Towards the Sustainable Use of Northern Territory Fishery Resources: Review Workshops Led by Carl J. Walters

edited by

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Table of Contents

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96/158 Towards the Sustainable Use of Northern Territory Fishery Resources: Review Workshops Led by Carl J. Walters

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Objective

Provide more reliable and ongoing advice on the status of the major fish stocks.

Non-technical Summary

"The Northern Territory looked to me, as an outsider, as providing a real chance to study a fishery situation that had not proceeded to the point many have reached around the world, where negotiations between industry and government becomes impossible, where cooperative solutions to management become impossible, where the whole syndrome of bad scientists, bad management, and bad everything is combined. In situations where scientific mistakes have been made, the characteristics of those situations is that they are all fisheries that were developed and managed on the basis of what I call the British model.

In our review of NT fisheries, we went through and looked at a series of fisheries ranging from the goldband snapper out on the edge of the Timor Sea, adjacent to the Indonesian waters, to mud crabs in coastal areas. We also looked at some of the coastal reef fish stocks which occur in shallow areas (golden snapper and jewfish), red snappers farther offshore in deep water, and barramundi. The barramundi fishery is probably one of the biggest areas of potential conflict here in the NT.

The review was very much an open process - people brought ideas and information and feedback and criticism along the way - not just a couple of biologists in an office some place staring at their navels. That fascinates me. I do not think I could have gone to any place in the world and done something like we have done in the last few weeks here. I travel around Australia doing stock assessment work very often, and we are gradually starting to develop a process for involving commercial fishing interests and other interests in the whole business of getting better data to do better assessments, but not anywhere near as nice as what is happening here, in the Territory.

Let me just tell you very generally what we have found in those assessments.
- *There is opportunity for growth in a few of the fisheries, particularly the red snapper fishery in deeper offshore waters.*
- *Some of the fisheries like barramundi and mud crab along the coast are fully developed now. That means that fishermen are already exploiting the stocks at a level that would be biologically safe, and in most places where fish are available.*
- *And there is one sad story of a fishery that is very likely to be overfished in the near future, not by Australians, but by Indonesians. Goldband snapper move back and forth across the border of Indonesia, and are likely to face overfishing by developing fisheries in the Indonesian sector.*

Another one of our findings is that we were grossly unable to access the abundances and future growth opportunities for a number of fisheries. One of the key reasons is that the data that had been gathered by the Fisheries Division, so far on stocks, was just inadequate. To understand what is going on in fish on small reef systems scattered along the coast, you have got to have data on each reef. Basically, the reef fisheries reporting system here is not adequate to provide that kind of information. Now this is not a criticism of the NT government or fishing industry. This problem is a global one. The statistics being recorded for use by scientists in fisheries worldwide have been grossly inadequate, and we have paid the price hideously in places like eastern Canada." Carl Walters, Darwin, October 1996

Keywords
fishery stock assessment, management, proven production principle, geo-referencing, Darwin

Background

In 1974, the then Forestry, Fisheries and Land Conservation Branch, Commonwealth Department of the Northern Territory, engaged Prof. Parcival Copes to assess the state of the Northern Territory fisheries and recommend directions for the future development and management. His recommendations shaped the directions of the fishing industry over the next two decades (Copes, P. 1975. Development prospects for the fishing industry in the Northern Territory. Report prepared for the Department of the Northern Territory). In 1976, the then Director of the Fisheries Section, Ian Kirkegaard, reported on the state of the Northern Territory fisheries, providing further direction in fisheries (Kirkegaard, I.R. 1974. A review of the Northern Territory Fishing Industry. 177 pp). When the Northern Territory attained self government in 1978, future directions were again reviewed and Cabinet provided increased human and financial resources for the newly created Fisheries Division to implement these directions. In 1987, a barramundi stock assessment and management workshop was conducted by Dr Bill Fox, with funding from Industry. Dr Fox mediated between the Industry and Division, and reviewed research and management, convincingly demonstrating that the fishery was in danger of over fishing; the management plan for that fishery was amended. Since that time there have been further reviews of individual fisheries, a number of reviews of the Division and its functions and directions, and a stock assessment workshop series partly funded by FRDC (Buckworth, R.C. 1993. Workshop on Stock Assessment of Australia's Tropical Fisheries. Project 91/96. *Final Report to the Fisheries Research & Development Corporation*).

In 1993, FRDC offered the states and the Northern Territory top-up funding of $30000 per year over 3 years to employ a stock assessment expert to assist in providing the latest stock assessment expertise to assist in refining stock assessments and fisheries management strategies. The Northern Territory Fisheries Division developed and secured a proposal ‘Towards the Sustainable Use of Northern Territory Fishery Resources‘ which combined this funding with additional FRDC funds (project T94/33). However, attempts to attract a stock assessment expert either from Australia or overseas failed, and the scope of the project was reviewed in December 1995. Following advice from FRDC and the Northern Territory Fisheries Research and Development Advisory Committee, it was decided not to continue with recruitment for a stock assessment expert, but rather, seek funding for short-term consultancies which addressed immediate issues in research and management within the Northern Territory. The first of these consultancies is reported here.

Need

Except for prawn fishing and pearl culture, the fisheries of the Northern Territory are generally small, in the world context, but all are important to the local economy. Many of the inshore fishery resources are important to the Aboriginal people, and some support large recreational fisheries There is good evidence that some fishery resources off the Northern Territory are under-exploited, even un-exploited, while others are shared with Indonesia and require complementary management measures. Although there have been significant advances in stock assessment methodology during the last decade, spectacular collapses of large fisheries in other parts of the world continue to occur, indicating that many of the methods being used may not have the reliability or precision to provide stock information that is adequate for the long-term sustainable management of fisheries. This unreliability has prompted leading fishery scientists, such as Dr Carl Walters of the University of British Columbia, Vancouver, to review the approaches to stock assessment and natural resource management, and seek new methodology (eg Walters, C., and Maguire, J-J. 1996. Lessons for stock assessment from the northern cod collapse. *Reviews in Fish Biology and Fisheries*, **6**, 125-137)

Objectives

To provide the Northern Territory with more reliable and ongoing advice on the status of the major fish stocks. Specifically,

- re-assess major fisheries in the Northern Territory (goldband snapper, red snapper, coastal reef fish, mud crab and barramundi);
- advise the Northern Territory Government on the biological status of these fisheries, any changes required in their management and any necessary changes to future research programs;
- provide comment on stock assessment and management strategies for other fisheries; and,
- provide Northern Territory fisheries scientists and managers training in recent stock analysis and resource management methodology.

Methods

Dr Carl Walters, Fisheries Centre, University of British Columbia, was invited to Darwin for a 4-week consultancy to review stock assessment and fisheries management strategies for:

- barramundi (*Lates*) in estuarine and fresh waters;
- goldband snapper (*Pristipomoides*) in the Timor Sea;
- mud crab (*Scylla*) in estuarine waters; and,
- red snapper (*Lutjanus*) and coastal reef fish.

The reviews were conducted by assessment teams led by Dr Walters. The teams consisted of Northern Territory scientists and managers, and some visiting scientists. Consultations with industry and other interested parties were used extensively throughout the reviews. Each team spent approximately one week per fishery, based on the following general format:

- Day 1 - "This is the fishery" meeting with industry, managers and scientists to describe the fishery, management objectives, current research and data available;
- Day 2-4 - “Modelling workshop” to review recent analyses and management strategies, and provide a learning platform; then,
- Day 5 - “Open meeting” with industry, managers, scientists and other interested people to report on the week's findings, and review the fishery, research direction and management options.

The reviews were conducted at the Fisheries Division Day Street Laboratory during September - October 1996 (Table 1). A final presentation of review findings was made during a public forum “Future Directions in Northern Territory Fisheries” held in Darwin on 18 October 1996; about 70 members of industry, public, government and university attended.

Table 1. Timetable for review workshops held in Darwin during September-October 1996. All session were held at the Day Street Laboratory unless indicated otherwise.

Date	Start Time	Session	
GOLDBAND SNAPPER PROGRAM			
19 Sept	0830	Fishery operation, data, research, management	
	1200	BBQ lunch	
	1400	Visit boats and further talks with industry (wharf)	
20 Sept	0830	Resource assessment workshop	
23 Sept	0830	In-house assessment and review	
24 Sept	1300	Findings of assessment and review (Harbour View Plaza)	
MUD CRAB PROGRAM			
25 Sept	0830	Fishery operation, data, research, management	
	1200	BBQ lunch	
	1400	Visit boats or field visit (to be announced)	
26 Sept	0830	Resource assessment workshop	
27 Sept	0830	In-house assessment and review	
28 Sept	0900	Findings of assessment and review (Harbour View Plaza)	
RED SNAPPER AND COASTAL SPECIES PROGRAM			
7 Oct	0830	Fishery operation, data, research, management	
	1200	BBQ lunch	
	1400	Visit boats and further talks with industry (wharf)	
8 Oct	0830	Resource assessment workshop	
9 Oct	0830	In-house assessment and review	
10 Oct	0830	In-house assessment and review	
11 Oct	1300	Findings of assessment and review (Harbour View Plaza)	
BARRAMUNDI PROGRAM			
14 Oct	0830	Fishery operation, data, research, management	
	1200	BBQ lunch	
	1400	Visit boats or further discussion with industry (to be announced)	
15 Oct	0830	Resource assessment workshop	
16 Oct	0830	In-house assessment and review	
17 Oct	1300	Findings of assessment and review (Harbour View Plaza)	
PUBLIC FISHERY FORUM - Museum Theatrette			
18 Oct	1630	Get-together	
	1700	Introduction	Darryl Grey
	1710	Background	Carl Walters
	1730	Goldband Snappers	Julie Lloyd
	1750	Coastal Reef Fish	Tracy Hay
	1810	Break	
	1830	Red Snappers	David Ramm
	1850	Spanish Mackerel	Rik Buckworth
	1910	Mud Crab	Rosemary Lea
	1930	Barramundi	Roland Griffin
	1950	Conclusion	Darryl Grey
	2000	BBQ at Ski Club	

Transcript of Opening Remarks
Public Forum on Future Directions in Northern Territory Fisheries

Carl Walters

Fisheries Centre, University of British Columbia, Vancouver

The Northern Territory is a very special place right now. It is one of the very few areas in the developing world, or developed world, where there is an opportunity to change some of the horrible mistakes we have been making, worldwide, in the renewable resource management and, in particular, fisheries. We are seeing worldwide collapses in major fisheries. You need only read the newspapers to hear things like 30000 people out of work in eastern Canada, 10000 people out of work on the eastern seaboard of the United States, or other statistics about collapses. What you do not hear about, but people here in the NT Fisheries Division are very well aware of, is that fishery collapses are not due to the obvious things like the greed of commercial fishermen. There is considerable evidence now to suggest that the biggest and most catastrophic disasters that are pertinent to world fisheries are directly attributed to bad scientific advice and bad scientific assessments.

Off the east coast of Canada, now, we have 30000 people out of work and a $2 billion relief program in place just to feed those people. We have been able to trace the routes of that disaster back to one single stock assessment mistake made in 1978 by a small team of scientists working in much the same way as your people here in the NT. We are seeing, worldwide, an astounding dependence of fisheries sustainability on this thing we call 'scientific stock assessment' where we try to figure out how many fish are out there, and what kind of harvest rates they are able to withstand on a sustainable basis.

The NT looked to me, as an outsider, as providing a real chance to study a fishery situation that had not proceeded to the point many have reached around the world, where negotiations between industry and government becomes impossible, where cooperative solutions to management become impossible, where the whole syndrome of bad scientists, bad management, and bad everything is combined. In situations where scientific mistakes have been made, the characteristics of those situations is that they are all fisheries that were developed and managed on the basis of what I call the British model.

The basic British model of fisheries management is that fishermen go out to fish, and do their best to make a living, and the government sits back and watches what those fishermen do, and collects what data it can from their fishing activities. The government then puts a squeeze on fishermen, at some appropriate time, to prevent them from overfishing. But that model does not work. It does not work any more in a modern world of high technology and rapid depletion by fishermen, and the capabilities they have. It does not work in any of the places where it is being applied including even off the coast of Great Britain. Some scientists have been struggling for ways to beat the horrible information problems that have arisen in these traditional fisheries. And here I see an opportunity to do something really different in the NT. I see a community of people that care about their resources and their future. I see some extraordinarily capable biologists and scientists, extraordinarily capable and well educated fishing interests and fishermen. I see a government small enough that you can fight the bad guys. One of our biggest problems in Canada is that you can not even figure out who the bad guys are. There are so many of them and they are so well hidden in the political system.

In our review of NT fisheries, we went through and looked at a series of fisheries ranging from the goldband snapper out on the edge of the Timor Sea, the fishery adjacent to the Indonesian waters, to mud crabs in coastal areas. We also looked at some of the coastal reef fish stocks which occur in shallow areas (golden snapper and jewfish), red snappers farther offshore in deep water, and barramundi. The barramundi fishery is probably one of the biggest areas of potential conflict here in the NT.

We approached each of these fisheries by running a simple workshop process in which we sat down with a few fishermen who were willing to come in and talk to us about their views about the resource with biologists, with outside visitors, and with anybody else who felt they might have useful knowledge about each of the fisheries. We did some interesting field trips to see what the fisheries are really like in the field. I caught a couple of real big ones! It was good. And then we sat down and tried to redo some of the computer based analyses that are widely used today in fisheries stock assessment, and correct some of the problems that have caused major fisheries collapses. We tried to make those models and methods work for NT data, and that was by and large not successful. We did a lot of analysis of what would really be needed in the NT in the way of information, data and science in order to develop sustainable fisheries. We spent considerable effort trying to devise policy options that could meet some of the information on sustainability needs. The review was very much an open process - people brought ideas and information and feedback and criticism along the way - not just a couple of biologists in an office some place staring at their navels. That fascinates me. I do not think I could have gone to any place in the world and done something like we have done in the last few weeks here. I travel around Australia doing stock assessment work very often, and we are gradually starting to develop a process for involving commercial fishing interests and other interests in the whole business of getting better data to do better assessments, but not anywhere near as nice as what is happening here, in the Territory.

Let me just tell you very generally what we have found in those assessments.

- There is opportunity for growth in a few of the fisheries, particularly the red snapper fishery in deeper offshore waters.
- Some of the fisheries like barramundi and mud crab along the coast are fully developed now. That means that fishermen are already exploiting the stocks at a level that would be biologically safe, and in most places where fish are available.
- And there is one sad story of a fishery that is very likely to be overfished in the near future, not by Australians, but by Indonesians. Goldband snapper move back and forth across the border of Indonesia, and are likely to face overfishing by developing fisheries in the Indonesian sector.

Another one of our main findings is that we were grossly unable to access the abundances and future growth opportunities for a number of fisheries, including coastal reef fishes and bottom fishes. One of the key reasons is that the data that had been gathered by the Fisheries Division, so far on stocks, was just inadequate. To understand what is going on in fish on small reef systems scattered along the coast, you have got to have data on each reef. Basically, the reef fisheries reporting system here is not adequate to provide that kind of information. Now this is not a criticism of the NT government or fishing industry. This problem is a global one. The statistics being recorded for use by scientists in fisheries worldwide have been grossly inadequate, and we have paid the price hideously in places like eastern Canada.

Part of the problem was that world scientists, until very recently, did not really start speaking out on what an unholy mess the data we were trying to use was. It is something to really speak out on, and you will hear about it in the other presentations. Also, there is a really critical need for getting out there and looking carefully at the habitat available for fish instead of just trying to stick catch statistics into a computer. That critical need says ‘get out there and really look at the fish’, and look at the environment they live in much more closely. You have got the capability here to do this, what has been lacking, I think, is the incentive in the form of people like me coming and saying ‘guys, the computer is not going to give you your answers, you have got to get out in the field’.

There are a few situations which I personally consider to have extremely dangerous latent effort, and where historical licence policies have lead to a high number of fishermen with the potential to enter the fisheries. Maybe the number of licences issued is fine, but there is no way known that we can tell this and so, from a fishery view, those licences present an extreme conservation risk. A couple of fisheries could develop so rapidly that it would be impossible for existing information, or even anticipated changes of information gathering, to catch them before they collapse, or at least partially collapse.

Let me highlight for you the main recommendations that I personally want to make, and I would hope maybe you will keep an eye out for it as you hear the presentations on the individual fisheries by biologists. Let me emphasise that these are my personal recommendations to the NT government, about things that the government needs to do to improve its management position.

Firstly, and I do not think there is any general disagreement about this, there is a fundamental need to revise the information gathering system of fisheries so that the biologists and fishery managers are provided the kind of data they need to get on with the job of sustainable fisheries management. There is a critical need for some very innovative experimental management approaches to find out how many fish are out there. Some of this work is already going on. There is some well known work here in the Territory, known worldwide, for the quality and innovation, and you will hear about some of it tonight. There is a need to deal with the latent effort problem in the developing fisheries, and to bring that latent effort under control, by some means. At the very least, there is a need to relabel some of the inactive licences as exploration fishing licences so that investors in those licences understand that the government can not assure fish without better information. We need to eliminate, somehow, some of the inactive fishing licences and change the licensing system so it creates incentives for people who engage in fisheries development. These people may then go out and fish, and provide the information needed to determine whether they can do so safely.

A second recommendation, that I expect is going to have to be implemented in some situations around the world, is to set up what we call TURFs (Territorial Use Rights in Fisheries). The basic idea here is to assign a fishing interest, whether it be a commercial tour operator or a commercial fisherman, or whoever, exclusive use of an area of coastline where fish are produced. This is the only method that we know of to ensure some kind of sustainability in situations where fishermen can roam around a great deal, and sequentially deplete parts of a resource, such as the mud crab fishery. We do not know a simple way to regulate sequential fishing on a sustainable basis, except by carving up the resource so that at least the owner of each area has some say to protect the resource which is under their control. I guess it is really the only radial recommendation that I have made to the government here is to begin considering use of these TURFs. It’s a funny word, it really means trying to make fishing in some areas be more like farming, where there are strong local incentives to protect the productive capability of the resource under control.

Finally, we may have found a way through the bitter conflict that has occurred between recreational and commercial fishermen over barramundi and the potential conflict which may develop shortly over some of the other coastal fish species as well - this was a highlight for me. I have worked a great deal on recreation and commercial fishing conflicts in Canada, and I fully expected to see a situation in the barramundi fishery where it would be best to eliminate commercial fishing in favour of the very valuable tourist industry development of recreational fishing. What we found in the analysis was that there has been substantial recovery of barramundi stocks in recent years, even before strict controls were placed on recreational fishing. There has apparently been no major increase in recreational fishing in conjunction with at least the controls put on the Mary River to try and enhance it for recreation. When you put these two facts together, what they suggest is that there are some real opportunities for commercial and recreational fishermen involved to live with one another, and to work together towards a more productive fishery for everyone. Stop fighting and get on with the development of a useful philosophy arrangement.

Problems with the assessment and management of goldband snapper stocks

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Summary

Traditional fisheries stock assessment methods cannot be reliably applied to the goldband snapper fishery, and there is huge uncertainty about the current stock size. Estimates of current biomass in the Timor Box range from as low as 3000 t to 20000 t or more, depending on how historical catch, catch rate, age composition, and survey data are interpreted. If the stock is near the low end of this range, even current catches are unlikely to be sustainable. Catches might be doubled if the stock is near the high end. There is also large uncertainty about current and future impacts of Indonesian fishing on the stock, both in terms of illegal fishing in Australian waters and depletion of fish moving back and forth across the fishing zone boundary.

It is likely there is at least some mixing of fish across the Indonesian zone boundary. High year to year variation in apparent availability of fish to the Taiwanese trawl fishery and the Australian line fishery, and in how Indonesian vessels crowd the boundary, are suggestive of substantial shifts in fish distribution over time. This means that even legal Indonesian fishery development will impact on future sustainable yields in the Australian zone, and vice versa. Calculations of the present economic value of the fishery (discounted sum of future catch values less fishing costs) as a function of fishing effort by both fisheries indicate that both countries would be better off to negotiate a cooperative harvest policy with each country taking somewhat less than it would take if it ignored the policy chosen by the other country. A key incentive for each country to seek this “cooperative game” policy solution is the ability of the other country to threaten overfishing in the event of noncooperation (work with us, or we will take away your opportunities for future economic value from the resource by overharvesting now).

There is a critical need at this point to either obtain direct stock size assessments via some method such as localized depletion experiments, or to develop a management regime for directly limiting exploitation rate without having to know the absolute stock size (e.g., large closed areas). There is a further critical need to obtain information about interaction with the Indonesian fishery, which should involve assessment of their effort/catch development, and also tagging studies to estimate movement rates of fish between the Australian and Indonesian fishing zones.

Methods of Assessment

We have attempted to apply three assessment methods to available data from the fishery:

1. fitting surplus production models to the catch and cpue data, using trawl survey data to constrain the stock size parameter estimates.
2. fitting a delay-difference age structured model to the catch and catch per unit of effort (cpue) data, again using trawl survey data to constrain stock size parameter estimates.
3. fitting a full age-structured model to catch and catch age composition data (stock synthesis model), in hopes that total mortality rate information evident in the age composition would make it unnecessary to constrain the biomass estimate by also using survey data.

These methods cover the range of techniques and types of data generally used in fisheries stock assessment. The third method in particular is designed to use virtually all the available data simultaneously in an integrated way. The only known assessment method that we have not employed is the use of change-in-ratio data from tagging or stock composition changes; such data are not available for this fishery. This section describes key assumptions and difficulties in applying each of the methods to the goldband data.

The surplus production method treats the stock as a simple pool of biomass, with all components of production (growth, recruitment, natural mortality, immigration and emigration from the fishing area) lumped into a single overall production rate that is assumed to depend on stock biomass. Fitting such a model to cpue time series data is then essentially the same as fitting a depletion model, except that we attempt to correct the depletion pattern for effects of production over time. For such a method to work, the stock must be depleted sufficiently to show substantial decline in cpue, and the cpue index must be strictly proportional to actual stock size. Unfortunately, fisheries on schooling fish like the goldband snapper rarely exhibit cpue proportional to stock size; cpue can remain high and show no signal of stock decline until most or all of the schools have been severely depleted. The goldband cpue data show no decline over time, indicating under surplus production analysis that either (1) the stock is very large and has not been depleted at all, or (2) the stock is small but is turning over very rapidly due to local production and/or exchange with surrounding populations outside the Timor Box, or (3) the stock is small and is being depleted rapidly, but cpue is remaining high due to effective targeting by the fishery on remaining schools.

Delay-difference model fitting is essentially the same as surplus production analysis, except that we compute recruitment, growth, and natural mortality components of production so as to make production rate estimates consistent with independent data on these component processes. The goldband snapper is slow-growing and long lived, and we supply the assessment procedure with independent estimates of growth rates based on otolith analysis, along with an estimate of natural mortality rate derived from the growth rate data and from maximum longevity seen in age samples (most fish show natural mortality rate M about equal to the body growth K parameter, which is about 0.13-0.18/yr for goldband snapper). We could in principle adjust the natural mortality rate to reflect emigration of fish from the Timor Box, but we have not done this as yet since there are no field estimates of movement rates (increasing the natural mortality rate in this manner leads to more optimistic assessments of sustainable harvest rates). Recruitment rates are estimated as part of the process of fitting the model to time series data. Like production model analysis, the fitting procedure depends on seeing informative changes in cpue over time, and on cpue being strictly proportional to stock size. Estimates of overall production rate obtained from the delay-difference model, for a range of assumptions about total stock size (i.e., when initial stock size in the fitting is constrained by using trawl survey data) similar to those used in the surplus production analysis, lead to considerably smaller estimates of sustainable harvest than indicated by the production models. Either earlier production models gave overestimates of production rate in order to keep predicted cpue from declining, or else there is considerable immigration from outside the box, or else the stock size is drastically larger than indicated by survey data.

Age structured (stock synthesis) models were fitted to the catch and cpue data as for the other two assessment methods, but these models also predict age structure changes as a function of fishing mortality. In some situations, the age structure data can be used to estimate fishing mortality rate and stock size independent of survey data, provided the age structure data give a good signal about the total mortality rate (how fast older fish disappear from the age structure). Age data can also be used to estimate the partial vulnerability schedule for smaller fish, which is useful in assessments of optimum yield per recruit. Unfortunately, the age composition data show a strong peak of younger fish (ages 6-10), with apparent very rapid disappearance of fish (dropping about 50% per age) over the age range 7-10. If we knew that fish of all ages greater than 7 were equally vulnerable to fishing, this pattern would indicate a very high fishing mortality rate and hence a small current stock size and sustainable yield. Further, this steep age-abundance pattern should not have developed so early in the fishery, unless the stock was already being harvested at high rates when the Australian fishery began. From discussions with fishermen, we suspect that what is actually going on is not high fishing mortality rate, but rather selective targeting by fishermen on larger schools of smaller fish during parts of each fishing season (then on smaller schools of larger fish dispersed over a wider area of bottom at other times in the season), so the assumption of equal exploitation rate over older ages is violated. Since changes in age selectivity are confounded with (cannot be distinguished from) effects of mortality on the age structure, we simply cannot use the age composition data to provide additional information on stock size and exploitation rate beyond that provided in the production model and delay-difference assessments.

It should be noted that severe problems in use of commercial cpue data, and difficulties in interpretation of age composition data, are not unique to this fishery. There is a general move now in fisheries assessment away from use of cpue data in particular, in favor of abundance indices from fishery-independent surveys, after we discovered that collapse of several major fisheries around the world (cod in Canada, herring in North Sea) was caused in part by misleading assessments based on cpue. In a few cases where fishermen have provided detailed log-book information on the spatial distribution of catch rates (e.g., New England trawl fishery in U.S.) it has been possible to use spatial statistics methods to devise spatially weighted cpue indices that are closely proportional to actual changes in stock size, but these cases all involve highly developed fisheries where severe competition has driven the fishermen to cover the fishing grounds very thoroughly. Spatial statistics methods cannot be used in a developing fishery like the goldband snapper where there are large holes in the spatial distribution (coverage) of fishing effort relative to the stock distribution.

Alternative Hypotheses About Stock Status and Sustainability

Global experience with long-lived species like the goldband snapper indicates that sustainable annual harvest rates rarely exceed the natural mortality rate, and are more likely to be on order 0.4-0.6 times the natural loss rate. This means for the goldband that annual harvest rate should not exceed 10-15% per year of the stock. Such situations are difficult for fishermen to accept, since they involve leaving a very large number of fish in the water for every fish taken ("there are plenty of fish out there; why can't we take more?").

While we can provide a reasonable estimate of the best harvest rate as a percentage of the stock, we unfortunately cannot at present translate this into an operational estimate of the effort needed to produce this harvest rate or the annual catch that will be sustained. If we assume for example that the stock is presently on order 3000 t (low end of survey estimate range), then the current harvest rate is around 400/3000 for 1000 boat days effort, which would mean that the current effort level is too high. If we assume instead that the stock is on order 9000t (not unreasonable given likely trawl gear efficiency), the current harvest rate is only 400/9000 for 1000 effort units, and effort could safely be expanded to at least 2000 boat days/yr.

So one critical set of alternative hypotheses concerns the current size of the stock. For optimistic hypotheses (9000+ t), effort could be at least doubled without short term risk of stock collapse. For pessimistic hypotheses, the stock is already being overfished. There is no point estimate of biomass that can be considered a "best guess" at this point in time. It should be noted that even for the most pessimistic hypothesis that appears reasonable in view of available survey data (around 3000 t), there is no immediate risk of stock collapse. If the stock is indeed that low, stock size will erode slowly over the next decade as the accumulated stock of older fish is taken, until the fishery has to rely mainly on new recruitment; then, catches will fall to on order 250 t.

A second set or dimension of hypotheses concerns movement of fish between Australian and Indonesian fishing zones. It is very likely that Indonesia will continue to pursue an aggressive fishery development policy in the region, and will not be willing to negotiate strong effort restrictions for goldband (minor species in their overall catch). This means that if movement rates of fish across the boundary are high, the stock will suffer high exploitation rates no matter what effort policy is adopted on the Australian side. Simulations with a two-area population management game, developed for this assessment, indicate that movement (fish exchange rates) on order 20% per year or higher imply that there will eventually be no sustainable harvest on the Australian side at all, even if the Australian stock is currently near the high end of the range of estimates from survey data.

<u>Information required for Future Assessments</u>

There are three really critical information needs in this fishery. In order of priority, these are:

1. Assess movement rates of fish between the Australian and Indonesian fishing zones, using tagging experiments and analysis of logbook and survey data on spatial shifts in fish concentrations from year to year.
2. Assess the current, and likely future trend, in Indonesian fishing efforts and catches in areas bordering the Australian fishery (including illegal fishing on the Australian side), using records from aerial surveillance and whatever statistics can be obtained directly from the Indonesian government, fishermen, and processors.
3. Develop a multi-method procedure for directly estimating the current size of the Australian stock, using a combination of tagging, broad area density surveys, and localized depletion experiments. Tagging can be used to provide both mark-recapture (unreliable) estimates of biomass, and also estimates of current exploitation rate (reliable if low tag loss rates can be achieved). Depletion experiments can be used to estimate local densities and as a cross-check on the estimates from tagging. Broad area surveys (acoustic, trawl) can be used to map the local density estimates up to larger spatial scales.

None of these information gathering activities will be cheap. But it is very unlikely that continued application of traditional assessment methods based on commercial fishery data analysis will solve either the stock size or movement estimation problem. The difficulties we encountered (see above: inability to use cpue and age composition data) will continue to plague the analysis.

Management Options

There are at least four short term options for management of the fishery without taking extreme risk of stock collapse:

1. allow latent effort to enter the fishery to increase the total to around 2000 boat days/yr, while initiating regular surveys and other information gathering to monitor stock density changes that could eventually be plugged into traditional assessment models to provide estimates of total stock size.
2. eliminate latent effort and maintain the current effort level, which is very unlikely to cause rapid stock depletion and would avoid the risk of substantial asset loss if the worst-case scenarios for fish movement and Indonesian impact prove correct.
3. Combine either policy (1) or (2) with closure of a substantial proportion (preferably inshore) of the fishing area to insure limitation of the exploitation rate no matter how efficient the fishery becomes at exploiting parts of the stock exposed in the area that remains open. Closing on the inshore side of the fishing area would provide the largest possible buffer against impacts of Indonesian fishing, and allow Australian fishermen to capture the largest possible share of fish originating from Indonesian waters. The closure policy will fail from a conservation standpoint only if movement rates of fish turn out to be very high.
4. Combine policy (2), and perhaps a reduced closed area as well, with an industry funded cooperative program for tagging and biomass assessment, to resolve the stock size and movement questions as soon as possible and before further effort development is permitted. The essential idea here is to treat the current minimum stock size estimate from surveys as a “proven production potential”, with the onus on industry to invest in information needed to “prove up” any further potential for effort and catch increase.

It is simply a waste of time at this point to speculate about the long term future of the fishery. That future depends very much on movement rates of fish into Indonesian waters, and on future Indonesian fishery development policy. All we can say at this point is that no public commitment to, or industry investment in, a long term management strategy should be permitted until the movement issue is resolved.

Status and Future Development Potential of the Mud Crab Fishery

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Summary

The mud crab fishery probably takes a very high proportion (70% or more) of the available stock each year in the areas that are now fished, so that the fishery depends primarily on newly recruited crabs rather than an accumulation of crabs from several past breeding years. This means that any future development potential for the fishery would have to involve finding new fishing areas in remote areas that have not been economically or physically accessible to fishermen to date. There appear to be few such areas, so the fishery should be viewed for management purposes as fully developed at present. It is very unlikely that large new grounds will be found (that the fishermen have not already exploited), or that much more catch can be taken from existing grounds. It is also very unlikely that catches can be improved through simple management controls such as changes in size limits. On the other hand, there appears to be little risk of a conservation problem in the form of recruitment overfishing; good recruitments have been produced in spite of high exploitation rates since the early 1980s, and there is a partial refuge from exploitation for female crabs because of their offshore spawning migration (into areas that are not fished). The only hint that recruitment overfishing could become a problem has come from limited experience with the Adelaide River, where crab densities have remained low since a period of very high effort in 1989; with the current wide distribution of fishing effort, it is unlikely that such a situation would arise again or commonly over the fishery, unless there is substantial increase in the number of vessels licensed to fish and move widely over the territory.

We cannot be certain that there is not a larger biological population than indicated by exploitation statistics and depletion experiments, consisting of individuals that for some reason are not vulnerable to crab pots. But the possible existence of such a "pot-inactive" population will remain purely a matter of academic interest unless some change in fishing techniques reveals its existence, and depletion of it reveals that it is somehow important to maintaining recruitment to the population that is vulnerable to crab pots. Continued monitoring of catches, spatial distribution of fishing efforts, and fishing techniques should reveal any such scenario in time to avoid risk of serious overfishing.

Methods of Assessment

Catch-effort models and assessment methods based on catch-rate data cannot be used in this fishery due to non-randomness in the spatial pattern of fishing effort; fishermen appear to systematically deplete local areas then move on to other ones through the fishing season, so as to maintain hyperstability in catch per effort (see below). Likewise, traditional length-based methods for estimating mortality and growth rates are invalid due to the way crabs grow (by molting rather than continuous body growth) and to the lack of discrete length cohorts in the stock (due either to high variance in individual growth rates or rapid disappearance of cohorts due to mortality).

We have therefore chosen to base assessments on the simple approach of recognizing that the fishing mortality rate (F), defined as F=(catch)/(stock size), can be estimated directly by obtaining a stock size estimate from local fishery depletion and/or depletion experiments, then dividing this stock estimate into the measured catch. To obtain a stock size estimate for typical or average years, we use the fact that total stock size consists of the product of two factors that can be independently estimated:

stock size=(crabs per unit habitat area) x (total habitat area).

We made rough estimates of total habitat area for several fishing locations along the coast for which local catch statistics are available, and estimated crabs per unit area within these locations by two methods that agreed quite closely: (1) swept area for a single pot based on pot spacing used by fishermen (assume each pot sweeps a circular area with 50 m radius, ie 7800 m^2, based on how fishermen have found that pots should be set around 100 m apart), and (2) depletion and mark-recapture estimates made in a small creek by Ian Knuckey. Both these methods indicate mid-season crab densities of roughly 150 crabs/km^2 of creek/shallow coast water surface area. Taking these densities times estimated total habitat area for several locations, then dividing this total into measured catches, gives annual exploitation rates of around 70-90%.

Another way to estimate an upper bound (worst case scenario) for the fishing mortality rate F is to calculate the total “swept area” by pots and to divide this swept area by the total area of habitat. Assuming each pot set sweeps an area of 7800 m^2, multiplying this times total pot lifts and dividing by habitat area gives maximum F values ranging from 2.7 in the Adelaide River to 4.0 in the Roper River and 6.4 in the MacArthur River. These swept area values imply annual exploitation rates of 93-96%, and agree fairly well with the habitat area/density calculations if we assume that about half the crabs in each area swept by a pot actually enter the pot during any set.

Further evidence of high exploitation rates was obtained by examining the seasonal pattern of recruitment of new crabs to the fishery, and using this to predict changes in average size of crabs through the season under alternative assumptions about the numbers of larger, older crabs still alive at the start of the season. If there were a substantial carryover of older crabs, average body sizes near the start of each season should be considerably larger (170-200 mm carapace width) than later in the season when new recruits enter the fishery at carapace widths of 140-160 mm. Average body sizes from fishery sampling change from 152-153 mm carapace width in the early February-March period prior to major recruitment, to around 157 mm in the July-November period. The observed pattern is thus indicative of extremely high exploitation rate, and very little carryover of larger crabs from previous years’ recruitments.

We attempted to still further cross-validate the assessment that F is very high by fitting a seasonal population dynamics model developed by Ian Knuckey (including seasonal recruitment, growth, vulnerability, and natural mortality effects as well as interannual carryover of crabs) to the monthly time series of catch and cpue data for 1985-95. When fitted to both catch and cpue data, this model indicates annual F values of around 2.0. However, when the model is fitted only to catch data, the parameter estimates converge to a very low F, high recruitment scenario in which the fishery is estimated to have had almost no impact on the stock. This optimistic scenario occurs because the computer fitting procedure sees increasing catch with increasing effort over the years, and can fit such a pattern most readily by assuming the increasing effort has had no impact whatsoever on stock size. When we force the impact of fishing to be large, either by fixing catchability or by including seasonal cpue depletion data in the fitting, the model fits imply a recruitment anomaly trend that is positively correlated with fishing effort; such a pattern could happen if either recruitment is stimulated as increasing fishing mortality removes more large, cannibalistic crabs or if effective recruitment increases as fishermen include more fishing areas in their activities (and hence a larger effective population size in the statistics they report).

If exploitation rates are as high as we estimate, then why has fishing success as measured by catch per effort remained high as total fishing effort has grown? Such hyperstability in cpue is usually associated with schooling fish, where fishermen can target on schools to keep success rates high even if school size or number of schools declines greatly. Here we likely have the opposite behavioral situation, with aggressive behavior and risk of cannibalism driving the crabs to spread themselves more evenly over the habitat than would be expected from chance variation in recruitment seeding or availability of juvenile nursery areas. If spacing behavior were continually driving the crabs to stay as far from neighbours as possible, densities would decline uniformly over the whole fishing area during each season and catch rates would closely reflect the seasonal depletion. The data do not show a seasonal pattern involving more rapid depletion with increasing fishing effort. Partly this lack of clear change in seasonal pattern is due to recruitment of new crabs molting into the sizes that enter pots, especially during the middle of the fishing season (March-August), and this tends to mask strong cpue decline until late in the season. Another possible effect is that only a proportion of the crabs at any site are behaviorally vulnerable to entering pots during any short fishing bout; in some pot fisheries (such as WA, SA rock lobsters) this proportion is quite low so multiple visits are necessary to generate high annual exploitation rates.

There are two likely reasons for lack of cpue response to increasing exploitation rates. First, the harvest process involves “sequential depletion” of small fishing sites, where fishermen apparently remove most of the crabs from each site then move on to new sites. In such effort movement situations and where densities at all sites are initially similar, cpue is expected to remain high until all sites have been fished at least once, then to decline sharply when fishermen revisit sites that now have only new recruits available. Second, there is an economic threshold to keep fishing, such that it is uneconomic to keep fishing (cannot meet operating costs) when cpue drops below about 0.2 kg/pot lift (season average is around 0.5 kg/pot lift). Fishermen that cannot achieve this threshold (due to local crab density conditions, operator skill, luck) are expected to drop out of the fishery earlier in each season than other fishermen who are luckier or more skilled, so that cpue statistics later in the season come only from the fishermen who are still achieving higher catch rates. This “effort sorting” process can bias the cpue statistics upward considerably from levels that would be expected if all fishermen stayed out. As a side comment, effort sorting effects are particularly notorious in recreational fisheries where fishing skill varies enormously among individual fishermen; in such fisheries, cpue is almost completely independent of fish abundance, and the best indication of changes in stock size is changes in fishing effort.

Alternative Hypotheses About Stock Status and Sustainability

Main alternative hypotheses about the future of this fishery concern the possible existence of substantial inshore areas that have not yet been heavily fished. There are only a few such areas. Fishermen report good crab abundances in the Arnhem Land, but this area is difficult to access and raises aboriginal issues. There may be some potential for development in inaccessible locations on the Gulf of Carpentaria, but we strongly suspect that fishermen would already have found such areas if they existed, and would have found ways to gain access to them other than by the usual land routes.

Information required for Future Assessments

There are three key needs for future assessments in this fishery:

1. refined estimates, and estimates from more spatial locations around the fishery, of crab densities per unit habitat area;
2. refined estimates, using maps, GIS computer mapping techniques, and discussions with experienced fishermen, of total habitat area and density variation across different habitat types (e.g. open coast versus mangrove creeks).
3. development of a more precise fishery reporting system for spatial location of catches, changes in fishing techniques, and size distributions of crabs taken and released from traps.

Note that all of these needs can be met most efficiently and cheaply through cooperative work between fishermen and government. If depletion experiments (with buffer zone around each depletion area to measure and reduce effect of immigration into the area) are used to estimate local crab densities, an obvious way to do these is to have a fisherman do the depletion harvesting under supervision, following a time period during which the experimental area is closed to fishing to insure that catch rates in the area are likely to be high enough to be attractive to the fisherman. Likewise, fishermen have an incentive to cooperate in providing their knowledge and experience for habitat area mapping, since demonstration that there are areas currently not being utilized would help to provide confidence that the existing fishery need not be restricted further to reduce the risk of overfishing. Improved reporting is an investment by fishermen to protect the asset value of the fishing license, since better information will provide a warning system to help reduce the severity of any stock collapse that might be triggered by increased exploitation rate due to improved gear efficiency.

Management Options

This fishery is currently under an input control management system with limits on the number of licenses and pots fished per license. Pot fisheries managed this way in Australia (e.g., rock lobsters) have generally performed quite well from a conservation viewpoint, and I know of no instances where rapid changes in potting gear efficiency have led to dangerous increases in fishing mortality rate (but see above about need to monitor for such changes).

Major management options concern whether to allow limited expansion of fishing licences, and whether to restrict the location(s) where each license holder is allowed to fish. Data presently available on crab densities and habitat area suggest that increasing license numbers would not result in substantial increases in catches, and would instead reduce incomes per license holder already in the fishery. Thus increases in the number of licenses should be viewed as an option for distributing income from the fishery more widely (generating more employment), but not for increasing net production for the industry as a whole.

Allowing fishermen to move freely among fishing areas has led in the past to some social and economic problems (competition for fishing sites), but has likely helped at least some fishermen to stabilize their incomes by shifting their effort in response to local variations in crab abundance and number of competing fishermen. However, some crab fishermen are now voluntarily restricting their operations to single areas, and are trying to treat these as exclusive fishing territories. It is likely that much of the crab fishing area of the NT will evolve into informal fishing territories no matter what the government policy is on this matter. Perhaps it is time to explicitly recognize and even deliberately protect this emerging fishery structure.

The primary arguments for restricting all fishermen to single, at least partially exclusive areas are: (1) having one fishing site without unpredictable competition from other license holders can allow operators to reduce costs and learn to fish the site more efficiently; and (2) being restricted to one area creates an incentive for the operator to support prudent conservation and management (if he cannot move, he must live with economic consequences like reduced license asset value if he engages in destructive practices or overharvesting). The second of these arguments is particularly compelling from a public conservation perspective. Further, the argument by fishermen that they have to move a lot to find good fishing opportunities and stabilize incomes is somewhat misleading; some variation in fishing success is due to natural variation in abundance from place to place over time, but much of the variation is created by the fishermen themselves when they move about trying to beat one another to the best fishing sites (when a fisherman encounters low catch per pot in a site, this low success is as likely to be due to someone else having cleaned out the site within the past few days or weeks, as it is to be due to overall low abundance independent of fishing pressure). Also, under an exclusive area license system there would presumably be nothing to prevent operators from acquiring rights to several locations should they deem it wise to do so based on personal preferences regarding risk spreading and ability to fish different sites successfully. I cannot venture to say what option would be best overall for fishermen and for the Australian public, but the matter of localized and exclusive licensing should be a central subject of debate and policy analysis in the near future.

Status and Management Options for the Coastal Reef and Red Snapper Fisheries

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Summary

There appears to be considerable potential for further development of the coastal and red snapper fisheries. Stock size estimates are grossly uncertain for coastal species, but estimates of abundance based on fish densities in similar habitats around the world suggest potential yields could be as high as ten times what is presently being taken. Red snapper yields could most likely be safely increased by at least five times. However, there are big barriers to development of this potential. These barriers include: (1) uncertainty about existence of economic concentrations of fish (there may be plenty there, but too spread out to be worth fishing); (2) there are far too many inactive license holders, and this latent effort creates a substantial risk for any fisherman (that his investment will be lost if he is initially successful, to competition for both fish and markets by other entrants who follow his example); and (3) it is unsure whether markets can be developed to take far more fish at prices similar to what the few active fishermen are now getting. Uncertainties about stock sizes and concentration patterns could be addressed most efficiently by developing cooperative arrangements between biologists and fishermen to undertake extensive habitat mapping and local density estimation surveys, and by eliminating latent effort in favor of a licensing strategy that requires new entrants to finance stock assessments that demonstrate clearly that the resource is there to support them. Existing stock assessment methods based on commercial catch-effort statistics will not remedy the stock size uncertainty situation in the foreseeable future, though it will help considerably if fishermen are required to provide far more detailed logbook information. There is a critical need to develop economical methods for obtaining fishery-independent indices of stock abundance and trend.

Methods of Assessment

Standard fishery stock assessment methods rely on detecting effects of fishing through catch per effort (trend index) statistics. Such statistics cannot be used for the historical coastal fishery, since fishermen have moved in a highly non-random manner from place to place in search of economical aggregations of species like golden snapper and jewfish. This movement can be described as a sequential depletion process, where dense aggregations and are cropped down forcing fishermen to move progressively further from Darwin in search of aggregations large enough to provide decent earnings relative to their operating costs. Sequential movement like this does not in itself imply any serious risk of biological stock depletion; there can still be very large stocks spread over the habitat at densities too low to attract fishermen using existing fishing methods (but watch out if someone finds a way to exploit these lower densities economically, using methods such as trapping instead of drop lines!). However, a typical pattern of cpue trend when there is sequential cropping of aggregations is for cpue to increase rather than decrease over time, as fishermen move onto progressively more distant and productive locations that have not been subject to historical fishing by other interests (like recreational anglers near Darwin). Such fisheries have a nasty way of suddenly ending when fishermen run out of economic aggregations (within an economical distance from port), with no prior warning to the management system in terms of changes in traditional logbook catch and effort statistics.

Our general assessment approach for coastal and red snapper involved two steps: (1) estimation of optimum long term exploitation rates (sustainable annual proportion of stock harvested) from growth data, using the idea that natural mortality rate and optimum exploitation rate are generally about equal to the growth curve parameter K; (2) application of this exploitation rate to estimates of unfished and current stock biomass based on a method known as stock reduction analysis (SRA). SRA is based on assuming knowledge of either the stock size at one moment in time (e.g., red snapper biomass in 1990 around 24000 t based on trawl survey) or on a guess at the relative reduction in stock size that has occurred over a period of time. This knowledge or guess is then entered into a spreadsheet along with a model that accounts for stock production/loss components over time (measured growth rates, estimated natural mortality and recruitment rates, and measured catch removals), and the model is run with different initial (unfished) stock size estimates until an estimate is found that matches the known biomass or assumed relative stock size reduction. SRA has been widely used in fisheries assessment, mainly in circumstances where we cannot obtain a reliable index of relative abundance changes over time from commercial harvest or survey statistics. SRA does not usually provide a precise stock size estimate, but is an excellent way to place broad bounds on likely stock size and potential for future harvest.

Estimates of optimum annual exploitation rates range from 10-30%, but are low for most coastal species examined and for red snapper. Due to slow growth and low natural mortality rates, the stocks are expected to have accumulated large natural biomasses. But only low yields can be taken safely each year from such accumulations, so the high abundance seen in many areas should not be taken as evidence of high sustainable yields.

There is a key need to assess recreational fishing effort and cpue. Recreational fishing may be maintaining depleted abundance in areas that were originally fished down by professionals. Recreational survey data should soon be available to compare areas near Darwin that have been heavily fished for some years, with areas to the southwest where recreational and commercial fishing pressure has been high for a few years, and with areas to the north-east where fishing pressure is still low.

A large catch-effort data base on Taiwanese trawling for red snapper provides an excellent example of why commercial harvest statistics alone cannot be used by scientists to provide reliable stock assessments. The Taiwanese data span 1973-93, and include detailed reporting of trawl locations. With such data, we hoped to be able to map spatial patterns in catch rates and fishing effort, and to be able to detect such dangerous phenomena as sequential depletion of fishing sites. In aggregate catch and effort data, depletion phenomena are “invisible” to the assessment scientist (catch rates remain can remain high due to movement of fishing effort), and stocks can be severely depleted before the scientist sees any change in catch per effort or catch indices of stock health. We found no evidence of sequential depletion of red snappers in the Taiwanese data, but we found that there were (1) huge gaps in the spatial data due to large-scale shifts in fishing locations, and (2) sudden changes in catch per effort of snappers that could not be explained by stock size changes and are likely due to the Taiwanese switching between targeting demersal species versus mid-water trawling for squid. We also found gross inconsistencies between the logbook data and overall catch-effort statistics reported by the Taiwanese in summary reports on fisheries statistics.

In the end, for red snapper assessment we had to rely mainly on simple stock reduction analysis (SRA) as for the coastal species, to provide rough estimates of how much the red snapper stock was reduced by foreign fishing and hence what its long term potential might be for Australian development. In the red snapper analysis, we varied the unfished stock size to see what stock would have to have been present in 1970 (before major removals by foreign trawl fleets) in order that the stock have been reduced to 24000 t (NT trawl survey estimate) in the Australian zone by 1990. This method gave unfished stock size estimates of the order of 50000 t for the AFZ, which in conjunction with measured growth rates implies a sustainable annual harvest of 1500 t. So it would appear that there is at least some room for expansion of the NT trawl fishery.

We attempted to use estimates of reef fish densities and production rates from around the world to provide at least rough bounds for stock sizes of the coastal species. Based on the world experience, we would expect combined densities over the major demersal species of order 2-20 t/mi^2 of reef habitat. However, we were unable to expand these density estimates to overall stock size estimates for the coastal species, due to gross uncertainty about the total reef area available inside the 30m depth contour along the NT coast. Estimates of reef area range from 1% to 5% of the total bottom area, and with such a wide range we must admit that species like golden snapper may be anywhere from already overfished (if densities are near the likely golden snapper share of a 2 t/mi^2 lower limit and if reef area is only 1% of bottom area), to having substantial potential for further development. Further, coastal fishing has only been economical so far near Darwin and Gove, so probably less than half the productive bottom area has even been “highgraded” by commercial fishing.

Alternative Hypotheses About Stock Status and Sustainability

Estimates of sustainable yield for the main coastal species mix (snappers, jewfish), in areas that are presently economically accessible for commercial fishing, range from on order 100 t/yr to over 1000 t/yr. The situation with red snappers is a bit less uncertain, with the range of estimates for sustainable yield in the Arafura Sea being on order 1500 to 2500, i.e. 7 to 10 times the current harvest. There is also great uncertainty about whether stable markets can be developed to take higher catches at good prices, and about whether current latent effort would quickly enter the fisheries so as to substantially reduce incomes per license holder even if stock sizes and markets prove favorable; latent effort is currently far in excess of that needed to take even the most optimistic estimates of sustainable harvest economically (with a reasonable income to each license holder). A key issue is not just total abundance, but also spatial concentration patterns. Stocks could be quite large, but spread out so that commercially viable concentrations are rapidly being removed and will only slowly be restored through recruitment and movement into concentration areas by fish that are now spread out; new and more efficient fishing technologies (eg, traps for coastal species) could make it economical to seek fish at lower concentrations.

Recreational fishing impacts on coastal species may be growing rapidly, especially near population centres and areas favored by larger party boats. Further growth in the recreational fishery could make commercial fishing uneconomical in the more accessible areas, and prevent recovery of stocks following commercial highgrading of major stock concentrations. If this hypothesis is correct, there will be a considerable decline in the quality of recreational fishing near Darwin, and this decline will spread to more distant areas. Even if recreational exploitation rates are now high in areas like Darwin Harbour, it is likely that the removals are being balanced by dispersal of fish into such areas from more distant areas that still have high abundance. This spatial renewal process will disappear if depletion spreads to the distant areas, further exaggerating the decline in quality of recreational fishing near Darwin.

Information required for Future Assessments

It would be possible in principle to quickly improve the total stock size and potential yield estimates for both coastal species and red snapper, by investing in two types of information gathering: (1) detailed mapping of spatial habitat patterns (coastal and deep water reef structures), to assess total area over which to apply stock density (fish/habitat area) estimates; and (2) use of depletion experiments, tagging experiments, and direct visual surveys (divers, video) to obtain estimates of stock density. Biomass estimates from this two-step analysis could then be used in conjunction with productivity assessments from growth data (which gives natural mortality rate and recruitment rate estimates) to provide good estimates of stock fish-down times and sustainable harvests.

An obvious way to proceed with the two types of information gathering would be to develop close collaborative arrangements between NT government scientists and experienced commercial fishermen. Fishermen have already accumulated a wealth of information on habitat patterns (e.g. GPS records of bottom structure locations), and mapping this information could lead to efficient programs for filling spatial data gaps by cooperative government and fishermen surveys conducted in conjunction with normal fishing operations. Depletion and tagging experiments could be most easily carried out by cooperative commercial fishermen working in conjunction with biologists doing survey visual counts and video assessments (this sort of cooperative arrangement has worked very well for example in coral trout studies on the Great Barrier Reef, organized by Conrad Beinsen and others). Particularly for coastal species, the density assessments would have to be done at a large number of sites to be meaningful, preferably in a stratified design that uses existing depletion patterns as a basis (compare Darwin Harbour to S.W. coast to Melville Island and Van Diemen Gulf, to obtain estimates over a gradient from heavily fished to nearly unfished conditions). To do this, a very efficient protocol for fishing and survey followup will have to be developed, such that the experimental protocol can be carried out very quickly (a few days at most) on each experimental site.

There is also a critical need to gather basic catch and effort data on the recreational fishery, and to track its development in space. It is very likely that recreational fishing will reduce densities of the most vulnerable species (e.g. jewies) dramatically in the most accessible areas like Darwin Harbour, and that a spreading "wave" of increasing effort and local depletion will spread along the coast to progressively more remote areas. This wave needs to be carefully documented, so that cooperative options for limiting its extent and impact on tourist businesses can be developed.

Management Options

There is considerable development potential for the coastal and red snapper fisheries. I see three basic options for the way this development might proceed:

Wait and see
This appears to be the current management strategy. With luck, new markets will be developed that attract latent effort to enter the fisheries. NT scientists and managers will attempt to track the impact of this development using commercial catch-effort statistics, and will very likely be unable to detect depletion problems from such data until at least some of the stocks are in serious trouble. This is a classic fisheries development pattern, played out around the world so many times that its progress and eventual outcome are drearily predictable. It is a fool's option. We cannot do either the science or fishery regulation to manage it successfully.

Provide development incentives for current license holders

The basic idea here would be to kick-start the development process by public investment in gear development research, demonstration of fishing methods, and development of markets both within Australia and overseas. Such a policy would bring latent effort into the fishery more rapidly, and if used in conjunction with improved information gathering (e.g. requirement for accurate location referencing for all fishing activity through a more detailed logbook system) would provide a more rapid assessment of development potential and impending depletion risks. Economic overcapitalization would be a major risk under this option, as would stock depletion if scientists prove unable to interpret the detailed logbook information (see discussion above about problems interpreting data from Taiwanese logbooks).

Clean the slate and initiate a sound approach to development and sustainable harvesting

Under this option, the NT government would begin by cancelling all inactive licenses to eliminate latent effort from the fishery. Then it would offer to provide two things: (1) assistance with market development, and (2) issuance of new licenses based on demonstration by applicants of "proven production potential" (PPP). The basic concept in the PPP step is to shift the burden of proof, and the basic cost of assessing resource potential, onto the private investor and industry just as is done with other primary resources like minerals. The license applicant would have to agree to finance conduct of stock assessments (habitat area mapping, direct density estimation as described above) to demonstrate the existence of enough stock to support an addition to sustained harvest equal to what the applicant would expect to take. This demonstration might take the form of showing that there is reasonable stock abundance in areas that have not previously been surveyed or fished, or of contributing to conduct of broad-area surveys that provide more precise abundance estimates within areas that are already being exploited. If NT government effort and catch limits are based on conservative stock size estimates (lower limits of ranges of estimates based on statistical analysis of data), it should be possible for NT scientists to advise fishermen quite precisely on the best investments to make in order to narrow the range of estimates (narrowing the range will generally "create" proven production potential by increasing the lower, proven bound for stock sizes). Note that the PPP approach will not work if existing latent effort (inactive licenses) is left in place. Latent effort would continue to act as a drag on development, by increasing the risk to fishermen that their investments will simply be lost to competition with people that begin fishing as "free riders".

Whatever development strategy is followed, I have a strong word of warning about future management of the red snapper fishery; this warning will likely also apply to the coastal fishery. Bill Passey has developed a fishing technique that involves precise targeting of snapper aggregations and very short trawl tows, coupled with accumulation of a GPS data base about where to find the aggregations. It would be wise to assume that future trawlers will adopt this technique as well. When such a technique is used, scientists cannot use fishery statistics for assessments of stock trend and health. Catch per effort statistics in particular will show pathological hyperstability, with cpue only dropping if there is massive depletion of aggregations over the whole fishing ground. The scientists might be able to spot a decline by using spatial patterns in detailed logbooks, or logbook statistics on travel time or search time between shots, but even this is doubtful if fishermen are at all clever about choosing travel and search strategies that minimize time needed to access likely good spots. If the fishery is to be managed on a sustainable basis in the face of growing catches in the future, it will be necessary to develop some fishery-independent system for gathering relative abundance and stock trend information (e.g., acoustic or standardized trawl survey, perhaps conducted by the fishermen on an opportunistic basis while fishing). Should a cooperative industry/government approach to surveys prove impractical, future assessments will likely have to be based on occasional, relatively expensive government surveys like the ones conducted in 1990 and 1992. The risk of stock collapse will increase substantially if surveys are only done once every several years.

We were severely hampered in this assessment by lack of detailed logbook information on spatial locations of catches and efforts in the Australian coastal fishery. Lack of precise spatial data in logbooks will continue to make it impossible for scientists to advise wisely on stock trends in all the NT fisheries. In my view, public resources are being placed at increased risk through this lack of accurate reporting, on the really dubious excuse that it is inconvenient for some fishermen to record their activities precisely. The NT government should pay no attention to complaints about inconvenience, and should move immediately to require precise georeferencing on all commercial catch and effort reporting. Failure or refusal to provide such information should be taken as immediate grounds for license cancellation. Logbook reporting should not be a matter for negotiation with fishermen at all.

The highly nonrandom fishing pattern followed by both red snapper trawl and coastal line/trap fishermen will create serious problems for management as well as assessment. In such situations, traditional input controls on fishing effort (gear, vessel size, number of vessels, etc.) are generally ineffective at preventing severe overfishing once a stock decline starts. This is because the fishermen are able to continue targeting remaining fish concentrations as the decline proceeds, thus driving stock sizes far lower than would be expected if catch per effort were proportional to abundance (in technical terms, the commercial catchability coefficient or fraction of stock taken by each unit of effort increases drastically as stock size decreases). Alternative management controls will have to be devised for these fisheries, involving either (1) output controls coupled with accurate stock size assessments, or (2) measures to directly limit exploitation rates independently of fishing effort, through measures like large closed areas.

Status and Management Options for the Barramundi Fishery

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Summary

The NT barramundi stocks are generally in good health. Stocks were reduced substantially by commercial fishing during the 1970's and early 80's, and some have increased considerably since the mid 1980's in response to commercial effort reductions. Three major stocks (Roper, McArthur, Daly) are at near optimum levels for production of commercial yields, and a few have recovered to almost natural levels (Mary, Kakadu) following near complete closures to commercial fishing in 1990-91. Recruitments were almost certainly not impaired at any time during the peak period of commercial catch removals; high recruitments were apparently maintained by increased juvenile survival rates during periods when total egg production was much reduced, and these increases in survival rates were likely due to reductions in cannibalism by older fish on the juveniles. Studies at Corroboree show a dramatic inverse relationship between abundance of age 0 juveniles and abundance of age 1 juveniles, indicating that cannibalism by age 1 fish on the younger juveniles is a major factor limiting recruitment rates. Recreational fishing efforts have not responded to increases in abundance in the Mary River following almost complete closure of the commercial fishery; other factors like water lily invasion, access development, and increased availability of fish caused by the barrage appear to be major determinants of the recreational fishing effort pattern. It is also possible that a significant proportion of the fish taken by commercial fishermen on the Mary have been mainly juveniles that have reared entirely in salt water, rather than from the stock of juveniles that rear in freshwater and have been the main target of recreational fishing until recently. Considering the Mary River experience, it is not clear that substantial net economic benefits, in the form of new income and job creation caused by attracting more recreational angling effort, will accrue to the Territory from further reduction of the commercial fishery in favor of recreational fishing. Most of the potential benefits to recreational fishing from increased stock size due to reduced commercial fishing have already taken place, and in fact had already occurred by 1990. Remaining conflicts are primarily over localized competition for fish in particular fishing spots. There are substantial opportunities for further development of the guided recreational fishing industry (tour operators), and a major area of future conflict may well be between tour operators and local recreational anglers rather than between recreational and commercial net fishermen. There is a key need for better monitoring of the development of recreational fishing, and for comparison of recreational and tour operator performance between river systems that have been subject to different degrees of restriction in commercial fishing.

Methods of Assessment

Barramundi stocks have shown "classic" responses of catch per unit effort and body size to violent changes in commercial fishing effort. Stocks were depleted rapidly during the 1970s, then recovered substantially following effort limitation programs in the early 1980s. With long data histories (1972-1995) clearly showing the depletion and recovery pattern, it has been possible to apply a variety of standard fisheries assessment models (surplus production, delay-difference, age-structured) to the data, and to have these alternative methods give remarkably consistent estimates of unfished stock sizes, degree of depletion, and optimum exploitation rates for long term yield. Attention in our analyses focused on evaluating possible violations in the assumptions of the standard methods, including (1) possibility that cpue was not proportional to stock size, and instead decreased either more or less rapidly than would be expected if commercial fishing were randomly distributed in space; (2) violation of statistical assumptions about process versus observation errors; (3) effect of ignoring the complex size-age selectivity of commercial and recreational harvesting caused by the way fishing is concentrated on particular age groups and on immature/male fish. We tried various statistical assumptions in the estimation procedures, constructed detailed age-structured models to represent the complex selectivity pattern, and used multiple-stock joint estimation procedures to make use of shared information across several stocks about parameters that are likely to be the same in several river systems (catchability, basic productivity per spawner at low stock sizes). The bottom line of these investigations and tests is very simple: all methods and approaches give virtually identical estimates of key stock assessment parameters, and possible violations of assumptions have not had serious impact on the estimates. None of the assessment models suggest any decrease in recruitment rates for any river system during the peak period of commercial depletion; in order to explain sustained yields and stock recovery during the 1980s and 1990s, we have to assume that recruitment rates were either stable or even increased during that period (when we forced the population models to exhibit recruitment overfishing during the late 1970s to early 1980s, the models consistently predicted lower population densities and catches than actually observed during the 1980s and 90s).

Considerable attention has been directed in recent NT stock assessments to estimation of the effects of changes in rainfall and freshwater rearing habitat on recruitment and vulnerability to fishing. Our analyses suggest that rainfall effects in particular may not be as straightforward as has been assumed. Direct estimation of recruitment anomaly time series suggests that there are large scale, correlated patterns of recruitment variation over time that are not related in any obvious way to known climate or freshwater habitat size factors. Rainfall effects on recruitment to the commercial fishery may even be negative, implying either that the main stocks fished commercially are derived from juveniles that rear in salt water (and whose rearing opportunities may even be reduced in wet years), or that wet years create ephemeral rearing habitats that later become "death traps" for many juveniles as the habitats dry down. Examination of age 0 and age 1 abundances measured in the "barracade" depletion experiments that have been carried out at Corroboree on the Mary River for the past 10 years reveals a very striking pattern that may explain the lack of correlation between recruitment and environmental factors such as rainfall and development of barrages to prevent salt water intrusion into upstream floodplain areas. The barracade data show a very precise alternation of high and low abundances of age 0 fish, with age 0 numbers being up to an order of magnitude larger every other year. These high age 0 years are followed by high age 1 abundance the next year, and usually high age 2 abundance the following year. Alternation of high and low years for age 0 survival is also suggested in juvenile sampling data from Kakadu and from commercial catch age composition statistics for 1986-7. Especially in view of considerable direct evidence for cannibalism from examination of barramundi stomach contents, it is quite likely that the alternation in age 0 abundances is caused by massive cannibalism of age 1 animals. That is, high age 1 abundance in any year leads to massively reduced survival of age 0 fish the same year. Then the next year, the resulting low abundance of age 1 fish allows much better age 0 survival, which leads the next year to high age 1 abundance to start the cycle again. This "density-dependent" feedback mechanism is very likely the reason that barramundi stocks have been able to withstand extremely high exploitation rates without showing any sign of recruitment failure: reduced abundance of larger fish by fishing has led to increased survival rates of juveniles and hence to maintenance of high overall recruitment rates.

Estimates of optimum annual exploitation rates vary from 20-30%. Current exploitation rates by commercial fishing range among rivers from less than 3% (Mary, Kakadu) to 10-20% (Daly, McArthur, Roper). Exploitation rate by recreational fishing can be estimated only for the Mary River, and there it is about 5-10% annually of the juvenile stock. Thus three major stocks now appear to be harvested at near maximum sustained yield levels by commercial fishing (Daly, Roper, McArthur), and two are now exploited at rates far below their commercial potential (Mary, Kakadu rivers). Historically, ease of access and related economic factors led to mobile commercial fishermen putting too much effort into a few rivers and too little into others; regionalization of fishing licenses and regional effort restrictions in order to prevent such problems would have been a major issue in this analysis were it not for the overriding impact today on the commercial fishery of closures aimed at providing better recreational fishing. Such closures have forced redistribution of commercial effort into a smaller number of fishing sites, but have not led to overfishing in such sites as yet. The commercial fishery is now operating at roughly 30% below its economic potential in the absence of restrictions related to recreational fishing and aboriginal fishing rights.

Analysis of Territory-wide commercial fishing opportunities, and expected restrictions due to aboriginal fishing rights and continued pressure to reduce competition with recreational fishing, suggests that the commercial fishery may soon be restricted to only a few widely scattered fishing areas. Should this happen, it is questionable whether the remaining commercial license holders would be able to maintain an economically viable fishery.

The central issue in the barramundi fishery today is whether to continue restricting commercial fishing in favor of recreational fishing development. This political and economic issue cannot be clarified by any simple calculation of relative benefits to the people of the Territory from allocating catch to one type of fishing or the other, as indicated by the following discussion. A common argument is that recreational fishing should be allowed to take over from commercial fishing because each fish in the recreational catch is much more "valuable" than each fish in the commercial catch (recreational fishermen spend much more per fish than the value of that fish when harvested commercially, and this spending may be much more beneficial to the regional economy than the income from commercial fishing). This argument is misleading in two respects. First, economic value of sport fishing to a regional economy derives not from catch, but rather from fishing effort. Some of the world's most valuable recreational fisheries in terms of creating income and jobs for local economies, such as the Florida Keys tarpon and bonefish fisheries, have no harvest at all. Second, regional benefit is gained from measures such as stock enhancement and restriction of commercial fishing only if these measures attract more recreational fishing effort (and economic activity, jobs, income deriving from this effort) than they cost in terms of direct public outlay or lost income and jobs from commercial fishing. A management policy that simply reallocates catch from commercial fishing to local sports anglers (who would have spent much of their recreational time and money in the region anyway) is not a wise economic policy from a regional perspective. Further, it is not always true that increasing abundance of fish (due for example to reduced commercial fishing) will lead to more recreational fishing effort of the kind that generates net economic value to the region (people spending money in the region that they would otherwise have taken elsewhere). It is quite possible for the increases in abundance to result in "more fish in the esky" for local anglers, more crowding in the best recreational fishing spots, and hence to competition among anglers for the best spots that causes success rates per angler to decrease to the point that some areas even become less attractive for tourist fishing than they were before the reallocation.

The problem of evaluating tradeoffs between commercial and recreational fishing is further complicated by the fact that there are two distinct types of benefit from recreational fishing. One of these is directly measurable economic benefit to the region that derives largely from tourists bringing money into the region. The other is wealth for Territorians created by having a unique recreational opportunity and fish for home consumption. This wealth may be far more important in the end to Territorians than jobs and income from either tourists who come specifically to fish or from commercial fishing. Economists sometimes try to measure this wealth by estimating the amount of money that people spend, or would be willing to spend, for the recreational experience; the value of such calculations is dubious, and invites misunderstanding of the basic policy problem for Territorians. The policy question for local anglers should not be whether recreational fishing is more valuable than commercial fishing, but rather whether the loss of wealth caused by commercial fishing is large enough to warrant foregoing the long term economic values of the commercial fishery (jobs, income). Further, local anglers need to ask at the same time whether the impact of competition with other anglers, both local and tourist, at favorite fishing spots might well have a much larger impact on the quality of their fishing than does commercial fishing. Fisheries stock assessment cannot go far to help in the analysis of such questions, except to provide objective information on the impact of commercial (and recreational) fishing on the abundance of fish.

The above discussion is not meant to imply that there should be no further restriction of commercial fishing in favor of sports fishing development. It might well be that the Territory would be ultimately better off economically if the commercial fishery were eliminated. But data now available for the Mary River, where commercial fishing has been drastically reduced since 1991, cast doubt on whether a net benefit can be achieved by the simple expedient of just turning an area over to sports fishing in general without further policy changes related to allocation of catch and effort opportunities within the sport fishing “community”. Sport efforts have been measured in the Mary since 1989. From stock rebuilding models and commercial effort statistics, it appears that the stock in this system has increased by roughly 20% since 1989 (following a much larger rebuilding during the mid to late 1980s). Sport efforts have varied greatly, but have not shown a consistent trend related to the stock rebuilding. Effort appears to have been impacted more by a water lily increase that peaked in 1991-2, by development of access at Corroboree and Shady Camp, and by concentration of fish at the barrage at Shady Camp. Recreational catch per unit effort, an obvious indicator of fishing quality and a “take home” measure for tourists who might consider coming again or directing others to the area, has actually not increased over the last few years. This lack of an increase could be due to increased effort by less experienced anglers who are taking advantage of improved access, but it may also reflect increased competition among anglers for favored sites. Competition will likely intensify in the future with further development of general recreational fishing and fishing tour operations.

There is a key need to develop methods for predicting the effect of changing fish abundance and competition among anglers on recreational fishing effort and success rates. Some success at such predictions has been obtained in North American situations (Pacific salmon, trout, warm water lake fisheries) by combining three types of observations: (1) recreational catch per effort is about proportional to the abundance of fish available; and (2) recreational fishing effort is also roughly proportional to abundance of fish present at any moment during a fishing season (actually, effort responses lag abundance changes by a few days to a few weeks, due to sports fishermen having imperfect information about changes in the quality of fishing; these lags are not critical in the following argument); and (3) the abundance of fish available to angling (number of fish that will respond to fishing gear) is only a small part of the total stock, and this available abundance can be subject to rapid short-term depletion even if exploitation rate on the total stock is very small. Combining these three relationships leads to a model that predicts total fishing effort over each fishing season as a function of abundance at the start of the season. The mathematical form of this model is a logarithmic increase in total effort with abundance, ie total effort does not increase as rapidly with abundance as might be expected. [For technical readers: if available abundance N changes during each fishing season according to $dN/dt=-FN$, where $F=qE$ is fishing mortality, and if effort $E=aN$ at any moment during the seasonal change, then the available stock changes as $dN/dt=-qEN=-qaN^2$. This pattern of seasonal decline implies that the instantaneous abundance N at any moment t during the season will be given by $N_t=N_o/(1+aqN_ot)$, and the cumulative effort over the season will be given by $E_{total}=(1/q)\log_e(1+aqN_ot)$]. The reason why total effort does not vary as rapidly with abundance as might be expected from the strong short-term effort response to immediate abundance is that abundance increases are translated into increases in catch per effort (which reduces available abundance) as well as into attracting more effort, unless the recreational catch is deliberately restricted using measures such as catch-release regulation or very low bag limits. In North America, there have been many attempts to attract or support more recreational fishing effort by increasing fish abundance via techniques such as hatchery stocking of trout and closure of commercial fishing; these attempts have produced more modest effort increases than expected (except where there have been severe bag restrictions), due to the logarithmic effect: having more fish improves success rates (cpue) early in fishing seasons, this attracts higher early season efforts, but then catch rates fall rapidly so that total season effort (and economic value) is only modestly improved over the situation before management intervention.

Alternative Hypotheses About Stock Status and Sustainability

Sustainability of the NT barramundi stocks is not an issue of immediate concern. The stocks have shown remarkable resilience in the face of extremely high exploitation rates and habitat changes such as barrages that limit access to freshwater rearing areas. There is no evidence to suggest that stock structure (spatial pattern of genetically distinct substocks using local spawning and rearing areas) has been eroded by past fishing.

Stock assessments indicate that the major river stocks have recovered, or are continuing to recover, toward natural abundances following reduction in commercial fishing in the mid 1980s. There is some uncertainty about how rapid the recoveries have been in areas where commercial catch per unit effort abundance indices have become unreliable due to shifts in fishing effort patterns in response to local closures. But even in these cases other indicators of recovery, like increasing mean body sizes of fish in the catch, all point to a healthy situation.

The main uncertainties in this fishery are about economic values, and in particular whether greater benefits to the NT economy would occur if commercial fishing were eliminated in favor of recreation. The economic value of recreational fishing derives from effort, not catch. So the question is whether increased abundance due to reduced commercial fishing would attract enough more effort to generate more jobs and income than would be lost from commercial fishing, or instead just result in increased recreational catch rates to a minority of expert anglers with no visible increase in success rates for tourists who are the main ones adding economic value to the region.

Information required for Future Assessments

There are a few remaining needs in terms of basic stock assessment. One of these is to compare commercial and recreational catchability coefficients (relative vulnerabilites) over stocks, by conducting more local depletion experiments like “barracade” in cooperation with commercial fishing operations and by relating catchability coefficients to sizes and structure of fishing areas. It may also be helpful in stock size assessments to obtain regional estimates of carrying capacity parameters using juvenile rearing habitat mapping. There is an obvious need to continue research on the mechanisms and spatial patterns involved in the age 0-1 abundance alternation found at Corroboree, to determine whether this pattern is in fact general over the fishery and whether it breaks down under some juvenile rearing conditions. There is also an obvious need to obtain more data on the relative contribution of salt water reared versus freshwater reared juveniles to the recreational and commercial catches for various river systems.

The debate over recreational versus commercial fishing will most likely focus in the near future on the McArthur River. There is an opportunity in this situation (and in others like the Adelaide and Victoria Rivers) to develop a carefully planned comparison with the Mary River, by closely monitoring recreational activity and by testing approaches to (1) reducing recreational/commercial conflict by shifting fishing effort in space and time; and (2) dealing with conflicts within the recreational fishery (e.g., locals versus tour operators) through policies such as exclusive tour operator territories, catch-and-release fishing, and careful planning of access development.

Management Options

There are three main options for future development of this fishery:

Maintain status quo
This policy would involve freezing commercial fishing areas at their present positions, encouraging continued development of the recreational fishery, and continuation of standard fisheries monitoring and regulatory practices to avoid overfishing risks associated with future growth in fishing power. It would not address recreational assertions that further reduction in commercial fishermen would be economically beneficial to the Territory by allowing better recreational fishing, and it would not provide useful information about such assertions.

Move to eliminate the commercial fishery
This is the policy that will most likely be followed, in view of recent experience worldwide with the politics of recreational/commercial fishing conflicts. The main potential drawback with this policy is that it may result in net loss of employment and income to the Territory, if in fact recreational fishing and effort levels are not enhanced by elimination of commercial fishermen. Evidence to date from the Mary River suggests that such a net loss is probable, but the evidence is by no means conclusive.

Defer further commercial reductions pending a demonstration program on the McArthur River. This may be a win-win option for both commercial and recreational fishermen. The basic concept would be to test whether recreational development is compatible with limited commercial fishing, and whether the Mary River experience is representative of conflict situations elsewhere in the Territory. Using the McArthur River, where in-river commercial fishing is still permitted and recreational fishing is apparently growing very rapidly, the NT government would undertake to provide enhanced recreational fishing opportunities without eliminating the commercial fishing, for a several year "trial period" that does not involve any permanent commitment to either fishing interest. As inducement for recreational fishermen to cooperate with this demonstration program, at least the following incentives would be offered: (1) an access development program (roads, boat ramps) to provide better recreational access as quickly as possible; (2) provision of a full time fisheries liaison officer in the area to not only monitor the fisheries development but also to help ensure compliance with fishing controls in the area; and (3) elimination of recreational closures that are not likely of significant conservation benefit in other areas, particularly the Mary and Daly Rivers. On the commercial fishing side, the best inducement would be to declare a moratorium on further barramundi fishing area closures elsewhere in the Territory, until results of the demonstration program become available. An exception to this moratorium should be made only in the demonstration area, where it would be useful to introduce a two-year closure to commercial fishing in at least part of the area inside the McArthur where commercial fishing is now allowed, during the middle of the trial period, that would provide a clear and immediate demonstration of whether the commercial fishing does in fact influence recreational success rates.

Benefits

The review indicated that:

- there is opportunity for growth in a few of the fisheries, particularly the red snapper fishery in deeper offshore waters;
- some of the fisheries, like barramundi and mud crab, are fully developed now - this means that fishermen are already exploiting the stocks at a level that would be biologically safe, and in most places where fish are available;
- the goldband snapper fishery is very likely to be overfished in the near future, not by Australians, but by Indonesians - goldband snapper move back and forth across the border of Indonesian, and are likely to face overfishing by developing fisheries in the Indonesian sector.

Intellectual Property and Valuable Information

Intellectual property and valuable information gathered during this project will be published and made freely available to the industry and public.

Further Development

Goldband snapper

There is a critical need at this point to either obtain direct stock size assessments via some method such as localized depletion experiments, or to develop a management regime for directly limiting exploitation rate without having to know the absolute stock size (e.g., large closed areas). There is a further critical need to obtain information about interaction with the Indonesian fishery, which should involve assessment of their effort/catch development, and also tagging studies to estimate movement rates of fish between the Australian and Indonesian fishing zones.

Mud crab

There are three key needs for future assessments in this fishery:

1. refined estimates, and estimates from more spatial locations around the fishery, of crab densities per unit habitat area;
2. refined estimates, using maps, GIS computer mapping techniques, and discussions with experienced fishermen, of total habitat area and density variation across different habitat types (e.g. open coast versus mangrove creeks); and,
3. development of a more precise fishery reporting system for spatial location of catches, changes in fishing techniques, and size distributions of crabs taken and released from traps.

Coastal reef fish and red snapper

It would be possible in principle to quickly improve the total stock size and potential yield estimates for both coastal species and red snapper, by investing in two types of information gathering:

1. detailed mapping of spatial habitat patterns (coastal and deepwater reef structures), to assess total area over which to apply stock density (fish/habitat area) estimates; and,
2. use of depletion experiments, tagging experiments, and direct visual surveys (divers, video) to obtain estimates of stock density.

Biomass estimates from this two-step analysis could then be used in conjunction with productivity assessments from growth data to provide good estimates of stock fish-down times and sustainable harvests. An obvious way to proceed with the two types of information gathering would be to develop close collaborative arrangements between NT government scientists and experienced commercial fishermen. Fishermen have already accumulated a wealth of information on habitat patterns, and mapping this information could lead to efficient programs for filling spatial data gaps by cooperative government and fishermen surveys conducted in conjunction with normal fishing operations.

Barramundi

The main uncertainties in this fishery are about economic values, and in particular whether greater benefits to the NT economy would occur if commercial fishing were eliminated in favor of recreation. The economic value of recreational fishing derives from effort, not catch. So the question is whether increased abundance due to reduced commercial fishing would attract enough additional effort to generate more jobs and income than would be lost from commercial fishing, or instead just result in increased recreational catch rates to a minority of expert anglers with no visible increase in success rates for tourists who are the main ones adding economic value to the region. The debate over recreational versus commercial fishing will most likely focus in the near future on the McArthur River. There is an opportunity in this situation, and in others like the Victoria River, to develop a carefully planned comparison with the Mary River, by closely monitoring recreational activity and by testing approaches to (1) reducing recreational/commercial conflict by shifting fishing effort in space and time; and (2) dealing with conflicts within the recreational fishery through policies such as exclusive tour operator territories, catch-and-release fishing, and careful planning of access development.

Staff

The workshops were run on a Division wide basis, and involved staff from all 3 programs: Aquatic Resource Management; Client Services and Development; and, Aquaculture.

Final Cost

The final cost of the project was about $86000, of which $19894 was contributed by FRDC. The other contributors were the Northern Territory Fishing Industry, Northern Territory Fisheries Division, University of British Columbia, Bureau of Resource Sciences, CSIRO Fisheries Division, Queensland Department of Primary Industries, Victorian Marine and Freshwater Research Institute and Western Australian Fisheries Department.

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