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The biology, socioeconomics and management of the barramundi fishery in Papua New Guinea's Western Province

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The biology, socioeconomics and management of the barramundi fishery in Papua New Guinea's Western Province

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Cover: Barramundi breeding stock being fed at a temporary holding facility on Daru Island, Western Province, Papua New Guinea. Photo © Ian Middleton

Foreword

Barramundi was once the fourth most valuable export commercial fishery in Papua New Guinea (PNG), with total catches of greater than 200 tonnes/year. In about 1990, however, the unregulated commercial operations collapsed because catches had plummeted to about 4 tonnes/year. Although the commercial fishery virtually ceased, the fish nevertheless remained important economically for artisanal fishers in PNG's Western Province.

Rehabilitating the barramundi populations in PNG's Western Province thus became an important issue. The Australian Centre for International Agricultural Research (ACIAR) funded a 1-year study in 1996, which revealed there were large gaps in knowledge about many aspects of the biology of barramundi in the area and of the operations of the traditional fishery.

The study led to a project that drafted a management plan for the barramundi fishery. The plan passed into law in 2003. In addition, biological and socioeconomic research laid the foundation for the development of a bioeconomic model that could be used to analyse various management options.

ACIAR commissioned the Centre for International Economics to undertake an impact assessment of the work, to determine whether the barramundi fishery management plan induced change in fishing practices and whether the introduction of the plan had led to any significant benefits for fishing communities.

The assessment concluded that, although the project generated knowledge that will enable better management of the fishery, the management plan has so far not brought any enduring benefits to the community. On the other hand, the assessors were able to highlight a number of outputs that have brought much greater understanding of the complex interactions of the fishery that will guide future research directions.

Important take-home messages were the need to regularly review and update fisheries management plans to ensure they align with changing circumstances, together with the caveat that there is little point developing regulations that cannot be enforced. The assessment also underlined the need to carefully determine that markets affected by the research and development are large enough to ensure that the benefits gained outweigh the costs of research.

Nick Austin
Chief Executive Officer, ACIAR

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Abbreviations

BFMP	Barramundi Fishery Management Plan
BMAC	Barramundi Management Advisory Committee
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
JCU	James Cook University
NFA	National Fisheries Authority (PNG)
OTML	Ok Tedi Mining Limited
PNG	Papua New Guinea
TAC	total allowable catch

Summary

Barramundi have been an important source of income and food for communities in the Fly River and adjacent coastal areas of Papua New Guinea's Western Province. A commercial fishery was established in the late 1960s and early 1970s and, by the mid 1980s, the annual catch was around 200–300 tonnes (Blaber 2003, Appendix 1, p. 14). However, a sharp decline in catches in the early 1990s led to the closure of the commercial fishery.

Following the recommendations of a preliminary study, the Australian Centre for International Agricultural Research (ACIAR) provided funding for project FIS/1998/024, 'The biology, socioeconomics and management of the Barramundi fishery in the Fly River and adjacent coast of Papua New Guinea', which aimed to draft a barramundi fishery management plan for Papua New Guinea (PNG) that was acceptable to all stakeholders. The project ran from July 1999 to December 2003 (including an 18-month extension) and was led by CSIRO Marine Research in partnership with the National Fisheries Authority (NFA) in PNG. James Cook University and Ok Tedi Mining Limited also collaborated on the project.

Outputs and adoption

The project delivered the draft of a Barramundi Fishery Management Plan (BFMP). The plan includes a number of fishery management measures including:

- gear restrictions
- area closures
- a total allowable catch.

The development of the BFMP was underpinned by research that increased the knowledge of the biology of the fishery and of some of the relevant socioeconomic factors. The biological research—and to a lesser extent the socioeconomic research—also fed into the development of a bioeconomic model that was used to analyse various management options. Figure 1 shows the pathway to project impacts.

Outcomes

The BFMP was passed into PNG law on 15 April 2003 and gazetted by the PNG Government the following day. This in itself represented a change in practice by PNG policymakers and was a significant achievement of the project.

Although there is little formal enforcement, the BFMP has been successful in inducing some changes in fishing practices. In particular, the commercial fishing companies and the main net wholesaler no longer supply gill nets with a mesh size greater than 6 inches, a management measure to protect the large breeding stock. Another successful management measure is the refusal by commercial processors to buy undersize fish. Nevertheless, small fish continue to be sold in local markets.

Impacts

The impact of the ban on nets with larger mesh size is measured against a counterfactual scenario in which 7-inch nets continue to be used. If 7-inch nets continued to be used, the probability of stock collapse would increase over time. If the fishery collapsed, the annual catch would fall to zero.

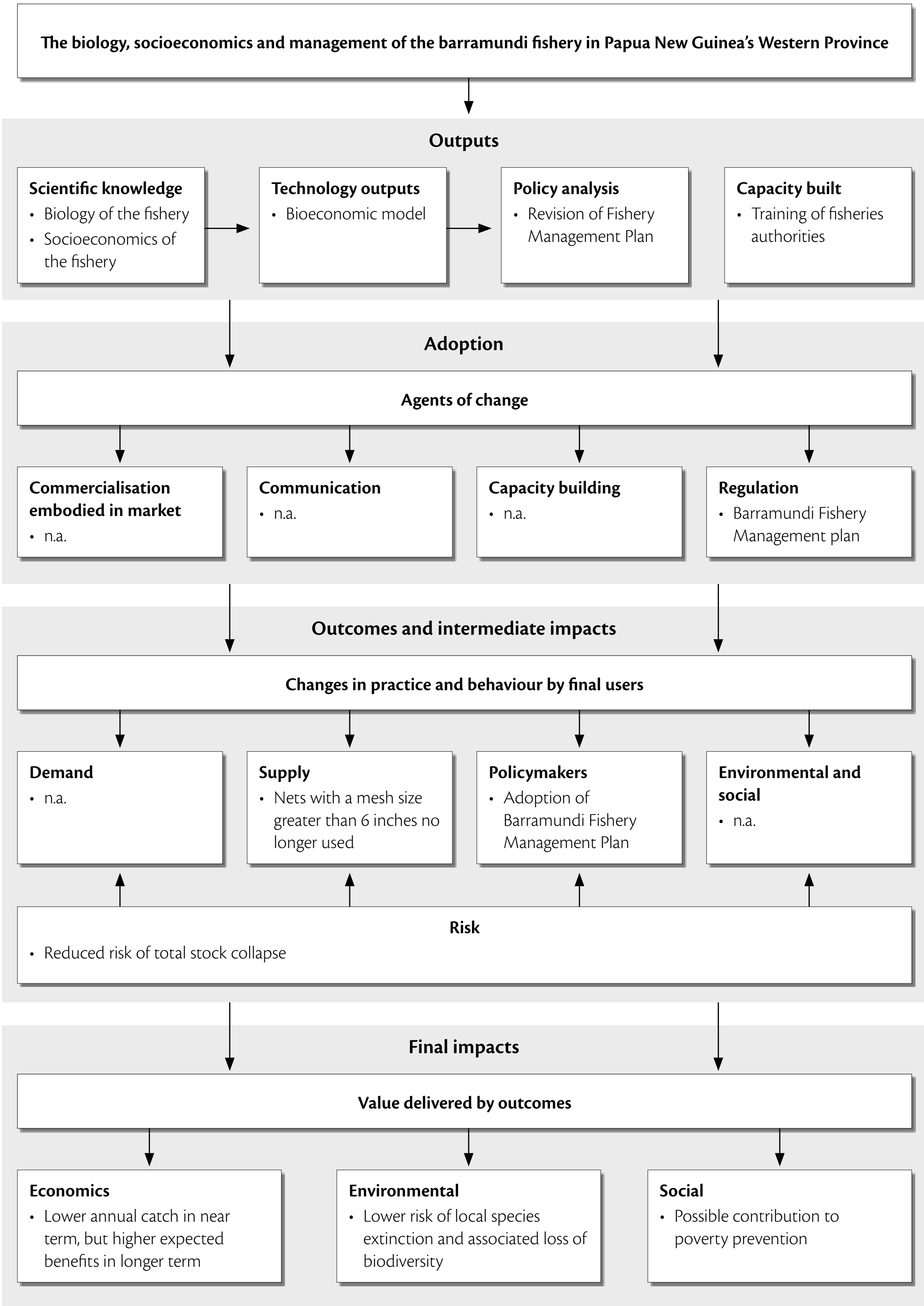

Figure 1. Pathway to impacts from project FIS/1998/024. Source: The CIE.

The main benefit of the ban on nets with larger mesh size is the reduced probability of total stock collapse. The bioeconomic model suggests that, as a result of the ban, the spawning biomass in the fishery (a measure of mature adults within the fishery) is likely to be significantly higher than it otherwise would have been. A higher spawning biomass reduces the probability of stock collapse. Therefore, the expected benefits of the ban increase over time as the probability of stock collapse in the absence of the ban also increases.

However, the ban on nets with larger mesh size also has a cost. The ban reduces the proportion of the population susceptible to netting. Therefore, in the event that the stock did not collapse without the ban, the annual catch would be lower under the ban than it otherwise would have been. The bioeconomic model projects that the annual catch will be persistently lower when 6-inch nets are used than when the banned 7-inch nets are used. Effectively, the ban on nets with larger mesh size involves a trade-off between a lower expected catch in the near term and a higher expected catch in the longer term.

The increasing use of lures, which unlike gill nets are not selective in the fish they catch, means that many females continue to be caught before spawning. This may have eroded the benefits of the BFMP over time. This means that, while the short-term costs have been incurred, the longer term benefits may not be realised. In addition, the restocking program means that the loss of future benefits in the event of stock collapse before restocking will be temporary rather than permanent.

The net cost of the ban on nets with larger mesh size will be borne by processors. Since processors earn a significant margin on the barramundi they process, the lower catch in the near term will therefore reduce their profits. The ban is, however, unlikely to have a significant impact on the welfare of artisanal fishers. The reduction in the proportion of the population susceptible to netting will discourage fishing effort, and the resources (including labour and capital) previously used for fishing are likely to be of equal value in an alternative use.

Estimated impacts

Assuming that the BFMP reduces by 25% the probability of total stock collapse over a 10-year period, the project is estimated to deliver a net loss of A$2.7 million (2008–09 dollars) in present value terms, using a discount rate of 5%. The present value of the impacts delivered by the BFMP is estimated at a loss of around A$255,000 in 2008–09 dollars, mainly borne by processors. The short-term costs associated with a lower annual catch have already been incurred, while changing circumstances mean that the intended longer term benefits (the lower risk of total stock collapse) are likely to be less significant than expected. The total project costs were around A$2.4 million expressed in similar terms. This implies a benefit:cost ratio of around –0.10 and an internal rate of return of –31.1%. Although these estimates are sensitive to the assumptions used, the general conclusions drawn from them are robust to varying the key assumptions within a plausible range.

Conclusions

While the project made a significant contribution to the knowledge required to successfully manage the Western Province barramundi fishery, the BFMP and therefore the project do not appear to have delivered any significant benefits to the community.

Several other factors seem to have prevented the BFMP from delivering greater benefits to the community:

- inadequate enforcement
- failure to deal with the problem of over-fishing with lures
- a total allowable catch that appears to be too high and may not be enforceable anyway.

Nevertheless, the project may yet deliver some significant benefits to the community if its scientific outputs are used to underpin revisions to the BFMP.

The following lessons that may be useful in guiding future projects have emerged from this impact assessment and the project more broadly.

- First, without meaningfully restricting fishing effort (including restrictions on entry), any fisheries management plan is unlikely to deliver significant long-term benefits to fishers. Any successful measures to increase the productivity of the fishery will increase profits and encourage an increase in effort that, over time, will erode the benefits (see Panayoutou 1982). Similarly, directly subsidising fishing is unlikely to deliver long-term benefits in an open-access fishery that is already over-fished. Restricting operator licences is also likely to be an ineffective strategy for restricting fishing effort.

- It is essential for fisheries plans to be updated regularly as circumstances change.

- There is little point in developing regulations that cannot be enforced. The enforcement mechanism needs to be carefully considered in the design of the regulations. The project has also shown that, even without formal enforcement, some level of compliance can be achieved when the supply chain (both upstream suppliers and downstream buyers) can be controlled.

- It is important to carefully consider the size of the markets affected by the research and development project and whether the potential benefits are likely to be large enough to outweigh the cost of the research.

1 Introduction and background

Background

Barramundi fishing has previously been an important economic activity in the Fly River and the adjacent coastal region of Papua New Guinea's Western Province. Barramundi has also been an important food source in the region.

The commercial barramundi fishery was established in the late 1960s and early 1970s, with processing and distribution centres set up in the province. By 1969 there were three types of commercial operations established (Blaber 2003, Appendix 1, p. 14):

- A Daru-based artisanal[1] coastal fishery was using gill nets to target mainly adult barramundi that were migrating to breeding grounds west of Daru near Sigabaduru village during September–January (late dry season – early wet season). Gill nets are highly selective. Fish that are smaller than the target size are able swim through the net, while larger fish do not get caught in the mesh. The size of the fish caught therefore depends on the mesh size.
- Refrigerated fishing vessels were operating with their own gill nets and also bought catch from artisanal fishers.
- Village-based freezers of five tonnes capacity had been set up at selected villages in the middle Fly River and the Fly River mouth regions. These freezers were operated by village cooperatives that sold their catch to the Daru wholesalers or the refrigerated boats.

By the mid 1980s, the total catch of the commercial fishery had reached around 200–300 tonnes/year, caught mainly in the Daru area. However, the annual catch of the Daru-based fishery declined significantly in the early 1990s, to as low as 4 tonne/year. This decline led to the closure of much of the commercial fishery.

The ACIAR project

Following the decline in the total catch and the subsequent collapse of the commercial fishery, the Australian Centre for International Agricultural Research (ACIAR) provided funding for research project FIS/1998/024 on 'The biology, socioeconomics and management of the Barramundi fishery in the Fly River and adjacent coast of Papua New Guinea'.

The project had four main elements (CSIRO 1998, pp. 18–21):

- biological research to complement the existing knowledge from Papua New Guinea (PNG) and elsewhere, including genetic population studies, life history and reproductive biology, and the biology of the Fly River population

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1 Although there is no formal definition, FAO (see <http://www.fao.org/fishery/topic/ 14753/en>) describes artisanal fisheries as:

> … traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips close to shore, catching mainly for local consumption. In practice, the definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20-m trawlers, seiners or long-liners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries providing for local consumption or export. They are sometimes referred to as small-scale fisheries.

- a socioeconomic study of the barramundi fishery, including determining the importance of barramundi to the economy of Western Province, catching and marketing methods for barramundi (and other fish products), the significance of barramundi (and other fish products) as a food resource and accounting for local knowledge in developing management plans
- development of a bioeconomic model for barramundi management that linked biological, social and economic data into an integrated model that could be used to evaluate management options for the fishery
- development of a management plan and definition of a recovery strategy for the artisanal barramundi fishery.

The project was initially intended to run from 1 July 1999 to 30 June 2002 but, following a project review, it was extended until December 2003.

This project followed an 18-month preliminary study (FIS/1996/081) funded by ACIAR, CSIRO Marine Research and the PNG National Fisheries Authority (NFA) that aimed to collate and analyse the original commercial barramundi logbook data collected since 1970 and, with the cooperation of Ok Tedi Mining Limited (OTML), to amalgamate these data with data collected by OTML since 1984 on barramundi in the Fly River (CSIRO 1998, p. 6).

Objectives

The ultimate objective of the project was to develop a draft 'barramundi fishery management plan' (BFMP) for PNG that was acceptable to all stakeholders (CSIRO 1998, p. 5). Management of over-exploited fisheries can increase the benefits that they provide to the community.

To achieve that overarching objective, each element of the project had more specific aims as follows (Blaber 2003, pp. 2–4).

- The biological research had five specific objectives:
  - to identify genetically separate stocks of barramundi and their relative contribution to the spawning populations
  - to estimate vital life-history parameters including growth rates, age at first maturity, and fecundity, to establish any changes or differences from published data
  - to determine the location, seasonality and extent of spawning
  - to identify temporal and spatial changes in the size distribution in the barramundi population throughout the Fly River system since OTML began monitoring in 1988
  - to estimate the relative contribution of barramundi to the artisanal and commercial catches in the middle Fly River and their relationship to the theoretical potential yield of barramundi based on empirical relationships with catchment and floodplain area.
- The objectives of the socioeconomic research were to describe the relative importance of barramundi to the economy of villages in the Fly River and adjacent coast, to understand the local knowledge of the barramundi life cycle and to identify management options that are agreeable to local and provincial stakeholders.
- The objective of the bioeconomic model was to enable quantitative evaluation of a range of management options.

Collaborators

CSIRO Marine Research was commissioned to undertake the project in partnership with the NFA. This project continued a long-standing collaborative relationship between CSIRO Marine Research and the NFA.

James Cook University (JCU) collaborated on the socioeconomic research. OTML also had significant involvement, given the overlap with the environmental monitoring work they were already undertaking in the Fly River.

Other relevant development projects and research

In addition to the preliminary study, CSIRO and NFA have collaborated in a further two ACIAR-funded projects:

- research for sustainable uses of bêche-de-mer resources in Milne Bay province, PNG (FIS/2001/059)
- biology and status of the prawn stocks and trawl fishery in the Gulf of Papua (FIS/2002/056).

The project was also initially intended to complement a broader AusAID funded coastal zone management (CZM) study. However, shortly after the ACIAR project commenced, the CZM study was postponed indefinitely.

The ongoing environmental monitoring by OTML on the possible effects of mining (toxicity testing, histopathology) on both riverine and coastal stocks also complemented this project.

More recently, the PNG Sustainable Development Program provided K27.4 million to Western Province Sustainable Aquaculture (I. Middleton, pers. comm., 3 December 2009). Components of this activity are:

- a barramundi hatchery facility in Daru
- a wild fishery restocking program
- commercial barramundi farming and feed trials
- an awareness program.

This followed pilot trials for aquaculture undertaken by OTML in 2001 and a larger feasibility study in the middle Fly River lakes in 2005–06 (B. Figa, pers. comm., 18 March 2010).

An ACIAR-funded scoping study on invasive species that threaten juvenile barramundi is also currently underway in Western Province (B. Figa, pers. comm., 18 March 2010).

While all of these development projects are broadly related to the barramundi fishery, only the ACIAR-funded preliminary study was a necessary precondition to the project and contributed directly to the project's outputs. While the other projects will have important impacts on the barramundi fishery, none of them was essential for the BFMP developed during the project to deliver benefits (if any). Therefore, only the costs associated with the preliminary study will be included as project inputs for the purpose of this impact assessment.

While the data collected from OTML's environmental monitoring work were necessary for the project's completion, this monitoring work would have occurred without the project. These costs can therefore be treated as sunk. Only OTML's direct contribution to the project is therefore treated as an input.

Funding

Including the preliminary study, ACIAR contributed around A$830,000 of the total nominal project costs of around A$2.1 million (Table 1). This is slightly below 40% of the total project cost. There were also large contributions from OTML and CSIRO Marine Research and smaller contributions from JCU and the NFA.

The total cost of the preliminary study was around A$675,000, with ACIAR contributing about A$150,000. However, the preliminary study also included research into the tropical rock lobster, bêche-de-mer and Gulf of Papua prawn fisheries. Only the cost of the research related to barramundi should be included as an input into the subsequent barramundi project. Therefore, the costs incurred by CSIRO Marine Research in conducting lobster and bêche-de-mer surveys (A$278,000) was excluded from the analysis and 25% of the remaining budget was estimated to relate to barramundi.

The initial project budget was estimated at around A$1.9 million but there were two major variations. The first variation was necessary due to abandonment of the AusAID-funded CZM study, which was initially intended to be a delivery vehicle for the ACIAR-funded project. The abandonment of the CZM study meant that a project coordination committee (PCC) consisting of the project leaders and community representatives had to be formed to ensure the acceptance and subsequent adoption of the project outputs. This required additional funding of A$58,204 (Blaber 2003, p. 9).

A second variation, amounting to A$36,779, followed the project review in April 2002. The reviewers were concerned about the level of understanding in the community about the scientific findings, the (then) draft BFMP and the implications for fishing activity. Additional funding was required to hold two more PCC meetings to improve community awareness, receive feedback from fishing communities and address the issues identified by the NFA Board that were preventing the plan from being gazetted (Blaber 2003, pp. 9–10).

Table 1. Nominal project costs

	ACIAR	CSIRO	JCU	NFA	OTML	Total
	A$'000	A$'000	A$'000	A$'000	A$'000	A$'000
1996–97	32.2	23.8	–	13.1	–	69.1
1997–98	5.2	23.8	–	1.0	–	30.0
1998–99	–	–	–	–	–	–
1999–2000	270.8	133.3	51.2	42.3	175.0	672.6
2000–01	253.8	136.4	51.4	41.3	175.0	657.9
2001–02	232.9	136.4	53.3	41.3	175.0	638.9
2002–03	36.8	18.2	–	–	–	55.0
Total	**831.7**	**471.9**	**155.9**	**139.0**	**525.0**	**2,123.5**

Source: ACIAR project budget

2 Project outputs and adoption

This chapter describes the outputs delivered by the project and discusses the extent to which they have been adopted.

Outputs

The final output of the project was the Barramundi Fishery Management Plan (BFMP). However, there were also a number of intermediate technical outputs that underpinned the development of the plan. The relationship between these intermediate and final outputs is shown in Figure 2. The outputs are discussed in more detail below.

Intermediate outputs

The key intermediate outputs that underpinned the development of the BFMP were:

- increased scientific knowledge of the biology of the fishery
- increased understanding of the socioeconomic factors related to the fishery
- a bioeconomic model linking biological and socioeconomic data.

Increased scientific knowledge of the biology of the fishery

The project produced a number of scientific papers and made important contributions to the understanding of the biology of the barramundi fishery. Key findings included the following (Blaber 2003, p. 6):

- Conclusive genetic and biological evidence demonstrated that there is only one stock of barramundi in the Fly River and associated coastal waters. The stock also extends into Irian Jaya, but differs from barramundi found in the far east of PNG. This finding contrasted with the prior expectation—based on studies conducted in Australia—that there would be more than one stock of barramundi in the fishery. The finding has important implications for the effective management of the fishery because fishing practices in one area potentially affect fishers throughout the region.
- The biological studies found no evidence of changes from earlier estimates of the biological parameters of growth, reproduction and feeding. However, otolith microchemistry data showed that, in contrast to the behaviour of barramundi in Australia, the migration patterns of barramundi in the Fly River and adjacent coast are irregular.
- Analyses of net selectivity for barramundi, together with reproductive data, indicated the importance of conserving large, breeding females.

Increased understanding of the socioeconomic factors relevant to the management of the fishery

The socioeconomic study found that villages along the Fly River and on the adjacent coast had no indigenous knowledge of the complex breeding and migratory habits of barramundi. Furthermore, there was no appreciation that barramundi are a finite resource and must be managed for sustained yield. Although some coastal villages and river clans claimed rights (contested by other groups) to exclude outsiders from waters over which they claimed tenure, no traditional resource management practices were evident (Blaber 2003, p. 32).

Under certain conditions, community management of the fishery can be effective and no formal regulation is required. However, the socioeconomic research

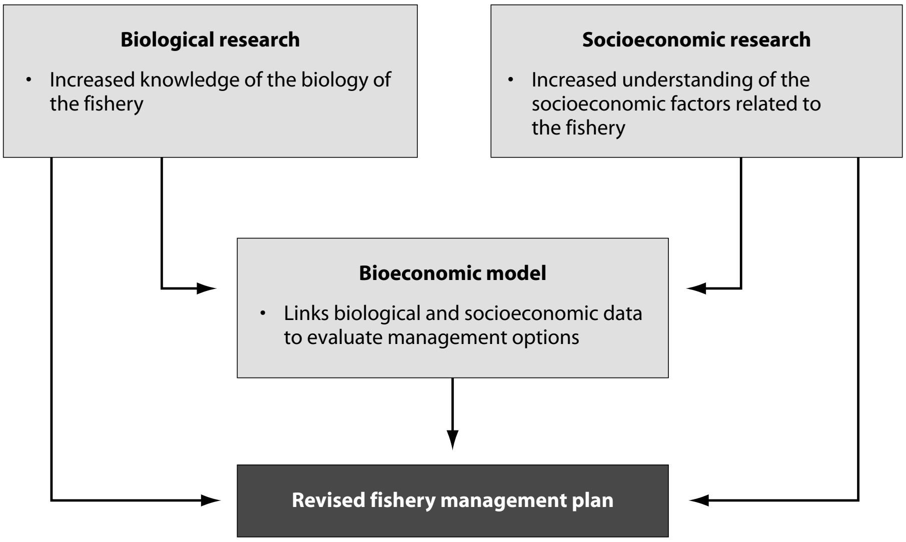

Figure 2. Relationship between project outputs. Source: The CIE.

suggested that the Western Province barramundi fishery is not characterised by such conditions.

Bioeconomic model

The findings of the biological and socioeconomic research informed the development of a bioeconomic model. The model has the following key features (R. Little, pers. comm., 11 November 2009):

- It allows disaggregation into four regions: coastal, lower Fly, middle Fly and Lake Murray.
- It incorporates key socioeconomic variables that determine where and how much people fish.
- It tracks growth and migration of fish, including migration of spawning adults.
- It specifies by age the spatial distribution of fish throughout the river system at a given time.
- It accounts for temporal change in the fish age distribution of each region.
- It details the relationship between regional fish populations through time.
- It incorporates the influences of management strategies and human activities on the fish population.

The model was used to compare the effects of various net mesh sizes on the fish population.

The Barramundi Fishery Management Plan

The objectives of the BFMP are:

- to protect the barramundi stock in the management area from depletion or stock decline
- to ensure sustainable fisheries development practices for the participation and benefit of traditional resource users.

The management measures in the plan include the following key elements:

- There are licensing requirements for fish buyers, fish export facilities, fish storage facilities and collector vessels—under the plan, licences cannot be issued to non-citizen companies, individuals or joint venture arrangements and preference is given to traditional resource owners. The plan also prevents products for export from being moved to another province for sale or export without clearance from the NFA.
- The total allowable catch (TAC) is 260 tonnes per annum—the NFA is required to close the fishery as soon as the TAC is reached.

- Fishing prohibitions include:
  - size restrictions preventing barramundi with a total length of less than 36 cm from being taken for sale or export
  - the owners of licensed collector vessels are prevented from catching barramundi.
- There are gear restrictions on the nets that can be used in the fishery, in particular the plan prohibits the use of:
  - gill nets and beach seine nets with a mesh size greater than 6 inches (15 cm)
  - gill and beach seine nets with mesh size between 2.5 inches (6.35 cm) and 5 inches (12.7 cm) during the peak period of juvenile recruitment (1 March – 30 April) in the coastal waters from Sui village in the east to the PNG/Irian Jaya border in the west
  - gill nets with a mesh size greater than 5 inches (12.7 cm) during the peak migration period (1 September – 31 October) in the coastal waters from Sui village in the east to Buzi village in the west.
- The main spawning and breeding grounds between Sigabaduru village and the PNG/Irian Jaya border are closed to commercial fishing during the peak spawning period (1 September – 31 October) each season.
- There are reporting requirements for exporters and collector vessels.

Capacity building

A number of capacity-building activities were also undertaken as part of the project (Blaber 2003, pp. 7–8):

- OTML staff visited JCU following a preliminary trial of the socioeconomic survey. They were provided with basic training in community mapping, social mapping and community entitlements analysis.
- CSIRO (Cleveland) provided training to a scientist from the OTML environment section on the analysis of existing barramundi length–frequency data.
- CSIRO (Cleveland) provided training on database creation and management.
- CSIRO (Cleveland) provided training on analysing data collected by OTML on barramundi catches, water chemistry, water quality and hydrology. Training on ageing barramundi using fish scales and otoliths was also provided.
- CSIRO (Hobart) provided training on the workings of the bioeconomic model for barramundi in PNG and how to use it to derive projections of the overall population.
- CSIRO (Cleveland) provided training on the operational basics for Microsoft® Access software, database management and preliminary analyses of the OTML barramundi length and weight catch data, including water quality and other environmental data.

Two project participants have also been awarded ACIAR John Allwright fellowships, which allow partner country scientists involved in ACIAR-supported collaborative research projects to obtain postgraduate qualifications at Australian tertiary institutions.

To varying degrees, these capacity-building activities appear to have contributed to the outputs of the project. The capacity built during the project may subsequently have also been used elsewhere and therefore have delivered additional benefits. However, it is beyond the scope of this study to trace any subsequent benefits—to both the individuals involved and the organisations that employ them—flowing from these capacity-building activities.

Adoption

For the outputs produced by the project to deliver any benefits, it is essential that they are adopted. This section discusses adoption issues relating to both:

- the intermediate technical outputs
- the BFMP.

Intermediate technical outputs

The intermediate technical outputs were adopted during the development of the BFMP. As shown in Figure 2, the findings of the biological research fed into the bioeconomic model and directly into the development of the BFMP. Due to the research methods chosen and other factors, the socioeconomic research was less useful in the development of the bioeconomic model. Nevertheless, some of the information collected from the socioeconomic research aided development of the bioeconomic model and was also used directly in the development of the BFMP. In turn, the bioeconomic model was used to evaluate management options during the development of the plan.

The adoption study highlights the importance of regularly updating any fishery management plan (Blaber 2007b, p. 16). Together with the capacity-building activities, there is scope for the bioeconomic model and the other technical outputs to be used to guide any future revisions to the BFMP. Some of the benefits flowing from any future revisions could therefore be attributed to the ACIAR-funded project.

The possibility of revising the plan was raised in discussions with the NFA (L. Baule, pers. comm., 1 December 2009). However, the barramundi fishery appears to remain a low priority for the NFA, and the interim Barramundi Management Advisory Committee—formed under the BFMP to advise the NFA on the management of the fishery—has not met since its initial meeting in September 2003. This suggests that there is a significant chance that the BFMP will not be revised in the foreseeable future. Furthermore, pre-empting the shape of any future revisions to the plan and attributing them in part to the project outputs would be speculative and has not been attempted as part of this study.

The Barramundi Fishery Management Plan

For policy outputs such as the BFMP to have any impact it is essential that they are adopted by the relevant authorities and the government more broadly. In this regard, the plan was signed into law on 15 April 2003 and gazetted by the PNG Government on 16 April 2003 (Blaber 2003, p. 6). As will be discussed in the next chapter, however, not all elements of the plan have been complied with.

3 Project outcomes

The BFMP passing into PNG law is an outcome in itself, as it represents a change in practice by PNG policymakers. This was a significant achievement of the project. However, for the BFMP to have any impact, it is essential for fishers and commercial operators to comply with it. The ultimate outcomes of the project are therefore the behavioural changes that have occurred as a direct result of the operation of the BFMP.

Compliance with the management plan

Compliance can occur through either formal or community enforcement or voluntary compliance. Currently, there appears to be little formal enforcement of the measures contained within the BFMP. Nevertheless, there does appear to be compliance with some aspects of the plan. The adoption study notes that there was a change in fishing practices following the promulgation of the new regulations (Blaber 2007b, p. 10). The following two key elements of the BFMP are being complied with:

- Nets with mesh sizes greater than 6 inches, which are banned, are no longer imported into or sold in Western Province.
- The NFA has implemented a catch-reporting system for the companies that buy most of the barramundi and this has been adhered to by the three companies in Daru, but not by the Obo Fishing Company.

However, there appears to be less compliance with other aspects of the plan. The adoption study notes that while the commercial fish processors are refusing to buy fish less than 36 cm overall length, large numbers of undersize fish are still sold on the open market (usually after the commercial processors have refused them) in Daru (Blaber 2007b, p. 10).

An important part of the new management plan was the formation of the Barramundi Management Advisory Committee (BMAC), composed of government, technical, community and industry representatives. According to the BFMP, the committee should meet once a year to monitor, review and recommend any changes required to the legislation as the fishery changes. As mentioned previously, this committee has not met since its inaugural meeting in 2003.

The impact of other aspects of the BFMP is less clear. The TAC provision has been unimportant to date because the total commercial catch has not reached the 260 tonne limit stated in the BFMP. While recent declines suggest the commercial catch is unlikely to reach this level in the foreseeable future, Western Province Sustainable Aquaculture's restocking program may see the 260 tonne TAC become increasingly relevant (at least temporarily). It is therefore not clear whether this component of the plan would be successfully enforced should the catch reach that level.

Factors affecting compliance

There is a range of factors that have both supported and hindered compliance with the BFMP.

Factors supporting compliance

As there is little in the way of formal enforcement of the BFMP, compliance depends on community enforcement or voluntary compliance. Support for the plan from all the relevant stakeholders was therefore essential. The adoption study notes that the BFMP was adopted because it was widely seen as necessary and timely (Blaber 2007b, p. 13). Close community consultation and efforts to promote community awareness, including the 6-monthly project community consultation meetings with representatives from both coastal and Fly River communities and stakeholders, and the information pamphlet distributed to fishing communities, are factors that are likely to have been critical in gaining community support for the BFMP.

The support of the commercial fish processors and the main net supplier in Western Province has ensured that at least some of the BFMP's management measures have been complied with. Their refusal to supply the banned nets with larger mesh size has greatly reduced their use, though there may be some still in use that were either purchased before the ban took effect or have been imported into Western Province from Indonesia or Port Moresby (M. Yarrao, pers. comm., 3 December 2009). Furthermore, the commercial processors are refusing to purchase juvenile barramundi. However, these undersize fish continue to be sold in local markets. It is thus in those components of the BFMP for which the supply chain for the artisanal fishers (either upstream gear suppliers or downstream buyers) can be controlled to some extent that the greatest level of compliance has been achieved.

Barriers to compliance

A lack of resources for the NFA to adequately enforce the BFMP appears to be a key barrier to more widespread compliance. Formally enforcing fisheries restrictions can be costly and the barramundi fishery remains of relatively low priority compared with other more lucrative fisheries such as tuna, prawns and rock lobsters.

The adoption study also notes that cost seems to be a factor behind the apparent demise of the BMAC. The absence of the BMAC makes it less likely that the BFMP will be revised as circumstances change and therefore that the intermediate project outputs will be used in any analysis to support the revisions.

The lack of formal enforcement means that where elements of the BFMP cannot be controlled by the commercial processors, communities are responsible for managing the fishery and ensuring compliance with the plan. However, a number of the preconditions for effective community management are missing (Fegan 2002; Blaber 2003, Appendix 4, p. 36). In particular:

- There are no restrictions on the number or length of nets or lines/lures.
- The BFMP continues to allow open entry, as it does not provide village governments with the legal authority to restrict the entry of new fishers.
- The BFMP does not provide a village-level TAC.
- There is no attempt to limit the catch that is not processed by the commercial operators.

Fundamentally, this means that the BFMP does not address the issue of property rights. There therefore remains an incentive for individuals (or villages) to contravene the regulations and free ride on the compliance of other fishery participants. So long as there is a lack of formal enforcement of the plan and there is an incentive for individual fishers and groups to break the rules, there is likely to be some level of non-compliance.

4 Impacts

This chapter sets out an economic framework for analysing and measuring the impacts of the BFMP.

The Western Province barramundi fishery

To analyse the impacts of the BFMP, it is important to understand the incentives faced by the fishery's main participants and how these incentives have shaped the fishery over time.

As the barramundi stock is a living resource that responds to changes in fishing effort, the relationship between inputs (effort) and output (catch) is less straightforward than for the production of most other goods (Panayoutou 1982). The total barramundi catch in the Fly River and adjacent coast therefore depends on a combination of both biological and economic factors; more specifically, the relationship between sustainable catch and effort.

The key biological factor determining the quantity of barramundi that can be caught on a sustainable basis is the net natural growth of the stock. Net natural growth (or growth) is the increase in the biomass of the barramundi population between two points in time. It is equal to recruitment (new young fish entering the stock) plus individual growth of fish already in the stock minus natural mortality (Panayoutou 1982). The growth of the fish stock represents the quantity of fish that can be caught without affecting the size of the stock. Clearly, the stock level will remain constant if the quantity of fish removed from the stock through fishing (and natural mortality) is equal to the growth of the stock through natural recruitment or growth in the size of the existing fish.

As with other fisheries, there is likely to be an inverted U-shaped relationship between the stock of barramundi in the fishery and growth. When the stock is low, there are fewer barramundi to breed and therefore growth through recruitment is lower. A lower stock also means the absolute growth in biomass through increase in size of the existing fish is lower. Increasing the stock from low levels will therefore also increase growth. However, the potential size of the barramundi stock in the Fly River and adjacent coast is limited by environmental factors such as food and space. So, at some point, growth would start to decrease as the stock increases.

Fishing effort refers to all inputs—including labour, boats, fuel and nets—used to realise a catch. There is typically a negative relationship between fishing effort and the size of the stock—the more intensively the fishery is fished, the fewer fish there are remaining.

Combining these two relationships implies an inverted U-shaped relationship between effort and sustainable catch. Since total revenue from the fishery is simply the catch multiplied by the average price received, this also implies an inverted U-shaped relationship between total revenue and effort. However, there is a positive relationship between effort and total cost, since increased effort requires more inputs of labour, boats, nets and fuel. The relationship between total revenue (TR), total cost (TC) and effort is shown in Figure 3.

Open access and the problem of over-fishing

As is often the case with unregulated fisheries (unless the conditions for effective community management are present), the lack of property rights over the fishery has led to over-fishing. While other factors, such as lower export prices or little to no migration from the Fly River to the coast over 2–3 years (Haddon and digim' Rina 2002, p. 10), may have contributed to the sharp

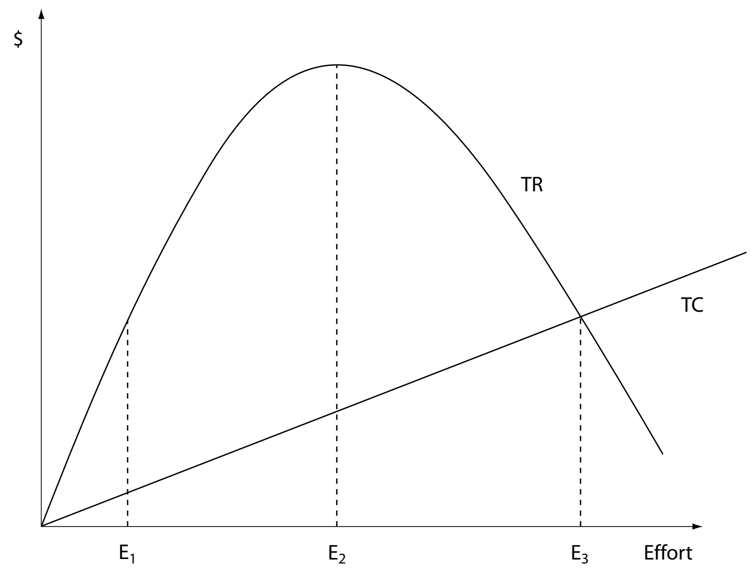

Figure 3. Relationship between total revenue (TR), total cost (TC) and effort for the Western Province barramundi fishery. Sources*:* Panayoutou (1982); Centre for International Economics

decline in the commercial catch in the Daru area in the early 1990s, over-fishing nevertheless appears to be the primary cause.

Before the establishment of the commercial barramundi fishery in the late 1960s and early 1970s, the fishing effort in the Fly River and adjacent coast was largely confined to small-scale fishing for local consumption. The construction of commercial processing facilities introduced larger scale commercial fishing, and linked many artisanal fishers to larger markets. On the simplified depiction of the fishery shown in Figure 3, the pre-commercial level of effort is likely to have been at a point such as E_1, where the fishery is under-exploited. At this point, the total revenue received by fishers exceeds the total fishing costs.

These surplus profits—or resource rents—encouraged increased fishing effort. However, there was no management control on the harvest of barramundi by the commercial barramundi fishery (Blaber 2003, Appendix 3, p. 26). Fishers therefore had no property rights over the unharvested resources, but obtained property rights by harvesting. The incentive was therefore to 'rush to harvest'. Up to the level of effort E_2, the increased catch associated with greater effort can be sustainable. Increasing effort beyond that point may increase the catch in the short term but is not sustainable in the longer term. The lack of property rights over the unharvested barramundi also meant that fishers had little incentive, or insufficient understanding (as suggested by the socioeconomic study), to take actions that would have contributed to the fishery's sustainability. These actions include restricting their fishing effort, particularly during spawning and migration seasons, and reducing the number of juveniles and breeding females caught.

Nevertheless, the resource rents provided an incentive to increase effort beyond the maximum sustainable catch (corresponding with the level of effort E_2 on Figure 3), even although additional effort reduces the total catch (and therefore revenue). The effort of each fisher imposes costs on the other fishers: by catching more fish, there are fewer fish available for others to catch and fewer breeding adults to replenish the stock. Therefore, as a result of an increase in effort from one fisher, all other fishers catch fewer fish for a given level of effort. However, individual fishers do not take into account those external costs imposed on others in making their decisions on the level of effort devoted to fishing for barramundi. Up to the level of effort E_3 in Figure 3, total revenue exceeds total cost, so there is an incentive to increase effort. However, there is no incentive to increase effort beyond that point because total cost will exceed total revenue. The point where total revenue equals total cost (which corresponds with the level of effort E_3 in Figure 3) is called the bioeconomic equilibrium.

The commercial catch of 200–300 tonnes of barramundi per year during the late 1980s appears to have been well beyond the maximum sustainable catch. The excessive fishing effort during that period contributed to the declining catch in the early 1990s. The level of effort may have even extended beyond the bioeconomic equilibrium because the cost of equipment such as nets and boats that have already been purchased may be treated as sunk and therefore not considered in fishing decisions (Panayoutou 1982).

The current Western Province barramundi fishery

While the commercial fishery collapsed in the early 1990s, the coastal artisanal fishery continued. Artisanal fishing has also increased in the middle Fly region around Obo. Fishing for barramundi in the region is therefore largely undertaken by small artisanal or subsistence fishers using nets and lures. The supply chain for the Western Province barramundi fishery is shown in Figure 4.

Artisanal fishers in the coastal region around Daru and in the Fly River delta mostly sell their catch to the three commercial fish processors based in Daru. Freezing facilities were established at selected villages, but not all of these are still functional. The fishing companies based in Daru send collector vessels to pick up the catch from nearby villages. The Daru-based fishing companies are privately owned and sell the processed barramundi mainly in domestic markets, although barramundi are at times exported to Australia (M. Maina, pers. comm., 17 December 2009).

Catch data suggest that the Daru-based fishery has to some extent recovered from the low levels recorded in the 1990s. According to the adoption study (Blaber 2007b), records of sales by fishers to the Daru-based processors since 2003 indicated that the fishery had stabilised on the coast (Figure 5).

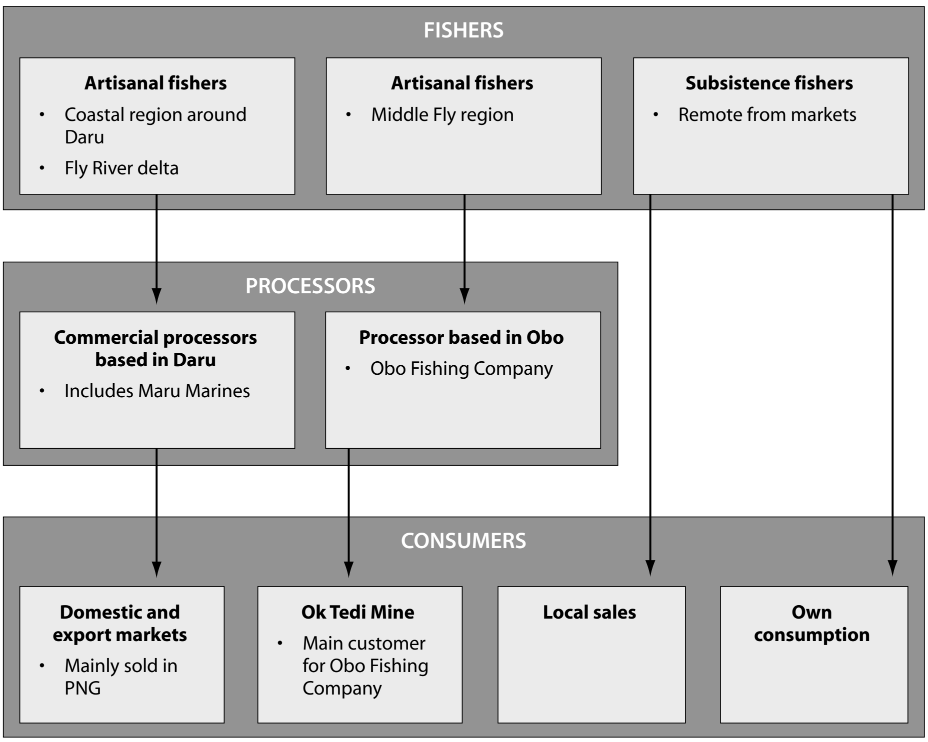

Figure 4. Supply chain for Western Province's barramundi fishery. Sources: Blaber (2003); Centre for International Economics

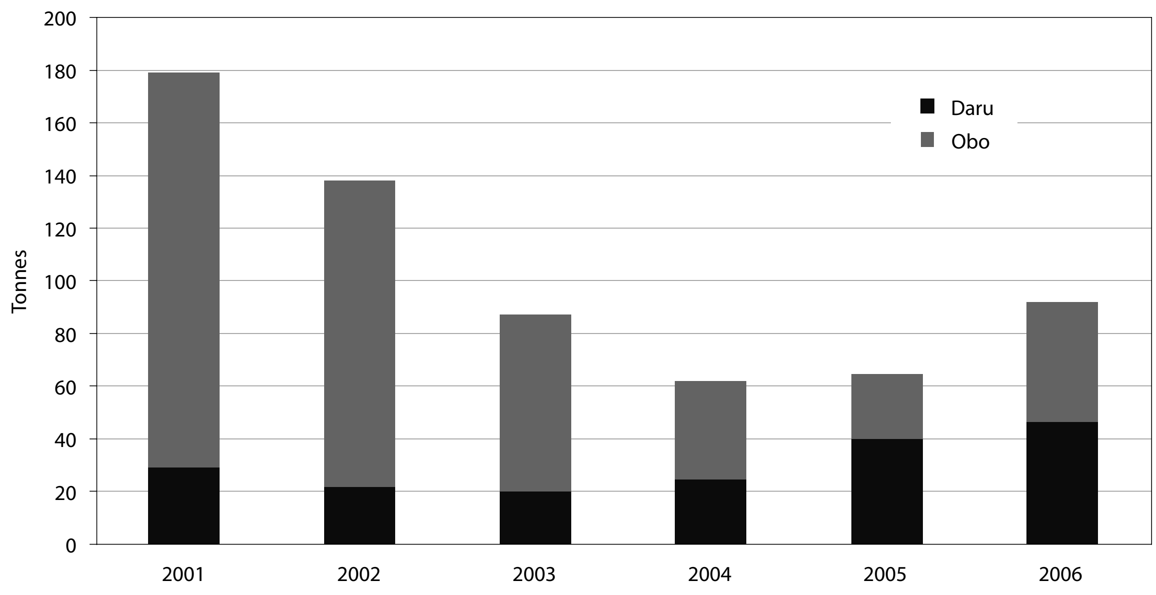

Figure 5. Total commercial catch of barramundi in Western Province, 2001–06. Data source: Blaber (2007b)

The establishment, with significant assistance from OTML, of the Obo Fishing Company—a cooperative fish-processing facility owned by local fishers—encouraged greater fishing effort in the middle Fly region. The company employs about 10 local people in the plant as process workers, and supports up to about 100 local fishers delivering barramundi to the plant (Blaber 2007b, p. 10). OTML subsidises 100% of the company's fuel and management costs. The Ok Tedi mine is also the main buyer from the Obo Fishing Company.

While the catch data from Obo showed a significant decline in barramundi sold to that processing plant since about 2001, the adoption study suggested that this may not have been solely the result of over-fishing. Instead, the decline may have been due to a range of factors including:

- a reduction in the numbers of fishers
- less fishing activity due to high river levels
- changes in the migration patterns of the fish as a result of environmental changes
- the high proportion of people in the Obo region now receiving OTML compensation payments, thus reducing fishing effort.

More recent data show that the total commercial catch has continued to decline at Obo and at Daru also (V. Bola, pers. comm., 1 December 2009). Environmental monitoring undertaken by OTML indicates that the barramundi stock has not declined to the extent indicated by the catch data (M. Yarrao and P. Nagai, pers. comm., 3 December 2009). This suggests that other factors have been reducing fishing effort. In particular, as noted above, OTML is currently providing compensation payments to communities in the Fly River region. This alternative source of income appears to be reducing the effort devoted to fishing. Over-fishing nevertheless also appears to be a significant factor contributing to the declining catch (I. Middleton, M. Yarrao and P. Nagai, pers. comm., 3 December 2009).

It is also important to note that not all barramundi caught in Western Province are sold to the commercial processors. Fishers that are remote from the commercial processing plants catch barramundi for sale in local markets or for their own consumption. Barramundi caught close to the processing plants can also be sold in local markets. Fegan (2002) notes that the price received in some local markets in Daru is competitive with the price offered by the commercial processors (Blaber 2003, Appendix 4, p. 38). While there are no data measuring the catch sold in local markets and for own consumption, it is estimated that these outlets account for around 40% of the total barramundi catch in Western Province (I. Middleton, pers. comm., 3 December 2009).

Impact of the Barramundi Fishery Management Plan

The BFMP appears to have been unsuccessful in protecting the Western Province barramundi fishery from over-fishing. It may, however, have contributed to the prevention of total stock collapse. The impacts of the plan must be assessed against a plausible counterfactual scenario; that is, what is likely to have occurred without it. Project participants broadly agree that the ban on nets with larger mesh sizes is the only component of the plan to have had any impact.

Gill nets are highly selective. Fish that are smaller than the target size can swim through the net, while larger fish do not get caught in the mesh. Nets with a mesh size greater than 6 inches target larger barramundi. Barramundi are juveniles for around the first 4 years of life, mature into males at around 4 years and typically become females at around 7 years (Blaber 2003, p. 13). The larger fish are therefore typically breeding females. The ban on nets with larger mesh sizes increases the survival of breeding females and reduces the problem of recruitment over-fishing—that is, when the mature adult population is depleted to a level where it no longer has the reproductive capacity to replenish itself.

The ban on nets with larger mesh sizes was a precaution against a total collapse in the barramundi stock. Projections from the bioeconomic model show that the spawning biomass (a measure of mature adults within the stock) is significantly higher with 6-inch nets than with 7-inch nets (Figure 6).

However, the total annual catch is a function of effort and catchability as well as biomass. While the ban on nets with larger mesh size increases the biomass in the fishery, it also reduces catchability (R. Little, pers. comm., 10 December 2009). The bioeconomic model suggests that the combined effect is a persistently lower annual catch (Figure 7). So there is a trade-off between the risk of total stock collapse and annual catch.

While the bioeconomic modelling suggests the ban on nets with larger mesh sizes may have an impact on the level of biomass and the annual catch, the increasing use of lures is likely to reduce these impacts over time. Unlike gill nets, lures are not selective, and breeding females can be readily caught using them. Under the BFMP, NFA can consider prohibitions on line-and-lure fishing but this has not occurred and it remains largely unregulated.

Lure fishing has therefore become increasingly popular among artisanal fishers in the region. Lures cost around

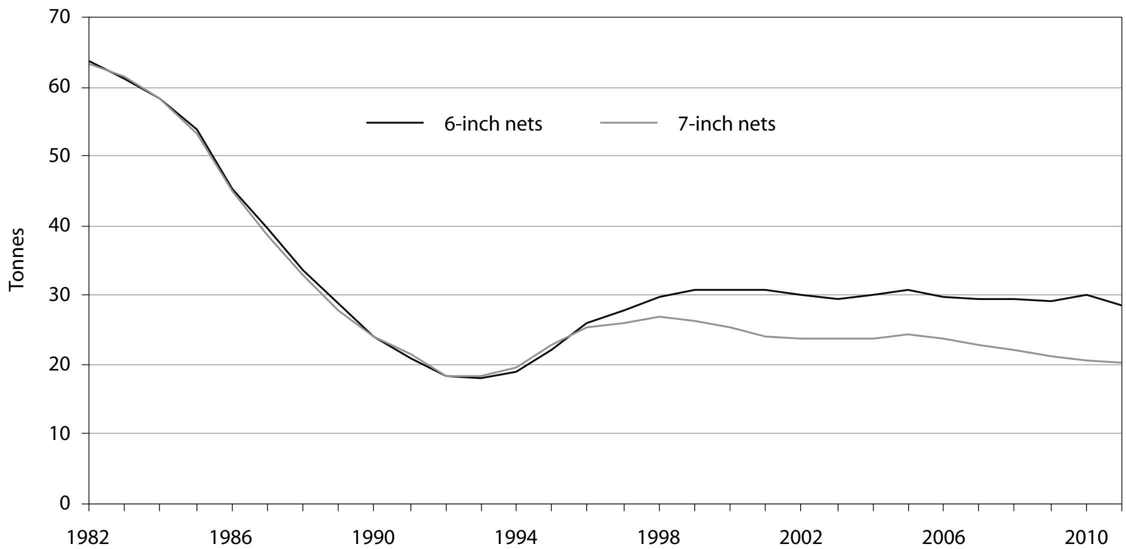

Figure 6. Projected spawning biomass of barramundi under different management options. Data source: R. Little (pers. comm., 11 November 2009)

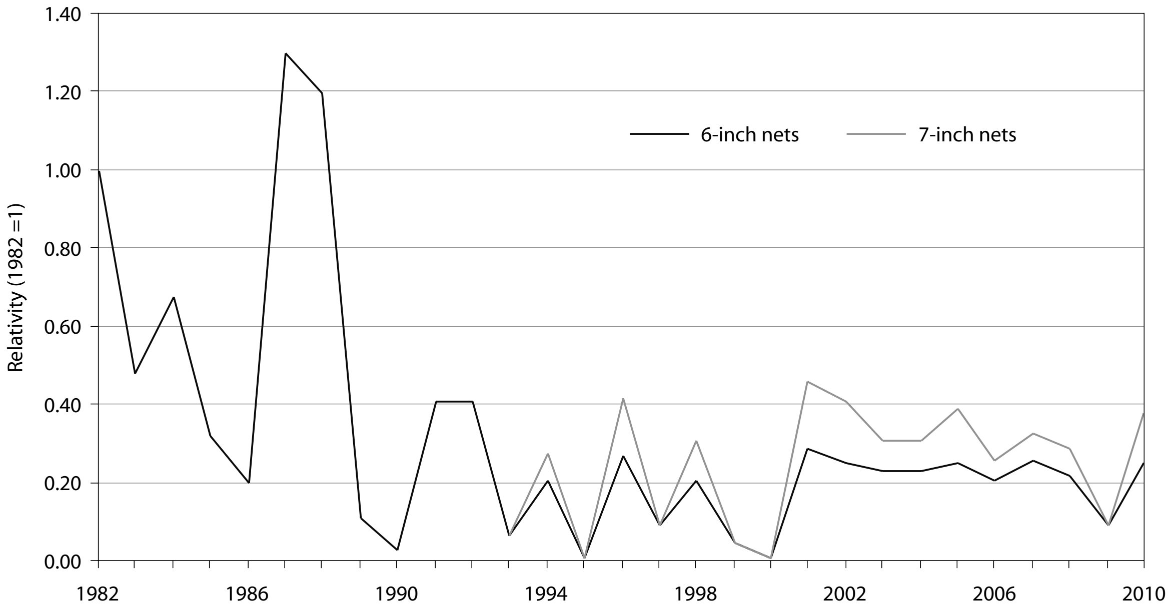

Figure 7. Projected annual catch of barramundi under different management options. Data source: R. Little (pers. comm., 11 November 2009)

35–40 kina, compared with around 2,000 kina for a net. Artisanal fishers have also become increasingly skilled at catching barramundi using lures (I. Middleton, pers. comm., 3 December 2009). It is now estimated that most barramundi in the coastal fishery are caught using lures (M. Maina, pers. comm., 18 December 2009) and their use is also increasing in the middle Fly region (I. Middleton, pers. comm., 3 December 2009).

The increasing use of lures is likely to erode both the benefits (the lower probability of total stock collapse) and the costs (the lower annual catch) of the BFMP.

Impact of the BFMP on artisanal fishers

Since the total revenue curve is the sustainable catch multiplied by the price received, the impact of the ban on nets with larger mesh size is depicted as a downward shift in the total revenue curve to TR_1 (Figure 8). At the existing level of effort (E_3), the total catch, and therefore the total revenue, are likely to have decreased, while total costs remain the same. This means that total costs exceed total revenue, so some of the resources allocated to fishing are more valued in alternative uses. Panayoutou (1982) notes that, even in areas where unemployment is high, small-scale fishermen invariably derive a small but crucial portion of their incomes from non-fishing activities such as farming, small businesses and trade. Therefore, even although there are few alternative forms of employment in the region—implying that the opportunity cost of labour is low—over time, fishers are nevertheless likely to decrease effort, until the point where total revenue equals total costs (E_4). Under the ban on nets with larger mesh size, the total catch is actually likely to be higher when the level of effort is at E_4 compared with E_3.

This characterisation appears to be consistent with actual experience. The minutes of the inaugural BMAC meeting noted that the total catch was lower as a result of the ban on nets with larger mesh size (Blaber 2003, Appendix 2, p. 21). More recent observations that the barramundi stock is not as low as the catch data suggest are also consistent with the projections from the bioeconomic model (higher biomass but lower annual catch than would have been the case without the ban), although other factors such as the OTML compensation payments have also contributed.

On the other hand, the ban on nets with a mesh size greater than 6 inches may have prevented the barramundi stock from collapsing completely. Under this scenario the catch and therefore total revenue and effort would permanently fall to zero.

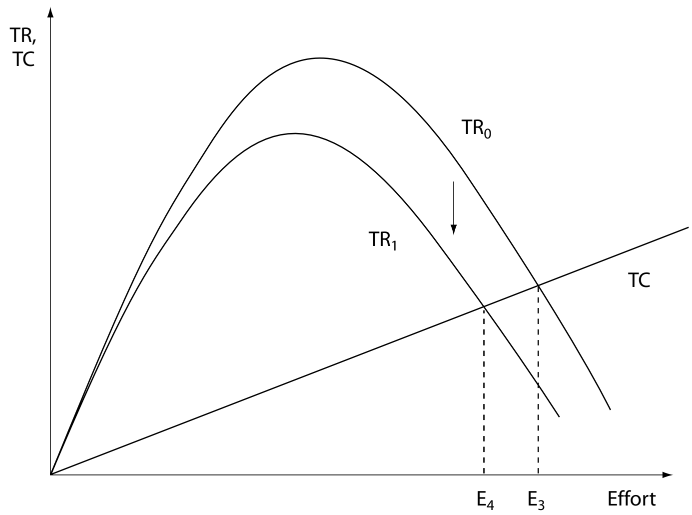

Figure 8. Impact on barramundi fishery costs and returns of the ban on nets with larger mesh sizes.
Sources: Centre for International Economics; R. Little (pers. comm., 10 December 2009)

Impact of the BFMP on the fish processors

The ban on nets with larger mesh size will also have had an impact on the commercial fish processors. A distinction needs to be made between the commercial processors at Daru and Obo.

Daru-based commercial processors

The Daru-based commercial fish processors are privately owned and therefore have a commercial focus. The Daru-based market for processed barramundi is depicted in Figure 9.

The PNG Government applies a 25% tariff to the import of most fresh and frozen fish products (WTO Tariff database at <http://www.wto.org/english/res_e/ statis_e/ statis_e.htm>, accessed 18 December 2009). As a result, processors receive a more favourable price in the domestic market (P^{w+t} than in export markets such as Australia (P^{w}) (M. Maina, pers. comm., 17 December 2009). The premium currently received in the domestic market appears to be broadly equivalent to the tariff. This implies that the price in the PNG market is set by the price in the Australian market plus a mark-up for the tariff.

The BFMP shifts the quantity of barramundi available to process from Q_0 to Q_1 in the 'no collapse' scenario. If the stock does collapse, the catch falls to zero permanently.

We have assumed constant marginal cost. The main variable costs for processors are the unprocessed fish, labour, packaging and the fuel required to collect from nearby villages the fish caught by artisanal fishers. The capital costs, including collector vessels and processing facilities, are treated as sunk. These facilities are also used to process a greater volume of other species including lobsters, prawns and jewfish (M. Maina, pers. comm., 17 December 2009). It therefore seems unlikely that there would be diminishing marginal returns from adding more labour in the existing facilities at the quantity of barramundi currently being processed. This implies that the marginal labour costs associated with processing barramundi are likely to be constant.

Although the existing Daru-based processors have a profit motive, there does not appear to be effective competition for the scarce barramundi caught by the artisanal fishers. The largest barramundi processor in the region recently took over the second-largest buyer and now handles around 90% of the Daru-based commercial market (I. Middleton, pers. comm., 18 March 2010). Furthermore, the NFA is unlikely to issue additional commercial operators licences in a fishery that is already over-fished (L. Baule, pers. comm., 1 December 2009). This prevents new entrants from competing away any excess profits received by the commercial processors. Therefore, when fewer barramundi are caught, competition between processors does not bid up the price paid to the artisanal

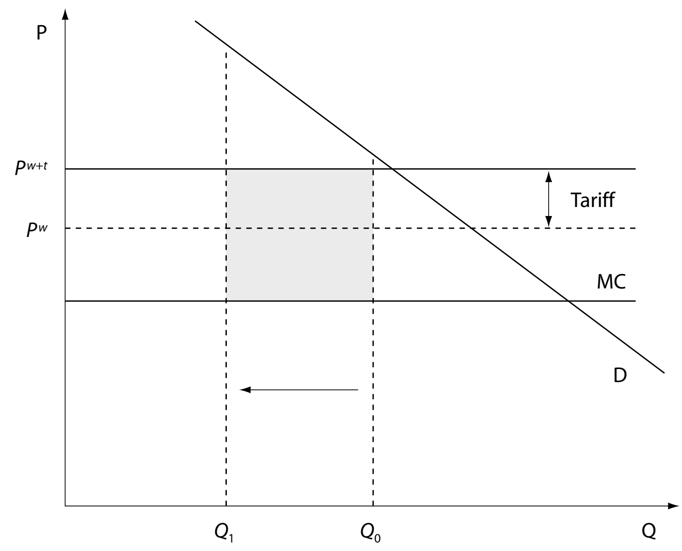

Figure 9. The Daru commercial market for processed barramundi. Source: Centre for International Economics

fishers. When availability is low, the processors may offer a slightly higher price to artisanal fishers (M. Maina, pers. comm., 17 December 2009) but this is more to encourage them to increase effort than to compete with the other processors. Since the level of competition between processors is not sufficient to compete away any rents, processors receive a significant margin from processing whatever barramundi are available.

The Obo Fishing Company

By contrast, the Obo Fishing Company is a cooperative owned by the local fishers. It is currently commercially unviable and continues to receive significant subsidies from OTML (H. Vira, pers. comm., 16 December 2009). As such, it essentially acts as a facility for local fishers to process their catch and gain access to markets. The Obo Fishing Company sells the barramundi mainly to OTML and is therefore not subject to external competition. The price offered to OTML is essentially a mark-up to cover part of the processing costs (Figure 10). The remainder of the costs is covered by the subsidies.

The price received for an additional kilogram of processed barramundi appears to exceed the marginal cost of processing it. However, the losses incurred by the Obo Fishing Company suggest that the price does not exceed the average cost. Therefore, the lower catch would increase the losses of the company, requiring greater subsidies from OTML.

The subsidies provided to the Obo Fishing Company have been critical to the establishment of the facility that has linked artisanal fishers in the middle Fly region to markets. It has also brought other services such as power and banks to the region (H. Vira, pers. comm., 16 December 2009). However, the subsidies also appear to have increased fishing effort in the region, which may have contributed to over-fishing.

Environmental and social impacts

Total collapse of the barramundi stock would reduce biodiversity in the Fly River and adjacent coastal region, which is an environmental cost. More effective preservation of breeding females therefore reduces the risk of incurring that environmental cost. Total collapse of the barramundi stock could also have flow-on effects for the ecosystem. However, these possible environmental benefits are difficult to quantify and this has therefore not been attempted.

In discussing the social impacts of the BFMP it is useful to make a distinction between poverty reduction and poverty prevention. Poverty reduction describes a situation where people are becoming measurably better off over time due to their involvement in economic activities. Poverty prevention, on the other hand, refers to the role of an economic activity in helping people to maintain a minimum standard of living (even when this

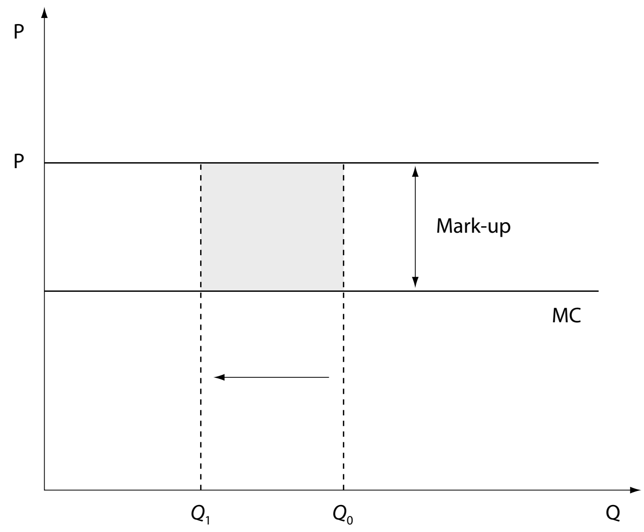

Figure 10. The Obo market for processed barramundi. Source: Centre for International Economics

minimum is below a given poverty line) and prevent their falling any deeper into destitution (Bené 2006).

The BFMP is unlikely to contribute significantly to poverty reduction in the long run, since under open-access conditions artisanal fishers are unlikely to receive more than their opportunity cost of labour at the bioeconomic equilibrium. With few alternative employment opportunities in the region, the opportunity cost of labour is likely to be low.

The BFMP may, however, temporarily contribute to poverty prevention to the extent that it averts the complete collapse of the barramundi stock. Bené (2006, p. 15) notes:

> … that the role of small-scale fisheries as a poverty prevention activity for the rural poor is crucial from a social point of view, especially in remote areas where alternative employment may be scarce and social security programs either minimal or non-existent.

The possible contribution to poverty reduction also encompasses an increase in food security. Since barramundi is mainly fished for income, this contribution is mainly indirect. However, some barramundi in the region is also fished for own consumption. In reducing the risk of total stock collapse, the BFMP may therefore also directly contribute to food security.

Factors shaping the barramundi fishery in the future

There are a number of other factors that will shape the fishery in the foreseeable future. They include:

- the closure of Ok Tedi mine
- the increasing importance of aquaculture
- the restocking program of Western Province Sustainable Aquaculture
- the introduction of predatory exotic species into the fishery area.

Closure of Ok Tedi mine

The Ok Tedi mine is currently scheduled to close in 2013. However, environmental and economic feasibility studies are currently looking at the possibility of extending its useful life to 2020 (M. Yarrao and P. Nagai, pers. comm., 3 December 2009). The closure of the mine would have a number of impacts on the Fly River barramundi fishery.

First, OTML is the only customer of the Obo Fishing Company and also continues to subsidise it. The operation is currently commercially unviable without that assistance (H. Vira, pers. comm., 16 December

2009). The closure of the Obo Fishing Company would cut off the market for fishers in the middle Fly region.

In terms of finding replacement customers, there is significant demand for barramundi within PNG and in external markets. A major liquefied natural gas development is also likely to boost demand for barramundi in the area (L. Baule, pers. comm., 1 December 2009). The eventual closure of the mine will create some logistical difficulties, because it will significantly reduce boat traffic passing through Obo. However, these logistical issues are unlikely to be insurmountable. The Ok Tedi Development Foundation has purchased ships to service the area and a proposal is being considered to relocate the facility a short distance away to Aiambak where it could service a proposed aquaculture development in Lake Murray (farming trials will be conducted in 2010) as well as the wild fishery (I. Middleton, pers. comm., 3 December 2009). This would ensure its viability.

The other way the closure of the Ok Tedi mine could impact on the barramundi fishery is through the cessation of the compensation payments. This appears to be one factor that has restricted fishing effort. Some fishers' objective may be to earn a certain level of income, rather than maximise income (Panayoutou 1982). With an alternative source of income provided by the compensation payments there is less reliance on fishing. Cessation of the compensation payments when the mine closes could put more pressure on the barramundi fishery.

Increasing importance of aquaculture

The importance of aquaculture appears set to increase, which will significantly increase the quantity of barramundi produced in the region. The Papua New Guinea Sustainable Development Program has provided K27.4 million to Western Province Sustainable Aquaculture, a project that includes barramundi farming trials, a hatchery facility based in Daru and an awareness program. This is likely to facilitate a range of aquaculture projects, including some in Lake Murray in the middle Fly region (I. Middleton, pers. comm., 3 December 2009).

Restocking program

The Western Province Sustainable Aquaculture project also includes a restocking program for the wild fishery. The restocking program involves the staged release of 500,000 juvenile barramundi, beginning in 2010. If successful, this program will significantly add to the wild barramundi stock from around 2013.

Exotic species

There have been reports that exotic species are becoming established in the region, which could have a significant impact on the barramundi fishery. In particular, the Asian snakehead fish has recently appeared near the main spawning grounds. This species is a predator of juvenile barramundi (B. Figa, pers. comm., 9 December 2009).

How are these factors likely to affect the project impacts?

While all of these factors will play major roles in shaping the barramundi fishery in the future, they will not necessarily affect the impacts attributed to the project. One factor that will affect the project impacts is Western Province Sustainable Aquaculture's restocking program. If successful, the restocking program means that the loss of future benefits in the event of total stock collapse before restocking will be temporary rather than permanent.

The remaining factors are unlikely to affect the project impacts because they are estimated against a counterfactual scenario in which there is no BFMP. If these factors affect the fishery in the same way either with or without the BFMP, the difference between the two scenarios (the impact of the BFMP) is unchanged.

Ultimately, the closure of Ok Tedi mine is unlikely to affect the project impacts. The Obo Fishing Company is likely to continue to exist beyond the life of the mine and replacement buyers will be found.

The development of aquaculture will provide alternative employment opportunities in the region and therefore raise the opportunity cost of labour. While the wild fishery will continue to be exploited, the increase in the opportunity cost of labour is likely to reduce fishing intensity and the probability of total stock collapse. By contrast, the arrival of Asian snakehead fish will increase the probability of total stock collapse. However, these factors have not been considered in the quantitative estimates.

5 Benefits and costs

This chapter attempts to quantify the impacts of the BFMP identified in the previous chapter. These quantified impacts are then set out in a benefit:cost analysis framework.

Quantifying the impacts

As discussed in the previous chapter, the ban on nets with a mesh size greater than 6 inches affects both artisanal fishers and commercial processors.

Artisanal fishers

The resource rents associated with the fishery are a measure of its value to the community (Panayoutou 1982). In the absence of any meaningful restrictions on effort, resource rents are likely to be close to zero with or without the BFMP. So even although the catch and therefore total revenue are likely to be lower under the BFMP (unless the collapse scenario is realised), artisanal fishers are likely to be no worse off in the long run because there is likely to be a corresponding reduction in effort and therefore total cost. They may be worse off in the short-run due to losses as the level of effort adjusts to the new bioeconomic equilibrium, but these temporary losses have not been quantified.

The converse is that, with no resource rents flowing to them, there are few long-term benefits for the artisanal fishers in preventing the barramundi stock from collapsing completely. We previously noted that the fishery may be playing some role in preventing fishers from falling further into poverty in instances where there are no other employment opportunities. However, this role is unlikely to be significant with the catch at low levels. Even when the opportunity cost of labour is low, the fishers are equally well off devoting the resources (labour, capital and fuel etc.) currently used to fish for barramundi to an alternative use, such as fishing for other species.

The clear implication is that, without any meaningful restriction on fishing effort, the benefits of the fishery to artisanal fishers in the region are likely to remain close to zero. Even actions to increase the productivity of the fishery—such as a successful restocking program—are unlikely to produce permanent benefits for artisanal fishers. Over time, the level of effort will increase to the point where total revenue equals total cost. The increase in effort could come from existing fishing communities or from immigrants. Both Fegan (2002) and Blaber (2007b) note the expanding population in the region. The eventual cessation of compensation payments when Ok Tedi mine closes will also increase pressure on the fishery in the Fly River.

The BFMP is unlikely to be effective in restricting effort. As highlighted by Fegan (2002), the BFMP allows open entry (Blaber 2003). It does not limit the number of people who can enter the fishery; nor does it limit the length of nets or the use of lures.

The main way the BFMP attempts to restrict fishing effort is through the TAC. Once the commercial catch reaches 260 tonnes, the BFMP requires the NFA to suspend the fishery. However, the total catch of the commercial fishery has not reached the TAC at any time since the BFMP was promulgated. It is therefore not clear how effective the TAC would be in restricting effort. Furthermore, it may be set too high. There is already evidence that the fishery has again been over-fished, even although the TAC has not been reached.

Fegan (2002) also notes a number of implementation issues for the global TAC (Blaber 2003). In particular, the TAC provisions rely critically on timely and accurate statistics. However, no statistics are collected for barramundi that are not sold to the commercial processors. This is estimated to be up to 40% of the total catch (I. Middleton, pers. comm., 3 December 2009). Further, any delay in collating statistics will make it difficult to detect, in time to suspend the fishery, that the TAC is being approached.

Commercial processors

The BFMP has both costs and benefits for commercial processors, and its overall impact on commercial processors therefore depends on both.

Cost of the BFMP

The cost of the BFMP is the lower annual catch.[2] The bioeconomic model indicated that the ban on the nets with larger mesh size reduces the catchability of barramundi and results in a lower annual catch. The cost of the BFMP at time t (C_t) can therefore be expressed as:

$$C_t = M\left(Q_t^{BFMP} - Q_t^{CF}\right) \qquad (1)$$

where M is the processors margin, Q_t is the catch at time t, and the $BFMP$ and CF superscripts indicate the scenario with and without (the counterfactual) the BFMP.

The processors' margin is the selling price minus the marginal cost of producing processed barramundi. The marginal labour and raw-material cost of processing each additional kilogram of barramundi is estimated at around K7/kg of barramundi fillet (M. Maina, pers. comm., 17 December 2009). This includes around K4/kg paid to artisanal fishers, plus about K3/kg in processing costs (including labour, fuel and packaging). Daru-based processors receive, on average, from around K22 to K30/kg of fillets (M. Maina, pers. comm., 17 December 2009). The average price received by the Obo-based processor is around K20/kg (I. Middleton, pers. comm., 18 March 2010). The facts that the Obo Fishing Company does not operate on a fully commercial basis and that OTML is currently both its only customer and grants it subsidies explain the difference in the price received. This information suggests that the margin on each kilogram of barramundi processed is around K19 in Daru and around K13 in Obo (Table 2).

Table 2. Estimated marginal cost of processing a kilogram of barramundi fillets

	Daru	Obo
	Kina/kg	Kina/kg
Selling price	26.00	20.00
Processing costs		
Unprocessed fish	4.00	4.00
Other costs[a]	3.00	3.00
Total	7.00	7.00
Margin	19.00	13.00

a Including labour, fuel and packaging. Fuel is the most significant cost other than the unprocessed fish.

Sources: M. Maina (pers. comm., 17 December 2009); I. Middleton (pers. comm., 18 March 2010), Centre for International Economics

Data are available on the annual catch at Daru and Obo from 2004 to 2006. Since 2006 the total commercial catch has declined to around 20 tonnes/year, with around 75% caught in Daru (I. Middleton, pers. comm., 3 December 2009). We assume that the catch will remain at that level in the medium term.

The bioeconomic modelling provides an indication of the change in the annual catch as a result of the ban on nets with larger mesh size. Figure 7 showed that the catch is likely to be persistently lower when these nets are banned. The data shown in Figure 7 are scaled to the catch in 1982. While we have been unable to obtain the data, various reports suggest that the catch during the 1980s ranged between 200 and 300 tonnes. Assuming that the catch in 1982 was the midpoint of this range (250 tonnes) the bioeconomic modelling suggests that the average annual catch would be around 18.7 tonnes higher without the ban on 7-inch nets (i.e. nets with a mesh size greater than 6 inches).

However, it is necessary to take into account the impact of lure fishing. Since lures are not selective and can therefore catch large breeding females, the impact of the BFMP will be significantly reduced by the increasing use of lures. We therefore assume that both the costs

2 Unless the fishery collapses. The lower probability of collapse under the BFMP is considered later as its benefit.

(in terms of lower annual catch) and benefits (in terms of the lower probability of stock collapse) of the BFMP will fade after 10 years. This is consistent with observations that most barramundi are now caught using lures. We therefore assume that the higher catch under the counterfactual scenario (if the stock does not collapse completely) gradually falls to zero after 10 years. The estimated annual catches used in the quantitative analysis are shown in Table 3.

The cost of the BFMP to the processors in each region is the difference between the catch in that region with and without the BFMP, multiplied by the margin (Table 4). The cost is shown as a negative amount.

Benefits of the BFMP

We turn now to the benefits of the BFMP to commercial processors, which derive from the lower probability of total stock collapse. Expected benefits are the probability-weighted average of the range of possible outcomes. For simplicity, we assume there are two possible outcomes in any year:

- The first is that the barramundi stock collapses completely, permanently reducing the annual catch to zero (at least until the restocking program starts to take effect). The probability of this outcome being realised is lower under the BFMP.
- The second is that the stock does not collapse, in which case the benefit of the fishery to commercial processors is the catch multiplied by the processors' margin.

The expected benefit of the BFMP to commercial processors is the expected benefit of the fishery under the BFMP minus the expected benefit in the counterfactual scenario (without the BFMP). The expected benefit of the BFMP can therefore be expressed as:

$$E(B_t) = \left(1-p_{x<t}^{BFMP}\right)Q_t^{CF}\,M-\left(1-p_{x<t}^{CF}\right)\,Q_t^{CF}\,M \qquad (2)$$

where $E(B_t)$ is the expected benefit and $p_{x<t}$ is the probability that the stock collapsed (x) in a previous period. Since this equation represents only the benefits of the BFMP and not the total impact (the costs are

Table 3. Estimated annual catches (kg) of barramundi with and without the Barramundi Fishery Management Plan (BFMP)

	With BFMP			No BFMP (counterfactual)		
	Daru	Obo	Total	Daru[a]	Obo[a]	Total[a]
2003–04	20,031	67,077	87,108	24,326	81,459	105,785
2004–05	24,592	36,892	61,484	31,316	46,978	78,294
2005–06	40,257	24,239	64,496	49,583	29,854	79,437
2006–07	46,601	45,365	91,966	53,226	51,814	105,040
2007–08	15,000	5,000	20,000	23,404	7,801	31,205
2008–09	15,000	5,000	20,000	22,004	7,335	29,339
2009–10	15,000	5,000	20,000	20,603	6,868	27,471
2010–11	15,000	5,000	20,000	19,202	6,401	25,603
2011–12	15,000	5,000	20,000	17,801	5,934	23,735
2012–13	15,000	5,000	20,000	16,401	5,467	21,868
2013–14	15,000	5,000	20,000	15,000	5,000	20,000

[a] Assuming the fishery does not collapse

Note: Since most barramundi are caught during the spawning season in the second half of the calendar year, the catch data reported on a calendar year basis are assumed to be equivalent to the catch in the financial year ending on 30 June of the following calendar year.

Sources: Blaber (2007a,b); R. Little (pers. comm., 11 November 2009); I. Middleton (pers. comm., 11 November 2009); Centre for International Economics

Table 4. The cost of the Barramundi Fishery Management Plan to processors

	Cost to Daru processors	Cost to Obo processors	Total cost to processors
	Kina	Kina	Kina
2003–04	−81,602	−186,961	−268,563
2004–05	−127,740	−131,114	−258,854
2005–06	−177,193	−72,998	−250,191
2006–07	−125,868	−83,836	−209,704
2007–08	−159,684	−36,419	−196,103
2008–09	−133,070	−30,349	−163,419
2009–10	−106,456	−24,279	−130,735
2010–11	−79,842	−18,210	−98,052
2011–12	−53,228	−12,140	−65,368
2012–13	−26,614	−6,070	−32,684
2013–14	–	–	–

Note: Costs are shown as a negative amount

Source: Centre for International Economics' estimates

quantified above), the relevant catch estimate to use in both the first and second terms on the right-hand side is the catch under the counterfactual scenario.

Quantifying this benefit relies on an estimate of the probability of total stock collapse both with and without the BFMP. Since the benefits attributable to the BFMP depend on how the probability *changes* as a result of the BFMP, we can assume for simplicity that the probability of total stock collapse with the BFMP is zero and rewrite equation (2) as:

$$E(B_t) = Q_t^{CF} M - \left(1 - p_{x<t}\right) Q_t^{CF} M \qquad (3)$$

where $p_{x<t}$ represents the change in the probability of total stock collapse under the BFMP.

Unfortunately, we have not been able to obtain a reliable estimate of the change in the probability of complete stock collapse as a direct result of the BFMP. However, we note that the bioeconomic model projections do not suggest that the stock would collapse completely, even if 7-inch nets continued to be used. Rather, the spawning biomass was projected to gradually drift lower to around 20 tonnes by the end of the projection period. This is still higher than the estimated spawning biomass in the early 1990s. On the other hand, the bioeconomic model projections suggest that the spawning biomass would be significantly higher when 6-inch nets are used, stabilising at around 30 tonnes.

This implies that the probability of complete stock collapse at some point over the 10 years to 2013–14 is likely to have been somewhere between zero and 0.5 if the nets with larger mesh size continued to be used. We therefore assume that the probability of stock collapse is lower by 0.25 (the midpoint of this range) under the BFMP.

The impact depends on the year in which the stock collapses. If we assume that the probabilities of the stock collapsing in any particular year of the 10-year period are equal, this implies that the unconditional probability of collapse in any year is around 0.028, implying that the probability that the stock does not collapse in that year is 0.972. The conditional probability that the stock has not collapsed in a previous period is therefore given by:

$$p_{t>x} = \left(1 - p(x)\right)^{t-1} \qquad (4)$$

where $p(x)_{t>x}$ is the conditional probability that the fishery has not collapsed in a previous period and $p(x)$ is the unconditional probability of collapse in any year.

The 10-year period over which the BFMP is likely to have some impact coincides with the timing of the restocking program, which is expected to begin having an effect on the fishery in around 2013. Therefore, if the fishery had collapsed completely, reducing the annual catch to zero, the restocking program would reintroduce barramundi to the region and cancel out the loss of future benefits.

Table 5 shows the flow of expected benefits with and without the BFMP. The flow of expected benefits with no BFMP is estimated by multiplying the expected benefits under the BFMP by the probability that the stock has not collapsed in a previous period. As this probability decreases over time, the expected benefits without the BFMP fall relative to the expected benefits with it.

The expected benefit attributable to the BFMP is the difference between the benefits expected with the BFMP and those without it. This is estimated in Table 6.

Estimated impacts

The overall impact of the BFMP depends on both the costs associated with a lower annual catch (under the 'no collapse' scenario) and the benefits associated with a lower probability of stock collapse (Table 7). The impacts are estimated in PNG kina and converted to Australian dollars using the historical annual average exchange rates up to 2008–09. For 2009–10, actual exchange rates are used to the end of November 2009. The average monthly exchange rate in November is then held constant for all future periods.

ACIAR's guidelines require that in cases where the benefits of a project are considered to be permanent, they are converted to an annuity once they reach a steady state. However, this is not necessary in this case because we have assumed that, due to the impacts of lure fishing and the restocking program, the benefits of the BFMP last for only 10 years.

Table 5. Expected benefits with and without the Barramundi Fishery Management Plan (BFMP)

	BFMP		Probability stock has not collapsed	No BFMP (counterfactual)	
	Daru	Obo		Daru	Obo
	Kina	Kina		Kina	Kina
2003–04	462,198	1,058,962	1.000	462,198	1,058,962
2004–05	594,996	610,710	0.972	578,123	593,391
2005–06	942,070	388,105	0.944	889,397	366,405
2006–07	1,011,285	673,581	0.917	927,667	617,886
2007–08	444,684	101,419	0.891	396,347	90,395
2008–09	418,070	95,349	0.866	362,059	82,575
2009–10	391,456	89,279	0.841	329,397	75,126
2010–11	364,842	83,210	0.818	298,296	68,032
2011–12	338,228	77,140	0.794	268,694	61,281
2012–13	311,614	71,070	0.772	240,532	54,858
2013–14	285,000	65,000	0.750	213,750	48,750
2014–15	–	–	0.729	–	–

Source: Centre for International Economics' estimates

Table 6. The benefits of the Barramundi Fishery Management Plan (BFMP) to processors

	Benefit to Daru processors	Benefit to Obo processors	Total benefit to processors
	Kina	Kina	Kina
2003–04	–	–	–
2004–05	16,873	17,319	34,192
2005–06	52,673	21,700	74,373
2006–07	83,618	55,695	139,313
2007–08	48,337	11,024	59,361
2008–09	56,011	12,774	68,785
2009–10	62,059	14,154	76,213
2010–11	66,546	15,177	81,723
2011–12	69,534	15,859	85,393
2012–13	71,082	16,212	87,294
2013–14	71,250	16,250	87,500
2014–15	–	–	–

Sources: M. Maina (pers. comm., 17 December 2009); I. Middleton (pers. comm. 3 December 2009); Centre for International Economics' estimates.

Distribution of impacts

The expected losses associated with the BFMP are largely borne by the commercial processors based in Daru and the Obo Fishing Company (i.e. OTML through subsidies in the medium term). There may also be some temporary losses to artisanal fishers as they adjust to the new bioeconomic equilibrium.

However, it should also be noted that the impact of the BFMP may not be uniform across all fishers. For example, measures to reduce the catch of larger breeding females are likely to adversely affect those fishers near the main coastal breeding grounds, such as those from Sigabaduru village. In effect, these fishers are prevented from catching the large reproductive females during the breeding season, so that the fishery is more productive for other fishers (many of whom are already receiving compensation from OTML).

Project costs

The nominal research costs shown in Table 1 are converted to real 2008–09 dollars using the Australian GDP deflator published by the Australian Bureau of Statistics. Nominal and real (in 2008–09 dollars) project costs are shown in Table 8.

Summary measures

In present value terms, the estimated impact of the project is a loss to commercial barramundi processors of around A$255,000 (in 2008–09 dollars), using a discount rate of 5% (Table 9). Nets with larger mesh size were banned under the BFMP as a precaution against total stock collapse. This involved a trade-off in terms of a lower annual catch. These short-term costs have been incurred; however, changing circumstances mean that the intended long-term benefits will be lower than may have been anticipated. In particular, the increasing

Table 7. Estimated impacts of the Barramundi Fishery Management Plan (BFMP)

	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP	Exchange rate	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP
	K'000	K'000	K'000		A$'000	A$'000	A$'000
1996–97	–	–	–	N/A	–	–	–
1997–98	–	–	–	N/A	–	–	–
1998–99	–	–	–	N/A	–	–	–
1999–2000	–	–	–	N/A	–	–	–
2000–01	–	–	–	N/A	–	–	–
2001–02	–	–	–	N/A	–	–	–
2002–03	–	–	–	0.46	–	–	–
2003–04	–269	–	–269	0.38	–101	–	–101
2004–05	–259	34	–225	0.46	–119	16	–103
2005–06	–250	74	–176	0.44	–111	33	–78
2006–07	–210	139	–71	0.43	–90	60	–30
2007–08	–196	59	–137	0.40	–79	24	–55
2008–09	–163	69	–94	0.51	–84	35	–49
2009–10	–131	76	–55	0.43	–56	33	–23
2010–11	–98	82	–16	0.42	–41	34	–7
2011–12	–65	85	20	0.42	–27	36	9
2012–13	–33	87	54	0.42	–14	37	23
2013–14	–	87	87	0.42	–	37	37
2014–15	–	–	–	0.42	–	–	–

Source: Ozforex website, http://www.ozforex.com.au/, accessed 8 December 2009, Centre for International Economics' estimates.

use of lures for fishing is likely to erode over time the benefits of banning nets with larger mesh size, and the restocking program is likely to mean that cost of total stock collapse is temporary rather than permanent.

When the costs of the project are taken into account, the total losses are estimated at around A$2.7 million. The benefit:cost ratio of the project is estimated at –0.10, with an internal rate of return of –31.1%.

Sensitivity analysis

The benefits estimated above are based on a range of assumptions. In this section, the robustness of the conclusions drawn from these estimates to variations in the assumptions is tested. We also analyse an alternative scenario in which the effects of lure fishing and the restocking program are ignored.

Table 8. Project FIS/1998/024 inputs

	ACIAR	Other sources	Total	Deflator	ACIAR	Other sources	Total
	Current A$'000	Current A$'000	Current A$'000	Index 2008/09 =100	2008–09 A$'000	2008–09 A$'000	2008–09 A$'000
1996–97	32	37	69	67.5	48	55	103
1997–98	5	25	30	68.4	8	36	44
1998–99	–	–	–	68.4	–	–	–
1999–2000	271	402	673	69.8	388	575	963
2000–01	254	404	658	73.2	347	552	899
2001–02	233	406	639	75.3	309	539	848
2002–03	37	18	55	77.5	47	23	70

Sources: ACIAR; Australian Bureau of Statistics Catalogue No. 5206.0; Centre for International Economics

Table 9. Summary economic measures

	Discount rate 1%	Discount rate 5%	Discount rate 10%
Present value of impacts (A$'000)	– 350	– 255	– 174
Present value of costs (A$'000)	2,819	2,433	2,047
Net present value (A$'000)	−3,168	−2,689	−2,221
Benefit:cost ratio	−0.12	−0.10	−0.09
Internal rate of return	−31.1	−31.1	−31.1

Source: Centre for International Economics

Sensitivity analysis

The key assumptions upon which the quantitative estimates are based are that:

- the probability of stock collapse at some point over the 10 years to 2013–14 is 0.25 lower with the BFMP
- the total annual commercial catch remains at 20 tonnes in the medium term
- the total annual commercial catch would be 18.7 tonnes higher without the BFMP in the 'no stock collapse' scenario
- the processors' profit margin is K19/kg in Daru and K13/kg in Obo.

We test the robustness of our results to variations in these key assumptions using Monte Carlo simulations. The assumptions we made about the distribution of these variables are detailed in Table 10. In general, where we have reasonable information about the possible range for a variable we have assumed a triangular distribution. For the other variables, we have assumed a normal distribution with a standard deviation equal to one-third of the mean.

The frequency distribution of the estimated impact of the BFMP, based on 5,000 iterations, is shown in Figure 11. The maximum impact was A$105,993 and the minimum –A$779,967, while 95% of iterations fell in the range between –A$544,461 and –A$38,184 (these numbers are expressed in 2008–09 dollars, using a discount rate of 5%). Only 0.6% of iterations were

Table 10. Assumptions about the distribution of key variables

Variable	Distribution	Details
Probability of stock collapse before 2013–14	Triangular	We assumed a minimum of zero and a maximum of 0.50 and a most likely estimate of 0.25.
Total commercial catch	Normal	We assumed the mean of the distribution was 20,000 kg with a standard deviation of one-third of the mean. We also imposed a minimum of zero on the distribution.
Change in commercial catch	Triangular	We assumed a minimum of 14,941 (implying 200 tonnes were caught in 1982) and a maximum of 22,412 (implying 300 tonnes were caught in 1982).
Daru profit margin	Normal	We assumed a mean of K19 and a standard deviation equal to one-third of the mean. We also imposed a minimum of zero on the distribution and assumed a correlation of 0.9 with the Obo profit margin.
Obo profit margin	Normal	We assumed a mean of K13 and a standard deviation equal to one-third of the mean. We also imposed a minimum of zero on the distribution and assumed a correlation of 0.9 with the Daru profit margin.

Source: Centre for International Economics

greater than zero. This suggests that our conclusion that the BFMP ultimately imposed a net cost on the community is robust.

Similarly, the benefit:cost ratio (in 2008–09 dollars using a discount rate of 5%) based on the same 5,000 iterations is shown in Figure 12. The maximum benefit:cost ratio was 0.04, the minimum –0.32, and 95% of the distribution fell between –0.22 and –0.02.

However, there is a further upside risk to the central case estimates presented in this report that has not been quantified. The estimates have implicitly assumed that the project's intermediate outputs will have no further uses. Although we consider it unlikely in the foreseeable future given the low priority placed on the barramundi fishery by the NFA, there is nevertheless a possibility that the BFMP will be revised to overcome some of its shortcomings. Any future revisions are likely to draw on the biological and socioeconomic knowledge of the fishery developed through the ACIAR-funded project. In these circumstances, some of the future benefits delivered by a revised BFMP could be attributable to the project. Since it is impossible to pre-empt the shape of any revisions to the BFMP, we have not attempted to quantify this upside risk.

Scenario analysis

The rationale for the ban on nets with a mesh size greater than 6 inches is a lower catch (and therefore profits) in the near term, traded off against a lower probability of stock collapse and therefore higher expected benefits in the future. Table 7 shows that, based on our assumptions on the probability of total stock collapse, the expected benefits of the BFMP start to outweigh the costs in around 2011–12. However, the overall costs of the BFMP are estimated to outweigh the benefits (using a reasonable discount rate). This is because, based on information provided by various fishery stakeholders, we have assumed that:

- the increased use of lures reduces the impact of the ban on nets with larger mesh over time, meaning that near-term costs are incurred, but the longer term benefits are not realised
- the restocking program means that the reduction in the benefits of the fishery in the event of total stock collapse (zero catch and therefore profits) are temporary rather than permanent.

The effects of these factors were either unknown or not fully appreciated when the BFMP was developed. An interesting scenario to test is thus whether the BFMP is likely to have delivered net benefits in the absence of these unexpected recent developments.

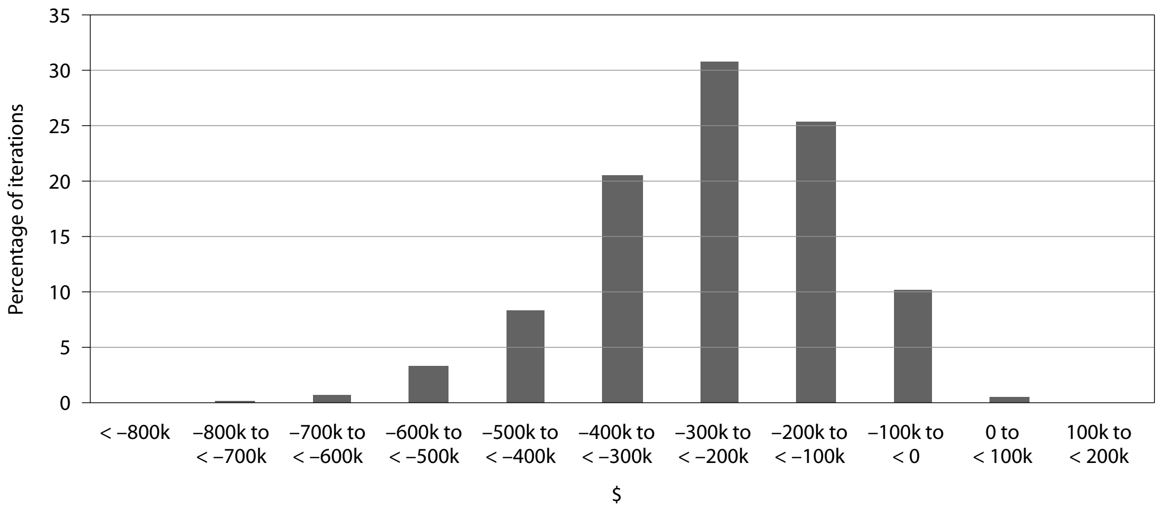

Figure 11. Frequency distribution of estimated impact of the Barramundi Fishery Management Plan. Data source: Centre for International Economics

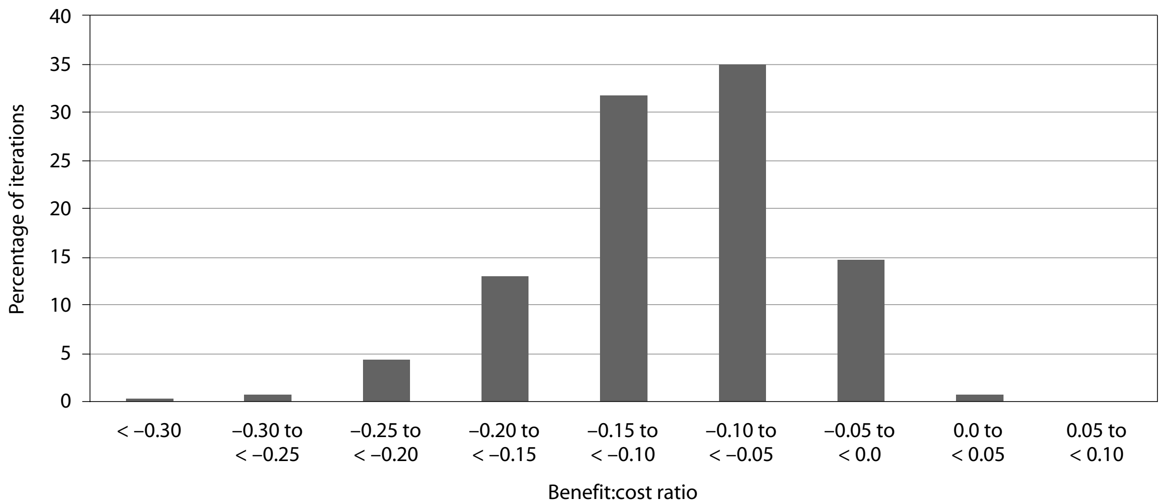

Figure 12. Frequency distribution of the benefit:cost ratio. Data source: Centre for International Economics

We therefore estimate the impact the BFMP may have had, assuming no lure fishing and no restocking program. In the absence of lures, we assume that catch remains at the 2006 level of around 91 tonnes (with the BFMP). We also assume that the annual catch is around 18.7 tonnes higher in the absence of the BFMP (as suggested by the bioeconomic modelling), if the stock does not collapse. If the stock collapses, the catch is assumed to fall permanently to zero. We use the same estimate of the probability of stock collapse in any year over the 30 years from 2003–04 to 2032–33 as that under the no BFMP scenario; i.e. 0.028. This implies that the probability of total stock collapse at some stage during that period is 0.57 higher without the BFMP. For this scenario, we assume that the impact of the BFMP is permanent. We therefore convert the estimated impact in 2032–33 to an annuity to calculate the summary measures (this is equivalent to assuming that if the stock does not collapse over the 30 years to 2032–33 it will never collapse). The impact of the BFMP under these assumptions is shown in Table 11.

The estimated benefits of the ACIAR project under these assumptions are shown in Table 12. Under this alternative scenario, the BFMP is estimated to deliver benefits of almost A$2 million in present value terms (using a discount rate of 5%). Nevertheless, these estimated benefits still fall around $0.4 million short of the total costs of the project. This shows that the relatively small size of the fishery and the relatively large cost of the research means it would have been difficult for the project to achieve a positive net benefit, even if the plan had been successful.

This finding also highlights the importance of revising fishery management plans as circumstances change.

Table 11. Estimated impacts of the Barramundi Fishery Management Plan (BFMP) under alternative assumptions

	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP	Exchange rate	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP
	K'000	K'000	K'000		A$'000	A$'000	A$'000
1996–97	–	–	–	N/A	–	–	–
1997–98	–	–	–	N/A	–	–	–
1998–99	–	–	–	N/A	–	–	–
1999–2000	–	–	–	N/A	–	–	–
2000–01	–	–	–	N/A	–	–	–
2001–02	–	–	–	N/A	–	–	–
2002–03	–	–	–	0.46	–	–	–
2003–04	−269	–	−269	0.38	−101	–	−101
2004–05	−259	34	−225	0.46	−119	16	−103
2005–06	−250	74	−176	0.44	−111	33	−78
2006–07	−210	139	−71	0.43	−90	60	−30
2007–08	−210	183	−27	0.40	−84	74	−10
2008–09	−210	226	16	0.51	−108	116	8
2009–10	−210	267	57	0.43	−90	114	24
2010–11	−210	307	97	0.42	−88	129	41
2011–12	−210	346	136	0.42	−88	145	57
2012–13	−210	384	174	0.42	−88	161	73
2013–14	−210	421	211	0.42	−88	176	88
2014–15	−210	457	247	0.42	−88	191	103
2015–16	−210	492	282	0.42	−88	206	118
2016–17	−210	526	316	0.42	−88	220	132
2017–18	−210	559	349	0.42	−88	234	146
2018–19	−210	591	381	0.42	−88	247	159

Table 11. (continued)

	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP	Exchange rate	Expected costs from lower annual catch	Expected benefits from lower probability of stock collapse	Net impact of BFMP
	K'000	K'000	K'000		A$'000	A$'000	A$'000
2019–20	−210	622	412	0.42	−88	260	172
2020–21	−210	652	442	0.42	−88	273	185
2021–22	−210	681	471	0.42	−88	285	197
2022–23	−210	709	499	0.42	−88	297	209
2023–24	−210	737	527	0.42	−88	309	221
2024–25	−210	764	554	0.42	−88	320	232
2025–26	−210	790	580	0.42	−88	331	243
2026–27	−210	815	605	0.42	−88	342	254
2027–28	−210	840	630	0.42	−88	352	264
2028–29	−210	864	654	0.42	−88	362	274
2029–30	−210	887	677	0.42	−88	372	284
2030–31	−210	910	700	0.42	−88	381	293
2031–32	−210	932	722	0.42	−88	390	302
2032–33	−210	953	743	0.42	−88	399	311

Source: Centre for International Economics' estimates

Table 12. Summary economic measures of the Barramundi Fishery Management Plan under alternative assumptions

	Discount rate 1%	Discount rate 5%	Discount rate 10%
Present value of impacts (A$'000)	24,602	1,996	316
Present value of costs (A$'000)	2,819	2,433	2,047
Net present value (A$'000)	21,784	−437	−1,731
Benefit:cost ratio	8.73	0.82	0.15
Internal rate of return	−1.5	−1.5	−1.5

Source: Centre for International Economics

6 Conclusions

Knowledge is critical to the successful management of a fishery. The project was successful in expanding this critical scientific knowledge of the Western Province barramundi fishery and to a lesser extent improving the understanding of the socioeconomic factors relevant to its management. The project was also successful in developing a management plan for the fishery and having it passed into PNG law. However, the fishery management plan developed through the project does not appear to have delivered any significant benefits to artisanal fishers or commercial processors in the region.

The BFMP is estimated to have resulted in a small loss to commercial processors of around A$255,000 (in present value terms using a discount rate of 5%). This conclusion is robust to variations in the key assumptions underlying the estimates. A key reason why the BFMP is estimated to produce a loss is the trend towards lure fishing. Lure fishing—which is not covered by the BFMP—reduces the impacts of the plan over time. The BFMP in effect traded off a lower annual catch in return for a lower risk of total stock collapse and therefore higher expected benefits in the future. The shift towards lure fishing has meant that the short-term losses (in terms of lower annual catch) have been incurred while the longer term benefits (higher expected benefits due to lower probability of total stock collapse) have been eroded. In addition, the fishery restocking program means that the potential loss of future benefits associated with total stock collapse before restocking is temporary rather than permanent.

In the absence of these unanticipated developments, it is estimated that the BFMP would have delivered benefits to commercial processors. That unanticipated developments prevented the BFMP from producing benefits highlights the importance of regularly updating fisheries plans as circumstances change.

Nevertheless, even without the impacts of lure fishing and the restocking program, the benefits attributed to the project are still estimated to fall short of the cost of the research. Given the small scale of the fishery it would have been difficult for the benefits of the project to match the relatively high project costs. Other factors that have prevented the BFMP and therefore the project from delivering greater benefits to the community include:

- inadequate enforcement of the plan
- the failure of the plan to restrict fishing effort in any meaningful way.

As highlighted by Panayoutou (1982):

> The importance of the control of effort to fully reap the gain in productivity to be accrued from regulations on gear selectivity cannot be over-emphasized, as no long-term improvement in individual incomes and economic surplus can be expected in the absence of effort regulation.

Successfully restricting fishing effort would mean that artisanal fishers as well as commercial processors could benefit from the BFMP.

The BFMP needs urgent revision to remedy these critical shortcomings. Western Province Sustainable Aquaculture's restocking of the fishery will commence in 2010, but this is unlikely to be successful in the longer term unless these problems are solved in the near future. Resurrecting the Barramundi Management Advisory Committee immediately would be a critical first step in this direction.

The possibility of revisiting the management plan was raised in discussions with the NFA. The project's scientific outputs, including the bioeconomic model, would be used in any analysis underlying revisions to the plan, meaning that the project outputs could still deliver significant benefits. However, pre-empting the shape of any revisions to the plan would be speculative and this has therefore not been included in the analysis. It nevertheless represents an important upside risk to the estimated losses.

How to remove the BFMP's shortcomings in any future revisions is difficult. The aim of fishery management should be to maximise resource rents. While this is difficult to achieve with limited information and ability to enforce any restrictions, it nevertheless seems likely that any effective measures to restrict effort would lift the resource rents above zero and therefore increase the benefits to artisanal fishers.

In this context is it important to deal with the issue of property rights. The global TAC approach does not achieve this. Allocating village-based TACs and providing village governments with the authority to restrict fishing in the waters over which they claim tenure, as suggested by Fegan (2002), is one possible solution.

It also appears to be essential that all villages perceive that they are better off as a result of the management plan. Villages that consider they lose from the plan—such as those located near the spawning grounds—are less likely to comply. Some form of compensation for such villages could be considered.

Several lessons have emerged from this impact assessment and the project more broadly that may be useful in guiding future projects.

- First, without meaningfully restricting fishing effort, any fisheries management plan is unlikely to deliver significant long-term benefits to fishers. Any successful measures to increase the productivity of the fishery will simply encourage an increase in effort that, over time, will erode any benefits. Similarly, directly subsidising fishing is unlikely to deliver long-term benefits in an open-access fishery that is already over-fished. Restricting operator licences is also likely to be an ineffective strategy for restricting fishing effort.
- It is important to update fisheries management plans regularly as circumstances change.
- More generally, there is little point in developing regulations that cannot be enforced. The enforcement mechanism needs to be carefully considered in the design of the regulations. The project has shown that, even without formal enforcement, some level of compliance can be achieved when the supply chain (both upstream suppliers and downstream buyers) can be controlled.
- The size of the market affected by fisheries research and development projects needs to be carefully considered to ensure that the potential benefits are likely to be large enough to outweigh the costs of the research.

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11	Chudleigh P. 1998.	Postharvest R&D concerning tropical fruits	PHT/1983/056 and PHT/1988/044
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