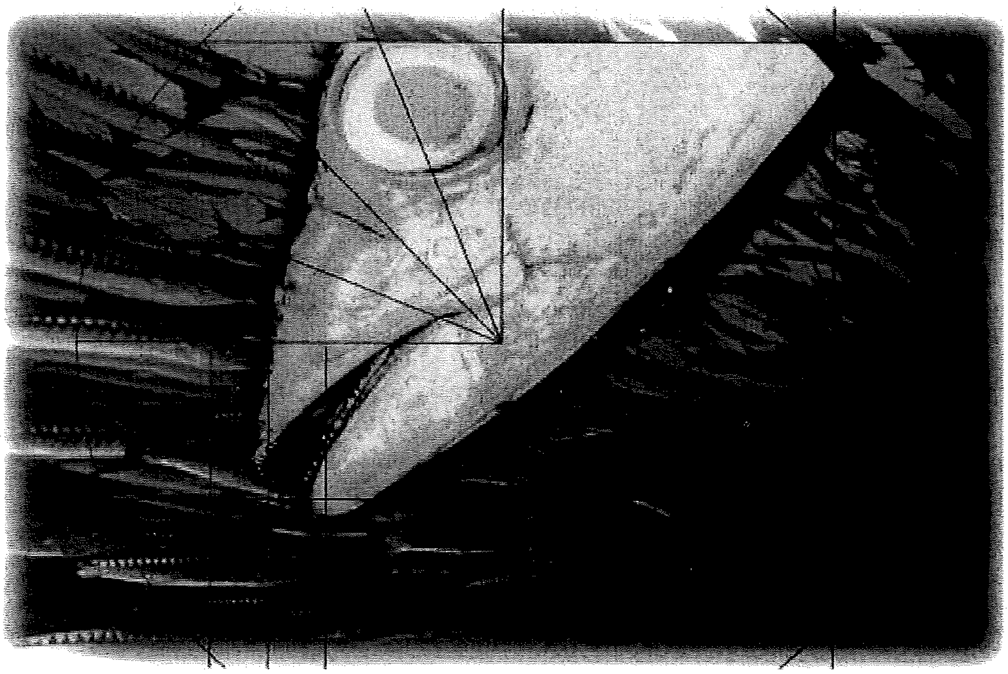
Fisheries Research and Development Corporation



Evaluation of Selected FRDC Research Impacting the Environment

BDA Group

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Contents

Evaluation Summary

What we did

eSYS Development and BDA Group were contracted by the FRDC to carry out an economic evaluation of eleven completed research projects. The projects selected were believed to have generated significant environmental benefits, and in some cases, significant commercial benefits as well. An important objective of the study has been to include, to the extent practically feasible, environmental valuations into the assessment framework, so that the total payoff to research can be considered more meaningfully. To date there has been little quantitative evaluation of FRDC projects targeted at environmental impacts. Projects included;

1. Abalone habitats and impacts of sea urchin colonisation.
2. Environmental impacts of disease prevention – EHNV virus.
3. Rapid assessment techniques to determine biological interactions in the SE Fishery ecosystem.
4. By catch reduction in NSW prawn fishery.
5. Orange Roughy stock assessment.
6. Fish Use o sub-tropical salt marsh habitat.
7. Impacts of ponded pastures on barramundi and other finfish populations in tropical coastal wetlands.
8. An assessment of populations of commercially and recreationally important fish and invertebrates utilising large restored wetlands.
9. Restoration of estuarine fisheries habitat.
10. Impact of Prawn effluent on coastal waterways.
11. Physical effects of hauling on seagrass beds.

Approach

- Benefit cost analysis provided the evaluation framework within which an estimate of each project's expected economic pay off was derived. Pay off was measured by a project's net present value (the difference between project benefits and costs over a 30 year period) and benefit cost ratio (the ratio of all project benefits to all project costs).

- Industry benefits considered included lower production costs, increased fishery productivity, higher quality production and industry development. Environmental benefits associated with habitat preservation, increased recreational fishery production and sustainable commercial fishery yields were incorporated in the cost-benefit framework.

- As accurate information on the ecological relationships and cause and effect between ecosystems and commercial activities such as fishing is rarely, if ever, completely available, the evaluation method chosen for each project was based on the availability of key information. These methods included the quantitative estimation of benefit cost ratios, estimation of threshold values and qualitative assessments.

Estimated Pay-Off

- Commercial and/or environmental benefits were estimated for each project. Threshold values, or the value of industry or environmental benefits that are required to justify project expenditures were derived where key drivers of project value were unclear.

PROJECT	APPROACH	COMMENT	PAY-OFF
1. Abalone	Commercial BCR = 4.3 Value of environment & recreational benefits explored	High commercial payoffs with environment & recreational benefits likely to be high compared to available benchmarks	***High***
2. EHNV	Threshold benefits estimated	Estimated threshold is only $84,000 annually, but commercial benefits appear small and insufficient information to identify any environment benefits	***Marginal***
3. SE Fishery	Threshold benefits estimated	Annual threshold value of $209,000 appears low compared to available benchmarks	***High***
4. By-catch reduction	Commercial BCR = 3.2 Total BCR range = 3.3-5.0	Includes benefits from commercial fishery, recreational fishing and marine conservation	***High***
5. Orange Roughy	Positive commercial BCR estimated Environment & recreational benefits discussed	High commercial payoffs with positive additional Environment & recreational benefits	***High***
6. Saltmarsh	Threshold benefits estimated	Environment & recreational benefits appear significant. Due to low project cost, only 42 ha of saltmarsh would require protection for break-even	***Moderate***
7. Ponded barramundi	Commercial BCR = 1.5 Value of environment & recreational benefits explored	Commercial payoffs small but likely environment & recreational benefits significant compared to available benchmarks. Benefits curtailed by limited market potential. Only 18,777 recreational fishers would need to increase catch for projects to breakeven	***Moderate***
8. Restored wetlands	Commercial BCR = 0.3 Threshold analysis of environment & recreational benefits	Commercial payoffs small but likely environment & recreational benefits significant compared to available benchmarks. Only 10,416 recreational fishers would need to increase catch for projects to breakeven	***High***
9. Estuarine Habitat	Commercial BCR = 3.5 Value of environment & recreational benefits explored	Significant commercial pay-off. Only 3,427 recreational fishers would need to increase catch for projects to breakeven, largely as a result of the small size of the project.	***High***
10. Prawn farm effluent	Threshold commercial benefits estimated	Threshold appears low. Only $159 per prawn farm hectare in reduced environmental compliance costs would have to be realised for breakeven	***Moderate***
11. Seagrass	Commercial BCR = 0.7 Threshold analysis of environment & recreational benefits	Commercial payoffs small but likely environment & recreational benefits significant compared to available benchmarks. Only 19,900 recreational fishers would need to increase catch for projects to breakeven. Pay-off hindered by risk	***Moderate***

- Investment in Abalone and By-catch Projects are forecast to generate substantial commercial benefits. Benefit-costs ratios of 4.3:1 and 3.2:1 were estimated for these projects respectively. In the case of Abalone, a ratio of this order suggests that for each dollar invested in research, $4.3 dollars in industry benefits will be realised.

- The estimated commercial benefits for effects of hauling on sea grass and restored wetlands projects are likely to be marginal, although, only small increments in recreational fishing production would justify the financing of these projects. For each of these projects, at least 19,900 and 10,416 recreational fishers per year would need to net increased catches for the projects to break-even.

- Given some 120,000 fishers in 1996 were identified as belonging to fishing clubs, and 3 million Australians have identified fishing as an important leisure activity (ABS 2001) the required number of recreational fishers to justify project expenditures represents a small proportion of the total recreational fishing population. In the case of estuarine habitat restoration (Project 1994/041) only 3,427 recreational fishers would need to benefit for the project to break-even.

- The area of wetlands that would need to be protected, in part as a result of research activities, was estimated for the salt marsh investigation project. Only 42 ha, of the vast area of the ecosystem would need to be preserved for the project to justify financing.

Identification of Evaluation Issues

A major challenge for marine conservation in Australia is the necessity to maintain ecosystem function and integrity in the face of pressures from economic activities, and poor scientific information regarding basic habitat descriptions, ecological relationships and sparse monitoring and long-term quantitative information on impactor effects. As a result, assessing the contribution of projects to ultimate commercial or environmental gains is challenging, and a range of assessment approaches, including some qualitative measures, have been employed in order to assess research payoffs. Issues relevant to on-going R&D management include:

✓ Generally, the link between R&D output and targeted industry/environmental outcome was not clearly stated in project reports. In some cases, further research, development and extension is required prior to the research evaluated in individual cases studies being made available to industry. In a number of evaluation case studies, possible follow-on budgets were specified.

✓ The use of a range of approaches has generally not prevented an assessment of whether or not research payoffs are likely to be positive. However, it does prevent the relative merits of alternative projects to be confidently assessed. This underlines the importance of ensuring that selected projects are chosen to fill identified priority information gaps and R&D efforts are viewed from a portfolio perspective.

✓ A number of evaluated projects were designed to contribute to the stock of knowledge about marine ecosystem function. In these cases, research selection should focus on ensuring the cost-effective provision of strategically targeted and integrated R&D into predetermined priority areas.

✓ FRDC invests in projects aimed at generating economic and / or environmental impacts. In some cases projects targeted at economic impacts may have significant environmental impacts. Investment in these projects may have far more influence over the level of environmental benefits generated by the R&D portfolio than those included in the ecosystem protection program. The use of screens is a realistic option that could be applied at project selection to ensure that environmental benefits across the FRDC R&D portfolio are maximised.

✓ Future environmental assessments of research projects could be improved through the support of marine environment valuation studies. Economic valuations of all major Australian marine ecosystems would prove prohibitively expensive and time consuming. However, strategic investment in environmental valuation and benchmark studies and in collating available valuation information held by FRDC, State Fisheries departments and universities, among others, are likely to be worthwhile. This would complement current FRDC funded research into providing a conceptual framework for the estimation of marine economic benefits. In addition, the outcomes of ex-post studies, such as in this report, could contribute to on-going assessment of research proposals.

✓ Making evaluation assumptions explicit enables debate to focus on key drivers of industry and community benefit. The evaluation framework developed under this consultancy could be successfully applied to other areas of FRDC's investment portfolio. This would strengthen the current assessment of economic and environmental impacts of both proposed and completed investment projects. "Value for money" will remain paramount.

Evaluation Approach

It has not been the role of this study to assess the technical outcomes from research projects, or the performance of researchers in conducting their research and administering FRDC grants. The contribution of research outcomes to the realisation of commercial and environmental benefits has drawn significantly on the opinion of researchers and fisheries managers. The evaluation approach adopted here is benefit cost analysis, and is detailed in attachment 2. Methods used to value environmental impacts are outlined in the next section. Each project evaluation has been reported in a consistent manner with key assumptions made explicit. The format used is described in the box below.

BOX 1: REPORTING FORMAT FOR INDIVIDUAL EVALUATIONS

BACKGROUND

- Why was the project undertaken and over what period?
- What outcomes were targeted?

PROJECT OBJECTIVES
RESEARCH GROUP

- Which research organisation carried out the project?

PROJECT COST

- What was the total cost of the project?
- How much did the FRDC contribute to the project?

RESEARCH OUTPUTS AND OUTCOMES

- What were the key deliverables from the project?
- How have the outputs been used to generate economic and environmental impacts?

ECONOMIC IMPACT

- What has been the economic impact of project outputs on the commercial operations of state and commonwealth managed fisheries?
- What is the value of these generated benefits in monetary terms?

ENVIRONMENTAL IMPACT

- What has been the environmental impact of project outputs?
- Have these impacts generated benefits for fish based ecosystems or the wider environment?
- What is the monetary value of these benefits across the community or specific community groups such as, for example, recreational fishers?

ADOPTION

- To what extent have project outputs been adopted to date?
- What is the expected rate and level of adoption in the future?

BENEFITS

- What is the total value of benefits that can be attributed to the project?

PAY OFF

- What is the estimated pay off, in monetary terms, on the project investment?
- Economic performance measures such as the project's net present value, break-even value and benefit cost ratio are reported where appropriate.

COMMENT

- Has the project yielded significant environmental or economic benefits?
- What has been the main driver of the pay off on the project investment?
- Has the investment delivered significant net benefits, where project benefits are likely to exceed project costs?

Valuing Environmental Impacts

The valuation of marine resources requires an understanding of the services provided by these resources and the importance placed on those services by the Australian community. In this chapter, Australian marine policy is firstly examined, as it reveals an implied valuation of the marine environment. The nature of marine environmental services is then considered followed by a review of methods to value marine environmental services. Available valuations pertinent to this study are also canvassed. Lastly, the valuation approach adopted in this study is described.

Management of the marine environment

Australia's ocean ecosystems and their marine biological diversity are core national assets. The biodiversity significance of an area depends upon the ecosystems it embraces, as well as on the genetic information contained in the genes of individual plants, animals and micro-organisms. Ecosystem relationships are complex and are not well understood. Consequently the removal or disturbance of one part of the ecosystem may have unforseen impacts on another part of the ecosystem and biodiversity prevalent. (NVAC 2000)

Fishing can cause significant pressure on the marine environment through the taking of target species, the taking of by-catch species and through disturbance of habitat (such as trawling impacts on seagrass beds). These effects can then lead to indirect effects on population structures and food chains (including increased populations of scavenger species), which in turn can affect the diversity, abundance and range of marine species (DEST 1995).

Other impacts on the marine environment arise from pollution, transport (eg; oil spills, introduced organisms via ballast water), petroleum exploration, coastal modification, and land management practices which effect nutrient and sediment loads into coastal waters.

Until the introduction of the Environment Protection and Biodiversity Conservation Act in 1999, there were no broad Commonwealth, State or Territory legislation covering the conservation of biological diversity, although there are a number of laws covering the management and conservation of the environment and natural resources.

The concept of ecologically sustainable development (ESD) was embraced formally in Australia with the development in 1992 of the National Strategy for ESD. This strategy's goal is:

> *'Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends'*

In addition to economic and social objectives, a core objective of the strategy was 'to protect biological diversity and maintain essential ecological processes and life support systems'. An important guiding principle identified was the 'Precautionary Principle' that states 'where there are treats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation' (Environment Australia 1998).

The aims of this strategy were incorporated into the National Strategy for the Conservation of Australia's Biological Diversity in 1996. The goal of the strategy is to protect biological diversity and maintain ecological processes. The strategy calls for identification of the condition or state of biological diversity and of the pressures on it.

To satisfy Commonwealth Government requirements for a demonstrably ecologically sustainable fishery, a fishery must operate under a management regime that meets principles 1 and 2 below (Environment Australia 2001).

PRINCIPLE 1.

> A fishery must be conducted in a manner that does not lead to over-fishing, or for those stocks that are over-fished, the fishery must be conducted such that there is a high degree of probability the stock(s) will recover.

PRINCIPLE 2.

> Fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem.

Australia's Oceans Policy, launched in December 1998, is a major initiative aimed at developing an integrated and ecosystem-based approach to planning and management for all ocean uses in areas under Australia's jurisdiction. The Oceans Policy specifies action including developing an improved understanding of the marine environment, including environmental baseline surveys and sustainability indicators, monitoring and improved assessment of the impacts of commercial and recreational activities (Commonwealth of Australia 1998).

In 1998, the OECD evaluated Australia's performance in protecting marine biodiversity and concluded;

> *'Australia's recognition of the importance of international co-operation for ecosystem and biodiversity management is evidenced by its early ratification of major conventions and the active, often leading role it has played in developing national responses and new international regimes for marine issues.*
>
> *'The 1996 National Strategy for the Conservation of Australia's Biological Diversity is supported by sectoral strategies. New legislation introduced throughout Australia has resulted in improved fishery management.*
>
> *'(However) the extent and intensity of pressures leading to habitat loss and modification, for both terrestrial and aquatic ecosystems, continue to present an extremely serious threat to Australian biodiversity, with a very high number of threatened and endangered species. The status of some marine species, including mammals, reptiles and fish, is of particular concern.' (OECD 1998)*

A key recommendation was to further improve the knowledge base for Australian biodiversity management; expand research efforts, notably to support the preparation of inventories, improved monitoring.

Implications of Marine Policy to Ecosystem Values

In broad terms, Australia has already determined that the benefits of key marine environmental research are likely to be significant, and payoffs to well-directed research are high. Through its commitment to ESD and international agreements, Australia has implicitly placed a high value on species and ecosystem conservation. Commonwealth and State policy commits Australia to improving the knowledge base for biodiversity management and to expand research efforts, such as to support the development of marine inventories.

Moreover, Commonwealth and State legislation now requires, as a prerequisite to the commercial exploitation of fisheries, that catches can be taken while maintaining the ecological sustainability of the marine environment. In this context, a lower-bound estimate of the ecological value of a fishery is the opportunity cost of not commercially exploiting it. That is, the willingness of the Australian community to forgo the commercial benefits of exploiting marine resources reflects a higher valuation of the ecological benefits of those resources that would be put at risk. This willingness is also witnessed in the various fishery closures, restrictions and Marine Parks established to protect marine environments.

Methods for valuing marine biodiversity

Marine areas provide a broad range of goods and services with economic value to society. Many of these are captured in commercial activities such as fishing, tourism and recreation. These 'use-values' of marine areas can generally be revealed through observing prices at which these goods and services are traded, or by applying surrogate market techniques where values can be inferred through reference to other observable prices.

Non-use values provided by marine areas include the benefits derived from reliance on natural ecosystems for life-support functions and the conservation of biodiversity. Because these functions are not traded in markets, they cannot be valued through observing market prices. To determine these values, economists have developed various 'stated preference' techniques, which seek to elicit people's willingness to pay for these benefits. The most widely used method is contingent valuation, although an alternative technique called choice modeling is receiving significant interest (NVAC 2000).

Because stated preference and some surrogate market techniques are expensive in both time and money, economists have employed a range of techniques and assumptions to infer environmental values. Two key applications are summarized below;

Benefit transfer

Drawing on values estimated in previous studies of similar environmental goods is called benefit transfer. This inexpensive technique can be appropriate in the right circumstances, but sound judgement is required in its application. It is generally agreed that the goods being valued must be very similar at both the original site and at the site of application. The (human) populations whose values for the environmental goods are being inferred must also be demographically similar.

The major limitation on using this technique is the availability of suitable studies from which to transfer value estimates. The NSW Environment Protection Authority (EPA) has compiled a database, called ENVALUE, of some 450 existing environmental valuation studies. The benefit transfer approach, drawing on studies in the ENVALUE database, has recently been used by ACIL (1999) when evaluating the impact of research projects funded by Land and Water Australia.

Key studies from the ENVALUE database and elsewhere applicable to this project are shown in appendix 1. Some key observations from these studies are reported below.

There have been few studies into the value of marine ecosystems and biodiversity. Available studies have particularly focused on forests, remnant terrestrial vegetation and wetlands. These studies have been for a range of sites in Australia and overseas and in quite disparate policy settings and demographics. Consequently it is difficult to directly infer any values to Australia's marine ecosystems and biodiversity from these studies. However some broad observations into the order of magnitude of estimated values is instructive.

The study by Loomis and White (1996) reviewed applications of contingent valuation in the USA up to that time. These studies considered the value of conserving a range of species including several fish species. A distillation of these studies produced an average willingness to pay by US households for the preservation of a species at $A22. More recent Australian studies have estimated preservation values of between $4 and $11 per household.

It is also useful to note that households outside of the country that species live in will place a value on conservation of those species. This was shown in the study by CIE (1998) in relation to values held by Australians for the preservation of forests in Vanuatu. It is also consistent with debt for nature swaps, conservation grants, etc where conservation in other countries is clearly valued.

In addition to the conservation or existence values of species, Simpson et al (1996) explored the value of genetic diversity to the pharmaceutical industry. While acknowledging the limitations of their model, they estimated the value of the marginal species to pharmaceutical research at $A13,721.

Therefore, based on the available literature and potential benefits, it would seem reasonable to propose a **conservation value for marine species** found in Australian waters at $5 to $10 per Australian household – and with around 7.2m households in Australia, this represents an aggregate value of between $36m - $72m per species. It is not intended that this value be directly used in benefit-cost analyses, but be used as a reference or benchmark value in threshold analysis (discussed later).

A range of studies has sought to estimate the value of **preserving particular ecosystems**, rather than specific species within those environments. Two studies by Hundloe, Carter and Vanclay (1987) relate to the Great Barrier Reef Marine Park.

Willingness to pay of the Australian population for management of the Crown of Thorns Starfish was estimated by Hundloe et al (1987) at A$15.6 million per year. This may be thought of as equivalent to measuring the willingness to pay to maintain the hard coral diversity parts of the region. However as it only identifies a single threat and a single group of animals, it is therefore likely to be a considerable under-estimate of the value of maintaining the biodiversity of the Great Barrier Reef.

Hundloe et al (1987) also measured part of the existence value together with the option value for the Great Barrier Reef, via a mail survey of a sample of Australians. This contingent valuation study estimated a A$45 million/yr consumer surplus, with visitors willing to pay A$4/visit to ensure that the Great Barrier Reef was maintained in its current state. This study underestimates these values as it excludes Australians who have not visited the reef and also excludes overseas residents, who are likely to value the area significantly.

Other environments and estimated values per household to preserve them are shown in Appendix 1 for the following ecosystems;

- Wetlands
- Remnant vegetation
- Beach preservation
- Lake and river preservation

Again it is difficult to extrapolate from such a diverse range of studies and environments, but it does however demonstrate the significant ecosystem values held by the Australian and international population.

The NSW EPA (1997), using benefit transfer techniques, estimated the value of **improved water quality**. Reported values are for that proportion of residents (20%) and tourists (2.5%) estimated to express positive willingness to pay for water quality improvements and are based on Mattison & Morrison 1985, Desvouges et al 1987 and Green & Tunstall 1991

- Willingness to pay to avoid algal blooms = $57/year by residents and $2/ visitor
- Willingness to pay to improve water quality from boatable to fishable = $47/year by both residents & visitors (based on health factors for fish being edible rather than promoting higher populations of recreational fishing species or improved fishing amenity values)
- Willingness to pay to improve water quality from fishable to swimmable = $ $23/year by both residents & visitors

Improved water quality and the management of commercial fishing pressures on marine populations will also promote catches and fishing experiences had by **recreational fishers**. Some 120,000 fishers in 1996 identified as belonging to fishing clubs, and some 3m Australians have identified fishing as an important leisure activity (ABS 2001)

Specific studies into values held to protect recreational fishing sites have identified a willingness to pay for sites along rivers in Eastern Australia in excess of $25 per household per annum, rising to several hundred dollars per recreational fisher in relation to protecting major wetlands used for recreational fishing in the USA. See Appendix 1 for a summary of US and European studies (eg. Desvouges *et al* 1987, Morey and Shaw 1989, Mitchell and Carson 1981) which outline willingness to pay for increased recreational fishing yields and improved water quality

Opportunity cost

This approach estimates the cost of using resources by examining the forgone benefits from other uses of the resource. It is especially useful in valuing unique natural resources whose benefits are difficult to identify or quantify, or both. Rather than measuring directly the benefits gained from preserving a resource, one measures what has to be given up for the sake of preservation. A well known example of the use of this technique is the Hell's Canyon Study in USA by Krutilla and Fischerin1985(NSW EPA 1993).

The opportunity cost approach has recently been used by Atech (1999) when evaluating the impact of research projects funded by Land and Water Australia. In examining environmental returns to revegetating the Australian landscape, Atech noted that too few studies existed to allow benefit transfer techniques to apply and that direct valuation would be too difficult as;

- the environmental consequences are often numerous and spatially dispersed
- there are long delays between investment and return, and
- the dose to response relationships are often uncertain.

As an alternative, Atech observed that the community had already decided that some land and water resources should be returned to environmental uses, and in doing so had implicitly valued the environmental benefits greater than the marginal value of otherwise using those resources (principally in agriculture). Consequently, the current market prices of these resources provides a conservative estimate of the environmental values.

In an evaluation of riparian management, Atech argue that the imbalance between the allocation of resources to economic and environmental uses is thought by the community to be so profound that they assume the community is willing to pay 50% more than the value of forgone economic goods. That is, the environmental values are 1.5 times the value of forgone economic benefits.

In the fisheries context, the cost of fishing restrictions introduced to promote sustainable fish stocks or ecosystems can be considered a conservative estimate of the value the community place on these environments. In the case of marine parks, their value would be reflected in the opportunity cost of not establishing commercial fisheries.

Environmental Valuation approach used in this project

The environmental valuation approach used varied depending on the broader assessment framework adopted for each project. While valuation techniques are continually being refined to overcome their limitations, it is important to recognise that regardless of the technique chosen, accurate information on the ecological relationships and cause and effect between ecosystems and activities such as fishing is required. This information is rarely, if ever, completely available. As a result, the evaluation framework chosen for each project is based on the availability of key information. The three frameworks used are described below.

Benefit cost analysis

The benefit-cost analysis evaluation method is described in Appendix 2. The development of quantitative environmental assessments to feed into benefit-cost evaluations were possible where research was directed at clearly identified outcomes, and where these outcomes could be observed and measured. In these circumstances, benefit transfer and opportunity cost techniques were applied to derive broad estimates of environmental values.

Threshold analysis

Notwithstanding the difficulties of establishing the contribution of many environmental research projects to ultimate management changes and ecosystem benefits, it is still often possible to assess projects using threshold analysis.

Often it is not necessary to estimate all of the benefits of a research project to develop an understanding of its merits. In many instances the value of the readily estimated benefits of research may be inadequate for a project to deliver net benefits (that is, a BCR exceeding 1) without knowing the value of the more intractable ecosystem benefits. Therefore a strategy adopted in some studies has been to estimate how large the ecosystem benefits need to be in order for the project to deliver net benefits.
This 'threshold' value can then be compared with available benchmarks in order to assess its reasonableness. In some instances, the probability of certain actions being undertaken in the 'without project' scenario has been the most uncertain information, and so this probability has been set as the threshold variable to be determined and assessed.

Qualitative analysis

Some projects are not designed to deliver a commercial outcome – many just contribute to knowledge. This comment is equally valid in relation to the assessment of environmental projects which are baseline and incremental in nature. That is;

- Many project outputs are likely to represent <u>'baseline information'.</u> This could include information on the basic biology and population dynamics of individual species, characteristics of particular fisheries or habitats. In such circumstances it is difficult to quantify market or environmental benefits arising from the research – rather the information is generated as an input to broad research and policy processes aimed at promoting marine conservation.

- It is often the case in fisheries research that the <u>cumulative efforts</u> of many research projects are needed to provide sufficient information to achieve desired benefits. Benefit-cost assessment of an individual project is inappropriate where project outcomes contribute to, but are not sufficient in themselves, to make any measured improvement.

In these circumstances of unclear 'cause and effect' relationships, attempts to place a value on resulting environmental benefits at the project level would be extremely difficult and perhaps misleading.

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1. The Abalone Fishery and Sea Urchins in NSW (1993/102)

BACKGROUND:

The FRDC funded project 93/102 *Interactions between the abalone fishery and sea urchins in NSW*, was begun in 1993 and a final report was produced in 1998. The focus of the research was to undertake baseline stock assessment surveys of abalone and sea urchins across different habitat in southern NSW.

PROJECT OBJECTIVES:

- To quantify changes in the abundance of sea urchins and abalone on reefs in southern NSW
- To describe the extent of the "barrens habitat" and the degree to which it is expanding on reefs in southern NSW
- To describe the influence of habitat type on the abundance of abalone
- To describe the effects of habitat type sea urchin density and harvest time on the quality of roe harvested from sea urchins
- To gather preliminary data on the potential for a sustained fishery for this species in NSW

RESEARCH GROUP:

The research was undertaken by the NSW Fisheries Research Institute at Cronulla, with Neil Andrews being the principal investigator.

PROJECT COST:

FRDC provided $374,612 while NSW Fisheries provided around $320,000[1] representing a total research budget of $694,612.

RESEARCH OUTPUTS AND OUTCOMES:

Key deliverables from the project were;

- Sampling programs and baseline stock assessments for both abalone and sea urchins,
- The extent of 'barrens' habitat was mapped and it's significance for the abundance of abalone identified – including the potential role in modifying sea urchin populations and in turn the recruitment, survival and growth of abalone, and,
- Identification of factors influencing the quality of sea urchin roe.

The baseline information and stock assessment methods have been adopted and applied in annual stock assessments now being undertaken by the NSW Abalone fishery. These assessments in turn are being used in setting annual TACs, with the aim of maximising sustainable yields from the fishery.

The information on sea urchin populations is being used in the development of a management plan for this fishery. It is also expected that the ultimate management plan will be developed such that returns in the fishery and the abalone fishery collectively are maximized. That is, reducing densities of sea urchins will encourage the recovery of abalone populations, which can be further facilitated by the transplant of abalone broodstock (Worthington, pers. comm. 18/5/01)

ECONOMIC IMPACT

Overfishing of abalone populations have led to the collapse of some fisheries, such as at Kiama, where commercial catches have fallen from around 50t to zero. Concern over the sustainability of catches in the broader NSW abalone fishery in the 1990s was likely to have led fishery managers to significantly reduce TACs, potentially even by half (Worthington, pers. comm. 1/5/01).

The stock assessment research undertaken in this project identified significant young recruits coming into the fishery and provided confidence in the introduction of only a small cut in the TAC in 2000 – from 333t to 305t. With an increase in abundance during 2000/01, it now looks as if around a 10t TAC increase may occur in 2001 and a return to around a TAC of 330t in 2002 (Worthington, pers. comm. 18/5/01).

Consequently, the research is likely to have enabled significantly higher catches this decade than would have been allowed basing TACs only on catch records. The value of this work is also reflected in the approximately $350,000 the industry now pays annually to NSW Fisheries for on-going stock assessment work (Worthington, pers. comm. 1/5/01).

The sea urchin research can be expected to both speed up the development of this new fishery (as there will be greater confidence in setting sustainable TACs) and increase the quality of product (roe) captured.

This fishery has increased in size from around 10t (live urchins) when the research was initiated to around 500t currently. However the longer-term size and commercial viability of this fishery is still yet to be confirmed, and the contribution of the research by NSW Fisheries cannot be determined at this stage.

ENVIRONMENTAL IMPACT

The setting of sustainable TACs and measures to limit the illegal taking of abalone is directed primarily at protecting the commercial value of the fishery. However these actions also act to safeguard against the collapse of abalone populations and any flow-on impacts to marine ecosystems. Total benefits from the research therefore include the commercial benefits of higher sustainable TACs and the unpriced 'spillover' environmental benefit of conserving abalone populations.

Rolfe et al (2000) estimated the average willingness of Brisbane households to pay to avoid each 1% loss in the population size of non-threatened species from land clearing in the Desert Uplands region at $1.69 – or more than $1m in total (given 616,000 Brisbane households in 1999 (ABS 2001)). While these results cannot be directly used to infer values for maintaining abalone populations in NSW, it does indicate the potential magnitude of such values.

The broader baseline ecosystem information on sea urchins and interactions with abalone populations provided by the research is likely to also yield other environmental benefits, but the nature of these yet unknown benefits prevents their valuation.

ADOPTION

The outcomes of the research have essentially been fully adopted, and have led to higher TACs and catches than otherwise can be expected to have prevailed over the period 2000 to 2010. The research may have also enabled higher catches beyond this period, but likely differences are more speculative.

BENEFITS

Two alternative estimations of commercial benefits can be made. Firstly, the willingness of the industry to commission on going stock assessments by NSW Fisheries is an expression of the minimum value of the work to the industry. This approach would yield an estimated benefit of $3.5m over the assumed adoption period and a BCR of 4.3

Alternatively, the benefits will be reflected in the difference in industry profits expected with the higher TACs and catches over the adoption period. Without detailed stochastic modeling and research, it is not possible to estimate this difference. However the threshold level at which increased TACs over this period would lead to higher rents in the fishery equivalent to the research costs is estimated below.

PAY OFF

The graph below shows the stream of benefits (ie; increased fishery rents) required to equal the cost of undertaking the abalone research. This threshold is around a 4.4% increase in annual catches over the period 2000 to 2010.

For illustrative purposes only, if each NSW household placed an environmental value of $1 on each 1% increase in abalone populations achieved, this would equate to additional benefits of around $11m per year from the research.

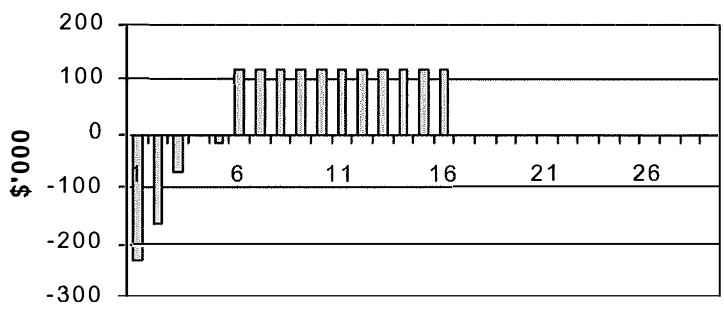
COMMENT

Significant commercial and environmental benefits are likely to have resulted from this project. It has not been possible to estimate all benefits. However based only on commercial benefits to the abalone fishery, the project would yield a BCR of 1 if it has facilitated an increase in TACs of 4.4% or higher over the period 2000-2010, equivalent to an increase in profits of $115,000 annually over the period.

As TACs may have been cut by potentially up to 50% in the absence of this research, the industry is willing to pay some $3.5m over 2000-2010 for continued stock assessment work. Using this conservative estimate of the value of the research to the abalone fishery yields a BCR of 4.3.

Consequently, it can be concluded that the research has delivered significant net benefits purely on commercial benefits to the abalone fishery. The

Benefits and costs through time



likelihood of significant additional benefits to the sea urchin fishery, to recreational fishers and to marine conservation further supports the expectation of high payoffs from this research.

ABS (2001), Year Book Australia 2001, Canberra

Worthington, D. (2001), Pers. Comm., Duncan, NSW Fisheries, 1 May and 18 May.

Rolfe, J.C., Bennett, J.W. and Blamey, R.K. (2000) An Economic Evaluation of Broadscale Tree Clearing in the Desert Uplands Region of Queensland, Research Report No. 12, Choice Modelling Research Reports.

2. Diagnostic Tests for the Detection of the EHNV Virus (1992/066)

BACKGROUND:

Project 92/66, *National diagnostic tests for the detection of EHNV and certification of EHNV-free fish*, commenced in 1992/93. The researchers successfully developed a test to enable the detection of Epizootic haematopoietic necrosis virus (EHNV) in field samples. A single isolate of EHNV, which can affect both redfin perch and rainbow trout, was identified, and other tests developed to enable the differentiation of EHNV from other iridoviruses in Australia.

PROJECT OBJECTIVES:

- Select optimum EHNV detection protocols and establish these as national tests
- Investigate the use of inactivated antigen in antigen capture ELISAs which would facilitate the distribution of the diagnostic tests
- Use diagnostic tests to determine the minimum sampling sizes and types of samples required for disease-free certification of commercial stocks
- Optimise immunological tests that detect EHNV and anti-EHNV antibodies, from field animals
- Identify tissues/organs within host organisms where the virus replicates
- Differentiate the major strains of Australian iridoviruses

RESEARCH GROUP:

The CSIRO Animal Health Laboratory and the Elizabeth Macarthur Agricultural Institute in NSW undertook the project.

PROJECT COST:

FRDC contributed $367,578 to this project, while the research collaborators provided $846,275. In total, the project cost about $1.2 m.

RESEARCH OUTPUTS AND OUTCOMES:

EHNV is a notifiable disease under the International Aquatic Health Code. In the late 1980s, EHNV had been identified (through post-mortem laboratory analysis) on a dozen or so occasions in SE Australia, largely in wild populations (Hyatt 2001).

This led to a ban in the movement of live fish or spawning product (eg; ova) from EHNV infected zones – such trade however was small in commercial terms.

The movement of live fish or spawning product is now allowed from EHNV infected zones if accompanied by a certification that the consignment is EHNV-free. This project directly facilitated the development of a diagnostic test kit for EHNV and the development of the certification procedures. The improved virus management procedures have resulted in relatively infrequent detection of the virus in commercial populations now (Hyatt 2001).

ECONOMIC IMPACT

EHNV currently impacts the rainbow trout industry, but can also affect salmon. EHNV affected farms are still permitted to sell fish and fillets. Consequently, the economic benefits from the project appear to be;

Prevention of the spread of EHNV to commercial finfish in Australia, overseas or to amphibians and reptiles;

- There is little objective information on the extent that the test and management changes have reduced the spread of the disease to commercial fisheries. Hyatt (2001) notes that the dozen or so incidences of the virus identified in the late 1980s were primarily in wild populations. Outbreaks identified in commercial populations remain very low.

- EHNV was found to 'cause low mortality rates which do not exceed rates commonly found in rainbow trout farms' (FERM 2000).

Based on the available information, the impacts of EHNV on trout farms may not have represented a significant management cost.

Facilitating the export of live fish & ova from EHNV zones in SE Australia;

The project has facilitated certification practices and hence trade of live fish and ova from EHNV zones in Australia to elsewhere in Australia and overseas. This is particularly an issue with the supply of fingerlings or ova from hatcheries to trout farms.

However export of these products from infected zones is very small. In 1999/00, only 8t of the 1.9kt of trout produced in Australia came from outside of NSW & Victoria (ABARE 2001). Consequently the additional cost incurred by producers outside of the EHNV zone in sourcing alternative supplies or limiting production is likely to be small.

Demonstrated Australia's commitment to disease management;

The development of the diagnostic test, subsequent disease management strategies and certification procedures have proved valuable in demonstrating internationally the importance placed by Australia on disease management. Most recently this has assisted representations to WTO in relation to the imposition of bans on Canadian salmon exports to Australia (Nunn 2001).

Provided knowledge on virus characterization;

A better understanding of viruses gained from this project has been instrumental in dealing with a number of other animal health issues (Hyatt 2001). These included a review of proposed biological controls for the cane toad and research into the decline of native frog populations.

While it is clear that the research has generated benefits, FERM (2000) concluded that a quantitative assessment of commercial benefits was not possible because there was no basis to estimate the *likelihood* of disease outbreaks in commercial fisheries with & without the project. Even if this were possible, there was no basis to estimate the *impact* of the virus on the mortality of commercial stocks.

ENVIRONMENTAL IMPACT

The project will have led to environmental benefits if the test, diagnostic kits and subsequent screening practices or related programs have;

- reduced the likelihood of the disease spreading to native fish populations, and;

- the disease would have led to significant mortalities or otherwise affected species abundance, diversity or range.

EHNV is already prevalent in rivers of SE Australia, but testing has prevented the spread of EHNV to other wild rivers (such as through trout restocking in Northern NSW and Queensland) and from hatcheries to trout farms,

EHNV has been transmitted, under laboratory conditions, to a range of native fish including Macquarie and silver perch and Murray cod – posing an (unknown) threat to the conservation of native fish.

Outbreaks of EHNV in redfin populations have had up to 95% mortality, implying that potential impacts to native fish populations may be significant. While EHNV is already prevalent in SE Australian rivers, its future impact on native fish populations is simply not known. Similarly, the potential impact of introducing the virus in other Australian rivers and native fish populations cannot be determined (Nunn 2001).

Consequently the estimation of conservation or tourism values of reduced mortalities in wild native fish populations is not possible.

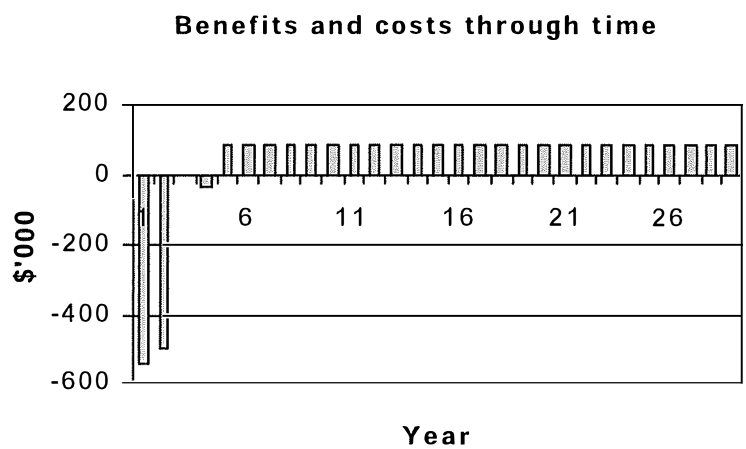
Nevertheless, the development of the diagnostic test and introduction of certification procedures is consistent with a 'precautionary' approach to protecting Australia's marine environment.

ADOPTION

By 2000 research results had been fully adopted. Some 24 testing kits had been distributed to animal health laboratories in Australia, and further kits had been provided internationally. This has enabled effective and routine screening for EHNV, and the certification of live product from EHNV zones in Australia.

BENEFITS

It has not been possible to quantify the impact that research outputs and subsequent management responses have had on commercial fisheries or native fish populations, let alone to value these impacts.



PAY OFF

To provide some understanding of the level of research costs compared to potential research benefits, a threshold analysis to estimate breakeven benefits has been prepared, and is shown below. The breakeven benefits are estimated to equate to only $84,000 per year.

COMMENT

Opinion on the likely commercial benefits stemming from this research varies, due to a poor understanding of the risks of the EHNV virus spreading and mortalities experienced when outbreaks do occur at trout hatcheries and farms. Perhaps the greatest commercial benefits resulting from the research is its contribution to Australian trade and quarantine policy.

It is also likely that the research and subsequent health management practices adopted have reduced the likelihood of the virus spreading to waterways outside of SE Australia. However the risk that the virus poses to native fish is not known. Given the major decline in the abundance and range of many native fish species in Australia, the research and management response is consistent with the precautionary principle and policies to promote marine conservation.

Ultimately, FRDC need to determine whether on balance they believe these benefits are likely to exceed $84,000 per year. Given the highly subjective nature of any such assessment, no determination has been made here.

ABARE 2001, Australian Fisheries Statistics 2000, Canberra.

Fisheries Economics, Research and Management Pty Ltd (2000), Ex-post benefit-cost analysis of project 96/108, report to FRDC.

Nunn M. 2001, National Office of Animal and Plant Health, pers comm. 9 May.

Hyatt D. 2001, CSIRO, pers. Comm. 9 May.

3. South East Fishery Ecosystem (1994/040 & 1996/275)

BACKGROUND:

Australia has committed to protecting its marine ecosystems. This has also required a commitment to a program of knowledge creation and definition of marine bioregions as a basis for managing marine sustainability. Previously, marine regions have been described using measures of species diversity and abundance (ie; biodiversity) rather than of ecological communities.

In 1994 CSIRO started a program of research to identify ecosystem features of the SE Australian continental shelf. The two major projects have been;

94/040 *Habitat and Fisheries Production in the SE Fishery Ecosystem* – this project, commenced in 1994 and was completed in 2000, identified the significant ecosystem features in this fishery and those that were of most importance to sustaining fisheries productivity.

96/275 *Development of a Rapid-Assessment Technique to determine Biological Interactions of Fishers, and their Environment, and their role in the Ecosystem* - this project, commenced in 1996 and was completed in 1999, developed a classification system for the SE Australia shelf ecosystem that is based on ecological processes.

PROJECT OBJECTIVES:

- **94/040** - Survey the structure of habitat types and associated fish assemblages in the SEF shelf ecosystem
- Assess the selectivity of different commercial gear types for quota species in different habitats
- Assess the relative abundance, age composition, distribution and vulnerability to fishing gear of key commercial species
- Define the major trophic linkages of SEF quota species by habitat type and identify the relative importance of benthic, pelagic and inshore sources of production to quota fish species
- **1996/275** - Measure the functional morphology of 50 prevalent species (including quota species) in the SEF shelf trawl fishery, including internal and external features.
- Analyse these morphological features to determine the structure of species assemblages, habitat use, and potential biological interactions.
- Compare the information on community structure, habitat use and biological interactions derived in this study against independent information on habitat use, water column distribution and diet, to determine which morphological features provide useful information on the fishes ecological role.
- Ascertain the potential of functional morphology to provide rapidly and efficiently the information on species
- interactions, habitat use, and susceptibility to fishing gears, that is essential to fishery management using ESD principles.

RESEARCH GROUP:

This research program was undertaken at the CSIRO Division of Marine Research at Hobart and was led by Drs. Nicholas Bax and Alan Williams.

PROJECT COST:

FRDC provided $653,717 while CSIRO provided $2,384,860, representing a total research budget of just over $3m.

RESEARCH OUTPUTS AND OUTCOMES:

The key deliverables from this research were;

- A description of the relationship between fish communities and ecological processes in the SE fishery,
- Identification of key 'leverage points' where management action may improve the productivity of the SE Fishery (these being in relation to minimizing the catch of immature fish and identifying habitats where catch to effort could be maximized), and,
- A methodology for the rapid assessment of fish communities and their ecological role in the absence of detailed taxonomic, habitat and dietary data.

ECONOMIC IMPACT

The research program has provided baseline information on the habitat of commercial fish species, and ecosystem features important to sustaining the productivity of the SE Fishery. This information will allow the development of better management plans for the fishery that could be expected to increase returns to fishers.

To date, information from this research is being drawn on to assist stock assessments of the fishery – such as relationships between fish size and depth, by-catch and spatial distribution of different habitat types (Bax 2001; Towers 2001). However the contribution of this information to improving stock assessments and ultimately catches in the fishery is indeterminate at this time.

ENVIRONMENTAL IMPACT

It is anticipated that this research will lead to an improved ecosystem-based approach to marine planning and management, with early application in the SE fishery (Bax 2001; Johnson 2001).

In particular, the availability of the rapid assessment technique may lend itself to changing methods of marine eco-system characterisation to support regional planning under Australia's Oceans Policy (Johnson 2001).

Collectively, these impacts may change marine conservation policy and fishing activities and in doing so increase the likelihood that all ecosystem types are protected and environmental values maintained.

Two potential applications are instructive. Firstly, the habitat mapping may help identify significant marine habitats and the establishment of area closures in the fishery to protect them (Towers 2001).

Secondly, camera system technologies developed during the research program are being adopted, both in Australia and overseas. This technology is being utilised in a $2m survey of the SE Fishery being undertaken by the National Oceans Office, and in follow-on research by CSIRO (supported by FRDC) into mapping habitat in the SE fishery (Bax 2001). In relation to this work, Senator Hill, Minister for the

Environment and Heritage recently commented on its importance;

> *"This research will help provide baseline data to support the management of Australia's first marine plan area, the South-east Regional Marine Plan, which covers more than two million square kilometres of water.*
>
> *"Marine planning at this scale is a world-first ... (and) ... will help balance commercial, conservation and cultural interests in this area," Hill (2001).*

While the ecological information generated by the research has contributed to the knowledge base underpinning ongoing research and planning activities relevant to the SE Fishery, no technical assessment of research outputs and their adoption is available.

The value of the rapid assessment technique is also still to be determined. Further application and development of the technique is being conducted, and further scientific review and validation work will be required to demonstrate its scientific efficacy (Bax 2001).

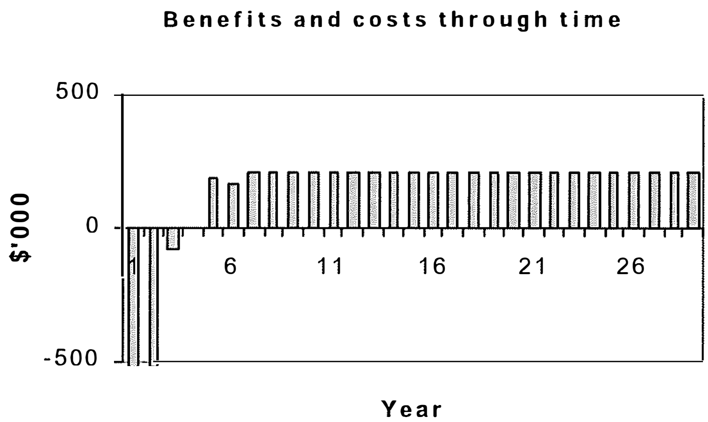
Nevertheless, subject to the technique being proven, it does offer a more holistic means to characterise marine ecosystems, and the National Oceans Office is considering its broader application in future marine planning to be undertaken by the Office (Johnson 2001).
While it is too early to determine the ultimate uptake of the research outputs, fishery managers and marine planners believe the research promises significant improvements in marine planning and conservation outcomes (Towers 20011; Johnson 2001).

ADOPTION

Research outputs have been communicated to key researchers and fishery managers, with some applications of the research information identified. However the longer-term adoption of the research findings are indeterminate at this time.

BENEFITS

While it is not possible to directly estimate the benefits of this research to either commercial fishing or to protecting marine ecosystems, it is useful to examine the level of benefits needed to meet research costs. That is, the threshold value of benefits for the research to be assessed as generating positive net benefits.



Based on the research costs, the threshold level of benefits is $209,000 annually.

This is less than 4% of the $72.2m in gross returns generated annually from commercial fishery operations in the SE Trawl Fishery (ABARE 2001).

The present value of threshold benefits (around $3m) also appears small when compared to the benchmark values established for what Australian are willing to pay to protect a single threatened species (between $36m-$72m) or major ecosystem (say ballpark of $50m – $200m).

The SE Fishery ecosystem is also important for maintaining populations of key fish species sought by recreational fishers. If all fishers who belonged to recreational fishing clubs in Australia were willing to pay $10/year each to maintain this ecosystem, this alone would yield a present value of almost $20m.

PAY OFF

The cost of the research is small relative to both the commercial value of the fishery and likely conservation values held by the Australian community. In this context, payoffs to well targeted research are likely to be high.

COMMENT

The projects represent baseline research required for Australia to meet international and domestic obligations for fostering marine conservation and the development of an improved knowledge base for that purpose. The SE region of Australia is also the first area for which a Regional Marine Plan under Australia's *Oceans Policy* is being prepared. Consequently the Australian community has already placed a high value on improving ecosystem knowledge in this region.

It is too early to assess the exact contribution that this research has made to that knowledge base, or the changes in marine management and ecosystem benefits that it may yield.

However the cost of the research is small relative to the available benefit benchmarks. Based on feedback from fishery managers and marine planners, the projects appear to represent a sound investment with probably high net benefits.

ABARE (2001), Australian Fisheries Statistics 2000, Canberra.

Bax N. (2001), CSIRO, pers.comm.10 May.

Hill R. (2001), Minister for the Environment and Heritage, Media Release 11 May.

Towers I. (2001), AFMA, pers.comm.15 May.

Johnson D. (2001), Manager Planning and Assessments, National Oceans Office, pers.comm.15 May

4. By Catch Reduction in the NSW Prawn Fishery (1993/180 & 88/108)

BACKGROUND:

Concern rose in the 1980's that prawn trawlers were discarding high levels of by-catch, including juveniles of species targeted in other commercial and recreational fisheries. This led to NSW Fisheries seeking FRDC funding for a 3-year by-catch assessment project 88/108 - *Observer-based Survey of By-catch from prawn trawling in NSW.*

With confirmation that large by-catches of juveniles were occurring, NSW Fisheries secured further FRDC support for a subsequent project to explore and develop ways to reduce by-catch capture and mortality; project 93/180 – *Development of by-catch reducing prawn trawl and fishing practices in the NSW prawn trawl fisheries*. This latter project also examined the effects of increasing mesh size in fish trawls.

PROJECT OBJECTIVES:

- To develop and test a variety of modified prawn trawl gears
- To investigate the impact on catch and bycatch due to increasing mesh size in fish trawls from 90mm to 100mm
- Describe the distribution & abundance of by-catch species.

RESEARCH GROUP:

NSW Fisheries undertook the projects. The first project (88/108), was undertaken between 1989 and 1992, and the second (93/180) between 1993 and 1998.

PROJECT COST:

FRDC provided $906,338 while NSW Fisheries provided $335,357, representing a total research budget of $1.2m.

RESEARCH OUTPUTS AND OUTCOMES:

The project successfully developed by-catch devices (BRDs) & practices for application in the estuarine and oceanic fisheries.

FERM (2000) argues that as a result of this project, NSW Fisheries introduced regulations in 1999 that made BRD's mandatory in the oceanic trawl fishery and in the Botany Bay and Port Jackson estuarine fisheries. Subsequent legislation has made BRDs mandatory in the fishery's 3 other major estuaries (Clarence, Hunter and Hawkesbury Rivers).

The outcomes of this research have now also been transferred to other fisheries, including Shark Bay and Exmouth Gulf in WA and Gulf St Vincent in SA.

ECONOMIC IMPACT

Commercial benefits to the NSW fishery were estimated by FERM (2000) to be;

Product quality – with reductions in by-catch, the bruising of prawns in nets has been reduced and a price premium for the improved product observed in some markets. This was estimated at $540,000 per year.

Juvenile by-catch of other commercial species – an estimate was only made for the oceanic fishery, taking into account estimated reductions in by-catch quantities, market prices and factors such as growth and mortality rates which will affect catch changes in the other fisheries. An annual benefit of $468,750 was determined.

NSW Fisheries believe this estimate grossly undervalues the true value. This is due to firstly, differing views on assumed growth and mortality rates and the market value of landings, and secondly, as no account was made of the cumulative population benefit arising from the increased survival of juveniles (Kennelly 2001)

Savings in fuel and labour costs – the reduced by-catch was expected to reduce the drag on nets, leading to fuel savings, and crew time sorting catches. No estimates of these benefits were made.

Improvements in recreational catches – reduced by-catch of recreational species can be expected to improve catch rates in the recreational sector. However because few biological data on individual by-catch species or the range of species were available, FERM (2000) attempted no estimation.

Nevertheless, FERM's analysis implied that some 438 tonnes annually of juvenile by-catch of commercial species can be expected to survive due to the by-catch reduction devices and which are not subsequently caught by commercial operators.

ENVIRONMENTAL IMPACT

The taking of by-catch can have significant ecological implications. Alterations to population structures of the non-target species and changes in food chains can lead to ecosystem changes with potentially significant impacts on species diversity & abundance. In addition, increased populations of scavengers such as sea birds, sharks and crabs may also lead to ecosystem impacts.

However while perceptions of the continued degradation of marine ecosystems through the taking of by-catch were widely held by the community, actual degradation avoided by this project may not have been significant. The impact of 40 years of trawling with essentially the same technology may have already modified the marine ecosystems in these fisheries, such that *rapid* ecological change may no longer be occurring (Broadhurst 2001).

It is difficult to directly assess the environmental benefits stemming from this research due to;

- The reduction in the quantity of *non-commercial* species of by-catches was not recorded (although estimated for the estuarine fishery);
- It is too soon to observe the impact of changes in by-catch population sizes & dynamics, and such observations would require major stock assessment studies; and,
- The impact of changes in the populations of (fish) by-catch species on wider ecosystems is largely unknown.

An alternative way to measure recreational and environmental benefits is by using the replacement cost technique. Prior to this project and the subsequent introduction of BRDs, there had been strong and vocal community concern about the impact of by-catch on recreational fishing and marine conservation. In many other countries, similar concerns have led to permanent closures of (particularly) estuarine fisheries. NSW Fisheries officers (Broadhurst 2001), have indicated that some closures of estuarine, and potentially even oceanic, fisheries may have eventuated in the absence of the (earlier) introduction of BRDs.

The cost to the commercial fishery that such closures would cause can be used as a conservative proxy for the recreational and environmental values held by the community.

ADOPTION

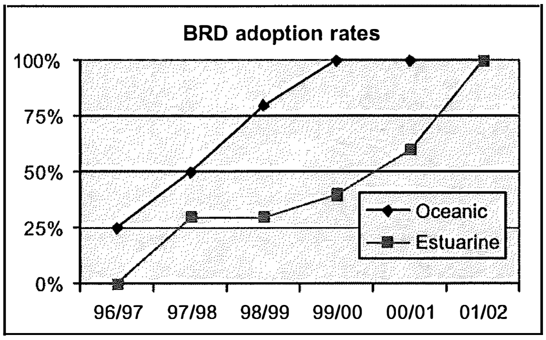
Adoption rates assumed by FERM (2000) are shown in the graph below.

FERM also argues that trends in the management of Australian and overseas fisheries would have led to the development and introduction of BRDs in the NSW prawn fishery by 2004/05 in the absence of the FRDC projects. Hence any benefits from the use of BRDs beyond 2004/05 were not considered in their evaluation.

However NSW Fisheries does not support this argument. While acknowledging that the importation of BRD technology from elsewhere would ultimately occur in the absence of this research, the selection of 2004/05 is seen as arbitrary. For this study, the FERM assumption of benefits ceasing in 2004/05 has been used, noting that this will result in a conservative estimate of benefits relative to the position of NSW Fisheries. (Kennelly 2001)

BENEFITS

FERM (2000) estimated the net benefits of introducing BRDs to the commercial fishery at $2.7m, net of research costs and at a 6% discount rate. This represented a BCR of 5.8. However this analysis assessed only the payoffs to FRDC funds rather than



payoffs to total funding provided by the research collaborators. When total costs are included, the net benefits are reduced to $2.3m and BCR to 3.2.

FERM did not seek to value the benefits flowing to the recreational fishing sector or broader environmental benefits.

The estimated 438t of juvenile by-catch that becomes available to the recreational fishery due to the by-catch reduction devices, is estimated to have a commercial value of $1.1m (based on the FERM analysis). However only a fraction of these fish are likely to be actually caught by recreational fishers, although on the other hand, the recreational value of each fish caught is likely to exceed it's commercial value.

The recreational and environmental benefits from the project estimated using the replacement cost technique is provided below. Profits in the fishery have been assumed at 20% of GVP due to the highly depreciated nature of capital (boats) employed in the fishery, although some studies have indicated profits as high as 40% (Read and Sturgess 1996).

PAY OFF

In the absence of the (earlier) introduction of BRDs, there is a strong likelihood that closures of estuarine, and potentially even oceanic, fisheries may have eventuated between 1997/98 and 2004/05.

The graph below includes the cost of closing the 5 major estuarine fisheries as the recreational fishing and environmental benefits of the by-catch research. The total benefits equal these otherwise lost profits from the fisheries over the period, plus the commercial benefits to the oceanic fishery estimated by FERM. Based only on these benefits, the research is estimated to yield net benefits of $4.1m and provide a BCR of 5.0

If fishery closures had only been restricted to the more heavily populated estuaries where community pressure would have been greatest (Port Jackson and Botany Bay), the lost profits from these fisheries would only have been $181,000, resulting in a BCR of 3.3

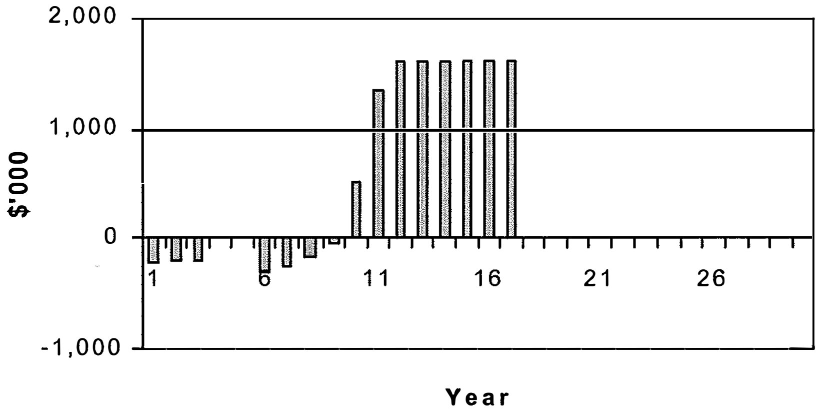
COMMENT

The FRDC funded research into by-catch in the NSW prawn fishery is consistent with national priorities to reduce the impact of fishing operations on marine populations and ecosystems.

By avoiding alternative policy responses to protect these environments, the research is estimated to have prevented losses in the fishery possibly in excess of $4m. For the reasons outlined, NSW Fisheries argue that this is a significant underestimate of commercial benefits.

Some confidence can therefore be placed on the conclusion that the research represents a sound investment purely on commercial grounds.

Benefits and costs through time



The fact that the project may have also prevented fishery closures to protect environmental and recreational values further underlines the high return of this research program.

Fisheries Economics, Research and Management Pty Ltd (2000), Ex-post benefit-cost analysis of project 93/180, report to FRDC.

Broadhurst M. (2001), NSW Fisheries pers. comm., 31 April.

Read. P. and Sturgess, H. (1996), Tuckean Swamp Economic Study – an evaluation of options for managing problems associated with flooding, drainage and acid sulfate soils, Consultant Report to Tuckean Swamp Management Committee

Kennelly S. (2001), Chief Scientist NSW Fisheries, pers. comm. 18 May

5. Stock Structure of the Orange Roughy Fishery

BACKGROUND:

This evaluation focuses on returns to Orange Roughy stock assessment research funded by FRDC up until 1995/96. This research includes 8 projects dating back to 1983/84. The broad purpose of this suite of projects was to improve understanding of the abundance, distribution and population dynamics of Orange Roughy in the South East Fishery so as to improve stock yield assessments. In turn this information has been used to set total allowable catches from the fishery.

PROJECT OBJECTIVES:

This suite of FRDC funded projects included;

94/143 – Review of Orange Roughy Assessment
90/025 – Development and use of acoustic techniques for the assessment of **deepwater commercial fish stocks**
90/009 – Development and use of the egg production method to assess the biomass of Orange Roughy off Eastern Tasmania
88/025 – Parasites as indicators of Orange Roughy biology
87/131 – Investigation of the distribution, abundance and biomass of Orange Roughy in mid-slope waters off and adjacent to NSW
87/129 – Abundance, distribution movements and population dynamics of Orange Roughy in SE Australian waters
87/065 – An assessment of the orange Roughy resources off the coast around Tasmania
84/051 – Parameters for stock yield assessments in the developing Orange Roughy and Blue Grenadier fisheries
84/027 – Identification of deep water trawl fish stocks using parasites as markers.

RESEARCH GROUP:

Researchers at AFMA, CSIRO, the University of Queensland and the University of Tasmania carried out the projects undertaken in this group.

PROJECT COST:

FRDC provided $1,991,743 while research organizations provided $1,118,809, representing a total research budget of $3.1m.

RESEARCH OUTPUTS AND OUTCOMES:

Each project has incrementally enhanced our understanding of the stock structure in the Orange Roughy fishery.

Collectively, the stock assessment research has been drawn on by AFMA in developing management plans for the fishery. Specifically, AFMA believe it is almost certain that without the stock assessment research and subsequent management interventions, commercial extinction of the species was inevitable (Towers 2001).

The resulting difference in management plans and TACs due to the stock assessment research has provided benefits through;

- Maximizing the long-term catches in the fishery, and
- Protecting the sustainability of the fishery.

The body of research completed before 1995/96 also provides the scientific base from which ongoing stock assessment work is being conducted. Consequently the earlier research will also provide future benefits as our understanding of the fishery increases, management plans are refined and further gains realised. Because these benefits are not included in this evaluation, estimated research payoffs will be conservative.

ECONOMIC IMPACT

The stock assessment research reduced the level of uncertainty surrounding stock structure and sustainable yields. This has allowed TACs to be determined which pose less risk of reducing fish biomass to unsustainable levels. It is also likely to have led to greater returns in the fishery compared to that which may have eventuated through a management approach based on incremental adjustments in response to annual catch performance.

McDonald, et al (1996) used Monte Carlo simulation techniques to estimate the likely commercial returns to improved stock assessment knowledge in the Orange Roughy fishery. This was done through determining TACs that are likely to have been set in the absence of stock assessment research, and comparing the net present value of returns in the fishery over a 100 year period based on these TACs and those that would be set by AFMA in light of available stock assessment information.

McDonald, et al (1996) assumes fishery management plans are amended directly in response to the stock assessment data and that industry fishing effort and catch complies with these plans. In particular, management strategies are directed at maintaining fish biomass above 30% of the 1986 biomass. To the extent that this does not occur, the fishery may be over-exploited and future catches are likely to be impacted, reducing longer-term benefits.

ENVIRONMENTAL IMPACT

The setting of TACs on a trial and error basis is likely to lead to either periods of overly conservative TACs and lower catches and/or, more probably, periods of unsustainably high TACs and possible collapse of the fishery. Given the breeding intervals of this species, rapidly increasing catches and the tendency for orange roughy to congregate in large easily exploited aggregations, the latter problem was of considerable concern.

While commercial extinction of fish populations rarely leads to ecological extinction, large reductions in orange roughy populations could pose significant environmental impacts both through reducing the sustainability of remaining populations (to other threats) and also through food chain impacts to other species and ecosystems .

While changes to TACs in response to the stock assessment research have been directed primarily at protecting the commercial value of the fishery, it has also acted to safeguard against the collapse of orange roughy populations and any flow-on impacts to marine ecosystems.
Available estimates suggest Australians would be willing to pay between $36m-$72m to protect a single threatened species. And if whole ecosystems were threatened by the collapse of orange roughy populations, the Australian community is likely to be willing to pay even greater amounts. However the nature of the fishing

threat to these populations and ecosystems remains largely unknown, and so directly imputing a conservation value is highly problematic.

Therefore, the commercial benefits of facilitating the setting of sustainable TACs will be considered as a conservative estimate of total benefits – commercial and environmental.

ADOPTION

In this evaluation it has been assumed that the results of the identified projects were fully adopted by AFMA by 1996. The benefits of changes in TACs beyond this time are explicitly considered in the analysis by McDonald, et al (1996).

BENEFITS

McDonald, et al (1996) estimate the return to stock assessment research up until 1996 at $63.7m, using a 6% discount rate.

Research costs and benefits are shown in the graph below. For illustrative purposes, the benefits have been represented as an annuity over 20 years that would yield the same present value of benefits estimated by McDonald, et al (1996).

PAY OFF

The benefits of the orange roughy stock assessment research program are estimated to be $37.6m, net of research costs and at a 6% discount rate. This yields a BCR of 27.

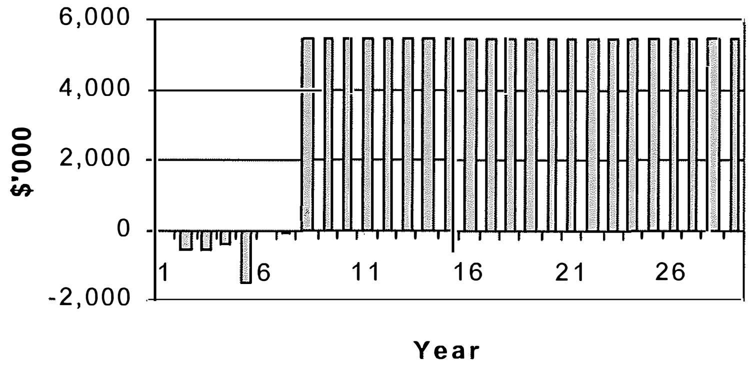
However because of the modeling assumptions used by McDonald, et al (1996), this is likely to significantly overestimate the commercial benefits of the research. On the other hand, no value was included for the potential ecosystem losses that may have eventuated under management strategies developed without the benefit of this research. In addition, any broader environmental benefits that may flow from the 'baseline' information developed have not been included.

COMMENT

Based on the available information, it is reasonable to conclude that the orange roughy stock assessment research funded by FRDC has yielded high returns.

The success of this and subsequent work to guide management in ensuring the sustainability of the fishery will become more apparent over time.

Benefits and costs through time



However there will always be uncertainty over the management strategies that otherwise would have been adopted and the significance of the stock assessment research to both management decisions and fishing effort.

Nevertheless, the research was consistent with national priorities to improve our understanding of marine populations and ecosystems, and to promote sustainable fishing operations. In this context, and subject to confirmation of the technical merits of the research, the program of research could be considered a sound investment irrespective of the (significant) commercial benefits it is likely to have generated.

McDonald, Smith and Davidson (1996), *Evaluating the costs and benefits of research on stock structure for management of the orange roughy fishery*, final report to FRDC, FRDC Project 96/109

Towers I. (2001), AFMA, pers. comm. 15 May

6. Fish Use of Sub-Tropical Salt Marsh Habitat (1997/203)

BACKGROUND:

Salt marshes in Australia are generally found on the inland side of mangroves and on the high side of the intertidal zone. In some cases, marshes can extend for vast areas (kilometres inland) and typically are dominated by succulent bushes from the family Chenopodiaceae and saltcrouch grass *Sporobolus virginicus* (Thomas and Connolly, 2001)

Fish are known to use salt marshes for feeding and juveniles as a source of shelter. The types of species occurring on marshes, sizes of different species using marsh habitat and fish densities across the range of a marsh were unknown. Given the encroachment of agriculture, off-road vehicle use and modification of marsh drainage patterns to control insect pests are threatening salt marshes, it was important to better understand salt marsh ecology. Such an understanding would lead to more informed land usage decision making.

To address these issues, FRDC and the School of Environmental and Applied Sciences at Griffith University commenced the project, "Fish use of sub-tropical salt marsh habitat" in 1997

PROJECT OBJECTIVES:

- To determine which fish species, in what abundance, directly use saltmarsh flats in subtropical east coast waters
- To compare the use by fish of vegetated (saltcouch) and unvegetated (saltpan) habitats on the marsh flats
- To make clear recommendations to managers of fisheries and the environment about the impacts on fisheries of human activities affecting saltmarsh habitat, and advise on the direction of future research

RESEARCH GROUP:

The project was commenced in 1997, as project 1997/203 and involved researchers from School of Environmental and Applied Sciences at Griffith University and a number of volunteers to help with field studies..

PROJECT COST:

The project had a budget of $63,800. These costs include both FRDC and School of Environmental and Applied Sciences at Griffith University contributions.

RESEARCH OUTPUTS AND OUTCOMES:

Major project outputs taken from Thomas and Connolly (2001) include,

- Fish were sampled at two sub-tropical salt marshes in Queensland. The first site was at Meldale in Moreton Bay, and the second, Theodolite Creek in Hervey Bay. The study comprised two sampling periods - one being in winter during nightly high tides, and the second, during summer daytime high tides.
- At Meldale, fish of 15 species were caught, while at Theodolite Creek fish of 21 species were caught across the sampling period. Marshes were found to be

dominated by estuarine species such as *Ambassidae, Atherinidae, Gobiidae* and *Sparidae.*

- A comparison of fish caught at vegetated and unvegetated habitats within the salt marshes showed no significant differences.

- The pattern of fish density across water depth and distance onto the marsh was also examined. It was evident that fish move across the entire marsh. Sampling at Meldale found fish as far away as 413 m from the sub-tidal zone, while at Theodolite Creek fish were trapped at 201 m from the low tide. In the case of Theodolite Creek, similar fish densities occurred at a range of distances onto the marsh.

As a result of the project, it has been shown that fish use all of a saltmarsh, and consequently, degradation of any part of a marsh is likely to disrupt function and production of adjoining fisheries. The data set generated as part of the study could be used to prevent development of crtictial salt marsh habitat, ensuring long term sustainable production of Queensland marine resources.

ECONOMIC IMPACT

An economic evaluation is undertaken to estimate the benefits of saltmarsh fish usage data for maintaining the integrity of this habitat in Queensland.

Production benefits from maintenance of salt marsh – salt marsh provides a nursery and source of food for key commercial species. A portion of the current Queensland wild catch of $177 million per year would utilise salt marshes. Without data to demonstrate the value of this habitat, development is likely to further degrade existing salt marsh.

It is difficult to determine the magnitude of fisheries production declines would be apparent in the event that more salt marsh was developed, largely the physical relationship between abundance of salt marsh habitat and fish densities is unclear. Consequently, a threshold analysis is conducted to determine what percentage of wild catch reduction, as a result of saltmarsh degradation, would be required to justify research project costs associated with 1997/203. This analysis is presented in the results section.

Attribution of benefits to 1997/203 – A number of factors, in addition to salt marsh fish usage data, would be required to prevent salt marsh development. For example, environmental protection groups may have to commit resources to lobbying regulatory agencies to prevent ecosystem destruction. Correspondingly, it is assumed that 25% of any economic benefits from appropriate (ie. improved land use decision making) salt marsh protection can be attributed to 1997/203. The information generated in the project would be utilised through court cases, land use petitions, and no costs of extension are required.

ENVIRONMENTAL IMPACT

Protection of saltmarsh will have positive implications for the commercial fishery and the environment. Studies in the USA outlined by Mumphrey *et al* (1978) suggested that Americans are willing to pay $924-2,176 per hectare for wetland protection. The estimates accommodate the gross value of fishing, fur harvests and recreational fishing and hunting on Louisiana's coastal marshes. Given that some of these activities do not occur in sub-tropical Australia, an analysis is conducted to determine how many hectares of sub-tropical marsh – valued at $500/ha, would have to be protected to justify investment in 1997/203.

ADOPTION

The research project has only recently been completed, with key publications such as Thomas and Connolly (2001) being made available. It is difficult to ascertain when development applications will emerge and be challenged using data generated within 1997/203.
Consequently, threshold analysis is used in the economic analysis to determine what level of commercial fishery production loss needs to be avoided, or hectares of saltmarsh saved, to justify investment in the research.

PAY OFF

The following graph shows the cost and benefits of project 1997/203 where only commercial fishery value is included in a threshold analysis.

For the project to break-even, a Queensland commercial production decrease of 0.01% would need to be avoided as a result of salt marsh protection.

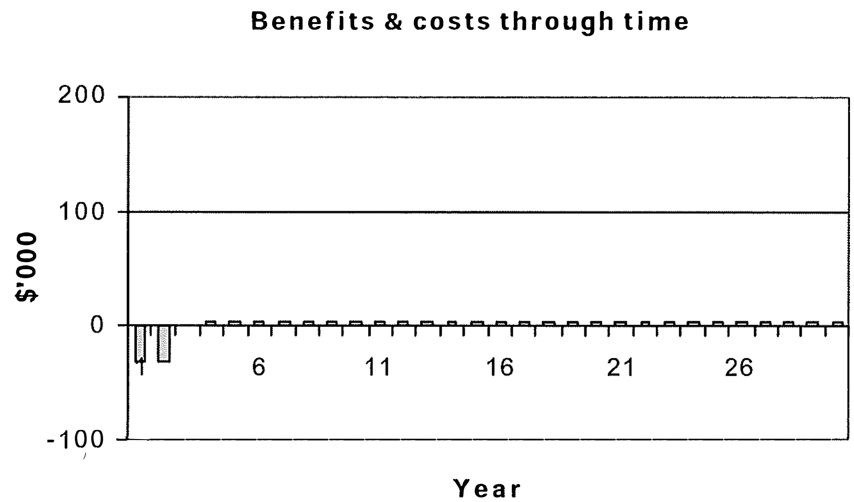
Alternatively, if a value of salt marsh of $500/ha is included in the analysis, at least 42 ha would need to be (in part) protected as a result of research in 1997/203 to justify the investment.

COMMENT

The research represents value for money, as a very small area of salt marsh would need to be preserved to justify the project. Given there are many thousand hectares of salt marsh in Queensland, it is likely that the threshold value will be attained.

Mumphrey, A.J., Brooks, J.S., Fox, L.B., Fromberg, R.J., Marak, R.J. (1978), *The Valuation of Wetlands in the Barataria Basin*, Urban Studies Institute, University of New Orleans, New Orleans.

Thomas, B.E. and Connolly, R.M. (2001), Fish use of sub-tropical saltmarshes in Queensland, Australia: relationships with vegetation, water depth and distance on the marsh", *Marine Ecology Progress Series*, 209, pp. 275-288.



7. Barramundi and other Finfish in Coastal Wetlands (1997/201)

BACKGROUND:

In 1998, approximately 721 tonnes of 'wild catch' barramundi (*Lates calcaroifer*) were landed in Queensland (Queensalnd Fisheries, 1999) making this species economically important. The catch was valued at $5 million – the fourth most economically important species behind coral trout, mullet and Spanish mackerel.

Barramundi utilise coastal wetlands as nursery habitat (Russell and Garrett, 1985). Much of this habitat has been modified throughout coastal Queensland, particularly by the grazing industry – who impound watercourses using earthen banks and introduce exotic pasture species to increase cattle production (referred to as ponded pastures).

Such modifications disrupt water flow and restrict movement of barramundi. To determine the impact of ponded pastures, and any potential remediation measures, the project "An investigation of the impacts of ponded pastures on Barramundi and other finfish populations in tropical coastal wetlands" was undertaken.

PROJECT OBJECTIVES:

- To document the extent of ponded pastures and other pondage systems in and adjacent to coastal wetlands on the central coast of Queensland.
- To assess the movement, growth and survival of barramundi in ponded pastures.
- To assess the utilization by barramundi of ponded pastures and wetlands dominated by exotic grass species.
- To identify appropriate wetland management strategies for facilitating barramundi movement and survival in ponded pastures and other pondage systems.
- To document the fish bycatch and their relevant abundance in ponded pastures.

RESEARCH GROUP:

The project was commenced in 1997, as project 1997/201, and involved researchers from Queensland Fisheries, now referred to as AFFS.

PROJECT COST:

The project had a budget of $741,251 and ran from 1996/97 to 2000/2001 These costs include both FRDC and Queensland Fisheries contributions.

RESEARCH OUTPUTS AND OUTCOMES:

Major project outputs taken from the project summary report (Hyland 2001) include:

- ➢ The extent of ponded pastures in the coastal areas of central Queensland was documented using aerial photographs and field visitation. It is estimated that there are more than 16,000 ha of ponded pastures in central Queensland.

- ➢ Movement, growth and survival of barramundi was assessed at field sites in Broad Sound, Fitzroy estuary and Corio Bay (in central Queensland). Including barramundi, 23 fish species were found in ponded pastures and water quality in these systems was periodically poor (high pH, low dissolved oxygen and high temperature). Ponds are typically shallow, un-shaded and dry-out during low rainfall season.

- Small (50-200mm) barramundi were entrapped in pondage systems, with rates of entrapment as high as 39%-78% at one site
- Barramundi were not found in shallow ponds dominated by para grass, possibly due to the low oxygen content of water in these systems

An important outcome of the project was the demonstration that the movement of three stages in the life cycle of the barramundi can be disrupted by poorly located pondage banks. The movement of post-larval or early juvenile stages from estuary into nursery areas can be disrupted with high mortality under low flow conditions. The movement of late stage juveniles from ponded pastures to adjacent water-courses can be disrupted under low to medium flows with high mortality where ponds dry completely. Mature barramundi moving from freshwater to estuarine habitats can also become entrapped in pondage systems during low to medium flows

As a result of the project it was demonstrated that a balance between agricultural and fisheries uses of the pondage systems is required to maximise the barramundi productive potential of these wetlands. Specifically, deep water refuges and shading could be incorporated in ponds, along with layout being modified to facilitate fish movement. For example, a series of short cascading embankments could be used to impound water, therefore providing more flexibility for water flow manipulation than commonly used single embankments.

ECONOMIC IMPACT

The project has demonstrated that current pondage systems entrap juvenile barramundi and could be improved to increase the production of this species in coastal Queensland.

Costs of improving ponded pastures – The cost of improving the function of ponded pastures is likely to be site specific and vary considerably depending on topography, soil type and other physical characteristics of the wetland. Accurate assessment is further confounded by the fact that optimum pondage system configuration to promote barramundi development is yet to be determined. In some cases, optimal ponded pasture infrastructure development costs may not differ from current practice, and consequently, any additional costs from optimal system adoption are not factored into the analysis.

Production benefits from improved ponded pasture – wetlands provide a nursery and source of food for barramundi. The restoration of ecological function is likely to increase the productivity of this species in coastal Queensland. Increases in survival of barramundi by improving ponded pasture systems will not necessarily translate directly into increased barramundi landings due to natural mortality of the barramundi after they have emigrated from the improved pondage system. Further experimental work is required to develop reliable models of barramundi production in modified and unmodified wetlands or nursery areas is required to determine the magnitude of any production increases.

It should be noted that the actual rate of improvement in production will also be partially dependent on the ratio of modified nursery area (ie ponded pasture) to unmodified nursery area and this will vary from region to region. In the study area (Fitzroy estuary, Corio Bay and Broad Sound regions), there is a large (>50%) proportion of nursery areas that have been modified and even a small uptake of restoration should result in a substantial increase in production for this region. The same applies to a number of other areas (eg. the Burdekin delta and Trinity Inlet), while other areas such as the estuaries of Cape York Peninsula are likely to have a low proportion of modified wetlands.

Again, further work is required to examine spatial patterns in the distribution of nursery areas, ponded pastures and barramundi landings as well as the development of a reliable model of barramundi production.

It is assumed that production will increase by 25% in areas where optimum ponded pasture systems are adopted. If 25% of barramundi population benefited from ponded pasture adoption, the increase in fish landings is valued to be $0.3 million per year .

Research costs – Further research would be required to determine optimum ponded pasture design for barramundi production. It is assumed that a 3 year project, @$100,000 per year would be required to undertake this research.

Probability of research outcome – technical and market risks need to be overcome if ponded pasture research were to result in industry benefits. As a result of these risks, a probability of industry outcome of 50% is included in the analysis.

ENVIRONMENTAL IMPACT

Restoration of wetlands will have positive implications for the commercial fishery and the environment. Most notably, recreational fishers could benefit from an increase in barramundi stocks. A number of studies have been conducted to gauge how much recreational anglers would value an increase in catch. Selected results cited in Read and Sturgess (1996) including Desvouges *et al* (1987), Mitchell and Carson (1981), Morey and Shaw, (1989) noted that recreational fishers were willing to pay between $13-17 per person to improve the catch.

In the absence of survey data for recreational fishers in Queensland it is difficult to arrive at a willingness to pay for increased recreational catch in this region. A lower annual estimate of $10 per angler is used in a threshold analysis, to determine the number of anglers (benefiting from improved fishing) required to justify investment in the project.

ADOPTION

Given the need for a follow-on project, it is assumed that research results are first extended to coastal Queensland in 2004. Approximately, 25% of ponded pastures were assumed to be modified. Maximum adoption is estimated to be achieved in 5 years after initial extension to industry.
Incentives for the cattle farming sectors need to be defined to improve the adoption of wetland/ ponded pasture management strategies. Some of these that could be explored might include improved water quality for livestock use and for household use.

Improved water quality may also reduce the incidence of blue green algal blooms, which can directly impact livestock production.

PAY OFF

The previous graph shows the cost and benefits of project 1997/201.

The inclusion of commercial benefits generates a BCR of 1.5 and NPV of $0.4 million. For the project to break-even, a barramundi landing increase of 17% would be required within areas where ponded pasture function had been improved.

A major driver of industry benefits is the estimated probability of a commercial outcome. Despite research being undertaken to demonstrate the possible value of improved ponded pasture systems design, a modest chance of a commercial outcome being delivered is included in the analysis, as financial incentives for farming sector adoption need to be clearly defined

The development of improved ponded pastures would benefit recreational fishers in Central Queensland. If recreational fishers value an increase in barramundi catch by $10 per person per year, at least 18,777 fishers would have to realise recreational gain, in the absence of commercial benefits, for the project to break-even.

COMMENT

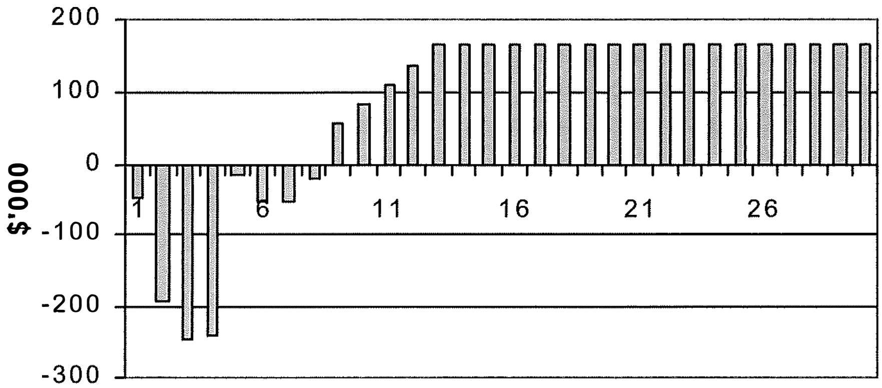
Without recreational benefits, the project represents a marginal investment. Recreational benefits, are however, likely to be substantial as barramundi is a premium sports fish and is highly valued by recreational anglers. Incentives (financial or social) for adoption of improved ponded pasture system design need to be considered to maximise pay-off from the research.

Desvousges, W.H., Smith, V.K. & Fisher, A. (1987). `Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River'. *Journal of Environmental Economics and Management*, 14: 248-267.

Hyland, S.J. (2001), An investigation of the impacts of ponded pastures on Barramundi and other finfish populations in tropical coastal wetlands, Draft Final Report to FRDC, FRDC, Canberra.

Mitchell and Carson (1981), An Experiment in Measuring Willingness to Pay for Intrinsic Water Pollution Control Benefits, Report to the US Environmental Protection Agency, cited in *Envalue* – NSW EPA, june 1995.

Benefits & costs through time



Year

Morey, E. & Shaw, W. (1989) "An economic model to assess the impact of acid rain: a characteristics approach to estimating the demand for and benefits from recreational fishing", in Shaw, W.D. (1989). `Valuing the Effect of Acidification Damages on the Adirondack Fishery: Comment'. *American Journal of Agricultural Economics*, 217-222.

Queensland Fisheries (1999), Queensland fisheries resources: condition and trends 1988-95, Queensland Fisheries (now AFFA).

Read, M.P. and Sturgess, N.H. (1996), Tuckean Swamp Economic Study – an evaluation of options for managing problems associated with flooding, drainage and acid sulfate soils, Consultant Report to Tuckean Swamp Management Committee, July 1996.

Russell, D.J. and Garrett, R.N. (1985), "Early life history of barramundi, *Lates calcarifer* (Bloch), in NE Queensland, *Aust. J. Mar. Freshwater Research*, 36, pp. 191-201.

8. Fish and Invertebrates Utilising Restored Wetlands (1995/150)

BACKGROUND:

Urban development and the expansion of agricultural activities in coastal areas have resulted in the loss of wetland habitat. Importantly, large-scale flood mitigation schemes have acted to impede tidal flow and disrupt the functional complexity of many coastal wetland areas.

Disruption of tidal activity has important ecological ramifications for the surrounding marine ecosystem, as juvenile fish and macro-invertebrates utilise wetlands as shelter and key commercial species use these areas as a food source

Wetland preservation and remediation have been, and are continuing to be, undertaken with the objective of restoring functional integrity of these ecosystems. As part of this effort, it is important that rates of system recovery be established along with demonstrating that fish and invertebrates use 'restored' areas. In 1995, FRDC and NSW Fisheries commenced the project "Utilisation of Restored Wetlands by Fish and Invertebrates" to investigate this key research question.

PROJECT OBJECTIVES:

- To demonstrate whether fish and invertebrates use 'restored' wetlands.
- To determine if the changed habitat within the wetlands sustains fish and invertebrate communities similar to other sites within the Macleay and Hunter estuaries and at sites within comparable reference estuaries.
- To determine appropriate mechanisms for minimising the impacts of releasing low dissolved oxygen and low pH water to the estuary when the levees and floodgates are initially breached.
- To identify the initial rate of recovery following opening / removal of the flood mitigation works and to determine whether additional intervention is required to assist the regeneration of fish habitat

RESEARCH GROUP:

The project was commenced in 1995, as project 1995/150, and involved researchers from the Office of Conservation, NSW Fisheries.

PROJECT COST:

The project had a budget of $484,775 and ran from 1995/96 to 1999/2000.

These costs include both FRDC and NSW Fisheries contributions, along with funding from the NSW Environmental trust grant scheme. Approximately, $106,390 was sourced from this agency.

RESEARCH OUTPUTS AND OUTCOMES:

Major project outputs taken from the project summary report (Gibbs, P., McVea, T. and Louden, B. 1999) include:

➢ Samples of marine fauna were taken from Yarrahapinni Broadwater (Macleay River), Hexham Swamp (Hunter River) and Rockdale Wetlands Corridor (Botany Bay) at restored, or proposed restored wetlands, degraded wetland and three other reference estuary sites (Wallis

Lake, Manning River and Nambucca River). Information on species composition, size and age of captive fish, along with salinity, temperature and pH were recorded.

- In the case of the Yarrahapinni Broadwater, the proposed floodgate opening did not occur during the research project. Consequently, all samples were taken from a wetland where there was no tidal exchange. The fish community was dominated by freshwater species such as gudgeons (*Philypnodon spp.*, *Gobiomorphus spp.*), the goby (*Pseudogobius olorum*), southern blue eyes (*Pseudomugil signifer*) and aquatic insects.

- At Hexham swamp, controlled opening of floodgates during 1995/150 enabled researchers to examine the change in marine community structure during the initial impact of a restoration project. It was found that the community became very diverse, containing some of the freshwater species outlined above, but also estuarine species (including sea mullet, bream, school prawns) found in the main channel of the Hunter River.

- The Rockdale wetlands is connected to Botany Bay via a 700 m underground channel, and therefore represents a highly modified wetland system. Despite this fact, a large number of commercial species were found in the wetlands (including striped trumpeter, silver biddies, blackfish, prawns and bream) and the site appears to be an important nursery area

As a result of the project it was demonstrated that partial opening of floodgates, such as at Ironbark Creek, can provide access for adult and juevenile animals, which is likely to increase the population of commercially important species. In addition, the importance of the artificial wetland (Rockdale Corridor) on Botany Bay was demonstrated.

ECONOMIC IMPACT

The recent opening of the Yarrahapinni Broadwater (Macleay River) and preservation of the Rockdale Corridor in Botany Bay can be, in part, attributed to the findings of this project. An economic evaluation is undertaken to estimate the benefits from these achievements

Production benefits from opening of Yarrahapinni Broadwater – wetlands provide a nursery and source of food for key commercial species. The opening of the wetlands, and resulting restoration of ecological function, is likely to increase the productivity of the Macleay River. During 1998, the river yielded $0.28 million finfish (Tanner and Liggins, 1999). It is difficult to determine the magnitude of production increase following the opening of the Yarrahapinni Broadwater. A survey of commercial fisherman in the nearby Richmond River, noted that the restoration of Tuckean Swamp may increase fish landings by as much as 20-40% per annum. (Read and Sturgess 1996). An opening of this swamp would help address the pronounced acid sulfate soil problems in the Richmond catchment that affect fish populations. For the Macleay it is assumed that landings would increase by 5% per year. This increase is valued to generate industry net benefits of $14,000 per year as most estuary commercial fishing costs are likely to be fixed for a marginal production increase of this order. The cost structure of a north coast estuary fishing enterprise was reviewed by Read and Sturgess (1996) and contained a large fixed cost component.

Production benefits from preserving the Rockdale Corridor - Botany Bay is a major prawning ground and yields a substantial volume of commercial finfish. During 1999, the estuary yielded approximately $0.2 million eastern king prawns and $0.5 million in finfish (NSW Fisheries 1999). Major finfish species include bream, mullet, whiting, eels, flathead and luderick. It is assumed that a decline in prawn and finfish landings of 5% per annum has been avoided by the maintenance of the Rockdale Corridor. There have been a number of development applications, which in the absence of 1995/150 and demonstration of the wetland's value, may have been approved - resulting in loss of this important habitat.

Attribution of benefits to 1995/150 – A number of factors have led to the recent opening of the Yarrahapinni Broadwater and maintenance of the Rockdale Corridor. Correspondingly, only a proportion of the commercial fishing benefits from improved, or sustained wetland function, can be attributed to 1995/150. For the purposes of the analysis it is assumed that 30% of industry benefits can be traced back to the demonstration of wetland function resulting from research undertaken in this project. The information is likely to be used in development applications, land use petitions and/or court cases.

ENVIRONMENTAL IMPACT

Restoration of wetlands will have positive implications for the commercial fishery and the environment. Most notably, recreational fishers could benefit from an increase in fish stocks within Botany Bay and the Macleay River. Both these estuaries are heavily utilised by recreational anglers, who would value an increase in the recreational catch. A number of studies have been conducted to gauge how much recreational anglers would value an increase in catch. Selected results cited in Read and Sturgess (1996) include:

- Desvouges *et al* (1987) found that anglers would be prepared to pay $16 per visitor trip to have improved water quality for fishing in the Mongahela River, Pennsylvania.

- A survey conducted by Mitchell and Carson (1981) indicated that housholds were willing to pay $80 per year for improved water quality for fishing in the USA.

- Anglers were willing to pay $13-23 per year for a 25% recreational fish catch increase in the Adirondacks (USA) (Morey and Shaw, 1989).

- Water Research Centre (1989) in the UK estimated an annual willingness to pay of $17 per household for improved water quality and fishing in Britain.

- Van Bueren *et al* (1993) found that west Australian recreational anglers were willing to pay $5.5 per additional salmon caught

- Burns *et al* (1995) noted that south Australian recreational anglers were willing to pay $0.72 per additional whiting caught

In the absence of survey data for recreational fishers of Botany Bay and the Macleay River, it is difficult to arrive at a willingness to pay for increased recreational catch in this region. A lower annual estimate of $10 per angler is used in a threshold analysis, to determine the number of anglers benefiting from improved fishing required to justify investment in the project. A value of this order is on the lower bound of willingness to pay for recreational fishing in Australia. Read and Sturgess (1996) valued the net economic value from recreation on the Richmond River at $10-40 per visitor day depending on whether the visitor was from the north coast region.

ADOPTION

Opening of the Yarrahapinni Broadwater was approved this year and research data from Botany Bay has been used to protect the Rockdale Corridor since completion of the project. Correspondingly, increased Macleay River productivity benefits are projected from 2001, while benefits from protection of the Rockdale site are incorporated from 2000, until the end of the evaluation period in 2015.

BENEFITS

If both the Botany Bay and Macleay River estuaries were to experience a 5% production increase from preservation and restoration of the wetlands, an annual industry benefit of $0.05 million would be apparent.

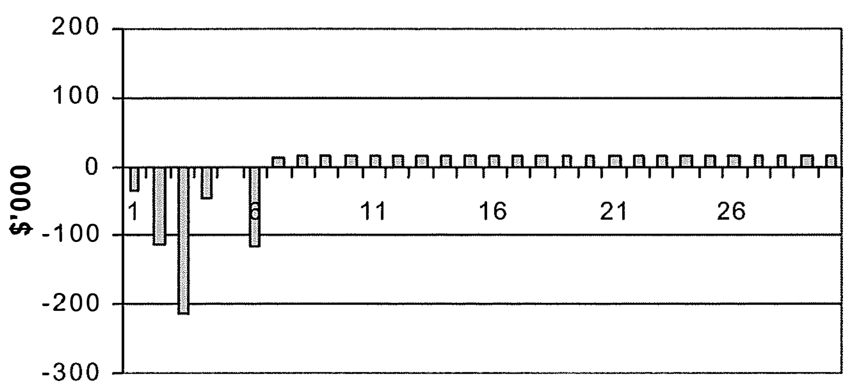
PAY OFF

The following graph shows the cost and benefits of project 1995/150.

With the inclusion of commercial benefits only, the research is estimated to provide a BCR of 0.3 NPV of -$0.4m. For the projects break-even a production increase of 18% would be required within the target estuary fisheries.

Under the base assumption of a 5% increase in commercial fishery yields, an increase in recreational fishing value would be required to justify R&D expenditure. Under the assumption that recreational fishers would value an increase in catch by $10 per person, at least 10,416 fishers would have to use or reap benefit from

Benefits and costs through time



increased productivity of Botany Bay or the Macleay River.

Given that Read and Sturgess (1996) found 120,000-170,000 recreational fishing visits (episodes) on the Richmond River alone, the recreational value of increased catch in the highly fished Botany Bay and the Macleay River are likely to be substantial.

The value of additional recreational catch has been valued for whiting and salmon in Australia (Van Bueren *et al* 1993, Damania *et al* 1995) and ranged from \$0.72-\$5.50 per fish. If an average of \$3.11 per fish is assumed, an additional 33 thousand recreational fish would have to be landed per year for the project to break-even.

COMMENT

The research appears to be attractive on recreational fisher benefit alone. Commercial yields would need to increase by 16% per annum, for the projects to break even if fishing industry benefits were only being considered.

Burns, M., Damania, D. and Coombs, G. (1995), The Economic Value of King George Whiting and Snapper, FRDC Final Report – Project 95/140, FRDC, Canberra

Desvousges, W.H., Smith, V.K. & Fisher, A. (1987). `Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River'. *Journal of Environmental Economics and Management*, 14: 248-267.

Gibbs, P., McVea, T. and Louden, B. (1999), Utilisation of Restored Wetlands by Fish and Invertebrates, NSW Final Report Series, No. 16, June.

Mitchell and Carson (1981), An Experiment in Measuring Willingness to Pay for Intrinsic Water Pollution Control Benefits, Report to the US Environmental Protection Agency, cited in *Envalue* – NSW EPA, June 1995.

Morey, E. & Shaw, W. (1989) "An economic model to assess the impact of acid rain: a characteristics approach to estimating the demand for and benefits from recreational fishing", in Shaw, W.D. (1989). `Valuing the Effect of Acidification Damages on the Adirondack Fishery: Comment'. *American Journal of Agricultural Economics*, 217-222.

Read, M.P. and Sturgess, N.H. (1996), Tuckean Swamp Economic Study – an evaluation of options for managing problems associated with flooding, drainage and acid sulfate soils, Consultant Report to Tuckean Swamp Management Committee, July 1996.

Tanner, M. And Liggins, G.W. (1999), NSW Commercial Fishing statistics 1993/94-1997/98, NSW Fisheries.

Van Bueren, M.S., Lindner, R.K. and McLeod, P.B. (1993), An Economic Assessment of Reallocating Salmon and Herring Stocks from the Commercial Sector to the Recreational Sector in Western Australia, FRDC Final Report – Project 93/080, FRDC, Canberra

Water Research Centre and Flood Hazard Research Centre (1989). Investment appraisal for sewage schemes: the assessment of social costs - project Report. Water Research Centre: in Swindon, in Barde, J.P. & Pearce, D.W. (1991). *Valuing the Environment: six case studies*. OECD, Paris.

9. Restoration of Estuarine Fisheries Habitat (1994/041)

BACKGROUND:

Coastal wetlands are an important habitat for fish and macro-invertebrates – serving as a nursery for juveniles and feeding area for many commercially important species. Since European settlement of Australia, the area of coastal wetlands has substantially declined. Goodrick (1970) estimated that 60% of coastal waterfowl wetland in NSW has been lost over the last 200 years.

A large driver of wetland loss has been the expansion of agricultural areas, and consequent clearing and draining of wetlands, along with urban encroachment and development of transportation infrastructure. Loss of wetland habitat has created considerable concern for the on-going productivity of estuarine fisheries and generated ecosystem balance issues (Willams and Watford 1995).

To address the issue of degradation a number of rehabilitation programs have been initiated. These include the development of specilised weirs that allow fish passage and remediation of disturbed wetland areas. However, prior to remediation efforts, the nature of degradation needs to be determined and the most cost-effective means of restoring ecosystem function identified. FRDC and NSW Fisheries financed project 1994/041 with the specific objectives of identifying key degraded wetlands on the NSW coast and, if applicable, extend some of the wetland remediation work being conducted in the lower Hunter River to other parts of the state.

PROJECT OBJECTIVES:

- To extend an ongoing study to make the work relevant to the general coastline of eastern
- To identify key degraded wetlands on the NSW coast that have the potential to be rehabilitated

RESEARCH GROUP:

The restoration of estuarine fisheries habitat project (1994/041) was commenced in 1995 and involved researchers from the Office of Conservation, NSW Fisheries.

PROJECT COST:

The project had a budget of $203,119. FRDC committed $73,119 to the project, with NSW Fisheries contributing $76,000 and other parties the balance.

RESEARCH OUTPUTS:

Major project outputs outlined in Williams, R.J. and Watford, F.A. (1995), Restoration of Estuarine Fisheries Habitat, NSW Fisheries Project Report 1994/041 include:

- Anecdotal information about wetland degradation was collected using a questionnaire sent to the NSW Oyster Farmers Association, the NSW United Oyster Growers Council and officers in charge of 28 NSW fisheries coastal stations. Although responses from the survey were considered to be limited (Williams *et al* 1996), a range of problems in 70 waterways were noted. Situations relating to pollution, odours and nutrient loads were most frequently nominated.

- Tidal flow is considered to be an important parameter governing the health of coastal habitat. Consequently, possible structural impediments to tidal flow were analysed using maps and field inspection. Before field visitation 148 maps, (1:25,000 scale) were investigated to highlight structures that may obstruct tidal flow.

- Structures were categorized as bridges, culverts, causeways, fords, weirs and floodgates. Field visits were undertaken and sites categorized as either problem areas, or not.

- In total, 4229 structures were defined, identified and reviewed for their potential to be modified. Culverts (1795) were the most frequently observed structure followed by bridges (1187), floodgates (1037), weirs (96) and fords (36). Of these structures, 1388 had potential to be modified to improve tidal flow. Floodgates (1035) were the structure that could be most readily modified to improve tidal flow and consequent improved wetland function. Typically, most floodgates are closed for the entire year, whereas they need only be closed during high rainfall and flood events. Partial opening of these structures outside of flood events, would allow the passage of marine fauna and tidal flow.

- Over 94% of the floodgates identified as impeding flow, were situated in the Richmond-Tweed, Mid-north Coast and Hunter statistical areas.

In summary, the project created awareness that a large number of floodgates are impeding tidal flow – primarily in the northern coastal areas of NSW. Tidal flow could be improved by partial opening of these structures, without endangering on-farm production. NSW fisheries officers, drainage unions and other extension agents have been made aware of the project and the potential for improved floodgate management.

Further extension is required to create greater awareness of the floodgate problem and potential for improved management.

ECONOMIC IMPACT

In part, as a result of 1994/041, more floodgates are being optimally managed in the northern rivers region of NSW. Reduced impediment to tidal flow, and consequent enhancement of coastal wetland function, is likely to have increased the productivity of estuarine fisheries in this region.

An economic evaluation is undertaken to determine potential economic benefits from 1994/041. Initially, potential costs are outlined followed by a description of industry benefits.

Extension costs – Base research costs were provided in a proceeding section. On-going extension is also required to disseminate findings of the project. For the purposes of this analysis, it is estimated that 3 years of extension - @$50,000 per annum has been required.

Production implications – Finfish and prawn populations could potentially benefit from improved tidal flow and access to wetlands. In many northern catchments, acid sulfate soil poisoning has become a major problem following the death of fish, crustaceans and annelid worms along a 23 km stretch

of the Tweed River in 1987. The problem resulted from the presence of pyrite and jarosite in soils and resulting release of sulfuric acid into the marine ecosystem. Improved drain and floodgate management reduces the potential for acid drain waters to cause major marine fauna kills.
NSW estuaries yielded approximately $2 million prawns and $12 million in finfish in 1999. It is assumed that prawn and finfish landings would be increased by 5% per annum in northern estuaries (20% of state estuary catch), as a result of improved floodgate management.

ENVIRONMENTAL IMPACT

Improved floodgate management is likely to have a number of environmental benefits:

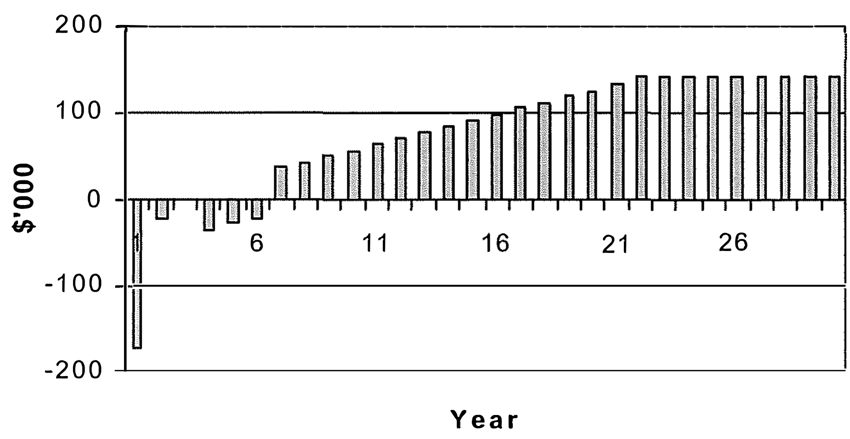
- Recreational fishers target many species within northern river systems. Any enhancement to these areas is likely to increase recreational fishing stocks and enjoyment of recreational fishing. It is assumed that recreational fishers value increased landings at $10 per fisher per year. Selected results cited in Read and Sturgess (1996) including Desvouges *et al* (1987), Mitchell and Carson (1981), Morey and Shaw, (1989) noted that recreational fishers were willing to pay between $13-17 per person to improve the catch. The number of fishers that need to realise this benefit are described in the pay-off section.
- Non-target commercial and recreational species, that form an integral part of the food chain or element of ecosystem function may benefit from floodgate management improvement.

ADOPTION

Northern NSW estuaries (Tweed) would be the primary target for the research project. It is estimated that these river systems account for 20% of NSW estuarine fisheries landings.

The project was completed in 1996 and results have already been extended to industry. It is assumed that commercial adoption of project outputs first occurred in 1997 and will increase at 1% per annum until 20% of the state's estuarine fishery benefit from improved floodgate control.

Benefits and costs through time



BENEFITS

If 20% of NSW estuarine fisheries were to benefit from improved floodgate management and experience a 5% production increase in production, an annual industry benefit of $140,000 would be apparent.

PAY OFF

The previous graph shows the cost and estimated benefits of the project.

The research is estimated to provide a BCR of 3.5 and NPV of $0.8 million. For the project to break-even, a production increase of 1% would be required.

If recreational fishers value an increase in landings by $10 per person per year, at least 3,427 fishers would have to realise recreational gain, in the absence of commercial benefits, for the project to break-even.

COMMENT

The research therefore represents a sound investment. Only a small number of recreational fishers would need to benefit from the project for positive benefits to be attained.

In the longer term, oyster farming may expand in northern river systems as a result of improved floodgate management and the consequent enhancement in water quality. Although this potential benefit is difficult to quantify and not incorporated in the cost-benefit framework, its inclusion would further increase the economic attractiveness of the project.

Desvousges, W.H., Smith, V.K. and Fisher, A. (1987). `Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River'. *Journal of Environmental Economics and Management*, 14: 248-267.

Goodrick, G.N. (1970), A Survey of Wetlands of Coastal NSW. Technical Memo, No.5, September 1970. CSIRO Division of Wildlife Research, Canberra, 36 pp.

Mitchell and Carson (1981), An Experiment in Measuring Willingness to Pay for Intrinsic Water Pollution Control Benefits, Report to the US Environmental Protection Agency, cited in *Envalue* – NSW EPA, june 1995.

Morey, E. and Shaw, W. (1989) "An economic model to assess the impact of acid rain: a characteristics approach to estimating the demand for and benefits from recreational fishing", in Shaw, W.D. (1989). `Valuing the Effect of Acidification Damages on the Adirondack Fishery: Comment'. *American Journal of Agricultural Economics*, 217-222.

Read, M.P. and Sturgess, N.H. (1996), Tuckean Swamp Economic Study – an evaluation of options for managing problems associated with flooding, drainage and acid sulfate soils, Consultant Report to Tuckean Swamp Management Committee, July 1996.

Williams, R.J. and Watford, F.A. (1995), Restoration of Estuarine Fisheries Habitat, NSW Fisheries Project Report 1994/041.

Williams, R.J. and Watford, F.A. (1996), An inventory of impediments to tidal flow in NSW estuarine fisheries habitat, Wetlands 15(2), pp. 44-54.

Williams, R.J., Watford, F.A. and Taylor, M.A. (1996), A Summary of Aspects of the FRDC Project 94/041 - Restoration of Estuarine Fisheries Habitat, Relevant to tidal restrictions in NSW estuaries, NSW Fisheries Project Report.

10. Impact of Prawn Farm Effluent on Coastal Waters (1997/212)

BACKGROUND:

Prawn farming has expanded rapidly in Australia, with current production estimated to be 2,950 tonnes in 1999-2000 - valued at $51 million (ABARE, 2001). Much of this production occurs in Queensland, although capacity is developing within NSW and other states.

The impact of prawn farming on the surrounding marine environment has become a significant issue for the industry (APFA, 2000), largely as a result of experiences in SE Asia, Central America and South America, where industry production expanded quickly resulting in adverse off-site impact.

Of particular importance, has been the development of effective environmental management systems. Development of such systems requires an understanding of pond ecology, feed and sediment dynamics, the composition of pond effluent, the effectiveness of effluent treatment systems and the fate of discharge (Preston *et al* 2000).

To better understand the impact of effluent discharge, the Australian Institute of Marine Science (AIMS) and the FRDC commissioned the project – "Quantifying and predicting the impact of prawn farm effluent on the assimilative capacity of coastal waters".

PROJECT OBJECTIVES:

- Quantify the assimilative capacity of the receiving environment for the major nutrients and sediments in prawn farm effluent by describing the dynamics of C,N,O,P pathways in the substrate and water column of discharge channels and creeks, and thereby determine the environmental impact of prawn farm effluent.
- Refine and extend existing hydrodynamic models of the Hinchinbrook Channel and Pt Douglas estuaries in order to predict the behaviour of prawn farm effluent entering coastal waterways, thus enabling simulation modelling of the carrying capacity of the environment for prawn farming

RESEARCH GROUP:

The project commenced in 1997 as project 1997/212 and involved researchers from the Australian Institute of Marine Science and CSIRO.

PROJECT COST:

The project cost of $734,539 includes both FRDC and AIMS contributions. FRDC committed $358,997 of the total project budget,.

RESEARCH OUTPUTS AND OUTCOMES:

Major project outputs taken from the project summary report (Trott and Alongi, 2001) include:

- An improved understanding of the flushing and dilution of farm effluent in tidal creeks was attained. Field data and video simulation suggested that more nutrients and sediments move further downstream during periods of high discharge or when ponds are being harvested. In the case of the Muddy Creek field site, the assimilative capacity of the landward end of the creek was exceeded during the later stages of the prawn farming production cycle. Discharges of nutrients and sediments are highest during this time.

- Prawn farm effluent was largely in particulate form. (80-90% for nitrogen, 60-80% for phosphorus and 50-70% for carbon) which settled quickly during low currents. The bulk of pond derived matter accumulated on the creek bottom.

- Algal growth and zooplankton grazing rates were found to be very high during discharge periods. The removal rate of increased algal growth during periods of high discharge was insufficient in upper reaches of Muddy Creek during later stages of the prawn production cycle.

- Re-packaging of farm derived nutrients into algae, zooplankton and grazing by small fish provides a mechanism to disperse the effluent in to the coastal food web. The major nutrient pathways in mangrove creeks were investigated.

- The supply of carbon and nitrogen in discharge exceeded the assimilative capacity in Muddy Creek. Farm derived carbon was buried in sediments (as opposed to being mineralized), due to the rate of carbon supply exceeding the respiration rates and the removal rate via photosynthesis. Denitrification accounted for small losses of farm derived nitrogen.

ECONOMIC IMPACT

To date there have been limited economic benefits flowing from the projects although 5-6 farmers were given a moratorium on monitoring costs for the duration of this research which accounted for at least $50-70,000 per annum in one case. Research has generated awareness that nutrients in prawn farm effluent output may not be assimilated in tidal creeks during periods of high discharge. In addition, the sediment in discharge may accumulate in tidal creeks.

It is difficult to determine what economic impact this information will have for the prawn farming industry. Conceivably, the data may result in prawn farms having to adopt production practices (ie. optimize feeding regimes, change stocking rates) or install filtration and/or new treatment pond configurations to reduce nutrient. If this scenario were the case, the project would generate negative economic benefits for the industry, but positive benefits for the environment if current outputs were restricted due to the link between discharges and impact on the environment.

On the other hand, it is possible that the generation of a data set of this nature may result in unnecessary monitoring costs and other environmental compliance measures being levied on the industry. Again, it is difficult to estimate the likely magnitude of these costs. A break-even analysis is provided in the pay-off section to illustrate what annual increase in monitoring or other environmental costs, per hectare of prawn farm, would have to be avoided for the research project to break-even in financial terms.

ENVIRONMENTAL IMPACT

The increased understanding of effluent output and nutrient fate may result in the preservation of mangrove creek ecosystems which support multi-million dollar commercial and recreational fisheries. Studies in the USA outlined by Mumphrey *et al* (1978) suggested that Americans are willing to pay $924-2,176 per hectare for wetland protection. The estimates accommodate the gross value of fishing, fur harvests and recreational fishing and hunting on Louisiana's coastal marshes. Given that some of these activities do not occur in Australia, an analysis is conducted to determine how many hectares of sub-tropical wetland – valued at $500/ha, would have to be protected to justify investment in 1997/212.

ADOPTION

The research project has only recently been completed. It is uncertain when results of the research project would have an impact on industry monitoring or environmental compliance costs. For the purposes of the analysis it is assumed that any cost saving would be realised from 2005 onwards.

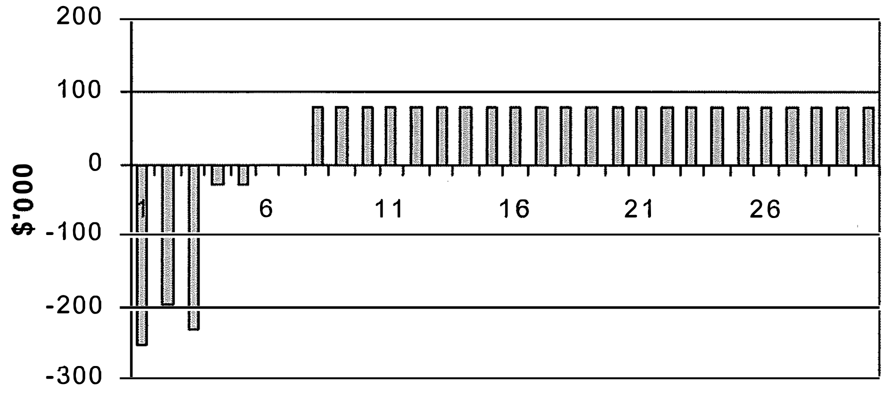
PAY OFF

The following graph shows the costs and benefits of 1997/212.

For the project to break-even a monitoring cost saving of $159/ha would have to be realised from 2005.

If environmental benefits were only considered in the evaluation, at least 159 ha of tidal creek wetlands would need to be preserved as a result of research undertaken in the project.

Benefits & costs through time



COMMENT

It is difficult to ascertain whether the generation of effluent output data will result in increased production costs (such as improved discharge treatment systems), or whether long term monitoring costs would be reduced as a result of improved understanding of effluent fate and dynamics. In the event that monitoring costs could be decreased, only a relatively small saving of $159/ha would be required to justify expenditures in 1997/212.

ABARE (2001), Australian Fisheries Statistics 2000, ABARE, Canberra.

Australian Prawn Farmers Association (2000), Research and Development Plan, APFA, Brisbane.

Mumphrey, A.J., Brooks, J.S., Fox, L.B., Fromberg, R.J., Marak, R.J. (1978), *The Valuation of Wetlands in the Barataria Basin*, Urban Studies Institute, University of New Orleans, New Orleans.

Preston, N., Jackson, C., Thompson, P., Austin, M., Burford, M. And Rothlisberg, P. (2000), Prawn Farm Effluent: Composition, Origin and Treatment, FRDC Project Report, FRDC, Canberra.

Trott, L.A. and Alongi, M. (2000), Quantifying and predicting the impact of prawn farm effluent on the assimilative capacity of coastal waters, Final Report to FRDC, FRDC, Canberra.

11. Physical Effects of Hauling on Sea Grass Beds (1996/286)

BACKGROUND:

Seagrass is an important habitat for fish and macro-invertebrates. Many areas are, however, under threat as a result of urban activities – such as run-off, which increase water turbidity and diminishes available sunlight to seagrass communities. Dredging and the impact of commercial fishing nets being hauled across the estuary floor also have an adverse affect.

Previous studies have demonstrated that a reduction in the density of seagrass (Bell and Westoby, 1986, Connolly, 1994) reduced the size of fish and invertebrate populations within target seagrass beds. In the case of NSW fisheries, the impact of seine nets on seagrass (hauling) was not clearly defined, along with the nature of any population impacts resulting from potential disturbances to seagrass communities from this activity

To address this information gap, NSW fisheries and the FRDC funded a series of projects (95/149 & 96/286). The research groups, project outputs and potential economic benefits flowing from this investment is described in this section.

PROJECT OBJECTIVES:

- To identify whether the effects of estuary hauling on seagrass meadows is identifiable at the estuary level.
- To assess the 'within-estuary' impacts of hauling, if any, on seagrass frond height, density and
- To interpret the results in relation to known information on the utilisation of the seagrass habitat by fish.

RESEARCH GROUP:

The physical effects of hauling on sea grass beds project was commenced in 1996, as project 1995/149 and involved researchers from the Office of Conservation, NSW Fisheries.

Following the success of the first project, a second follow-on project (1996/286) was undertaken between 1997 and 2000.

PROJECT COST:

The initial project had a budget of $87,156, while $107,544 was committed to the follow-on project 1996/286. These costs include both FRDC and NSW Fisheries contributions, which when combined total $194,700.

RESEARCH OUTPUTS AND OUTCOMES:

Major project outputs taken from the project summary report (Otway and Macbeth 1999) include:

- Seagrass (*Zostera capricorni*) shoot and leaf length densities were sampled at hauled and non-hauled control sites in nine estuaries along the NSW coast (Wallis Lake, Port Stephens, Lake Macquarie, Tuggerah Lakes, Botany Bay, Lake Illawarra, St Georges Basin, Burrill Lake and Wallaga Lake).

- Hauling did not totally denude seagrass beds, but resulted in a reduction in shoot and leaf densities at some sites primarily during winter.

- Differences in winter leaf length between hauled and control sites varied according to estuary, with reductions of 17-39% occurring in all estuaries except Port Stephens and Wallaga Lake.

- Sampling during summer indicated that hauling had a lesser impact during this part of the year. It was postulated that compensatory growth during summer recovers losses in leaf length during the winter. Given that summer sampling only occurred once during the project, it is not clear whether compensatory growth would be sustained.

As a result of the projects (95/149 & 96/286) it is evident that hauling has an impact on seagrass communities during winter. Whether disturbances of this order impact upon the abundance and richness of fish recruits and macro-invertebrates still needs to be defined.

Further research objectives identified as a result of the projects, include:

- Determine the long-term physical affects on seagrass beds using a large scale field trial and measure whether the differences in seagrass found during projects 95/149 & 96/286 persist;

- Investigate whether hauling has an impact on other seagrass species and study the nature of site specific impacts of hauling; and

- Evaluate whether the percentage of seagrass damaged during hauling has ramifications for fish and invertebrate recruitment. If so, possible seagrass community management plans could be devised to ensure long term ecologically sustainable management of the fishery

ECONOMIC IMPACT

To date, there have been no economic benefits flowing from the projects. Information generated from the research has created some awareness that hauling has an impact on seagrass communities. For the projects (95/149 & 96/286) to have an impact, further research and extension are required to firstly determine whether hauling has a productivity impact on the fishery and, secondly, how seagrass and hauling should be optimally managed.

An economic evaluation is undertaken to determine what production increase would be required to justify continued resourcing of physical affects of hauling research. Initially, potential costs are outlined followed by a description of industry benefits.

Research costs – Large-scale field trials would be required to further determine the nature of hauling damage and implications for the fishery. It is assumed that a 5 year project, @$200,000 per year would be required to undertake this research. In the event that long term damage was observed, optimal management plans would need to be devised and extended to industry. For the purposes of this analysis, it is estimated that a 1 year project - @$100,000 would be required to design management plans for NSW estuaries.

Production implications – Both fish and prawn populations could potentially benefit from enhanced management of seagrass beds. Proper management of seagrass communities would lead to increases in commercial fish and prawn populations, as juvenile recruitment and survival would be enhanced. During 1999, NSW estuaries yielded approximately $2 million prawns and $12 million in fin-fish (NSW Fisheries 1999). Major fin-fish species include bream, mullet, whiting, eels, flathead and luderick. It is assumed that prawn and finfish landings would be increased by 5% per annum where sea-grass management plans were implemented.

Probability of research outcome – a number of technical, political and commercial risks need to be overcome if hauling research were to result in industry benefits. Firstly, it needs to be demonstrated that hauling has an impact on seagrass communities and marine populations. Secondly, management plans need to be devised and implemented. Management may involve rolling open and closures of differing segments of an estuary to allow seagrass re-vigouration. Such a plan may be met with industry resistance. As a result of these risks, a low probability of industry outcome of 15% is included in the analysis.

ENVIRONMENTAL IMPACT

Further understanding of the biology, and enhancement of seagrass communities are likely to have a number of environmental benefits:

- Recreational fishers target many species that inhabit seagrass areas. Any enhancement to these areas is likely to increase recreational fishing stocks and enjoyment of recreational fishing;
- Non-target commercial and recreational species, that form an integral part of the food chain or element of ecosystem function may benefit from seagrass bed improvement; and
- Research techniques developed in the follow projects may have flow-on benefits for non-NSW fisheries or other marine ecosystems.

Similarly to other studies, it is assumed that recreational fishers value increased landings at $10 per fisher per year. Selected results cited in Read and Sturgess (1996) including Desvouges *et al* (1987), Morey and Shaw, (1989) noted that recreational fishers were willing to pay between $13-17 per person to improve the catch. The number of recreational fishers that need to realise this benefit for the projects to break-even are described in the pay-off section.

ADOPTION

A considerable research lag would be apparent as a relatively large project would need to be financed prior to any benefits being realised. It is assumed that a lag of 7 years (from 2001) would be apparent prior to the possible implementation of seagrass management plans

It is assumed that NSW estuaries would be the primary target for the research projects. In 1999, it is estimated that $14 million worth of finfish and prawns were landed from these areas.

BENEFITS

If 40% of NSW estuarine fisheries were to adopt and experience a 5% production increase from the implementation of optimal seagrass management, an annual industry benefit of $280,000 would be apparent.

PAY OFF

The following graph shows the cost and benefits of projects (95/149 &

96/286) and the assumed follow-on projects.

The research is estimated to provide a BCR of 0.7, NPV of -$0.1 m if only commercial benefits are considered. For the projects to break-even a production increase of 6% would be required within the assumed 40% of the NSW estuary fisheries adopting management plans.

If recreational fishers value an increase in landings by $10 per person per year, at least 3,441 fishers would have to realise recreational gain (including commercial benefits) for the project to break-even.

COMMENT

In purely commercial terms, the research therefore represents a modest investment. The high risk of the project constrains industry benefits. Only a small number of recreational fishers would, however, need to benefit from the project for positive benefits to be attained.

Bell, J.D. and Westoby, M. (1986), "Importance of local changes in leaf height and density to fish and decapods associated with seagrass", *J. Exp. Mar. Biol. Ecol*, 104, pp. 249-274

Connolly, R.M. (1994), "Removal of seagrass canopy: effects on small fish and their prey", *J. Exp. Mar. Biol. Ecol*, 184, pp. 99-110.

Desvousges, W.H., Smith, V.K. & Fisher, A. (1987). `Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River'. *Journal of Environmental Economics and Management*, 14: 248-267.

Otway, N.M. and Macbeth, W.G. (1999), "Physical effects of hauling on seagrass beds", NSW Fisheries Final Report Series, No. 15, August 1999

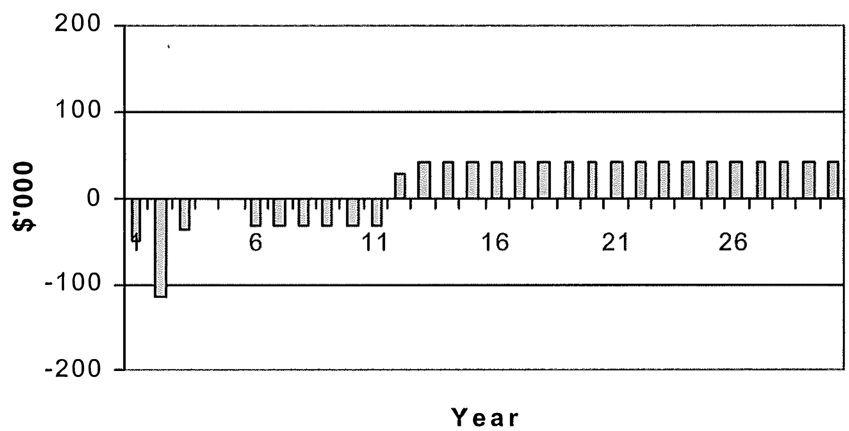
Morey, E. & Shaw, W. (1989) "An economic model to assess the impact of acid rain: a characteristics approach to estimating the demand for and benefits from recreational fishing", in Shaw, W.D. (1989). `Valuing the Effect of Acidification Damages on the Adirondack Fishery: Comment'. *American Journal of Agricultural Economics*, 217-222.

NSW Fisheries (1999), Estuary General Fishery Report - 1999, NSW Fisheries, Cronulla.

Read, M.P. and Sturgess, N.H. (1996), Tuckean Swamp Economic Study – an evaluation of options for managing problems associated with flooding, drainage and acid sulfate soils, Consultant Report to Tuckean Swamp Management Committee, July 1996.

Water Research Centre and Flood Hazard Research Centre (1989). Investment appraisal for sewage schemes: the assessment of social costs - project Report. Water Research Centre: in Swindon, in Barde, J.P. & Pearce, D.W. (1991). *Valuing the Environment: six case studies.* OECD, Paris.

Benefits and costs through time



Appendix 1 - Review of Environmental Values

Most of the studies reported in this appendix were drawn from the NSW EPA's ENVALUE database where full reference information is available. Full citations for other studies are provided Unless where otherwise stated, all values are reported in 1998 $A and full reference details are available from the ENVALUE database at www.epa.nsw.gov.au

Natural Areas / biodiversity

Loomis and White (1996)

- Willingness to pay (WTP) for species preservation per household lump sum = A$22.35
- Contingent Valuation Method

The paper provides a summary of the results of contingent valuation studies undertaken in the USA for threatened and endangered species. Where a range of estimates for an individual species were available in the literature an average was taken.

Species for which WTP values are reported include: northern spotted owl; Pacific Salmon/Steelhead; Grizzly Bears; Whooping Crane; Red-cockaded Woodpecker; Sea Otter; Gray Whales; Bald Eagles; Bighorn Sheep; Sea Turtle; Atlantic Salmon; Squawfish; Striped Shiner; Humpback Whales; Monk Seal; Gray Wolf and Arctic Grayling/Cutthroat trout.

Simpson, Sedjo and Reid (1996)

- Private value of the marginal species (in situ) for use in pharmaceutical research = A$13,721.41
- Private value of the marginal hectare of threatened habitat for pharmaceutical research = A$27.44.
- Estimation method = Demand Analysis

This paper established a model of the pharmaceutical benefits for marginal species on the basis of their incremental contribution to the probability of making a commercial discovery. Value of the entire collection of samples was given as a function of net revenue of a new product if successfully developed (gross of research and development costs), the number of species of organisms that may be sampled in the search for the new product and the probability that the first organism tested yields a commercially successful product.

While admitting that it is impossible to estimate the value of the marginal species with any precision, the authors used some general data from the pharmaceutical industry and a number of simplistic assumptions to solve the conceptual model developed and obtain an indication of the possible value of the marginal species.

Rolfe, J.C., Bennett, J.W. and Blamey, R.K. (2000), An Economic Evaluation of Broadscale Tree Clearing in the Desert Uplands Region of Queensland, Research Report No. 12, Choice Modelling Research Reports

- WTP per household to avoid the loss of an endangered species from the Desert Uplands region = $11.39

- WTP per household to avoid each 1% loss in the population size of non-threatened species from the Desert Uplands region = $1.69

- WTP per household to avoid each 1% loss in the area of unique ecosystems from the Desert Uplands region = $3.68

- Estimation method = Choice modelling

Willingness to pay of households in Brisbane for environmental factors associated with tree clearing in the Desert Uplands region of central-western Queensland. The Desert Uplands bioregion is an area of acacia and eucalypt woodlands covering some 6.9M ha. The region is primarily used for beef grazing.

Lockwood. M., Walpole, W. and Miles, C. (2000), Economics of Remnant Vegetation Conservation on Private Property, L&WRRDC Research Report 2/00

- WTP per household to preserve remnant native vegetation on private property in the Murray catchment of NSW; CV = $95, CM = $138

- WTP per household to preserve remnant native vegetation on private property in NE Victoria; CV = $98, CM = $133

- Estimation method = Contingent Valuation Method (CV) and Choice modelling method (CM)

The study estimated the value that residents in NSW and Vic placed on preserving 113,313 ha and 203,429 ha of remnant native vegetation in NE Victoria and the Murray catchment of NSW respectively.

CIE (1998), Establishment of a Protected Area in Vanuatu, ACIAR Impact assessment Series #3, Canberra

- Average Wtp of Australian visitors to establish protected areas for 10,000 ha of forests in Vanuatu = $20 using CV

- Average Wtp of Australian households to protect forests in Vanuatu = $3 using CM

- Estimation method = Contingent Valuation Method (CV) and Choice modelling method (CM)

Studies for Natural Areas / Coastal

Pitt (1993)

- WTP of residents on the NSW north coast for dune and beach maintenance = A$4.71 per month.

- Estimation method = Contingent Valuation Method

Studies for Natural Areas / Wilderness

Lockwood, Tracey and Klomp (1996)

- WTP by Victorians to stop cattle grazing on Bogong High Plains in the Australian Alps, Victoria, giving nature conservation benefits = A$37.16 to A$41.67 ($ per respondent)

- Estimation method = Contingent Valuation Method

Studies for Natural Areas / Wetlands

Mumphrey *et al* (1978)

- Suggested that Americans are willing to pay $924-2,176 per hectare for wetland protection. The estimates accommodate the gross value of fishing, fur harvests and recreational fishing and hunting on Louisiana's coastal marshes.

Bell (1997)

- The present value of an incremental acre of wetland (saltwater marsh) on the east and west coast of Florida in supporting recreational fishing = A$13,409 (east coast) A$2,032 (west coast)
- Estimation method = Dose-Response Approach

Bergstrom, Stoll, titre and Wright (1990)

- Mean willingness to pay per recreationist per year = A$707
- Average annual consumer's surplus per ha = A$40
- Estimation method = Contingent Valuation Method

WTP to protect the fishing and hunting recreation uses of the Louisiana coastal wetland. The study area was approximately 1.32 million ha on the Gulf of Mexico coast of Louisiana and comprised a diverse ecosystem of freshwater marsh, brackish marsh, saltwater marsh, open water and dry land. The area is extensively used for outdoor recreation in particular, waterfowl hunting, freshwater fishing, saltwater fishing, recreation shrimping and recreational crabbing. The fish, shellfish and wildlife populations are dependent on the wetlands for food, shelter and life cycle support.

Gerrans (1994)

- WTP to preserve the Jandakot wetlands, Perth, Western Australia, in their current state. Median WTP per annum per household = A$36
- Estimation method = Contingent Valuation Method

Kirkland (1988) in Dumsday et al (1991)

- WTP per household to preserve environmental quality 0f Whangamarino Wetland NZ: Use value = A$0.86 (2) Option value = A$3.34 (3) Existence value = A$3.92 (4) Bequest value = A$8.34 (5) WTP for improved wetland quality = A$7.79
- Estimation method = Contingent Valuation Method

Morrison, Bennett and Blamey (1998)

- WTP per household for an additional endangered species = A$4.03
- Estimation method = Choice modelling
- WTP of Sydney households for improved wetland quality in the Macquarie Marshes, north-western NSW

Sappideem (1992)

- WTP per person per visit to preserve water quality from increased salinity to maintain the recreation value of a wetland (Victoria) = A$3.35
- Estimation method = Contingent Valuation Method

Studies for Natural Areas / Rivers and Lakes

Kelly and Bright (1992)

- Wtp of recreational trout anglers per annum to maintain trout stocks for those who were not members of fishing clubs = A$27.27
- Estimation method = Contingent Valuation Method

The study elicited the economic value associated with recreational trout fishing in the New England region

Sinden (1990)

- WTP per household p.a. for recreation at 24 sites along a river system: Day visits = A$27.71 Camping visits = A$46.60
- Estimation method = Travel Cost Method

Walpole (1991)

- WTP per household per visit for recreation at selected sites along the river system, Victoria = A$9.07 to A$38.16
- Estimation method = Contingent Valuation Method

Loomis (1987) in Young (1991)

- WTP per household for the protection of Mono Lake's, USA ecosystem = A$25.70
- Estimation method = Contingent Valuation Method

CIE (1997)

- Median household Wtp to improve quality of ACT's streams and rivers = $155 (CV)
- Mean household Wtp to reduce the threat to one (uncommon) species =$5 (CM)
- Estimation method = Contingent Valuation Method (CV) and Choice modelling method (CM)

Crase (1996)

- Aggregate WTP of Albury community (NSW) to fund establishment of wetlands =$1.95m
- Estimation method = Contingent Valuation Method

Kaoru (1993)

- Mean WTP per household per year = $227
- Estimation method = Contingent Valuation Method

WTP to improve the quality of water in the Edgartown Great Pond, Lagoon Pond and Sengekontacket Pond on the island of Maratha's Vineyard, Massachusetts, USA, so that they would be open for shellfishing year round.

Tay and McCarthy (1994)

- Wtp per angling trip from a 1% decrease in the concentration of phosphorous =$A0.44 per trip
- Estimation method = Travel cost Method

The study uses cross sectional data on anglers' characteristics and fishing destinations in the state of Indiana.

Water Research Centre and Flood Hazard Research Centre (1989).

Wtp per UK household for improved water quality and fishing =$17 per household per year

Desvouges et al (1987)

Wtp per visitor trip for improved water quality and fishing in the Mongahela River, Pennsylvania =$16 per trip

Mitchell and Carson (1981)

Wtp for improved water quality and fishing in the USA =$80 per household per year

Morley and Shaw (1989)

Wtp per recreational fisher for improved fishing (25% increased catch) in the Adirondacks (USA) as a result of reduced acidification =$13-23 per fisher per year

Van Bueren *et al* (1993)

Found that West Australian recreational anglers were willing to pay $5.5 per additional salmon caught

Burns *et al* (1995)

Noted that south Australian recreational anglers were willing to pay $0.72 per additional whiting caught

Appendix 2 - Details of Evaluation Method

In this section the fundamentals of BCA are discussed to a level of detail that will enable readers to work through the individual evaluations of selected completed FRDC projects.

There are two critical aspects in the benefit cost assessment of a research and development project. The first involves an assessment of what technology (be it a product, process or information) has been made available for use in the industry. The second involves an assessment of how the technology will increase industry profits, recreational benefits or deliver environmental improvements. The first part requires consideration of the technical outcomes from a project while the latter involves a valuation of economic and environmental impacts.

Two of the main strengths of using benefit cost analysis are that assumptions can be made explicit and evaluation results can be readily reproduced.

What is BCA?

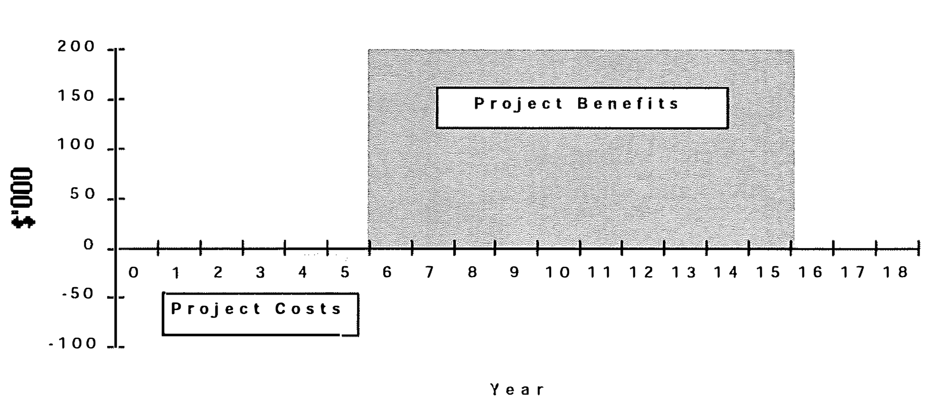
Benefit-cost analysis is simply a comparison of project benefits against project costs that are realised or incurred through time. Project costs are the costs incurred in carrying out a given research project plus the costs involved in developing research outcomes for direct commercial application in fisheries industries.

Project benefits are the gains realised by fishing industries and the Australian community at large from the application of research and development outcomes.

In Figure 1 a representative stream of project costs and benefits through time is illustrated.

In this example, annual project costs of $100,000 are planned for 5 years after which annual benefits of $200,000 are generated for a period of 10 years. In total, $500,000 is invested in the project for a return of $2 million. But, is the investment worthwhile?

Figure 1 : Illustrative Project Costs and Benefits



Two measures of project pay off are used to answer this question. The first is the net value of the project, measured by the total value of benefits minus the total value of costs. In our example, the net value of the project is $1.5m, and as this sum is greater than zero the project would represent a profitable investment.

The second measure reflects the relative attractiveness of a project and is called the benefit/cost ratio. It is calculated by dividing total project costs into total project benefits. In our example the benefit cost ratio is equal to 4. Hence, for every dollar invested in the project a return of $4 is realised.

An important consideration in BCA is the treatment of project costs and benefits that are incurred or generated at different points in time. Generally speaking, in a decision to have a dollar today or at some later date, individuals would show a preference for having the dollar today. In a commercial environment, the extent to which an individual would be prepared to postpone having the dollar is at least equal to the rate of interest that could possibly be earned from having the dollar today and investing it. In other words, if you could get an interest rate of 6% over a year so that after one year your dollar was worth $1.06, then, to compensate you for waiting one year to have your dollar, it would be necessary to offer you $1.06 after the year.

In BCA the extent to which individuals prefer a dollar today as opposed to a dollar in a later period is called the discount rate. The discount rate utilised for these benefit cost analyses is 6% each year, and reflects market interest rates (net of inflation) on borrowed capital.

Handling project benefits

The estimation of project benefits is usually the most difficult part of any BCA. Project benefits are the total net gains realised directly by users of R&D outcomes and indirectly by other participants in the industry or the community at large. To determine project benefits, a clear understanding of the anticipated direct industry impact is essential. In BCA there are three aspects that need to be considered when estimating project benefits. These are the size of the gain to individual users, the number of users realising the gain (target market and adoption), and the likelihood that R&D will be successful in delivering the anticipated outcomes.

Estimating individual gains

The net gain to an individual user can be measured by the difference in profits that could be earned with and without the use of the developed technology (commercial R&D outcomes in the form of a product, process or information).
Technological improvement can increase profitability of a given business in several ways. It can:

(i) increase yields or the volume of output given existing resources.

(ii) enable higher prices to be realised on output sold.

(iii) decrease the unit cost of inputs used.

(iv) decrease the volume of inputs used.

In most cases, these impacts can be adequately expressed in terms of a given unit of production, for example, per kg of fish sold. Offsetting these impacts are the costs to the individual of purchasing and using the technology.

Adoption

To derive total net gains from the use of a developed technology it is necessary to estimate the net gain to all individuals that could potentially benefit from adoption and use of the technology, and then sum these gains. Obviously, this would not be practical, and instead, a representative business for the target group of potential beneficiaries should be selected and net gains estimated for this business alone. This group would therefore represent the potential users of the technology, and adoption would reflect the extent to which the technology would be taken up within this group.

The rate and level of adoption of a new technology in the derivation of total net gains is usually very understated in benefit cost analysis. The total net gain in any given year is simply the sum of individual net gains that are generated in that year. The effect of halving net individual gains on total net gains is the same as halving the anticipated rate of adoption of the new technology.

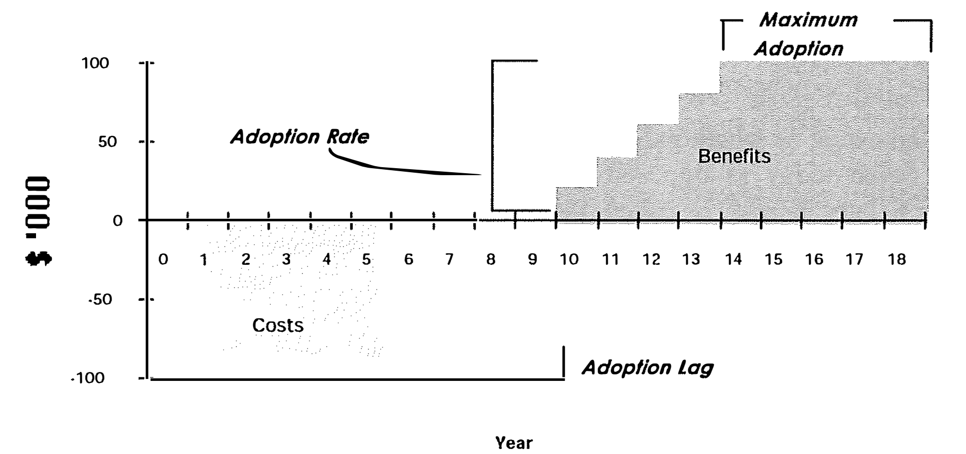
Technology adoption has three components critical to benefit cost evaluation. These components are illustrated in Figure 2.

1. Adoption Lag - the time lag between successful R&D and the first commercial use of a technology (adoption lag).

   Once the R&D project has been brought to a successful close the technology would then be ready for commercialisation and release into the market. During this phase the technology would be produced in commercial quantities, marketed and distributed. While the costs incurred during this phase are reflected in the price at which the technology is sold, the time taken from project commencement to the first commercial use of the technology is important because, as the realisation of benefits is delayed in time the attractiveness of the project declines.

2. Adoption Rate – the rate at which a technology is taken up within the target market.

Figure 2 : Impact of Adoption on Net Gains



The rate of technology adoption is important because, like adoption lag, it influences the extent to which gains are realised in any one year. In practise, technology adoption tends to occur gradually at first, then quite rapid for a while before tapering off. In prospective evaluations a constant rate of adoption through time (linear) is a reasonable assumption to make in the absence of detailed market survey information. The main factors that will influence the rate of adoption through time are the size of the benefit realised by the user, the complexity of use of the technology, the ease with which the technology can be integrated into existing business practices, the degree of financial risk and the communicability of benefits between users.

3. Maximum Adoption – the ultimate level of technology take up within the total market.

   The final component is the maximum level of adoption within the target group. The factors described above that influence the rate of adoption also affect the adoption ceiling.

Dealing with project costs

Project cost is the total expenditure incurred by all parties involved to reach a commercial outcome. IN some cases it will be necessary to estimate additional costs from project completion to account for the cost of "brining a technology to market".