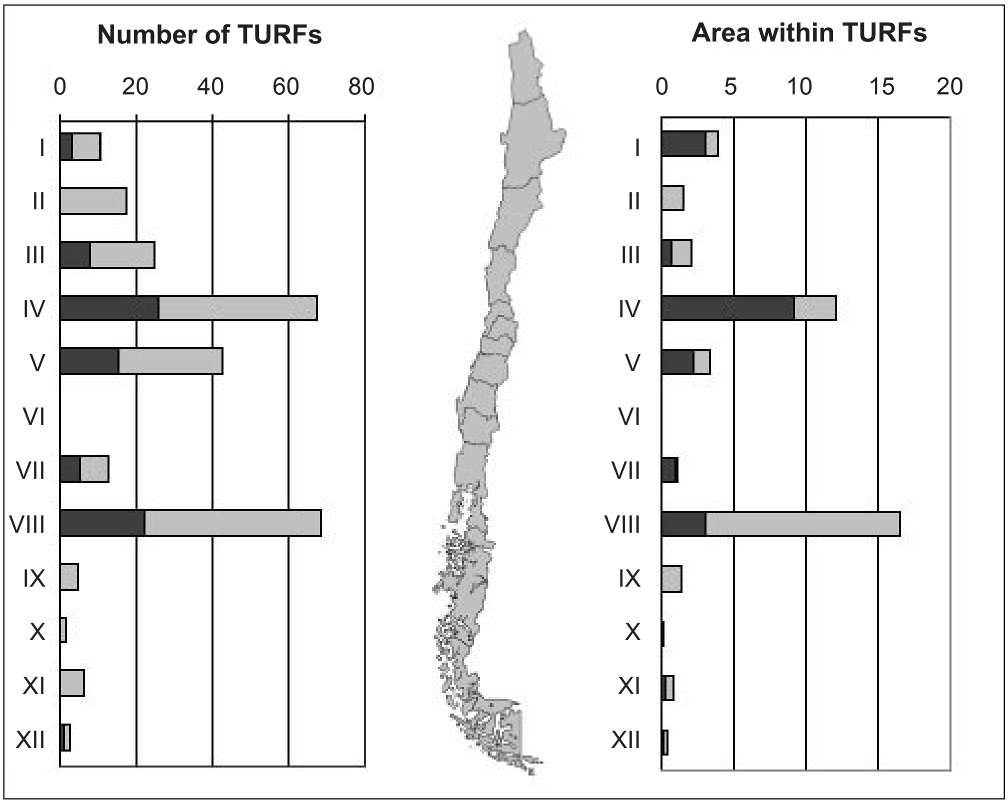

Figure 4. Number of approved TURFs and thousands of hectares within TURFs by Region, number in correlative order from I in the north to XII in the south. Light bars: assigned TURFs; dark bars: TURFS with approved management plan.

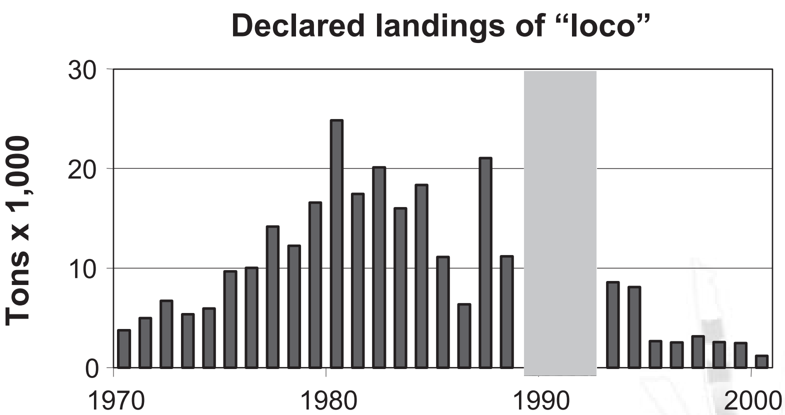

Figure 5. Trends in landings of loco *(Concholepas concholepas)* from the artisanal diving fishery in Chile. Shaded areas indicate periods when the fishery remained closed.

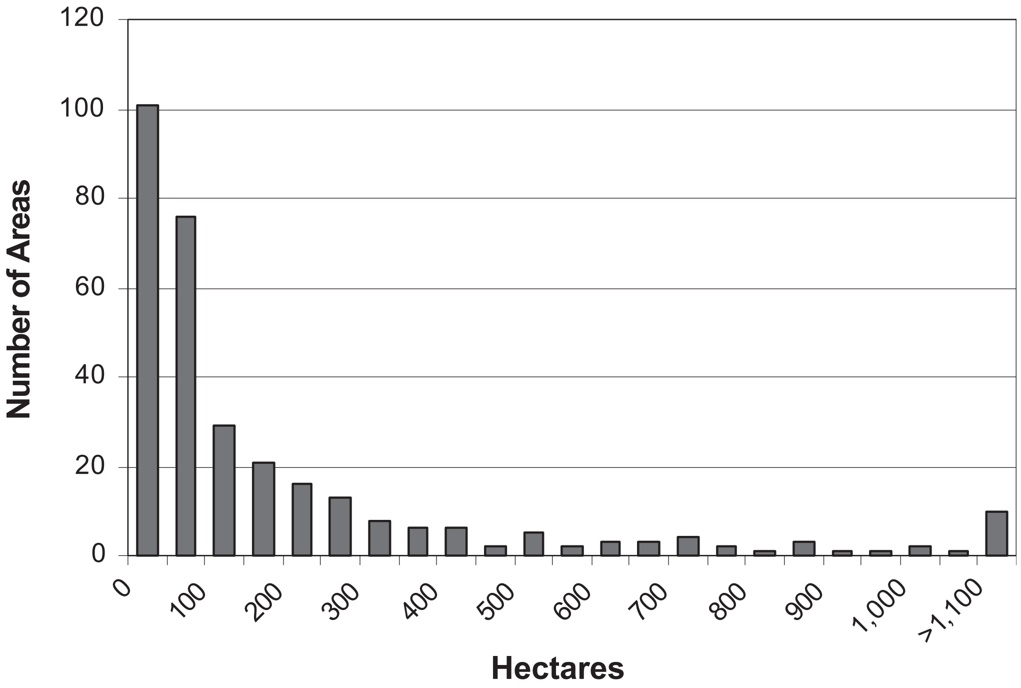

Figure 6. Chilean TURFs: area frequency distribution.

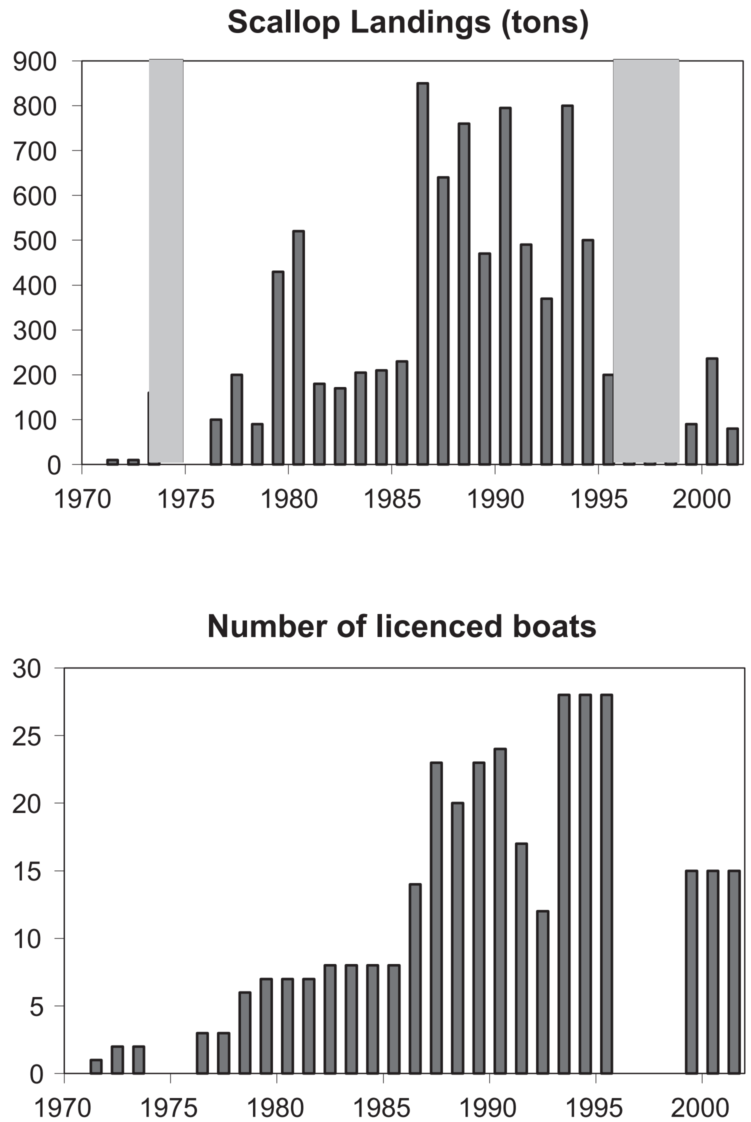

Figure 7. Landings of the techuelche scallop *(Aequipecten tehuelchus)* from San José Gulf, Argentina, and number of boats with permits to participate in the fishery. Shaded areas indicate periods when the fishery remained closed.

Keynote Address

Discussion, questions and answers

Rapporteurs: Dan Gaughan and Gary Jackson

Ana Parma's address

Malcolm Haddon (TAFI) suggested that the challenge presented is how the system of TURFs and ITQs described can be transferred to Australia. The transfer would be problematic since the Australian management system does not like giving exclusive access rights to the seabed. Malcolm pointed out that the examples given from South America focused on localised, non-mobile species. He asked if Ana has any examples of more mobile species or where a TURF approach was not adopted.

Ana Parma. "No. The TURF system should work for any reef fishery with localised fishing, but would not work, for example, with shark. Spatially structured management also would not work for halibut. Maybe territorial user-rights should have a more important place in fisheries management than they have done historically."

Malcolm Haddon. "Australian managers don't like territorial user rights, full stop."

Ana Parma. "Management is species based, dealing with fishing rights for benthic species. The notion of territory does not apply to other species."

Malcolm Haddon asked if there are any recreational fishers for loco, and if so, how are they dealt with.

Ana Parma. "This is the most difficult part. Many colleagues consider recreational fishers to be the 'worst' user group to deal with, partly because they are not organised. Until allocation problems are resolved they will remain so. It is a big political issue. Our challenge is to get the recreational sector interested in the same sort of goals as fishery managers have. We need to do a better job of selling, and offer incentives to recreational fishers. Until then the problem will remain."

Tony Fowler (SARDI) expressed interest in the Chilean situation and asked if there are any inter-fisher disputes. Does Ana have evidence of individual fishers defending their area with aggression?

Ana Parma. "Villages or co-ops in the north have their traditional fishing grounds with little overlap and no conflict. Along the mid-Chilean coast there is more overlap. The legal framework developed resulted in fishers modifying their behaviour in response to management. Fishers chose or defined their grounds, in advance, so that there would not be overlap. How they managed this is not known, but they did. We thought the south coast would be an area of greatest conflict as overlap was almost 100%. However, fishers accepted the territorial system and recognised its benefits, so worked it out."

Peter Stephenson (Fisheries, WA). "When the Petro Madra scallop fishery changed from trawl to hookah, was there an issue of increased operating costs and profitability for industry?"

Ana Parma. “Solving this was the key. The fishing in the 1970s had been centred in another gulf to the north, which underwent the gold-rush phase, followed by collapse. There was fishery (rather than environmental) concern about the effect on recruitment from habitat loss or destruction by scallop dredges. When the fishery later moved into the next gulf to the south, biologists were in place prior to the move. Yes, industry raised profitability issues. Chileans were brought in to help design a sustainable system that was also profitable. The hookah fishery remains competitive with the trawl fishery at these depths, and it provides a better quality product. Both fisheries co-exist in adjacent gulfs; dredging is losing favour.”

Peter Stephenson. “At what depth does the hookah fishery operate?”

Ana Parma. “Fifteen to 20 metres. There are some diver health problems when they operate at nearer 30 metres.”

Murray MacDonald (Fisheries, Victoria). “Are there significant, other users of these shellfish resources, such as recreational fishers? If so, how are their interests accommodated?”

Ana Parma replied that there is no significant recreational diver fishery. The limited number of shore gatherers (visitors) are not popular with locals as they cause damage to intertidal areas. Ana said that the issue remains to be worked out; and that introduction of zoning may be one way around it.

Murray MacDonald asked what monitoring is in place to assess for sustainability, both of catch and of environment, where TURFs are in place (in Chile).

Ana Parma replied that loco catches are monitored, and consultants are involved. Monitoring environmental issues is one of the challenges and is one reason the central government designed a complex process to obtain data on diversity and other factors. Although it is not working at present, Ana suggested that it may be in 20 years’ time when there will be sufficient data.

Lindsay Joll (Fisheries, WA). “Centralised management systems allow breaches of arrangements to be dealt with under rule of law. How are internal and external (outsiders coming in) TURF breaches dealt with?”

Ana Parma. “There were many initial problems. Co-ops protected their TURFs externally and took the law into their own hands. New co-ops work with enforcement personnel to protect their rights. The tangible benefits of the TURF system drive the need to protect the property. Internal problems are dealt with internally, i.e. each co-op manages its own business with respect to its TURF and the fishers who work within that TURF. As part of this, support is provided to build leadership capabilities (with the assistance of Canada), since good leadership is a key element of the TURF system working well.”

Lindsay Joll. “Dealing with open systems, are biological connections between TURFs recognised?”

Ana Parma. “This is an important issue. Louis Botsford was brought in to address the issue of larval dispersal within the meta-population. The stocks seem to have a natural resistance to over-harvest by way of semi-cryptic behaviour; thus, locos removed appear to leave habitat that is ‘recolonised’ by locos from extensive natural refuges, possibly in deeper water. There is thus a replacement mechanism to counteract local loco depletions.”

THEME SESSION ONE
Ecologically sustainable development

Chair: Rick Fletcher

ESD, environmental sustainability, EPBC, ecosystem based management, integrated fisheries management, EMS's:

How will we ever cope?

R. Fletcher

Rick Fletcher is a Supervising Scientist at the Department of Fisheries – Research Division, WA Marine Research Laboratories, PO Box 20, North Beach WA 6920, and is also head of the ESD Sub-Program of the Fisheries Research and Development Corporation (Canberra). Email: rfletcher@fish.wa.gov.au

Introduction

Over the last ten years the area of fisheries management has been inundated with a series of new initiatives and, increasingly, their acronyms. The acronyms themselves tend to take on a meaning of their own and often get used interchangeably. This practice appears to be the result of a lack of understanding about the objectives of the initiatives and, most importantly, how they relate to each other.

Each of these initiatives will affect the core business of all Australian fisheries management and research agencies during the next ten years (and in many cases the effect has already started). It is important, therefore, to have a clear understanding of these initiatives, their implications and how they interact with each other.

In the remainder of this presentation, I will briefly describe each of the main terms mentioned in the title and their relationships to each other. Following this, I will discuss some possible strategies and principles that should be remembered to help fisheries managers complete what seems like an impossible set of tasks.

Descriptions and relationships amongst the terms

Ecologically sustainable development vs Environmental sustainability

Ecologically sustainable development, or ESD, as it is often termed, is defined in the National Strategy (Commonwealth of Australia 1992) as "using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased". With respect to fisheries, this concept means that we need to manage not only the effects of the fishery on the target species (the species that the fishery wants to catch) but also the effects the fishery may have (both direct and indirect) on the broader ecosystem. Furthermore, the concept recognises that a fishery will have both social and economic effects (both positive and negative) at a number of different scales. Finally, the appropriateness of the governance arrangements (the processes and procedures) that are implemented to enable the management of the fishery also requires assessment.

Achieving ESD requires taking into account both long and short-term objectives and incorporating the 'precautionary principle', which I will detail later. Overall, ESD should be seen as a means, not an end: you cannot say you have actually 'achieved' ESD, as the elements within ESD are not fixed, particularly because of the ever-changing social and economic values of society.

Whilst ESD has often been wrongly assumed to address only environmental issues ('*Environmental sustainability'*) the national strategy on ESD recognised that continued development (i.e. utilisation of economic and social resources in a sustainable manner) is a necessary element to meeting the overall objective that total quality of life can be increased. It is the integrated approach of including the wider economic, social and environmental implications within decision-making processes that is the cornerstone, and major innovation, of ESD.

Social and economic factors must be included in the assessment of ESD for fisheries because natural resource management needs to have more than just minimum standards for viable populations. To some degree, most fisheries management agencies have taken account of social and economic factors over the last 50-100 years, even if they have not done so explicitly. Moreover, any alteration to the environment (which will result from any level of harvesting) must have a social or economic benefit otherwise society would class the effect as vandalism.

Depending upon societal (moral) values, the acceptable level of harvesting or effect can vary significantly. For example, several species could be harvested if the sustainability of populations was the only criterion, but the community has decided on moral grounds that for some species (e.g. dolphins) any harvest whatsoever is unacceptable. Whilst there may be no intrinsic environmental reason for such decisions, they are still consistent with ESD and such examples are likely to become more common.

To assist fisheries agencies in understanding how to implement and report on ESD, the FRDC[1] funded a project coordinated by the Standing Committee for Fisheries and Aquaculture (SCFA[2]). The result of this project was the development of a national ESD reporting framework to compartmentalise, in an efficient and pragmatic way, the various elements of ESD (Figure 1; Fletcher et al. 2002). This framework covers the retained species, non-retained species, indirect effects on the environment, social benefits and costs of the fishery, governance arrangements (allocation of access being a key factor) and effects of the environment on a fishery (including perturbations caused by other human activities).

The EPBC Act (Export Approvals – Strategic Assessments)

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC), which now incorporates the *Wildlife Protection (Restriction on Exports and Imports) Act 1982,* requires the assessment of export fisheries and all Commonwealth managed fisheries against the *'Guidelines for the ecologically sustainable management of fisheries'*. These guidelines state that a fishery must maintain viable stock levels of target species, must not threaten bycatch species and must minimise the impact of fishing operations on the ecosystem generally. In other words, the EPBC Act mainly relates to the ecological side of ESD (Figure 2) but it does include some elements of governance associated with management arrangements. It does not involve any social or economic analyses.

[1] FRDC – Fisheries Research and Development Corporation (Canberra).

[2] A review of all Standing Committees resulted in the SCFA being replaced by the Marine & Coastal Committee of the Natural Resources Management Standing Committee in 2001.

Ecosystem based management

Ecosystem based management is, in many respects, a subset of ESD (Figure 3). Like ESD, it is a philosophy for which the definition varies depending on the particular fish species or region being examined. Thus, it can vary enormously in scope from the huge ecosystem for southern bluefin tuna (Indian Ocean, Southern Ocean and South Pacific Ocean), to an ecosystem as small as one tributary of a river for the stocks of some other species.

Harden Jones (1994) defined ecosystem based management as '*the necessity of understanding multi-species interactions and questions of altered structure of the biological community'*. This understanding involves assessment of both the direct and indirect impacts of fishing; and to this can be added the environmental impact of other human activities on a fishery.

Integrated fisheries management

In many jurisdictions, the commercial and recreational sectors are managed in relative (or in some cases total) isolation from the activities of each other. The need for more explicit management arrangements to be developed is recognised and those arrangements should also include sectors that require 'no-take' areas and indigenous fishing rights. Integrated fisheries management (IFM) therefore, is the process that seeks to manage access to the resources by all stakeholders in an explicit and sensible manner such that the exploitation of stocks by all sectors can be managed in an integrated way.

The information that is required for IFMs includes data on retained species and costs and benefits associated with the various forms of fishing so that appropriate decisions regarding allocation can be assisted (Figure 4 and Fletcher & Curnow 2002).

In summary, the issues that need to be addressed through applications under the EPBC Act and initiatives related to ecosystem based management and integrated fisheries management are all subsets of ESD. Consequently, if an ESD assessment is completed this will cover all these issues.

Environmental management systems

The final three-letter acronym is EMS, which stands for environmental management systems. The development of an EMS can be used to achieve or improve the level of performance for some or all issues of an individual fishing operation or of an entire fishery. An EMS can be certified by an external body, the most well known of these being the systems accredited by the International Standards Organisation. The development of an EMS relies on identifying an objective or level of performance that is required to be met, determining the actions that are needed to achieve this objective or performance, implementing those actions, monitoring the outcomes and revising the actions if necessary. In many cases, Codes of Practice are a way of formalizing the set actions needed across an industry group.

Many of the issues identified as part of the ESD assessments can be addressed through the development of an EMS. Thus the two systems are complementary.

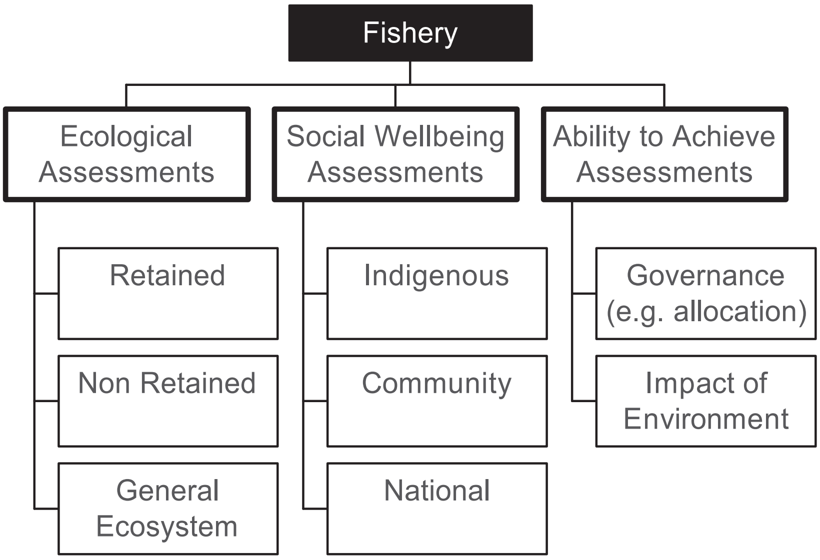

Figure 1. The national ESD reporting framework (see www.fisheries-esd.com for details).

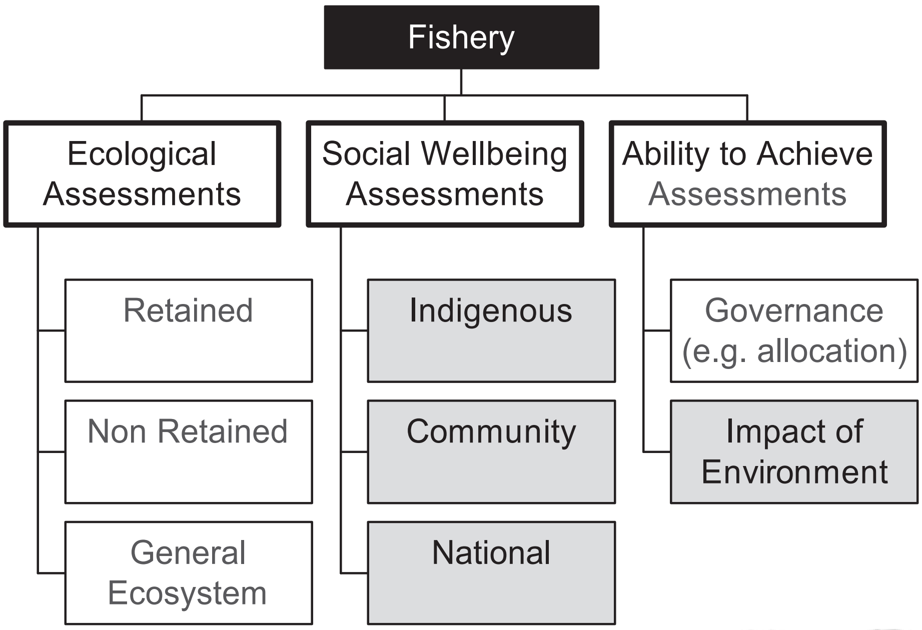

Figure 2. The issues that relate to the EPBC Act compared to the ESD framework. The ESD issues shaded grey are not directly relevant to the EPBC assessment process.

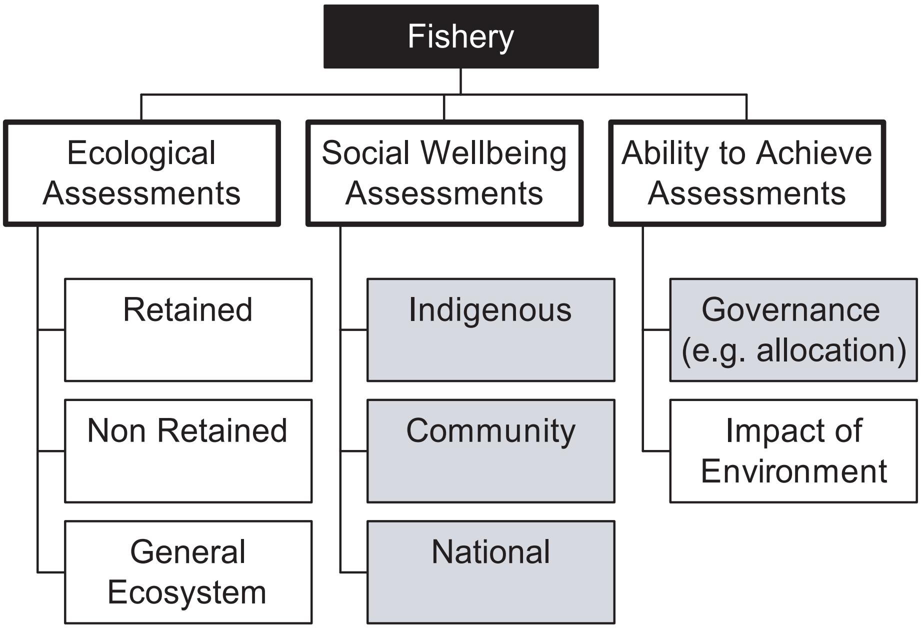

Figure 3. ESD components relevant to ecosystem based management (grey shaded components are not examined).

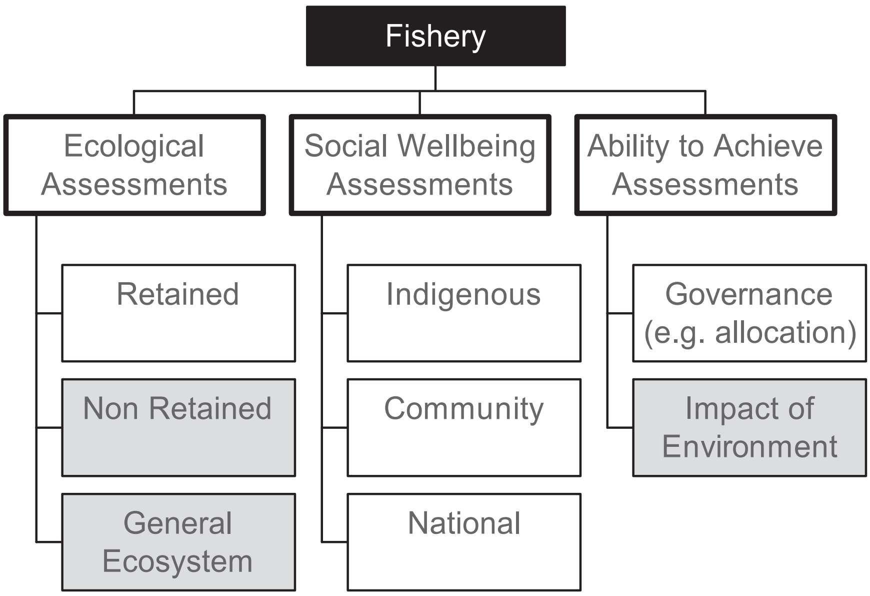

Figure 4. The issues that relate to integrated fisheries management (IFM) compared to the ESD framework. The ESD issues shaded grey are not directly relevant to the IFM process.

Implications of these initiatives for fisheries agencies

Materiality of issues and definition of acceptable impact

So how do we deal with all of these initiatives, particularly the increases in reporting and assessment requirements that they will generate?

I believe that the initiative to require third party assessment of the performance of fisheries, such as the EPBC Act, could be perhaps one of the best things to happen for fisheries management in the long term – so long as it is handled appropriately. It could also be a significant risk if handled incorrectly.

There are a number of risks associated with these assessments due to the uncertainty and 'materiality' of the issues to be addressed. When planning the assessment of a fishery, it is possible to generate a list of many issues that could be examined; but only some of these issues are important while others have the perception of importance or simply reflect ignorance of the actual fishing operations.

Possibly the biggest challenge is to determine what is acceptable performance for a fishery. Given that all activities result in some level of alteration to the environment and that stopping an activity also has effects, the real question is: 'How do we determine when the level of change becomes unacceptable?' For example, in one of the case study workshops held to develop the ESD framework, one participant concluded that a rock lobster pot falling off a boat and chipping off a small piece of the limestone reef below was a catastrophic event and was therefore a major impact of the fishery. Is such a conclusion reasonable? Unless we use sensible levels of acceptable change in the EPBC process, leading to appropriate assessments of the adequacy of performance, significant discrepancies and difficulties will ensue.

Information levels

Another major issue relates to the levels of information available on which to base sensible assessments of performance. There are approximately 140 fisheries in Australia, 100 of which could be classed as data-poor even if only the information related to the target species is assessed. And that is the vast majority. Moreover, even those fisheries that are relatively data-rich are usually only data-rich in a few of the ESD components. In most cases once assessments move beyond the main target species, all fisheries have elements for which minimal data are available. So not having sufficient data is a problem that will affect the assessment of *every* fishery.

Is the answer to go out and collect more data? As explained in another paper presented at this conference (Chesson et al. 2002), collecting more data may sound great but in most cases the cost of doing so will mean it is unlikely to occur. Even if a fishery potentially has resources to collect data, the data collected may not be needed and resources may be wasted which could have been more effectively used elsewhere. In other words, an assessment of the real value of collecting extra data needs to be made before any new monitoring programs are initiated. In particular, one should first ask how will the data be used to effect management: if it will not change how the fishery is managed, why collect it?

Relationship between social attitudes and environmental impacts

Another potential problem is confusion of significant environmental impacts with changes in social attitudes. Like the dolphin example mentioned above, many issues are more about society's viewpoint from a moral stance and not necessarily a 'real' environmental issue. To give a non-fishery example, although forestry science can determine the intensity of logging of 'old-growth forests' and find the level where this is *environmentally* sustainable because of forest regeneration times, many people still protest against chopping any of these trees because they want to have 'old' forests, not just 'functioning' forests.

I think that social attitudes are likely to become even more important as drivers of natural resource management policy in the future.

Interactions amongst fishing sectors

One of the main problems that faces minor fisheries is that most of them catch a large number of species which are often targeted by other fisheries besides their own (including recreational and often other commercial fisheries). Many of these fisheries operate in high profile areas near large population centres where management decisions are significant politically. Moreover, there are usually limited data available for many of the species caught in the fisheries and it is likely that cost will preclude sophisticated stock assessments for all of the target species. In addition, any ecosystem effects will not be simple to address because little direct information will be available.

When ESD assessments are completed for inshore commercial fisheries, it is likely that recreational fisheries will need to be done at the same time because of the many issues interacting between fisheries. If there are 'no-take' areas present, they may need simultaneous assessment. This timing of assessments raises the ultimate aim of having effective regional marine planning policies, and for that we will need to have an effective framework to tie the issues together while using suitable allocation or reallocation mechanisms.

Possible strategies to deal with these issues

Scientific inference

A method that will be of great value if we are to deal with the breadth of issues that will confront most fisheries assessments over the coming years is the use of scientific inference; i.e. we should use all of our current understanding and knowledge. There is a vast wealth of material available in the scientific literature, and other resources, that can be used to assist decision making in an explicit matter. After all, there is a fundamental difference between 'uncertainty' and 'no knowledge'. There are a few issues for which we have no knowledge but I know of no issues for which we have full certainty.

Implementing the Precautionary Principle

At this point it may be useful to expand on the Precautionary Principle which states that *'the absence of full scientific certainty should not preclude action where irreversible or major detrimental effects are possible'*. This does not mean, however, that full certainty about all potential impacts is required before an activity can proceed, but rather that the level of caution required to allow an activity needs to be proportional to the level of potential impacts, the level of information available, and the safeguards and review periods imposed.

Risk assessment

I see that the risk assessment methodologies will be useful tools to assist in prioritising how issues will need to be addressed. All fisheries have been managed using a risk assessment approach to minimise the risk of overfishing. Whereas previously this was done implicitly, we now must move to a more formal, transparent process to satisfy community concerns. To assist in this process, a part of the National ESD Reporting Framework includes a set of Consequence tables and Likelihood tables that can help to determine the materiality or priority of issues.

Retained species

The Consequence table developed for retained species includes a gradation of impacts from negligible (for which there will be no measurable effect on the species) to a catastrophic impact where local extinction will occur (details in Table 1). Most fisheries should be operating at a level which avoids having more than a moderate level of impact; i.e. where the fisheries are considered to be at full exploitation but exhibit little chance of recruitment overfishing.

We know the general dynamics of most fish species and have some understanding of what potential effects their life histories can have on their vulnerability to fishing. What we need to do when assessing the risks associated with having a fishery is to ensure that the level of data available is appropriate for the exploitation rate applied to the stocks and the vulnerability of the species involved. Thus, the higher the level of risk or harvesting, the greater the level of information that will be needed to manage the fishery.

Determining the risk for each species involves assessing a number of factors including its growth rate, longevity, migration and dispersal of larvae. For example, if a fishery catches a species that has limited dispersion, low fecundity and is long-lived, taking a limited data approach may not be acceptable for monitoring its performance.

There is value in understanding the total distribution of a species in relation to the area where it is allowed to be fished. If there are ample refuge areas, then having detailed data may not be necessary because the availability of refuge areas should ensure sustainability.

In summary, if a species does not have a high exploitation rate, catch and effort are likely to be sufficient to monitor performance. If the species is high risk and requires aggressive management, maximum information may be required (Table 2). In circumstances where there is a very high exploitation rate and little information is available, either the level of data must be increased or the exploitation rate must be reduced. The choice between these two options should depend upon the value of the fishery and its capacity to fund the monitoring.

Ecosystem impacts

With respect to assessing the broader ecosystem, there are many issues that could be affected by the operation of a fishery. Risk assessment methodology is a good way of determining which issues are sufficiently important to deal with in addition to the maintenance of the target stocks. As stated above, the major issue is how much change would be acceptable to the ecosystem.

A few concepts to keep in mind when assessing ecosystem effects and fishing include the following.

- Unlike agricultural systems, which generally rely on replacing a natural ecosystem with an altered state to produce a crop, continued fisheries production actually requires the natural ecosystem to be functioning to enable continued production.
- Fishing often occurs on many species within an ecosystem and therefore much could be learned from the data generated by all the fisheries in an area.
- Because fishing in most areas targets species representative of most trophic levels, if the ecosystem changes were significant it is likely that any indirect effect occurring to the community would be reflected in changed abundance or behaviour of at least some of those species.

Some very interesting scientific studies on trophic interactions have shown that reduction in a key predator or prey species can lead to major changes in ecosystem functioning, but such results are relatively rare. It is generally the case that only the studies revealing strong interactions are published; hence the literature is somewhat biased towards these. I believe that there are probably many unpublished studies that report only weak interactions.

I consider of greater importance the fact that I could not find one example of a fishery (i.e. the initial target species) that indirectly affected other trophic levels and which was still in good condition. Thus it seems that these ecosystem changes or trophic cascades only occur after a fishery has collapsed or has suffered a significant decline.

We already have a reasonable understanding of the physical impacts that each of the fishing methods has on benthic habitats. Consequently, conducting a specific study may not be necessary unless there is a need to show that a particular area is different. The easiest method of dealing with such issues is to leave areas of the habitat unfished with the relative amount left untouched increasing as the destructive nature of the fishing method increases.

Finally, I need to highlight that ecosystems vary naturally due to shifts in local climate, oceanography and random factors. Thus, they do not have some predefined “inviolate” state. There is no absolute state of equilibrium that must be “achieved”.

In summary, if there is a fishing activity that does not have a great deal of impact, it may occur everywhere; but if the fishing method is likely to have a big impact on the habitat, then it must be constrained and the level of constraint will depend upon the level of direct impact. In terms of trophic level effects, if there are no strong interactions, it should not be necessary to take this into account when determining the maximum exploitation levels for target species. However, if the target species is known to be a key species and the whole community is likely to change if such a target species’ population is altered, then more precaution will be required.

There was initially a fear that comprehensive studies and monitoring of ecosystems would be needed for every fishery. This should not, however, be the case. For some fisheries we may only need to articulate why such studies are not required; other fisheries may require more data to enable such a justification to be made; for yet other fisheries, an adjustment in their management strategy may be needed. Only for a small group of fisheries may explicit monitoring of community structure be needed.

Conclusion

ESD and all the other three-letter acronyms are now here to stay in one form or another. Whilst they will undoubtedly require a degree of thought for their implementation, if handled correctly they should mostly result in change to the way things are done and not a huge addition to what is done. The increased transparency of process that will result from their adoption will greatly increase the possibility of gaining broader community acceptance for our management decisions. Community acceptance is fast becoming the most important criterion for evaluating natural resource management agencies – just ask the foresters!

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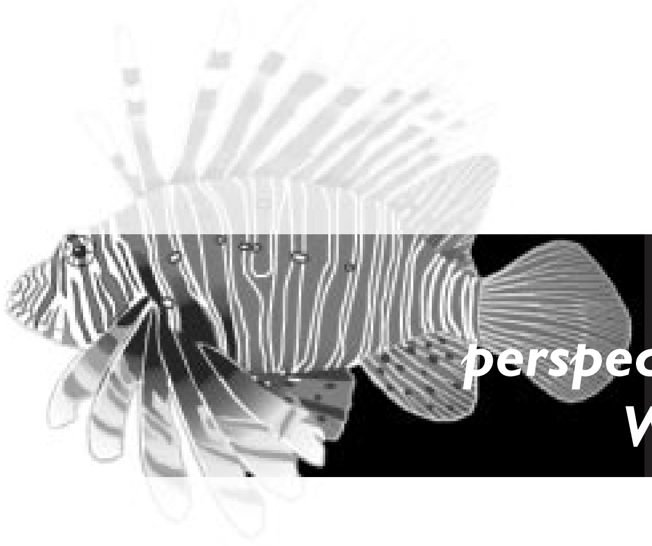
Table 1. An example of the consequence levels used in the National ESD Reporting Framework: retained species (target stock) (see www.fisheries-esd.com for full details of all seven Consequence tables and the full risk assessment process).

Level	Ecological issues (target species impacts)
Negligible	**Target**: Undetectable for this population *No recovery time needed*
Minor	**Target**: Possibly detectable. Little impact on population size but none on their dynamics *Rapid recovery would occur if stopped - measured in days to months*
Moderate	**Target**: Full exploitation rate where long term recruitment/dynamics not adversely affected *Recovery probably measured in months to years if activity stopped*
Severe	**Target**: Affecting recruitment levels of stocks or their capacity to increase *Recovery measured in years if stopped*
Major	**Target**: Likely to cause local extinctions *Recovery period measured in years to decades if stopped*
Catastrophic	**Target**: Local extinctions are imminent/immediate *Long-term recovery period will be greater than decades or never, even if stopped*

Table 2. Relationship between exploitation rates and information levels.

Exploitation rate/risk	Likely indicators/Limits required
Low	Catch or effort only/crude CPUE
Moderate	Reasonable CPUE. Possibly some extra/occasional biological sampling
High	Good CPUE and/or fishery independent surveys; probably biological sampling, leading to estimates of biomass and/or exploitation rates



A conservation sector perspective on ESD assessment in Western Australian fisheries

J. N. Dunlop

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Introduction

The current initiatives in the reporting and auditing of ESD in some Australian fishery jurisdictions are being followed with interest by the conservation sector, as are the Commonwealth's environmental assessment processes. The Department of Fisheries, WA farsighted, systematic and consultative approach in developing processes for ESD accountability has been welcomed by the conservation sector. In many ways the Department of Fisheries, WA is in the vanguard of incorporating ESD reporting into renewable natural resource management and the techniques being developed for fisheries may well have applications in land and soil management, water management, forests and nature-based tourism.

The WA conservation sector understands that the processes being developed for ESD assessment will continue to evolve over time and as such we have chosen not to "die in a ditch" over what we see as the current deficiencies. Many of the problems may only be solved when other agencies and economic sectors reach a similar stage in sustainability assessment, or better mechanisms are established to provide for a "whole of government" and ecosystem-based approach to ESD.

The conservation sector has identified several problem areas with respect to the current Standing Committee for Fisheries and Aquaculture (SCFA) ESD reporting and Environment Australia (EA) environmental assessment processes. These are:

- fisheries environmental assessment and ESD reporting in the context of ecosystem-based management; and
- the use of risk assessment to cover the ecological knowledge gap.

Ecosystem-based management

The national response to the emergence of ESD principles was organised on the basis of economic sectors (CoA 1991). This may have been a mistake because it mitigated against a systems approach to the problem. In the case of fisheries, it is difficult to set ESD objectives in the absence of over-arching ecological objectives for marine bio-regions or aquatic/estuarine catchments. Fisheries impose significant pressures on marine ecosystems but there are cumulative impacts from a range of anthropogenic sources. The objective setting process for ESD needs to address a range of questions that extend well beyond the historical domain of fisheries management.

- What are the limits of acceptable anthropogenic change in the aquatic ecosystem and how can these be used to set ecosystem-level objectives?
- To what extent should fisheries be permitted to contribute to change in aquatic ecosystems? What are the ecological objectives for fisheries? How are the acceptable levels of impact to be allocated between the sectors (e.g. wild fisheries, aquaculture, marine tourism, transport, offshore petroleum)?
- How do the various sectors/agencies share the responsibility for ecosystem-based management? How do fisheries management structures engage with other users?

The concept of ecosystem-based management underpins ESD but at this stage there has been no serious attempt to introduce it in Western Australian or Commonwealth fisheries. An ecosystem-based approach to fisheries management might be reflected by the following characteristics.

- The point of reference for fisheries management performance shifts from the fishing operation to the key interdependent components of the fished ecosystem.
- Fisheries management is conducted on a bio-regional (rather than on a stock distribution) basis under a set of objectives agreed by all stakeholders that address the cumulative impact of all human activities on the ecosystem. Under this approach the definition of individual fisheries may have to change from management units based on attributes such as target species, zone, and gear/fishing method to units defined by the ecosystem components such as the food chains or benthic habitats in which the fishery is operating.
- Performance measures include indicators of ecosystem condition as well as of operational outcomes. This will often require the existence of unfished reference areas within fishing grounds.
- Research and monitoring projects encompass interdependent ecosystem components that are not harvested or directly affected by fishing operations. In most cases a component at a trophic level above and below the target species level will be monitored. Monitoring designs that allow for the discrimination of fishery-induced changes from natural variations, and from the impacts of other human activities (e.g. climate change and land-based pollution) will also need to be developed.
- Data on ecosystem state will be collected using a range of fishery and fishery-independent sampling methods. (The current reliance on research by autopsy would not be acceptable in an ecosystem-based management regimen.)
- Decision rules will be constructed to provide for early and precautionary responses to unacceptable levels of ecosystem change.
- Whilst remedial measures will involve operational factors in the fishery the point of reference for measuring performance remains the ecological response. For example the Key Performance Indicator (KPI) for albatross mortality in a tuna and billfish fishery is the recovery of albatross populations not just improved bycatch statistics.
- The fishery is managed to facilitate benefits to the fishing and non-fishing sectors. For example marine no-take areas may have limited application for stock conservation in the Australian context but may be established by fisheries managers in order to meet wider community biodiversity conservation, scientific reference and other objectives.

Clearly these characteristics of ecosystem-based management are not currently within the scope of fisheries agencies. Fisheries management will not be able to "go it alone" in moving towards this sort of approach. In the meantime fisheries environmental assessment will occur without a viable planning framework and fisheries management will be based on essentially operational objectives with unknown and unspecified ecological outcomes.

Environmental assessment processes generally have two failings. Firstly they are project or activity focused and do not account for cumulative effects on ecosystems. Secondly, they place the onus of proof on respondents rather than proponents or operators. This second failing has become a matter of concern in the risk assessment processes that have been adopted to deal with the lack of information on the ecological effects of fishing.

Risk assessment

Both the SCFA ESD reporting and EA environmental assessment processes are utilizing risk assessment to deal with questions about the environmental and ecological effects of fishing. There are two perspectives on the purpose of risk assessment:

1. a rigorous discipline used to identify and prioritise the issues requiring management action; or

2. a rhetorical device used to argue that there is no problem or need for management action.

The outcomes may be largely determined by the underlying motivation.

From the conservation sector's point of view the credibility of any particular risk assessment will depend on how well the risks can be estimated from the monitored history of the activity. In most Australian fisheries there is little or no information on the structure of biotic communities prior to the introduction of intensive fishing activities or of how they have changed with fishing effort. The fishery situation is a bit like looking at apparently intact stands of native terrestrial vegetation today without the knowledge of what has been lost due to subtle changes in fire patterns. Without historical information it would be easy to draw the wrong conclusions about the condition of an ecosystem and the ongoing impacts of fishing or to set ecological objectives.

Reference

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Theme Session One

Discussion, questions and answers

Rapporteurs: Mervi Kangas and Jill St John

Gary Jackson (Fisheries, WA) asked Mark Flanigan (Environment Australia) or Rick Fletcher (Fisheries, WA): “Given the complexity (of ESD requirements), if the trigger for running the fisheries through the ESD process is signing off on the export market, how can ESD accommodate recreational fisheries, which in some areas is as large as the commercial sector?”

Mark Flanigan responded that within the scope of the guidelines set by Environment Australia, managers need to look at what other take there is in addition to the commercial take (such as the recreational take) and factor this into management decision making. This analysis ultimately leads to an allocation decision between sectors, and needs to be addressed by managers. The demands from the ecosystem, indigenous use and recreational and commercial operators should all be managed within the context of the biological parameters of the fishery.

Rick Fletcher (Fisheries, WA) also noted that in Western Australia, all fisheries will be assessed regardless of export basis. “As Peter Rogers pointed out in his welcoming speech, state based assessment will occur under our own EPA (Environment Protection Authority) and the office of the auditor general. All fisheries will be assessed directly or indirectly.”

Tony Fowler (SARDI) asked Mark Flanigan: “Who is responsible for driving the whole process of ESD reporting?” Tony wondered if Environment Australia has a responsibility to take fishers and fisheries agencies through this process.

Mark Flanigan replied that in a legislative sense EA is responsible, but because it runs the process it is doing it in a similar way to a standard environmental impact assessment, in that the proponent, the fisheries manager (who is making the management arrangements), asks the fishers to prepare an assessment report against the guideline in the first instance, and then the fisheries manager runs that report through the public consultation process. There is an option for the States to not only write the report, but also to run the public consultation process, as is being done in NSW. EA stays involved in the process and in the end takes its comments to the Minister. It is looking to managers who know the basis of the judgements they make with respect to managing their fisheries to write the justifications and then takes these into the public arena.

Tony Hart (Trophia) wondered where the idea of splitting issues into generic component trees came from. He thinks that these hierarchical boxes do not suit all people who may have a different view of the world.

Rick Fletcher highlighted that it is an interactive process and that this type of approach has been used before. For example, Jean Chesson used a hierarchical approach to identify issues in a sensible manner.

The ESD Reference Group (including fisheries managers, FRDC, EA, indigenous groups, recreational groups, commercial groups and a few other government agencies) met in June last year and spent time brainstorming which types of issues were relevant under those broad categories. However that discussion may not have been totally exhaustive. "It was a starting point and we wanted to be sure they had as good a starting point as we could develop, which others could adapt to their specific circumstances. It was not meant to be an absolute guide. We are only assisting people to conduct the process."

Mark Flanigan reiterated that from the EA perspective there is no compulsion to use these component trees as the basis of addressing issues within certain fisheries. The component trees allow the expansion of issues in a conceptual manner. He emphasised that the methodology was only a guideline even though it allows a fairly flexible approach to analysis of the various effects a fishery has on an ecosystem.

Peter Gehrke (Fisheries, NSW) raised some points of concern with the EA guidelines. Principal One of the guidelines makes the assumption that catch is not affecting population or stock size. This principal presupposes you have sufficient data to estimate the stock size accurately in the first place, and you are able to estimate what is a reasonable allowable catch. "Given that when history suggests the best available data doesn't provide any guarantee against stock crashes and stock sustainability – and also that most of our fisheries are data-poor – the best conclusion you came up with is to take a precautionary approach and to take a look at analysing uncertainty and risk assessments, this doesn't necessarily give a lot of confidence about the outcomes; except that there is a system of accountability if something goes wrong, and at least we can show the process we used to reach that outcome."

Mark Flanigan supported Peter's view in that often there is not good information, even on setting target species catch. "We are quite confident that the process, being a logical approach to justifying management arrangements, is far better than the existing situation whereby we just go along until the fishery crashes, and at that stage we can determine at what point we can induce a stock collapse, then we can restructure the fishery by working backwards. If you don't have the data and information and you don't have a robust system and are not confident that you know what the stock exploitation should be to ensure sustainability, then we say start winding back your management settings. There might be some short term cost in terms of economic return but you have a much more secure position in the long term and a much more secure economic position for fishers if you approach cautiously to the point of sustainable exploitation. This also raises another aspect with respect to data: in some fisheries there is no point in spending money in getting more information, but you should maintain a precautionary approach by keeping harvest levels at low levels."

Norm Hall (Murdoch University, WA) addressed a question to Mark Flanigan that "surely there is another approach to just using the precautionary principle. That would be to ensure that you have monitoring and feedback mechanisms so you can adjust management strategies in the face of declining stocks or if the system is getting out of sync."

Mark Flanigan agreed that this approach is fundamental to management. "For example, if you are looking at an issue such as bycatch, vulnerability analysis of bycatch species has been done for the Northern Prawn Fishery." However, there is currently no composition monitoring or any monitoring program using the knowledge of those species that are vulnerable to detect whether any changes are taking place to these species. What we want to see is consideration of the things we put in place to tell us if our assumptions are wrong and whether we see an impact emerging. "What should we be monitoring, at what scale, what is reasonable, and what indicators would we look for?" Managers need this information, as well as EA, to be coming through from the scientific community which often uses professional judgement initially, rather than a fully articulated scientific position. This information is best coming from the fishery scientists who understand it better than anyone.

Dan Gaughan (Fisheries, WA) wondered how the ESD process is going so far. Has it influenced the management arrangement of fisheries or harvesting levels of species; and if, at the end of 2003, there are no tangible differences in fisheries, will the conservation groups have a different view of the process than that they currently hold?

Mark Flanigan agreed this was a great problem with smaller fisheries. The assessment process has changed the management arrangements in a number of these fisheries. For the ones that are being currently assessed it is hard to say since most ESD risk assessment is still developing. A couple of examples: in Tasmania management strategies are being revised and this process is therefore having some impact. He also noted that recognition of benefits does not always occur. This was often the case when he worked in Regional Planning – "you never get to back the winners because people change their behaviour before you get to report the change but often have to cop the losses". If there are no significant gains in the industry then we need to reassess after 2003. Overall this is really putting good approaches to management and putting external rigour on the process whilst putting another jurisdiction into the mix. It is going through the process of documenting what should be good practice and in that sense we will see a gradual change over time. As an example he quoted the Tasmanian king crab fishery from which, for political and other reasons, exports had to be closed for two weeks. Environment Australia does not want this to happen again in any other fishery, as this is not in everyone's best interest.

Summary of Theme Session One by Rick Fletcher

- The whole of government needs to be involved in the process, although this needs to be at a slightly later stage in the process than where we are at now. Liken it to running before you can crawl if we try to incorporate all agencies now. The timing of this should occur when the process already has some momentum.
- There should be limits to the acceptable change to an ecosystem.
- The risk assessment technique described is problematic and the choices need good justifications to be acceptable. Take note of Nic Dunlop's concerns about this approach.
- Acknowledge the need to improve the process – it is currently evolving.
- Environment Australia recognises that there are data-deficient fisheries around.
- It is important to get a better public acceptance of the process and the justifications. Need to get NGOs comfortable with the process to accept the outcomes.

THEME SESSION TWO
Multi-sector aquatic resource status – past assessments, future problems?

Chair: Rod Lenanton

Historical fishery attributes and changing management expectations – a mismatch?

R. C. J. Lenanton

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Abstract
New ecologically sustainable development reporting requirements are forcing fishery managers to revise both the way in which fisheries are managed, and the directions of research and monitoring in relation to assessment of the status of the resource, the fishery and the supporting ecosystem. Nowhere will this change be more acutely felt than in the country's oldest and economically poorest, but arguably culturally richest fisheries. In order to resolve this issue, and have a clearer understanding of where we need to go in the future, we need to understand where we have been in the past. Highlighted as an introduction to this session are some of the characteristics that illustrate the mismatch between past fishery attributes, and future management and reporting expectations.

Introduction
Over past years, while the wider community has received specific high-quality advice on the status of retained species targeted by most of Australia's key fisheries, it has received at best, only broadly precautionary advice about the impacts of fishing on other components of the fish community and the ecosystem on which the fish depend. The community however, is no longer satisfied with this level of advice. Instead, it is demanding that the assessment of the impacts of fishing comply with Ecologically Sustainable Development (ESD) reporting requirements in their broadest sense, including benefits and costs, i.e. making explicit what for many years has been implicit. Nowhere will this change be more acutely felt that in the numerous inshore coastal, estuarine and freshwater wild harvest fisheries distributed along the entire Australian coastline. In the words of Gibbs (2000), as we focus on such fisheries, we are dealing with 'a dynamic complex multi-species and multi-harvest system with limited information'. Thus while the larger, more profitable fisheries (mostly invertebrate) are able to generate the level of funding required to support the assessment and reporting process, the numerous less profitable fisheries do not. The latter are mainly finfish fisheries, and include commercial and recreational fisheries, customary fishing, and non-extractive activities such as diving, with the predominant focus on inshore coastal, estuarine, and freshwater environments. Given the likelihood that these funding inequities will worsen in the near future, there is an urgent need to think of more innovative ways of 'doing more with less'.

The outcomes of this workshop may provide at least some solutions to this daunting problem. So that we can effectively move forward however, it is important that we first understand where we have been in the past.

Historical attributes and future needs

During the preceding session, the emerging issues and needs of fisheries management have been identified, together with the Standing Committee on Fisheries and Aquaculture (SCFA) conceptual reporting and assessment framework developed to address these needs. Broadly speaking, this framework covers both ecological and human well-being, and the means of achieving both. Management expectations delivered through the governance process as identified in the national ESD reporting framework will be in four main areas: captured species, environment, social well-being and economic well-being. Performance indicators need to be developed in each of these areas, and performance measures (against targets and limits) need to be determined in order to meet operational objectives that will deliver ecological sustainability. In the areas dealing with captured species and the environment (ecological well-being), we currently have a relatively poor understanding of the collective impact of the multi-sector, multi-gear fisheries involving a suite of coastal and inland species with complex and dynamic life histories. Thus there is a 'mismatch' between our current understanding and the level of understanding needed to successfully complete the required ESD assessment and reporting. This situation has been formally acknowledged and is now being addressed in Western Australia, through the Integrated Fisheries Management (IFM) initiative (Government of Western Australia 2000), and an associated review into customary (subsistence) fishing.

Particular characteristics of these older traditional coastal and inland fisheries have compromised the effective use of available fishery-dependent data in stock assessment and evaluation of fishery performance and, under the new and more demanding ESD reporting process, they will continue to do so. For commercial fisheries, these characteristics include:

- multi-species fisheries targeting a large range of finfish and/or invertebrate species;
- lifestyle/opportunism of fishers;
- variable market demand;
- significant fishery interrelationships, where effort expended often depends on performance of other fisheries;
- small sustainable catches of individual target species;
- relatively low value of the catch; and
- spatial heterogeneity of catches.

Stocks of many species are exploited by both commercial and recreational sectors, and within the commercial sector often by a number of independently managed fisheries either located entirely within one region, or spanning several regions. (Sea mullet, *Mugil cephalus,* and various shark species provide examples of stocks taken by a broad range of managed fisheries.)

Several other factors have compromised the use of data from commercial fisheries and two of them are cited here. Confidentiality provisions around the use of commercial catch and effort data collected during periods of low fisher participation have created additional problems over recent years: there is an urgent need to relax these provisions and thus maximise access to all available data. The commercial catches of non-target species have been poorly documented, and often the precise identification of these species has either been poor, or lacking altogether.

As a consequence of the shift from predominantly commercial to predominantly recreational fishing in recent years, fishers in some regions (e.g. Leschenault Estuary, Western Australia) are now exclusively recreational. Unlike commercial fishers, recreational, and to a large extent customary, fishers are primarily motivated by a desire to catch a feed and enjoy the experience, i.e. they are driven by lifestyle considerations. There are a large number of recreational and customary fishers and individually they take an extremely small proportion of the stock on any given outing. Historically, catch and effort statistics for recreational and customary fishing were either not, or only infrequently collected.

The life history characteristics of both fish and invertebrate species targeted by these fisheries have also contributed to the difficulties encountered using fishery-dependent data in the stock assessment process and include:

- the complex life history of target species, with many species using rivers, estuaries and nearshore marine coastal embayments and other marine habitats either seasonally, or at different life history stages;
- variable recruitment, often environmentally driven; and
- the schooling/aggregation behaviour of certain species.

Further, stock abundance is often a consequence of factors other than fishing, and thus the management of the impact of these factors is outside the control of the fisheries management agency. For example, the capacity of many of the nation's estuaries and inland waters to support fish and invertebrate stocks has been severely compromised as a consequence of past catchment management practices.

Although beyond the scope of this workshop, future efficient governance is also likely to be complicated by past management arrangements. These management arrangements were often developed during the earlier history of older fisheries on an individual needs basis, with little understanding of the complex biology and ecology of the targeted fish communities or the need to evaluate fishery performance. Difficulties include:

- the absence of management plans for some of these fisheries;
- 'multifaceted management', implemented through a complex set of licence conditions, permitted gear, spatial/temporal closures, size and bag limits, allocated fishing time, and in some instances quota; and
- management objectives often poorly defined (when plans did exist) and often not linked to performance targets, because of the difficulty of developing measurable performance indicators in the absence of management strategies and specific management objectives.

Thus within the biological, socio-political and economic context, these older traditional coastal and inland fisheries are complex and not readily divisible into simple management components. From a governance point of view therefore, there is a real need to simplify management arrangements in many of them.

Despite these shortcomings, and often only with poor quality data, scientists and managers did have access to long time series of commercial catch and effort data to enable determination of the status of exploited target species, and access to a commercial catch from which to gather regular and representative biological samples. However the demise of many of these fisheries as the result of voluntary 'buy-back' of commercial access has rendered these catch and effort data sets far less useful for assessing the status of these stocks today. This means that there is now a far greater reliance on the recreational sector and/or independent surveys to provide the data that is needed to satisfy the reporting needs of ESD.

When considering the best use of these data, a key question is how far has the emphasis shifted from management of fisheries in which the primary objective is the maximising of sustainable yields of exploited target species to ecosystem management which may result in less than optimal yields from target species in order to meet ‘ecosystem’ objectives.

Case history - Leschenault Estuary

An interesting and very relevant example of the type of problem that the managers of coastal and inland fish and invertebrate resources are facing is provided by the situation in the Leschenault Estuary, a system situated to the north of Bunbury, Western Australia (Figure 1).

Fishing was established in this system during the 19th century (Lenanton, 1984) and has persisted through the 20th century. However there was no formal facility for the collection of fishery data until the introduction of a statistical system in 1941. Annual catch and effort data collected from the commercial fishery has provided the basis for management advice for the last 60 years (Figure 2a, 2b) (Potter et al. 2000). However from about the early 1980s, commercial participation rates began to decline primarily in response to an intensifying level of conflict with the recreational fisheries sector. This decline continued during subsequent years, accelerating further following the initiation of the Government-funded estuarine licence buy-back in 1986; and again after 1996 as a direct consequence of the further injection of funds into the Government-funded estuarine licence buy-back scheme (Fishery Adjustment Scheme). The decline in the commercial estuarine fishery culminated this year (2001) with the surrender of the remaining commercial licences. There is now no commercial fishery in this estuary, despite the available data indicating that the fishery was performing well up until its closure (Figure 2b). With it has gone the valuable historical catch and effort database, the ability to gather representative biological samples from the stocks of the main target species, and the collective knowledge of a group of fishers that had a daily presence on the waterway. The first and only recreational creel survey ever conducted in this estuarine system was undertaken in 1998 (Malseed, Sumner and Williamson 2000). During that year, the estimated recreational blue swimmer crab (*Portunus pelagicus*) catch was 48 tonnes, while the recreational finfish catch from the estuary basin was estimated to be less than one tonne. The principal species in the finfish catch were whiting (various sillaginids), tailor (*Pomatomus saltatrix*) and Australian herring (*Arripis georgiana*). The comparable commercial catch during that year was 88 tonnes, only three tonnes of which were crabs, and 70 tonnes of which consisted of sea mullet and yelloweye mullet (*Aldrichetta fosteri*), which are of little interest to recreational anglers. During the current financial year, under conditions of heightened recreational participation (which include the ongoing activities of recreational netters) there will for the first time in more than 60 years be no data available from which to determine the status of the stocks, or measure the performance of this fishery.

Which way forward?

Similar scenarios have been and will be played out in many locations around the Australian coast, with the balance shifting away from the commercial sector in favour of the non-extractive users, recreational and customary fishing sectors, and the conservation lobby (i.e. marine parks). However, despite the changing nature of our fisheries and the associated difficulties we are experiencing acquiring the data and developing new assessment methodologies, the Government still has a legal obligation under the new ESD arrangements to report on the status of the stocks being exploited in our coastal and inland environments. The following two speakers will provide a more detailed account of where we have been in the past before some of the likely solutions are discussed in the subsequent sessions of this workshop.

Acknowledgements

The assistance of Gabrielle Nowara is gratefully acknowledged. The Department of Fisheries kindly allowed me the opportunity to participate in this workshop.

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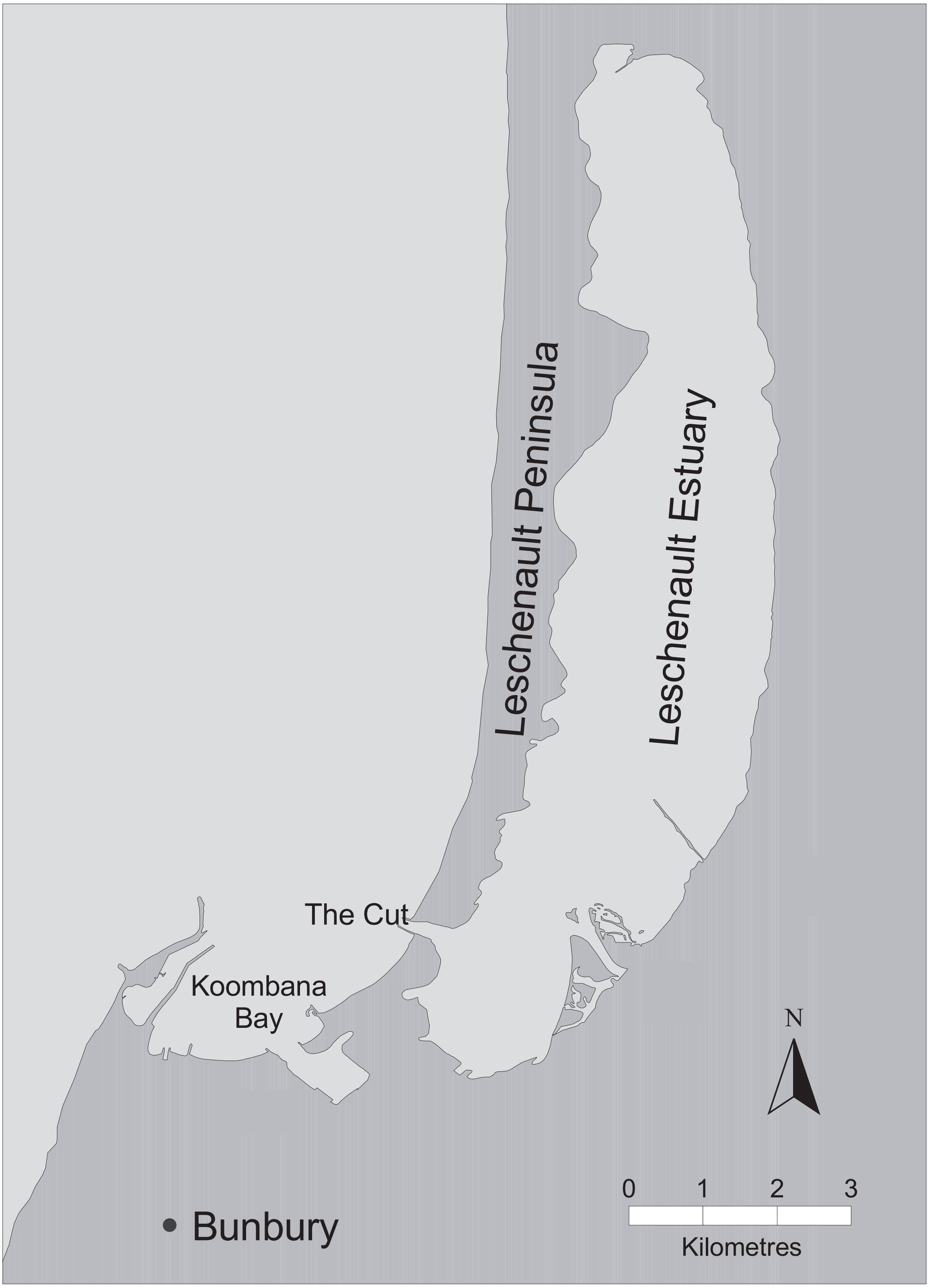

Figure 1. Leschenault Estuary.

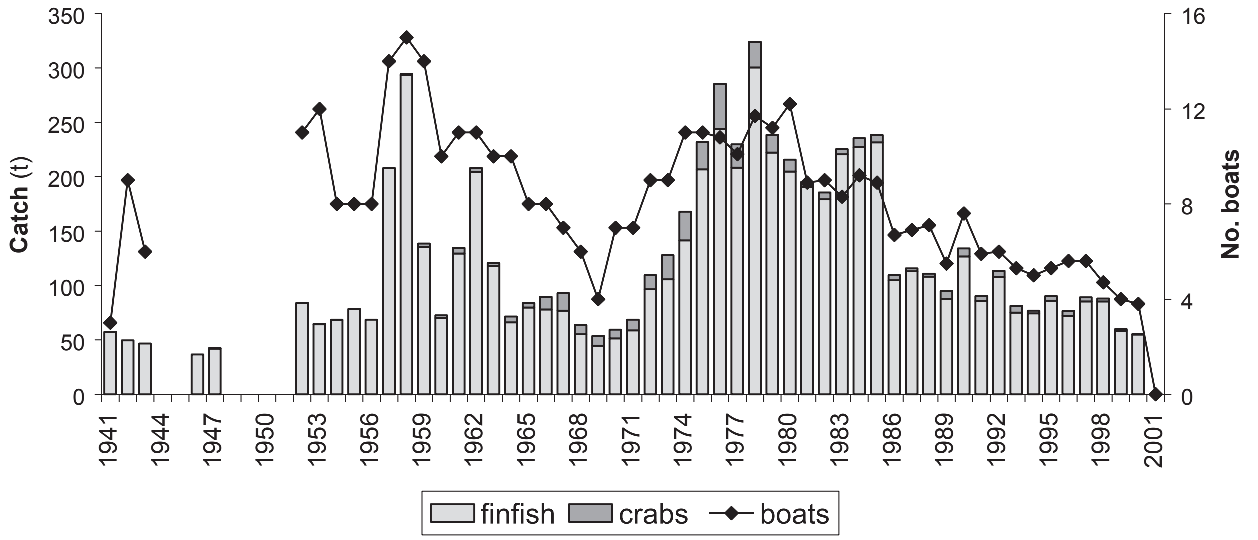

Figure 2a. The annual catch (tonnes) of finfish and blue swimmer crabs, and the number of commercial vessels operating annually on the Leschenault Estuary commercial fishery, from the commencement of the catch and effort statistical system in 1941, until the closure of the fishery in 2001.

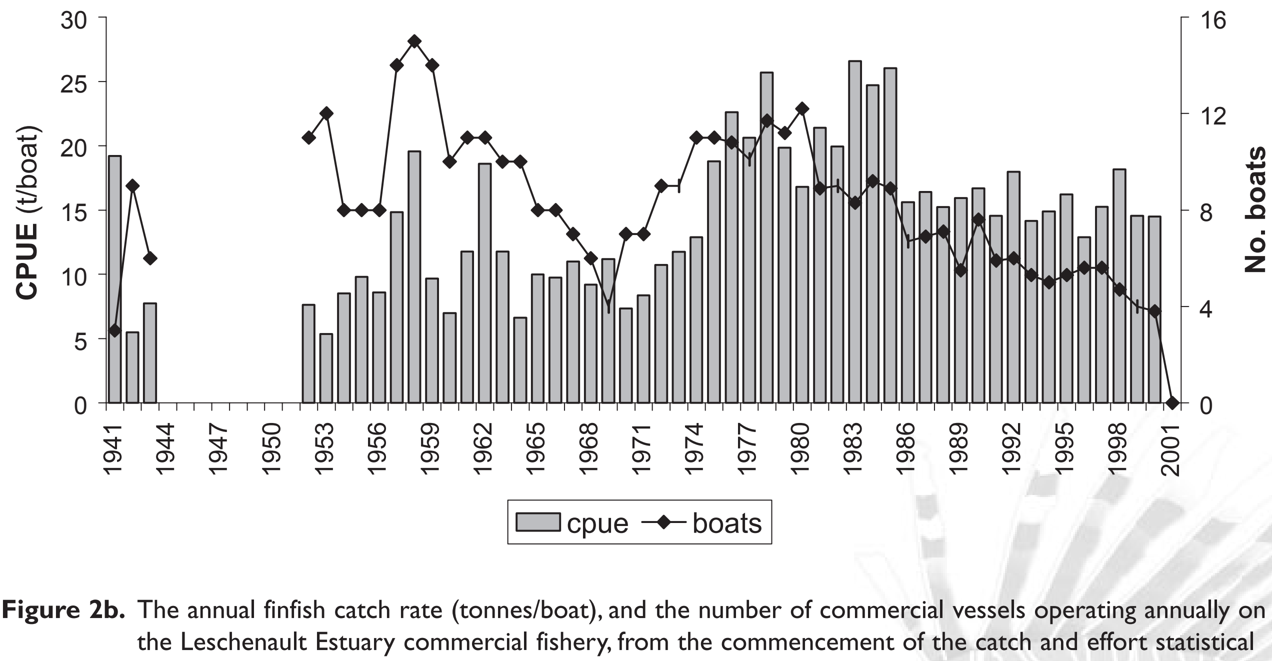

Figure 2b. The annual finfish catch rate (tonnes/boat), and the number of commercial vessels operating annually on the Leschenault Estuary commercial fishery, from the commencement of the catch and effort statistical system in 1941, until the closure of the fishery in 2001.

Nearshore and estuarine fisheries - or 'How did we get in such a state'?

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Abstract

The estuarine and nearshore fisheries of Western Australia may be characterised as multi-species, multi-gear, multi-sector finfish fisheries that are of relatively low value compared with the State's major rock lobster, prawn and shellfish fisheries. These fisheries are the target of most of the recreational fishing within the State, and are thus more likely to be affected by any increase in recreational fishing effort. While commercial catch and effort data for these fisheries are available, such data have been difficult to obtain for the recreational sector. Furthermore, although biological data are available for many of the more important fish species in the fisheries, biological data for other species are limited as are data on age and length compositions of the stocks involved. Past stock assessments for these fisheries have often ignored the lack of data from the recreational fishery, or have made strong assumptions to overcome the deficiencies. However, the inadequacies of the data and resulting imprecision of stock assessments can no longer be overlooked. Strategies to improve data collection, and models that are capable of using the types of data that can be obtained from these fisheries, are urgently required.

History of Western Australian stock assessments for estuarine and nearshore fisheries

The estuarine and nearshore commercial and recreational fisheries of Western Australia are invariably multi-species and focus on a variety of finfish, which are fished with a number of different fishing gears. The recreational fishery is a significant component of these fisheries, taking a considerable proportion of the annual catch. The nearshore fish stocks and the fisheries that exploit these stocks have a wide spatial extent and their distribution is heterogeneous, with fishing activity often concentrated around human population centres. Although the fisheries are of considerable importance to the community, they have relatively low value compared with the major fisheries of Western Australia, such as those that exploit rock lobster, prawn, scallop and abalone.

As a consequence of their value, considerably less investment has been made in obtaining research information for these fisheries than has been applied in the major fisheries of the State. Catch and effort data from commercial fishers are often obtained for the estuarine and nearshore fisheries from a small number of fishers in mandatory monthly reports to the Department of Fisheries, WA. Because of the small number of fishers, the data are often imprecise and provide only sparse coverage of the fish stocks and, furthermore, confidentiality concerns restrict access and publication of the commercial fisheries data. Data on discarded or released fish are rarely obtained.

It is only in the last decade that a strategy has been implemented to obtain regular catch and effort data from recreational fishers. Creel census surveys that have been introduced by the Department of Fisheries, WA are intended to provide information on the annual fishing activities of recreational fishers at intervals of approximately five years. These surveys have been supplemented by the recently completed National Recreational Fishing Survey (Fisheries Research and Development Corporation project), which provides a snapshot of recreational fishing throughout Australia.

Limited biological data often exist for the species that are exploited in these estuarine and nearshore fisheries. While information on weight-length relationships, growth curves and reproduction exists for the more important of the fished species, data are often lacking for many of the less important. Monitoring of the length composition of commercial catches for these fisheries has occurred occasionally on an ad hoc basis yet, until the introduction of the regular creel census surveys of the recreational fishery, limited data on the length composition of recreational catches were collected. Age composition data on the species, if they exist at all, are limited. Details of the fishing gear used in the fisheries, its selectivity, and/or of the technology that has been introduced to improve the efficiency of fishing methods, are rarely recorded or are unavailable. However, such gaps in knowledge are being addressed through research projects on some key species identified by fisheries managers and fishers as requiring study, and which have been funded by the Fisheries Research and Development Corporation.

Clearly, such inadequate data pose challenges for stock assessments, which must inevitably yield imprecise estimates of the current status of each of the finfish stocks. Prior to the 1980s, single species methods were applied to these stocks, thus ignoring the complexity of interactions between species or technological interactions that are brought about by fishers changing their target species or area of operations. Occasionally, the data for several species were combined and treated as those for a single ‘species’. With limited recreational data, stock assessment was often undertaken using only the data from the commercial fishing sector, thereby assuming that recreational effort and catch would have been proportional to the commercial effort and catch. To overcome the difficulties of different fishing gear, the equivalent effort that would have been required to take the catch obtained using a different fishing gear was calculated by dividing that catch by the catch rate of a standard gear, where the latter was usually the dominant fishing gear used by commercial fishers. However, the use of such effort measures usually ignored differences in the selectivities of the different fishing gears. Indeed, in many of the analyses, biomass dynamics models were applied, and gear selectivity was ignored under the assumption that it remained constant. The occasional measures of the recreational catch that became available were used to fix the magnitude of the recreational catch and allow extrapolation of the likely recreational catches in other years for which such data were not available.

More recently, in recognition of the multi-species, multi-sector nature of these estuarine and nearshore fisheries and the inadequacy of the data on the recreational catch and effort, time series approaches have been used in assessing the state of the stocks. These time series have attempted to use trends in catch rate and in catches to identify patterns and emerging problems. There have also been some attempts to use transfer functions and cross-spectrum analyses to relate multiple time series.

Recognizing the inadequacy of dynamic models with such incomplete data, attention inevitably turned to the use of equilibrium methods. The commercial fishery had provided the platform for obtaining samples for use in age, growth, and reproductive studies, and for obtaining data on the age or length composition of the catches. These data were used to derive yield per recruit and spawning biomass per recruit curves, while estimates of total mortality were obtained from analysis of age and length-based catch curves. The primary use of these data was to set appropriate minimum legal lengths, at or above the length at maturity, in anticipation that such controls might ensure that each female fish has the potential to spawn prior to capture.

The introduction of recreational fishing licences for some species, such as the western rock lobster (*Panulirus cygnus*) and abalone (*Haliotis* spp.), provided both a measure of participation by recreational fishers and a target population for statistical surveys. Regular mail surveys were conducted of some licensed recreational fishers, resulting in a time series of estimates of recreational catch that could be used when fitting dynamic models for the fishery. However, the spatial and temporal distribution of recreational catches and recreational fishing effort are not always the same as those of the commercial fishery, particularly in the case of the western rock lobster fishery. While the collection of such recreational data represented a major advance for our stock assessment of some of the estuarine and nearshore fisheries, the resolution and precision of the recreational catch and effort statistics still restrict their use in more detailed analyses of the data.

Our stock assessments have attempted to overcome deficiencies in data quality through the use of strong, but potentially erroneous assumptions. As an example, consider the stock assessments for the barramundi (*Lates calcarifer*) fisheries in the north-west of Western Australia. For these fisheries, random samples were drawn from statewide estimates of the rates of increase in recreational fishing participation, and were used to generate a time series of random values to represent the relative increase in recreational effort in the fishery through its history and into its future. The index of recreational effort was set to one for the current year. An estimate of the recreational catch was then randomly selected from a uniform distribution representing the range of estimated catches for the current year, which had been subjectively estimated by experienced research scientists. By comparing this estimated recreational catch to the current commercial catch, an estimate of the relative catchability of the recreational sector was obtained. Using this, together with the time series of relative effort levels for the recreational fishery, the time series of recreational catches was calculated. A biomass dynamics model was then fitted to the combination of recreational and commercial catches. The results of the analysis were stored, and the entire process repeated for a large number of trials. The resulting range of estimates was considered to represent the range of alternative scenarios of historical catches and was used to determine the likely outcomes of several different management strategies. Although the resulting assessments are the best currently available for Western Australia’s barramundi fisheries, the results are highly dependent upon the assumptions that were made. The truth is that we have no data on the catch of barramundi that is actually taken by the recreational sector. Assumptions are an inadequate proxy for research data!

The future

While innovative approaches such as that used for the barramundi fishery, or equilibrium approaches such as those used in many ‘per recruit’ studies, provide useful information for the management of our estuarine and nearshore fisheries, they are unable to identify the precise status of stocks or to allow assessment of the effectiveness of alternative management strategies. Prior to the 1980s, fisheries modelling and stock assessment was focused on major limited entry fisheries and there was little concern for the less heavily exploited finfish stocks of the estuarine and nearshore environments. In those early years, the approaches used to model the finfish stocks were adequate given the levels of exploitation that existed. However, increasing levels of exploitation and growth in participation in recreational fishing are placing greater pressure on fish stocks. This increasing pressure is leading to concern regarding the levels of exploitation for many finfish stocks, and there is an increasing need to ensure that management controls are effective in ensuring the sustainability of those stocks. In Western Australia, there are currently no controls that constrain the growth of the recreational fishing sector, and other controls, such as bag limits, size limits, gear controls and spatial or temporal closures, must be relied upon to constrain exploitation.

Adequate models that allow the assessment of the stocks of Western Australia's multi-species estuarine and nearshore fisheries are urgently needed. Exploitation is increasing, yet such increase is likely to be unsustainable, resulting in greater demand for appropriate stock assessment advice to balance precaution with optimal resource utilisation. Our models of these fisheries are inadequate and cannot ensure effective management controls. The lack of time series data on total catch and effort has constrained the use of traditional dynamic fisheries models. Furthermore, with an increasing share of the catch in many of the nearshore and estuarine fisheries gradually being re-allocated from the commercial to the recreational sector, the inadequacy of data will increase and commercial fishery statistics will become more imprecise.

It is unlikely that additional resources will become available for more research, yet there is increasing demand from managers for the scientific advice necessary to develop strategies that maintain the fisheries. Clearly, if models are developed using inadequate data, the uncertainty needs to be exposed to ensure that an appropriate level of precaution is considered when management plans are developed. Furthermore, feedback mechanisms should be established to ensure that, should the ecosystem move beyond the limit reference points, exploitation is reduced sufficiently to ensure recovery!

Conclusion

The inadequacy of past data does not preclude the establishment of improved systems of data collection. Systems that ensure continued collection of reliable data that are sufficient to monitor the fishery and provide necessary feedback must be established, particularly in those fisheries in which the recreational sector becomes the sole or major participant. For such systems, consideration may need to be given to the use of research surveys rather than the collection of fishery-dependent but less reliable data. Future stock assessments will need to use the limited data that are available, and to explore the uncertainty associated with those data. Strategies to manage recreational fisheries will need to be developed that will be responsive to the limited feedback (data) that may become available. Closed loop models are one strategy whereby the robustness of management strategies can be tested.

Acknowledgements

Drs Rod Lenanton and Suzy Ayvazian, and Ms Gabrielle Nowara, are thanked for their advice that aided in the development of the barramundi model. They, together with other scientists and fishery managers at the Department of Fisheries, Western Australia, contributed in many discussions to the concepts that are presented above.

Sustainability targets for integrated management of freshwater fish resources in the face of data uncertainty

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Abstract

Australia's freshwater fish resources are nationally in a state of decline. The severity of decline ranges from serious to unknown in different regions.

To sustain Australia's freshwater fisheries the fish resources need to be rejuvenated – not merely protected – and the ecological processes on which fish populations depend need to be rebuilt. Because of the complexity of interactions between species and between different trophic levels, managing fish stocks using targets based on the sustainability of individual species is unlikely to ever achieve ecologically sustainable development of a fishery. Whilst setting targets for recovery or rebuilding can be problematic, the adaptive management approach allows a trajectory of recovery to be defined, with performance criteria assessed by scientific monitoring programs.

Freshwater reserves have potential to provide large-scale spatial and temporal refuges from exploitation and environmental degradation, without the need for accurate stock assessment data and models. Future data requirements include indicators of ecosystem condition with fish indicators derived from recreational fisheries, commercial fisheries and independent surveys.

The outlook for sustainability of freshwater fisheries is uncertain. The concept of restoring or rebuilding an ecosystem involves the assumption that processes of decline are reversible, and that a system will revert to its previous condition once the threatening processes are removed. However, this assumption needs to be validated. The success of rebuilding is likely to be dependent on the level of commitment to adaptive management.

Introduction

Rivers have been identified as perhaps the most endangered ecosystems on a global scale, because of the way they are exploited for human water supply, agriculture, industry, water storage, power generation, and harvesting of biological resources. Harvest fisheries typically have low commercial value compared to other river-based industries, with the result that the environmental requirements for sustainable freshwater fisheries often receive low priority in political decision-making processes (Welcomme 2001). The sustainability of freshwater fisheries is therefore strongly determined by decision-making influences beyond the realm of fisheries management.

In this paper I attempt to identify targets for the long-term sustainability of Australia's freshwater fish resources by discussing their status at national level.

Status of freshwater fish resource sectors

Freshwater fish resource sectors can be divided conveniently into anthropocentric sectors focusing on commercial, recreational and indigenous uses, and ecocentric sectors emphasising conservation-based and public ownership uses. Each sector is likely to have different understandings of the concept of sustainability.

To establish realistic sustainability targets for fisheries based on native freshwater fish species it is necessary to consider the national status of the resource. An informal survey of fishery scientists from each State or Territory jurisdiction provided the overview that in the eastern mainland of Australia the native fish resource is either in a state of serious and continuous decline, or had undergone a decline previously but is stable (Table 1). In Tasmania, South Australia and the south-west of Western Australia, decline is also apparent but less of a concern, whilst in the remainder of Western Australia and the Northern Territory, freshwater fish resources are thought to be in good condition. Considering the plight of freshwater systems throughout Australia, and the limited knowledge of the interrelationships between fish and other components of freshwater ecosystems (Kearney 1997), these assessments may be optimistic. The Australian Society for Fish Biology recognises that over one-third of our freshwater fish species are threatened, with additional species known to have suffered declines but which do not meet the Society's criteria for listing. At a national level therefore, it appears that freshwater fish resources are declining and this decline ranges from serious to unknown. This conclusion is supported by published studies including those by Harris and Gehrke (1997) at State level, and Kearney (1997) at national level.

Rebuilding ecosystems: the key to sustainable freshwater fisheries

It is clear that existing uses of fish and freshwater ecosystems are not conserving, enhancing, nor maintaining the ecological processes that support fish production, and do not therefore meet the objectives of ecologically sustainable development (ESD). Maintaining existing levels of use will not arrest the decline of individual species, irrespective of whether species are recognised as threatened or not. Nor will it reduce the major threats posed by habitat degradation, poor water quality, altered river flows, barriers to migration, introduced species and harvest fisheries (Kearney 1997).

The goals for sustainability of freshwater fish resources are strongly influenced by the temporal perspective adopted. Short-term sustainability targets over several years tend to focus on maintaining the status quo, which in Australian freshwater systems equates to continued ecological decline and eventual socio-economic deterioration. In contrast, long-term sustainability of freshwater resources over decades requires current ecosystem declines to be arrested and reversed, with a re-structuring of harvest strategies to provide for true ecological sustainability and socio-economic well-being. Simply maintaining the status quo fails ESD objectives on social, economic and ecological levels. Therefore, to sustain the interests of Australia's freshwater fish sectors, fish resources need to be rejuvenated, not merely protected, and the ecological processes on which fish populations depend need to be rebuilt.

Targets for rebuilding freshwater systems

Following the decision to rebuild or restore an ecosystem the question arises of to which previous condition is the system to be restored. Setting the target condition under such circumstances can be highly problematic because numerous target conditions can be proposed and defended with equal vigour. Examples may range from a documented historical condition that existed before some recent disturbance, to a presumed condition prior to major disturbance – such as completion of a dam or large-scale catchment clearing – or to some earlier condition that pre-dates the arrival of European settlers in Australia. In contrast to such temporal targets, spatially-derived targets based on the best existing condition of a large number of catchments rely on the assumption that the best existing condition is not also seriously degraded. Any of these targets may have practical drawbacks that make them unachievable, but they share the common assumption that the key to future sustainability lies in the ability to revert to a previous condition. This assumption is central to the 'Back to the Future' concept of Pitcher and Pauly (1998). Alternative sustainability solutions may be proposed, but the philosophy that humans can design natural systems that are better than those that existed in the past involves a high level of risk and uncertainty as to the possible outcomes.

Rather than attempting to reach agreement on fixed targets for system rebuilding, it may be more practical to seek stakeholder agreement on the direction in which the system is to be managed, with achievable performance measures at various points in the agreed direction. Thus the *trajectory* of recovery becomes the target for sustainability instead of fixed targets that may give rise to dispute. Examples of trajectories that provide practical targets include:

- reduce abundance or impacts of pest fish;
- increase proportion of native fish;
- increase populations of threatened species;
- increase trophic complexity;
- increase size or value of catch;
- increase recreational catch; and
- return to defined historical condition.

Although the end-point of any trajectory may be impossible to define, expected performance measures can be established which allow progress along the trajectory to be monitored and assessed. For example, a trajectory focusing on control of pest fish may have a performance target of reducing carp biomass by a given percentage in a proportion of monitoring sites within a defined time, allowing achievement of the target on a probabilistic basis rather than on an all-or-nothing assessment (Koehn, Brumley and Gehrke 2000). Once this target is achieved, a subsequent target may be to reduce carp biomass further at those same sites, or to extend the same level of reduction to a larger proportion of sites. This approach lends itself well to an adaptive management framework in which scientific assessment is an integral component of the target setting and performance evaluation process (Walters and Holling 1990, Walters 1997). Rebuilding therefore becomes an iterative process that can be adapted over time to take advantage of new information as it comes to light while at the same time retaining sensitivity to changing stakeholder perceptions, expectations and values.

Data requirements for rebuilding freshwater ecosystems

Freshwater fisheries in Australia focus heavily on the upper levels of trophic organisation. Top predators such as Murray cod (*Maccullochella peelii*), Australian bass (*Macquaria novemaculeata*), golden perch (*Macquaria ambigua*) and eels (e.g. *Anguilla* spp.) are the main target species in many areas. Other target species at lower trophic levels include carp (*Cyprinus carpio*) and yabbies (*Cherax destructor*). Yet fisheries conservation issues cover all trophic levels from nutrients and producer communities right through to top aquatic predators and in some cases to terrestrial predators. Each level of organisation consists of numerous species, each with its own population dynamics, interspecific actions, physical habitat associations, and hydrology and water quality interactions (Figure 1). These interactions ultimately dictate that the data required to rebuild populations of a single species include many layers of complexity, extending to species and trophic interactions, harvest rates for different species, and ecosystem processes. Complex data requirements have long been recognised as a challenge for effective management at the level of fish communities and aquatic ecosystems (Evans et al. 1987) and this situation is exacerbated in fisheries which tend to be low-value, data-poor, and with limited scope to support expanded information gathering.

Many of the tools required for rebuilding fish resources are already available (Pitcher and Pauly 1998) and include information on population dynamics, ecosystem modelling, various fisheries management approaches (e.g. reserves, restrictions on gear, effort, and catches), knowledge of historical condition, and socio-economic cost–benefit assessments. Within freshwater systems additional tools for ecosystem restoration, such as enhanced environmental flow or reintroduction of woody habitat, are also available.

Whilst the basic tools exist, the availability of data to determine the sustainability of freshwater fisheries and to assess the performance of rebuilding programs remains a problem across Australia (Kearney 1997). Fisheries agencies surveyed in each State indicated that the recreational fishery sector is characterised by very poor data at a large scale, with most States awaiting the results of the Australian National Recreational Fishing Survey (Table 2). Specific components of the recreational sector have better data than the sector as a whole, examples being the extensive data generated by the Basscatch and Freshwater Angling Database projects run by NSW Fisheries. Monitoring programs such as the NSW Rivers Survey (Harris and Gehrke 1997) provide extensive data on species distributions and abundance, but even these large projects struggle to meet the data requirements of population or ecosystem modelling tools.

Not surprisingly, the best data is available from areas where fish are perceived to be under greatest threat, whereas from areas where threats are perceived to be low (such as the Northern Territory and large areas of Western Australia) there is limited data to assess current or potential threats. Therefore, when new threats are realised there is little historical data on which to base projected impacts.

Because of the paucity of biological data matched with economic value for harvested fisheries, the capacity to predict responses of fisheries to management intervention and environmental events is limited. The situation is worse for non-harvest species. Data on other trophic levels is patchy and is often held by agencies other than fisheries agencies. Accordingly, the limited amount of data available confers a high level of uncertainty over the likely outcomes of freshwater ecosystem management actions.

Solutions to data availability

The only solution to a lack of data is a data collection program. Where the species or life-history stages of interest are not collected by a fishery, an independent survey is required. But fishery-independent surveys are expensive to conduct, especially so where the spatial scale of interest is large; and the added cost of repeating the survey over time can be prohibitive. Programs such as the NSW Rivers Survey (Harris and Gehrke 1997) have developed efficiencies in the design of freshwater fish surveys in relation to the spatial and temporal intensity of sampling required and maximum gear efficiency, but cost remains a significant factor in data collection. In Australia, the cost of assessing freshwater fish resources is exacerbated by the lack of large-scale commercial fisheries that can fund the work. Instead, fishery-independent sources such as the water industry support many resource assessment activities. Even though data is being collected, the shortage of data remains as an impediment to sound fisheries and ecosystem management.

Walters (1998) observed that successful fisheries have large refuges in space and time not targeted by effort. Where effort is directed on only a small portion of the resource, the impact of the fishery is also small. In contrast, as advances in technology have allowed fisheries to expand, the refuges have diminished in size or duration, necessitating an increase in the level of management sophistication and concomitant data requirements to protect the stock from over-exploitation.

Most freshwater fisheries in Australia have large refuges in space or time not targeted by fishing effort and are characterised by poor data availability. Yet the refuges are seriously impacted by other disturbances that directly affect the fish. Examples are the commercial freshwater fishery in New South Wales which, before its closure in 2001, had access to only 5% of the rivers in the State (Reid, Harris and Chapman 1997) compared to the large-scale impact of altered river flows (Gehrke and Harris 2001). Large-scale freshwater reserves, as proposed by Walters (1998), would certainly provide protection from over-exploitation without the need for accurate stock assessment data and models, but to be effective in allowing fish populations to recover, reserves also need to provide protection, or allow recovery, from other forms of catchment degradation. Despite the difficulty of establishing effective reserves that provide refuge from degradation, freshwater reserves containing undamaged or rehabilitated habitat are a fundamental component of the process of rebuilding Australia's freshwater fish resources.

Future data needs

The data to develop and assess the success of restoring aquatic ecosystems need not replace fish stock assessments, but rather needs to include fish assessments. Such a broader framework could involve indicators of ecosystem condition linked to target trajectories through performance measures. Fish indicators could be derived from catch-effort data from recreational and commercial fisheries (where they exist) and independent surveys to fill data gaps at an appropriate level of resolution. An approach along these lines is currently being implemented for the Sustainable Rivers Audit by the Murray-Darling Basin Commission.

Outlook for sustainability

The outlook for true sustainability of freshwater fisheries – that is, rebuilt aquatic ecosystems that support fish populations that can be harvested without risk – is uncertain. The concept of restoring or rebuilding an ecosystem involves the implicit assumption that processes of decline are reversible, and that a system will revert to its previous condition once the threatening processes are removed. This assumption has not been validated at a general level and remains a matter of conjecture.

The success of target trajectories in rebuilding is likely to be dependent on the level of commitment to adaptive management to evaluate achievement of performance targets, and to establish new targets. Philosophical differences in approach between scientists and managers make it difficult to maintain an effective adaptive management program unless all parties are fully committed to the intended outcomes (Walters 1997).

Another source of uncertainty lies in the ability of existing environmental management programs. Despite the intentions of a historical legacy of programs to halt environmental degradation, degrading processes continue throughout Australia. If we cannot halt degradation on a large scale, is it realistic to consider that we have the ability to rebuild functional aquatic ecosystems?

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Table 1. Stress status of freshwater fishery sectors by State or Territory jurisdiction. Black cells: seriously stressed and declining; dark grey cells: stressed but stable; light grey cells: little stress or in good condition. Empty cells indicate a non-existent sector in that jurisdiction. SE: south-east; N: north; SW: south-west. (Source: informal survey of freshwater fishery scientists in each jurisdiction.)

Sector	Qld		NSW	ACT	Vic	Tas	SA	WA		NT
	SE	N						SW	N	
Commercial										
Recreational										
Conservation										

Table 2. Data availability for freshwater fishery sectors by State or Territory jurisdiction. Black cells: little or no data; dark grey cells: data adequate for some purposes; light grey cells: data adequate for sector management purposes. Empty cells indicate a non-existent sector in that jurisdiction. (Source: informal survey of freshwater fishery scientists in each jurisdiction.)

Sector	Qld		NSW	ACT	Vic	Tas	SA	WA		NT
	SE	N						SW	N	
Commercial										
Recreational										
Conservation										

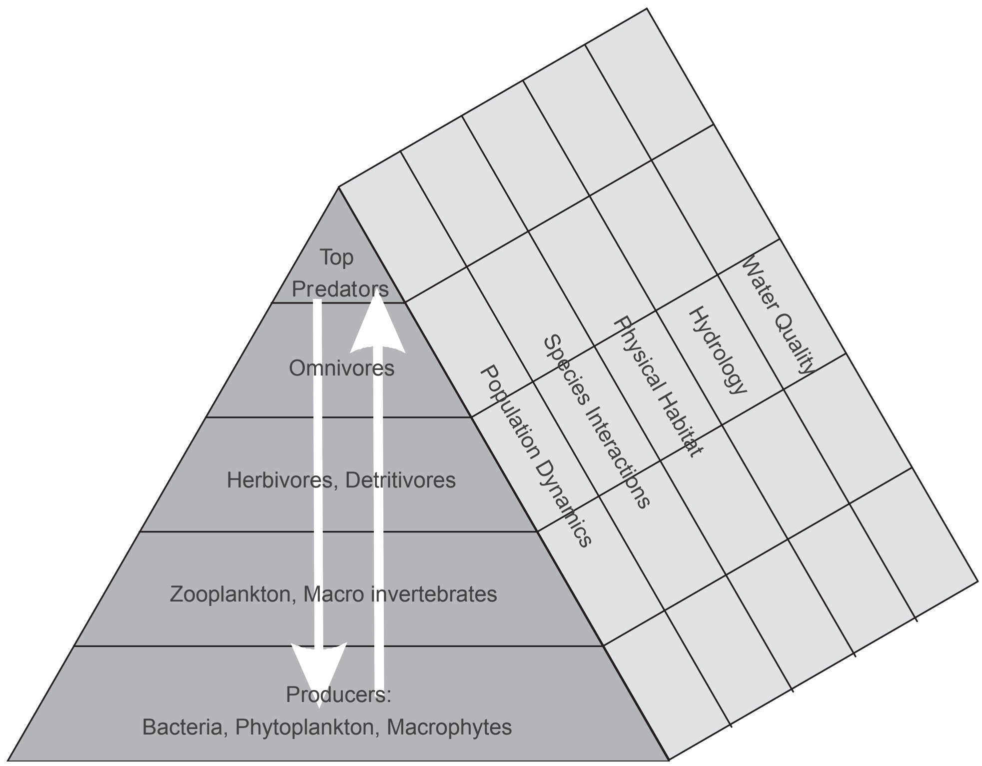

Figure 1. Diagrammatic representation of a riverine trophic pyramid, and the influence of some ecosystem processes on each interdependent trophic level. Arrows depict the influence of bottom-up (e.g. nutrients and prey availability) and top-down (e.g. predation, grazing) processes in interactions among trophic levels.

Theme Session Two

Discussion, questions and answers

Rapporteurs: Brett Molony and Gabrielle Nowara

Glen Young (Murdoch University, WA). “Rod, this question is for you. Given the impact of the commercial fishery on the estuarine catfish populations in the Leschenault Estuary, do you see any problems arising from the ultimate demise of the commercial net fishery and a flow-on to the unrestricted recreational netting? Do you see people filling a gap, in that they can’t buy local fresh fish, so they go out and catch extra fish themselves and we will have no information on that effort?”

Rod Lenanton. “With the catfish, probably not Glen. I think traditionally the recreational netters have not caught lots of catfish in that system. It has mainly been a commercial fishery and as you saw in that graph in the 1950s and 1960s, when very large catches were taken. Since then it has just sort of ticked over, but the recreational netters don’t target them; they mainly target the mullet and they get a lot of crabs in their catch as well. In terms of the second part of your question, where will they go for fresh fish; again I don’t know that will necessarily pose a problem for the catfish population. I think they will utilise other sources of fresh fish available in this regional centre from oceanic fisheries and so on and if you believe what they tell you, they’ll go out with their rod and line and catch alternative species, not necessarily catfish.”

Malcolm Haddon (TAFI). “Question for Rod and Norm. Both of you mentioned a closure of commercial fisheries and a shift to recreational fisheries but if anything the demand for fish products is increasing out there. So has anybody considered what is going to happen if the commercial fisheries remaining are going to have more effort imposed on them to provide the product required to the markets? In a way it’s like when you introduce a large MPA you displace a lot of effort or catch. So has anybody considered this as another source of uncertainty? What do you think the impacts of this will be?”

Rod Lenanton. “It’s a very good point and if I could, just by way of example, move to the south-west corner of the State where we have the Blackwood River Estuary which used to have not that many fishermen, it only has one commercial operator now. We have the burgeoning wine industry at Margaret River with the proliferation of fine restaurants and a huge demand for local fresh fish. The one guy that’s left there is flat out trying to keep a few fish up to that market, but there are relatively few opportunities to provide fish from estuaries to that market and there are some very nice quality fish like whiting and other things. And the other comment I guess is a survey done by the WA fishing industry (WAFIC) representatives who would endorse what you’re saying and are really very concerned about that. The surveys they’ve done suggest that a huge percentage (90% +) – I’m not sure of the exact figure – of the recreational fishing community actually like to go out and buy fish, and there’s data to show that’s the case. So yes, it is a real problem. I guess that the remaining nearshore commercial fishers are trying to provide the fish that’s necessary, but the real point is that as places like Margaret River develop and the coast continues to develop – it’s a huge expanding industry – the demand is going to continue to increase, with the declining inshore commercial fishery unable to meet this demand.”

Norm Hall (Murdoch University, WA). "It's actually not just the demand though that's going up in terms of the demand for fish; it's the fact that there's a demand from the communities that are growing in these areas to have access to recreational fishing and it's that that's driving the shift from the commercial sector. So we've seen in fact a number of buy-back schemes going on since about 1986 and a reasonably large injection of money – I think it was in 1993 another 10 million dollars. The intention really is to try to focus those buy-backs on the commercial fisheries that are overlapping the areas where the recreational fishers would like to be, so we see estuaries and nearshore fisheries being bought out. And yes, I think you'll see a great deal more frozen fish coming from overseas and being sold as fresh fish."

Peter Gehrke (Fisheries, NSW). "I suppose one corollary to the comment that Norm made is that I can see it going down basically the same way that we've gone with other sources of protein, in that we've gone from wild caught protein elsewhere. When it comes down to red meat, chickens, and other sources of meat we've got perhaps half a dozen species we derive most of our sources of meat protein from. I don't know how many different fish species we actually harvest in Australia, whether it's a couple of hundred… If they collectively are going to lose favour because of their lack of sustainability, then it may well be that they go down the road of only supporting small boutique markets for high demand products, and that a couple of species will end up being very selectively either harvested or reared in aquaculture facilities to provide the bulk fish market. And I can see that as one fairly real scenario."

John Pogonoski (Australian Museum). "Where do we start protecting fresh waters in NSW? Do we start protecting the waters within National Parks or is there another approach?"

Peter Gehrke. "When you say where do we start protecting them, I gather you're referring to where would we start introducing freshwater reserves? That's one we haven't worked out fully yet and there are differing opinions. There are some people who would say that we should start establishing freshwater reserves in areas that currently have received very low levels of degradation, which is basically the approach of locking up stuff which hasn't been irretrievably stuffed, before it gets a chance to be further damaged. That's one approach, but that's more the – I suppose – biodiversity 'lock up' scenario, where you want to protect little bits of everything over the mosaic of the whole State so that whatever's happening you've at least got some of it protected. In a rebuilding context, that's probably not going to achieve terribly much because a lot of those types of areas are going to be relatively small.

If we are going to try to improve the condition of freshwater systems then perhaps we would probably have to work on an experimental process where we take one area that's had a fairly major disturbance and then rebuild it. The Snowy River may be one very clear case in point. It's had its flows reduced to 1% of its natural level and now over a 10 year period its flow is going to be increased to somewhere in the order of 28% of its previous natural flow. So it's certainly not going anywhere near to its historical condition, but 28% of the natural flow, through a lot of national park and fairly inaccessible country is a damn sight better than 1% of natural flow. So there are some specific examples that we might be able to use in that context to evaluate how the concept works before we go open slather and all start grabbing on large freshwater reserves as the next flavour of the month in fisheries restoration work."

Dan Gaughan (Fisheries, WA). "This is more of a comment I guess on the Leschenault Inlet story. It seems to me that there is no real benefit to anyone in stopping the commercial fishery, so I guess – being cynical – in cases like that you've got to ask, who does benefit? – and perhaps we should consider the real estate market might have something to do with it."

Rod Lenanton "It's a good question. I guess the recreational community – or it was more the general community, not just the recreational fishing community – lobbied, as they have done for some years, to get rid of the commercial operators out of the Leschenault Estuary. We didn't have any data on what the actual recreational fishers caught and if we assume that the survey done in 1998 was representative, well what it showed us was, certainly in that year, the recreational fishing community caught very little fish in Leschenault Estuary; they mainly caught crabs. And the commercial guys had already decided not to target crabs because they knew they were a major target for the recreational fishers. So if you were basing it on objective information, you really needn't have persuaded them to leave the system."

Tony Fowler (SARDI). "I've got a question for Norm. You mentioned in your talk that we have a need for alternative data sources, given the switch over from commercial to recreational fisheries. I was wondering what your thoughts are on these alternative sources particularly in the context of the decreasing opportunity these days for independent surveys by scientists, given the burgeoning costs of scientific research."

Norm Hall "I think the first thing is that it's a plea not to completely delete the commercial fishing operation from the areas where they're fishing in the same locations as the recreational community – although I began to wonder in fact whether they were fishing the same part of the stock, when I saw the different data sets coming through from the recreational and commercial fisherman for Leschenault Inlet. But I think there's a real need to consider the fact that the cost of obtaining recreational catch and effort information is considerable and to actually get the same level of information from the commercial fishery is a lot easier. It [a commercial fishing operations] also gives you a base for obtaining some of the samples that you need in terms of the size and age composition of the stock, and so it was more a plea for that as the first consideration, that you actually weigh the costs of actually getting the data in some other way before you actually remove the commercial fishing effort.

The second thing is that when you consider the types of data that come through from the recreational community, we certainly do need total catch information. There's no doubt that that's going to have to be collected, but sometimes the data that you get from, say a recreational log book program, is decidedly hairy. I've tried analysing some of it, and it doesn't look at all delightful. I think I'd need much larger samples, and a much greater level of consistency. There's a lot of individual variation there, so what I'm beginning to wonder is, whether in fact, through a more well-defined scientific approach to doing a survey, to get some of that basic catch and effort information on a regular basis using a proper well-defined scientific survey, we wouldn't in fact be better off in many ways than trying to spend huge amounts of money to get data which is perhaps inadequate. So once again it's a question of costs and the benefit and the quality of the data that comes through.

I think really we're basically looking at two alternatives, and that is to go to the recreational fishers and get data from them, involving them in the process perhaps as Ana was saying, getting a group of these people who are in fact more committed to the work to provide the data. But at the same time, if we can't get that information I think we have to look seriously at trying to find some way of at least getting the data that we're going to need to be able to assess the state of those stocks and to be able to make management decisions. If you fail to do that I think you're essentially saying that you're going to let the stock go into a situation where you're no longer controlling it. And I'm not too sure whether we can afford to do it. Certainly the level of control that you need is less when the fishery is a lower valued fishery. But there's still a need for responsible management. I think you have to, in fact, take that view. So I suspect that if you took a regular survey, well defined, structured in such a way that it was comparable from year to year, perhaps do it every three to five years, you might in fact do something better with a scientific survey than relying completely on the recreational community."

Michael Mackie (Fisheries, WA). "You mentioned not having a definable end point to the re-building process. Does this create problems with getting funding and also convincing user groups, for instance, having to put up with hardships in the rebuilding process?"

Peter Gehrke. "It really depends, I suppose, on where you need to go to get the funding and I suppose on how you sell the message that you've got to provide. I'll use an example of where we're currently trying to rebuild the fish community of the upper Shoalhaven River system. In that case, we've got the Sydney Catchment Authority which is required by their legislation to conduct their business according to the rules of Ecologically Sustainable Development. So they have a legislative requirement to do something to provide fish passage to the catchment upstream of the dam, where ten species have gone extinct. We've got legislation that says that we can require fish passage. So in this particular instance, we've got funding from a local catchment water supply agency, we've got co-operation on the part of recreational fishers who have agreed not to apply for stocking upstream of Tallowa Dam so that when the fishway is built we know that all the migratory fish that start appearing have presumably come up via the fishway rather than having confounding effects of stocking as a fisheries management tool and a fishway, so that we can't determine which of the two, or where the fish are actually coming from. So that's probably one case where we've got support from the recreational fishers and from the conservation groups and significant funding coming from a water management agency; but it's probably not always going to be that easy. The only goal we've told them is that if we can provide fish passage, some of the species which are now locally extinct upstream of the dam will recover, and that the fishers will be able to have a naturally spawned bass fishery, rather than fish that are stocked from potentially suspect genetic lines. They've accepted that, and I might use that as an example of how we might apply the same approach in other areas, and we're working towards that."

Jim Penn (Fisheries WA). "Question for Rod Lenanton. From what you're describing we seem to have a lot of knowledge bound up in a lot of those coastal fishermen, many of whom are getting towards retirement age. I'm wondering, from your experience, are they willing to in fact become part of the research effort and actually contribute this sort of knowledge to our efforts in the future? – because it seems to me that they could be one of the keys as to how we could deal with some of those fisheries."

Rod Lenanton. "As I've said and you've said, there's relatively few left in most of the estuarine fisheries; there are more in some coastal marine fisheries. However, most of them, because they've been essentially limited entry and restricted transferability, we know them all pretty well, and yes I certainly think that all of the ones that remain are very helpful to us now, and I'm sure would be very helpful in the future. We've had some preliminary discussions with them through WAFIC about their future role and I think probably they understand that if they are going to be able to survive in these environments, they need to persuade the community at large that they're doing some helpful things in terms of managing the resource. And I think they're mostly very aware of that and I think it would be a very good thing if we could actually formalise that arrangement to have them help us in the future."

Sandy Morison (MAFRI Victoria). "Following on from that, the experience we've got in Victoria with our bay and inlet fisheries is that those guys certainly are willing to contribute in a whole range of ways. I suppose we were forced into a situation through having to rationalise research and monitoring that we actually used those guys for some of the monitoring that we were doing and there's no doubt – and this is a number of years ago – it pays off in a lot of ways in terms of they're involved in the research effort; they actually are willing to contribute a lot of their knowledge about how to go about sampling these populations. They've been doing it professionally for many, many years. In pre-recruit monitoring that we're doing in Gippsland Lakes for black bream, we now use commercial fishers who help build the nets, pick out the sites where we should be going to target these fish and actually we charter them to do it as well. We have research people with them and there are enormous benefits in doing that. Not only that – that's just for fishery data but also in terms of habitat assessment that we undertake as well, – we invited them along to those assessment workshops and found that they're more than willing to contribute a lot of knowledge about their observations about changes in the habitat as well, and they are often the only source of information that you have in terms of what's been going on in these habitats. And they're again quite happy to contribute that data, and it's invaluable. To the extent now that we've actually got a project up looking to sort of formalise the framework for them to be able to contribute [oral history] that sort of data to ongoing habitat assessment monitoring. And not just from the commercial guys, but also from recreational fishers and any others of the public who may want to contribute too. So we've got a project that's being funded by NHT and Fisheries Victoria to set up a framework to incorporate that sort of environmental data as well.

So our experience certainly is that these guys are more than willing to contribute and there are enormous benefits when you do get them involved in not only improving the dialogue but actually improving the science as well."

Summary of Theme Session Two *by Rod Lenanton*

I guess we all acknowledge that we're dealing with a complex set of fisheries and complex species in these inshore and inland areas. We may well need to operate and manage these fisheries a little differently in the future if we are to maximise our attempt to comply with ESD in my view. There's certainly been a real shift from commercial fishing to recreational, customary recognition and non-extractive use of these coastal resources. And there's a real problem in dealing with the demands of ESD, the increasing complexity of these demands, with reducing resources.

In terms of Norm's talk, I've got written against 'data', 'imprecise, occasional, infrequent, rare'; really the data sources are really inadequate for what we have been doing in the past, and more importantly for the sort of things we might need to do in the future. You ran through a number of historical approaches we have used in analysis of these data, culminating in the assessment of the status of the barramundi fishery, with probably the best information we did have with only a very clever way to incorporate the recreational participation to give us some projections under current commercial and recreational fishing pressure. The thing to note I guess was the huge variation around those projections and a good deal of uncertainty.

Therefore in terms of how you would manage those, I think there were probably a lot of other points he made but he did make a point of mentioning that in terms of the way we're doing things now, if you remove the commercial fishery, we remove clearly a source of a lot of information we have traditionally used and data that would be very useful for us to have on the future.

And Peter gave a slightly different slant on the freshwater environment: a refreshing look at that and we're mainly talking about marine and estuarine fisheries, and it's nice to have Peter here talking about freshwater fisheries, and I'm conscious of the fact that ASFB has significant freshwater membership, so I'm pleased Peter was able to come and give us the benefit of his knowledge.

Looking at the status of the fisheries across the country, there are clearly some serious declines in populations of these fish mainly I guess from NSW, Victoria and parts of Queensland, which says to me the Murray-Darling system, not being from over that way. In terms of the targets for sustainability we should rebuild ecological processes, and the fish resources really need to be rebuilt rather than just maintained, and that was the point Peter made fairly strongly. In terms of target setting, the trajectory of recovery, not a fixed target was something that was recommended, and incorporation of adaptive management with incremental steps. Most data is from top predators (targeted fishing species) and there is a lack of information from species at other levels. In regard to ecosystem restoration much is unknown about most of the fish species, even those that are keystones or cornerstones to this. There are very little data available, however, to do this, which I've already said I guess. However, solutions to the data availability do exist. Fishery independent surveys were mentioned, but we emphasised that we must allow for recovery of catchment degradation to have any chance of achieving the objectives. And finally I guess, a point that was raised earlier when we had our warm-up discussion, that you must develop indicators of ecological conditions and it is important really that we need to get away from the paradigm of thinking of fisheries sources to fund this. We really need to think of the broader issues and think of non-fisheries sources to fund this from broader initiatives, like catchment management and other things.

THEME SESSION THREE
Stock assessment

Chair: Malcolm Haddon

Fishery and ecosystem assessment with inadequate data

N. Hall

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Abstract

If management plans for fisheries are to be effective, they must ensure that the principles of ecologically sustainable development are achieved. Recognition of the need to consider the direct and indirect impacts of fishing activities on the fish community and the habitat with which it is associated has highlighted the inadequacy of the data that are available for many fisheries. For instance, data are often collected for target species that are recreationally or commercially important. However, there is often little information available regarding the interactions of those species with other members of the associated fish assemblages, or interactions between the target species and the habitats that they occupy at different stages of their life cycles. For many low-value Australian fisheries, research advice will continue to be provided within a context of inadequate biological and fishery data. Indeed, for most of Australia's fisheries, the immediate needs of fishery managers for research advice are likely to be met through intelligent use of inadequate data.

The modelling techniques that are used when faced with inadequate data are considered in this paper and an approach to deal with the problem is proposed. Appropriate use of the results from meta-analyses of the findings of other research studies may offer an interim solution to the problem of inadequate data for many of our ecosystems. The uncertainty associated with the use of inadequate data must also be recognised within the models that use these data.

Introduction

Estuarine and nearshore species of fish are exploited in Western Australian (WA) waters by both commercial and recreational fishers. The majority of these species have a relatively low commercial value compared to the various shellfish and crustacean species that are also fished in WA. It is likely that most of the stocks of these fish species are fully exploited, and some may be over-exploited. However, precise assessment of the state of the stocks is hindered by the inadequacy of the available data, precluding the use of many traditional fishery models. Although the numbers of commercial fishing vessels operating within the fisheries for these species are constrained, there are currently no controls on the number of recreational fishers. Most of Western Australia's recreational fishing is controlled using spatial and temporal closures, gear controls, minimum and maximum legal sizes, and bag limits.

Despite facing increasing levels of fishing effort arising from growth in recreational fishing, limited biological and fisheries data exist in WA for most exploited species of fish. Commercial catch and effort statistics may be available for these species, however only recently has a systematic five-yearly survey been established to obtain regular estimates of the recreational catch and fishing effort. It is unlikely that the quality of the data will be greatly improved in the future, because characteristics of the estuarine and nearshore fisheries make it both difficult and expensive to obtain biological samples and/or reliable catch and effort data for recreational fishers at more frequent intervals than the five-yearly survey periods. Factors contributing to this include the number of species involved, the geographic extent of the fisheries, the number of landing points, and the large number of recreational fishers.

The increasing exploitation of these Western Australian fish stocks will inevitably place a greater demand on fisheries managers and scientists to develop more effective strategies for sustaining the stocks. The challenge for fisheries scientists is to develop models that can use the types of data that are currently available for these fisheries, coupled with appropriate information drawn from general ecological principles and from comparative systems, to evaluate the current state of each ecosystem and the effectiveness of alternative fishery management strategies.

Possible approaches to overcome data limitations

A number of modelling techniques are frequently used when data are inadequate. For instance, the model assumptions can be simplified to avoid the need for missing or inadequate data, or to allow calculation of those data from other data. Data that would otherwise be required in fitting the model can also be used to calculate the missing or inadequate data, parameters that must be estimated can also be treated as missing data, and appropriate results from other studies can be applied to the models.

Simplifying assumptions are frequently used to avoid the need to utilise missing data. Examples of this approach are evident when we assume a model structure that is independent of age, length, sex, other species, habitat, and environment. We may also assume a closed unit stock, a constant natural mortality, or the homogeneous distribution of stock over a single area. Such assumptions may also enable missing data to be calculated from the existing data. An example of this is the assumption of an unfished equilibrium that enables the determination of the initial system state in an age-structured model. Such assumptions are not the only ones that are possible, and alternative results might be obtained by applying different sets of assumptions.

Another approach that is often employed when modelling is to reserve some of the data that would otherwise be used in fitting the model to calculate the missing data. Examples of this technique are evident in the calculation of an initial age structure from the first sample(s) of age composition, or in the calculation of initial biomass from the first observation(s) of catch per unit of effort. Occasionally, we may also use other available data. For example, an estimate of the growth of a species might be obtained from an independent sample of length-at-age data, and the resulting growth curves may then be used in the fishery model.

Missing data may also be represented as parameters within the model and their values estimated, with other parameters, when the model is fitted to the available data. The advantage of this approach is that the uncertainty associated with the parameter estimates of the missing data is recognised. Examples of this approach include the estimation of natural mortality, initial biomass, or initial age composition in an age-structured model.

Increasingly, results from other studies are used to provide information that is missing for the stock being modelled. Such meta-analysis has been used to determine many empirical equations that represent the general relationships that exist between parameters describing biological processes. For example, Pauly (1980) used the results from 175 other studies to develop an empirical relationship between natural mortality, the parameters of the von Bertalanffy growth equation, and water temperature. More recently, Froese and Binohlan (2000) have used numerous other research findings to describe the relationships between parameters including maximum length and length at maturity. Insights into the ability of a stock to compensate for a reduction in the abundance of spawners have been provided by Myers et al. (1999), using the results from the meta-analysis of a stock–recruitment database. This meta-analysis showed that the number of spawners produced per spawner each year at low populations is relatively constant among species. Finally, in ecosystem studies, data from FishBase (Froese and Pauly 2000) have been used to determine many of the initial values required in EcoPath and EcoSim (Christensen and Pauly 1992).

Before using results derived from such meta-analyses, it is important to ensure that the data are relevant to the species currently being studied. Thus, before the results of such studies are applied to Western Australia's estuarine and coastal fisheries, we need to ensure that the results are drawn from selected studies for similar species. Furthermore, when such data are applied as proxies, the uncertainties associated with estimates of the missing data must be considered when assessing the status of the fisheries to which they are applied.

Model selection

Although the approaches described above may assist in dealing with the problems that arise from the paucity of the data that exist for WA's estuarine and nearshore fisheries, the selection of models for these fisheries remains an issue. The traditional single species models and analyses that are used for fisheries stock assessment include biomass dynamics models, age- and sex-structured models, virtual population analysis (VPA) and stock synthesis or integrated analysis models. These models and methods of analysis may be extended further for analysis of data from a multi-species fishery, and incorporate interactions between species. Such interactions may be dependent on the age and size of the fish and of each predator and prey species. Multi-species VPA is frequently used for the stock assessment of such fisheries. Interactions between species may also occur as a result of fleet dynamics. Ecosystem models extend the multi-species framework further, by describing the flow of energy and elements such as nitrogen and carbon between functional groups within the ecosystem. These models thereby couple the physical and biological processes to describe primary production, trophic interactions and the effect of environmental variables on the ecosystem.

As model complexity grows, there is an increasing demand for data. While it is desirable to use an appropriate structure when modelling a fishery, the limitations of the available data must be considered. This consideration may require that simpler single species models are applied for the individual species in a multi-species fishery, or that simpler formulations (such as those of biomass dynamics models) are used. Such simplifying assumptions will inevitably introduce additional uncertainty into the results of stock assessments and must be considered when evaluating the sustainability of the fisheries.

Conclusions

Assessment of some of the data-limited fisheries of the nearshore and estuarine environments of WA may be enhanced by using data from meta-analyses of similar species and fisheries. These analyses can provide proxies for missing data, but the complexity of our ecosystem models needs to be appropriate to the quality of the data that are available. The uncertainty that is introduced through the use of data derived from other fisheries or that results from simplifying assumptions should be considered when evaluating the results of our assessments. While this may offer an approach by which the impacts on the ecosystems of these Western Australian estuarine and nearshore fisheries may be assessed, it does not eliminate the need to improve the quality of the data that exist for these fisheries. An essential element of the ecosystem models that are developed through this strategy should be an investigation of the areas in which research effort might be concentrated to achieve the greatest benefit from the resulting information.

Acknowledgements

This study, which is being undertaken by the Centre for Fish and Fisheries Research at Murdoch University, is funded by the Fisheries Research and Development Corporation. Their support is gratefully acknowledged.

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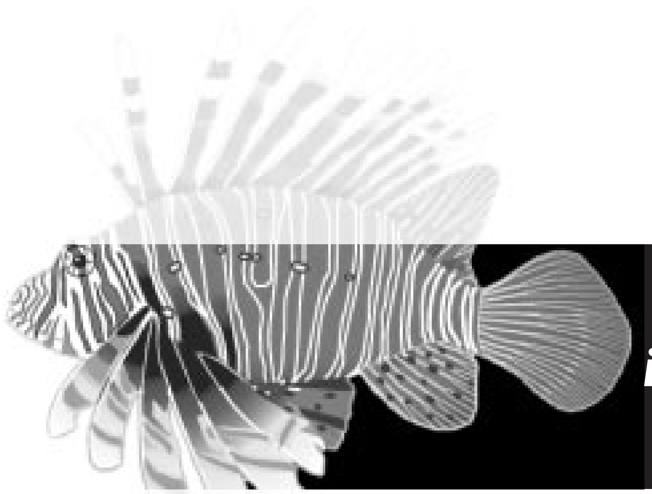

Commercial catches as an indicator of stock status in NSW estuarine fisheries:

trigger points, uncertainty and interpretation

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Abstract

NSW Fisheries has elected to use commercial catch as a temporary indicator of the state of stocks within the Estuary General Fishery until better indicators can be developed. One rule of management requires that if landed catch varies more than a pre-specified amount from the mean catch between 1984-85 and 1998-99 a review of the management arrangements is required. The trigger points have been defined for the principal species within the fishery and vary from a 10% to a 50% deviation from historical catch.

Monte Carlo simulation was used to analyse the effectiveness of this catch-based indicator for the detection of recruitment failure or survival failure (of the standing stock). Simulated catch data were generated with a lagged stock–recruitment biomass model and the performance of the indicator estimated. This analysis was completed by estimating the probability of obtaining false negative and false positive outcomes in the detection of recruitment/survival failure. Results suggest that if NSW Fisheries uses trigger points of around 25-40%, it should be able to detect both recruitment failure and survival failure. However, there will be a high rate of false positive outcomes. Analyses of this type require judgements to define:

1. *reference points;*
2. *the magnitude of change that represents a problem; and*
3. *acceptable probabilities of false positive and negative outcomes. Stakeholders should be involved in making these judgements. The precautionary principle implies that the rate of false negative outcomes should be minimised.*

1. Introduction

1.1 Background

For the NSW Estuary General Fishery, NSW Fisheries has elected to use landed or commercial catch as a temporary indicator of the state of the fishery. Ideally, catch rate or catch per unit effort are used as indexes of stock abundance. However, the data available on fishing effort in the Estuary General Fishery is seriously compromised by the inability to account for multiple gear use on the same day and questionable credibility of effort records. Scientific staff in NSW Fisheries are reluctant to use the effort data for the fishery and we concur with their misgivings. Indicators based on age and length structure are being developed and will be implemented in due course for species for which there is such data. Fisheries in NSW with credible fishery-dependent effort data or fishery-independent abundance data will use catch rate as an index of abundance rather than commercial landings.

Within the fisheries management strategy for the NSW Estuary General Fishery (NSW Fisheries 2001; Table 5, this paper) NSW Fisheries has defined the trigger points for landed catches of primary species that will generate a review of the management arrangements. Should future catches be greater or less than a percentage variation (e.g. 25% for yellowfin bream, *Acanthopagrus australis*) of the mean catch between 1984-85 and 1998-99 then a review will take place.

There are several advantages to this approach including:

- The aggregate catch is more accurately recorded than are most other entries in the catch records database.
- There are no elaborate calculations performed upon the catch data (such as standardising indices of abundance) and hence the process is transparent.

There are also disadvantages:

- Catch is determined by many important factors that are unrelated to stock size, including targeted fishing effort, non-targeted fishing effort (where the species is landed bycatch) and price.
- It can be difficult to determine what degree of variation from the mean catch should be considered important, and why.
- There is concern that triggers will trip when they should not have (false positive responses) or do not trip when they should (false negative responses). Interpretation of the results will be difficult unless these errors are explored.

The following modelling study investigates these issues by developing a simple model of the stock dynamics, calibrating this model to patterns of observed catch, and then simulating a recruitment failure or increase in stock mortality. The trigger points are then tested to determine if they successfully detected these changes, and the rates of their success and failure in detecting changes are estimated.

The model used is referred to as a lagged stock–recruitment model (Hilborn and Mangel 1997). This model is more complex than the standard biomass dynamics model but less complicated than a complete delay difference model (Hilborn and Walters 1992). Stock biomass is represented but at no point shall actual numbers be given as we are not confident that available numbers represent a real estimate of the biomass of each stock. The calibration exercise aims to determine the model parameter values that result in quantitatively similar patterns of catches. It does *not* represent the stock biomass.

The analysis described below (a slightly modified version of Chapter 7 of Scandol and Forrest 2001) has logical parallels with power analysis (Peterman 1990; Underwood 1990) in which the probability of Type II error of a statistical test is estimated. Type I and Type II errors are the same type of concept as the false positive and false negative judgements described below. Underwood (1997) noted that precautionary management strategies should be based upon statistical analyses with a low Type II error, or high power, but the exact requirements will depend upon the hypothesis being tested.

1.2 Indicators and the underlying system

A relationship between an indicator and an aspect of the system of interest is shown in Figure 1. The usual 'aspect of the system of interest' is the exploitable biomass, the usual indicator is catch rate, and the expectation is that catch rate is positively correlated to the exploitable biomass.

This diagram requires extension for it to be of value to decision-makers. First, a threshold state of the system needs to be specified that would be avoided by decision-makers. For example, if the system state (y-axis for Figure 1) was defined as the proportion of virgin biomass, then a limit reference point threshold would usually be 20% of B_0 (Gilbert et al. 2000). In our case the y-axis will represent a measure of recruitment failure or biomass survival failure. Second, a threshold value on the indicator axis that represents where action should be taken. Note that this value would be a trigger point, *not* a limit reference point. Such action would usually take place when the catch rate falls below a particular level, but in our case will represent the percentage deviation of landed catch from the historical average (Figure 2).

Once these two additional thresholds are defined, four regions are evident on the graph (Figure 2):

- True positive: the actual state is below the threshold and the indicator makes the correct inference.
- True negative: the actual state is above the threshold and the indicator makes the correct inference.
- False positive: the actual state is above the threshold and the indicator makes the incorrect inference.
- False negative: the actual state is below the threshold and the indicator makes the incorrect inference.

We are not proposing to quantify the biomass in this analysis but are looking to detect a change to the fishery to which a response should be made, if catch is used as an indicator. Two example issues have been selected that represent the sort of events that could occur: recruitment failure, and an increase in the mortality of the stock from sources other than commercial harvesting (e.g. an increase in natural mortality, illegal harvesting, or recreational catch). In our analyses, we have termed the second 'survival failure'. As in the Fisheries Management Strategy (NSW Fisheries 2001) we have used the deviation from average historical catches as an indicator for the stock. Once catches fall below (or exceed) this indicator then the trigger has tripped. We examine the appropriate level at which these triggers should be set to detect important changes to the fishery.

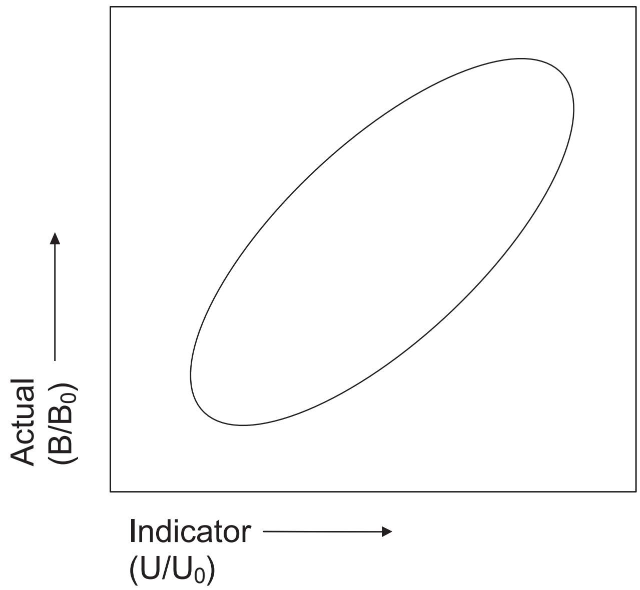

Figure 1. Example relationship between an indicator and the system state it represents. A meaningful indicator will be correlated to the system state, but the relationship will be uncertain (represented by the ellipse). The usual state represented is the ratio of current biomass to initial biomass (B/B_0) and an indicator could be the ratio of the current catch rate to the initial catch rate (U/U_0). (Diagram modified from Stewart 2000.)

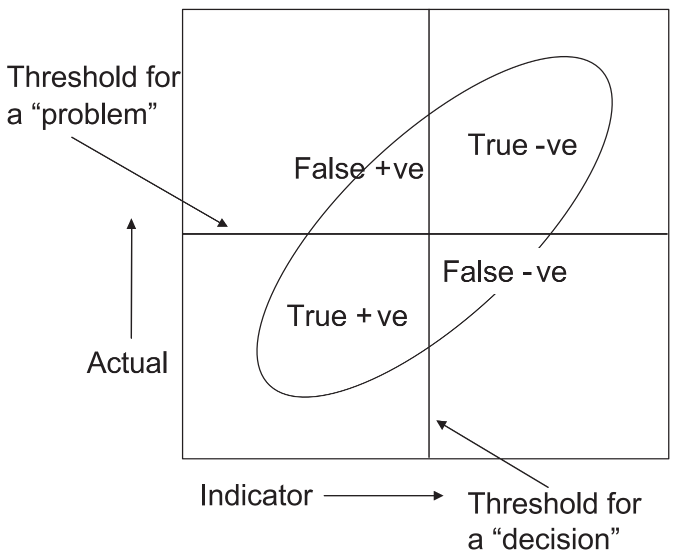

Figure 2. Extension of Figure 1, with the thresholds for problems and decisions annotated. When a decision is made there are four possible outcomes: true positives (state is *below* threshold, and this was *correctly* detected with the indicator); true negatives (state is *above* the threshold, and this was *correctly* detected with the indicator); false positive (state is *above* the threshold and this was *incorrectly* detected with the indicator); and false negative (state is *below* the threshold and this was *incorrectly* detected with the indicator). (Diagram modified from Stewart 2000.)

2. Methods

2.1 The model

The underlying model used to represent the stock is:

$$B_{t+1} = (1 - m) \cdot B_t + R_{t-lag} \cdot R_{err} - C_t,$$

where B_t is the biomass at the end of year t, m is the annual mortality of biomass during year t, thus (1-m) is the survival of the biomass during year t. R_{t-lag} is the recruitment to the biomass with a time *lag* reflecting the number of years from spawning to recruitment to the fishery. Recruitment error, R_{err}, is described below. Catch during year t is represented by C_t and the difference equation is initialised with a starting value B_0.

The initial recruitment is estimated by assuming:

$$R_0 = B_0 \cdot m$$

The stock–recruitment relationship used is a Beverton-Holt model that has been re-parameterised to the steepness of the stock–recruitment relationship and the initial biomass/recruitment. Thus:

$$a = \frac{B_0}{R_0} . \left(1 - \frac{z - 0.2}{0.8z}\right), \qquad b = \frac{z - 0.2}{0.8zR_0}, \quad \text{and} \quad R_t = \frac{B_t}{a + b \,.\, B_t},$$

where z is the steepness of the stock–recruitment relationship and a and b are the parameters of the standard Beverton-Holt stock–recruitment curve.

This transformation of the stock–recruitment relationship is common (Hilborn and Walters 1992), as it enables the steepness of the Beverton-Holt stock–recruitment relationship to be altered without changing the recruitment at initial stock size. The parameter z is defined such that when $R_t = z \cdot R_0$ then $B_t = 0.2 \cdot B_0$, where R_0 and B_0 is the initial recruitment and biomass respectively.

Two types of error are introduced in the system dynamics. Recruitment or process error (R_{err}) is a lognormal variate of mean 1 and standard deviation σ_R, which is calculated by transforming a normal variate N (mean 0, standard deviation 1) using:

$$R_{err} = exp(N \cdot \sigma_R - \frac{\sigma_R^2}{2})$$

The second type of error is catch error C_{err}. This error is a mixture of the usual process error and observation error because catch is the observable indicator used to assess the fishery, but variation in catches will also affect the system dynamics. The following calculations are performed in sequence:

$$C_{err} = exp(N \cdot \sigma_C - \frac{\sigma_C^2}{2}) \qquad C_t = \tilde{q} \cdot B_t \cdot C_{err},$$

where $\tilde{q}$ represents a catchability type constant (defined differently to the usual catchability), σ_C is the standard deviation in the catch error, and C_t is the catch during year t.

2.2 Model calibration

Non-linear optimisation was not used to calibrate the model because both process and observation errors were included in the model. Sampling-importance-resampling methods (McAllister et al. 1994) would have been ideal but were too technically complicated for this exercise. In lieu of these a simple random search strategy was used. The appropriate algorithm was:

1. Select random values of σ_C , σ_R and $B_0 / \overline{C}^{obs}$ from random distributions (see Table 1 for a summary of these sampling distributions). The value of $\tilde{q}$ was assumed to equal $\overline{C}^{obs} / B_0$.
2. Calculate ten replicate simulations for those particular parameter values, for each replicate calculate the mean and standard deviation of the simulated catches.
3. Calculate the average mean catch and the average standard deviation over those 10 replicate simulations. This results in an overall measure of the mean and variability of the simulated catches for the selected parameter values.
4. Calculate a goodness-of-fit criterion between the average of the simulations and observed catches using:

$$\Delta_i = \frac{\left(\overline{C}^{obs} - \overline{C}^{sim}\right)^2}{\overline{C}^{sim}} + \frac{\left(\sigma(C^{obs}) - \sigma(C^{sim})\right)^2}{\sigma(C^{sim})} \quad .$$

5. This goodness-of-fit criterion captures differences in both the average catches and the standard deviations of the catches for replicate sample *i*;
6. Repeat the sampling process 2000 times and sort the results in ascending order by Δ_i.
7. Select the best 5% (the top 100 replicates) of the smallest difference between the observations and the simulations of the samples (Δ_i). This gives values of σ_C , σ_R and $B_0 / \overline{C}^{obs}$ that generate similar patterns of simulated catches to observed catches.

Table 1. Summary of the parameters used and the distributions from which their values were sampled.

Parameter	Distribution	Minimum	Maximum
$B_0 / \overline{C}^{obs}$	Uniform	0	100
σ_C	Uniform	0	0.5
σ_R	Uniform	0	0.5

Once a set of parameter values is available that generates time-series of catches that are quantitatively similar to the observed catches for that fishery, the trigger point analysis can be completed. This analysis involved two stages: modelling stock failure, and estimating the error rates of various trigger points. These are discussed below in turn.

2.3 Modelling recruitment or survival failure

Biomasses and catches are projected for an additional five years from the last year of recorded catches. However during that time an 'impact' was imposed on the biomass dynamics to reflect either recruitment failure or increased mortality.

Given an impact value ϕ_r that varied from 0 to 1, recruitment failure was modelled with:

$$B_{t+1} = (1-m) \cdot B_t + \phi_r \cdot R_{t-lag} \cdot R_{err} - C_t ,$$

and survival failure was modelled with ϕ_m,

$$B_{t+1} = \phi_m \cdot (1-m) \cdot B_t + R_{t-lag} \cdot R_{err} - C_t \ .$$

Thus $\phi = 0$ reflected complete failure, and $\phi = 1$ indicated no failure. The threshold of what represents a significant failure is somewhat subjective but needed to be defined. We have assumed that a failure of $\phi < 0.5$ should be detected unless otherwise specified.

Simulated catches were generated using $C_t = \tilde{q} \cdot B_t \cdot C_{err}$ with the underlying biomass impacted by recruitment failure or survival failure.

2.4 Error rates of trigger points

The outcome of this exercise was to estimate the probabilities of true positive, true negative, false positive and false negative results for various levels of the trigger point. The trigger point level (τ%) is the deviation of future catches beyond the mean catch between 1984-85 and 1998-99, as this is the reference point set by NSW Fisheries in the Estuary General Management Strategy (NSW Fisheries 2001). Should the value of τ be set close to zero, the trigger point would trip every time (any future catch would be greater than a 0% deviation from the past). In this case we would expect all false positives or true positives. Alternatively, if the trigger point level was extremely high (~100%), the trigger point would never trip and we would expect all false negatives or true negatives.

The sampling process was similar to the scheme used for model calibration. For each type of impact (recruitment failure and survival failure) one hundred ϕ_r and ϕ_m values were given random uniform values between 0 and 1. Each of these 100 values was used in association with the 100 best solutions from the model calibration exercise. For each replicate calculation, 10 samples were calculated from the model and if a future simulated annual catch was less than (or greater than) τ% of the simulated mean historical catch between 1984-85 and 1998-99 then the trigger point was tripped. For each of these 10×100 calculations the overall result (e.g. numbers of false positive) was counted and then converted to probabilities by dividing by 10×100. These calculations were repeated for τ% values ranging from 0% to 100% in steps of 10%.

3. Results

3.1 Example calculation

We give an example using the NSW estuarine catches of dusky flathead (*Platycephalus fuscus*) before the formal results are presented.

Figure 3 illustrates observed catches of dusky flathead in NSW and also includes three replicate simulations of a stochastic model. Model parameter values were selected by the random search routine described earlier.

The important advantages of this method are that the temporal dependencies associated with the observed catch time-series are retained in the simulated data and the data can be projected into the future. Figure 3 also illustrates these projected time series when there have been no changes to recruitment or annual biomass mortality (*m*).

Unless otherwise stated, the assumed value of *m* was 0.9, the steepness of the stock–recruitment relationship (*z*) was 0.8, and the time lag between spawning and recruitment to the fishery was three years. The impact of these assumptions is evaluated in Section 3.3.

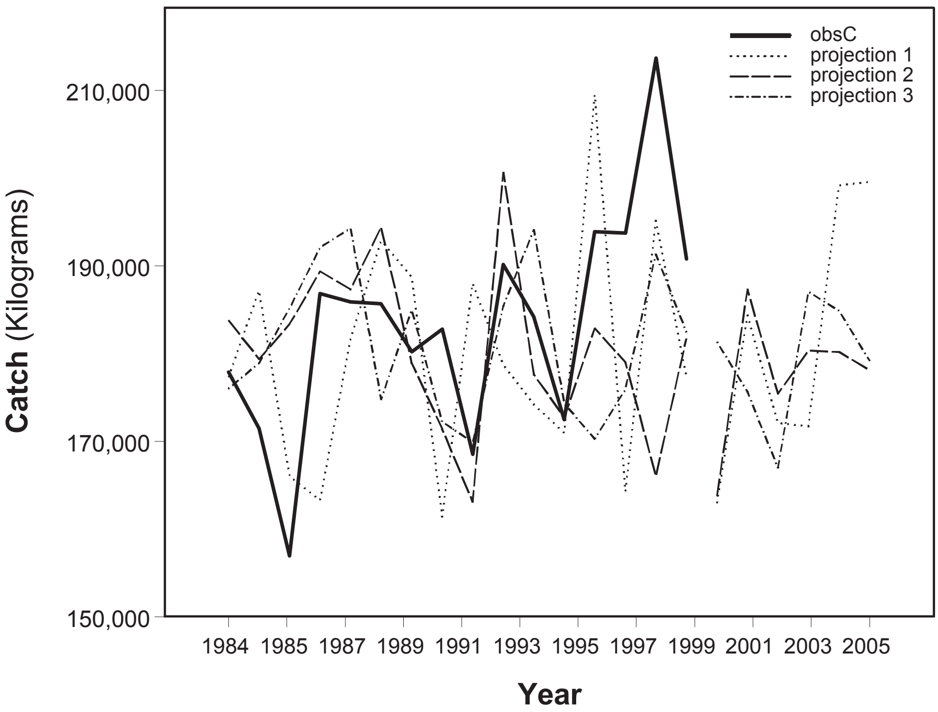

Figure 3. Observed catches for the NSW Estuary General dusky flathead fishery (solid bold line). Three replicate simulations of catches are annotated on the plot. Projected values of simulated catches (starting in 2000) with the same system dynamics are also illustrated.

The random search routine provides valuable insight into the sensitivity of the simulated catches with the values of the parameters. Following from the dusky flathead example are frequency histograms of the three parameters for the best fitting 100 sets of sampled parameter values (Figure 4). Figure 4a indicates the samples values of $B_0 / \bar{C}_{obs}$ where, apart from small values of this ratio, there is essentially random uniform distribution within the domain of the sampled distribution. The peak for values between 80 and 90 is probably sampling variation, but this is not an issue of importance. In contrast, Figure 4b indicates that the variation in successful values of catch error σ_C, is tightly constrained compared with the sampled distribution (uniform between 0 and 0.5). Only values less than 0.15 were permissible and the median of the distribution was 0.06. Similarly, only small values of recruitment error σ_R contributed to the better fitting models, though in this case values close to zero were frequently included. We have not included correlation plots of these optimal parameter values but report that there was no marked correlation between these parameters. The lack of marked correlation indicates that the model had sufficient but not excessive numbers of parameters.

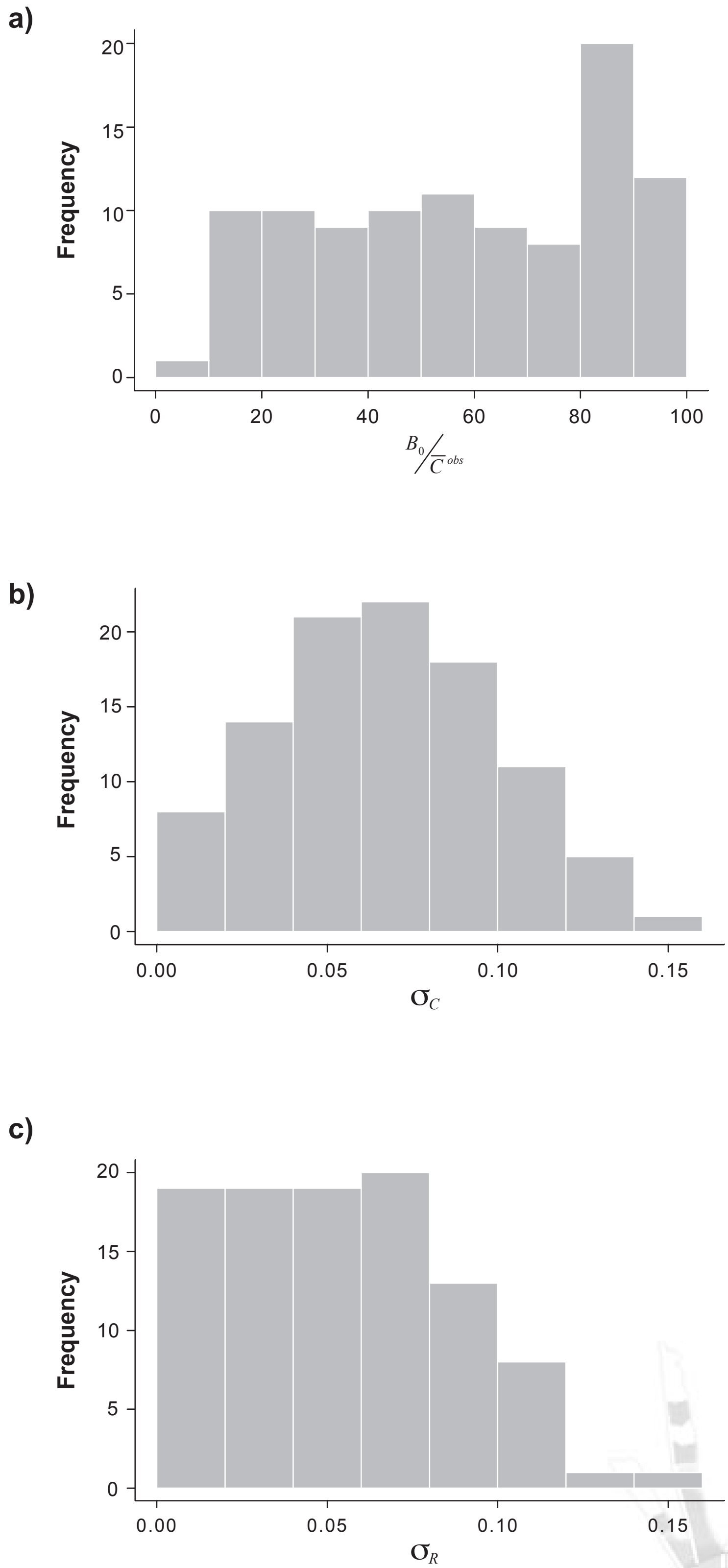

Figure 4. Frequency histograms of the parameter values of the best 100 simulations from the random search routine or model calibration procedure. (a) Parameter B_0/C^{obs}; (b) catch error σ_C; (c) recruitment error σ_R.

Using these best 100 solutions from the model calibration procedure the stock dynamics were projected into the future with recruitment or survival failure included (as discussed above). Figure 5 illustrates the consequences upon various outcomes when using τ% as the deviation from mean historical catches as the trigger point for dusky flathead in NSW. These examples illustrate that recruitment failure and survival failure yield quantitatively different results and should therefore be treated separately.

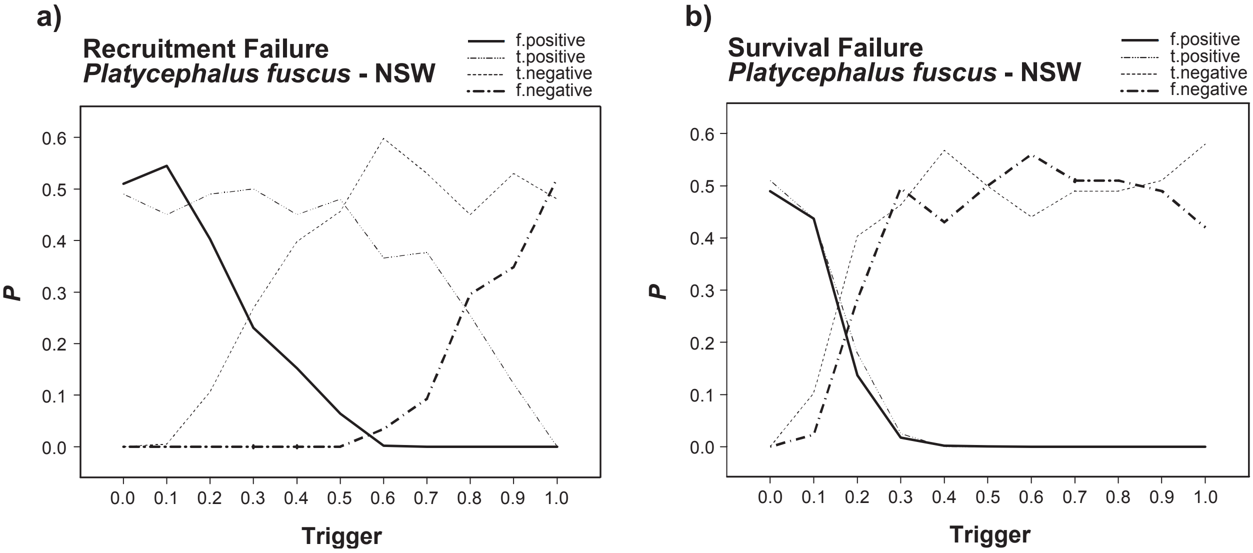

Figure 5. Examples of graphs showing the probability of false positive, false negative, true positive and true negative outcomes for a range of trigger points (τ) from zero to one, in the events of (a) recruitment failure and (b) survival failure for dusky flathead throughout NSW.

Figure 5a indicates that when τ is zero, then any deviation from historical catches will trip the trigger. Since the values for recruitment failure (ϕ_r) are sampled from a random uniform distribution bounded between zero and one, approximately half will be less than 0.5 (which we have defined as the threshold for a problem) and the converse proportion will be greater than 0.5. When the value of the catch trigger is 0.0 we expect approximately 50% true positives and 50% false positives as there will always be an indicated effect, but only half the time will there be an actual effect. In contrast, when the trigger value is 1.0, we will never detect an effect (0% of any catch is zero, and catches will always be above zero), and there will be a 50:50 ratio of false negatives and true negatives. Intermediate values of the trigger value generate intermediate results.

For recruitment failure (Figure 5a) the rate of false positives decays rapidly as we increase τ and the rate of false negatives does not become significant until the τ value is greater than about 0.5. Intermediate values of τ between 0.3 and 0.7 resulted in low error rates and high probabilities of successful detection of recruitment failure. Survival failure, where ϕ_m is similarly sampled from a uniform distribution, illustrates the same behaviour at the minima and maxima of τ as does the response to recruitment failure. Behaviour for intermediate values is however very different. False and true positives, and false and true negatives, essentially trace each other. Thus, there is no real differentiation between them. Trigger points can be set to minimise the number of false negative results but will do so at the expense of getting large numbers of false positive results.

This result enables us to discuss the selection of appropriate trigger points. Figure 5 shows that the probability of false negative outcomes tends to increase as the probability of a false positive outcome decreases. A decision needs to be made about acceptable probabilities for each of these types of error before an appropriate trigger point can be selected. The method we suggest is to select the largest probability of a false negative that is smaller than a previously agreed minimum probability (say 5%). In this way, the probability of false negative result is kept below an acceptable standard, whilst minimising as much as possible the probability of false positive result. An alternative is to select the trigger point under which the curves for false positive and false negative outcomes cross. In this way, the sum probability of making either type of error is minimised. This method, however, has a certain level of risk as the curves are likely to cross where neither probability is below an acceptable standard. This situation is illustrated in Figure 5b: here the curves cross at a trigger point where the probability of both outcomes being false is 20%, which in either case is likely to be an unacceptably high probability of error.

3.2 Evaluation of simulated catches

To evaluate the sensitivity of the analysis with differing types of data, four sets of simulated catch data were generated and the analysis done using each of these datasets. The four data sets had different, known properties, and showed either a) a decreasing trend in catches, b) an increasing trend in catches, c) constant catch with little variation, or d) random catches with large variation. Graphs of the four datasets are shown in Figure 6.

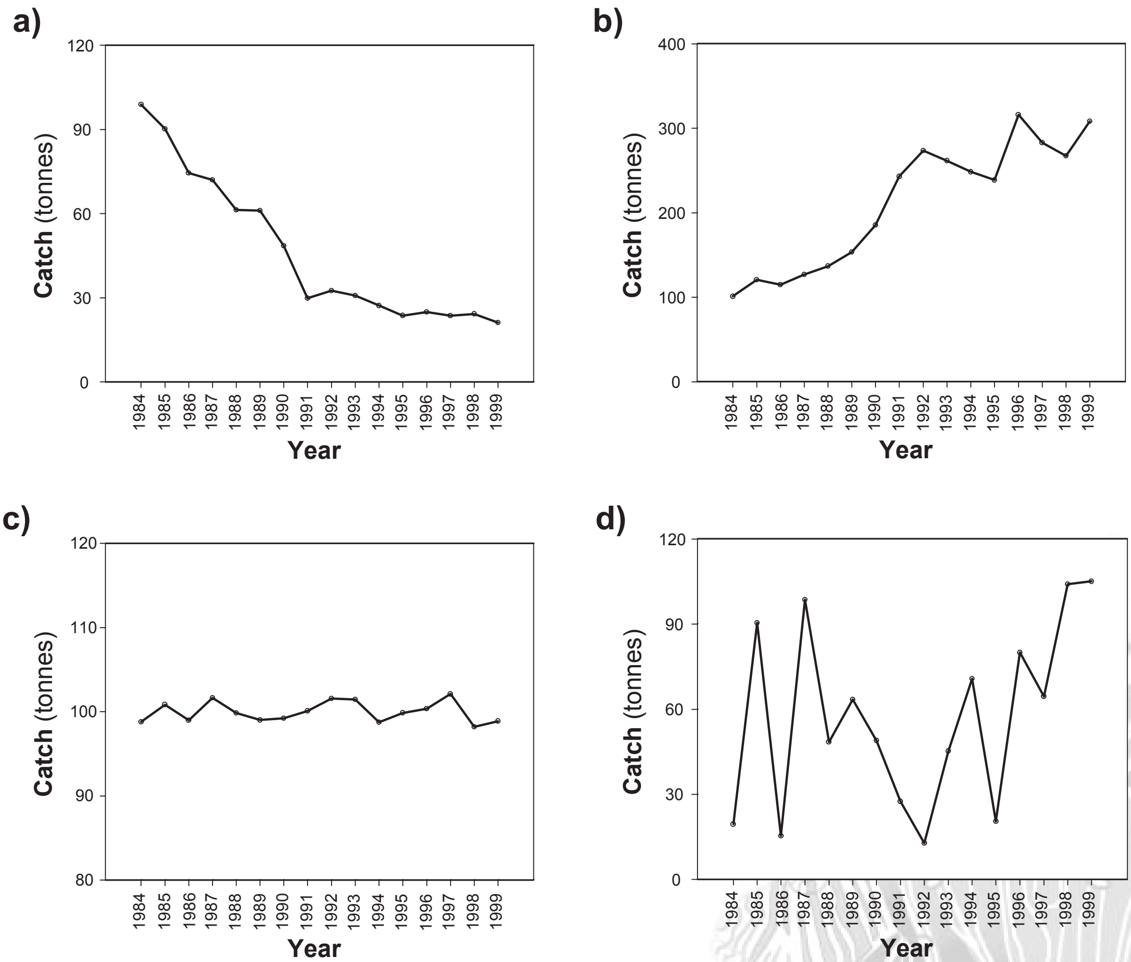

Figure 6. Graphs of the four simulated data sets showing trends in catches that are (a) decreasing; (b) increasing; (c) constant; and (d) variable.

Analyses of performance of trigger points for the events of recruitment failure and survival failure were done using each of the above fictitious datasets. Graphs of the results are shown in Figure 7.

Figures 7a and 7b illustrate the outcomes of the catch trigger analysis with these simulated datasets. These figures indicate that the results from the analysis are extremely robust and that similar results are generated for each type of stock failure regardless of the catch trend. Detection of recruitment failure is slightly more unreliable with decreasing catches, but survival failure is difficult to detect regardless of the catch history.

A similar comparison can be made with constant catches versus random catches. Figures 7c and 7d illustrate the results for constant catch history versus a highly variable catch history. With constant catch history recruitment failure can be reliably detected, but when the fishery has a highly variable catch history, recruitment failure is much harder to detect using variation in catches as an indicator. This is an intuitively reasonable result. As before, survival failure is difficult to detect under both catch scenarios.

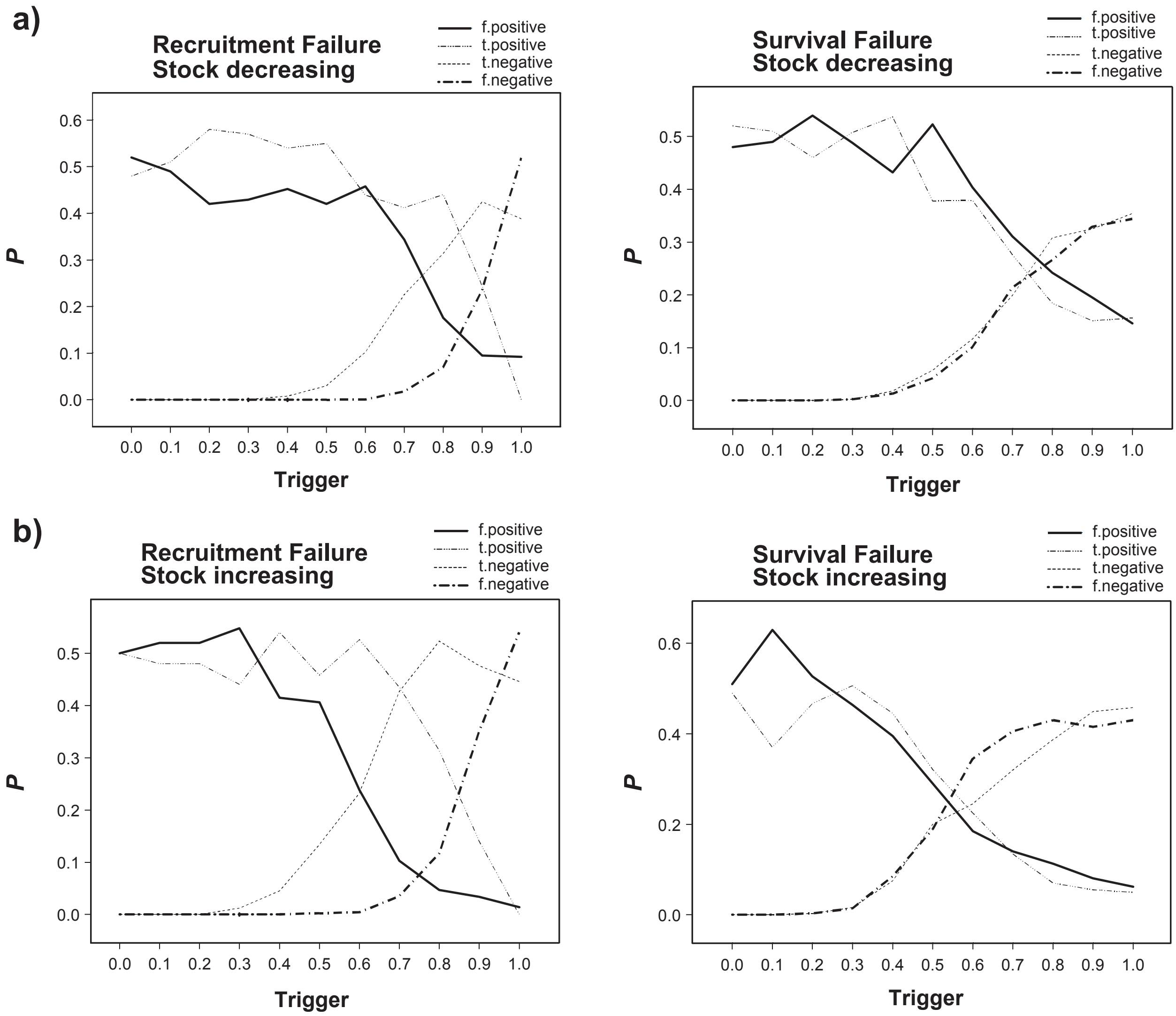

Figure 7. Examples of graphs showing the probability of false positive (bold solid line), false negative (bold dotted line), true positive and true negative outcomes for a range of trigger points from zero to one, in the events of recruitment failure and survival failure for data with (a) decreasing catches and (b) increasing catches.

In each case, the most appropriate trigger point selected was that which produced the largest probability of a false negative result less than 0.05. In this way, an acceptably low probability of a false negative was returned, whilst a low probability of false positive errors was maintained (see section 3.1). Table 3 gives the trigger points selected using this criterion for the events of recruitment failure and survival failure for the four fictitious data sets.

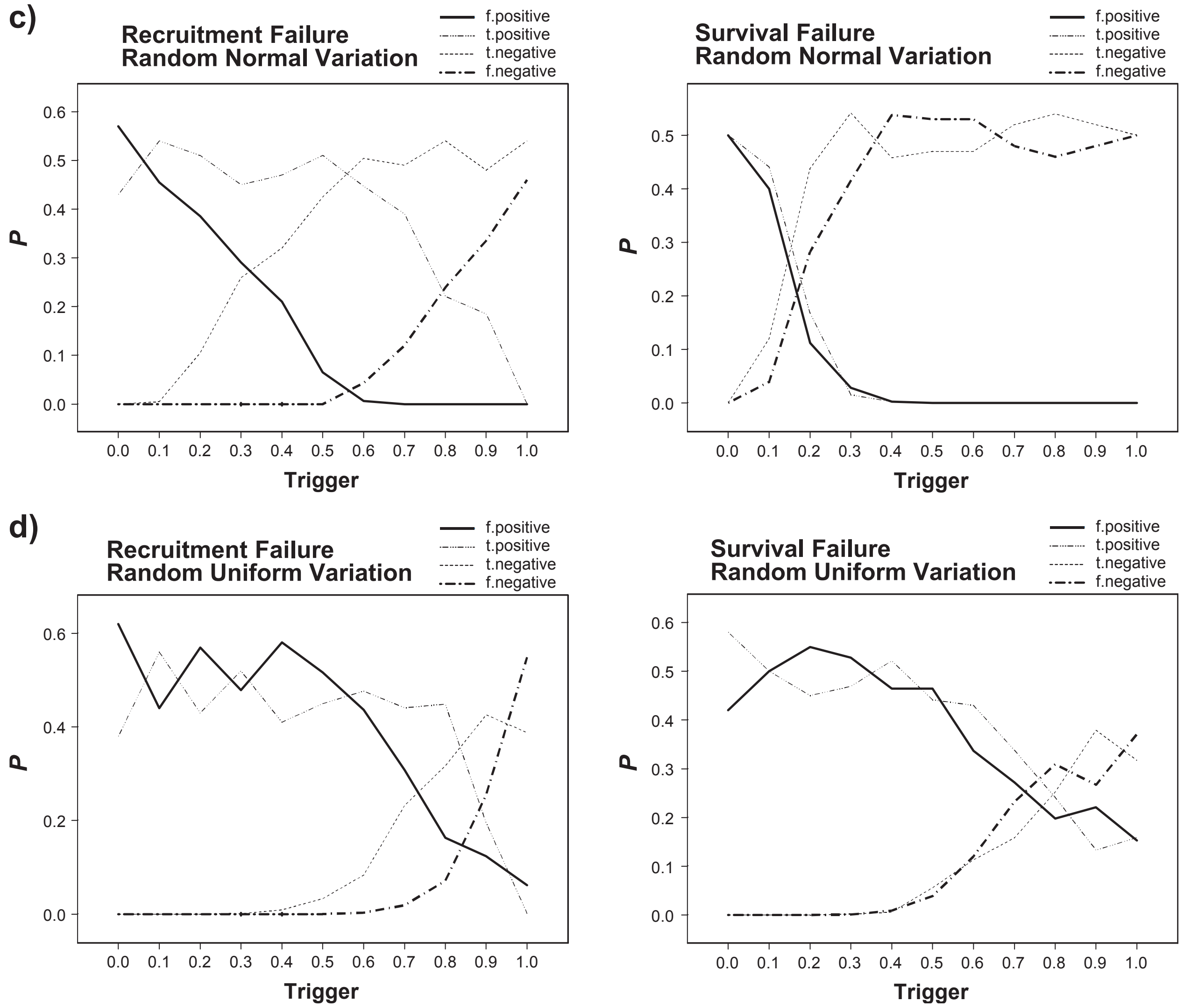

Figure 7 cont. Examples of graphs showing the probability of false positive, false negative, true positive and true negative outcomes for a range of trigger points from zero to one, in the events of recruitment failure and survival failure for data with (c) constant catches and (d) variable catches.

Table 2. Appropriate triggers for a (i) decreasing trend in catches; (ii) increasing trend in catches; (iii) constant catches; and (iv) variable catches, for the events of recruitment failure and survival failure.

	EVENT	
Trend shown by data	**Recruitment Failure**	**Survival Failure**
Decreasing	0.7	0.5
Increasing	0.7	0.3
Constant	0.6	0.1
Variable	0.7	0.5

Table 2 indicates that a relatively high trigger point value can be set to detect recruitment failure that will allow an acceptable level of false negative outcomes whilst generating very few false positive outcomes. Survival failure is much more difficult to detect and there is no consistent value of a trigger point that will allow for small rates of false positive and false negative responses.

3.3 Sensitivity analyses

The sensitivity of the analyses to the assumptions in parameter values *z* (the steepness of the stock–recruitment relationship) and *m* (the annual mortality of biomass during a given year) was also evaluated. The sensitivity analysis was completed using the dataset for dusky flathead in New South Wales. Performances were evaluated for intermediate values of *z* and *m*, then for four combinations of large and small values for these parameters. In each case, the most appropriate trigger point was selected to be that which produced the largest probability of a false negative that was less than 5%. Table 3 gives the trigger points selected using this criterion for five combinations of values for *z* and *m*. The multiplying nature of the mortality constant *m* led us to distribute the values of *m* in the sensitivity analysis with the logarithmic scale (i.e. 0.5, 0.9 and 0.95).

Table 3. Appropriate catch trigger point values for dusky flathead in NSW with (i) intermediate z and m; (ii) low z and intermediate m; (iii) high z and intermediate m; (iv) intermediate z and low m; and (v) intermediate z and high m, for the events of recruitment failure and survival failure. In all cases, recruitment lag was set at 3.

	EVENT	
Value of parameters	**Recruitment Failure**	**Survival Failure**
***z* = 0.8; *m* = 0.9**	0.6	0.1
***z* = 0.4; *m* = 0.9**	0.7	0.1
***z* = 0.95; *m* = 0.9**	0.5	0.1
***z* = 0.8; *m* = 0.5**	0.5	0.4
***z* = 0.8; *m* = 0.95**	0.6	0.0

Table 3 continues to illustrate the robust nature of detecting recruitment failure and the difficulty of detecting survival failure. Large changes to *z* or *m* cause little impact on the appropriate catch trigger point value when attempting to detect recruitment failure. A large reduction in the annual mortality of biomass (to *m* = 0.5) implies greater variation in catches should be accepted before we assume that an impact on the stock survival has occurred.

The parameters *z* and *m* cannot be calculated directly or easily estimated from available data. The steepness of a stock-recruitment relationship is difficult to estimate unless data with sufficient contrasting observations of stock size and recruitment are available. Access to all of this information is rarely the case, so z has to be assumed, and the sensitivity of results to this parameter evaluated. Values of *m* could be inferred if information about natural mortality and individual growth was available, but again, since natural mortality is often a 'guestimate', a similar strategy for dealing with this parameter is required. Fortunately the time lag from spawning to recruitment can be easily determined by inspecting catch-at-age data and noting how many years it takes for most (~ 80%) of the fish to recruit.

3.4 Analyses by species

Landed catch data were extracted from the NSW Fisheries catch records database. For dusky flathead, the analysis has been completed for the entire State and for three individual estuaries: Camden Haven River estuary (Northern Zone), Lake Illawarra estuary (Central Zone) and Tuross Lake estuary (Southern Zone). For the other finfish species examined in this report, data were only analysed for the whole State. This strategy was selected because the analysis is only preliminary and it appears that the results are quite general. Analyses were completed using the intermediate values of *z* and *m* given in section 3.3. Figure 8 shows the catches of flathead for NSW and for the three estuaries.

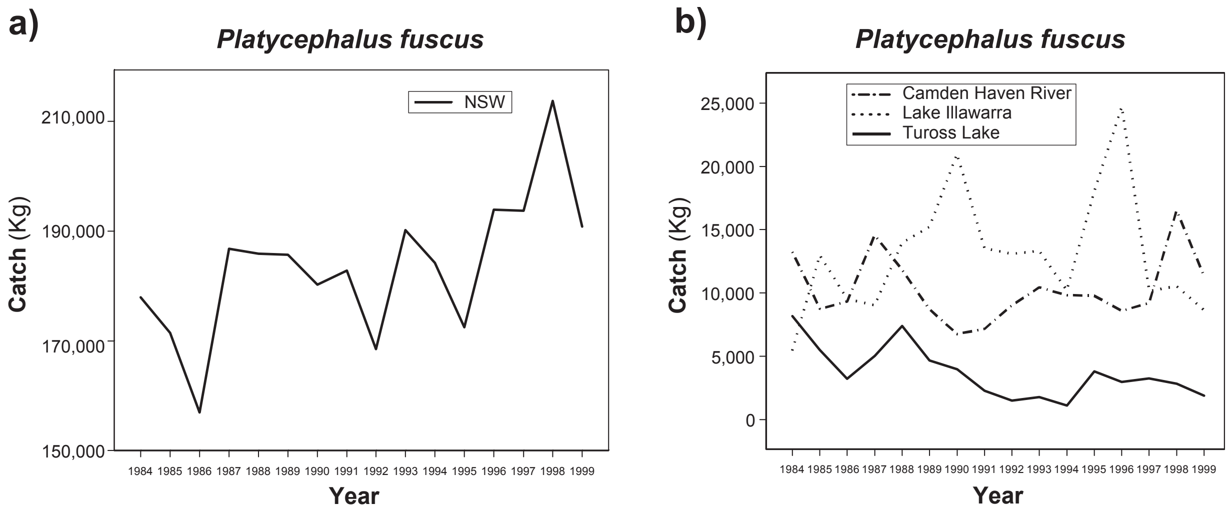

Figure 8. Time series of total landed catch of dusky flathead from 1984 to 1999 for (a) all of New South Wales and (b) Camden Haven River, Lake Illawarra and Tuross Lake estuaries.

The appropriate trigger points for dusky flathead for New South Wales and for the three estuaries are shown in Table 4. Graphs of the performance of triggers for dusky flathead in New South Wales comprise Figure 7.

Table 4. Trigger points for dusky flathead selected as the most appropriate for (i) all of New South Wales; (ii) Camden Haven River estuary; (iii) Lake Illawarra estuary; and (iv) Tuross Lake estuary, for the events of recruitment failure and survival failure.

	EVENT	
Location	**Recruitment Failure**	**Survival Failure**
New South Wales	0.6	0.1
Camden Haven River	0.6	0.2
Lake Illawarra	0.7	0.3
Tuross Lake	0.7	0.4

Time-series of catches for luderick (*Girella tricuspidata*), yellowfin bream (*Acanthopagrus australis*), sand whiting (*Sillago ciliata*) and sea mullet (*Mugil cephalus*) are shown in Figure 9. Graphs of the performance of triggers for these four species in New South Wales comprise Figure 10. The trigger points selected by the analytical process for each species and trigger points proposed for each species by NSW Fisheries are given in Table 5. Table 5 indicates that the trigger points proposed by NSW Fisheries will easily detect recruitment failure and are also within, or very close to, the boundaries required to detect survival failure.

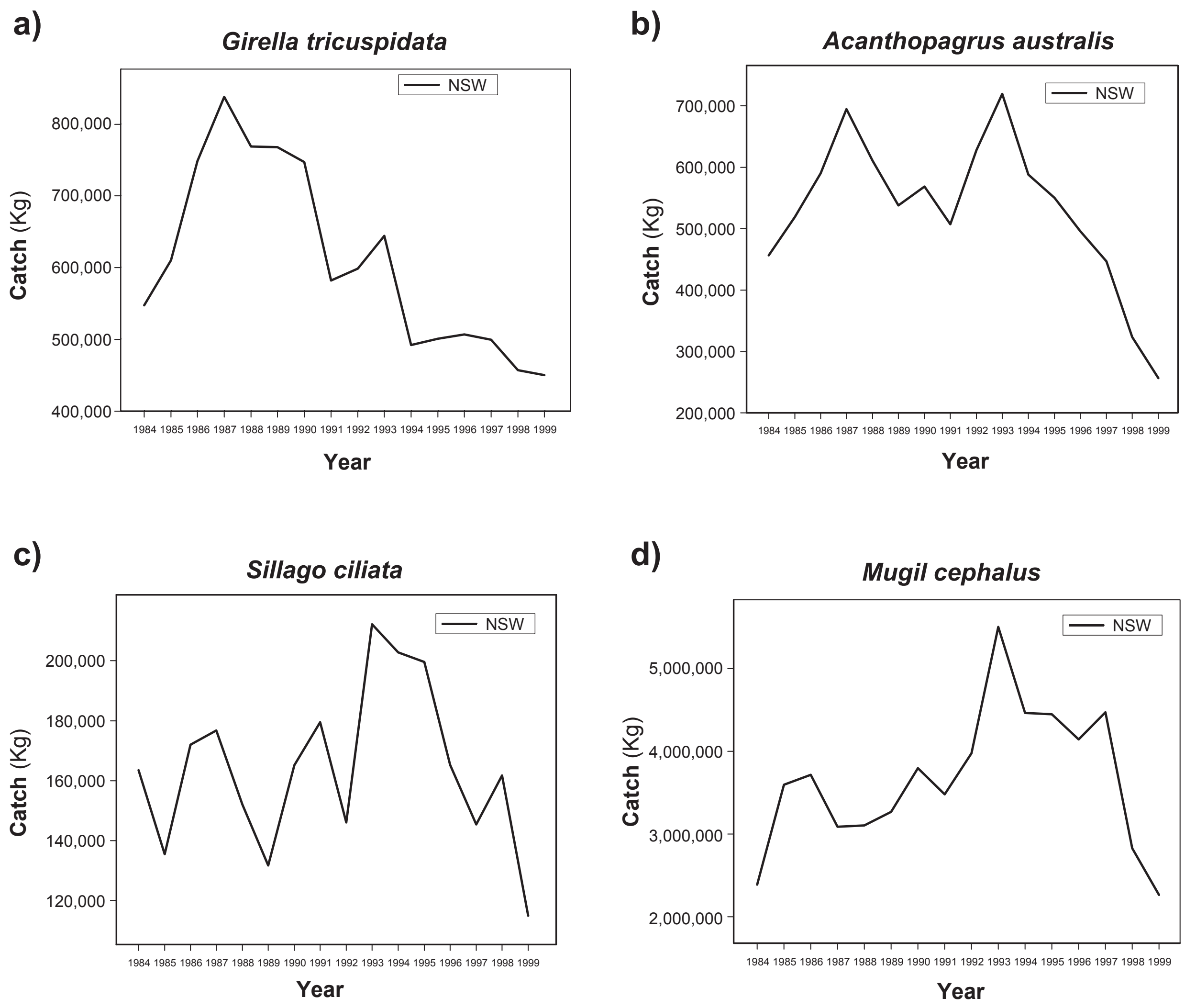

Figure 9. Time series of total landed catch from 1984 to 1999 for (a) luderick; (b) yellowfin bream; (c) sand whiting; and (d) sea mullet in New South Wales.

Table 5. Trigger points selected as the most appropriate for dusky flathead; luderick; yellowfin bream; sand whiting; and sea mullet in New South Wales, for the events of recruitment failure and survival failure. For comparison, trigger points proposed by NSW Fisheries are also shown. (Source: NSW Fisheries 2001.)

	EVENT		
Species	**Recruitment Failure**	**Survival Failure**	**NSW Fisheries, proposed trigger point**
Dusky flathead	0.6	0.1	0.1
Luderick	0.6	0.2	0.25
Yellowfin bream	0.7	0.2	0.25
Sand whiting	0.6	0.1	0.25
Sea mullet	0.6	0.2	0.1 (for 2 consecutive years)

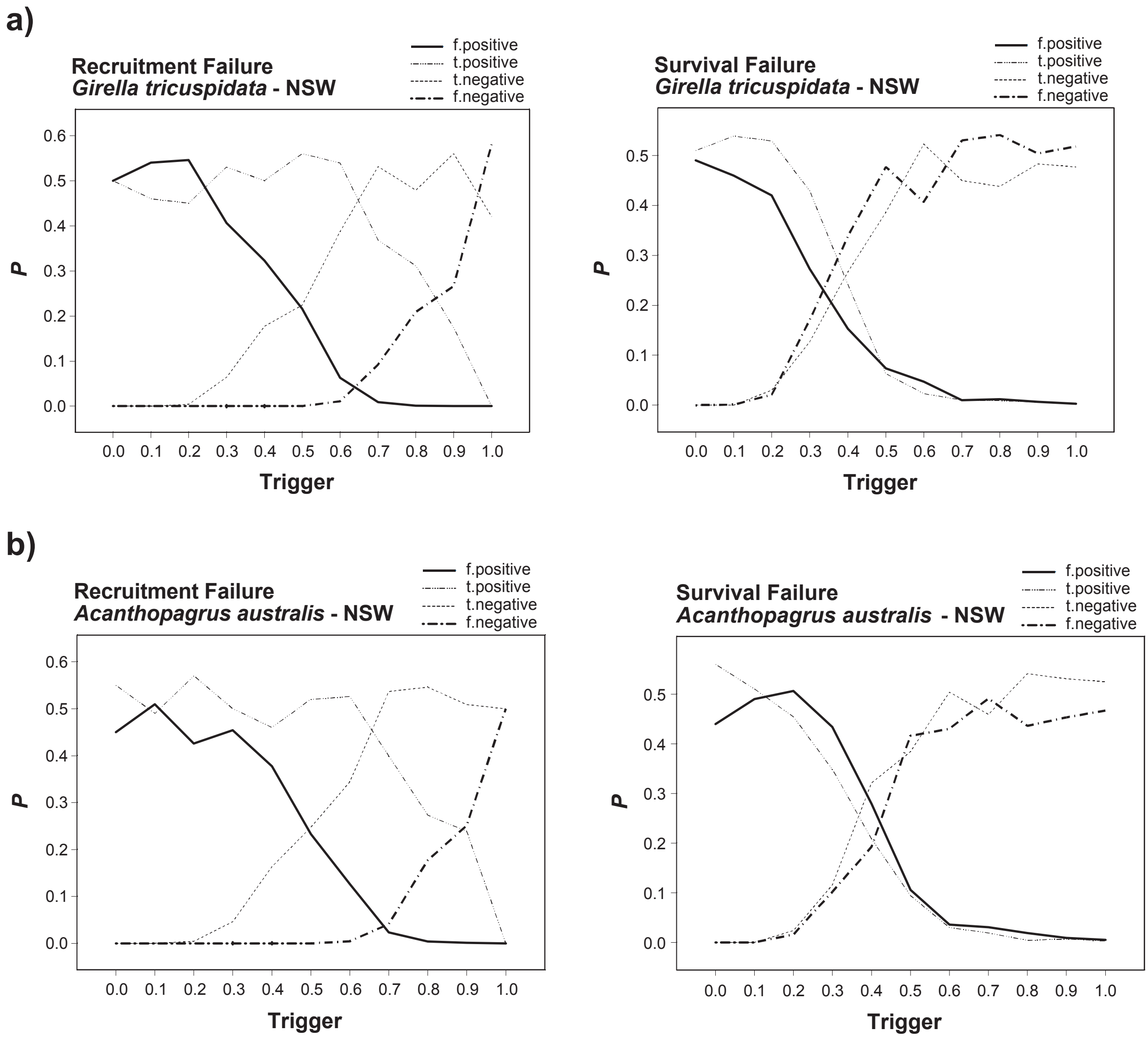

Figure 10. Probability of false positive, false negative, true positive and true negative outcomes for a range of trigger points from zero to one, in the events of recruitment failure and survival failure for (a) luderick and (b) yellowfin bream in New South Wales.

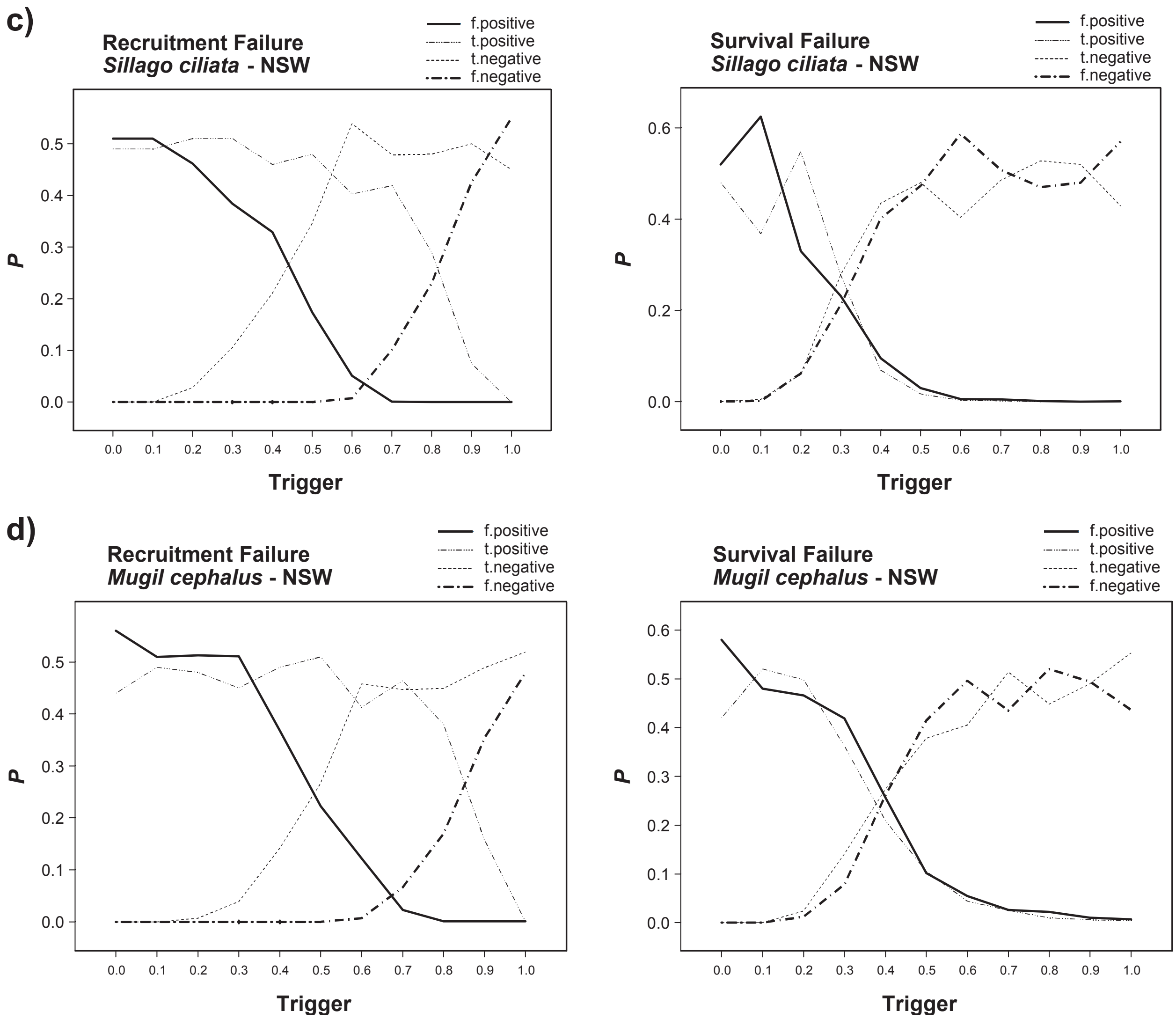

Figure 10 cont. Probability of false positive, false negative, true positive and true negative outcomes for a range of trigger points from zero to one, in the events of recruitment failure and survival failure for (c) sand whiting; and (d) sea mullet in New South Wales.

4. Discussion

The most important point about the practice of using catch as an indicator of stock biomass is that the outcomes appear to be extremely robust with regards to catch history. Failure of the existing biomass to survive is difficult to detect and requires that trigger points be set rather low (greater than 10%-40% variation from historical catches). This will result in a high probability of false positive declarations. In contrast, detection of recruitment failure is straightforward and can be completed with trigger points set at 50%-70% variation from historical catches. Such values will see relatively low probabilities of false negative or false positive results. The trigger points proposed by NSW Fisheries (Table 5) are well within the boundaries required to detect recruitment failure with very low probabilities of false negative outcomes for all species. They are also within or very close to levels required to detect survival failure.

Two parameter values, z (steepness of the stock–recruitment relationship) and m (survival of existing biomass) need to be assumed in this modelling study. Sensitivity analysis indicates that the conclusions for detecting survival failure are impacted by altering assumed values of m, but are robust to changes in z. Given that z is, for all intents and purposes, impossible to estimate from empirical sources, this is a welcome result. In principle, the values of m could be estimated from individual growth data and estimates of natural mortality, but these were not addressed in this study.

The contrasting results for survival failure and recruitment failure are very important. Survival failure is somewhat analogous to growth overfishing, whilst recruitment failure is essentially the same as recruitment overfishing. Thus, although survival of the stock is important, as long as there is sufficient spawning stock, the population will continue to recruit and the impact may not be seen in landings. In contrast, successive recruitment failure will eventually cause the collapse of a fish stock and have an obvious impact on landings. Triggers could be set at low values in an attempt to detect survival failure (~30%) but there will be a high frequency of false positive alarms.

Should such triggers be used within an operational scenario for finfish, once a trigger has been tripped there should be ample evidence from systematically collected catch-at-age or catch-at-length data to elucidate what type of event has occurred. Furthermore, that information will be much less ambiguous than variation in landed catches.

In fisheries where there is no other information available apart from landed catch information (for example, some low value invertebrate fisheries) use of catch as an indicator will be a valuable strategy. In the more valuable invertebrate or finfish fisheries, where catch-at-length and/or catch-at-age data is available, landed catch should only be used as a crude indicator of the state of the stock. Obviously, catch per unit effort information should also be collated when possible, even if it is a crude indicator such as catch-per-fisher. Such methods could be easily generalised to an index of catch rate.

There are several aspects of this analysis that need additional input from the stakeholders of the fishery. The first aspect is: what constitutes a problem? We have assumed in our simulations that when survival or recruitment become less than 50% of the historical value then that is the 'problem'. Like other reference points, this cut-off is somewhat arbitrary (Gilbert et al. 2000).

The other aspect requiring comment is the acceptable rate of false positive and false negative errors in the analysis. We described the conditions (Section 3.1) that we applied to the outcomes to select the appropriate trigger point value. This argument is based upon the level of commitment that stakeholders of the fishery and the NSW State Government have made to the application of the precautionary principle in the management of fisheries in NSW. Under that principle, the rate of false negative outcomes should be made as small as possible. The rate of false negative outcomes cannot be made zero as this would result in such high frequencies of false positive outcomes that the results could not be interpreted. The trigger points proposed by NSW Fisheries fall well within the boundaries required to detect recruitment failure, but managers and stakeholders need to consider the associated implication of increased likelihood of false alarms.

Appropriate trigger points for five species of finfish based upon statewide historical catches have been calculated. For dusky flathead the analysis was also completed for catches in three estuaries. To detect survival failure, a wide range (between 10% and 40%) of trigger values would have to be applied. In contrast, recruitment failure is reliably detected if a 60% deviation from historical catches is used as the trigger. These results appear to be robust across all species and estuaries.

This analysis did not use a particularly sophisticated modelling approach. An alternative method would be to base the population dynamics on a formal delay-difference model (Hilborn and Walters 1992, Quinn and Deriso 1999) and apply Bayesian sampling-importance-resampling (e.g. McAllister et al. 1994) methods to calibrate the model to the observed catches. It would, however, be surprising if the conclusions changed.

Using catch as an indicator of the stock is an acceptable strategy in low-value fisheries where catch is the only information available. Precautionary interpretations also need to be specified for quantitative and qualitative criteria within the analysis. The indicator seems particularly effective at detecting recruitment failure but is not a robust indicator of survival failure. The crudeness of the indicator, however, is such that it is absolutely imperative that NSW Fisheries continues to collect data about the age and/or length structure of commercial finfish harvests. It is only with this additional information that issues affecting the stock will be able to be elucidated. Resources also need to be applied to retrieve some historical effort information and better systems put in place to collect future information.

The tripping of a trigger point of 60% or 70% will indicate a serious problem with the stock. In such circumstances, NSW Fisheries should be prepared to take immediate and decisive action to control fishing mortality. Where possible, multiple sources of evidence should be available because the necessary decisions to control fishing mortality are likely to cause social and economic hardship.

Acknowledgements

This project was funded by NSW Fisheries as part of a research contract providing modelling services for the NSW Estuary General Fishery. The work benefited from the support of several individuals and organisations. At the Centre for Research on Ecological Impacts of Coastal Cities we thank Professor Tony Underwood, Dr Gee Chapman and Dr Mike Holloway. From NSW Fisheries, we thank Dr Kevin Rowling and Dr Duncan Worthington for their comments, and Dr Charles Gray and Ms Marnie Tanner for their extensive support. We also thank Dr Steve Kennelly for initiating this project in January 2001. Finally, we acknowledge the support of members of the Estuary General Management Advisory Committee.

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To be Bayesian or to Bootstrap:

What is the risk?

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Abstract

A discussion is presented on the advantages and disadvantages of both Bayesian methods and bootstrapping methods of stock assessment and harvest strategy evaluation. Neither is the perfect solution to the problems encountered in stock assessment. From the literature one could be forgiven for believing that a stock assessment not conducted using Bayesian methods is somehow inferior. This is not the case and the particular circumstances of each fishery should be considered when deciding what methods should be used. It could also be argued that both methods should be applied to determine whether they produce contrasting results, which hopefully would be enlightening about the system under study.

Introduction

When investigating the most likely outcomes of different management or harvest regimes one attempts to answer questions about risk. Typically, one may ask: 'If we manage a fishery in a given way (e.g. a particular Total Allowable Catch (TAC) or number of days fishing), how likely or probable is it that a particular performance measure will be achieved (e.g. stock biomass in five years' time will be greater than some reference biomass)?' One can be more specific and ask: 'What management strategy will lead to there being an X % chance that stock size will have increased relative to some reference biomass over a Y year period (where X and Y are your favourite numbers for this sort of question)?' The details of the management strategy and performance measure will differ depending on the fishery, but the essence of the problem is that the answer is not deterministic. The questions are about the risk of following a defined management strategy, with the risk being defined in terms of the performance measure used. To answer the questions we conduct risk assessments.

The analyses cannot be deterministic because we can only obtain uncertain information about the system being assessed. Not only will there be variation in the data but the parameters of the model used to describe the system are probably not constants as the models tend to assume. The first source of uncertainty would be termed 'observation error' while the second source is generally termed 'process error' . As we cannot be certain that the specification of the model used to describe the system will be sufficient to capture the important dynamics of the fishery there is also uncertainty over the structure of the model used in the assessment. Many assessment models only deal with the observation error and effectively ignore both the process error and model uncertainty. Even so, the practice of using multiple models of varying complexity when assessing fish stocks is becoming more common.

Through the 1990s, there developed a debate on how best to approach the problem of accounting for uncertainty in stock assessments for fishery resources and how that uncertainty could be included in risk assessments. The problem definitions and even the meanings of various terms used were refined and consistency achieved in the literature. Important contributions to this debate across a range of ideas, were produced by investigators such as Francis (1992), Punt and Hilborn (1997), and Chen and Fournier (1999). A major part of the debate was over the use of Frequentist methods versus Bayesian methods. The intensity and fervour of the arguments was remarkable but the odd thing is that of the fisheries modelling literature it appears that the Bayesian camp won the debate. Nowadays, in fisheries where sufficient information exists to seriously consider management strategy evaluation, resource managers tend to equate stock assessment with associated harvest strategy evaluation, by using Bayesian methods. Their action is, however, a mistake: it is not a necessity that Bayesian methods be used to characterise the uncertainty in a stock assessment and then conduct a risk assessment. There are advantages and disadvantages to both the analytical methods available for fisheries stock assessment; that is, Bayesian and Frequentist methods. In this document we will restrict our discussion of Frequentist technique to a discussion of bootstrapping methods.

Characterising uncertainty

Bayesian and bootstrapping methods deal with available data in different ways when attempts are made to characterise the uncertainty in an analysis. Superficially, both methods are similar because they both develop arrays of different parameter values and both can be used to characterise the uncertainty inherent in any model fitting exercise (stock assessment), generating the parameter estimates and model outcomes needed in an assessment. In addition, both can be used as the basis for developing the projections that are fundamental to harvest strategy evaluation. However, the parameter estimates and model outcomes are produced in very different ways and these differences are behind the controversy between the two methods.

Bootstrapping is a method that simulates multiple data sets equivalent to the original (Figure 1). The assessment model – if fitted anew to each of these bootstrap samples – produces a new optimum model, complete with new model parameter estimates and model outcomes. By collating a multitude of these separate parameter estimates, percentile confidence intervals can be produced. The bootstrap samples are generated by combining the expected values for the variable being modelled, taken from the optimally fitting model, with bootstrap samples of the residuals between the observed data and that predicted by the optimum model (Efron and Tibshirani 1993; Haddon 2001). A bootstrap sample is simply a random selection of the same number of observations from a set of observations with the selection being made by replacement (hence some observations can occur more than once and others can be entirely omitted). The emphasis is on the data rather than the parameter estimation.

One advantage of the bootstrapping approach that follows from this emphasis on the data is that if the parameter estimation is in any way biased then bootstrapping can provide an estimate of that bias (Efron and Tibshirani 1993). This does not arise with the Bayesian approach.

The Bayesian approach determines the relative quality of fit produced by different combinations of parameter estimates (along with the prior probabilities of each parameter set) (Figure 2). This relative fit is described by the posterior probability distribution for the parameter set. Because it does not involve fitting the model each iteration, the Bayesian approach sounds like it would be a good deal more rapid than the bootstrap process. However, the processes used to select parameter combinations that are likely to be of acceptable fit (Sampling Importance Resampling – SIR; Monte Carlo Markov Chain – MCMC) also take a very long time. The algorithms involved can be relatively simple (Gelman et al. 1995; McAllister and Ianelli 1997) but each is attempting to define the extent and shape of the posterior distribution of the model parameters.

To obtain an adequate description of a complex posterior for many parameters, and determining the model outcomes from those estimates, can take millions of iterations of parameter selection. In this way the emphasis in Bayesian analysis is on the parameter values.

Both bootstrapping and Bayesian posteriors can be used to determine the precision with which parameter estimates (and model outcomes) are obtained. Projections used in risk assessments can use the parameter sets applied to define the Bayesian posteriors, or from bootstrap analyses, as a starting point.

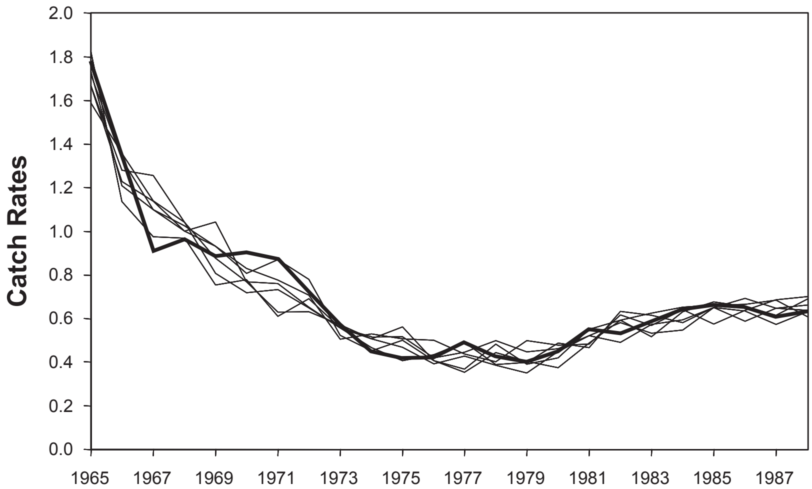

Figure 1. The raw catch rates of the Cape hake fishery (*Merluccius capensis* and *M. paradoxus*) off northern Namibia (listed in Polacheck et al. 1993, Table 1) are shown by the thick line. Six bootstrap samples are illustrated by the fine lines; these are produced by combining the expected catch rate from the optimally fitting model with bootstrap samples of the residuals between the observed data and that predicted by the optimum model.

Figure 2. Four independent MCMCs approaching the posterior distribution of two parameters from a simple stock assessment model (*cf.* Figure 11.2, Gelman et al. 1995). All of the starting points are out on the periphery but converge to an area that, if the MCMC procedure had been prolonged, would define the posterior distribution of both model parameters.

What are model parameters?

Both analyses are obviously highly dependent upon the original data used. Bootstrapping attempts to characterise uncertainty by a consideration of the relationship between the data and the optimal model fit; that is, it uses the residuals to generate alternative data sets that might have been. Bayesian analyses characterise uncertainty by investigating how the quality of fit to the sample data alters as the parameter set selected is altered. Bootstrapping approaches the problem by modifying the data and determining the implications, while Bayesian analysis modifies the parameter sets and determines the implications.

A potential problem with the Bayesian approach is illustrated by Press et al. (1989: 549) who were attempting to capture the notion of likelihood: 'It is not meaningful to ask the question, "What is the probability that a particular set of fitted parameters $a_1 \ldots a_M$ is correct?" The reason is that there is no statistical universe of models from which the parameters are drawn. There is just one model, the correct one, and a statistical universe of data sets that are drawn from it!'

Press et al. (1989) are saying that the data set actually obtained is only a sample from the world and that, under different circumstances, a slightly different set of data could have been possible. However, there is only one optimal model underlying the processes being modelled, from which the data was gathered. The observed data vary about the expected values in a manner that relates to whatever statistical distribution is used in the model (e.g. normal, log-normal). The parameter values do not vary in any known way or in relation to any known statistical distribution; they are not random variables, they are simply unknown variables.

These ideas capture some of the flavour of the philosophical disagreement between Frequentists and Bayesians. As stated by Dennis (1996: 1098): 'Bayesians, you see, are not allowed to look at their residuals. It violates the likelihood principle to judge an outcome by how extreme it is under a model. To a Bayesian, there are no bad models, just bad beliefs.' However, in practice, which method works best?

The origin of priors

One source of argument about the use of Bayesian methods is the dependence of Bayesian analyses on the prior distributions that are attributed to each parameter being considered. There are a number of problems with priors and their generation. At their most extreme, priors can be generated that include the opinions of informed individuals (expert opinion). Such informative priors can influence the outcomes of analyses.

When discussing the justification of the origin of priors, Punt and Hilborn (1997: 43) stated: 'We therefore strongly recommend that whenever a Bayesian assessment is conducted, considerable care should be taken to document fully the basis for the various prior distributions… Care should be taken when selecting the functional form for a prior because poor choices can lead to incorrect inferences. We have also noticed a tendency to underestimate uncertainty, and hence to specify unrealistically informative priors – this tendency should be explicitly acknowledged and avoided.'

The use of informative priors has been so controversial that Walters and Ludwig (1994) recommended that non-informative priors be used as a default in Bayesian stock assessments. Unfortunately however, there is a problem with trying to generate non-informative priors (Box and Tiao 1973). The problem with generating non-informative priors is that they are sensitive to the particular measurement system used (Punt and Hilborn 1997). That is, a prior that is uniform on a linear scale will not appear linear on a log scale (Fig. 3).

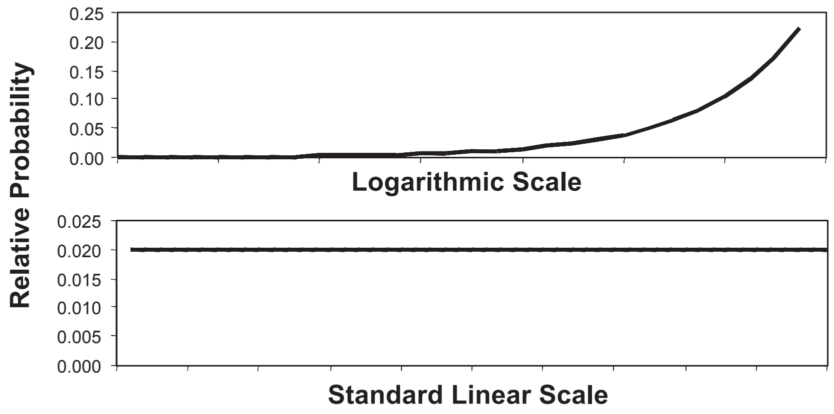

Figure 3. The same data plotted on a natural logarithmic scale (upper panel) and a linear scale (lower panel). The uniform distribution in the bottom panel appears distorted when viewed in logarithmic space. Note the effect on the vertical scales of the two graphs (after Figure 3.28 in Haddon 2001).

One strangely useful aspect of using uninformative priors is that when the available data are uninformative with respect to a particular parameter the posterior will be equivalent to the imposed prior.

Unknown and poorly estimated parameters

The two approaches handle unknown and poorly estimated parameters differently. A classical problem in fishery modelling is how to handle natural mortality. It is often assumed constant across ages and through time but attributing an exact value to the natural mortality rate is equivalent to claiming one knows this value without uncertainty (obviously a poor assumption). How Bayesian analyses handle such situations is often argued to be one of their greatest strengths. A Bayesian analysis would allocate a *plausible* prior distribution to such a parameter and the implications of this would be integrated over the different values during the generation of the posterior probability distribution of the remaining parameters. Thus, the uncertainty relating to such awkward parameters is dealt with in an elegant and simple manner. In effect, this is equivalent to including an element of process error into the analysis. However, this strategy can give the impression of a greater understanding of a situation than really exists. Integrating over such parameters is a fine idea except for the problem of selecting a suitable prior. Including process error into an analysis would be extremely valuable except, once again, it implies more knowledge than we have to hand. While reasonable arguments can be made for generating the required plausible priors it would still involve including informative priors in what is invariably a sensitive area of any assessment model. If there is no information about how, for example, natural mortality varies (the absence of such information is standard) then including such priors can give overly confident conclusions.

On the other hand, using bootstrapping there is no general method available for dealing either with process error and observation error or with difficult parameters such as natural mortality. The use of the Kalman filter to work with both process and observation errors is not yet a general solution to all assessment problems (Sullivan 1992). The only remaining option is to conduct classic sensitivity tests setting the parameters of concern (e.g. *M*) to a set of different values and determining the effect. The only advantage this has is that it explicitly identifies the uncertain parameters and permits any trend in the impact of changing their values to be determined.

Conclusions

In this brief essay it should appear obvious that my preference lies with non-Bayesian approaches. However, both Bayesian posteriors and bootstrapping are, in the end, just tools that can be used in the formal assessment of natural resources. Whether one wishes to ignore the philosophical issues and become known as a pragmatic Bayesian is not really a problem because occasions arise when the use of one approach would be preferred to the other.

As with many of these controversies it is possible that the solution lies somewhere in the middle of the alternatives. It is good practice to apply multiple models to the same situation. Speaking about surplus-production modelling versus age-structured modelling, Hilborn and Walters (1992: 329) stated: 'It is better to think of the two methods as simply different; if biomass dynamic methods provide a different answer than age-structured methods, then the scientist should try to understand why they are different and analyse the management implications of the different predictions, rather than concentrating on deciding which method is correct.'

I suggest that a suitably altered but identical statement could be made about using Bayesian and alternative methods as very often the results are surprisingly similar. However, different results should provide some insight into what is driving the differences. It seems quite possible that uncertainty is being underestimated by both methods in many assessments and that uncertainty may be more likely to come to light if both methods are applied. Of course, each of these methods can take a good deal of time so suggesting this option may not be as sensible as it may appear at first sight. Nevertheless, rather than risk throwing out the potential benefits with the bootstrapping bathwater I recommend that both methods be considered when conducting analyses, especially if the levels of uncertainty appear to be high.

Acknowledgements

This paper was written after the loss of the original conference paper and so may not be an accurate reflection of the contents of the talk given in 2001; a fact that explains its almost note-like brevity. I thank Dr Norm Hall for reminding me of a number of the things I spoke about at the workshop. In addition, I thank Dr Stephen Newman for his remarkably gentle reminders about deadlines.

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Theme Session Three

Discussion, questions and answers

Rapporteurs: Michael Mackie and Stephen J. Newman

Tony Hart (Trophia). "I guess I'll direct my question to Malcolm, but it's also for all of you. It's a question about probabilities in general and I was wondering whether you would like to speak about the difficulties associated with understanding exactly what probability estimates are."

Malcolm Haddon (TAFI): "Right, thank you. I suppose strictly the term is the 'likelihood' because our point probability will be infinitesimal; it's not going to be there. But you remember the normal distribution probability density function, for example, has a big interval in front of it? Well, one can dispose of that and work out what would be the likelihood of a certain value given a mean and standard deviation so for each data point that you have, you can find its likelihood relative to your expected model prediction. So your model predicts one value and your actual observed value may be slightly different from it. How likely is it that you are going to have that much deviation? Now, this is not the sort of thing that can be explained very easily without lots of diagrams and arm waving – actually you could read my book! I did put in a lot of effort about writing about likelihood. There are books on it, the academics argue about it; it seems like a very non-intuitive notion. Perhaps, Ana – or Norm – would you like to comment on that?"

Ana Parma (Centro Nacional Patagónico, Argentina). "Just forget it and live with the discrete world! Think of the probability for a given fixed area and that's what makes sense to managers and to everybody and that makes sense to you too."

Norm Hall (Murdoch University, WA). "I'd just like to add one thing and that is in the old days we used to come out always with deterministic results; we gave no indication of the uncertainty. As we've moved away from those point estimates, where we've said there's only one particular value that this prediction can take, we now really are trying desperately to understand the uncertainty. However, it's a conditional uncertainty which is based on the assumptions that you've used for the model; it doesn't really reflect the true uncertainty of the system, because there's all sorts of model structure problems as well, so essentially as you move away from that deterministic result where you have a single value, you are in fact recognising the uncertainty of trying to move towards this probability based approach."

Jim Penn (Fisheries, WA). "Norm, a question for you. In the last presentation, all of the individual species in the multi-species fisheries were being assessed to come up with, I presume, some TAC for each fishery. But the observation that I've made from the literature and experience locally, is that you rarely have all of the species operating at their optimum level at the same time and usually there's correlation between positive and negative correlations, with some up, some down, regularly. Is there anything in the modelling that we can look to which would give us some guidance in how we deal with this, because we're trying to manage an overall fishery in a multi-species situation?"

Norm Hall. "I think the first thing is that we're sort of dealing with a stochastic world – it comes through as having this variability. Our problem really is that we are still moving towards models which bring in the stochastic nature of the processes. We bring in the models which are often relating to the observation error rather than the process error. Accordingly for many of the things we are dealing with, we are failing to recognise the particular nature of our systems – that they do have the ability to bounce around from year to year. Our question really comes back then in terms of the predictions that we make, in an uncertain world, of what the future recruitment stream is likely to be. We tend to use modelling strategies that either assume a distribution to that variability such that we can try to predict ahead based on the distribution of properties that we have observed and estimated from our model. The alternative approach is to try and use predictions that are based on the observed series of recruitment in the fishery. Our difficulty then is of course that we start to need to bring in those time series aspects where there is auto-correlations that are coming through. But I guess the answer is yes, we do tend to bring it through in terms of predictions which allow for the uncertainty, and that allows us to try and assess the ability of the different harvest strategies to work within this rather stochastic world."

Ana Parma. "I interpreted your question as to how do you manage a mixed fishery when you cannot really shoot for the optimum for all of those. There are obviously many approaches and I think the second slide that Norm showed is an explanation for how they deal with that: they basically go with the most conservative one. So out of the list of species that the North Pacific Council does assessments for, they come up with TACs for all of them and then as soon as the TAC is reached for one of the species, the fishery is closed. It's a very conservative approach. In the Bering Sea they even have like a global quota for all the ground fish aside from pollock that says the total quota cannot exceed something. And that number came out of nowhere – they've inherited a lot of history – and they live with that. You see this developed as a foreign fleet, so measures were really tight because they were being applied to foreigners. And that's a tradition in the Council so that they are not shooting for the optimum; basically they are really trying to be very conservative."

Malcolm Haddon. "So I wouldn't mind commenting on that. When you put that slide up Norm, I was surprised, because it's a very brave thing to say 'we'll go for the minimum species' because I mean in terms of the catches, they're about a thousandth of the pollock catch – not right?"

Ana Parma: "Yes, but the pollock is mostly a single species fishery."

Malcolm Haddon. "Oh it is, so that's not by-catch?"

Ana Parma. "All of them are totally mixed. Some of them are more mixed than others, though the pollock is pretty much on its own."

Malcolm Haddon. "I was very surprised that they would shut down a million tonne fishery because octopus was getting a bit rare. I was impressed! Although for the other ones, that would be more similar to what we have in Australia I think, where they're more evenly balanced in their total catches, some of them worth maybe ten times greater than the octopus catch or something, and I think that's impressive. Have you seen things like that before, Norm?"

Norm Hall. "No, I don't think so, it's never been quite so strict. Most times the results are rather difficult to assess. The question is really whether you assign your TAC on a global basis, over species, or whether you actually assign it on a fishery by fishery basis. For the fisheries in the north-eastern part of the US, the TACs are set on the individual species. I didn't make enough mention of this overfishing limit. They have a requirement, by the way, in their fisheries legislation, that they must specify what is overfishing – overfishing as being distinct from overfished. Overfishing is where fishing mortalities are in excess of that which would create the optimal yield; the maximum sustainable yield. And so essentially as soon as you go past that overfishing limit, they are required to take action. I think in general though most of the species are done as single species in terms of the allocation of TACs so it is rather a brave move to move towards a global approach."

Ana Parma. "Just one more comment on the topic because this is probably not the best fishery on which to discuss this problem. In the US and Canada there are two fisheries that have the worst of the multi-species problems. In the US we are talking about the rock fish fishery. It is not that they are trying to shoot for the optimum; it is just that they cannot manage the fishery that way, because the assemblage is so mixed. The fishery is simply a schedule of openings and closures and discards that destroys all the credibility and all the relationships between the industry and the scientists. It has nothing to do with the quality of their assessment necessarily: it's just that their management is so poor and it breaks down the whole process. On the other hand, there is the same sort of fishery in Canada and it was just as bad as the US one until they went to ITQs. Carl Walters was doing some spatial analysis in the Canadian journal and trying to see if by spatially allocating the quota, you would be able to separate some of the species. He couldn't because these things operate at a much smaller spatial scale. We always say that the fishermen will be able to do it if they have the right incentives: the fishery moved to ITQs and the problem has been solved in, like, two years, simply because they were able to reallocate a spatial distribution of effort so that they could try to get to their ITQs for all the different species in the fishery."

Norm Hall. "You'd have to be very much aware of the gemfish industry in New South Wales. Talk to Kevin Rowling about this ability, for fishermen to avoid the gemfish."

Jim Penn. "I'd like to have another go at that Norm. I guess what I was looking at was that in a number of our fisheries where we have sort of switching between species within the fishery, the stock itself may be in good shape, but the availability of fish changes from one species to another. I'm wondering whether in fact we ought not to be looking more at time series analysis and looking at actually predicting from the presence of one species the abundance of the other; in other words, looking at the relationships between the species in some broad context, so that when you set an average, an overall TAC for the combined species, it's in some way manageable and will work as a management tool."

Norm Hall. "I think at this stage the modelling has moved away to some extent from species switching by fishermen. At one stage, this was a rather hot bed of work which was going on, I think, within Ray Hilborn's school and there may be one or two people who still work in this area, but it seems to have lost some of the emphasis. I think you're right, the problem really is that there is this ability of fishermen to change the species towards which they're directing their effort and the other problem is that you can't in fact set the optimum such that you optimise both of those, unless you've got somewhere clearly separating the two species: where there's overlap and where there's choice by fishers and you've actually set a global thing which allows them to make that decision. You haven't got the same sort of levels of control and one imagines there that what you're going to have to try and do is somehow reflect on the fact that they will be making decisions and that those decisions will determine the catch that they're making from the two species in combination. I think you're probably right, there is probably some information content in the data when you see the switching; it represents the relative success that's coming through from those species and the extent to which the fishermen switch their effort is going to probably give you some information about the other species. How it's going to be worked Jim, I don't know."

Malcolm Haddon. "Jim, you mentioned the global TAC for a mixed-species fishery and of course we all know the dangers of the risk of high grading, of discarding lower value species for higher value species – if they happen to catch them. You mentioned species composition as an indicator of perhaps multi-stock status and that's an area that may have some value. I forget who I was talking with now, but they were talking about doing a species composition survey across a large geographical area. Now there's a complication that species composition in any system is going to change through seasons through increased or changing vulnerability. Having looked at how species composition changes through time, whether they're natural or not, perhaps that's one good use for a large MPA. But without such non-fished areas, I think you'd be hard pressed to use species composition as any form of assessment technique."

Murray MacDonald (Fisheries, Victoria). "A question to all the panellists. As a general observation, it seems to me that the kinds of assessment approaches that were being described this morning, particularly for data-poor fisheries, were assessment approaches which were based on the fundamental assumption that fishing was the major, or at least a major factor, affecting the dynamics and community structure of the resources in question. Can you comment on the utility of these approaches in situations where fishing may not be a major factor – for instance, where habitat and environment factors affecting reproductive success and/or survival of individual populations and affecting community structure may be the primary factor in determining what's going on in the system? Can you perhaps suggest approaches which might allow us, in a cost effective way for data-poor fisheries and small fisheries, to determine the relative importance of fishing versus these other factors in driving the system?"

Malcolm Haddon. "I was wondering if somebody would point that out. I think the closest we can get to that is what Norm was talking about with the multi-species point of view and the system-wide study of such things. That brings us back to the integration of stock assessment advice with regional planning. You are quite right, these methods tend to ignore non-population-based inputs, unless there is a marriage between such strategies and regional planning; I mean in terms of the last talk we heard, the geographical scale of that is so vast, that it would have to be an amazingly large input to have an effect. But for a small clam fishery in George's Bay on the east coast of Tasmania, you wouldn't have to have much impact at all to just wipe them out. So without that marriage between regional planning and perhaps some of the more multi-species approaches discussed by Norm, you're right, that will be ignored and we'll just think that any decline we see is to do with fishing. Unfortunately, the two tend to be compounded. There's a history of excess fishing mortality in Australia and most developed countries, so it's very hard to tease them apart."

Ana Parma. "I think so too. It's very hard to tease them apart even if you have data, because these things tend to be confounded. Now I think the question is valid. Obviously the salmon in the States are a case in point, where people are trying to sort out what the effect of the hatcheries are. I mean, you name it, all kinds of things that are happening to the environment have nothing to do with the fishery itself, it's just that you need to adjust the management to at least know how to make it work. It's usually pretty hopeless, especially if you don't have data except for cases that are pretty obvious where you have some obvious environmental impact that is affecting the population."

Norm Hall. "I think the greatest problem we've got in many of the fisheries that we're trying to assess, is that the contrast in data is lacking in most cases. We're dealing with fisheries that have been exploited for a reasonably long time, that have reached a particular level of exploitation. What we're seeing in most cases is more variability to this related to environmental fluctuations, and these are probably going to dominate because we won't see the changes in stock size, unless these are reflected in fairly major events as a consequence of the environment. But then the untangling of the relationship between the impact of the stock size on the subsequent recruitment or the catches that are seen and the environmental factors is likely to be very difficult. You are not going to be able to see the contrast that you need with something or other which is occurring when you've got a high population size and which is driving you down to a small population size. You've got to get the same sort of response each time and it's going to in fact mask the variable that you are hoping to see within the data. It seems fairly clear from the work that Nick Caputi has been doing, that you need to start bringing in some of those environmental factors. This may be difficult, but I still see too many people going out and using a shotgun approach and trying to do this without thinking about the processes that might be involved. Unless you do bring these processes in, you've got no chance at all of trying to tease out the impact of the perhaps less dominant part of this particular process, which is the relationship between the stock and subsequent recruitment. I think that the question is really whether it's the fishing effort and the removals that are dominating the process or whether it's the actual environmental perturbations. And clearly one's going to have to sort of bring those in and start trying to assess them, in some sort of model, which at least allows for that approach to be explored."

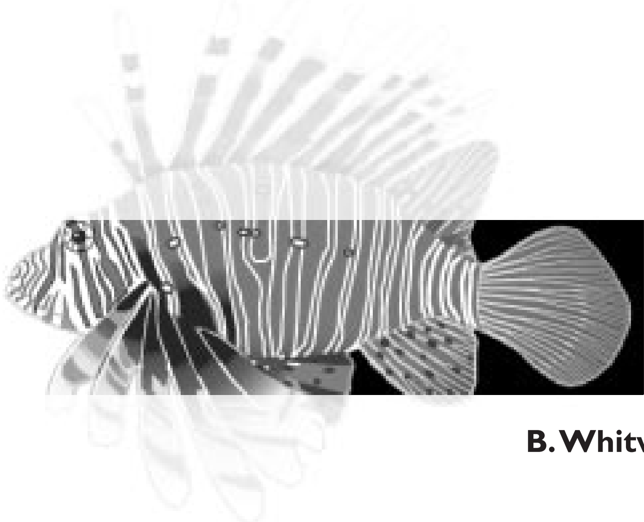
Summary of Theme Session Three *by Malcolm Haddon*

Malcolm Haddon. "I think that's it; but I suppose it's my job to summarise this past hour. I'll try and do it in four lines. Uncertainty might dominate potential advice from any stock assessment and there's not going to be a simple answer, so I reckon rather than making life easier for ourselves, people are going to have to become more sophisticated in their understandings of what's going on. We've seen that there are possibilities in taking very detailed looks at individual small fisheries, as with James Scandol's views. There are also multi-species possibilities and these areas are being investigated and pursued, obviously very actively. Finally, I was impressed with the last talk that described assessment methods so well adapted to the management options and objectives that have been adopted. I think that's a direction for us all to aim at. We need clear objectives in our management so that we can devise the best possible stock assessment methods that we can.

I'd like you to thank speakers, both present and not present, and that's it. Thank you very much."

THEME SESSION FOUR
Data issues

Chair: Sandy Morison



Is there more to the meaning of life than data?

B. Whitworth, J. Chesson, R. Fletcher and K. Sainsbury

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The title of this workshop suggests that there are two classes of fisheries – the haves and the have-nots – as measured by their data. But what does it mean to be data-rich or data-poor? Are data-rich fisheries happier than data-poor fisheries? Are data-rich fisheries just as data-limited as are data-poor fisheries?

We address these questions by asking why fisheries want or need data (A fishery is defined as a group of people who are involved with harvesting fish. They are usually specified in terms of the methods they use, the area they operate in and/or the species they catch.) Using the National Ecologically Sustainable Development Reporting Framework for Australian Fisheries developed by the Standing Committee on Fisheries and Aquaculture (see Fletcher et al. 2002) as a convenient way of structuring the discussion, we argue that it is a matter of matching the management of the fishery with the type and level of data collection.

Breaking the 'data-poor – collect more data' link

Fishery managers and scientists often link automatically the state of 'data-poor' with the strategy of 'collect more data'. However, this strategy is not always appropriate. To determine when data is limiting and to prioritise the order of data collection (because data collection is costly) we need to determine where data limitations are having the greatest impact on fishery management. Fisheries are managed according to the principles of ecologically sustainable development (ESD) and this is defined in the National Strategy for Ecologically Sustainable Development (1992) as 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased'.

The National ESD Reporting Framework for Australia's fisheries has divided ESD into the following major components and sub-components:

1. Contributions of the fishery to ecological well-being
   - Retained species
   - Non-retained species
   - Other aspects of the environment

2. Contributions of the fishery to human well-being
   - Indigenous well-being
   - Local and regional well-being
   - National social and economic well-being

3. Ability of a fishery to contribute
   - Governance
   - Impact of the environment on the fishery

Each of these components is further subdivided to suit the needs of a particular fishery using the component tree techniques developed by the Bureau of Rural Sciences (Chesson and Clayton 1998; Chesson, Clayton and Whitworth 1999). Further information on the National ESD Reporting Framework can be obtained from the web site: www.fisheries-esd.com or from Fletcher et al. (2002).

Component trees provide a convenient tool for identifying where data exist and where they do not. All fisheries are data-limited in at least some components. Even a data-rich fishery such as the Western Australian Rock Lobster Fishery lacks data on other retained species such as octopus and deep-sea crabs.

Figure 1 presents the generic component tree for the effect of a fishery on the general ecosystem.

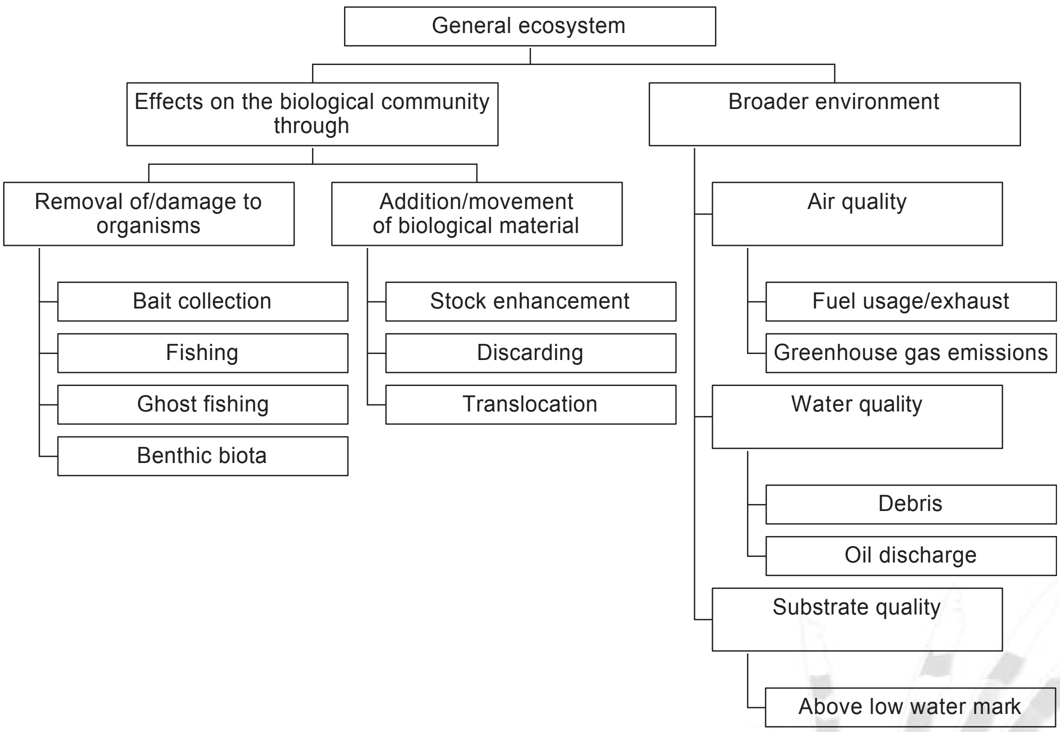

Figure 1. Effects of a fishery on the general ecosystem.

Is data collection the answer?

Often data are collected before it is clear what management action the data will inform. The report headings in the National ESD Reporting Framework create the link between the fishery objective, the management action and the data that are needed:

1. Operational objective (plus justification)
2. Indicator
3. Performance measure/limit (plus justification)
4. Data requirements
5. Data availability
6. Evaluation
7. Robustness
8. Fisheries management response
   - Current
   - Future
   - Actions if performance limit exceeded
9. Comments and action
10. External drivers

If the data do not address a clear objective their interpretation may be ambiguous and lead to more confusion. For example, in the Victorian Abalone Fishery the ecosystem can be independently monitored through the use of fishery divers. At present, however, it has not been determined what degree of ecosystem change is important, what level of change is critical, and what management actions would be appropriate if a change is detected.

Alternatives to data collection

Simple changes to management regimes may remove the need to collect costly data for monitoring and evaluation. For example, it may be simpler and cheaper to set a zero Total Allowable Catch (TAC) for the green lip abalone (*Haliotis laevigata*) in the Victorian Abalone Fishery, rather than collect extensive data for a stock assessment of this uncommon species. Another example is the Queensland East Coast Trawl Fishery where the mandatory use of turtle exclusion devices (TEDs) may ultimately eliminate the need to record turtle captures.

Smarter use of existing data

In some cases, particularly for social components of ecologically sustainable development, data may already exist. For example, the proportion of people from a regional community employed in a fishery may provide a proxy of community dependence on the fishery. This information may be collected from the Australian Bureau of Statistics and combined with State fishery agency data.

By cooperating with other fisheries, or by using national surveys, fishery agencies may be able to reduce the cost of data collection and analysis. For example, the Bureau of Rural Sciences is developing a project to survey community attitudes to fishing across Australia with the expectation that the acquired information could be used in a number of fisheries for a number of purposes. Similarly, the National Recreational and Indigenous Fishing Survey, funded through the Fisheries Action Program (Heritage Trust), Fisheries Research and Development Corporation (FRDC) and State fishery agencies, will provide 2000/01 data on these sectors and this may be used in fishery management. A report on the survey will soon become available from the funding agencies.

Data quality versus risk

The quality of data should reflect the probability of making a serious management mistake. In some cases it may be adequate to rely on anecdotal or aggregated data. For example the South Australian Lakes and Coorong Fishery suggest that interactions with whales could be monitored through anecdotal reports, considering the low risk of interaction. In the Queensland East Coast Trawl Fishery, non-retained species have been lumped together under the assumption that an overall reduction in non-retained species catch through bycatch reduction devices (BRDs) will safeguard individual species.

On the other hand it may be necessary to improve the quality of data collected for high-risk issues, such as effects on threatened species and the status of primary commercial species.

Conclusions

We argue that data are only the means to an end and not the end itself. Data need to inform management decisions. The National ESD Reporting Framework for Australian Fisheries shows that data are an integral part of the performance review cycle in fisheries management. The performance review cycle involves identifying the issues, determining objectives, selecting indicators and performance measures to monitor performance and specifying management responses. Only after their role has been identified, should data be collected. In some cases a precautionary management response negates the need to collect particular data. In other cases it may be possible to use data that already exist rather than collect more data. When it is determined that data are really needed then data quality should be tailored to the scale or risk of the issue.

We argue that the link between 'data-poor' and 'collect more data' must be broken. This breach can be achieved when data requirements are derived from a clear statement of fishery objectives, indicators and performance measures and the associated management responses.

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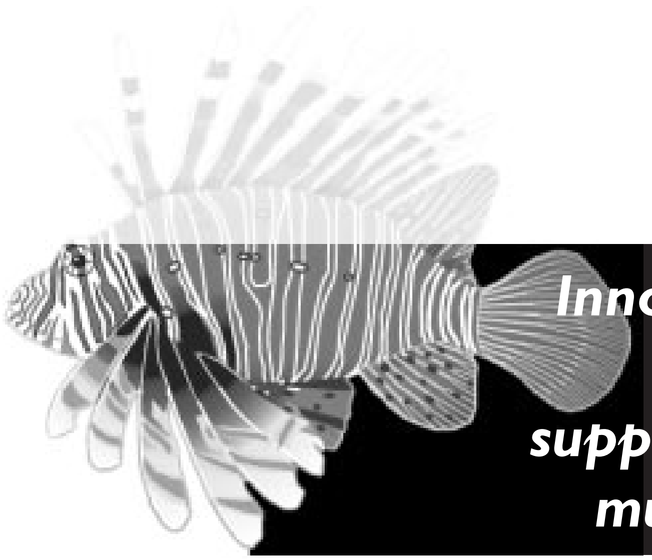

Innovative data gathering and assessment approaches to support future management of multi-sector coastal fisheries

J. Penn

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Abstract

The complexity of multi-sector, multi-species coastal fisheries will limit the ability of researchers to utilise traditional methods and data to assess the status of individual fish stocks for management purposes. For these fisheries, it is likely that a variety of methods will be used to generate an array of assessments and indicators for each stock. Management decisions in these circumstances are likely to be based on an overall 'expert' assessment of the stock supporting each fishery within a risk assessment framework.

Such a multiple assessment and monitoring approach will only succeed if all possible data sources are tapped, and in a cost-effective way.

This report will describe a variety of potential sources of fishery data to support this multiple assessment approach, including commercial, recreational and community volunteers, compliance data and targeted licensing systems. The implications for researchers into multi-sector fisheries in the future are discussed.

Introduction

The complexity of multi-sector, multi-species coastal fisheries will limit the ability of researchers to use traditional data sources and approaches to provide stock assessment information needed by management. Similarly, the management decision-making process will be more complex: it will need to take into account a variety of social and economic factors in each of the sectors (or user groups) in addition to addressing the underlying biological imperative of limiting harvests to sustainable levels. Due to the multi-species nature of the fishing activities, particularly recreational angling, it will not be possible in many cases to harvest every stock at its maximum sustainable level. In these circumstances, management controls will need to be based more on a risk assessment approach, to ensure that all stocks are maintained – even though some will be fished below, and others above, optimum levels.

To ensure appropriate and cost-effective data are gathered and appropriate analyses are carried out to support management needs, a clear understanding of the overall management framework is first required. This issue has been highlighted by the Ecologically Sustainable Development (ESD) reporting and assessment processes now being developed (Fletcher et al. 2002). For example, in the ESD reporting of fisheries of the west coast bioregion of Western Australia, the lack of a recreational management plan to match the long-standing commercial management plans has been noted as a deficiency to be addressed (Figure 1) (Fletcher 2002). Similarly, the lack of legislated links between commercial management plans and marine protected areas (which may in future quarantine significant amounts of some stocks from exploitation) needs to be addressed before attempting to set sustainable harvest limits for key target species in the region.

Future management frameworks for the coastal fisheries

Before considering the requirements of data for stock assessment, it is useful to consider the management arrangements which are likely to be employed. For practical reasons, in the future there will probably be a series of linked management plans, each dealing with a type of fishing activity or sector to be managed (such as commercial, recreational, charter). Appropriate cross-linkages between plans, setting shares of the overall catch (or fishing effort) compatible with meeting the fundamental requirements of stock sustainability and ecosystem-based management, will form an integral part of the new legislative structure. Against this background or assumed management framework there will clearly need to be data on the catches achieved and effort applied by each sector, as well as information on size composition of the catch relative to each species' size at maturity. This information is necessary to meet annual assessment and environmental audit processes as required by the current *Fish Resources Management Act 1994* in Western Australia and related State and Commonwealth environmental audit arrangements.

In terms of stock management strategies there are two broad approaches available: firstly, 'output' controls using methods such as catch quotas (i.e. individually transferable quotas, ITQs) and bag limits to directly control the catch; and secondly, 'input' controls in which methods such as individually transferable effort units (ITEs), time limits, spatial closures and gear controls indirectly control the catch by limiting fishing capacity. In Western Australia, where the commercial sector is predominantly managed by input controls (particularly the economically efficient ITEs: Rogers and Penn 2000) it is likely that similar approaches in terms of recreational fishing will be most compatible.

Typical coastal finfish stocks – Western Australian examples

To assess likely future management scenarios and corresponding needs for research information, a series of Western Australian coastal fisheries targeted by both commercial and recreational sectors were examined. These fisheries' commercial data sets (catch histories) illustrate the basic characteristics of four commonly fished Western Australian coastal finfish stocks.

The Australian salmon *(Arripis truttaceus)* commercial fishery catch data set (Figure 2) shows that the major catches are from the south and west coasts of Western Australia with a smaller, more consistent catch from South Australia (Ayvazian and Nowara 2002a). The major fishery along the south and west coasts targets a spawning migration and is the subject of a commercial beach seine fishery with long-term controls on fishing effort. Nominal effort is effectively constant (although market demand does sometimes limit catch) and as such the catch is a reasonably reliable measure of both abundance and spawning stock size. The stock on the south coast appears to undergo large cyclic variations, which apparently are environmentally driven and independent of fishing pressure. The west coast is even more variable, catches ranging from zero in some years up to 700-1000 tonnes in other years. The variation appears to be caused by effects of the Leeuwin Current on the species' migration around Cape Leeuwin and up the west coast (R.

Lenanton, pers. comm.). In the case of Australian salmon the highly variable stock abundance and inability of researchers to forecast regional catches indicate that only an effort-based management system will be effective. Research outputs will need to be tailored to meet this management requirement.

A similar situation occurs with the commercial Australian herring *(Arripis georgianus)* trap net fishery (Ayvazian and Nowara 2002b) on the south coast (Figure 3). This fishery, also under long-term management controls such that overall nominal effort is effectively constant, shows significant annual variation. As with Australian salmon, the variation is probably related to the environmental effects of the Leeuwin Current (Lenanton et al. 1991). The Australian herring stock supports the largest finfish component of the south and west coast recreational fishery (Ayvazian et al. 2000). The stock's characteristic and significant annual variations in abundance and catch need to be accounted for when assessing the type of research required for management.

Estuarine fish resources also make a valuable contribution to the commercial and recreational fisheries along the south coast. Two of the key fish species in these estuaries are black bream *(Acanthopagrus butcheri)* and King George whiting *(Sillaginodes punctata)*. Data on the commercial catches of these stocks (Figures 4 and 5) indicate that although effort is relatively controlled, the catch (and hence abundance) can be highly variable. In the case of black bream, spawning and recuitment occur essentially within the estuaries, while for King George whiting the catch is based on recruits located inside the estuary prior to their migration offshore to spawn (Ayvazian and Nowara 2002c). The degree of natural variation in abundance of these key angling species suggests that there are few available management options.

These cases all highlight the variable nature of coastal fish stocks, which are exploited in a multi-species fishery by the recreational sector and a series of commercial fisheries. In this context, the future management arrangements for commercial and recreational fishing are likely to be more appropriately based on input control mechanisms. This type of management generally relies on setting an exploitation rate such that a constant proportion of available stock is taken, rather than on a specific catch for an individual species.

With this background of high stock variability, the questions which are likely to be asked of researchers are:

- What is the total catch and what are the catch shares being taken by each sector?
- What is the long-term trend and variation in overall abundance for each of the target species in the fishery?
- What are the environmental factors influencing recruitment and future stock abundance?
- Are the breeding stock levels for the key species capable of maintaining acceptable recruitment levels?
- What are the average achievable ranges of sustainable catches for the major target species in each fishery?
- What is the impact of each fishing practice on the ecosystem where fishing occurs?

Fishery assessment and monitoring

To undertake the fishery assessments necessary to address the above questions, the data required are basic. The assessments are likely to support incremental changes to management, particularly where they relate to changes to sectorial catch shares. The data sets needed to answer the questions will be:

- reliable catch and standardised[1] effort measures or indices for each sector;

[1] Standardisation of effort is needed to take into account the impact of technological changes to fishing performance (over time) and hence catches achieved with a given amount of effort.

- a reasonable index of abundance for each stock (probably based on standardised commercial sector catch rates because these are more consistent and the data more reliable);
- an index of recruitment for key species, probably utilising catch per unit effort of juveniles in specific locations;
- annual size composition indices for each sector's catch;
- a general understanding of the life cycle, size at maturity, growth and natural mortality rates for each of the main target species; and
- a general oceanographic and climatic database against which regional fish abundance or availability can be correlated.

The assessment approaches to be adopted for these commercial and recreational fisheries are likely to use yield-per-recruit methods to establish the appropriate size at first capture for each target species. Simple stock production modelling and age-structured models for finfish (where there are sufficient data) are likely to be used to provide basic estimates of sustainable catch ranges. Multiple correlation methods are likely to be used to develop predictive relationships between:

- spawning stock levels, environmental factors and recruitment to fisheries; and
- recruitment indices, fishing effort and catch/residual spawning stock levels.

These analyses are likely to be based on selected commercial fisheries data sets as they are more consistent than data sets from other fishery sectors and contain data from a longer time series.

Existing data sources in Western Australia

In Western Australia three basic fishery data categories are available: records supplied by commercial fishers; data obtained by surveying recreational fishers; and fishery-independent research data.

Commercial fishers provide monthly catch and effort records required as a condition of fishery licences, and voluntary research log books are completed by dedicated commercial skippers. Landings records provided by fish receival companies are also a statutory requirement, and some information they contain validates commercial fishers' catch estimates. These vessel data sets, supported by an annual database on vessel sizes, gear and equipment, are supplied directly by the commercial sector at relatively low collection cost, and generally provide a consistent year-round data series capable of reflecting seasonal and inter-annual stock abundance. These commercial vessel data sets do, however, require research validation, particularly the effort measures, which also need to be standardised to account for technology changes. The distribution of fishing effort also needs to be recorded at a reasonably fine scale to allow effective effort to be calculated (Hall and Penn 1979). Once the calibrations have been added, these data sets are a particularly valuable resource for fisheries monitoring and stock assessment for management.

For the recreational fishery, Western Australia has established a series of 'creel' or catch surveys of recreational fishers in each of its four marine bioregions: north coast, Gascoyne coast, west coast and south coast. These large field surveys, each involving 12 months of field data collection and six months of analysis and reporting, are presently undertaken on a rotational basis, which means that each bioregion is surveyed approximately every six years. The surveys provide detailed information on recreational fishing effort, catches and size composition – for example, see Sumner and Williamson (1999). In addition, annual telephone and mail surveys to gather estimates of recreational catch, participation rates and effort, are carried out on high-value, specifically licensed recreational fisheries for rock lobster (*Panulirus* spp.), abalone (*Haliotis* spp.), marron (*Cherax tenuimanus*) and trout (*Oncorhynchus mykiss* and *Salmo trutta*) (reported in Penn 2002). Some recreational fishers also keep log books in which all their fishing activities are recorded, and most fishing clubs record competition catch in a series of recreational databases. Both of these record sets are volunteered to fishery managers and scientists. In both of these cases, the data collected are relatively inconsistent, reflecting varying effort levels which are not as directly related to fish abundance as is generally the case with commercial catch data. Overall these voluntary recreational data sets are relatively inexpensive to collect but do not provide a reliable basis to assess within-year changes in abundance or stock status. They can, however, be useful in assessing long-term trends in recreational catch rates and fish sizes.

The third category of data available in Western Australia is from fishery-independent research. This research provides more reliable data on matters such as general biology and size composition but is also very expensive to collect. However, reliable measures of abundance cannot usually be gathered from fishery-independent surveys as they cannot provide adequate levels or distribution of effort. Collection of such 'independent' data through direct collaboration with commercial fishing activities (i.e. on-board catch sampling, commercial vessel surveys and market sampling of catches) has generally proven in Western Australia to be the most cost-effective method of data gathering for fishery assessment. This approach of sampling on commercial vessels or from independent research vessels is most effective when used to calibrate the commercial fisheries data sets.

For environmental parameters, Western Australia is fortunate in having a very long time series of sea level data. This data provides a good indication of the strength of the Leeuwin Current, the most dominant oceanographic variable for Western Australian coastal waters. In addition, the State has the usual climatic data series for rainfall, evaporation, wind, and cyclonic activity, which is a key environmental factor in the north-west of the State. More recently, sea surface temperatures and ocean colour data sets have become available from satellite recordings.

For Western Australian fisheries management purposes, all of the above conventional categories of fisheries data, together with environmental/oceanographic data series, are utilised in the assessment process. For the major Western Australian commercial fisheries where extensive time series of data are available and major research projects are supportable, these data sources are clearly sufficient for management purposes. In contrast, for the smaller coastal fish stocks, which support relatively small-scale commercial fisheries and are also fished extensively by the recreational sector, these traditional sources of data do not provide sufficient coverage to support management decision-making needs.

New data opportunities

For the coastal multi-sector fisheries, new approaches to obtaining improved management data are emerging from the collaboration between fishers (both commercial and recreational) and fisheries researchers. They are:

1. Biological sampling by commercial fishers

Commercial fishers are often willing to collect detailed data on fishing effort/location, species caught, size and sex composition on either a voluntary or a limited payment basis. Examples of this activity include

Western Australian rock lobster fishers who voluntarily provide to the Department of Fisheries detailed data on the catch taken by the last ten pots pulled each day. In the Northern Prawn Fishery, crew members have collected detailed species and size composition samples from across the fishery for the Commonwealth Scientific and Industrial Research Organisation in return for a small payment per sample collected. In all of these cases, specific training for vessel crews and regular feedback is necessary to ensure consistency and reliability of the data collected.

2. Environmental recording by commercial fishers

In addition to direct fisheries assessment data, the operators in two small-scale fisheries, the Coorong fishery in South Australia (ABC Landline 2000) and the Bribie Island fishery in Queensland (Bribie Island Commercial Fishers Association Inc. 2001), have actively involved themselves in environmental monitoring of their fishery areas. As regular and expert observers of their environment, and as fishers, they have a direct interest in the relationship between environmental factors and fish abundance and recruitment.

Monitoring costs to record basic parameters such as temperature and salinity are minimal, and increasingly, these data are being recorded by skippers on a voluntary basis. With collaboration between researchers and such expert fishing groups, standardised and reliable environmental databases can be developed for regional coastal areas. Observations on relative fish abundance linked to environmental conditions can also be obtained from this collaboration, providing environmental data on a more local scale than is available from the more large-scale, regional oceanographic and weather data series.

3. Research surveys linked to commercial access

Commercial fishing is currently being phased out of many coastal and estuarine areas around Australia as a result of Government buy-back schemes. The absence of commercial fishing is leading to significant gaps in data availability for stock management. An opportunity exists for restricted commercial fishing surveys in these and other closed areas to be carried out under special licence conditions so that samples for research can be obtained. Sampling costs would be offset by returns from catches taken, as occurs in major Western Australian prawn fisheries (E. Sporer, pers. comm.). Similarly, in areas where commercial fishing is still permitted, specific research sampling could be undertaken, perhaps funded by licence fee discounts supplemented by the value of the catch.

4. Short-term recreational licensing systems

The current focus of most Western Australian recreational licence systems, and of those in other States, is to provide revenue for managing the fisheries resources. These licensing systems also have some limited research benefits in providing an identified group of people for catch survey purposes (Molony and Bird 2002). It is possible, however, and at minimal cost, to utilise the licensing systems themselves to directly obtain data on fishery-specific and regional recreational effort, and in some cases, catch. For example, daily or weekly licences sold through a regional network would provide direct measures of fishing effort and its distribution. For fisheries such as abalone where there is a high degree of certainty that the bag limit will be obtained, a short-term licence for a single bag limit would also give a direct measure of catch by region and time. It would also generate a fishery database for low-cost follow-up data gathering by targeted telephone interview.

While there would be an operational cost for licence sales and the recording and processing of the data from such a licensing arrangement, the current survey costs would be lowered, a more comprehensive data set would be created, and funding generated for general management purposes. Validation of such data would be provided by the regular compliance activities undertaken by the management agency in each case.

5. Indicator creel surveys

While comprehensive on-ground creel surveys are required, particularly for the management of resource-sharing, they cannot generally be economically undertaken on an annual basis. An opportunity exists for use of both compliance activities and recreational fishery volunteers to undertake short, low-cost surveys at peak periods identified by the results from full-scale 12-month creel surveys. These standardised 'indicator surveys' should be able to provide an assessment of annual variations in catch and effort, which would lead to an index of stock abundance from year to year. Such surveys, linking the larger creel surveys carried out at intervals of five years or more, have the potential to be a cost-effective means of monitoring catch and effort and thus provide indices of stock abundance, particularly if undertaken as part of a voluntary program.

6. Nursery area recruitment surveys

Many coastal aquatic species utilise protected coastal or estuarine areas as nurseries. Regular sampling of these areas for juvenile fish can provide an index of recruitment to the fishery independently and in advance of the fishery. Such a survey system is currently being developed for the south and lower west coasts of Western Australia, as a follow-on from sampling as part of a major study on Australian herring in Western Australia and South Australia (Ayvazian et al. 2000). Another example of this has been the successful use of a beach seine survey to measure juvenile tailor *Pomatomus salatrix* abundance carried out over several years by a high school biology class in Carnarvon, Western Australia (S. Ayvazian, pers. comm.). If similar surveys could be undertaken by student groups supported by trained teachers or volunteers at defined locations and times within a year, costs would be minimal. To ensure consistency in both sampling methods and levels of enthusiasm from year to year however, such activities require a formally trained research coordinator.

7. Compliance interview data

Fisheries enforcement officers on patrol regularly interview recreational fishers and examine their catches for adherence to the fishing regulations. Records of these interviews are being utilised in Western Australia in a Fisheries Research and Development Corporation-funded project designed to improve the targeting of compliance effort and measure trends in levels of compliance (J. McKinlay, pers. comm.). With minor changes, data gathered by fisheries enforcement officers could be used in biological and stock assessment research.

Firstly, by extending the recording to cover both legal and illegal catches, and by standardising the patrol timing from year to year at high recreational activity times, these data could provide 'indicator' surveys for abundance and fishing effort, as noted above. Secondly, by incorporating questions in the interview sheet about the frequency of fishing and whether the fisher has been interviewed previously, it would be possible to generate 'mark recapture' type estimates of the total number of fishers undertaking the activity. These 'effort' data, together with indicator catch rates from the patrols, can potentially provide estimates of total catch of target species, as well as more reliable estimates of levels of compliance with the regulations, which can assist in managing enforcement activities.

8. Recreational research volunteers

Many recreational fishers, with minimal incentives, are prepared to assist in generating research data. Current Western Australian examples include the following.

- Volunteers are used to catch newly recruiting (0+ age) tailor at a key location in the Swan River estuary over an eight-year period. Fishing times and durations (12 days over three months, and two hours per day at sunset) are standardised from year to year. Data generated provide an index of annual recruitment for cross-correlation with commercial catch rates and future correlation with subsequent recreational catches of older fish from adjacent ocean beaches. The financial cost of this work is limited to food (pizzas) and the time of expert research staff who coordinate the fishing and recording of the catch and effort data.
- A group of volunteers, some of whom travel 1000 kilometres to Shark Bay annually, assist researchers in the capture and tag-and-release of mature snapper *Pagrus auratus* during the spawning season. This work is providing female gonad maturity samples as part of the annual egg and larval survey (Jackson and Cheng 2001) to estimate spawning biomass for the discrete Shark Bay snapper stocks, and tagging to provide second estimates of spawner numbers and sizes based on mark recapture rates. The cost of this work is small subsidies on bait and boat fuel used in Shark Bay by four to six volunteers' vessels (6–7 metres in length) involving about 24 anglers, and training by the research team in tagging and recording methods.

There are significant opportunities to expand on these types of voluntary program for targeted recreational fishing and tagging. The programs can also be used to generate direct information on exploitation and mortality rates and relative catch shares between sectors.

9. Volunteer Fisheries Liaison Officer programs

In Western Australia there are about 250 recreational fishers who take part in fisheries education and compliance activities at times of peak recreational fishing activities. With appropriate training, these volunteers are able to undertake creel surveys as part of their education activities whilst on patrol. At peak fishing times, volunteers can be particularly useful for undertaking 'indicator' creel surveys (point *5* above) which measure year-to-year variations in fishing success.

Many of these volunteers also act as volunteer researchers (point *8* above) and are involved in collecting research information, e.g. on catch size composition of abalone and tailor. These volunteers are often recruited as fishing experts to undertake telephone surveys of licensed recreational fishers on a minimum payment basis.

In each of these approaches (points *1–9* above), the identified data gathering opportunities can be expected to contribute to the creation of databases on total catches (by species), relative fishing effort applied to each fishery, indices of abundance (particularly recruits) and size composition of the catch each season. Each data set will, however, require validation and cross-referencing to allow compilation of long-term standardised data sets capable of input to the various assessment models. This process will be the major specialised 'research' involvement and will require a high level of statistical treatment to integrate the various data and annual indices into reliable long-term databases.

Discussion – future directions

Researchers attempting to monitor and assess multi-sector coastal fisheries are unlikely to have the luxury of sufficiently detailed data and time series of information to undertake sophisticated species-specific stock assessments utilising the classical fisheries models. In many cases, however, there will be sufficient information available if all of the previously described sources are utilised to provide indicators capable of detecting significant changes in the abundance of the key target stocks. These data, together with a good understanding of the basic biology (growth, mortality and reproduction) of the key species being exploited, should as a minimum enable risk assessment modelling to be carried out with the purpose of setting acceptable catch (or effort) ranges for the fishery and the various sectors involved in it. Having generated appropriate (precautionary) ranges and trigger points for fishery management, the main purpose of the research activities becomes the generation of performance measures such as annual or season indices of sector catches and effort, and ideally, specific measures of recruitment and spawning stock levels. These indices can also then be examined for correlations with environmental factors, to detect where influences outside of fisheries management control may be affecting stock abundance independently of the effects of fishing itself.

In examining alternative opportunities for gathering research data for fisheries management purposes, it is also important to consider the whole process and costs involved in management. That is, in addition to the cost of obtaining research information needed for management decisions, the management process also involves stakeholder consultation and compliance monitoring. These all involve significant costs. Stakeholders involved in the research process become better educated about the impacts of fishing on the stocks and are more likely to understand the need for management of the fisheries involved.

The opportunities identified in this paper for gathering data via commercial, recreational and community collaboration can produce valuable data provided adequate resourcing is committed to the training and 'encouragement' of the people involved, and to the critically important validation process necessary to ensure the data sets are reliable. More significantly, however, the direct involvement of stakeholders in the research programs has additional benefits in generally educating the fishers and the wider community in fisheries research and stock assessment techniques. This ancillary education/extension process is particularly valuable in gaining the community's acceptance of the management processes flowing from data and research analysis, and can improve the efficiency and decrease the cost of community consultation normally required in the management process. Similarly, the overall cost of education to ensure compliance with the rules may be substantially reduced if the research program is specifically arranged to create community understanding of the fishery and acceptance that the scientific data supporting management is reliable.

This approach will, however, require the full integration of the research activities within the overall management planning process, and also that research projects are specifically designed to generate both reliable research data and positive education/compliance outcomes with the stakeholder groups. Optimally this approach should enable scarce financial resources to be allocated more efficiently to generate improvements in quality of data and management acceptance.

The major challenge for the fisheries researchers of the future will be to develop the skills needed to 'manage' the wider variety of people involved in research, while ensuring that the quality of the scientific information generated is maintained. The adoption of this approach may not substantially decrease the cost of research, but it has the potential to significantly improve the overall management outcome.

Acknowledgements

The Department of Fisheries' coastal finfish research group led by Dr Suzy Ayvazian and Ms Gabrielle Nowara kindly provided the time series data for a number of their fisheries. Many of the innovative methods and concepts for data gathering described in this paper have been developed from discussions with my colleagues in the Department's Fisheries Research Division and are now being implemented or are in the process of implementation by researchers at the Western Australian Marine Research Laboratories. Their valuable input to the paper is gratefully acknowledged. I also particularly thank Drs Rod Lenanton, Nick Caputi, Rick Fletcher and Greg Maguire for the many useful discussions we had and their inputs to the paper. Andrew Cribb, manager of the Department's Recreational Fisheries Program, also contributed significantly to the concepts and ideas contained in the paper.

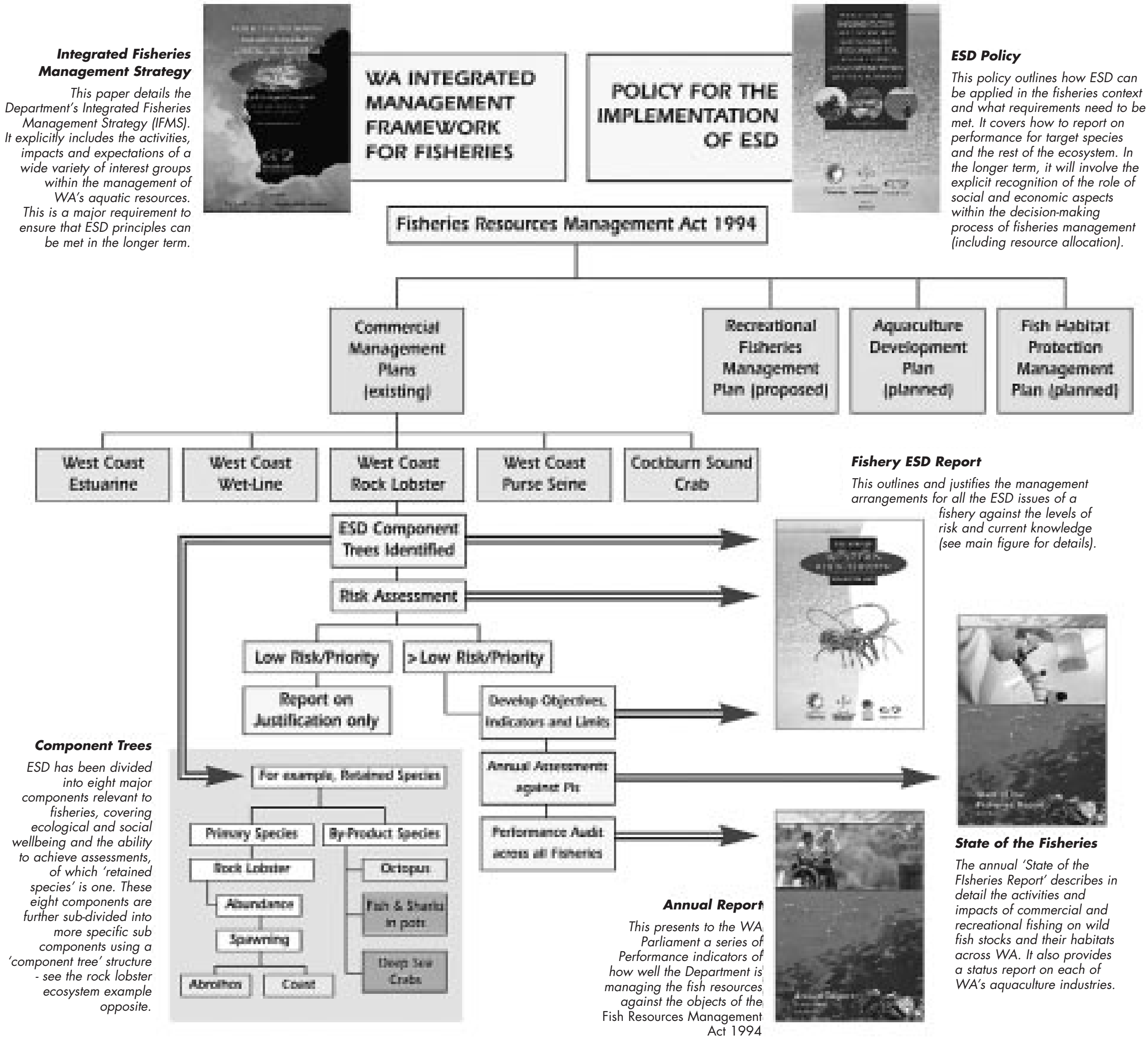

Figure 1. Summary of the process for completing ESD reports.

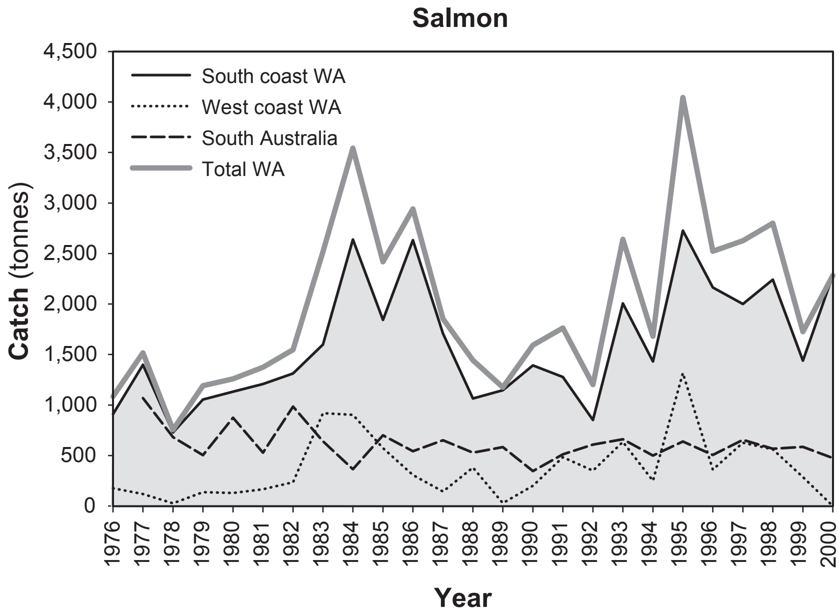

Figure 2. Australian salmon catches for South Australia and Western Australia for the period 1976 to 2000. Catches prior to 1977 for South Australia are unavailable.

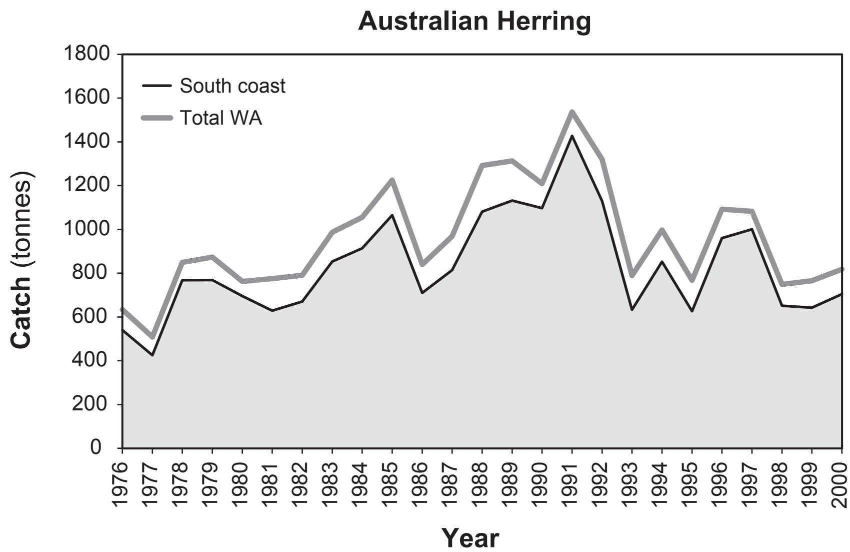

Figure 3. Catches of Australian herring from the south coast and the total Western Australian catch for the period 1976 to 2000.

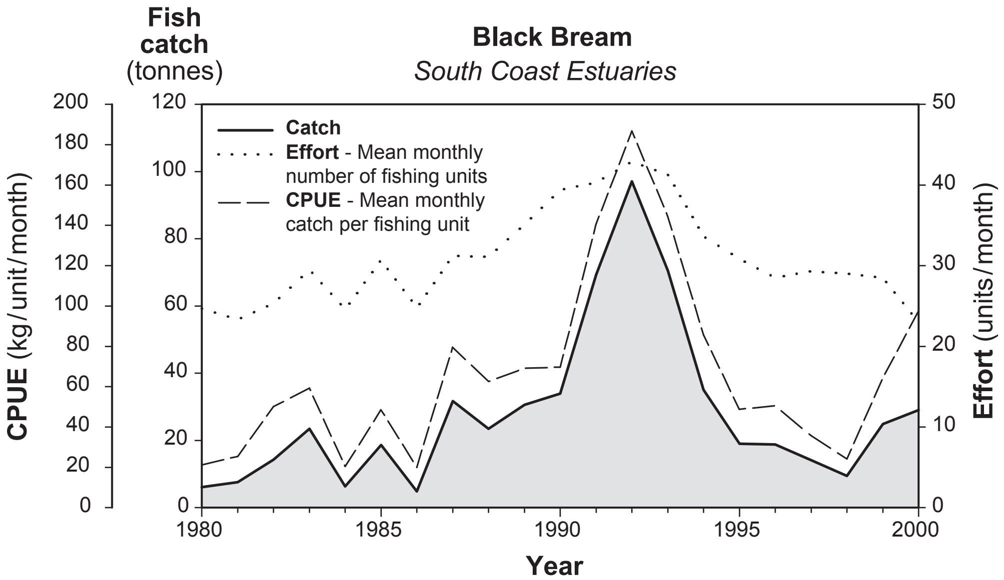

Figure 4. The annual catch, effort and catch per unit effort (CPUE) for the black bream *(Acanthopagrus butcheri)* fishery in south coast estuaries over the period 1980–2000.

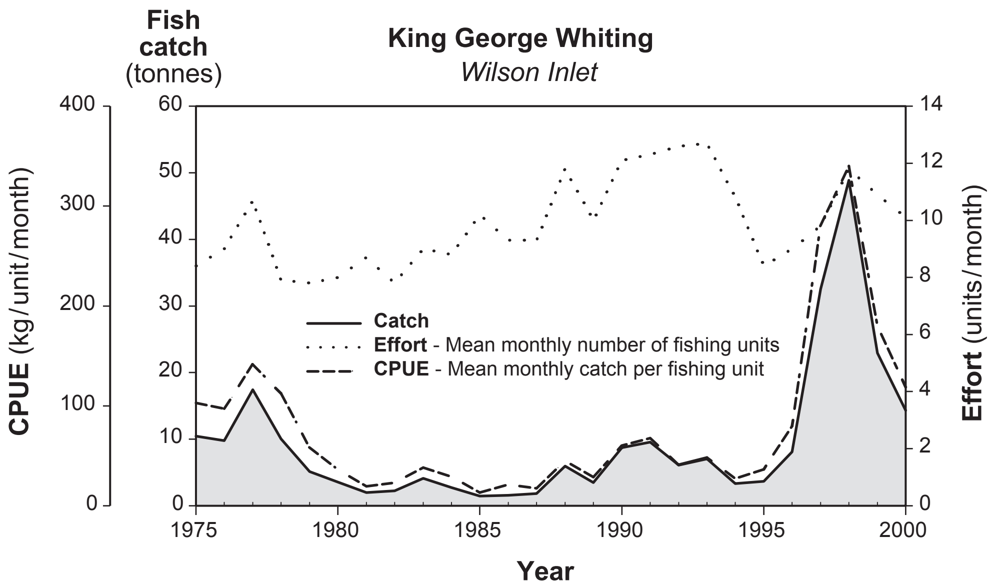

Figure 5. The annual catch, effort and catch per unit effort (CPUE) for the King George whiting *(Sillaginodes punctata)* fishery of Wilson Inlet over the period 1974–2000.

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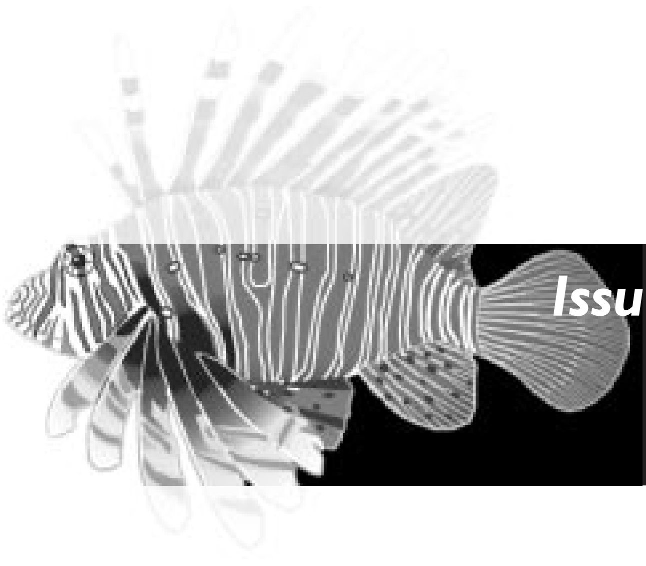

Issues concerning data-limited multi-sector fisheries in New South Wales

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Abstract

Because of its geographic location and the diversity of its coastal habitats, New South Wales has a rich fish fauna. In the 200 years since European settlement, a complex array of fisheries has evolved. However, despite the large human population base in New South Wales and the diversity and dollar-value of fishing activities undertaken, knowledge about the biology and dynamics of our fish resources is extremely limited. A high proportion of our fish stocks fall into the 'data-limited, multi-sector' category.

In common with other jurisdictions, NSW Fisheries is faced with developing appropriate management strategies and environmental impact assessments for each of its defined fisheries. As well as satisfying ecologically sustainable development objectives the environmental impacts of each fishery must be assessed against a detailed set of Government guidelines. In addition to New South Wales legislative requirements, the strategies must meet the requirements of two Commonwealth acts. Additionally, New South Wales is implementing a system of larger and smaller marine protected areas aimed at conserving biodiversity and maintaining natural processes in the estuarine and oceanic waters of the State. The recent introduction of a saltwater fishing fee has provided funding for the establishment of significant recreational fishing havens, from which commercial fishing will be totally or partially removed.

Community consultation mechanisms have been put in place to discuss the issues resulting from each of the processes listed above. These include public meetings and input from stakeholders through a set of Ministerial advisory councils and committees. The information requirements of each of these processes are extensive, and rarely does existing data provide for adequate assessments. Some innovative approaches have been utilised to gather information, including new monitoring projects and economic and social surveys.

Introduction

The coastal zone of New South Wales (NSW) extends over a range of almost ten degrees of latitude, or around 1000 kilometres (km) as the albatross flies. The ecology of the NSW coastline, and the near-shore ocean environment in this region, are strongly influenced by the mixing of the warm East Australian Current and cooler Tasman Sea waters (Godfrey et al. 1980). The seasonal north-south migration of the boundary between these two water bodies and the diversity of habitats found in the coastal zone of NSW, gives rise to a rich fish and invertebrate fauna. For example, more than 500 species of finfish have been recorded from Sydney Harbour (J. Paxton, pers. comm.), which far exceeds the number of species (around 200) described from the marine waters surrounding the British Isles.

The NSW coast is characterised by a relatively narrow continental shelf (15-20 km in width). Approximately 30% of the coastline consists of rocky foreshores and headlands (Andrew 1999), and there are 721 ocean beaches (Short 1993). Williams et al. (1998) identified 950 water courses along the NSW coastline, although the vast majority of these are ephemeral. There are 130 estuaries, of which 72 are permanently open to the sea. Included in these are 15 major river systems, about 50 minor rivers, 88 coastal lakes and eight drowned river valleys (e.g. Sydney Harbour). NSW ocean waters also contain 44 offshore islands, the largest of which is the World Heritage listed Lord Howe Island.

About 85% of the NSW population (or around six million people) live in the coastal zone; there are about 6700 commercial vessels registered in NSW (of which about 2000 are commercial fishing and charter fishing vessels) and about 173,900 recreational vessels. Apart from their direct impacts on fish stocks through commercial and recreational fishing, population pressures have resulted in a number of indirect (and unquantified) impacts on fish habitat. These include the reclamation of 'swamp and wetland' areas, the creation of fields of boat moorings in some bays and inlets, and extensive wharf and jetty structures along many kilometres of foreshores. There are many examples where significant alteration of the local environment has occurred, such as man-made harbours and river entrances, and 'canal estate' housing developments.

This paper describes the strategies and consultative processes being developed by NSW Fisheries to help address issues involved in the assessment and management of fisheries based on wild fish stocks in coastal NSW. The diversity of species exploited by NSW commercial and recreational fishers, and the limited knowledge of the biology and dynamics of the fish populations, means that most of these fisheries fall into the 'data-limited, multi-sector' category.

Legislative framework

In the next two to three years NSW Fisheries, in common with many other fisheries jurisdictions, must develop appropriate management strategies and environmental impact assessments for each of its defined fisheries. As well as satisfying the ecologically sustainable development objectives contained in the NSW *Fisheries Management Act 1994*, the environmental impacts of each fishery must be assessed against a set of guidelines issued by the Department of Urban Affairs and Planning (now 'Planning NSW') under Part 5 of the NSW *Environmental Planning and Assessment Act 1979*. This latter requirement stems from a decision in the NSW Land and Environment Court in January 2000, which required that the environmental impacts be assessed before the issue or renewal of each commercial fishing licence. Conducting an environmental impact assessment prior to the issue or renewal of individual fishing licences was considered to be impractical and ineffective (as the cumulative impacts of the fishery as a whole would not be assessed). The relevant legislation was therefore amended to provide for the development of a Fishery Management Strategy (FMS) for each defined fishery in NSW, with environmental impact assessment (by way of an Environmental Impact Statement, EIS) being undertaken on the strategy as a whole. There are also requirements under the Commonwealth *Wildlife Protection (Regulation of Exports and Imports) Act 1982* and the *Environment Protection and Biodiversity Conservation Act 1999*, and it is intended that the FMS and EIS process also meet the requirements of this Commonwealth legislation.

Management of fisheries on naturally occurring stocks in NSW will also be affected by the establishment of marine protected areas (MPAs) and recreational fishing havens under the *Fisheries Management Act 1994*, and by the creation of larger marine parks under the *Marine Parks Act 1997*. A draft Indigenous Fisheries Strategy is also currently under development in NSW, and it is possible that this may have an impact on the management of commercial and recreational fisheries in areas of the State.

Consultative processes

To consult with stakeholder groups on the development of fishery management policies and strategies, and to provide for a level of co-ordination in the overall process, the NSW Minister for Fisheries, the Hon. Eddie Obeid OAM MLC, has established a number of advisory councils and committees (summary in Figure 1). The most recently established body, the Fisheries Resource Conservation and Assessment Council (FRCAC), contains representatives from a wide range of fisheries interest groups, including commercial and recreational fishers, the seafood and aquaculture industries, indigenous people, conservationists, and State Government agencies. FRCAC has been established to provide broad-based advice to the Minister on the FMS and EIS process, and on other issues as requested by the Minister, such as the community consultation for recreational fishing havens. The other councils and committees provide advice relevant to their specific areas of interest, ranging from the commercial sector to the recreational sector (with a conservation representative on each advisory council).

NSW commercial fisheries production

The total reported commercial landings of finfish from NSW coastal and estuarine waters in 1998/99 was about ten thousand tonnes and was valued at around $30 million at first point of sale. While more than 100 species of finfish are regularly reported as landed by commercial fishers in NSW, in 1998/99 reported landings of 65 species or species groups were in excess of 10 tonnes (t), including 20 species for which catches exceeded 100 t. Adequate stock assessments are available for just a few of the most important species. For many important species there is a long time series of catch data, but very little is known about their biology and almost nothing is known about their population dynamics. Yet for many of these species concerns have been expressed about stock status, and in many cases there are expectations of management action to address these concerns. Two examples follow.

Mulloway *(Argyrosomus japonicus)*

The mulloway (or jewfish) is a large estuarine and near-shore species which is highly prized by both commercial and recreational fishers. Mulloway are taken by line and trawl in oceanic waters, and by handline, seine and gill net in estuarine waters. Mulloway appear to be a fast growing species, reaching about 45 cm after two years; but are relatively long-lived and may attain more than 20 years of age and 30 kg in weight (Wallace and Schleyer 1979; Smale 1985; Gray and McDonall 1993).

Commercial landings of mulloway in NSW (Figure 2) ranged between 100 t and 150 t per annum during the 1950s and 1960s, and increased to 200–300 t per annum during the 1970s. During the 1990s, annual commercial landings returned to around 100 t. Commercial landings from estuarine waters were relatively stable at around 50 t per annum throughout this period. The increase in catches during the 1970s was possibly associated with the increase in fish trawling in oceanic waters that occurred at about that time. The recreational catch of mulloway in NSW has not been documented, but is likely to be of a similar order of magnitude to the commercial landings.

There is not even a preliminary stock assessment for this species. The only population data available come from market measurement programs on the size composition of mulloway landed by commercial fishers (Figure 3). During the early 1970s, when no minimum legal length (MLL) applied to mulloway, the bulk of fish in commercial landings were between 30 cm and 50 cm long. In 1979 a MLL of 38 cm was applied to mulloway, and the bulk of fish in commercial landings during 1987–90 were 40–60 cm in length. In 1993 the MLL was increased to 45 cm, and recent sampling has shown a considerable improvement in the proportion of the catch which is comprised of fish greater than 60 cm in length. The relatively high proportion of large (more than 80 cm TL, and presumably old) fish in the commercial catch suggests that the mulloway stock is not subject to a high rate of fishing mortality.

Even so, following public concerns expressed about the status of the mulloway stock, NSW Fisheries has done research into the artificial propagation and stocking of this species (Fielder, Bardsley and Allan 1999) and debate about the desirability and impact of stock enhancement continues.

Eastern sea garfish *(Hyporhamphus australis)*

The eastern sea garfish is a small pelagic schooling species, which occurs between southern Queensland and north-eastern Victoria. The species is caught close to shore, mainly by fishers in the beach- and boat-based sectors of the NSW Ocean Hauling Fishery. Fishing is highly targeted, and small meshed hauling nets specifically designed and approved for catching garfish are used. Commercial landings increased following the development of an export market in the 1980s, and peaked at around 250 t in the mid 1990s (Figure 4). However, in recent years the NSW landings of eastern sea garfish have declined very significantly.

Unfortunately, limited biological research has been undertaken on eastern sea garfish, and there has been no routine monitoring of the size or age composition of commercial catches. It has therefore been very difficult to provide an assessment of the likely reasons for the collapse in catches. A similar species of garfish (*H. melanochir*) was shown to have low fecundity, and conservative management was therefore recommended (Ling 1958). Low fecundity, combined with the knowledge that the NSW fishery targets garfish aggregations through the summer months, suggests that the decline in catches may indicate a significant fishing down of the sea garfish stock. However, in the absence of a credible biological assessment, agreement on management measures aimed at rehabilitating the sea garfish stock has been difficult to achieve. This issue is one of the more contentious ones currently facing the development of the Ocean Hauling FMS and its associated EIS.

Responses

A number of initiatives have been introduced to gather information to help in the assessment of data-deficient, multi-sector fisheries in NSW, and three examples are summarised below.

The commercial finfish monitoring project

This project was established by the Commercial Research Branch of NSW Fisheries in 1998 and has two main objectives. They are:

1. to collect size and/or age composition data from landed catches of important commercial finfish species; and
2. to ensure the secure storage of all available size and age composition data for commercial finfish species in NSW, including data available from historic studies.

For most of the 65 finfish species with landings greater than 10 t in 1998/99 we have very little biological information and only rudimentary data on the fishery (catch per fisher per month, and the number of days fished with each gear type). The commercial finfish monitoring project collects size and some age composition information from the landed catches of important species, according to priorities established by the Commercial Finfish Catch Monitoring Committee. The list of 'priority' species is reviewed annually, taking into account the commercial value of the species, recent trends in catch or catch rate for the species, and the importance of the species to both the commercial and recreational sectors, or to other jurisdictions. Around 50,000 individual measurements and about 5,000 ageing samples from about 20 important species have been taken annually in recent years.

Over the past 50 years, a significant amount of information has been collected by a number of agencies on the size composition of NSW commercial catches of some important finfish species. Prior to the current project, much of this information was stored as originally recorded (handwritten paper records) where it was not readily accessible for use in stock assessments and was in danger of being lost. A secure electronic database has been established as part of the monitoring project, and both historic and recent data are being checked and added to this database as time and resources allow. As at August 2001, there were just over one million individual measurements recorded on the database, for a total of 41 finfish species, covering the period from 1945 to 1999. The total is expected to increase significantly over the next couple of years as many recent measurements are still to be incorporated in the database.

Recreational catch monitoring programs

Several new initiatives have recently been added to NSW Fisheries' long-term collection of information from recreational fishers. In conjunction with the establishment of a management plan for recreational charter boats, log books for the charter industry were introduced in late 2000 to collect catch, effort and biological data. Separate log books have been designed for charter boats operating in the offshore gamefishing, bottom and sportfishing, and estuarine fishing sectors (Lowry and Murphy, submitted). The results from the charter boat log book program will be combined with results from tournament monitoring, and NSW Fisheries' gamefish tagging study, to assist in the assessment of the status of species important to recreational fishers. In addition, NSW Fisheries is co-ordinating the first national survey of recreational and indigenous fishing, which is due for completion in early 2002. This survey is planned to provide the first estimates of total catches by recreational fishers on a state-wide and national basis.

Economic and social surveys

Until recently, information on the economic and social factors influencing commercial fishers was restricted to the small amount of data held by the NSW Fisheries' licensing and catch records sections, and the broad summary data collected and published by the Australian Bureau of Statistics. The NSW environmental assessment guidelines require that the economic and social impacts of proposed management strategies be predicted and assessed. Given the general lack of data to enable such assessment, consultants were engaged by NSW Fisheries during 2001 to undertake a series of surveys of commercial fishers. Results from these surveys relevant to the consideration of economic and social impacts of the planned FMSs are being included in the draft EIS for each commercial fishery (Dominion Consulting Pty Ltd 2001 is an example).

Development of FMSs and EISs for defined fishing activities

Under the legislative amendments introduced in 2000, FMSs and associated EISs need to be prepared within the next two to three years for the following designated fishing activities:

- eight marine commercial fisheries (Estuary General, Ocean Hauling, Ocean Trap & Line, Ocean Fish Trawl, Ocean Prawn Trawl, Estuary Prawn Trawl, Rock Lobster and Abalone);
- recreational fishing;
- fishing from charter boats;
- fish stocking; and
- beach safety (shark meshing) program.

The process to develop management strategies for these activities commenced in early 2001, and by August of that year the draft strategy and EIS for the Estuary General Fishery was nearing completion to the point of being open for public comment. Significant progress had also been made on draft strategies for the Ocean Hauling and Estuary Prawn Trawl fisheries. The relevant advisory committees and councils have been heavily involved in the preparation of these documents. NSW Fisheries will consider the comments received on each draft management strategy, then initiate a further round of consultation with the relevant advisory councils and committees before final approval is sought for each management strategy and EIS.

Marine protected areas

The conservation of biological diversity and the protection of key aquatic habitats are two of the primary management objectives of NSW Fisheries. Historically, these objectives have been addressed by the declaration of aquatic reserves (eight existing) and smaller intertidal protected areas (fifteen existing). In keeping with NSW Fisheries' commitment to the establishment of a National Representative System of Marine Protected Areas, and following recent research surveys, in May 2001 a discussion paper outlining proposals for further aquatic reserves was released for comment. Aquatic reserves are proposed for an additional fifteen rocky shores and sites within seven estuaries in two (the Hawkesbury Shelf and Batemans Shelf) of the five marine bioregions in NSW. Further candidate sites will be identified in the remaining bioregions at a later time.

Following the establishment of the NSW Marine Parks Authority in 1997, the process for the declaration of large, multiple use marine parks is now well underway. Proposed zoning and management plans for three such marine parks (Solitary Islands, Jervis Bay and Lord Howe Island) are currently in varying stages of public discussion. The most advanced of these is for the Solitary Islands Marine Park in the Tweed-Moreton bioregion, where a draft zoning plan is currently on public exhibition. The proposed plan incorporates a detailed zoning scheme, which specifies a range of protection levels from full sanctuary to general use zones. In some zones, existing commercial and recreational fishing will be allowed to continue. There has been considerable public debate about the merits of the proposed zoning scheme.

Recreational fishing havens

In March 2001 NSW Fisheries extended the freshwater recreational fishing fee to include saltwater areas. Funds raised are placed into trusts, and are to be used to improve the quality of recreational fishing in the State. Two angler committees oversee expenditure of trust funds. One of the major applications of these funds will be to provide for the establishment of recreational fishing havens by the purchase and retirement of commercial fishing businesses. Over 2,600 community nominations were received for areas to be considered for declaration as havens, and public consultation is underway regarding the designation of appropriate havens in eight coastal regions of NSW. A range of options is being evaluated for each region, with the outcomes dependent on the comments received from local communities in each area. On 31August 2001, the Minister announced the first of the recreational fishing havens, with Lake Macquarie and Botany Bay to be closed to all commercial fishing from May 2002.

Summary

As can be seen from the brief outline presented above, many changes are currently occurring in the management of fisheries and fish habitats in NSW. In a data-limited environment, extensive consultation with stakeholders and the community in general is taking place, to ensure that information from a wide spectrum of sources is taken into account. As the general community is becoming more aware of issues surrounding the sustainability of fisheries resources and habitat, the participation of the community at large, as well as stakeholders, can facilitate appropriate levels of conservation and sustainable utilisation of the aquatic resources of NSW.

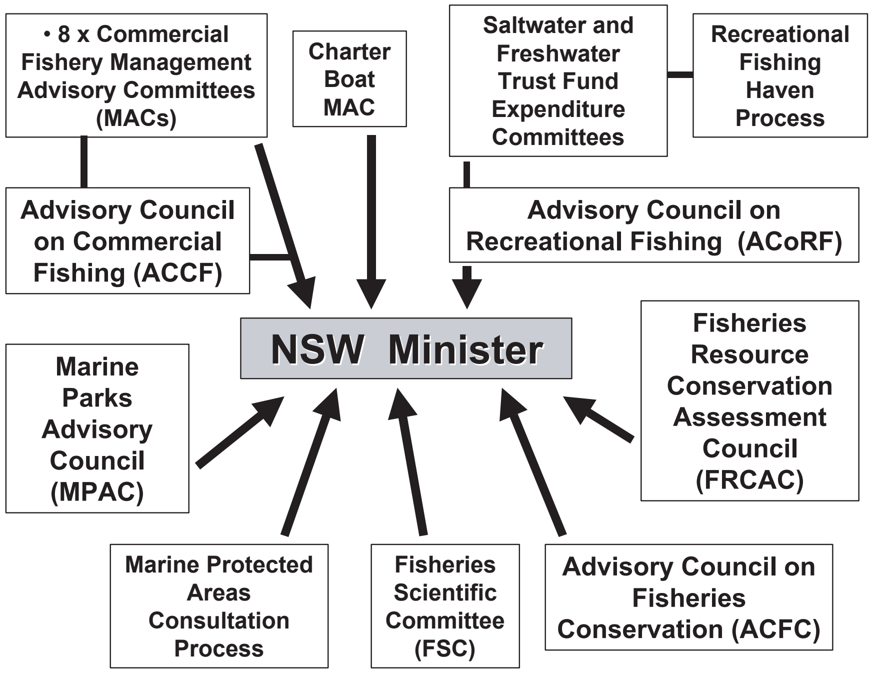

Figure 1. Summary of the consultative processes in NSW which impact on the management of marine commercial and recreational fisheries based on wild fish stocks.

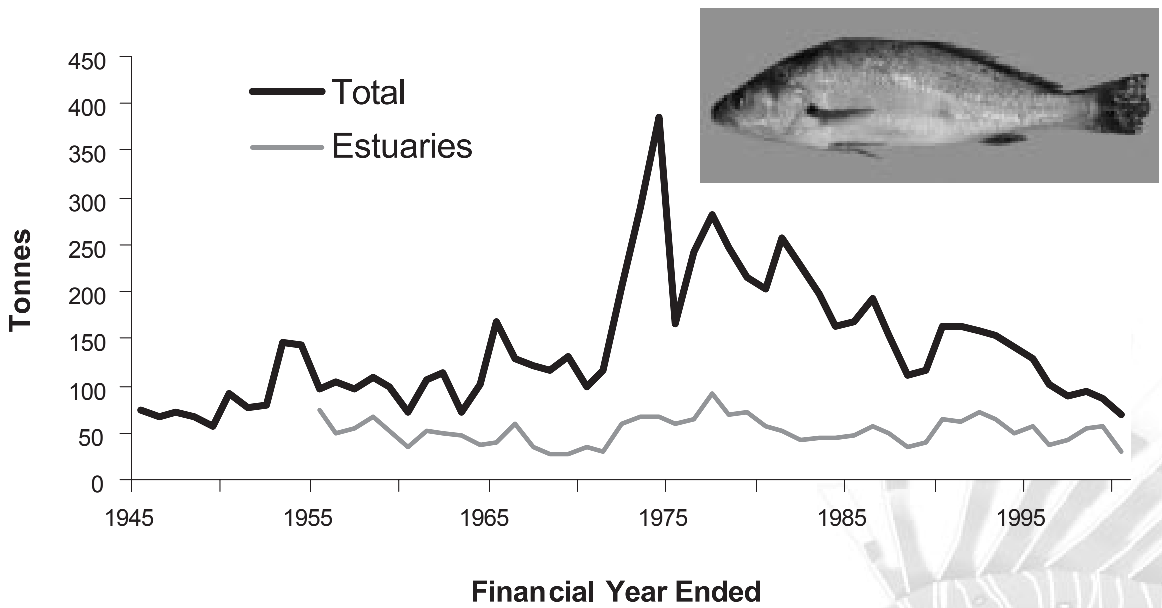

Figure 2. Annual landings of mulloway reported by NSW commercial fishers for the financial years ended June 1945 to June 2000.

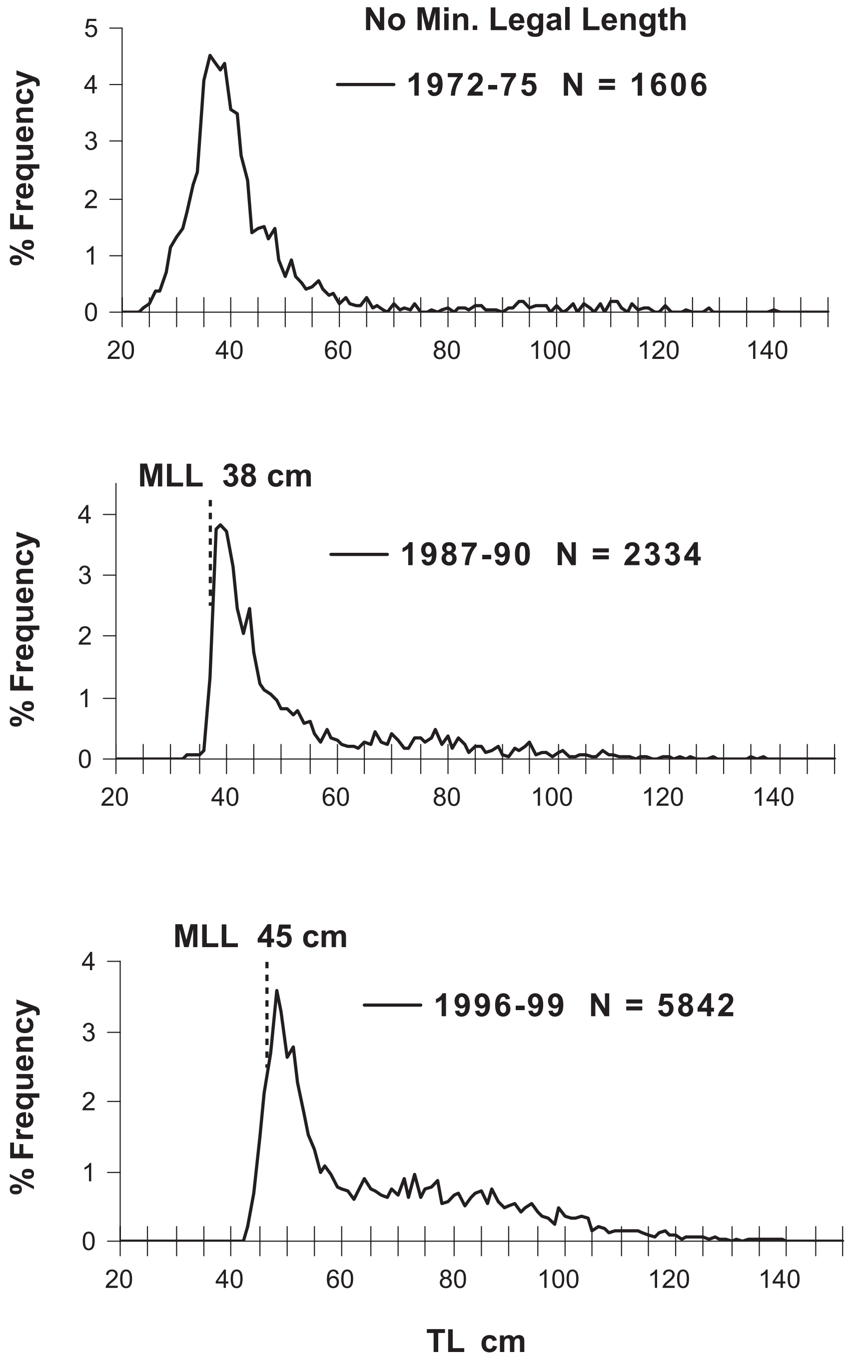

Figure 3. Size composition of mulloway measured from NSW commercial catches for the periods 1972-75 (no minimum legal length), 1987-90 (MLL = 38 cm TL) and 1996-99 (MLL = 45 cm TL). Explanation: MLL = minimum legal length (shown by a vertical dotted line); TL = total length; N = number of individuals measured.

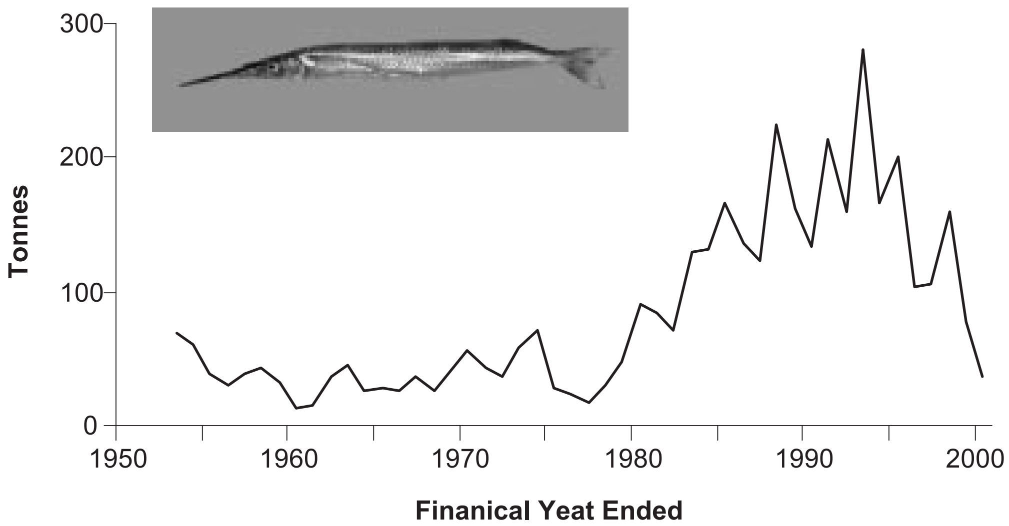

Figure 4. Annual landings of sea garfish reported by NSW commercial fishers for the financial years ended June1953 to June 2000.

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Theme Session Four

Discussion, questions and answers

Rapporteurs: Dan Gaughan and Gary Jackson

Norm Hall (Murdoch University, WA) said that in Canada, the strategy now being used is the collection of gut content data for key species as it provides information on diet composition. Norm stated that maybe we need to think about this in Australia where we consider that species interactions currently represent gaps in data collection.

Peter Stephenson (Fisheries, WA). "It is an interesting idea to allocate effort quota according to what data operators are willing to collect; i.e. quota allocation (to commercial or recreational fishers) based on return of data to researchers."

Jim Penn (Fisheries, WA). "A good idea, we already do that to a certain extent – e.g. in quota fisheries – and in cases where catch caught during an out-of-season fisheries survey may be kept. This concept/process is, however, more difficult with other sectors."

Sandy Morison (MAFRI, Victoria). "Care needs to be taken of how fishers 'provide' the data." Sandy pointed out that there are potential biases in some alternative data sources. He warned that some sectors are well aware of how data distortion may be beneficial to their short-term objectives. These situations are not well reported in literature. Sandy stated that we need to beware of possible pitfalls and treat some data cautiously.

Andrew Sanger (Fisheries, NSW). "I've got a question for Jim Penn. Jim, how do you propose to use effort controls for recreational fishing?"

Jim Penn. "It is possible but not ideal. One way may be to have a register of recreational fishers – for example, one based on the driver's licence system."

Jeremy Lyle (TAFI). "Data with many commercial fisheries is a mandatory requirement as part of licence conditions. What about the quality of the data? Researchers often make inferences about effort and hence catch rates. What about efforts to validate effort data?"

Jim Penn. "We spend effort trying to calibrate the effort data in WA." Jim believes it is an adaptive management process where managers just keep trying to shift the fishery to a better overall state. He said that in cases where effort data is not being used in the long term, historical sense year-to-year variations in terms of efficiency changes are not too bad. Jim agreed however, that validation of effort data is a core business of fishery science.

Rick Fletcher (Fisheries, WA). Rick referred to James Scandol's talk (given by Norm Hall) and observed that the effort data may be so bad in some cases that it tells nothing of abundance until a crash occurs.

Kevin Rowling (Fisheries, NSW). "NSW is restricted to monthly fishermen's returns. Catch data is probably OK but the effort data contained is very poor. NSW Fisheries is trying overall to improve data quality."

Roland Griffin (DPI&F, NT) commented on Jeremy Lyle's question. "Regarding collecting data from fishers, we need to understand what is the motivation for fishers' data falsification. The NT mud crab fishery is an example in which data can be validated as the entire catch is air freighted out and we simply follow the paper trail of air freight records."

Anne Coleman (DPI&F, NT). Question to Jim Penn. "You did not mention the indigenous sector at all. Do you see a need for WA to consider the issue?"

Jim Penn stated that Peter Rogers earlier had mentioned that the indigenous sector issue is being addressed. The Aborigines of the Kimberley region are the dominant group and the indigenous fisheries there will have to be managed. However, relative to the scale of other fisheries the issue and area are lower on the list for resource assessment and fisheries management priority compared to those in areas of high population density and subject to greater fishing pressure.

Rod Lenanton (Fisheries, WA) had a comment for Kevin Rowling. Regarding recreational-fishing-only (RFO) areas WA now has, by default, the Leschenault Estuary where commercial fishing is excluded, although it was never specifically designated as an RFO area as such. Such an outcome may lead to commercial fishers wanting reciprocal exclusive areas in which only they can fish. This scenario may lead to partitioning along the WA coast, which in turn implies allocation of property rights to various sectors.

Kevin Rowling. "In NSW, the situation is not as clear cut. RFO areas are being created by simply closing areas to commercial fishing. Proposals that incorporate a lot of public debate include method restrictions to achieve results. It is a very convoluted process: there are implications for the licensing system, buy-out implications, interaction between commercial sectors and we are still learning as we go." Kevin noted that it is often a regional, highly politically charged process, and in marginal coastal seats there are major implications, hence perceptions are very important.

Jim Penn observed that management should create its own data; and that there is a need for adaptive management.

Murray MacDonald (Fisheries Victoria). "A gap not adequately covered is that of the very small fisheries. For example, in some recreational fisheries there is no simple answer; we need money to collect data. Basically we are undervaluing the resource by not using licences or making them too cheap. What are the true costs of recreational fishery management?"

Summary of Theme Session Four *by Sandy Morison*

- Lack of data/data quality does not equate to an inability to manage.
- There is no one 'best' method.
- The information available should drive what is the best assessment method.
- Cultural importance should not be overlooked.
- Need to define the management objectives; search for the best approach; don't necessarily trust a single method; there is no single optimal approach.
- Need for multi-species models.

- Risk analysis/meta-analysis.
- Ecosystem needs consideration.
- Harvest below the optimum level.
- Need appropriate harvest levels.
- Australia’s fisheries management systems may be too rigid.
- Recognise that there are many solutions to the one problem.

WORKSHOP SUMMARY AND GROUP DISCUSSION SUMMATION

Session chairs: Rick Fletcher; Rod Lenanton; Malcolm Haddon; Sandy Morison

Discussion, questions and answers

Rapporteurs: Michael Mackie and Stephen J. Newman

Sandy Morison (MAFRI). "A comment – I think it was from Norm Hall – saying 'good models are not constrained by a lack of data' I thought was a good thing to say (tongue in cheek)! But it's probably also tongue in cheek when someone said that the EA was basically happy to acknowledge that there are fisheries where you can justify not collecting any extra data. That's not going to necessarily be an impediment to getting over the ESD hurdles. As well, there are situations where it's obviously clear that you don't need to go and get extra data to meet EA requirements. Peter Rogers earlier on said that we need to move beyond biology and ecology. I think that's a very pertinent point too, but I think it was you Malcolm, who talked about more data not necessarily equalling greater happiness in your assessments. I think it's something worth thinking about. Rick had said too, that this dichotomy of data-rich/data-poor doesn't necessarily mean that you know one end is where you really want to necessarily head towards because it's all going to be sweetness and light once you get there. But one of the things that I thought was particularly relevant was Ana's comment concerning the limitations for management, in that focusing on data limitations are going to distract you from what really are the significant issues and that lack of data is not necessarily going to be the major impediment."

Malcolm Haddon (TAFI). "I wasn't thinking so broadly as trying to summarise everybody's fields and I find that a very good effort. I suppose, considering this notion that there is one BEST method – hopefully people will conclude that there is *no* one best effort – one should be searching for the most appropriate method. I'm not really against Bayesian methods, they're perfectly fine. They're fine for some things, when there's good information available and that's what it comes down to. You do whatever you can if you can defend it and that comes down to management actions as well. The most appropriate method is going to be a function of what available information there is and I mean by 'information', not just biological information. But what are the constraints which are a function of the objectives and the issues that are going to limit the possible management actions that are going to derive from any advice you are going to provide on the status of the stock? If those actions are going to be fairly severe and the implications are large, then there's no choice: you're going to have to do a very detailed and thorough assessment. But they're only worth doing on either very socially important species – I mean, the King George whiting: South Australia has spent huge amounts of money on it because, culturally, it appears to be very important to the place. So it's not just intrinsic value. It comes down to the objectives – how much detail do we need; and it isn't a matter of what data, it's a matter of what management objectives need to be met: then we can decide what assessment details we need to go for. But, hopefully it's been seen that we should be testing those options that are available – both the performance indicators and the performance measures. We need to test those decision rules and the management options, and all the while there's this growth in the multi-species view of the world. I'm not talking 'Ecosim' or 'Ecopath' or any single particular model; I'm talking about the growth in this attitude of there is more than one single species out there. That field I think is wide open and

I'm going to watch what Norm comes up with, with great interest, because I imagine it will be better than 'Ecopath'. But we'll see, it will at least point out any of the strengths or weaknesses. So there is no single answer; each fishery is idiosyncratic and it does take attention to detail."

Norm Hall (Murdoch University, WA). "It is very essential that you don't actually make decisions that select too early; in other words you must run with a whole range of alternatives. The choice of a single approach limits you: it assumes that you know best and that you've already precluded all the options that are available from those other assessment techniques. So you have to continue running with a range of alternatives as you do your analysis, your assessment, your evaluation of the management strategies."

Malcolm Haddon. "That's a very good point I think. 'Appropriate' doesn't mean single method. In the summary that we put up on the board, we identified a diversity of methods, both assessment and simulation. So that's right, no single optimum approach. But we do need to search for the 'most appropriate sweeter methods' and test your options."

Rick Fletcher (Fisheries, WA). "A couple of points. One is that we need to further develop our risk assessment technology. I think risk assessment is going to be the basis of most of our decisions because it really is part of the process of making all the decisions in the previous three statements put on the board. We've only really just begun that process in fisheries and I think we need to work out the limitations of it, including our inability to actually figure out conditional probabilities. The other part of that process is actually turning what we've got in terms of qualitative understandings of issues into a matrix of quantitative tables in order to provide a little more certainty to the industry, and also to the people involved with the industry including us as the management agencies, about what is and isn't acceptable performance. At the moment there isn't a book we can actually pick up; there isn't one set of documents that actually provide it, so I suppose it's a meta-analysis of the information that's already out there to provide a reasonable level of guidance as to what we should be trying to achieve. I'd say those two things are the major elements."

Rod Lenanton (Fisheries, WA). "Thanks Rick. I guess if I've got one point to contribute I'll just reiterate what I was saying earlier. But in another way, to focus on management objectives, I think in the future management objectives will be not just to sustain a fishery, but to sustain an ecosystem, an environment or a habitat, depending on the scale you're talking about. The consequences for a fishery may be that you might have to harvest it below optimal level in order to satisfy those broader objectives, which I think the community in certain instances may argue in favour of. I also think that we're going to have to think harder about a broader range of appropriate indicators and targets. I think that's an important point and I think it's going to be an issue that we're all going to have to deal with."

Ana Parma (Centro Nacional Patagónico, Argentina). "I have some comments as an outsider – and they're all positive comments about what I see here is going on in Australia with all this ESD, and it's mostly compared to what I've seen in other management bodies in the United States. When environmental issues became a concern everybody understood they needed to be addressed. A lot of the management bodies ended up with a very rigid frame – sometimes without help – because scientists want very precise definitions so that they know what type of analysis needs to be done. And that's very dangerous, because then you start getting into things that have generic rules, and best approaches, and you end up operating under a very rigid regime: there is a lot of nonsense coming out of these approaches. What I really liked about some of the approaches presented here, is that a lot of the things are left open and some people may think there is a lot of *ad hoc*-ness here, but sometimes *ad hoc*-ness is good, because there's so many different solutions that you need to be flexible in your fishery or your particular system. Maybe there are things you can do with very little data, very little investment… whereas you may be creating a problem for yourself by expecting too much and providing reference points and things we don't really need to manage a fishery or to manage an ecosystem. Australia's always been at the forefront of being innovative and coming up with different things that may work here and not there, and I think you continue to move at it the way you are addressing them by your environmental concerns."

Jim Penn (Fisheries, WA). "If I can add a couple of points. I think one of the key messages that I've certainly got out of the last couple of days (and it really formulated I guess out of Ana's talk about the Chilean situation) is that the management arrangements should really be designed to aid in their own evaluation. In other words, a management arrangement should see itself as a step and think about what sort of data you are going to collect to evaluate whether it's successful or not, so that it can be improved. I think at the moment we tend to think about a management plan being put into place as the end point; not a management plan which encompasses its own data gathering mechanisms on the basis that you will come back and improve it when you've got that evaluation. So I think that's one issue. The other thing which I think has come through to some extent is that when we start talking about outputs for management, I've got the impression that we're tending to think about outputs which will re-design the whole system, as distinct from considering outputs which will allow us to adapt a management process of incremental change. It asks quite different questions of the research if you're asking which direction we ought to head as distinct from what is the TAC or what should the TAC be or what level of effort should we set. So I guess it's trying to get some idea that we will be in an adaptive management process and we need to gather data for that process."

Tony Fowler (SARDI). "I've got a perception, that I'll run past Rick; but I'll just open this up for discussion. The dominant feeling that I've got from the last couple of days is that the ESD framework provides the opportunity to really focus in on your fishery and to have a much closer look at it from a number of different perspectives – not just from the ecological perspective – and provides that opportunity for that assessment. I suppose what I was wondering, is whether or not there is some sort of opportunity for us to get some sort of assistance from you guys into actually guiding us through that process."

Rick Fletcher. "The answer is 'yes', part of the project is to help people with this. There's going to be a few outputs that will flow. One is we've got a website – people probably didn't even recognise that the website for this conference was actually fisheries-esd.com. Now that's going to be an ESD website when we get it up and running; there's a Beta version sitting there, so all the information that we're generating will sit on the website. The other aspects that we're going to provide (actually generate, hopefully, before the end of the year) is pretty much a 'how to' guideline so that people can go through the process in an independent sense. The other thing we want to do as well though is to get the scientific guts of what we've been talking about for the last few months put through a peer review system. In particular the consequence tables. Because unless you can get reasonable agreement of a qualitative sense that those consequence tables have some basis of approval from the general scientific community, then we're probably barking up the wrong tree. I guess what we want to again get out of this is a reasonable level of certainty. If you go through this process, you've got some understanding of where you fit in terms of overall performance – I suppose it's going to be run at a few different levels. The other thing is that FRDC has now set up an ESD reporting and assessment sub-program and that's going to again try and co-ordinate all of the aspects that are being done at a national level, including this project that we're on, the 'Greenchooser' Project that's being run out of Seafood Services Australia. And a few other projects as well. That will all be sitting on the website so that people can get access to information as it actually gets generated. But there's probably nothing that helps more than actually being part of a process and seeing it work first hand. We'll probably continue to do the odd case study around the country over the next 12–18 months until everyone's comfortable with it."

Dan Gaughan (Fisheries, WA). "Gary's been struggling up here to get these points down. I can't believe that everyone here is absolutely happy with those, not at the first go; you're allowed to ask questions about them or disagree. I don't feel as if that's summarised this conference myself, not at a first go. So have a think about them because we're not letting you out yet!"

Malcolm Haddon. "Do you actually think that it's possible to summarise the conference in one board? Because we've covered a very wide diversity of subjects. I think we can come up with a summary, but whether we'll ever be satisfied with it… because I think we've covered a diversity of subjects."

Dan Gaughan. "Yes, I'm happy for it to go that way as long as we come up with a summary that's sufficiently succinct for non-scientists or people who haven't attended here to understand and that is what groups contributed to or are happy with; that it reflects the views of this actual workshop."

Norm Hall. "I think Dan, as long as you accept the fact that the summaries which were provided by the groups just beforehand also encompassed a lot of the results from the workshop. It seems to me that that's where most of the original summary points were being made – not in just this particular session. But I think the panel is actually now looking at those things that were not really summarised in the points that came through from the individual group sessions."

Malcolm Haddon. "I think Norm is exactly right, as with the documents we've just gone through we've got a diversity of subject matter here. Personally I abhor this notion of 'you have to come up with an executive summary for someone who doesn't really give a damn that will capture the depth of the meaning of it all'. They've got to do some work as well. It's not a lot of work: it's only four pages instead of one. So, that's enough of me complaining. It's a good idea to try to get a summary – let's see if we can do it maybe."

Gary Jackson (Fisheries, WA). "Can I make a suggestion then, as somebody who is sort of involved with where this thing will end up in terms of Western Australia trying to produce proceedings and produce them in a timely manner. Would it be reasonable then that each of the panel chairs – you guys who have got these overheads – would be prepared to write dot points or paragraphs around those in a form that the guys who are actually going to be putting the proceedings together can deal with; so the onus is on you four to put the words on those overheads more succinctly and that will basically achieve what Dan and I have been unrealistically trying to achieve here. The other case is, as well as produce your own paper that you might have given, you're also going to be required to come up with that."

Rick Fletcher. "Really, what we should be doing now is getting people's opinions on what wasn't in those four presentations that they think should also go on that board. Not a summary of what's in the four papers; it's things in addition to what was in the four presentations."

Gary Jackson. "Well, if you can collectively come up with a way that Dan and I can get that done in the next two minutes, that's fine."

Andrew Sanger (Fisheries, NSW). "One thing about the ESD section that we spent a lot of time on in our group sessions is that there is considerable provision in the ESD framework for flexibility, and that that provision needs to be highlighted. This thing isn't a big stick that's going to kill everybody: it's got scope for improvement and there are corollaries in things like pollution reduction plans that you might have. You might operate a site – in fact I did operate a site, a trout hatchery – that failed its environmental requirements at one stage. But that didn't mean we were shut down; what that meant was that there was a negotiated solution with the environmental agency whereby they made a pollution reduction plan and we got a tick after a period of improvement. So I think that needs to be just highlighted somewhere in that ESD bit Rick, that there is some scope for an improvement allowed in the process."

Rick Fletcher. "We don't often see a lot of the benefits that come from people having to do these assessments, because often as they go through and do the assessments, they work out for themselves what they need to improve and by the time they get the assessment, the improvements have already been put into place. I think that's part of what this is: it's just a continual improvement process; we're just providing a framework for people who actually put good business practice into play. So it's not rocket science. I mean, this is probably classed as an environmental management system under any other program. There are probably lots of other buzz words you could use for it. It's just a matter of focusing people on what the issues are and how they're going to try and cope with them in a sensible manner. If that means you've identified something you're doing wrong, then as long as you work out a way of making it better, then that's good."

Murray MacDonald (Fisheries, Victoria). "Just a couple of comments about areas which I was hoping to hear a little more discussion about but which I haven't so far. One is identifying innovative cost effective approaches to collection of recreational fishery information in some of these small, low value fisheries in places like small estuaries. That information could be used in terms of alternative stock assessment approaches. The second one is, there isn't any more detailed consideration of how we can perhaps develop specific objectives, performance indicators, and identify appropriate information requirements for the area of trying to maintain habitat and environment. This is critical to the production of fish resources. Can we deal with that in this ESD fisheries reporting framework and how do we go about doing it?"

Malcolm Haddon. "Perhaps I can talk about the recreational fishing side of things. You said 'cost effective' – get them to pay for it; get them to have the licences"… [comment from someone in the audience: "These people haven't got much money"]. "Yeah. It depends, if there's a risk – it all comes down to the risk in association with our fishery. If there's perceived to be no risk, and nobody wants to pay for it, then that's the cost; that's a social decision. If there's a potential risk and it would be very expensive in terms of the culture or everybody's feeling of well-being, or indeed the ecosystem in which whichever species lives, then somebody's got to pay. That may be a consultative process involving a dozen committees or you may have a strong minister who says 'do this' and causes trouble for years after, but there is no simple answer. I think it takes consultation and I think it takes political will, but I'm willing to be argued with."

Rick Fletcher. "I suppose in terms of habitat, there are two areas where it comes up. One is if the fishery itself is having an impact on the habitat, then that gets identified as its impact. If the habitat itself is being affected by others, it comes up in the area of impacts of the environment on the fishery. Now, those things identified, where it's got a direct impact on it, there will be a specific performance measure in the objectives associated with it. The fishery will need to meet these if it becomes a little more problematic about where the other sectors fit it. I think that's come up in a lot of the talks, in a lot of the summaries here. Everyone's recognised this as an issue, except for the fact of trying to improve our performance so we can therefore put greater pressure on the other agencies in charge of those people who are having those effects. I'm not quite sure what more we can do; except I think that the National Oceans Office should be picking up and looking at some of these. If everybody did their assessments, then surely they should be going through and making everyone do these assessments, picking up all those components and actually using them to work out what should be occurring at a reasonable level and putting them all together. Now that's a nice thought and that's the way it should operate, but I guess the reality is it's unlikely to occur – well at least in the next five to ten years."

Malcolm Haddon. "Well, that's right… then I heard that the State organisations in general have not signed on to the notion of regional planning, as being conducted by the National Oceans Office. Their regional planning is constrained solely to Commonwealth waters. So I think you're right, but I don't see it happening."

Andrew Sanger. "Just in response to Murray's query about how to get data from the recreational fisheries sector, I think in general, in Australia, recreational fishers don't contribute enough towards the management of their resource. [In] those States that have licensing systems, the licences are generally too cheap, and for the States that don't have licensing systems, they're losing out badly altogether. If we compared our licensing charges to equivalent charges elsewhere in North America, New Zealand or Europe, we'd find that we do undervalue our resources in terms of how much recreational fishers are prepared to pay. It's a difficult political area to get into, but we really need to maybe have a look at what the true costs of managing recreational fisheries are and how you gather those funds together."

Peter Gehrke. "One particular comment that I'd probably like to see come through a bit more is that we've got flexibility in management. However, I get nervous when I see the word 'flexibility' used too much, as it's often used as a substitute for 'not having to make a decision'. Where we're talking about flexibility in management I think very strongly about developing sensible adaptive management programs where there is a structured process, or at least a logical process, for adopting and evaluating alternative management scenarios. That at least gives us the opportunity to consider different approaches to management in an experimental context. I think that one of the more powerful roles for fisheries scientists in the future is in evaluating the outcomes of different management decisions in an 'on-the-ground' basis. We certainly need to do it in a modelling context and simulation to understand the risks that are involved. But there's a very strong role for fisheries scientists to evaluate the outcomes of different management experiments and I think that's probably one of the failures that we do have: not approaching management as an experiment on an experimental basis where at least we can establish hypotheses and see if we're achieving the appropriate sort of outcomes. That's one of the things that I think we could take on and make more of; we've been hedging around it through the whole workshop."

Malcolm Haddon. "It's a nice idea Peter. The trouble with it is, it's an uncontrolled experiment. Now, you might be able to do a meta-analysis across States or wider jurisdictions. But if we do this – if you go north (you can't go south) – we would know what happens when we go north, but we could have been not much more successful had we gone to quotas or had we gone to effort controls or had we gone to any one of the other options; but we didn't, we only picked one. So you're quite right. I think we need to pay more attention to what happened, the outcomes of the results of management decisions… not for any reason [such as to find out] if they are saying 'there see, I told you so' or 'well done', but just to see under what conditions something works. But it's not an experiment, simply because there's no replicates, no alternatives. South Australia has input controls in the Southern Region for rock lobster and output controls in the Northern Region for rock lobster. That's still not really enough, but I mean at least you can see there is some differentiation. But the regions are different. So you know, we're a bit caught there. One of the summaries on the stock assessment side was that you need to do the simulations on a variety of things so you can come up with a good summary of management actions for different situations."

Andrew Cribb (Fisheries, WA). "I want to come back to the point about management objectives, which I think is fairly germane to what you were just saying then. I think there's a big risk. I've heard a lot of statements today about setting explicit objectives and then getting specific assessment systems to evaluate whether you're performing against those objectives. But there's a risk in setting management objectives that are too quantitative or left brained. I think that's particularly true for recreational fisheries, because you actually don't have control over all the factors that are going into those fisheries in any kind of rigid way. I mean, you don't have any real control over effort and all those sorts of things. Another comment I want to make about the cost of managing recreational fisheries is that in WA we know they cost about 10–15 million a year at this point in time. To raise the additional funds will probably mean a $40 licence fee for those who want to participate, and these are the sorts of numbers you'd be kicking around with a participation rate of 200,000 people in this State. I mean the real participation is much higher than that, but you're going to have to exclude a bunch of people, as NSW has done. The only other point I really wanted to make was that management objectives are likely to be qualitative for recreational fisheries. The reason for that is that's what people identify with. They're not going to identify with 20 tonnes of yield; they're going to identify with 'I want a high quality recreational fishing experience'. I think you've got to actually take that into consideration when you're doing your experimental design."

Malcolm Haddon. "You're right, but you must be careful not to confuse performance measures or performance indicators with objectives. I guess objectives might be to maximise employment in regional Australia. An old one might have been to maximise yield. They're gross; but you see there's quite a lot of objectives which are inconsistent and you can't have both. ESD always used to cop a lot of complaints because it said economics and development were sustainable and you know, the best sustainable fishery is where there is none. It can still collapse, but you know at least it's going to be sustainable. Somewhere there's that balance. But the warning's right. I mean we do have to be careful how tied down we get, because objectives can do that to you."

Tony Fowler. "I've got a very simple question to the group as a whole. Are there any disadvantages to having a recreational fishing licence?"

Andrew Cribb. "The biggest disadvantage is in fact the social equity issues that sit around it. What you're actually doing is creating a value for a fishery which then only allows entrance to that fishery to those that can afford the entrance. If the fee is set high enough, then you're actually excluding something that's been a social access fishery for as long as this country has been around. I don't think the people have really thought through the equity issues properly in terms of rec. fishing licences. The argument that needs to go back to government, at the end of the day, is you need an integrated funding strategy to run an integrated management program. That means you need to pick up funds from a variety of sources. So I don't think there's an argument against licences as long as they're keyed in with other funding strategies. But as a singular issue, I think they're not going to solve the problem."

Malcolm Haddon. "OK, I can't bear it. I spent time in New Zealand and they're very much user payers there. I agree there is this issue that, look, it was always free; but open access fisheries were always there too and we know that that was a mistake. We've got to be able to recognise the mistakes in the past; we've got to recognise that recreational fishing is growing really fast so that this traditional pastime may have doubled in the number of people fishing. It wasn't traditional for lots of these people. They're all new – our culture has to adapt to changing circumstances, and if recreational fishing constitutes a threat to a resource, either locally or globally, we need to do something about it. Lots of politicians love the leverage – you can provide this much money, we'll provide that much money. I'm not going to argue over recreational fishing licences (to me they seem reasonable) but I know to other people they won't. I'm just saying it's an option and it needs to be considered seriously if recreational fishing is perceived to be a problem."

Abstracts from the 2001 ASFB Conference

Following the 2001 ASFB Workshop, the society held its annual conference on 26-27 September.

The following abstracts reflect the oral presentations at the ASFB Conference in 2001.

Estimation of the recreational catch of abalone in Western Australia

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A survey of recreational abalone licence holders was conducted after the Perth metropolitan abalone season for 2000. A stratified random sample comprising 807 of the 18,300 abalone and umbrella licence holders was contacted by phone. Catch and fishing effort information for Roe's, greenlip and brownlip abalone was collected for the Perth metropolitan area and South Coast and West Coast bio-regions.

Abalone fishing in the Perth metropolitan area is permitted on six consecutive Sundays only, commencing the first Sunday in November. Fishing within 800 m of the shoreline is only permitted between 7:00 am and 8:30 am. Fishing in most other areas of the State is permitted throughout the year. A daily bag limit of 20 and a minimum size of 60 mm for Roe's abalone apply throughout the State. For greenlip and brownlip abalone the minimum size is 140 mm and daily bag limit is 10 (combined).

The total effort for recreational abalone fishing in the State was 44,600 fisher days. Almost half of the effort occurred in the Perth metropolitan area (49%). The total recreational catch of Roe's abalone for the State was 53 tonnes (whole weight) of which 34 tonnes was taken from the Perth metropolitan area. This is exceeded by the commercial catch of 108 tonnes (whole weight) of Roe's abalone of which 36 tonnes was taken from the Perth metropolitan area.

The total recreational catch of greenlip was 18 tonnes (meat weight). This was exceeded by the commercial catch of 71 tonnes (meat weight). The total recreational catch of brownlip was 5 tonnes (meat weight). This was exceeded by the commercial catch of 13 tonnes (meat weight).

Recreational fishers take a significant share of the total abalone catch for the state. The recreational catch and fishing effort for all species of abalone needs to be monitored to provide essential information required for an integrated management approach to ensure that current and future levels of fishing are ecologically sustainable.

Stock structure of pink snapper (Pagrus auratus) in Shark Bay: new genetic evidence at a finer spatial scale

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Comprehensive stock identification studies on pink snapper (*Pagrus auratus*) in Shark Bay undertaken since the early 1980s have provided a significant body of evidence (genetic and phenotypic) to suggest that multiple stocks exist within both the eastern and western gulfs of the bay, and also outside the bay.

A further genetic study utilising allozyme electrophoresis was conducted in 1998/99 to determine the extent of genetic differentiation among pink snapper within Shark Bay on a finer scale. The physical characteristics of the bay result in an increasing salinity cline ranging from oceanic to hypersaline at the head of both gulfs.

The genotypes of more than 600 snapper at 6 locations both within and outside of the bay were examined. A screening of 18 enzyme systems revealed 10 polymorphic loci that could be consistently scored. Of those loci, 4 were found to be significantly different across all locations; *Idh-1*, *Mpi-1*, *Ltp-1* and *Pgm-2*. Cluster analysis revealed the largest genetic distance to be between Freycinet (lower western gulf), and Koks Island, which is outside the bay adjacent to the eastern gulf. Other significant differences existed between the eastern gulf locations (Carnarvon, Cape Peron and Monkey Mia) and Koks Island, Denham (upper western gulf) and all eastern gulf locales (also Koks), and between Denham and Freycinet.

Results suggest that up to 4 separate genetic stocks exist in the Shark Bay region; Koks Island (ocean stock), Denham Sound (upper western gulf), Freycinet (western gulf) and the eastern gulf stock.

What Galaxias can teach us about biogeography on a global, regional, and local level

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Galaxias maculatus is a diadromous fish found in Australia, New Zealand, South America, and on some oceanic islands. Two hypotheses have been advanced to explain this widespread, disjunct distribution: vicariance (continental drift) and dispersal (of salt-tolerant juveniles through sea). Allozyme electrophoresis of muscle extracts of specimens from Australia, New Zealand, and Chile showed that populations from the western Pacific and eastern Pacific do not differ genetically and that no fixation of alternative alleles has occurred. The populations appear to be part of the same gene pool, indicating that gene flow via dispersal occurs today.

Galaxias vulgaris sensu lato is widespread throughout South Island of New Zealand. Populations in the southern part of SI represent a complex of 5 different species while populations in central SI are more genetically homogeneous. Isozyme electrophoresis was used to test whether a geologically recent region with low endemism shows low genetic diversity. The answer is yes. The low endemism is thought to be due to the combined effects of an Oligocene marine transgression, Pleistocene glaciation, and the unstable nature of the braided river systems of the central region. These factors, absent from the southern region, have prevented the isolation and subsequent speciation of populations in the central region.

A creek near Canberra was divided into 13 m sections. A total of 295 *Galaxias olidus* were fin-clipped and returned to the section of capture. Over a 77 day period, 86 marked fish were recaptured. Seventy-eight percent of recaptures were within the marking section or adjacent section, and 88% were no more than two sections from the marking area.

Molecular systematic study of some Australian desert fishes with respect to their evolution, biogeography and conservation status

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The Lake Eyre region of Central Australia is a semi-arid to arid environment in which conditions are extreme; despite this, it supports 34 native species, 3 translocated native species and 2 exotic species of freshwater fish. This region consists of several ephemeral wetlands and semi-permanent water bodies. The mound springs of central Australia are artesian fed permanent springs and are recognised as 'island' communities in that they are discrete patches of habitat surrounded by a contrasting environment. The fauna of island communities is recognised as being susceptible to rapid extinction rates.

This investigation examines the genetic variability among populations of desert fish and crustaceans in the Lake Eyre region in order to determine the degree of taxonomic and phylogenetic divergence. Within the Lake Eyre region arid conditions are maximal, and the habitats are fluctuating and tenuous. Recent investigations suggest that the unpredictable conditions and discontinuous nature of such freshwater habitats may favour speciation in freshwater fishes and invertebrates.

This study consists of two parts. One part aims to determine genetic divergence between populations in different river systems and focuses on four species: *Nematalosa erebi* (bony bream), *Leiopotherapon unicolor* (spangled perch), *Neosilurus hyrtlii* (Hyrtl's catfish) and *Triops australiensis* (shield shrimp).

The second part of the study is focused on the isolated mound spring communities of Central Australia and will involve determining the degree of isolation of these communities, by using molecular techniques to compare the fish populations of all the springs.

The results of this study will allow the development of effective conservation practices for inland desert aquatic communities.

The indigenous fishing survey in northern Australia – another methodological challenge

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The primary focus of the National Survey is estimates of catch and effort for all 'non-commercial' fishing activity in all areas of Australia. The vast majority of this information will be obtained from the telephone/diary survey of recreational fishing, which provides excellent coverage of the resident population. However, in areas of coastal northern Australia indigenous peoples are also an important, if not the major, non-commercial user of fisheries resources. A telephone/diary survey would not provide adequate coverage of these residents, so a survey module was designed to examine the fishing activity of indigenous fishers in northern Australia.

An innovative approach was needed to design a survey that had never been attempted before on such a large scale. Ultimately, the design needed to balance logistic and financial constraints whilst maintaining the focus on optimal data quality. The survey was based on general population sampling. Communities were stratified by location, with a random selection of 46 communities chosen. Within each community, dwellings were selected randomly and an initial face to face interview was used to collect household profiling information. All respondents from selected dwellings were then invited to participate in a twelve-month catch and effort survey. Respondents were visited regularly throughout the survey period and details of fishing activity for the week prior to the contact recorded.

While the recreational and indigenous components have different values to each State and Territory, the combination will provide a comprehensive picture of non-commercial fishing, and allow a more comprehensive description of the extractive sectors of Australia's fishing resources.

Estimation of the current age structure of mirror dory

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Mirror dory (*Zenopsis nebulosus*) is one of the species under quota management in the South East Fishery (SEF) for which there has been no quantitative stock assessment. To date, assessments have relied on examination of the time-series of length frequency distributions and data from catch and effort log books. In this study, a “snapshot” examination of the age structure of mirror dory was undertaken to aid in the future assessment of the status of mirror dory stocks in the SEF.

Samples of mirror dory otoliths were collected from commercial catches in the SEF by the Integrated Scientific Monitoring Program (ISMP). The samples were transferred to the Central Ageing Facility at the Marine and Freshwater Resources Institute where their ages were estimated. Comparisons were made between populations in the eastern and western regions of the SEF.

Estimated ages of the mirror dory ranged from 2 to 14 years for fish between about 30 and 65 cm TL. The size and age structure of populations in the eastern and western regions was significantly different. Furthermore, the mean length-at-age of mirror dory samples in the western region were considerably greater than those in the eastern region for all fish > 4 years old. Reasons for the difference in population structure and growth rates in the two regions are discussed and it is suggested that future assessments of mirror dory incorporate separate analyses for the eastern and western regions.

Activity patterns of giant kokopu** (Galaxias argenteus) **during 24 hour periods: a summer/winter comparison

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Habitat use and activity of giant kokopu, were monitored during winter and summer in small streams using radiotelemetry. Habitat use was determined by point-in-time locations of individual fish triangulated between one and three times per week. Activity was determined using a novel remote radiotelemetry system which recorded the signal strength received from tagged individuals. A large variation in signal strength indicated that fish were active whilst small variation in signal strength indicated little or no activity. Point-in-time habitat use data and activity data indicated that giant kokopu were strictly nocturnal during winter. Fish were always inactive and concealed amongst cover during daylight hours, whereas at night they moved actively around the pools in which they were resident. In contrast, during summer, periods of activity were less defined with fish exhibiting activity during both light and dark periods. Habitat use and activity data indicated that giant kokopu maintained restricted homeranges during both winter and summer. It is concluded that giant kokopu are primarily nocturnal in habit but will emerge during the day in summer presumably in response to increased metabolic demands and food resources.

Do effects on juveniles control the stock–recruitment relation in abalone?

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Sustainable management of almost any exploited stock depends on a density-dependent recruitment response to reductions in adult numbers. But there is often very little direct evidence available on either the mechanism or the form of this stock–recruitment relation. Abalone, unlike most fishery stocks, are amenable to experimental manipulation, due to their limited movement. Mariculture work suggests juvenile growth is highly density-dependent, and we have shown that growth in the field is extremely variable, such that cohorts may recruit to fishery sizes over several years. Furthermore, mortality is likely to decrease rapidly with size, so that pre–recruitment mortality may be strongly growth-linked, and depend largely on juvenile density in relation to resources. In conjunction with South Australian abalone divers, we aim to determine the relation between density, survival and growth in juvenile greenlip abalone. Six 3x2m reefs of optimum natural habitat (boulder piles adjacent to seagrass) have been established at each of 5 sites. Cultured juveniles (+/-25mm) will be placed at 3 densities on these reefs, and growth, migration and survival estimated. The effect of larger on smaller juveniles will be tested using a set of 16 reefs at another site. Pilot seeding experiments have been encouraging. Strong density-dependence would indicate that juvenile growth on a reef might be a good measure of the relative state of the stock. Density-dependence that is consistent across sites would suggest that juvenile habitat space limits the sustainable productivity of greenlip abalone stocks.

The fish communities of the Mary River coastal wetlands: implications of saline intrusion control bunds

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Over the past forty years, saline intrusion has destroyed large areas of coastal freshwater wetland in the Mary River region of the Northern Territory. Earthen walls and spillways have been constructed across the wetlands to reduce saline intrusion but their effect on the fish communities has not been described.

The fish assemblage of the Mary River Wetland was sampled using a combination of gill nets, cast nets and scoop nets between November 1998 and June 1999. Just over 6,000 fish belonging to 40 species and 23 families were collected.

Physiochemical water variables were recorded in conjunction with the faunal survey. Both these variables and faunal composition were shown to vary over the sampling period and between the locations sampled.

The placement of saline intrusion control bunds on the coastal wetlands was found to modify the water inputs into the wetlands and resulted in a decrease in species richness and abundance of the aquatic fauna when compared to that of an unblocked wetland. Furthermore, the blocking of tidal creeks by the bunds has the potential to impact on the migratory habitats of some important diadromous species, particularly barramundi and tarpon. The placement of fishways within the bunds was found to reverse the negative effects of the bunds by again allowing the mixing of marine and freshwater and thus the fish from both sources.

***Understanding the effect of density and habitat on the movement of blacklip abalone** (Haliotis rubra)*

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Abalone are generally perceived as sedentary, however individual movements of several kilometres have been recorded for some species. Blacklip abalone, *Haliotis rubra*, tend to form aggregations in areas of preferred habitat, presumably areas of greatest food availability. Abalone divers target these higher densities in an attempt to maximise their catch rates. Diver observations suggest that abalone will quickly reform these aggregations after fishing, enabling catch rates to be maintained despite reductions in population density. Significant movements of abalone toward areas of greater food availability would suggest density-dependence of growth. Understanding these movements, particularly in relation to density and habitat, is essential to determine the effect of fishing on abalone populations and interpret catch statistics.

A movement study was conducted at two sites in Victoria. Abalone were tagged within four plots at each site using *in situ* rivet tags and surveys were conducted approximately 4, 8 and 12 weeks after tagging and also one year after at Point Cook. Large abalone were removed in two of the plots at each site after the second survey. Movements were greatest in areas with the lowest density and the least amount of preferred habitat. Reducing the density of abalone by fishing increased the number and extent of movements, reforming aggregations approaching their original local densities within short time periods. Length frequency distributions before fishing and 8 weeks after were almost identical, suggesting that re-aggregation was formed by large abalone. Future studies could target density-dependent growth by ascertaining differences in growth rates between abalone from sparse and dense areas of the same population.

Thermal marking of rainbow trout** (Oncorhynchus mykiss) **otoliths

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A small-scale experiment was conducted to test the feasibility of thermally marking the otoliths of hatchery-reared rainbow trout fry that are released into rivers and impoundments in New South Wales. Rainbow trout fry were exposed to two different 48 h thermal cycles each of a cold and warm period. The two thermal regimes consisted of a cold water period at 4 °C and 8 °C for 18 h and 10 h respectively, followed by a warm period at 14 °C for the remaining time. Thermal cycles were repeated four and eight times for each thermal regime. Following a growth period after treatment, clear marks were visible on all treated otoliths and were distinct from otoliths for the control fish. The treatment with a 10 °C differential created the most visible patterns, and growth of these fish was not significantly different from the control fish. This marking method could be applied to normal hatchery practices to enable the evaluation of the effectiveness of large-scale rainbow trout stockings in NSW.

Size and age at 50% maturity in southern bluefin tuna: an integrated view from published information and new data from the spawning ground

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The size and age at which southern bluefin tuna (SBT) reach maturity is of critical importance within the SBT stock assessment. Several methods have been used to assess SBT maturity in the past, giving a range of results from 130 cm to 157 cm. At the 1994 CCSBT Scientific Workshop, an estimate of age 8 yrs was adopted as the 'mean size at first maturity' (size at which 50% of fish are mature) for SBT based on the conversion of length (130 cm) to age using available growth curves.

If SBT matured at age 8, we would expect significant numbers of 8-year-olds to be caught on the spawning ground. However, there are very few fish less than 12 years old in the Indonesian longline catch on the spawning ground. Questions have been raised, however, over the whether data from the Indonesian fishery are representative of the spawning population. This has been clarified to some extent by recent work on the size partitioning by depth of SBT on the spawning ground. However, there remains some uncertainty regarding the relative abundance of smaller/younger fish at different depths.

We use data from CSIRO monitoring of the Indonesian fishery to estimate the size and age at which 50% of the population has recruited onto the spawning ground. These provide a reasonably consistent estimate of size at maturity between 158.4 and 163.1 cm, which translates to an age in the order of 11 or 12 years.

Population structure and reproduction of yellowfin whiting (Sillago schomburgkii) in South Australia

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Yellowfin whiting, in South Australia, are at the south-easternmost part of their distribution. Here they occur mostly in the warm waters of northern Spencer Gulf where temperatures range from 12 to 24 °C. In the 1999/00 financial year this region produced 78% (88.2 tonnes) of the State-wide commercial catch of 112.7 tonnes. Catches are characterised by wide inter-annual variability and in 1998/99 the catch of 38.5 tonnes from northern Spencer Gulf was less than half that in 1999/00. This, and an increase in non-targeted CPUE in 1999/00, implied that more fish were available to the fishery in the latter year.

Age structures of the commercial catch ranged from 1 to 12 years but were dominated by 2- to 4-year-old fish, with abundances decreasing with age. L_{inf} was 306.2 (n = 487) and 336.8 (n = 867) for males and females respectively, with K estimates of 1.178 and 0.908. Survivorship was 0.5 (n = 777) for males and 0.58 (n = 441) for females. Males grew faster, but attained a smaller maximum size and were relatively less abundant in the older age classes.

Sexual maturity is attained by males and females at 222.8 and 238 mm TL respectively, with spawning from October to February and a peak in November. All developmental stages of oocytes occurred in the same ovary and POF's co-occurred with hydrated oocytes indicating that yellowfin whiting is a multiple-batch spawner with asynchronous development, indeterminate fecundity and can spawn on consecutive days. The spawning fraction ranged from 0.1 to 0.7 (n_f = 176) and the mean spawning frequency was 2.5 days.

A super-abundant year class, but regional variation for snapper (Pagrus auratus) in South Australia

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The commercial harvest of South Australian snapper in 1999/2000 was 576.2 tonnes, the highest ever recorded, being 174 tonnes above the long-term average, and much higher than the poor catch of 223 tonnes in 1994/95. Not all geographic regions contributed to the increase, which was mainly accounted for by Spencer Gulf, which contributed 89% of the State-wide catch. Other regions, such as Gulf St Vincent and Investigator Strait, still show low catches after the stocks collapsed through the 1980s-90s. In Spencer Gulf the increase in catch was mirrored by the CPUE, suggesting that the change reflected a substantial increase in fish biomass. To elucidate the population processes responsible, population size and age structures from the commercial sector were developed. They indicated the presence of a super-abundant year class, which at 9 years of age in 2000, originated from spawning in the summer of 1990/91. In 2000 in northern Spencer Gulf they contributed 34% and 16% respectively, of the handline and longline catches, and in the southern gulf contributed approximately 60% of catch from both gear types. There was also significant seasonal variation in population characteristics suggesting a behavioural influence over what part of the population is available to the fishery at different times of the year. Overall the results demonstrate the significance of inter-annual variability in recruitment of 0+ fish, and that the timing of availability of a strong year class to the fishery may depend on a complex, age-related migration phase where fish move between the continental shelf and Spencer Gulf.

Poor understanding of complex fish–ecosystem interactions may result in failure to detect global warming impacts: an example using the WA pilchard fishery

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The intensity of management of coastal fisheries has been in a J-curve for the past several years. Resource sharing issues have been particularly intense. Coastal communities blessed with easily accessible fishing grounds, nice climates, scenic vistas (±SeaLevel), sea mammals and/or marine birds, and the associated high real estate and tourism potentials, have been at the forefront of commercial/recreational/conservation conflict and subsequent change, e.g. estuary- licence buy-back schemes, MPAs. The general community are much more aware of the fact that aquatic resources are subject to sustainability problems and that resources thus need to be managed. However, another looming longer-term problem that has largely missed out on the coastal-fishery/community-concern J-curve is the impact of global warming. Neither is global warming a concern for commercial fisheries. Why not? Partly because cause and effect relationships within complex ecosystems are often impossible to determine in the classical scientific sense (i.e. control and effect experiments). This results in uncertainty, the management-decision scapegoat of the late 20th century. An example of how to approach this problem is provided using hypothesised impacts on WA pilchards. If global warming is influencing aquatic ecosystems, our understanding of populations for which we have only short time series of data may never be complete while that for well studied species may need to be revised periodically.

Identification, conservation and management of estuarine and marine nurseries for fish and invertebrates

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Nearshore estuarine and marine ecosystems, e.g. seagrass meadows and mangrove forests, serve many important functions in coastal waters. One of the most obvious is that they have extremely high primary and secondary productivity. Because of their effects on the productivity of macrofauna, these areas are often referred to as nurseries. This nursery role has been a common justification for the protection and conservation of many nearshore ecosystems. The nursery role concept, however, has rarely been stated clearly and this ambiguity reduces its use as an effective tool in conservation and management. In this talk, I develop a clear hypothesis with testable predictions and discuss how this work can focus our efforts in research, conservation, restoration and management. I suggest that a habitat is a nursery for juveniles of a particular species if its contribution per unit area to the production of individuals that recruit to adult populations is greater, on average, than production from other habitats in which juveniles occur. A clearer understanding of the areas that serve as nurseries, and the factors that make some sites more valuable as nurseries, will allow better expenditures of limited money, time, and effort.

Using elemental chemistry of otoliths to determine movements of fishes: spatial and temporal variation

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Determining movement between juveniles in estuarine nursery habitats and adults collected outside estuaries on reefs as part of a fishery is difficult. The elemental composition of otoliths of snapper was determined to investigate their utility as a natural tag of the nursery habitat. Juvenile snapper were collected and the chemistry of their otoliths analysed by inductively coupled plasma-mass spectrometry. In addition, snapper were collected in three years to determine whether temporal differences may be found in elemental fingerprints. Such differences may then confound subsequent assignment of adults to natal estuaries. Significant differences in otolith chemistry were found among estuaries and years. The nursery or natal estuary of adult fish can now be determined by analysing the juvenile region of adult otoliths, thus enabling connectivity between estuaries and open coastal populations to be determined.

The effects of density on the growth, survival and behaviour of post-larval Haliotis laevigata

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The relationship between stock levels and recruitment in abalone is one of the most vital, yet poorly understood links in their ecology. Comprehension of this connection would have enormous consequences for abalone fisheries and restocking programs around the world. I hope to solve a piece of this puzzle by investigating just how the post-larval phase of *Haliotis laevigata* is affected by the settlement density. Is their growth affected? Is their survival affected? Are these effects related to their behaviour? I will also examine the role food productivity plays on these factors at different densities.

Hatchery-raised *H. laevigata* post-larvae will be settled onto plates at three levels of density. There will also be two levels of food productivity – under high and low light. Plates will be monitored at regular intervals over 16 weeks for growth and survival. The experiment will be conducted in a hatchery where frequent and prolonged observation will allow the study of their behaviour. I also intend to place plates in the field to investigate whether the same patterns are observed in a more natural environment. While this limits the frequency of monitoring, it will allow investigation of factors such as predation and cryptic behaviour, and how they relate to the density of post-larvae.

Relationships between antecedent daily discharges and fish recruitment in the Murray-Darling River, Australia

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The recruitment of many fish species has been linked to antecedent flow conditions. Although these links have not been firmly established in Australia, many native fish species are thought to spawn under specific flows and river regulation has been identified as one of the major factors in the their decline. New management plans, incorporating environmental flows, have been implemented in most rivers of the Murray-Darling Basin over the last two years. This paper describes the relationship between flow conditions and young-of-year fish at sites within the Murray-Darling River system both before and during the new flow rules. The antecedent flow regime at 50 sites, over six years was described by calculating seasonal hydrological indices for each year from the daily flow record at each site. Indices were selected to describe aspects of the flow that are likely to affect fish recruitment and survival, including flood, medium and low-flow conditions. The relationships between flow conditions and fish recruitment were examined using correlation, principal components and redundancy analyses. The results will be used in the future to recommend the types and seasonality of environmental flows that are required to have a positive influence on fish recruitment.

What types of snags do trout cod use?

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The abundance and size of trout cod was related to features of snags in the Murrumbidgee River, NSW. Sampling took place along banks of a 1 km section of river using boat electrofishing. A range of habitat descriptors including velocity, substrate, proximity to bank, presence, density and depth of snags/shelter, macrophyte and riparian vegetation and water depth, temperature and turbidity, were recorded for every trout cod captured, and at every 100 m or after every second 5 minute shot. There were strong correlations between some variables, so principal components analysis was carried out to obtain new orthogonal variables. Trout cod abundance and size were related to these new variables using multiple regression analysis.

There was a complex relationship between the abundance of trout cod and the types of snags on which they occurred. In general, trout cod were more likely to be found on smaller snags that are located in faster currents, on snags oriented downstream in deeper water and on snags found away from the river bank. There was also a difference in the types of snags used by different sized fish. Smaller trout cod were found in wide, shallow river sections on more complex snags, with a downstream orientation and away from the river bank. Larger trout cod were generally associated with similar types of snags, but with those with an upstream orientation. This study suggests that a range of different types of snags would be required to rehabilitate river sections to account for the ontogenetic habitat requirements of trout cod.

Beam trawls, what a drag, why seines are better

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The densities of nekton were estimated by comparing catch rates of two previously uncompared gear types, a beam trawl and a seine net, in day and night in shallow seagrass (*Zostera capricorni*) habitat in Moreton Bay, Queensland, Australia. Sampling was done over ten days and ten nights with both gear types. The sampling area was standardised to approximately 80 m^2 for both gear types. A total of 39,676 fish and crustaceans representing 42 species were caught. The catch rates of nekton were 1.4 to 68 times higher at night than in the day for eight of the 17 common species, and were 1.4 to 9.2 times higher for seines than trawls for 11 of the common species. Night-time seine collections typically had a greater proportion of larger individuals than day and trawl samples. The differences in catch rates and size of nekton are probably a consequence of both gear avoidance and the movement of nekton out of seagrass during the day. Catch rates were estimated more accurately and precisely with the seine than the trawl, with higher catch rates at night. An analysis of the overall composition of the catch (based on presence/absence data) by multi-dimensional scaling separated the samples very clearly into four main groups: day-trawl, night-trawl, day-seine and night-seine. The results suggest that to effectively estimate nekton density and species richness in seagrass habitat, sampling should be completed by a seine net in the day and night, or night alone.

Evidence for multiple age-classes in a spawning population of the giant Australian cuttlefish

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Many cephalopod species are thought to be short-lived, i.e. have a life span of only 1-2 years, and have a single spawning period near the end of the life-cycle. For annually spawning species this life-history strategy often results in the population consisting of a single year class of similarly-sized individuals. Some small variation within the population is commonly attributed to differences in individual growth rates and hatching times. I investigated the size and age-distributions of an annually spawning population of cuttlefish in northern Spencer Gulf, South Australia, to determine if the population fits this general life-history model. The species, the giant Australian cuttlefish (*Sepia apama*) forms a large spawning aggregation at a highly localised site every winter between May and August. The predictable nature of the aggregation has made the population vulnerable to fishing.

Size distributions of male *S. apama* at the spawning aggregation during winter, and elsewhere at other times, consisted of several distinct size-classes. Analysis of the microstructure of cuttlebones representative of the different size modes, provides evidence that the different modes do represent different age classes. The results suggest that the longevity is greater than 1-2 years, and thus the life-history of this species is atypical for cephalopods. The situation for females is less clear because they have a smaller range of sizes than males, and distinct size modes in the size distribution are less clear. The implications of this extended life-history for cuttlefish in the context of targeted fishing on the spawning aggregation will be discussed.

The application of otolith microchemistry to the study of migratory dynamics and nursery origins of snapper *(Pagrus auratus)* in Victorian waters

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The Port Phillip Bay snapper fishery is by far the most important fishery for this species in Victorian waters. Despite this we have limited detailed information on snapper movement patterns between the bay and coastal waters and also on the role of the bay as a nursery for 0+ snapper and a source of adult snapper to the both the bay and coastal fisheries. The initial aim of this project is to investigate the potential to utilise nursery specific chemical fingerprints or ‘tags’ in the otoliths of 0+ snapper as a means to distinguish between snapper derived from the Port Phillip Bay nursery and those derived from other Victorian nurseries. This presentation will discuss spatial and temporal variation in otolith microchemistry of 0+ snapper collected from five Victorian bay/inlet nurseries during two recruitment seasons. Preliminary data and the potential for life-history variation in otolith microchemistry to yield information on the movements of snapper between the bay and coastal waters will also be discussed.

Molecular systematics and conservation biology of the southern pygmy perch

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Pygmy perch are a group under threat, with four of six known species considered 'threatened', along with other regional populations. The southern pygmy perch *Nannoperca australis* has experienced decline in the Murray-Darling Basin and in the Lower River Murray, this species is confined to the Mount Lofty Ranges (MLR) watershed, where it is locally 'endangered'. As a base for conserving *N. australis*, allozyme analyses provide a sound systematic framework for pygmy perches and permit in-depth examination of population structure in *N. australis* (45 locations). A field study in the MLR served to characterise local habitats. There is clear evidence that the current systematic framework is inadequate. The 'southern pygmy perch' almost certainly comprises three species with a morphologically cryptic taxon (*N.* sp. nov.) in Victoria and Tasmania and a second species (probably *E. obscura*) in the Lower Murray. *N. australis* s.s. contains two genetically distinctive lineages. One lineage includes populations in the Murray drainage and the isolated Inman River (a new western distribution boundary) and the second populations in other parts of Australia. MLR sites generally support few species, rarely with exotic taxa, and are prone to natural disturbance. Environmental change probably is a major cause of range contraction and continuing local extinctions.
It is recommended that Evolutionary Significant Units be evaluated and that future conservation involve further ecological studies, Population Viability Analysis and investigations of 'artificial refugia'. There are clear implications for re-stocking programs and strong community involvement is needed.

Differences in fish assemblages from different reef habitats in Hamelin Bay, south-western Australia

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Differences in the diversity of fish species between granite and limestone reefs, as well as between high and low relief reefs, were investigated in Hamelin Bay, south-western Australia. Hamelin Bay is unique in the south-west, in that both granite and limestone reefs are found in the area at similar depths. Video cameras were employed to record fish present along transects, in order to eliminate many of the biases associated with visual estimation. Multivariate statistics (ANOSIM, MDS and SIMPER) were used to analyse the data after the video footage was examined. It was found that there were indeed significant differences in the fish species presence and abundance on granite reefs, as opposed to limestone reefs. Where granite reefs were characterised by greater numbers of fish species such as *Coris auricularis* (western king wrasse), *Parma mccullochi* (common scalyfin) and *Dactylophora nigricans* (dusky morwong), limestone reefs had greater numbers of the fish species *Odax cyanomelas* (herring cale) and *Pempheris klunzingeri* (rough bullseye). A significant difference in fish diversity was also found between high relief (>2m relief) and low relief (<2m relief) limestone reefs in the same area. More species were found on the high relief reefs as opposed to the low relief reefs. These results highlight the importance of different habitats to different fish assemblages.

The biology of the West Australian dhufish (Glaucosoma hebraicum)

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The West Australian dhufish, *Glaucosoma hebraicum*, is restricted to coastal waters of south-western Australia. Although this species is one of the most commercially valuable and recreationally sought after finfish in Western Australia, there were very little reliable data on its biology prior to the present study. Numerous reports from commercial and recreational fishers and trends in commercial catch statistics strongly indicated that the abundance of *G. hebraicum* in areas closest to the coast had declined in recent years, particularly in the vicinity of Perth, where this species is heavily fished. This study was undertaken to provide the Department of Fisheries, Western Australia, with biological data that could be used to develop plans to conserve this important resource. The individuals of *G. hebraicum* obtained during the present study reached a maximum of 1100 mm in length, 23 kg in weight and 41 years in age. This species, which is a multiple spawner, breeds from November to April. Sexual maturity is typically reached by *G. hebraicum* at about 3 years of age and 300 mm, which is well below the minimum legal length (MLL) for capture of 500 mm. However, since *G. hebraicum* caught in water depths of >20 m often die upon release, the imposition of an MLL is of limited use. Alternative approaches, such as the restriction of fishing activity in highly-fished areas, a reduction of the daily bag limits for recreational fishers, the introduction of quotas and/or the review of certain commercial line fishing licences are thus more likely to provide effective conservation measures.

Bayesian state-space surplus production model outperforms classical alternative

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Surplus production models are used in fisheries to estimate biomass through time, based on the catch per unit effort and total catch from a fishery. The Bayesian state-space version of this model gives different results from a classical analysis. This motivated a comparison of the performance of the methods against a ‘gold standard’. I developed a stochastic model that generated the type of data used in these models, based on data from a tuna fishery. For each set of data generated, I ran both of the estimating models (Bayesian state-space, implemented in the Bayesian statistical package BUGS, and frequentist observation error, implemented in Microsoft Excel), and estimated model parameters. I compared the ability of the two estimating models to reconstruct the parameters and distributions that were originally used to generate the data. The Bayesian model consistently outperformed the classical model, giving considerably more accurate estimates of both parameters and biomass trajectories. The Bayesian state-space estimating model worked better because it incorporated both process and observation uncertainty, while the frequentist model could include only one of these uncertainties.

***Modelling for management of longfin eels** (Anguilla reinhardtii)**, with comparison to** A. australis **and** A. dieffenbachii*

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Anguillid eel life history is unique, and human activities affect their population dynamics differently from most other fished species. Recruitment is a serious problem in eel fisheries internationally - it appears to have declined dramatically in most eel species in recent years. Managers require a tool for understanding how human activities, and changes in regulations (e.g. area closures, minimum legal size), affect eel spawning biomass and fishing yield. In this paper I describe an interactive model of eel management and population dynamics, designed to give an understanding of eels' unusual management characteristics. The model is implemented in the widely-used spreadsheet Microsoft Excel. The model essentially takes a yield per recruit approach, and follows an idealised cohort of eels from recruitment to maturity, taking into account variation in growth rate and length at maturity. It works in terms of relative production at equilibrium (biomass per area per unit time). The model is applied separately to male and female eels, and to Australian longfin eels (*Anguilla reinhardtii*), New Zealand longfins (*A. dieffenbachii*), and Australasian shortfins (*A. australis*). I demonstrate that, for longfin eels in particular, female spawning biomass is most effectively maintained through the use of unfished areas, with unrestricted access to the sea. Australian longfin eels are slightly less vulnerable to overfishing than New Zealand longfins, mainly due to their faster growth.

Effect of density on the growth of post-larvae and juvenile blacklip abalone in aquaculture

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Density plays a major role in aquaculture as it may greatly affect the productivity and the economic results of abalone farms. However, the importance of density is poorly understood and density levels are usually determined empirically. Can farmers use high stocking density and maintain an optimum productivity?

Three experiments were conducted in which the growth of blacklip abalone post-larvae and juveniles were monitored in relation to density and the availability of food (diatoms and *Ulvella lens*).

Post-larval growth was much more affected by density when the level of food available was low. In a second experiment where food and density were not limiting factors, the growth rates of two size classes selected from the same cohort 4 months after settlement were very similar. Individual variation in the growth of these post-larvae was large even amongst siblings and in conditions of low density and plentiful food.

Density also significantly affected the growth of larger juveniles, even when food was not limiting. Water quality and velocity did not have a significant effect. The major impact of density on the growth appeared to be related to the surface area of shelter available in the tanks.

The reproductive biology of the common sawshark (Pristiophorus cirratus) harvested off southern Australia

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The common sawshark (*Pristiophorus cirratus*) is endemic to southern Australian waters. It is distributed from Jurien Bay in Western Australia to southern New South Wales, in depths up to 310 m. It is the third most important species of the southern shark fishery after gummy shark and school shark, contributing about 7% of the annual harvest. With a move to manage the fishery by Individual Transferable Quotas, there is a need to better understand its reproductive biology for fishery stock assessment. Maturity, fecundity, and breeding frequency of females, period of gestation, and embryonic growth are investigated by macroscopic examination of the uteri and oviducal glands; by measuring the diameters of the three largest ova in the ovaries; and by recording the number, size and weight of *in utero* eggs and embryos. Maturity of males is investigated by macroscopic examination of the testes, seminal vesicles, and clasper calcification; by weighing the testes; and by measuring the claspers. Maturity, breeding, and other reproductive variables are related to the total length and age of the animals, where age is estimated from samples of sectioned vertebrae.

Artificial reefs: their effects on fish stocks

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Australia has approximately 72 artificial reefs mostly located in sheltered water between 3 and 25 m. Queensland has three significant multi-component artificial reefs, located in Moreton and Hervey Bays. The debate regarding the productivity benefits of artificial reefs has not been resolved despite extensive international research efforts. The objectives of this study were to summarise the environmental factors associated with artificial reef construction and examine design, location deployment and ecological considerations from a Queensland perspective. Artificial reefs are most successful in providing additional productivity to a region when located distant from surrounding reef structures. Productivity increases can arise through additional recruitment, or the development of an encrusting benthic community. Monitoring of experimental artificial reef units identified that structurally complex reef modules, and those providing shaded shelter, held the highest abundance and species richness; this is in agreement with international research results. Queensland artificial reefs should be located distant from existing natural reefs and consist of structurally complex modular reefs made from non-polluting compounds. Artificial reef proposals should recognise potential interaction with existing fisheries and attempt to minimise any associated conflict. This reflects the artificial reef policies of other developed countries with active artificial reef deployment programs.

Queensland Fisheries Service – Long Term Monitoring Program

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Queensland Fisheries Service is responsible for managing the use of Queensland's fisheries resources and protecting the habitats in which these species live. Following a series of statewide stock assessment workshops in 1999, a Long Term Monitoring Program was established to undertake annual data collection on a series of priority fisheries resources in Queensland waters. The Long Term Monitoring Program consists of two teams, based in Cairns and Deception Bay, and is responsible for conducting the monitoring programs.

The Program commenced in July 1999, with fishery-independent techniques used to survey mud crabs, reef fish, barramundi, freshwater fish, scallops and spanner crabs, and a combination of fishery-dependent and fishery-independent techniques used to survey barramundi, mackerel, stout whiting, mullet and tailor. The data being collected provides information on relative abundance and population size, sex and age structure, providing the framework for the formal stock assessment of each of these resources. Habitat data is also collected in the freshwater fish, mud crabs, barramundi and reef fish surveys, where habitat change is known to have impacts on the dynamics of these resources.

Key objectives of the program are to:

- monitor priority fisheries resources on an annual basis to provide data for detailed assessment of the status of fish stocks;
- provide data for reporting on the state and sustainability of key fished stocks in Queensland waters; and
- complement and build upon resource information coming from commercial fisheries log books and surveys of indigenous and recreational fishing to provide an assessment of the status of the resource and its use.

BRD implementation in Western Australian trawl fisheries

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The implementation of bycatch reduction devices for trawl fisheries has been occurring in Australia over the last ten years. In Western Australia, the Shark Bay and Exmouth Gulf prawn fisheries are tackling the issue first. Long-term quality data sets of commercial catch and effort exist for both Shark Bay and Exmouth Gulf prawn fisheries.
The evaluation of changes in fishing power as a result of the introduction of bycatch reduction gear is required to maintain these important data sets used in stock assessment. Experimental trials and an observer program on commercial vessels towing grid(s) on one side and standard (no grid) net(s) on the other is providing this information. Each of these fisheries has specific characteristics that require the modification of currently available technology.
A collaborative approach and an innovative fishing industry has provided solutions to unique problems. The Shark Bay prawn fishery occurs in an area with naturally high quantities of drift seagrass, mainly *Amphibolis antarctica.* Due to the presence of high volumes of seagrass, traditional grids and associated settings proved at times to be unusable and resulted in substantial loss of product in some areas of the fishery. Modifications to improve grid performance in weed for minimizing the take of large animals, particularly turtles, and reduction of overall bycatch volume are described.
In Exmouth Gulf, a bottom-opening grid was adopted due to presence of rocks and sponges in areas and preliminary trials during the 2001 season are showing positive results.

Distribution, population structure and habitat preferences of the endangered Oxleyan pygmy perch (Nannoperca oxleyana) near Evans Head, north-eastern New South Wales

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Honours research into the distribution, population structure and habitat preferences of the endangered Oxleyan pygmy perch *Nannoperca oxleyana* near Evans Head, north-eastern New South Wales, was conducted in the year 2000. Sampling involved the use of unbaited traps and a pocket seine net. Quantified aquatic habitat features included depth (m), water velocity (m. sec^{-1}), per cent coverage and type of substrate, per cent cover of overhanging vegetation, aquatic vegetation and leaf litter, extent of steep/undercut banks and density of snags. *N. oxleyana* was recorded from 13 creeks and 12 lakes, with the species being the second most widely distributed and third most abundant species sampled. Individuals in the sampled population ranged in size from 15 to 55 mm in total length with the majority of fish being recorded in the 17 to 37 mm size class. *N. oxleyana* preferred tannin-stained, acidic (pH 3.32 – 5.10) freshwaters (90 – 320µS. cm^{-1}) where it frequented low flow environments (< 0.298m. sec^{-1}) in moderate water depths (<1.3m). Multilevel Poisson regression analysis revealed that higher abundances of *N. oxleyana* were caught near steep/undercut banks rather than amongst aquatic vegetation and also within these two microhabitats rather than in open water ($P<0.05$). Catches of the species also increased as habitats became shallower, substrates were composed of more sand, and contained more leaf litter, snags, steep/undercut banks and aquatic vegetation ($P<0.05$). This study has provided important baseline data, which is currently assisting NSW Fisheries to develop a recovery plan for the species.

Carp (Cyprinus carpio L) in Australian waterways: a perfect invader at the right time

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Carp are now the most abundant large freshwater fish in south-eastern Australia, particularly in the Murray-Darling Basin. Why have they been such successful invaders? What have been their ecological impacts? What are the prospects for further range expansion and additional impacts? What is the future for their control?

A comprehensive, retrospective analysis of the species was used to address these questions. This included a comparison of the ecological and physiological attributes of carp with native fish species, including trophic levels, diets, fecundities, spawning times, growth rates, habitat requirements, dispersal mechanisms, environmental tolerances and behaviour, which has illustrated their distinction from most of our native fish species. An analysis of trends in the populations of native species, particularly predatory species, shows an absence of predatory pressure over much of their distribution. Similar analysis of trends in environmental variables shows that trends and changes in ecological condition have been to the advantage of carp and disadvantage of those native species which may have exhibited predatory control. Such trends have been of great assistance to carp's successful invasion. The distribution, ecological attributes and known impacts of carp are reviewed to provide the background for a quantitative risk assessment which predicts the potential future for range expansion of this species, and their ability to inflict additional environmental damage. Donor regions, dispersal mechanisms and pathways and the invasion history of carp are all explored.
Gaps in our understanding are identified and predictions for further ecological impacts of carp in Australia are made. Future management options are discussed in light of this assessment.

Acid avoidance behaviour in juvenile snapper (Pagrus auratus)

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Chronic acid drainage in acid sulphate soil catchments may affect recruitment of migratory and catadromous fish and invertebrates. For example, the population collapse of Australian bass in the Hastings and Manning rivers was due to recruitment failure, which has been attributed partially to acid drainage. If chronic acid drainage in a system does result in avoidance behaviour of new recruits, this may result in partial or complete recruitment failure in this particular system. The aim of the present study is to investigate the possible existence of such acid avoidance behaviour in recruits of various commercial and recreational species. Juveniles are given a simultaneous choice between two water qualities in a laboratory raceway, and their positions in the test area are recorded by digital video camera. Here, we present the results of preference behaviour of juvenile snapper, *Pagrus auratus*. The test fish completely avoided water that was approximately one unit lower than the pH of the water in which they had been reared. The results are discussed in relation to water quality and recruitment in acid sulphate soil catchments.

Assessing the recreational rock lobster fishery in Tasmania: issues and future options

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Rock lobsters comprise the basis of a major commercial and recreational fishery in Tasmania. Commercially, the species is targeted using pots whereas recreational fishers are permitted to use rings and dive collection methods as well as pots. Surveys of the 1996/97 and 1997/98 rock lobster seasons estimated that the recreational harvest represented about 5% of the total rock lobster catch, although in some areas the recreational harvest was comparable to that of the commercial sector. Since those assessments, the commercial sector has come under quota management with a total allowable commercial catch of 1,500 tonnes introduced. In real terms, this was a reduction in catch compared to the 1,800 tonnes harvested in 1997/98. Conversely, the total number of recreational fishers issued rock lobster licenses has risen from 8,550 (1995/96) to 13,250 (current), an increase of 55%. This significant growth, set against restrictions on the commercial catch, suggests that the recreational share of the total catch has increased in both absolute and relative terms. A 2000/01 survey aims to assess the total recreational harvest and to provide reliable estimates of catch and effort by fishing method, season and region. With the relative size of the recreational harvest identified as a management performance indicator for the fishery and an important parameter in rock lobster stock assessment, these estimates will directly input into these processes. A further objective of the 2000/01 project is to evaluate the cost effectiveness of such surveys as an ongoing means of assessing the fishery, based on the trade-off between sample size (cost) and precision. Other issues include the appropriateness and cost benefits of alternative assessment methodologies.

Review of the Timor Reef Fishery (Northern Territory) 1990–2000

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This paper describes the development of the Timor Reef Fishery, including recent major changes. The NT Department of Primary Industry and Fisheries has been monitoring this fishery since its inception in 1987. The target species of this fishery are goldband snapper (*Pristipomoides multidens)*, saddletail snapper (*Lutjanus malabaricus*), red emperor (*Lutjanus sebae*), and red snapper (*Lutjanus erythropterus*). During the ten year period 1990–2000, the Timor Reef Fishery has changed from a developing to a multi-million-dollar fishery, with 8 boats actively operating and 7 inactive licences. While earlier vessels in this fishery were usually fairly basic, both in terms of electronic and fishing gear, present-day vessels are extremely sophisticated and efficient. Since 1999 there has been a change from droplines to traps, which has enabled operators to fish longer hours and with greater efficiency. Catches have increased substantially since the introduction of traps and there has been a move to exploit new grounds. Since 1996 Indonesian fishing vessels (iceboats) have been targeting snappers along the Sahual Banks adjacent to the Timor Reef Fishery. The number of iceboats has increase from 233 in 1996 to 431 by 1999 (Coastwatch data). Recent test drilling in the Fishery by petroleum companies has revealed commercial quantities of LPG and methanol exist in this area. Concern has been expressed by the fishing industry to the effects that this will have on fishing in this area. The development of the Fishery over the last 10 years and the issues affecting it will be discussed in this presentation.

The National Recreational Fishing Survey – an innovative methodology

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In early 2000, the States and Territories, in conjunction with the Commonwealth, embarked on an ambitious collaborative project to provide the first reliable and comprehensive assessment of the recreational fishery in Australia. Objectives of this project were to describe the characteristics of recreational fishers (participation rates, socio-demographics); evaluate effort and catch by species, method and region; and assess the economic impacts of recreational fishing.

To achieve these objectives, an innovative approach was required to address the range of logistic and financial constraints on such an undertaking whilst maintaining the focus on optimal data quality. The result was a multi-faceted design, the central component being an integrated telephone and angler diary survey. Based on general population sampling, an initial telephone interview was employed to collect household profiling information and identify intending fishers. This was followed by a twelve-month diary survey in which intending fishers were invited to participate. Respondents were contacted regularly by telephone throughout the diary period and details of fishing or expenditure activity since the last contact recorded. By placing responsibility for data collection primarily with survey interviewers, problems that typically arise with self-administered diary systems (low response rates and variable data quality) were minimised. In addition, a rigorous approach to other design aspects was adopted, involving a range of quality control and validation measures to address various response biases and other sources of non-sample error.

The outcomes of the national survey, along with those from previous state-wide studies employing this method, clearly demonstrate its efficacy and indicate a wider applicability and policy relevance to recreational fisheries elsewhere.

Socially induced sex-change in a small serranid

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The cues controlling sex-change have been elucidated for several species of hermaphroditic fishes that inhabit coral reefs, but not as yet for the epinepheline serranids. Serranids are important food fishes and information about the mechanisms of sex-change is essential for understanding the impact of fishing on exploited species. Whilst the lifestyle and habitat of many serranid species precludes the intensive field work needed to learn more about what causes them to change sex, the abundance and accessibility of chinaman cod (*Epinephelus rivulatus*) at Ningaloo Reef, Western Australia, makes this species amenable to such studies. A male removal experiment conducted on an assemblage of *E. rivulatus* demonstrated that protogynous sex-change in this species is socially controlled, apparently by the suppressive dominance of the males and more dominant females. Given the opportunity, a reproductively ripe female can change sex and become a male with ripening testis within three weeks, although interactions with males may delay this process. Sex-change begins with an influx of somatic tissue into the gonad and resorption of the oocytes. As the female tissue is resorbed, spermatic tissue proliferates, with putative Leydig cells appearing in large numbers later in the transition process. The experiment indicates that populations of *E. rivulatus* maintain a constant sex ratio under conditions of low fishing mortality. However, this species may be less resilient to higher levels of fishing pressure.

The Western Australian spanish mackerel (troll) fishery

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The narrow-barred Spanish mackerel is an important resource to Western Australia. Preliminary biological information shows that peak spawning occurs between September and January in northern waters, with little or no spawning occurring south of Exmouth Gulf. When spawning is completed most mackerel disappear from coastal waters for 5-6 months. Estimated size at 50% sexual maturity in males and females was 706 and 898 mm TL, respectively. The oldest fish collected was a 22-year-old male. Females reach larger sizes than males but are less common in older age classes. Considered a premium sport and food fish, Spanish mackerel are targeted from Geographe Bay to the NT border by recreational and commercial fishers using trolled lures and baits. Most of the commercial catch is obtained between May and October, with 305 tonnes taken in 2000. Recreational catches equal commercial catches in the Gascoyne and West Coast regions (data for other regions unavailable). Little information is available on the status of mackerel stocks in WA. However, scientific and industry concern has led to recent research and review of an interim management plan aimed at restricting access to the commercial fishery. The recreational fishery will also be reviewed as part of the proposed integrated management of WA fisheries. Spanish mackerel comprise approximately 80% of the WA troll fishery. Management of this fishery suffers from a lack of credible effort data and may require novel approaches to stock assessments. There is potential for further development of the troll fishery through increased exploitation of grey mackerel.

Recreational catch and fishing effort for pink snapper in Shark Bay, Western Australia

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Pink snapper (*Pagrus auratus*) is the prime species caught by recreational fishers in Shark Bay. However, intense recreational fishing pressure on spawning aggregations has caused a dramatic decline in adult fish numbers in recent years. Several management measures have been introduced to protect pink snapper stocks. Two 12-month creel surveys of recreational boat-based fishing in Shark Bay have now been completed.

The first survey conducted between April 1998 and March 1999 estimated the total annual boat-based recreational fishing effort in Shark Bay as 50,000 fisher days. The total pink snapper catch in the western gulf of Shark Bay during this period was estimated to be 38 tonnes, 26 tonnes from Freycinet Estuary near Nanga and 12 tonnes from Denham Sound near Denham. The eastern gulf has been closed to the take of pink snapper since June 1998.

The second 12-month creel survey of recreational boat-based fishing in Shark Bay was conducted between May 2000 and April 2001. The total annual boat-based recreational fishing effort for Shark Bay had dropped to 35,000 fisher days. The total pink snapper catch from the western gulf had also dropped to 25 tonnes, 16 tonnes from Freycinet Estuary and 9 tonnes from Denham Sound. Pink snapper, however, still made up 50% of the 50 tonne total recreational boat-based catch of all finfish species in Shark Bay in 2000-01.

The catch reductions are largely due to the introduction of management measures designed to protect pink snapper stocks. For the western gulf, a minimum size limit of 450 mm, bag limit of four and a limit of two fish over 700 mm per person was introduced in 1998. Due to ongoing concerns for pink snapper stocks in the western gulf, revised regulations were introduced from 25 August 2000. These included a minimum size limit of 500 mm, bag limit of two and a limit of one fish over 700 mm per person. A closure in Freycinet Estuary (south of Goulet Bluff) between 15 August 2000 and 30 September 2000, during the spawning period, was particularly effective in reducing the catch of this stock.

Rock lobsters, reserves and redundancy

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Marine reserves around the world are important to numerous exploited species because they can assist recovery of overexploited stocks and maintain harvest stability. Along the South African Cape Peninsula, rock lobsters are protected within three dedicated sanctuary areas and several smaller marine reserves.

Over a two year period ending March 2000, an intensive survey involving the use of commercial rock-lobster traps, ringnets and SCUBA divers estimated rock-lobster abundance, size-frequency distributions, sex ratios, catch and egg production from both protected and fished areas.

No rock lobsters were caught or observed during dives in either the St Helena Bay sanctuary or adjacent area. For the other three areas surveyed, data show that rock lobsters were not more abundant in the protected areas compared to fished areas, although protected areas did contain generally larger individuals.

Individual female rock lobsters collected from protected and fished areas produced similar numbers of eggs. We estimated that protected areas produce 7% of the total annual rock lobster egg production. This is approximately equal to the proportion of coastline over which rock lobsters are protected (6.6%).

The reserves do not seem to be fulfilling the roles for which they were designed and the St Helena Bay sanctuary ranks as a classic example of a misplaced sanctuary. The others were likely to have been selected on inadequate information and contain large areas unsuitable as rock-lobster habitat. Consequently there is a real danger that they misrepresent any conservation image they may hope to project.

Systematics and ecology of polychaetes that bore in abalone shells in Victoria

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Very little is understood regarding species distribution of polychaete borers and whether they have an effect on their host. In Victoria there are several stunted populations of *Haliotis rubra* with high levels of boring in their shells. This study investigated the infestation by polychaetes of abalone shells and their effect on the health and growth of the abalone. Twenty-two polychaete species were identified including 10 that may be introduced or exotic species. The frequency of borers increased with the size of *H. rubra* shells. Borers showed a preference for particular sections of the shell. *Polydora woodwicki* and *Dipolydora armata* colonised *H. rubra* and *H. laevigata* shells in the laboratory over a short period of time. *Haliotis rubra* shells over 60 mm were found to be more susceptible to these polydorids probably because the rugosity of their shell provides more shelter for settling larvae. Larvae from both species were observed to colonise specific places on the shell, and these patterns of infection were different between the two abalone species. A technique was devised to observe burrow morphology and growth using x-ray photographs, and demonstrated the burrow shapes of *Boccardiella* MoV 3840, *Polydora woodwicki* and *Dipolydora armata* for the first time in abalone shell. *Boccardiella* MoV 3840 were found to cause the host abalone to form mud blisters. The rate of burrow formation was determined using sequential x-rays. High levels of boring correlated with shell thickness, reduced condition of host abalone, using several indices, and reduced growth of abalone within Port Phillip Bay.

Towards ecologically sustainable development of Australian fisheries

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The *National Strategy on Ecologically Sustainable Development* (1992) was agreed by all Australian governments. All Australian fisheries agencies remain committed to implementing ESD.

The Standing Committee on Fisheries and Aquaculture (SCFA) of the Ministerial Council on Fisheries, Forestry and Aquaculture (MCFFA) is developing a national framework for policy and reporting on ESD. When fully implemented, this would have a number of applications, including meeting fisheries and environmental legislative requirements, fisheries status reporting, State of the Environment reporting and domestic/international market access. The framework includes a risk assessment process to consider the range of potential consequences of an issue such as ecosystem impacts arising from a fishery and assign a risk ranking to the issue.

The *Environment Protection and Biodiversity Conservation Act 1999* provides an environmental assessment process for Australian fisheries, consistent with the precautionary approach and ESD principles. The first Commonwealth fisheries to be formally assessed will be the Heard and McDonald Islands Fishery and the Bass Strait Central Zone Scallop Fishery.

Fish fauna in solar salt fields: the impact of salinity on the diversity of fishes

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Solar salt fields are large producers of industrial salt. Typically, estuarine or oceanic water is pumped into a series of large, shallow ponds (covering hundreds or thousands of hectares with an average depth of less than 1 metre). As part of the pumping process, small and juvenile fishes are moved from adjacent creeks into the first concentrator ponds, where they become trapped in the system. Water within these ponds is moved into ponds of greater and greater salinity via water pumped into the first ponds and the effects of evaporation. However, rainfall can rapidly reduce the salinity in ponds.

As part of a major faunal study, we surveyed five concentrator ponds in Port Hedland over a period of 12 months. During this period, salinity varied between 40 and 114‰. Forty-two species of fishes were recorded from the ponds, with fewer species in the ponds of higher salinity. Although typical salt-tolerant species were recorded from ponds of high salinity (e.g. *Chanos chanos*, *Elops hawaiiensis*), the presence of other species, such as *Amniataba caudovittatus*, was not expected, based on their distribution in temperate areas. Further, evidence of successful reproduction by some of these species was collected. The results are discussed not only in relation to fish biology, but also with regard to the nutrient balance within the salt fields and the potential for harvesting selected species.

The role of physical disturbance in determining fish assemblage structure and post-settlement planktonic dispersal

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Post-settlement losses have recently been attributed to predation, food limitation and habitat complexity, but the effects of physical disturbance after settlement are poorly understood. Our experiment investigated:

- 1) how assemblage structure of fish, and specifically numbers of King George whiting, vary under different disturbance regimes; and
- 2) if physical disturbance caused by onshore, wind-induced wave action, can resuspend and transport King George whiting following settlement.

Species richness was unaffected, but species abundance decreased during onshore winds and high wave heights (high physical disturbance). Under the same physical conditions, species richness and abundance increased in plankton samples 200 m offshore. Higher numbers of post-larval King George whiting were sampled in seagrass beds during offshore wind conditions; lowest numbers were sampled during onshore winds. The opposite was true for post-larval whiting in the plankton immediately offshore from seagrass beds. Wind and wave disturbance events in seagrass beds have a high potential to cause post-settlement dispersal. This post-settlement dispersal has implications for the eventual spatial distribution of juveniles.

Quantification and survival of bycatch in Victorian haul seine fisheries

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A two-year study, funded by FRDC and Fisheries Victoria, was undertaken to quantify bycatch levels in Victoria's haul seine fisheries and determine the survival rate among discarded fish. On-board observations of commercial fishing operations in Port Phillip Bay (PPB) and Corner Inlet (CI) revealed that about one third of the total catch was retained by fishers. In PPB the discards were predominantly non-commercial species by both weight and numbers; in CI the discards included equal numbers of non-commercial species and under-sized commercial species, but the non-commercial species predominated by weight. Sea-cage survival experiments undertaken on the discarded species found that overall survival was 89% over 18 species from PPB and 97% over 5 species in CI. Southern sea garfish was the only species with low survival rates. Overall, the ratio of retained fish to dead discards was in excess of 4.5:1. Mortality of under-sized King George whiting meshed in nets had been a concern in PPB. However, experiments conducted with polyethylene mesh in one wing of a commercial net recorded a more than 25-fold reduction in the number of meshed fish, compared with the normal nylon mesh. This netting material has now been widely adopted among commercial fishers. These results demonstrate that when correctly used, haul seines are quite selective for marketable fish, and cause relatively low levels of mortality among discards.

Biological monitoring of the decommissioned HMAS Swan Artificial Reef, Dunsborough, Western Australia

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The Geographe Bay Artificial Reef Society Inc. sank the decommissioned HMAS *Swan* 2.4 km off Point Piquet, Dunsborough, Western Australia in 30 m of water as a dive wreck, artificial reef and tourist attraction on December 14th 1997.

Environment Australia requested rigorous surveys of the colonisation of the vessel by fishes and encrusting marine life. Biological monitoring of the fish community that became established on the *Swan* wreck over a three year period has shown an increase in average richness from 2 to 34 species and an increase in average abundance from 10 to nearly 1,300 individuals when compared with a nearby reference site. The fish community on the vessel has rapidly shifted from omnivorous weed/sand fishes to one dominated by planktivorous and carnivorous reef fishes. The species richness and abundance on the *Swan* wreck is beginning to approximate that of other natural reefs in the region; however, the species composition on the vessel is still distinctly different.

Monitoring of encrusting marine life over the same period has shown that the first biota to colonise the vessel were hydroids, that after four months had covered approximately 70–90% of the area surveyed. Substantial algal growth was present during the summers of 1998, 1999 and 2000 and dominated the encrusting marine life on the starboard and upper surfaces. Other faunal groups such as sponges, ascidians, anemones and soft corals are showing marked signs of proliferation on the shaded portions of the vessel; however, the areas receiving full sunlight are less well colonised.

Maturity of Photololigo etheridgei and its application to the management of squid fisheries in NSW

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Squid are ecologically and commercially important animals. In New South Wales, trawl fisheries that operate in the Hawkesbury River produce half the landed squid in the State. Fishing effort and catch in the Hawkesbury River have increased in the last ten years. Despite this, there are few controls on squid fisheries in NSW and few data to make managerial decisions. This study will concentrate on the biology and ecology of the squid *Photololigo etheridgei* Berry, 1918 in the Hawkesbury River.

To make managerial decisions, there must be sufficient knowledge of size and structure of populations, age and size-at-maturity, life-span, fecundity, spawning and causes and rates of migration and mortality. This information will allow assessment of potential fishing grounds and seasons and minimal size limits. This talk will concentrate on the reproduction of these squid.

A common goal of fisheries management is to ensure that individuals have the opportunity to spawn at least once. It is important to know, therefore, at what size and age squid spawn, how many times they spawn and where and when they spawn.

Maturity stages of each squid were assigned and age will be inferred by counting the daily increments that are present on squid statoliths. Seasonal patterns will be investigated using comparisons of squid that:

- 1) were caught in the same season; and
- 2) hatched in the same season.

This research will provide valuable information for the management of the squid fishery in the Hawkesbury River and also for other loliginid fisheries world-wide.

Characteristics of the fish fauna of nearshore unvegetated habitats in Shark Bay, Western Australia

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The fish fauna over bare sand in two widely spaced regions in both the western and eastern gulfs of Shark Bay were sampled at bimonthly intervals for a year using a fine mesh seine net (3 mm) during both the day and the night. Although a total of 61 species representing 32 families was recorded, the fish fauna was dominated numerically by members of the Clupeidae (62.1%) and Atherinidae (25.9%).

The species diversity and density of fish was greatest in the eastern gulf. This was particularly evident during summer and early autumn when the new juvenile recruits of a number of species made a significant contribution to the fish fauna in this gulf. The number of fish species and the biomass of fish and, to a lesser extent the density of fish, were greater during the night than during the day.

Community composition based on density data was significantly different between regions and particularly between the two gulfs. Although no diel difference in community structure was observed, the regional difference became more pronounced at night, illustrating the fact that the composition of the fish fauna was more homogenous during the night than during the day.

When biomass data were subjected to ordination both regional and diel differences in the community composition were identified. This was attributable to the fact that the larger representatives of certain species, usually represented by a few individuals, tended to move inshore at night and thereby make a more substantial contribution to the community at that time.

Fish faunas of a temperate estuary and nearby embayment in Bunbury

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Fish faunas of nearshore shallow waters in the Leschenault Inlet are dominated by the small gobiid *Favonigobius lateralis*, the clupeid *Hyperlophus vittatus* and the atherinids *Leptatherina presbyteroides* and *Atherinosoma elongata.* Of the 42 species caught in this estuary, 20 were marine species that use Leschenault Inlet as a nursery area, while 13 complete their life cycle in the estuary. However, nearly 70% of fish caught represent species that complete their life cycles in this estuary. The success of these species is probably related to the maintenance of high salinities during the late spring and summer when these species typically spawn. Fish faunas in the estuary differ markedly from those in the nearby embayment (Koombana Bay), with the most abundant species in that bay, the leptoscopid *Lesueurina platycephala*, never being recorded in the estuary. The catches in offshore deeper waters of the basin of Leschenault Inlet were dominated by marine species that use the estuary opportunistically and by the semi-anadromous clupeid *Nematalosa vlaminghi*. The composition of the deeper-water faunas in the basin differed markedly from those in its tributary (Collie River), reflecting the greater number of species in the former region of the estuary, including the mugilid *Aldrichetta forsteri*, the pomatomid *Pomatomus saltatrix* and the arripidid *Arripis georgiana*, and the greater numbers of *N. vlaminghi* and the mugilid *Mugil cephalus* in the river. Each species in the estuary was allocated to one of the following feeding modes, namely (1) herbivore, (2) detritivore, (3) omnivore, (4) lower-order carnivore or (5) higher-order carnivore.

The conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes

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During 1999-2000, the Biodiversity Group of Environment Australia commissioned the authors to prepare a conservation overview and action plan for Australia's threatened and potentially threatened marine and estuarine fishes. To assist with this project, a specialist workshop was held in conjunction with the Annual Conference of the Australian Society for Fish Biology in September 1999, at which some 40 expert ichthyologists from Australia and elsewhere discussed and commented on draft species conservation synopses prepared for over 100 such species. The final Overview and Action Plan considered 114 species in some detail, out of the roughly 4,200 marine and estuarine fish species present in Australian waters. Of these, no taxa were listed as Extinct, 3 as Critically Endangered, 6 as Endangered, 8 as Vulnerable, 16 as Lower Risk (conservation dependent), 13 as Lower Risk (near threatened), 53 as Data Deficient, and 15 as Lower Risk (least concern). The main groups which consistently stood out as being at risk in this analysis were the sharks and rays (elasmobranchs), the larger groupers and rockcods (serranids), and the endemic handfishes (brachionichthyids). The seahorses and pipefishes (syngnathids) and larger wrasses (labrids) were also listed as groups with significant conservation concerns, as were several commercially important food fish species such as the gemfish (a gempylid), southern bluefin tuna (a scombrid) and orange roughy (a trachichthyid). The main threats to these fishes were found to include fishing mortality (including by-catch), habitat degradation, introduced marine invertebrate pests, the traditional medicine trade, the aquarium fish trade, the live food fish trade, targeted overfishing, and/or in some cases poor fisheries management.

Development of the Port Jackson shark embryo

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The Port Jackson shark (*Heterodontus portusjacksoni*) is an oviparous shark that breeds once annually, during spring. Each egg contains one embryo and is encased in a thick (1-2 mm) protective capsule. The egg capsule has two respiratory slits, one located at each end of the capsule, however during the first four months of incubation, the respiratory slits are plugged with a thick wedge of albumen, sealing the embryo from the external environment. During this time, the embryo undergoes substantial changes in its morphology in preparation for survival in potentially difficult conditions. The most substantial changes involve the production of external gill filaments and vascularisation of the yolk sac which serve to increase the surface area available for gaseous exchange. After four months, the plugs dissolve and the embryo is in direct association with the external seawater environment. The embryo actively ventilates the open egg capsule with vigorous scooping movements of the tail that draw water into and out of the egg capsule through the respiratory slits, ensuring a continual supply of oxygen, thus stimulating growth. The embryo grows exponentially until reaching a short plateau phase near hatching. Embryos hatch at 180 mm long and 55 g. This relates to between 77-85 % of the initial dry mass of yolk being transferred into hatchling mass at 18-22°C. Water temperatures around South Australia vary between 12 and 22°C, resulting in long incubation periods of over 12 months. Incubation period in the laboratory was, however, strongly influenced by temperature, with embryos hatching after 400 days at 18°C and after 310 days at 22°C.

What can be done about the systemic overfishing in the South East Trawl Fishery?

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The South East Trawl Fishery is one of Australia's oldest ocean fisheries, having commenced in continental shelf waters off New South Wales around 1920. The fishery supplies the bulk of fresh fish consigned to the major regional markets in Sydney and Melbourne, and supports a small processing sector. Following expansion of the fishery to include upper continental slope grounds in the 1970s, and the more recent introduction of modern navigation and fish-finding technology, the impact of the fishery on the target and non-target resources significantly increased. In 1992, management controls in the form of individual species Total Allowable Catches were introduced, and much research has been undertaken to support the setting of the annual TACs. This paper presents catch and size composition summaries for six of the important species trawled in the eastern sector of the fishery – tiger flathead, redfish, silver trevally, ocean perch, ling and mirror dory. Data covering the period from the 1970s to the present suggest that many of these resources are now 'growth overfished', due mainly to the inappropriate selectivity of the trawl gear being used in the fishery. Species which have been quantitatively assessed show very significant stock depletions. However for most species no quantitative assessment is available. Management initiatives are suggested to satisfy the requirements of the *Environment Protection and Biodiversity Conservation Act 1999*, including the use of more appropriate gear, the implementation of significant closed areas and a reduction in the level of fishing effort in the fishery.

Listing of threatened fish in NSW – a review of the first three years

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Threatened species provisions were added to the NSW Fisheries Management Act in 1997. These included provisions for listing of endangered species, populations and ecological communities, vulnerable species and key threatening processes.

A Fisheries Scientific Committee (FSC) was established in 1998 to make recommendations on these listings, and to provide independent advice on a number of other matters relating to threatened species management. After three years of operation the FSC has made a number of recommendations that have resulted in substantial addition and amendment to the list of threatened fishes in NSW.

The listing history is reviewed, with a discussion on the relevant strengths and weaknesses of the process in NSW in comparison with other jurisdictions. Significant decisions are highlighted, including those relating to grey nurse and great white sharks, an extinct seaweed, several species of finfish found in the Murray Darling Basin, three aquatic invertebrates, and the aquatic community in the lower Murray River catchment.

Possible future developments in the threatened species listing process in NSW are also discussed.

The humble mullet

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Commercial landings of sea mullet are among the largest and most valuable of any finfish species in NSW. The fishery is also historically significant, with some of the earliest fisheries records describing sea mullet landings.
Mullet are caught in estuaries throughout the year, and on ocean beaches during the winter pre-spawning run. Tagging has revealed that individuals can travel hundreds of kilometres northwards before spawning. The ocean fishery expanded significantly during the early 1990s and mainly targets females for the roe export market. Despite the economic and social significance of the fishery, stock assessment is rudimentary and relies on commercial catch level as an index of abundance. Annual NSW landings fell from approximately 5000 t to approximately 2000 t over the last 7 years. NSW Fisheries began to monitor the length and age structure of commercial landings in 1995. Declines in average age of fish coincided with declines in catch. The cause(s) of these declines are not clear, and there is some evidence for natural recruitment variability. However, targeting of pre-spawning fish at unprecedented rates of harvest may also have affected stock levels. Unfortunately, absence of a reliable index of abundance severely hinders quantitative stock assessment of this species. This paper presents an overview of the biology and fishery for sea mullet, discusses some the problems associated with stock assessment, and describes some new monitoring initiatives.

Release mortality of line-caught pink snapper – a study in depth

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Target species in hook and line fisheries are commonly protected using legal minimum lengths (LML). LMLs are based on reproductive maturity, when known, and are set at the size that allows smaller fish to spawn at least once before removal by fishing. Undersize fish, however, are caught by hook and line and thus the effectiveness of LML as a management tool depends on their survivorship after release. Release mortality of line-caught pink snapper was examined in and near Shark Bay, WA during June and July 2001. A total of 459 pink snapper were caught by line from four depths (15, 30, 45 and 65 m), then caged (3 to 5 fish per cage) and returned to the same depth of capture. Cages were retrieved 1, 2 and 3 days later. Catch information included hook type (standard J type and circle hooks), hooking point, ascent time and time on deck. Before caging, alternate fish were vented with a hypodermic needle to assess the impact of venting on mortality. Depth of capture was the major source of mortality in the caged snapper. Mortality after 3 days increased with depth, but not linearly. Mortality was drastically lower in the shallow sites (4% (n = 103) at 15 m and 7% (n = 71) at 30 m) than in the deeper sites (71% (n = 100) at 45 and 84% (n = 37) at 65 m). Also, gut hooking was mostly fatal, but rare. Venting fish, however, did not affect mortality in caged snapper.

An experimental approach to determination of effort levels in the Pilbara trawl and trap fisheries

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In 1993/94 a major project using an experimental approach was conducted to determine the fishing mortality of five key species in the Pilbara demersal trawl fishery. This experiment determined that at the 1995 level of effort two long-lived species, red emperor and Rankin cod, were over-exploited and three short-lived species (flagfish, blue-spot emperor, and rosy threadfin bream) were under-exploited.

To bring fishing mortality of red emperor and Rankin cod to sustainable levels and to maximise economic return, the trawl fishery was divided into six areas (Figure 1) and effort quota was allocated to each area of the trawl fishery in 1998 and to the entire trap fishery in 2000. A Vessel Monitoring System was used to determine the effort used by the fleet.

The fishing mortality of the over-exploited species, red emperor, was determined using effort levels from 1994 to 2000 using skippers' log book and VMS data. To determine the effectiveness of the management arrangements, the fishing mortality was compared to the biological reference point $F_{0.1}$.

Observations of sperm in the oviducal gland of the gummy shark (Mustelus antarcticus)

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To determine the structure and function of the paired oviducal glands of the gummy shark, *Mustelus antarcticus*, the glands of mature, maturing and immature animals were examined by light microscopy. The oviducal gland of *M. antarcticus* has been found to have the same fundamental zonation as found in several other chondrichthyans, with an anterior club zone, followed by a papillary zone, baffle zone and terminal zone. The microscopical organisation and histochemical nature of the zones display similar patterns to other species. The tubule epithelium of the club, papillary and baffle zones contain two types of cell: secretory cells and ciliated cells. The secretory cells of the club and papillary zones stain periodic acid-Schiff and alcian blue positive whereas those of the baffle zone stain periodic acid-Schiff and alcian blue negative. The tubules of the terminal zone contain four types of cell: ciliated cells, alcian blue positive secretory cells, periodic acid-Schiff and alcian blue negative secretory cells, and periodic acid-Schiff and alcian blue negative cuboidal cells. Sperm are observed in the terminal zone of the maturing and mature animals. Sperm are also observed in the tubules of the baffle zone of half of the maturing and mature animals and in the tubules of the papillary zone of the maturing animals. It is uncertain whether or not sperm is actually stored in these two zones. The terminal zone is considered to be the site of true sperm 'storage'.

Movement of male and female school shark in southern Australia

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School shark (*Galeorhinus galeus*) are found in southern Australia and have been tagged and released during three separate studies (6,507 during 1947–56, 631 during 1973–76 and 2,688 during 1990–99). The 1990s tags were released in three general regions (Bass Strait, Tasmania and South Australia (including the Great Australian Bight)); the earlier releases were mainly in Bass Strait and Tasmania. The recapture rate during the 1990s is 20% and includes 10 recaptured in New Zealand. In addition, 26 NZ tagged sharks were recaptured in Australia. Results are presented from a model designed for estimating proportions of the population moving between the regions. The model takes account of the different levels of fishing effort and the highly length-selective characteristics of the gill-nets of various mesh-sizes deployed throughout the fishery. Initial analysis confirmed widespread movement between the Great Australian Bight and Eastern Australia but model results highlight differing movement patterns of sub-adults and mature adults and of males and females. For adult males, 7% per annum move from Tasmania to South Australia, and 8% from South Australia to Tasmania, whereas 43% of females move from Tasmania to South Australia and 25% move from South Australia to Tasmania. These differences support hypotheses of females aggregating in the north and males aggregating in the south, which have implications for school shark population models.

Fisheries management strategies and environmental impact statements: a framework for sustainable fisheries management in NSW

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The principles of ecologically sustainable development are central to fisheries management in NSW. Early last year the NSW Land and Environment Court decided that the environmental impacts of an individual commercial fishing licence had to be assessed at the time of issue or renewal. The NSW Government responded by establishing a framework for the development of fishery management strategies and environmental assessments. Fisheries management strategies provide a detailed description of the fishery, and outline the management goals, objectives, controls, performance indicators and monitoring programs applying to a particular fishery for at least five years. The environmental impacts of fishing activities authorised under each proposed strategy are being assessed by NSW Fisheries in accordance with guidelines issued by the NSW Department of Urban Affairs and Planning, and taking into account Commonwealth assessment guidelines. This process includes an assessment of the potential impacts on target species, by-catch, threatened species, the biophysical, social and economic environment, and the impacts of non-fishing activities. Strategy development commences with input from fishery management advisory committees, and endorsement holders. Broader stakeholder input is then sought through sector-based Ministerial Advisory Councils and the cross-sector based Fisheries Resource Conservation and Assessment Council, prior to public consultation. Following a review of submissions, a final strategy is prepared for approval by the Minister for Fisheries. Management strategies and environmental impact statements for each major commercial fishing activity must be finalised by June 2003. Significantly, they will also be prepared for other major fishing activities including recreational fishing, charter fishing, fish stocking and the beach safety (shark meshing) program.

Fish faunas of unvegetated and vegetated habitats in Shark Bay, Western Australia

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Fish in seagrass and over bare sand in nearshore shallow and offshore deep waters of Shark Bay were sampled using an otter trawl net at bimonthly intervals for a year. Ninety-two species of fish were recorded during the study, with the catches being dominated numerically by *Monacanthus chinensis* (33.5%), *Apogon rueppellii* (18.6%) and *Pelates quadrilineatus* (12.1%). The densities and species diversity of fish were greater in seagrass than over bare sand, irrespective of water depth and species of seagrass, i.e. *Posidonia australis* or *Amphibolis antarctica*. These differences presumably reflect the greater structural complexity of seagrass habitats and their provision of more food and shelter from predators. The species compositions in seagrass in shallow water underwent progressive cyclical changes that were attributable to sequential movements of certain species into and out of the seagrass meadows. The characteristics of the fish faunas in shallow waters underwent diel changes over bare sand but not in seagrass, reflecting movements of certain species, and in particular *A.rueppellii,* from seagrass to over bare sand at night. The number of fish species and density of fish was higher in meadows of *Posidonia australis* than in adjacent beds of *Amphibolis antarctica.* The ichthyofaunal compositions also differed between the two seagrass species, with *Siganus fuscescens* and *Apogon rueppellii* being relatively more abundant in *P.australis* and *Paraplotosus albilabris* being relatively more numerous in *A.antarctica*.

Otolith marking of rainbow trout** (Oncorhynchus mykiss) **fry by immersion in low concentrations of alizarin complexone

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Rainbow trout (*Oncorhynchus mykiss*) support important recreational fisheries in New South Wales, Australia and over three million rainbow trout are produced annually by state hatcheries and released to supplement fish populations. No assessment of the success of these stockings has taken place. Experiments to evaluate the feasibility of chemically marking the otoliths of small rainbow trout fry *Oncorhynchus mykiss* (less than 30 mm total length) using alizarin complexone (ALC) were conducted at Gaden Trout Hatchery, Jindabyne, NSW. Fish were immersed in three concentrations of a solution of the chemical (10, 20 and 30 mg/L) for four time periods (6, 12, 18 and 24 h). The pH of the solutions was adjusted to almost 9 with sodium bicarbonate, which increased the solubility of the alizarin complexone. All fry treated at a concentration of 10 mg/L survived for all exposure times, however mortalities at 20 mg/L and 30 mg/L were unsustainably high. Marks were always detectable at all experimental concentrations under reflected light and/or ultraviolet light microscopy. A batch of 10,000 rainbow trout fry was also mass-marked to evaluate mark retention. Otoliths from these treated fish still had clear marks when harvested 157 d after treatment. The successful marking of rainbow trout with total survival using a concentration far lower than has been previously reported makes this treatment suitable and economical for the batch marking of large numbers of small fish.

The influence of the Dawesville Channel on the fish fauna of the shallows of the Peel-Harvey Estuary

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The Peel-Harvey Estuary, located in south-western Australia, has become very eutrophic since the early 1970s. This extreme eutrophication is reflected by a vast increase in macroalgae and massive seasonal blooms of blue-green algae. Increases in macroalgal growth, particularly in the Peel Inlet, have been accompanied by increases in fish abundance, whereas, in the Harvey Estuary, the spring blooms of the blue-green alga *Nodularia spumigena* have resulted in a movement of the more mobile fish species out of this area and to the death of a number of individuals of the more benthic and less mobile species. In an attempt to alleviate the eutrophication problem, the Dawesville Channel was constructed in 1994 between the Harvey Estuary and the ocean to help discharge nutrients to the sea and reduce algal growth. Intensive seine netting was undertaken in 1996 and 1997 at the same sites and using the same net as that used in previous studies of the fish fauna of the Peel-Harvey Estuary 15-20 years earlier. The results of the multivariate analyses used to determine patterns in species abundance and distribution of fish and the influence of region and season on fish both prior to and after the construction of the Dawesville Channel will be presented.

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