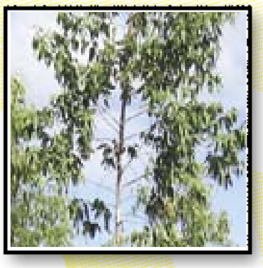
ACIAR fisheries projects in Indonesia: review and impact assessment

IMPACT ASSESSMENT SERIES **55**



Australian Government
Australian Centre for International Agricultural Research

ACIAR fisheries projects in Indonesia: review and impact assessment

Greg Martin
IDA Economics

2008

Australian Government
Australian Centre for
International Agricultural Research

The Australian Centre for International Agricultural Research (ACIAR) operates as part of Australia's international development cooperation program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

ACIAR seeks to ensure that the outputs of its funded research are adopted by farmers, policymakers, quarantine officers and other beneficiaries.

In order to monitor the effects of its projects, ACIAR commissions independent assessments of selected projects. This series reports the results of these independent studies.

Published by the Australian Centre for International Agricultural Research (ACIAR)

GPO Box 1571, Canberra ACT 2601, Australia
Telephone: 61 2 6217 0500
aciar@aciar.gov.au

Martin G. 2008. *ACIAR fisheries projects in Indonesia: review and impact assessment*. ACIAR Impact Assessment Series Report No. 55, 76 pp.

This report may be downloaded and printed from <www.aciar.gov.au>.

ISSN 1832-1879
ISBN 978 1 921531 01 9 (print)
ISBN 978 1 921531 02 6 (online)

Editing and design by Clarus Design Pty Ltd
Printing by Elect Printing

Foreword

The Australian Centre for International Agricultural Research (ACIAR) is shifting its impact assessment study activities to have a broader program focus and context. This shift also involves using random samples to select research efforts for assessment, instead of choosing projects with expected high returns.

Indonesia is ACIAR's largest partner-country research program and the fisheries program is a significant component. This study was commissioned to review all ACIAR projects in Indonesia's fisheries program and to undertake a formal impact assessment of two projects.

The review identified two main areas of research emphasis—capture fisheries management and aquaculture improvement. There has been a strong integration of several sets of projects to generate impacts that, especially for capture fisheries management, are a complex story. The selection of the group of projects for the impact assessment studies was more complex than a stratified random sample, which was the starting point.

Two impact assessment studies are reported and both indicate that the research and related implementation efforts—some funded by a range of other agencies—have had a significant impact.

The southern bluefin tuna (SBT) management research was found to have made a substantial contribution to Indonesia becoming a member of a regional management group. The benefits of this membership through expected increases in the SBT catch for all members was estimated to have a net present value (NPV) of A$168 million for the research and development (R&D) attributable to the ACIAR investment. On the funds invested this represents a benefit:cost ratio (BCR) of 179:1 and an internal rate of return (IRR) of 210%. These returns are shown to be attributable to the substantial capacity building that the ACIAR projects provided and the confidence this contributed to Indonesia's capacity to manage complex fisheries.

ACIAR and its partners' research activities about the causes of diseases in smallholder shrimp farming have provided a major breakthrough in understanding the reasons for a major collapse in a significant part of this industry. The technologies developed to overcome these problems were found to have substantially improved the profitability of shrimp farming over a potentially large area. Significant re-entry into traditional shrimp farming is taking place and the Indonesian Government Plan for Revitalisation of Aquaculture reflects the R&D findings. The study shows that the returns to the ACIAR project investment are expected to be high, with a NPV of $547 million, a BCR of 52:1 and an IRR of 26%.

The study shows that, to achieve these gains, there was a requirement for a complex set of research activities that first identified the causes of major problems and then developed research and capacity building to provide technologies and expertise to solve them.

These are important results for our major partner, Indonesia, and for Australia.

Peter Core
Chief Executive Officer
ACIAR

Contents

Figures

Tables

Boxes

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
ASS	acid sulfate soil(s)
BCR	benefit:cost ratio
BMP	better management practices
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DAFF	Department of Agriculture, Fisheries and Forestry (Australian Government)
DGCF	Directorate General of Capture Fisheries (Indonesia)
IOTC	Indian Ocean Tuna Commission
IRR	internal rate of return
IUU	illegal, unreported and unregulated [fishing]
MMAF	Ministry of Marine Affairs and Fisheries (Indonesia)
NPV	net present value
OFCF	Overseas Fisheries Cooperation Foundation (Japan)
R&D	research and development
RCCF	Research Centre for Capture Fisheries (Indonesia)
RICA	Research Institute for Coastal Aquaculture (Indonesia)
SBT	southern bluefin tuna
WCPFC	Western and Central Pacific Fisheries Commission

Acknowledgments

The author thanks the researchers and support staff in the various ACIAR-supported R&D projects in Indonesia for their help in understanding the nature of the research being undertaken and its potential impacts. The author benefited greatly from the welcoming and open discussions with Indonesian and Australian researchers and government officials during the field trip to Indonesia in February 2008.

The author thanks, in particular:

- Mr Barney Smith, Fisheries Research Program Manager, ACIAR
- Dr Jes Sammut, School of Biological, Earth and Environmental Sciences, University of New South Wales
- Dr Mike Rimmer, James Cook University, Aceh Aquaculture Rehabilitation Project
- Mr Craig Proctor, CSIRO Marine and Atmospheric Research, Hobart
- Dr Reza Pahlevi, Ministry of Marine Affairs and Fisheries (MMAF), Indonesia
- Dr Purwito Martosubroto, MMAF, Indonesia
- Dr Richard Callinan, Faculty of Veterinary Science, University of Sydney
- Dr Fatuchri Sukadi, MMAF, Indonesia
- Dr Ketut Sugama, MMAF, Indonesia
- Mr Akhmad Mustafa, Research Institute for Coastal Aquaculture (RICA), Maros, Indonesia
- Mr Tarunamulia, RICA, Maros, Indonesia

This report also benefited significantly from comments by Dr Jeff Davis of ACIAR.

Mr Barney Smith and staff in ACIAR's Indonesian office provided invaluable assistance with the arrangements for the Indonesian trip.

Summary

Background

The Australian Centre for International Agricultural Research (ACIAR) uses impact assessment studies to enable a broader, program-based approach to examining the nature and impact of its investments in research and development (R&D). This approach, accompanied by a random selection of projects for assessment, helps us better understand the reasons for success or otherwise and thus guides the future approach to investment and project design.

ACIAR has been investing substantially in fisheries R&D in Indonesia since the early 1990s. Initially the activities focused upon identifying the problems and possible research strategies, including the opportunity for developing partnerships between Australian research agencies and Indonesian researchers and agencies. Subsequent research projects have sought to investigate specific problems and typically that process has led to the identification of new research areas. It is mostly these latter areas of investment that have begun to deliver results that have the potential to benefit Indonesia as well as other countries.

Scope

This impact assessment presents an overview of the ACIAR–Indonesia fisheries R&D portfolio—a portfolio that now totals over $20 million in nominal terms. The review has found that the R&D can be grouped into three broad areas:

- wild, or capture, fisheries
- sustainable, productive, shrimp production
- other areas, principally other aquaculture.

The linkages between the projects within these areas are presented in the review and provide an important basis for a better understanding of the origins of projects and the opportunities for applying research techniques and findings across project areas.

A brief review of the projects has identified that they have succeeded in:

- developing a partnership between Australian and Indonesian researchers and agencies
- achieving the research goals especially in terms of improving data collection and analysis, and improving the understanding of the fisheries and the requirements for sustainable aquaculture production
- delivering proposed management plans for major fisheries, especially those crossing national borders
- enhancing the capacity of researchers and research agencies to undertake research and operational support for both research and other activities of government such as fisheries management and land capability assessment
- delivering research outputs that have the potential to deliver significant economic, social and environmental benefits.

IAS and selection of projects

ACIAR's impact assessment process is intended to examine a randomly selected sample of projects.

In this analysis, one project area from the capture fisheries and one from aquaculture were selected based on availability of data, likely expected impacts (that is, reasonable certainty that the impacts could be foreshadowed) and recognising that, in most areas, projects were linked to either previous or subsequent projects.

As it turns out, there are important caveats to the analysis, which suggests that caution is required in seeking to generalise from the investment analysis of the two project areas.

The two project areas selected were:

- capacity development to monitor, analyse and report on Indonesian tuna fisheries (ACIAR project nos FIS/2001/079 and FIS/2002/074)
- remediation of tambaks (small, landowner ponds for shrimp production) and associated better management practices (FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2002/076, FIS/2005/169, FIS/2006/144).

Indonesia tuna fisheries

The principal tuna fisheries that involve Indonesia are the southern bluefin tuna (SBT), yellowtail and bigeye tuna fisheries. In each of these fisheries, other nations, besides Indonesia, have a vital interest in the future sustainability and economic performance of the fishery. Historically, the SBT fishery has been under the greatest pressure, having collapsed in the early 1970s and again in the late 1980s.

Further, the area of the fishery that lies within Indonesian waters is the only known breeding area for SBT, making management of that part of the fishery of vital importance for the fishery as a whole. Australia (in fishing and value-adding SBT) and Japan, Korea and Taiwan (with an added consumer interest), through the Commission for the Conservation of the SBT (CCSBT), sought Indonesia's membership of the commission in order to ensure better management of the fishery. Membership of the commission also would enable Indonesia to market SBT into the high-priced Japanese, Korean and Taiwan markets.

While Indonesia has had a basic catch-monitoring system at fishing ports, it has not had the capacity to collect reliable, accurate, catch and other (environmental) data to permit the type of fishery modelling necessary for future sustainable management of the fishery. The two ACIAR projects have established that a structured observer program on board fishing vessels can deliver the quality of data required. Further, the research has led to improved modelling of the fishery as well as capacity building in Indonesia for future data collection and modelling.

In April 2008, Indonesia became a member of the CCSBT. It appears that the ACIAR-funded R&D played a significant part in achieving that outcome. The analysis in this report suggests that around a quarter of the benefits of the CCSBT can be attributed to the investment in better quality Indonesian catch data and the past and future investment needed to maintain the quality of data collection. It is estimated that the ACIAR component of this past investment (and future investment by others apart from ACIAR) is around 15% of the gains from the better catch data supporting Indonesian membership.

Analysis outside the ACIAR projects has estimated significant economic gains from better management of the SBT fishery. It points to gains (producer plus consumer surplus) of the order of $4,550 million in net present value (NPV) terms from a set of quota arrangements proposed by the CCSBT (which included a catch quota for Indonesia) compared with non-inclusion and thus uncontrolled fishing by Indonesia and other South-East Asian fishing interests. Most of this gain accrues to Japan, Korea and Taiwan, given that the quota arrangements extend the life of the fishery and SBT are valued very highly by consumers in these three countries. The Australian SBT fishing industry also benefits, especially as the SBT that are harvested form the basis of the South Australian SBT aquaculture industry.

On the basis of the assessed importance of better catch data leading to Indonesian membership and commitment to the CCSBT, and the relative role of the ACIAR R&D investment, the return to the ACIAR investment is estimated at $168 million (NPV over 20 years). Given the ACIAR R&D cost involved, this represents an investment return of 179:1 (benefit:cost ratio, BCR) and an internal rate of return (IRR) of 210%. These are substantial investment returns.

In addition to the impact on the SBT, the ACIAR projects have contributed significantly to better understanding of, and improved data collection in, the yellowfin and bigeye tuna fisheries. This work is continuing and further investment by ACIAR and others is proposed.

Remediation of the tambaks

During the 1980s a substantial investment was made in Indonesia in tambaks—smallholder, earthen bank, brackish-water ponds for shrimp production. However, production from the tambaks collapsed during the late 1980s as disease problems (in particular white spot disease, caused by a virus) led to substantial production losses and subsequent abandoning of most of the ponds. It is estimated that around 100,000 ha of tambaks lie idle or have only for low-productivity uses.

Initial ACIAR-funded workshops focused on the issue of disease losses. Subsequently it was recognised that a major causal factor was acid sulfate soils that reduced the general health of shrimp, leading to greater vulnerability to disease.

The initial ACIAR project (FIS/1997/022, *Remediation and management of degraded earthen shrimp ponds in Indonesia and Australia*), focused on remediation techniques. Subsequent projects have extended the research findings in three directions: first, a focus on land capability assessment and suitability for activities such as shrimp farming (FIS/2002/76); second, an extended investment in disease-control programs and better on-farm management practices (initially FIS/1997/125 and, subsequently, FIS/2000/61 and FIS/2005/169); third, capacity building, especially on Aceh following the 2004 tsunami (FIS/2005/028 and, later, FIS/2006/02 and FIS/2005/09). These later projects are still current.

Although a process for remediation was developed (comprising liming and cleansing of ponds; aquaculture rotations and polyculture; disease-free broodstock and maintaining isolation from disease-infected ponds) there has been relatively little adoption of the remediation procedures. A range of contributing factors has been identified, including risks facing farmers, up-front costs and limited access to credit, and limited government extension services. A key feature of those limited areas where adoption has been more successful has been the very close involvement of the researchers in establishing trial ponds and working closely with interested farmers. This latter factor has focused attention on the potential role of government extension services to promote the technology.

In 2006 the Indonesian Government launched an aquaculture revitalisation plan. An element of this strategy is the remediation of abandoned tambaks for white shrimp (*Litopenaeus vannamei*) and black tiger shrimp (*Penaeus monodon*)[1] production. It is proposed that a major investment will be made in extension services (through national funding of local government extension services) as well as provision of working capital to enable purchase of lime, fertiliser and other materials for remediation of the tambaks. At the core of the tambak remediation effort are the technologies and better management practices developed through the ACIAR-funded projects.

Using the production goals of the plan it is estimated that if these goals are achieved the gains from the cost reductions would deliver a gain to farmers (producer surplus) of around $2,000 million (NPV over 20 years). However, this scenario (reported as scenario 1) seems overly optimistic on the grounds that it will require a substantial investment in local extension services (which historically are recognised as having failed) and a major increase in farmer numbers over a very short interval. Against this background two other scenarios are outlined and the economic impacts explored.

1 Shrimp is the name commonly applied to these crustaceans in Asia and used in this report, whereas in Australia they are usually called prawns.

Scenario 2 is based on achieving the plan's goals, but in a longer time frame. Scenario 3 is based on a much lower production increase (about half that outlined in the plan) and again taking much longer. The expected outcome was a 66% likelihood of scenario 2 and a 33% likelihood of scenario 3.

On the basis of this expected outcome, the ACIAR project (which comprises ACIAR funding, Australian research agency funding and partner funding in Indonesia) is estimated to return benefits (producer and a limited consumer surplus) of $547 million (NPV over 20 years). The investment return is estimated at 52:1 (BCR) and a 26% IRR.

Other benefits are expected from the ACIAR project. A major achievement has been the development of technology for assessing land use suitability, based on location of acid sulfate soils, and associated mapping for land-use planning. These maps are being recognised by local governments as relevant in the land planning process and it is expected that their use could reduce planning mistakes.

The capacity for research and application of findings developed by the Indonesian researchers has been demonstrated in the reconstruction effort in Aceh. Again the acid sulfate soil issue was important but not recognised by the main reconstruction agencies. Part of the ACIAR project investment was the implementation, at short notice, of activities aimed at assisting with the reconstruction and establishment of tambaks. This project, which has established training schemes, is expected to benefit farmers on Aceh as well as in other regions of Indonesia.

Conclusions

This impact assessment of ACIAR's investment in fisheries-related R&D in Indonesia has identified that fisheries R&D has relatively long lead times, especially research related to better data collection and analysis for capture fisheries. Nonetheless, as has been demonstrated for the SBT fishery and Indonesia's membership of the CCSBT, the potential economic gains can be substantial.

A key issue for ACIAR's investment in aquaculture is the level of adoption of research findings.

Although the two project areas examined in this impact assessment show high rates of return to ACIAR's investment in fisheries R&D in Indonesia some caution is required in generalising from these findings. First, the estimated returns are expected returns and rely significantly on future, rather than past, outcomes. Second, adoption in the case of the SBT analysis was driven by external interests in particular. Such drivers do not always exist with respect to domestic or other international fisheries. Third, the adoption of tambak remediation is based largely on a government plan. While the analysis is more cautious on the level and timing of the production increases, there remain uncertainties as to the extent of future production increases.

A major achievement of the ACIAR projects has been the substantial capacity building within Indonesia to undertake fisheries-related R&D.

1 Introduction

1.1 Background

The Australian Centre for International Agricultural Research (ACIAR) has been undertaking impact assessment studies for more than 20 years. ACIAR uses these studies to enable a broader, program-based approach to examining the nature and impact of its investments in research and development (R&D). Impact assessments are a significant part of ACIAR's accountability process and provide important guidance for the direction and management of continuing and future projects.

ACIAR has provided substantial support for fisheries research in Indonesia since the early 1990s with an increasing focus up to the mid 1990s. This research has covered both management of wild stocks and aquaculture. Some 41 projects have been funded since 1983, to over $20m in nominal terms (not adjusted for inflation or the opportunity cost of funds). Most have now been completed.

This report provides an overview of the ACIAR investment. Specifically, it outlines the development of the program and the associated linkages between the projects. A brief review of the scope and outputs of the main projects is presented.

The review of all projects found that most projects have looked at issues related to either capture fisheries management or aquaculture production. All projects were stratified on the basis of these two different fishery subsectors. The intention was to then randomly sample projects within the two groups to choose one from each for detailed impact assessment.

However, the review showed three important things. First, in all cases a preliminary set of research activities (including focused workshops) was required to clearly identify the problems and establish the capacity of the research groups to undertake the appropriate applied research to reach appropriate solutions. Second, many of the projects were linked to each other and so needed to be assessed as a group. Third, much of the research has only recently been completed or is being completed, and there are thus limited impacts to date.

As a result, instead of a purely stratified random sample to choose the activities for the impact assessments, the two projects were chosen on the basis that they had been finished long enough to allow time for an impact or potential impact.

1.2 Report structure

The report is structured as follows:

Section 2 outlines ACIAR's fisheries R&D projects in Indonesia since 1995, and their interlinkages.

Sections 3 and 4 present overviews of ACIAR's investment over the period in capture fisheries and aquaculture, respectively.

Sections 5 and 6 present detailed impact assessments for the two projects selected:

- *Capacity development to monitor, analyse and report on Indonesian tuna fisheries*
- *Remediation of tambaks—small landowner ponds for shrimp production.*

Section 7 presents the conclusions.

2 ACIAR's Indonesian fisheries research and development projects

ACIAR's investment in Indonesian fisheries can be broadly grouped into:

- wild fish, or capture, fisheries, the principal focus being collection and analysis of catch information and the development of fishery models to enable improved management of wild-fish fisheries
- shrimp aquaculture, where the main focus has been investigating disease and more general management problems in traditional shrimp farming
- other fisheries R&D, where the focus had been primarily marine finfish, mudcrab culture and reservoir fisheries.

In all three areas, current or recent projects have evolved from earlier ACIAR projects that had identified specific problem areas. The linkages and time frames of the ACIAR projects in each of these groups are shown in Figures 1–3.

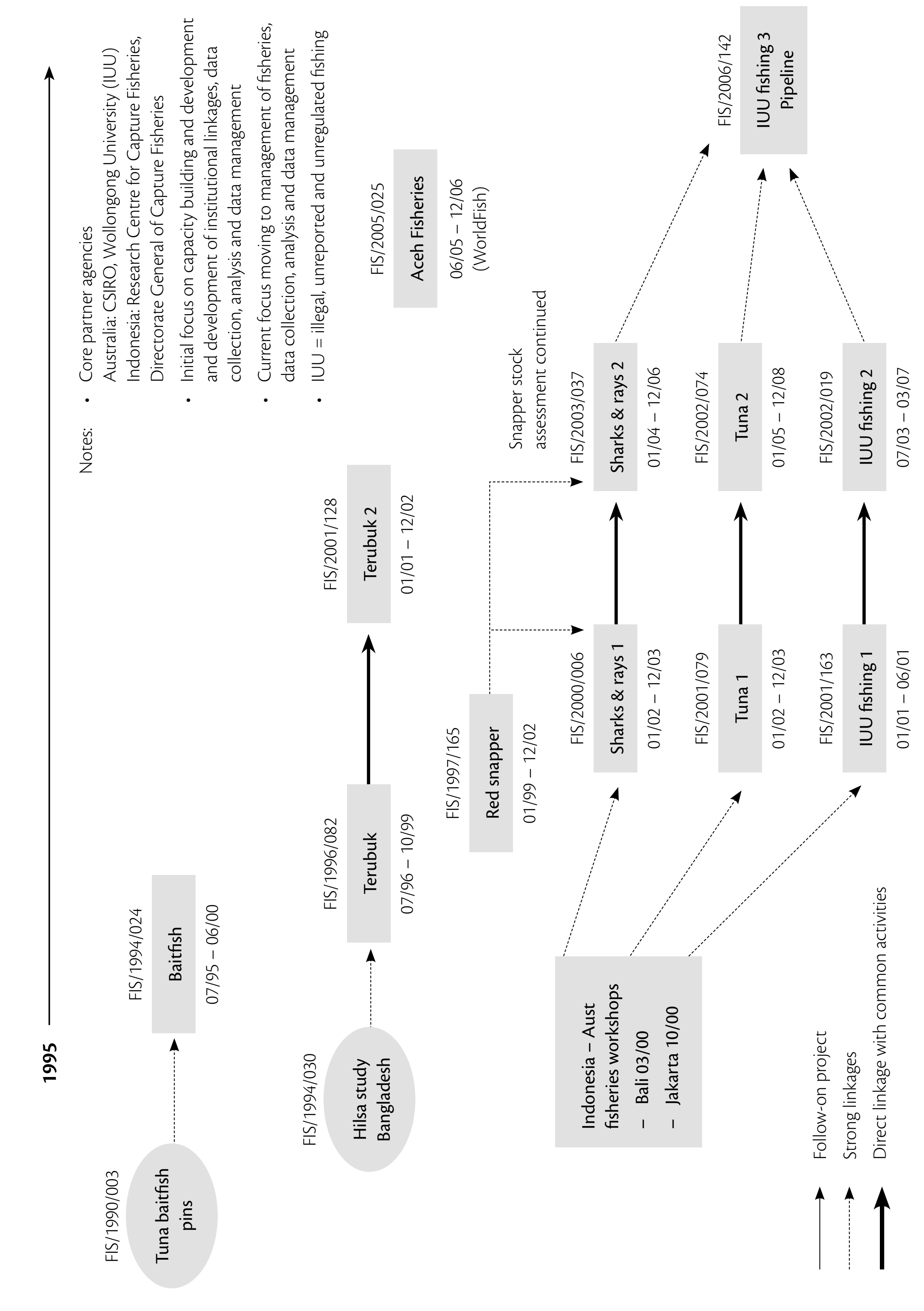


Figure 1. ACIAR fisheries projects Indonesia: capture fisheries. Source: developed in collaboration with Barney Smith, Fisheries Research Program Manager, ACIAR

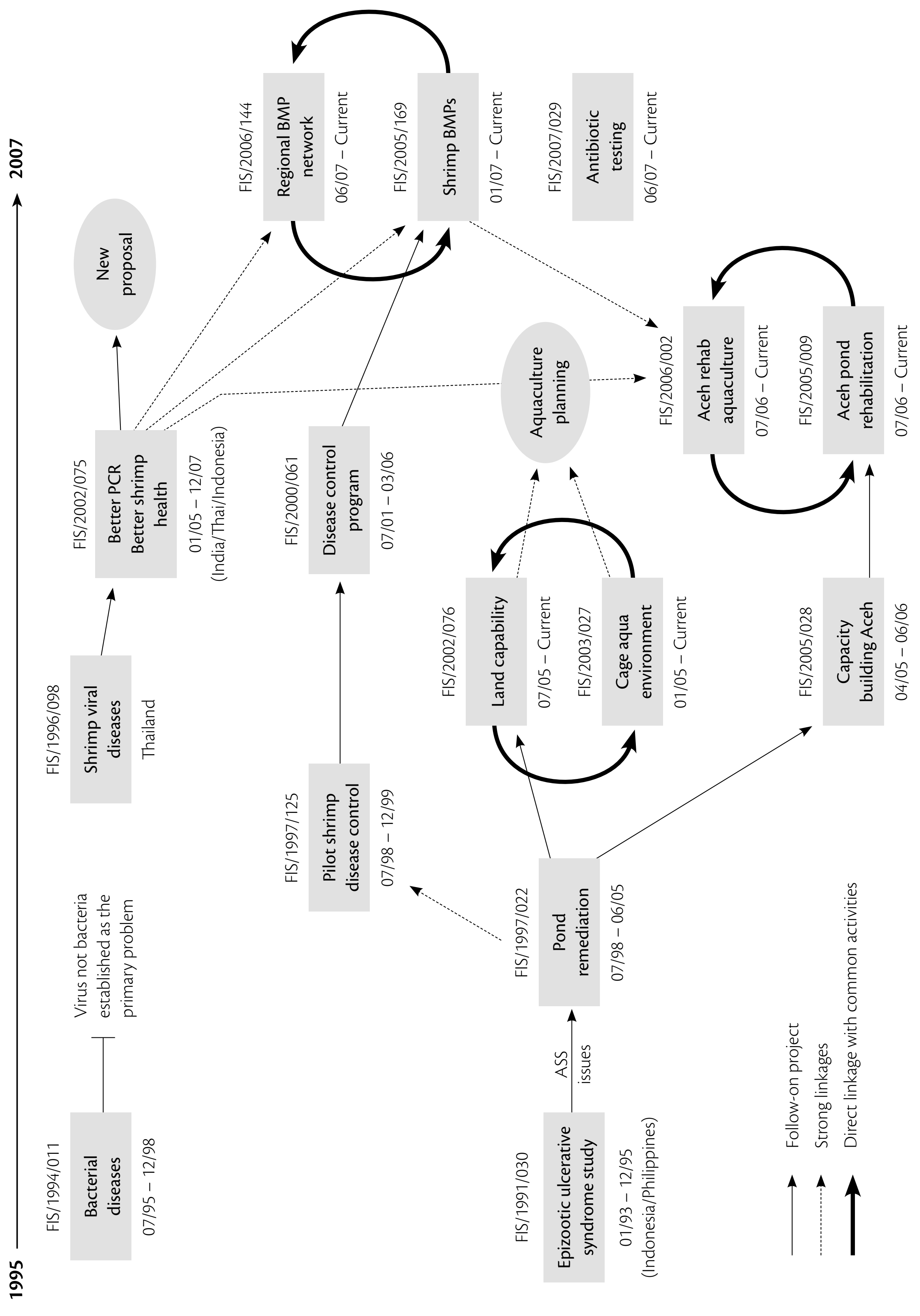


Figure 2. ACIAR fisheries projects Indonesia: aquaculture (shrimp) fisheries. Source: developed in collaboration with Barney Smith, Fisheries Research Program Manager, ACIAR

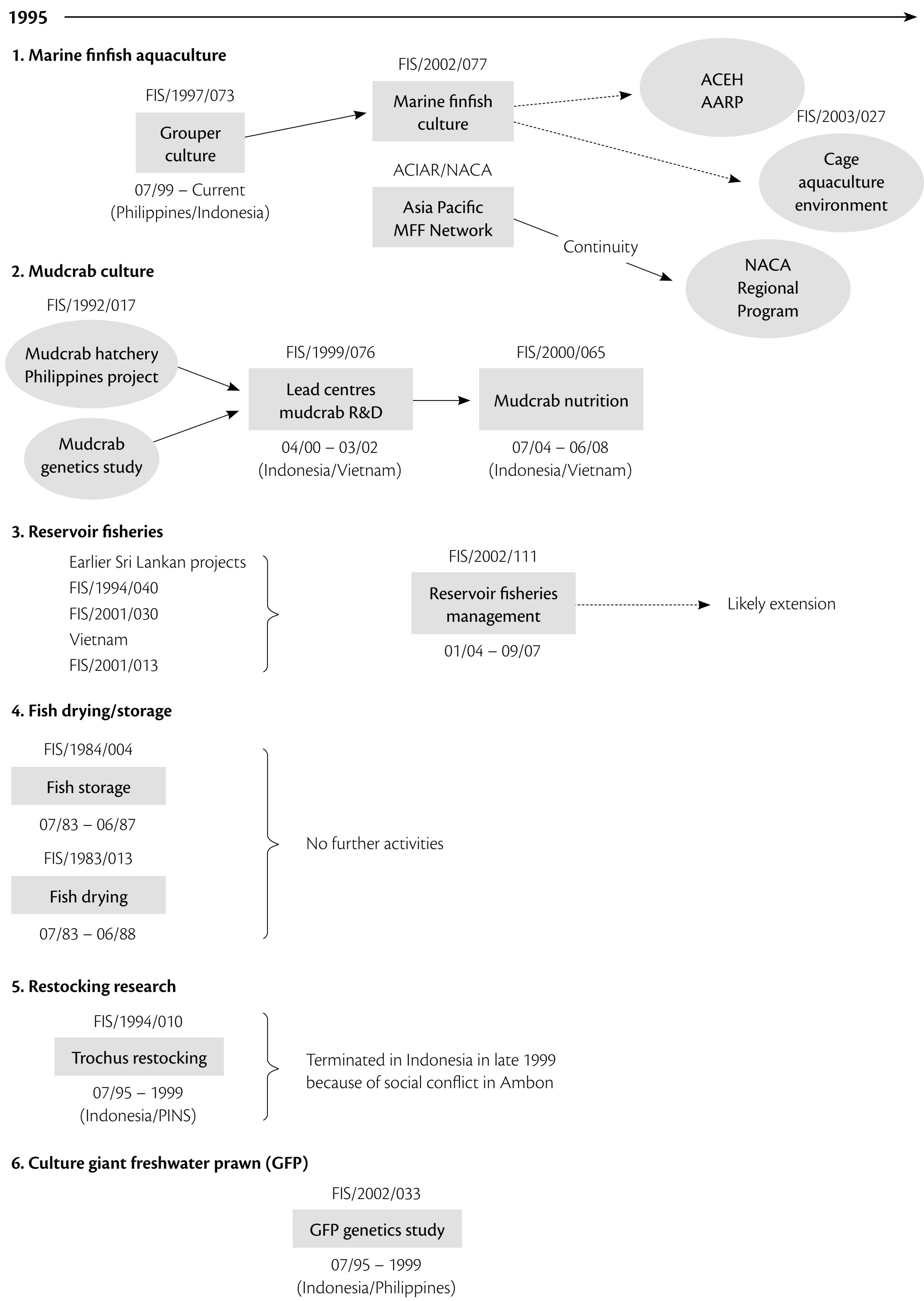


Figure 3. ACIAR fisheries projects Indonesia: other fisheries. Source: developed in collaboration with Barney Smith, Fisheries Research Program Manager, ACIAR

3 Overview of capture fisheries research and development

3.1 Management of shared fisheries

In the early 1990s the exploitation of fish stocks shared between Australia and Indonesia was becoming an issue and, at that time, a series of high-level consultations on fisheries cooperation between Indonesia and Australia identified the need for cooperative research and management action on shared fish stocks. Coordinated management of cross-boundary fisheries is essential if these fisheries are to remain viable. ACIAR's involvement and support for capture fisheries followed, recognising both the shared responsibility for management and the capacity within Australian research agencies to help develop monitoring strategies, fishery models and management policies.

Indonesia's analysis of its fishery potential in the 1990s continued to promote fishing on the basis that the level of utilisation (catch), relative to the estimated maximum sustainable yield (MSY) was typically less than two-thirds of the MSY, although there were significant differences between fish species. In 1999 the level of utilisation for tuna was reported as 67% (Jusuf and Dahuri 1999). However, by the late 1990s there was evidence that fisheries stocks were being depleted, with consequent implications for future sustainable fishing yields.

3.2 Motivation for the projects

The original project (FIS/1997/165, on red snapper), begun in 1999, focused on fish resource assessment. Australia and Indonesia share the red snapper and goldband snapper resources of the Arafura and Timor seas. There were increasing concerns that the fishing catch was above the sustainable yield of the fishery.

Earlier Australia–Indonesia workshops on the fisheries of the Arafura Sea (1992 and 1994) had included participants from both countries and concluded that there was a possibility that the two countries might share stocks. At that time, no information was available about the stock structure, distribution and movements of each stock. Moreover, data on the population biology and commercial catches were inadequate. Such data are crucial for stock assessment and management. At the time when the ACIAR project was initiated, it was thought that the artisanal fishery in Indonesia was likely to be taking a significant portion of the Indonesian catch of the red and goldband snappers.

However, it was also recognised that a large fleet of foreign vessels also fished for these species in Indonesian waters. Subsequently, reflecting the achievements of the CSIRO researchers in bringing Australian and Indonesian fisheries managers together through increased understanding of the fishery (culminating in two workshops in 2000), three other ACIAR projects were established: FIS/2000/06, shark and rays; FIS/2001/079, tuna; FIS/2001/163, illegal, unregulated and unreported (IUU) fishing. Again these projects sought to improve fishery resource knowledge, particularly at a time when the standard view was that these fisheries were substantially underexploited.

3.3 Outputs

The following sections list the key outputs of the four projects.

3.3.1 Red snapper

- The project provided scientifically sound evidence that the Australian and Indonesian fleets fishing the red and goldband snappers of the Timor and Arafura seas are exploiting common, shared populations of these species.
- It demonstrated that, because of the population biology of these species, it is likely that current levels of catches are unsustainable (the biomass dynamics model demonstrated that, despite the quality and paucity of data, current levels of catch from the Arafura Sea are unlikely to be sustainable).
- The project determined that the Indonesian snapper fishery comprises
  - a small-scale, artisanal fishery
  - a semi-industrial scale fishery of about 500–600 Indonesian boats using bottom longlines, droplines and lines
  - a much larger, industrial-scale, net (trawler) fishery of around 700 boats that operates in the Arafura Sea and transfers frozen catches directly to export carrier ships. These vessels are often re-flagged Thai trawlers that transfer catches directly to carrier vessels. Product is shipped directly overseas without landing in Indonesia and without a value-adding return to Indonesia.
- It was shown that the net sector of the Indonesian fishery is having considerable impact on the stocks of snapper as, due to the small mesh size of the nets used, and possibly the locations that are fished, the fish taken by this sector include much smaller and younger fish than those taken in other sectors of the fishery.
- The project recommended that managers of the fishery should seriously consider further control of illegal fishing.

A Snapper Management Policy Advisory Committee (initiated for the ACIAR project) enabled the issues of stocks and fishing in the shared fishery to be discussed and resolved at a technical level. The committee's role has subsequently been expanded to responsibility for other shared stocks. The decision to embed policy- and decision-makers and fishery managers within the project was important. It meant that they became more aware of the science and provided input on the impact and appropriateness of alternative management strategies that might be considered for future management of the fishery

3.3.2 Shark and rays

Sharks are highly vulnerable to over-fishing since, though long lived, they are slow maturing and have low levels of fecundity. Thus, overexploitation can result in quick population declines. FAO and other international agencies are requiring countries to develop national plans to sustainably manage these fisheries. Indonesia did not have a national plan before the ACIAR project.

The initial project (FIS/2000/06) established baseline data. It proved the existence of a higher level of diversity in the species of the group than was previously thought, and established basic biological parameters for some species and the socioeconomic characteristics of the artisanal fisheries. Project FIS/2003/37 developed a national plan, documented the huge range of shark and ray fauna in Indonesia, and produced an easy-to-use 'Field guide to Indonesian sharks and rays', thus facilitating better catch identification for consistent data collection. More than 30 new species were discovered. Genetic analysis of stock structure showed that some key species are shared between Australia and Indonesia and will need joint management. Also provided was a detailed compilation of fisheries management options and recommendations.

3.3.3 Tuna

Tunas of the eastern Indian Ocean are fished by commercial and artisanal sectors. Australia and Indonesia are two countries with exclusive economic zones in the area. Indonesia's Indian Ocean tuna catch is highly significant and accounts for 15% of the total catch of tunas by all nations fishing the Indian Ocean. The Indonesian longline fishery is the second biggest harvester of yellowfin and bigeye tunas, after Taiwan and China (IOTC 2006). Declining catches (total weight and average size) for yellowfin, bigeye and southern bluefin tunas have been reported since 2000, suggesting the fishing level is unsustainable and collapse of the fishery is possible.

The fishery is an important spawning ground for many tuna species and, while port-based, catch-monitoring programs were in place, they were not able to reliably deliver the quality of catch-per-unit-effort information required for future fishery management. The trial scientific observer program that was established with ACIAR support tackled this problem. The 'Review of eastern Indonesia tuna fisheries' activity (within project FIS/2002/074) sought to create a basis for establishing an appropriate monitoring program for catches and landings. A full-scale monitoring program has been proposed for 2008–10.

The trial scientific observer program also contributed to capacity building, leading to skills development for 12 trainees (6 Indonesian and 6 from Timor Leste). Each of the Indonesian observers has gone on to complete at least seven trips to sea for a variety of trip lengths during the past 3 years. Future development is to focus on the breadth of data collected by observers. Stock assessment capability was improved through the training of two personnel at the Research Centre for Capture Fisheries (RCCF) and CSIRO/University of Tasmania, Hobart. The trainees subsequently made presentations to the respective coordinating committees and at international conferences.

3.3.4 Illegal, unreported and unregulated fishing

Illegal, unreported and unregulated (IUU) fishing is viewed as a major impediment to sustainable management of fisheries, since catch data are not recorded. In March 2001, FAO introduced an international plan to prevent, deter and eliminate IUU fishing, with national plans required by October 2004. The Sulawesi fishery shared by Indonesia and the Philippines was identified as having a significant IUU problem due to lack of an agreed maritime boundary, complex administrative/legal structures (national, provincial and local interactions), difficulties of harmonising management and policy, and a high level of incidents of illegal foreign fishing. Project FIS/2000/163 initiated discussions between the two countries, leading to a cooperative framework to tackle IUU fishing. Project FIS/2002/019 led to increased awareness of IUU fishing and strengthened cooperation between the two nations. It also improved the exchange of information cooperation between government and the fishing industry. Workshops have been conducted in both countries, with national plans now being drafted. Policy recommendations arising from the project have been used to amend fisheries legislation and management. Project FIS/2006/142 encompasses a continuation of funding for tackling IUU fishing issues.

4 Overview of aquaculture research and development

ACIAR project investment on aquaculture in Indonesia has focused on shrimp farming and the development of new, high-value industries.

4.1 Shrimp farming

Disease outbreaks have caused catastrophic losses in the traditional Indonesian 'tambak', small (less than 1 ha) brackish-water ponds used to raise shrimp.[2] In areas of South and East Sulawesi large developments (dating back to the 1980s) and involving the conversion of rice paddies into many thousands of tambaks now effectively lie idle, apart from limited milkfish production for local consumption. It was reported that in South Sulawesi alone there are around 100,000 ha of tambaks that are no longer used for shrimp production due to disease and the presence of acid sulfate and sandy soils.

Initial ACIAR projects (FIS/1994/011 and FIS/1996/098) focused on combating disease outbreaks caused by viruses and bacteria that were leading to major losses in hatcheries and in pond grow-out of farmed shrimp; that is, on directly addressing shrimp health. Subsequent projects, and other ACIAR projects in East Sulawesi (FIS/1997/022 and FIS/2002/076), identified a high correlation between generally poor shrimp health, reflecting underlying adverse water quality, and disease outbreaks. The main contributing factors were identified as the influence of acid sulfate soils (disturbed when rice paddies were dug deeper to provide the ponds needed for shrimp production), high levels of organic matter, and limited circulation of cleaner water to and from the ponds as, for example, when the inlet water source was the outlet supply from other ponds, or the distance from the ocean (in some cases 30 km) was such that there were no tidal flows and seawater flushing.

The importance of the acid sulfate soils and general disease management issues led to further projects focused on pond rehabilitation across Indonesia (including projects FIS/2005/169 and FIS/2006/144).

The aim of these projects was to develop and have adopted cost-effective and simple farm-level disease control and prevention practices. A 'better management practices' (BMP) system has subsequently been developed, with step-by-step manuals for farmers in particular, as a means of helping traditional farms adapt to a more semi-intensive farming system.

The understanding of both the disease issues and the underlying influence of acid sulfate soils on pond health enabled a rapid response to the rehabilitation needs following the tsunami that devastated much of Aceh in 2004. The Aceh aquaculture rehabilitation projects (FIS/2005/009 and FIS/2006/002) focused on tambak rehabilitation and more general rehabilitation of aquaculture.

2 In contrast, highly intensive shrimp farms have been able to avoid these losses through water circulation systems involving regular and frequent high-volume pumping of water from the ocean. Typically, the intensive operations adjoin ocean areas.

4.2 New, high-value aquaculture industries

Aquaculture of high-value reef-fish species has the potential to become a valuable industry, directed mainly at lucrative export markets in southern China. Groupers are well suited to aquaculture production. However, cultured grouper larvae have low survival rates, and food sources for growing-out juvenile fish are limited. Research to develop improved hatchery and grow-out technology in, for example, projects FIS/1997/073 and FIS/2003/027, has identified the importance of larval density, aeration and grow-out stocking rates. Lower-cost substitutes for trash fish used as grow-out feed have been identified.

4.3 Overview of ACIAR-funded aquaculture projects

An overview of the objectives, outputs and outcomes to date of the major projects in the aquaculture program follows. It is important for two reasons.

- First, it outlines the major projects and their status in terms of what has been achieved to date against the intended objectives.
- Second, it incorporates observations gleaned during discussions with researchers and follow-up of research outputs and outcomes. A key point is that researchers and officials alike are concerned to focus on outcomes and impacts, not simply the inputs (including costs) and outputs.

The major projects in the aquaculture program are outlined briefly below. (FIS/1997/022 is reviewed in more detail in a subsequent section.)

FIS/1997/022: Remediation and management of degraded earthen shrimp ponds in Indonesia and Australia

Until recently, problems of production in shrimp farms of the Asia–Pacific region have been linked to disease and farm management practices. There was little understanding of the effect of acid sulfate soils (ASS) on pond productivity. An earlier ACIAR study in Indonesia, the Philippines, India and Australia found a link between ASS and disease in wild and pond-cultured aquatic animals, so severe in some circumstances that shrimp ponds were abandoned.

The failure of shrimp ponds in these systems has led to reduced land value, economic hardship, altered social structure, lower standards of living and long-term environmental degradation. Farmers often responded by reconstructing new ponds in similar environments, leading to further losses and environmental degradation.

The project has developed low-cost technology to remediate and manage ASS in extensive (tambak) shrimp-production systems. The strategies include more efficient liming based on different liming materials and application methods, improved pond bottom and dyke preparation, restoration of problematic dykes, improved water management and more efficient fertiliser application.

Pond yields have been dramatically improved in ponds that were once low yielding or abandoned. Milkfish, seaweed and juvenile shrimp production in net enclosures were tested as alternatives to higher risk shrimp monoculture in severely degraded ponds. These production systems were developed for farmers operating in severely acidic soils that are too costly to remediate. The production systems can be run separately or as polyculture and enable farmers to manage economic risk.

The chemical processes that cause soil acidification and metal contamination were rigorously studied in Australia. The work showed that the dyke soils are a more significant source of acid and metals than is the pond bottom, which is often the focus of management. The work showed that metal hydrolysis accounts for most of the mineral acidity generated in pond soils and must be factored into the net acid-generating capacity of ponds. The findings of this study were used in Indonesia to test the effectiveness of modified dyke-soil management strategies leading to successful soil remediation strategies that are also applicable to intensive farming in Australia.

Soil-conservation strategies were tested in Australia. The work showed that acid and salt tolerant plant species can dramatically reduce soil erosion from dyke walls. Vegetation decreased splash erosion, rills and wave erosion by reducing the erosivity of water and the erodibility of the pond soils. These soil-conservation strategies, including the use of mangroves, were also applied in South Sulawesi to stabilise dykes.

The project also developed soil-mapping models to map the distribution of ASS in the aquaculture areas of Indonesia. This subsequently led to project FIS/2002/076, *Land capability assessment and classification for sustainable land-based aquaculture systems*. A mapping laboratory and a specialised soil testing facility were established under the project to build the research and service capacity of the Research Institute for Coastal Aquaculture (RICA).

Substantial capacity has been developed within Indonesian researchers and support staff. A Land and Evaluation Research Team was established in 1998 and is now the pre-eminent land-evaluation group in the Indonesian aquaculture sector. The team provides soil assessment and remediation support to farmers and other agencies across Indonesia. As a result of the research expertise developed under this project, RICA is now a 'Centre of Excellence in Soil and Land Assessment for Coastal Aquaculture'.

FIS/2000/061: Development and delivery of practical disease-control programs for small-scale shrimp farmers in Indonesia, Thailand and Australia

The world production of farmed shrimp in 1996 was valued at over $10 billion. About 80% of the crop is produced in Asia, largely by small-scale farmers. In Thailand, 90% of shrimp farms are smaller than 1.6 ha, while in Indonesia almost 50% are less than 2 ha. In Australia, the bulk of producers are also small farmers who operate, on average, 15 ha ponds.

When the project began, *Penaeus monodon* was the most important farmed shrimp species in South-East Asia and Australia. More recently, *Penaeus vannamei* has become important in many Asian countries.

Infectious diseases are consistently identified as the major threat to the long-term viability of the shrimp-farming industry in the Asia–Pacific region, and recurrent massive outbreaks of viral diseases have caused serious financial losses among smallholders. To meet this problem, researchers have worked towards developing effective farm-level, shrimp disease control programs. This work has now produced relevant expertise and information, but because of lack of definitive, on-farm program validations and inadequacies in the delivery of extension programs, smallholders have generally failed to benefit. In retrospect, validations were definitive for semi-intensive farms in geographically suitable areas, but lack of extension services and access to credit blocked adoption. These deficiencies are now being tackled under FIS/2005/169, noting that though a manual and a CD on shrimp health management were widely disseminated, independent follow-up implementations were generally unsuccessful, reportedly due to limited capacity and resources

The main aim of this project was for farmers, scientists and extension workers in Indonesia, Thailand and Australia to acquire the necessary knowledge, practical skills and willingness to implement, retain and further disseminate the shrimp disease control programs that were developed for small-scale shrimp farms. These were adapted 'best guesses' based on from information from intensive shrimp-farming systems.

The overall objectives of the study are first, to develop more effective and informative site-selection criteria and land capability assessment techniques to produce land-classification schemes and maps for a variety of land-based aquaculture systems in Indonesia; and second, to identify environmental constraints and improve existing site-selection criteria and land capability assessment and mapping criteria in Australia. A key issue is the identification and documentation of ASS and sandy-textured soils.[3] The project is also the first to integrate social factors and a range of environmental constraints into an overall coastal aquaculture decision-making process. The planned outputs target government officers, consultants and farmers. The Indonesian component involves training extension officers to use the planning tools more effectively.

The Indonesian component of the project is developing land capability assessment protocols using geospatial data and satellite imagery for regional-scale environmental assessment. This activity is based on detailed field investigations and critical validation of secondary

3 Significantly, the issue of acid sulfate soils and their implications for Indonesia extends well beyond aquaculture. It is apparent that large areas of cleared rainforest in Kalimantan are presenting the same challenges for rice production. In these areas, rehabilitation by forestation is being proposed.

sources of data. The project will also develop an overall coastal classification scheme in collaboration with ACIAR Project FIS/2003/027 to meet the needs of both land- and sea-based farmers.

The project has developed draft land suitability maps that are being tested in 2008 by stakeholders. Fundamental to the successes of the project's dissemination and adoption strategy is the establishment of a national steering committee that brings together all stakeholders at the national level. The committee provides a forum for researchers and stakeholders to identify needs and more effective pathways for adoption of technology across Indonesia. A local advisory committee (LAC) was established in South Sulawesi to enable effective information exchange between researchers and stakeholders, including agencies not directly involved in fisheries but interested in the land capability assessment of the coastal zone. The LAC model is now being considered for inter-agency projects in Aceh.

FIS/2003/027: Sea cage project

In South-East Asia, cage farming of fish is at least as productive as pond culture of shrimp, and is growing rapidly. Most nations in the region share concerns about maintaining appropriate environmental standards for this developing industry, but the environmental effects of cage culture of fish are poorly understood in the tropics. The tropical environments of Indonesia and northern Australia potentially used for cage culture are dissimilar to better-known Northern Hemisphere systems in a number of ways (e.g. biological turnover rates, tidal regimes, sediment types, water chemistry and rainfall regimes). Aquaculture target species in the tropics also differ greatly in biology from those grown in temperate Northern Hemisphere environments.

The overall project goal is to develop and apply planning tools to establish sustainable capacity thresholds for tropical finfish cage aquaculture. The project aims to collect, synthesise and model environmental information from coastal environments used for cage aquaculture in Indonesia and Australia, and use this to develop management tools to establish sustainable capacity thresholds, including stocking rates.

The results on tropical fish cage culture in Indonesia are intended to be linked to results from the parallel ACIAR project on pond-based aquaculture (FIS/2002/076) to deliver a classification scheme and appropriate management tools to facilitate the development of aquaculture in the coastal zone of South Sulawesi. The Australian study site, a 1,000+ tonne barramundi farm at Bathurst Island, Northern Territory, will facilitate extension of planning tools to macrotidal environments.

FIS/2002/075: Application of PCR for improved shrimp health management in the Asian region

Polymerase chain reaction (PCR) screening of seed prior to stocking, for the virus that causes white spot disease, can be very effective in reducing the risk of shrimp crop failure. Although PCR is now widely used, disease continues to seriously reduce production due to variations in the reliability of screening, compounded by on-farm factors that may result in disease even when seed has been properly screened.

This project built upon previous R&D and training activities of ACIAR, the Network of Aquaculture Centers in Asia Pacific (NACA) and other agencies in Australia, Thailand, India and Indonesia designed to overcome some of the main problems that continue to limit effective shrimp health management in Asia and deliver solutions to farmers. That research, through the work at CSIRO, had developed a kit that enables very low levels of white spot disease infection to be detected.

A major component of the project for Indonesia has been to provide PCR training to scientists and laboratory staff, and to assist harmonisation of PCR through inter-laboratory calibration of testing standards. This component also developed and disseminated guidelines for more effective health management on farms and in hatcheries, drawing on a more precise knowledge of the causal factors and transmission pathways of shrimp disease.

FIS/2002/111: Culture, capture conflicts: sustaining fish production and livelihoods in Indonesian reservoirs

Inland cultured fish production is a growing industry in Indonesia. This takes two main forms: pond culturing and cage culturing. Inland aquaculture makes a significant contribution to the livelihoods of many households, this being a major factor in its rapid expansion. In 1986, the Cirata reservoir held seventy-four 1 m^3 cage units; by 2000 this number was more than 30,000. Expansion has not been without its problems. Poor fishers relying on capturing wild stocks from reservoirs and other inland water sources have been left behind during this expansion.

The Indonesian Government, which has encouraged cage culturing in reservoirs, has not been able to keep pace with the rate of growth. Regulations and data on stocks of wild fish are not yet in place. As cage culturing has expanded, pressures on wild stocks have steadily increased. Recently, this has contributed to a growing number of fish kills, affecting both caged and wild stocks.

Poor fishing families relying on wild stocks have been left without an income source for 4–6 months while stocks regenerate following fish kills. Culture fishers have financial resources and can deal with income losses from fish kills. Poor fishers, without this fallback, often resort to activities such as bamboo harvesting that damage reservoir catchments and ecosystems, possibly increasing the frequency of cycles causing fish kills.

The primary objective is to develop suitable implementation plans that will lead to co-management strategies for sustainable utilisation of the reservoir resources, harmonised development of fish culture and the capture fisheries, and overall environmental integrity.

FIS/2005/028) and FIS/2005/009: Technical capacity building and research support for the reconstruction of tsunami-affected, brackish-water aquaculture ponds in Aceh; and C2004/105: Technical training and capacity building program for the restoration of tsunami-impacted brackish-water aquaculture ponds in Aceh

The 26 December 2004 tsunami caused widespread devastation of tambak-based aquaculture on the western and north-eastern coasts of Aceh, Indonesia. 'Tambak' is the commonly used Indonesian term for brackish-water aquaculture ponds. Over 20,000 ha of tambaks were put out of production by the tsunami. Before the tsunami the local aquaculture industry produced 10,300 tonnes of shrimp and 6,100 tonnes of milkfish annually. The farm-gate value of shrimp is estimated to be US$46.5 million and of fish US$9.6 million. Brackish-water aquaculture accounted for approximately 32% of the total local fishery value. Over 90,000 people were directly employed in the aquaculture industry before the tsunami and most survivors have no alternative source of income.

The primary objective was to provide immediate and longer term technical and research support to the tambak redevelopment activities, with a particular emphasis on building technical capacity.

The two projects have successfully built technical capacity in government agencies, non-government organisations (NGOs) and other donor programs to overcome soil constraints and pond engineering issues, and to develop more effective environmental management strategies for reconstructed ponds. The project operates in parallel with the Aceh Aquaculture Rehabilitation Project (AARP) by delivering joint training workshops and community-based extension activities.

FIS/2005/169: Improving productivity and profitability of smallholder shrimp aquaculture and related agribusiness in Indonesia

Shrimp is the most important export product in Indonesia's fishery sector. About 200,000 ha of brackish-water ponds (40% of the total) are used for growing shrimp in Indonesia. Of these, 75% are farmed extensively (using 'traditional' or 'traditional plus' systems, sometimes in polyculture with milkfish), 15% semi-intensively and 10% intensively. There are 35,000 and 104,000 ha of brackish water ponds, respectively, in the project's two target provinces, Central Java and South Sulawesi. However, much of the South Sulawesi area lies idle in terms of shrimp production.

All levels of government actively promote the three intensification levels of shrimp farming to lift prosperity of coastal communities and to generate foreign exchange. In 2004, Indonesia produced 239,000 tonnes of farmed and wild-caught shrimp, of which 143,000 tonnes were exported—mainly to Japan, the EU and USA. The exports generated over US$1 billion, with farmed shrimp, primarily from intensive operations, contributing 93% of that amount.

Farming at each level can be profitable and sustainable, as long as biosecurity, productivity, environmental and social requirements are properly managed. To remain competitive and to protect export market access, governments and industry supply chains are increasingly recognising the importance of international food safety standards, and of marketing and value-adding as effective competitive strategies.

The project aims to improve productivity and profitability for 'traditional' and 'traditional plus' shrimp producers and associated supply chain micro-to-small enterprises (MSEs) by improving biosecurity and enabling compliance with product quality and food safety standards for export and premium domestic markets.

Specific aims are:

- to improve biosecurity, product quality and food safety through adoption of contextualised better management practice (BMP) programs by smallholder farmer groups and associated MSEs in selected district-based supply chains in Central Java and South Sulawesi
- to facilitate participation in appropriate BMP compliance certification programs by farmer groups and associated MSEs in participating supply chains
- to provide market intelligence to smallholder farmer groups and associated MSEs in participating supply chains
- to provide information on credit access and value-adding processes for farmers, farmer groups and/or associated MSEs in participating supply chains
- to improve extension capacity and health management capacity by training selected extension staff, technicians, diagnosticians and epidemiologists.

4.4 Outputs of the research

4.4.1 New knowledge and technology

The research has produced new information about disease and management for shrimp and aquaculture more generally, as well as rehabilitation strategies for shrimp ponds, with an emphasis on improving soil quality, redesigning for more efficient canal and pond layouts and applying alternative farming practices to manage environmental and economic risks more effectively. Specific outputs that can be listed include the following:

- Remediation techniques and programs for the rehabilitation of shrimp ponds lost to problems arising from ASS. First developed for East Sulawesi, the same general approach has been applied in other areas, including South Sulawesi, East Java, Aceh and Kalimantan.
- Efficient pond engineering practices and pond management protocols to improve water quality and shrimp health.
- An understanding of the underlying causes of white spot disease, relationships with the farm environment (water, soil, infrastructure), the role of BMP in achieving improved performance by farmers (FIS/2000/061) and constraints to adoption (limited technical institutional capacity and resourcing, limited extension capacity and resourcing, limited access to credit/finance by smallholders)
- Improved hatchery management.
- PCR testing.
- Application of GIS and other remote-sensing analysis for effective land-use mapping for Indonesian aquaculture (shrimp and caged fish in estuaries). FIS/2002/076 has delivered land classification systems with accompanying land capability maps for sustainable pond-based aquaculture and, where required, combined land and water classification schemes. The classification scheme uses mapping units that identify land suitability for a range of land- and sea-based aquaculture systems and prescribes important farm management practices to address common environmental limitations. These, in turn, are likely to provide guidelines for district and local planning on matters of location, stocking rates (sea-based aquaculture) and general management. The district and local government agencies responsible for planning welcomed the analysis and maps, and said that they would be used in future land use guidelines. The key underlying objective of FIS/2002/076 is to ensure that problematic soils, and social and environmental constraints, are considered in site selection to prevent further degradation of coastal lands and to improve the productivity of new ventures.

- Immediate and longer term technical and research support to the tambak redevelopment activities within the Centre for Brackishwater Aquaculture Development (CBAD), Ujung Batee, Aceh (FIS/2005/028) and FIS/2005/009), including technical capacity building and research support for the reconstruction of tsunami-affected, brackish-water aquaculture ponds in Aceh. In partnership with the Aceh Aquaculture Rehabilitation Project (AARP), technical expertise has been developed within the district Dinas Perikanan (Bureau of Fisheries) to implement district-level technical extension teams, and to provide direct technical support to NGOs and farmers involved in the reconstruction effort. Train-the-trainer programs have been conducted and, as part of that, a simple BMP checklist manual for farmers to use in rehabilitation of ponds has been published. The activities in Aceh have enabled the transfer of proven technologies to this region as well as quick intervention in the early stages of farm rehabilitation programs, thereby reducing the risk of unsustainable redevelopment of the industry.
- Development of yield prediction models and general guidelines for management arrangements for reservoirs, including agreed institutional responsibilities and stakeholder participation, particularly through local reservoir committees. A significant outcome was realisation by stakeholders of the need for a holistic approach to sustain both the fishing and aquaculture sectors in the long term and to minimise conflicts. In the case-study reservoirs that showed impacts on capture fishing, fish farmers have agreed to relocate cages and have acknowledged the need to reduce the intensity of activities, agreeing to each reduce the stocking rate by 10%.
- Demonstration of the role of thorough analysis in assessing the significance of heavy metals concentration in farmed fish in reservoirs. This issue was affecting marketability and farm-gate prices, particularly at Saguling reservoir. Analyses of farmed fish and feeds were undertaken and the results indicated that the concerns of the public were unfounded. The results were publicised and farm-gate prices and consumer acceptability are reported to have returned to almost original levels.

Much of the research remains in progress.

4.4.2 Capability and capacity building

A major outcome of the projects has been improved capacity within Indonesia for research and extension as well as technical capability to support future research. Train-the-trainer programs have been instigated.

The response in Aceh to the Boxing Day 2004 tsunami provides a major illustration of the gains from the level and nature of the capability that had been developed during the course of the ACIAR projects. The tsunami destroyed or severely damaged more than half of the province's tambaks. A project to build technical capacity and support research for the reconstruction of tsunami-affected tambaks in Aceh has delivered regular technical training workshops covering soil assessment, soil remediation, pond and canal engineering, and pond management.[4] In the context of the devastation of the traditional ponds in Aceh, Indonesian researchers trained through the ACIAR projects, in collaboration with Australian researchers, were able to quickly respond to the situation. For example, the researchers:

- identified ASS and sandy-textured soils as a major constraint to effective restoration of the shrimp ponds on Aceh; other researchers, internationally recognised, had dismissed ASS as an issue simply because the sample depth for soil analysis was too shallow. The ACIAR project has mapped over 470,000 ha of ASS in Aceh and shown that many ponds are constructed in soils that have a high risk of acidification.
- identified the problem of sandy-textured soils and provided technical advice on their assessment, limitations and practices for managing them
- questioned the wisdom of conventional engineering approaches to pond reconstruction that was proceeding on Aceh, driven by external aid and international engineering expertise

---

4 ACIAR and the AusAID-funded Australia–Indonesia Partnership (AIP) are also cooperating on the reconstruction and rehabilitation of the Regional Brackishwater Aquaculture Development Centre at Ujung Batee, a technology development and extension centre for aquaculture in northern Sumatra that suffered extensive damage in the tsunami. This centre is being rebuilt and is expected to be available for training purposes towards mid 2008.

- developed software to assist stakeholders with otherwise complicated calculations required to determine lime requirements, pond and canal dimensions, and hydrological conditions
- drawing on the research experience in South Sulawesi, eventually (after several failed attempts by international engineering groups) gained support for applying BMP for pond reconstruction in an ASS environment by ensuring that the reconstruction of tambaks, dykes and canals followed sound engineering and environmental principles in the context of the Aceh physical environment
- avoided significant damage to pond rehabilitation by challenging recommendations of other agencies about liming practices (rehabilitation requires the application of agricultural lime or dolomite, not slaked or hydrated lime as had been proposed by other agencies)
- developed better management practice manuals and other material for use by shrimp farmers. In this context is has to be remembered that much of the traditional farming and technical expertise on Aceh was lost in the tsunami. Note that most shrimp crop failures are due to interactions between the shrimp, pathogens (usually the virus causing white spot disease) and environmental factors in the pond. It is critical to implement biosecurity procedures at pond, farm and locality levels in concert with environmental issues if crops are to succeed.
- assisted future development by mapping of soils thus identifying land suitable for shrimp farming in the future.

In the absence of the capability that had been developed it is highly probable that the shrimp farm recovery on Aceh would have been delayed and may have totally failed since the underlying problems of shrimp farming in ASS are not well understood outside the ACIAR-funded research.

4.5 Outcomes: evidence of adoption

As noted above, the research outputs have yet to be widely adopted and the focus of this analysis is thus potential adoption and the associated issues of the extent of possible adoption, the factors affecting adoption levels, proposed approaches to facilitate dissemination and adoption, and the time frame and costs involved.

In project FIS/2000/061, programs in East Java were successfully implemented on research clusters of semi-intensive as well as extensive farms in two districts, with an overall success rate (proportion of shrimp clear of white spot disease) of 88% on the farms involved.[5] Project extension staff produced a health management manual and a CD (in Bahasa Indonesia) that is being widely disseminated amongst farmers and extension providers at both existing and new-entrant project sites. Nonetheless, the impact of the research findings has been very limited. Initial interest was significant and the farmers involved were confident of achieving the yield gains of the research sites. Further, one innovative farmer, became a promoter of the BMPs, enlisting and advising over 30 other farmers for a share of their increased income. The lack of widespread adoption has been attributed to the absence of an active dissemination program (passive dissemination is insufficient), unrealistically high expectations of local extension staff (who have no budget and competing priorities), lack of understanding of local community approaches to new ideas and the lack of credit/finance to enable the adoption of BMPs. That said, the lessons learned in terms of adoption issues are being applied in subsequent projects (in particular, FIS/2005/169) in seeking to improve productivity and profitability of smallholder shrimp aquaculture and related agribusiness in Indonesia.

5 By contrast, identical programs implemented in two districts in South Sulawesi produced a failure rate of 90%, this being attributed to an unexpected risk factor, namely the light, sandy soil in the South Sulawesi sites which apparently facilitated disease transmission from infected, non-participating farms to adjacent project farms.

Steering committees are playing an important role. Projects FIS/2002/076 and FIS/2003/027 established a national steering committee to coordinate the dissemination and adoption of the projects' findings. The committee is a high-level working group comprising representatives from government agencies in Indonesia involved in coastal resource management and coastal industry development. Further, a local advisory committee (LAC) for South Sulawesi was established in 2006 to facilitate interaction between the two research project teams and local authorities. The LAC comprises representatives from provincial and regency-based agencies as well as the project leaders from the land-based and sea cage projects. Researcher presentations made to the LAC in the course of this review endorsed the importance of such a committee, especially in terms of gaining acceptance of research findings and their adoption at the local level.

5 Impact assessment: tuna fisheries

Tuna fisheries of the eastern Indian Ocean are fished by commercial and artisanal sectors. Australia and Indonesia are two countries with exclusive economic zones in the area. Indonesia's Indian Ocean tuna catch is highly significant and accounts for 15% of the total catch of tunas by all nations fishing the Indian Ocean. The Indonesian longline fishery is the second biggest catcher of yellowfin and bigeye tunas, after Taiwan and China (IOTC 2006).

Since 2000 both the tuna-fishing industry and the artisanal sectors in Indonesia have reported declining catches for some species. For the longline industry operating in the Indian Ocean this decline has been twofold: in total catch numbers and in the average size of the fish caught. These trends are important indicators of the health of a fishery. The larger the catch numbers and fish sizes the healthier the fishery. Declines in either, and more so in both, indicate fishing is unsustainable and that the collapse of a fishery is likely if the downward trends continue. Of particular concern to fisheries managers in Indonesia and Australia is the impact of the Indian Ocean tuna fisheries on key spawning grounds for tuna species. These waters are known to be the spawning areas for many tuna species and are the only known spawning areas for southern bluefin tuna (SBT) (Figure 4) (ACIAR Summary report FIS/2002/074).

The SBT catch has declined substantially since the mid 1980s and has remained under 20,000 tonnes per annum since that time (Figure 5). The Commission for the Conservation of Southern Bluefin Tuna (CCSBT) was formed in 1994, following a decade of informal management of SBT by Australia, Japan and New Zealand. Its objective is to ensure the conservation and optimal utilisation of the SBT stock. In the decades up to the end of the 1980s, high levels of fishing for SBT caused serious depletion of the adult SBT stock. Scientific studies suggest that stock levels may now be less than 10% of the 1960 level, when substantial fishing had already occurred.

The deteriorating health of the SBT tuna fishery is also evident from the declining size of the fish in the catch and the falling age of the catch (and thus the reduced capacity to breed). As CSIRO researchers point out, relying on a single indicator, such as fish size and catch, may mean that important changes in population distribution or reproduction rates are missed.

The ACIAR tuna projects have aimed at enhancing capacity to monitor, analyse and report on Indonesian tuna fisheries.

5.1 Research undertaken

5.1.1 Agencies and countries involved

The agencies involved were CSIRO Marine and Atmospheric Research in Australia, and the Research Centre for Capture Fisheries and the Directorate General of Capture Fisheries in Indonesia.

5.1.2 Research period

Project FIS/2002/074 commenced in January 2005 and is due to be completed in December 2008.

5.1.3 Previous research on which the work built

The research built on project FIS/2001/079, which was completed in 2003.

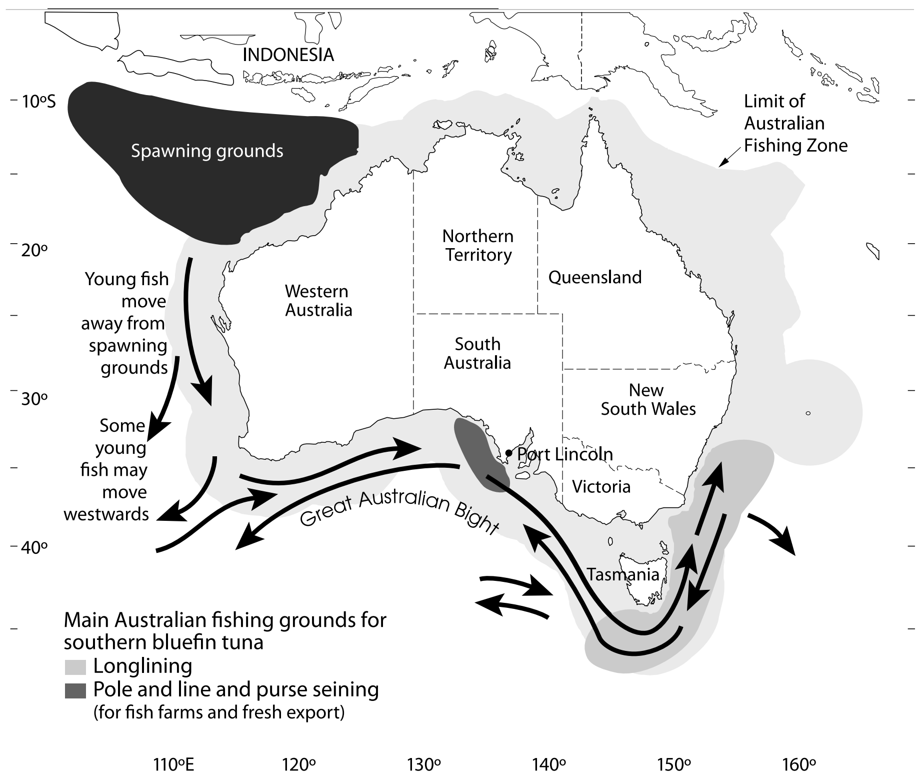


Figure 4. Movement of southern bluefin tuna around the Australian coastline, and associated fishing effort. Source: ABARE (2007, p. 66)

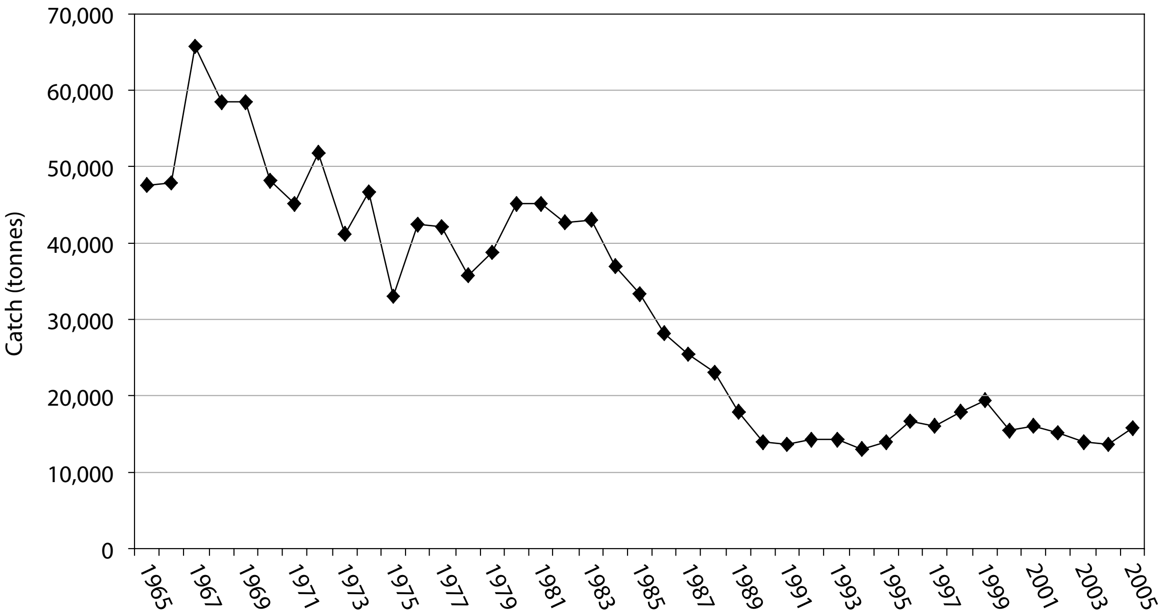


Figure 5. Southern bluefin tuna catches, 1965–2005. Note by the CCSBT: The catch data provided here do not include estimates of past, unreported catches, which may have been substantial. Source: CCSBT at <http://www.ccsbt.org/docs/data.html>

5.2 Expenditure on the research

ACIAR

ACIAR's investment in FIS/2001/079 totalled $208,754 and in FIS/2002/074 $718,548.

Australian Government Department of Agriculture, Fisheries and Forestry (DAFF)

For the past 15 years Australia has directly (in addition to and separate from the ACIAR project) supported the SBT scientific research program. Australia has contributed around $3 million over the past 3 years for research relating to SBT monitoring.[6] Of this, about $150,000 per year is estimated to have been in support of developing capacity in Indonesia to ensure that there are good quality data on the spawning population for the annual stock assessment process. This capacity development has also contributed to Indonesia's CCSBT membership. Current DAFF funding support is likely to terminate in June 2008, and Australia has made the argument to the CCSBT that this activity (monitoring) needs to continue if the CCSBT is to be well informed of SBT stocks (CCSBT 2007). For this analysis, the same level of funding is assumed to continue, although not necessarily sourced from Australia.

Indonesia

To this point, Indonesian investment has primarily been through significant commitments from the Indonesia research agencies in terms of researcher and support staff involvement. This commitment has helped with the project as well as developing capacity within the research agencies. There has been some contribution by industry in terms of facilitating the observer program. However, establishing monetary values for these investments is difficult. For the future, an investment in maintaining the program and the associated databases will be required and the cost of this has been estimated at $0.5 million per annum.

Other nations

Other nations, in particular Japan, have contributed to the Indonesian SBT catch monitoring, although specific investment details are not available. Japan contributes through the Overseas Fisheries Cooperation Foundation. During the 2001–2006 period it contributed to the operating costs of the monitoring programs at Muara Baru (Jakarta) and Cilacap, and provided some funds for the Benoa program.[7]

5.3 Research focus

The objectives of the research were to further improve Indonesia's capacity to independently monitor and assess its tuna and billfish fisheries, and capacity for reporting to international management organisations—critical steps towards the higher goal of achieving capacity for effective management procedures and sustainable fisheries—by:

- improving and extending existing national systems and capabilities for the collection, compilation and analysis of reliable, high quality fisheries data for its Indian Ocean tuna longline fisheries
- conducting a thorough review of Indonesia's tuna fisheries operating in the eastern region, including the Banda Sea and western Pacific Ocean waters
- developing a broader-based capacity within the Ministry of Marine Affairs and Fisheries to analyse and interpret fisheries data, and for Indonesia to ultimately be able to independently produce and report fisheries assessments in line with international requirements for shared fish stocks.

6 DAFF at <http://www.aph.gov.au/Senate/committee/RRAT_CTTE/estimates/bud_0607/daff/13ff.pdf>.

7 Overseas Fisheries Cooperation Foundation at <http://www.ofcf.or.jp/english/3/3-1.html>.

5.4 Outputs of the research: new knowledge and capacity building

Achievements of the project to date have been to establish a trial observer program and, through that, collect better quality data about the catch, operational aspects of the fishing and environmental parameters. In addition, there has been an improved capacity for data interpretation and analysis of specific fisheries.

Trial scientific observer program

The establishment of a trial observer program for the longline vessels operating out of Bali has helped overcome the lack of catch-per-unit-effort information. The trial program commenced in August 2005 after delivery of training to six Indonesian observer trainees and six trainees from Timor Leste.

The establishment of the program has included development of an observer database into which the observers enter their data after return to port and from which they produce their trip reports.

The database is also the primary source of data for analysis by Ms Lilis Sadiyah, a stock assessment trainee and holder of a John Allwright Fellowship awarded by ACIAR.

This project's trial program (which relies on voluntary involvement of industry) is viewed as a solid base on which to build a formal fisheries observer program as proposed by the Directorate General of Capture Fisheries (DGCF), in collaboration with the Research Centre for Capture Fisheries (RCCF), the Directorate General of Marine Fisheries and Resources Surveillance, the Indonesian Tuna Commission and other industry bodies such as Asosiasi Tuna Indonesia and Asosiasi Tuna Longline Indonesia. A key point is that the trial program has established credibility with industry and government.

In terms of capacity building, the trial scientific observer program resulted in skills development for the 12 trainees, with the Indonesian observers having gone on to each complete at least 7 trips to sea of varying lengths over the past 3 years. Future development will focus on the breadth of data collected by observers. Stock assessment capability has been improved with the training of two personnel at RCCF and CSIRO/University of Tasmania, Hobart.

The emphasis of the project is now on further developing the individual skills-base of the observers and on expanding the breadth of information and data collected through the observer program. The success of the trial has enabled the development of a broader, more formal, national fisheries observer program, covering a wider range of vessel types.

Enhancement of stock assessment capacity

The principal achievement is the development of a broader based capacity within Indonesia's Ministry of Marine Affairs and Fisheries (MAFF) to be able to better analyse and interpret fisheries data for stock assessment purposes and to be in a stronger position to report those assessments to international fisheries management agencies and organisations.

The main focus of capacity development has been on further improving the skills and knowledge base of the two stock-assessment trainees at RCCF. One of the trainees has given presentations to high level meetings on the project's trial observer program and the analysis of shark and ray survey results. Both trainees have participated in several meetings linked to ACIAR projects during 2006, have assisted in preparation of presentations and in the organisation and running of these meetings, and have helped RCCF scientific staff to develop the database for the Benoa, Bali, observer program.

Future work will focus on further developing the skills-base within RCCF and DGCF. Most of that focus will be on the project's two stock assessment trainees but will also extend to improving the understanding of all RCCF and DGCF staff on the principles and requirements of effective fisheries stock assessment.

Review of eastern Indonesia tuna fisheries

As part of an overall objective of Indonesia, in collaboration with the Western and Central Pacific Fisheries Commission (WCPFC), to improve the health of tuna stocks in the western Pacific Ocean and to ensure sustainability of tuna fisheries that rely on those stocks, this project was contracted to review tuna fisheries in the eastern sector.

The focus of the review was tuna fishing by pole-and-line, handline, longline, trolling and purse-seine fleets in waters of the western Pacific, close to Papua, and also the waters of the Banda, Maluku, Arafura, Sulawesi, Ceram and Halmahera seas.

The key findings and recommendations were presented to the first eastern Indonesia tuna fishery data collection workshop, held in Jakarta in January 2007 and, more recently, to the second Indonesia and Philippines data collection project workshop for eastern Indonesia in May 2008. These findings provided the baseline information necessary for decisions on which ports were the most appropriate for initial implementation of the monitoring and for the trial of newly developed sampling protocols. The review outcomes were used by DGCF and RCCF to secure funding from the WCPFC, and it is anticipated that funding for longer term monitoring will be secured from the Global Environment Facility as a result of this work.

Linked to the above, the ACIAR project has also been active in assisting the Agency for Marine and Fisheries Research in its plans to establish, at Bitung, a centre for tuna fisheries research and monitoring for the fisheries that operate in the Sulawesi, Seram and Banda seas and adjacent western Pacific Ocean waters. The centre will be modelled to a large degree on the existing station at Benoa, a product of the previous ACIAR tuna fisheries project (FIS/2001/079).

In a broader sense, the ACIAR project has been successful in strengthening Indonesia's participation in the overall management of western Pacific Ocean pelagic fisheries. Although Indonesia has yet to achieve status as a full member of WCPFC, meetings aligned to the project have afforded an opportunity for Indonesia to have an important role as a cooperating non-member, and to work hopefully towards becoming a full member during 2008. A meeting of the Steering Committee for Monitoring and Assessment of Indonesia's Tuna Fisheries, held in Jakarta on 27–28 May 2008), brought together participants from the Indian Ocean Tuna Commission (IOTC) and WCPFC (i.e. 'east' meets 'west') to discuss a coordinated approach to common issues with respect to the Indonesia's pelagic fisheries across both ocean areas. The expansion of the meeting beyond its previous focus on only the Indian Ocean was an initiative of the ACIAR project and was funded by it.

Summary for the purposes of assessing the impact of the project

The ACIAR support has to be seen in the context of Indonesian membership of the CCSBT, which it joined in April 2008. Indonesia had commenced applying a system of fisheries management control from 2004 by introducing a catch monitoring program. To improve its own management information systems, particularly on statistical data collection, Indonesia has been collaborating with IOTC/Overseas Fisheries Cooperation Foundation (OFCF) as well as with the Australian Government through ACIAR, CSIRO and DAFF. More generally, the ACIAR project aimed at providing Indonesia with the improved capacity to meet its reporting requirements to the CCSBT and other regional fisheries management organisations, including the IOTC and WCPFC.

In summary, the ACIAR-supported research has led to a better understanding of the tuna fisheries.

- Systems have been developed to better monitor the Indonesian catch. Monitoring the Indonesian SBT catch is important because the catch is taken from SBT spawning grounds. This importance is recognised by the CCSBT. At its 13th meeting the CCSBT discussed the importance of continued monitoring of the Indonesian catch of SBT, especially in light of the unreliability of other data series (CCSBT 2006). The funding of the monitoring program by Australia provides an important, continuous data series on catch and landings from the port of Benoa.
- Skills have been developed to maintain the monitoring and help expand that capacity under a formal (regulated) observer program.
- Catch data are being analysed in more detail, with the result that more reliable estimates of catch can be provided for the purposes of biomass modelling and subsequent fisheries management.
- Analysis has been incorporated into the fisheries modelling undertaken for the CCSBT. That analysis has been undertaken primarily by CSIRO.
- SBT fishery management has potentially been improved with consequential implications for the level and value of the catch within and beyond Indonesia.

Furthermore, the monitoring program has enabled Indonesia to meet its reporting requirements to the IOTC and WCPFC.

In summary, it seems fair to draw the following conclusions:

- The objective of the primary level of cooperation has been achieved; that is, the scientific understanding to enable the CCSBT in particular to move further toward achieving its aim.
- The secondary level of cooperation—active management of the resources—is in the process of being achieved within Indonesia. This requires allocation of harvest shares between fishing interests within Indonesia, determination of optimal resource management programs through time, and the effective implementation and enforcement of cooperative arrangements. However, achieving this cooperation is complicated by the institutional structure—national, regional and local government—and more particularly by the transition of fisheries management responsibilities under the localisation policies of the Indonesian Government.

5.5 Impact assessment

The aim of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) is to

> …ensure, through appropriate management, the conservation and optimum utilization of SBT.

This has been interpreted in various ways. For the purposes of this impact analysis the most appropriate interpretation is that which reflects an economic welfare framework (producer and consumer surplus). A paper by Campbell et al. (2002) examined the concepts of conservation and optimal utilisation within such a standard welfare economics framework. Optimal utilisation was interpreted as maximising the use values of the fishery, measured in terms of the present values of the net economic welfare benefits generated, where these benefits were defined as the sum of the change in producer profits and change in consumer surplus (for all interests along the value chain).

The incentive for Indonesia to join the CCSBT requires an understanding of the origins of the CCSBT and the implications for Indonesia since, ordinarily, it is not clear why a country (such as Indonesia) would look to restrict its catch for the seeming benefit of other countries. These important issues are discussed below.

CCSBT (http://www.ccsbt.org/) is a regional governance organisation for international fishing within the meaning of the 1982 Law of the Sea Convention and the related 1995 Straddling Migratory Stocks Agreement. The CCSBT is responsible for southern bluefin tuna fishing in the Pacific Ocean surrounding South-East Asia, including marine areas around Indonesia. The CCSBT was formed by Japan, Australia and New Zealand in the early 1990s. Its original membership omitted, as well as Indonesia, nations such as Korea and Taiwan that are major fishers of these waters.

The challenge for the SBT fishery is twofold.

- The fishery cannot be realistically managed unless all parties landing the fish provide reliable statistical information on the catch. SBT fishing stocks have already crashed (in the early 1970s and further in the late 1980s). No country, including Indonesia, will profit if the stocks again crash due to over-fishing.
- As the vast majority (>95%) of the world SBT catch is of sub-adult fish, without the monitoring of Indonesia's catch, the CCSBT would have no reliable information on the size and age composition of the SBT spawning stock against which to gauge the impact of current and future management measures on the spawning stock composition.

There are problems beyond fisheries management with non-membership in the CCSBT. The success of the CCSBT hinges on regulating enough of the fishery to provide effective long-term management. Inclusion of Indonesia is doubly important since its waters comprise the SBT spawning grounds and it exploits the fishery. As the responsible international regional organisation for managing the fishery, CCSBT sets fishing quotas. The original quotas were established for members. Non-members can fish normally but potentially have trouble selling their catch internationally (because Japan as the chief SBT market could determine, legally, to exclude that source of supply under trade law). Thus, Indonesia might be able to consume domestically the tuna it catches outside the quota, but faces potential export restrictions, legal under World Trade Organization rules, if it wished to sell its catch in Japan as the chief market.

Membership of the CCSBT carries obligations. These include agreeing to catch limits and applying fisheries management strategies to limit the catch to those limits.

Indonesia has been allocated 750 tonnes for 2007–09 (Table 1). There is a limited official total catch recorded for Indonesia but it is generally concluded that, on average, the Indonesian catch has been around a 1,750 tonnes per annum.

The prospective gains to Indonesia from joining the CCSBT accrue in terms of the following:

- Of direct benefit to Indonesia is a sustainable level of catch in the medium to longer term (a higher catch than would otherwise have been the case). However, to the extent that Indonesia's quota allocation is less than the catch might otherwise have been (in those years) there is also a short term cost to joining the CCSBT.
- There is continued capacity to sell SBT to Japan, a higher value market than other market options, including domestic sale, and the avoidance of seemingly justified trade restrictions in the absence of joining the CCSBT.
- A final issue is whether there are other aspects of conserving the SBT stocks as, for example, implications for other fisheries that would be impacted if the SBT fishery collapsed, specifically the resource impacts through changes in feed for other fish or as a result of greater exploitation of those fisheries to meet village subsistence or income needs. There may also be a loss in biodiversity values.

Further, there are indirect benefits under other agreements and international support since longer term sustainability of the SBT fishery increases producer returns in other countries, including Australia, from both growing-out fish (catch from the Australian SBT purse seine sector is transferred to farms off Port Lincoln)[8] and catching SBT for sale direct to market.

It is relevant to note that Japan and Australia in particular have strongly encouraged Indonesia to join the CCSBT and have backed this endeavour with both direct support (through ACIAR and other technical assistance and funding) to meet the conditions of membership and support under other agreements.

Catch monitoring is *the* critical element in effective fisheries management and this is especially important in the context of a fishery exploiting a migratory species such as SBT. However, other members of the CCSBT must have confidence in the catch monitoring system and the subsequent stock modelling. ACIAR funding through CSIRO and the associated capacity building in Indonesia have been important, if not crucial, in that regard.

In the absence of Australian support, both from ACIAR and DAFF, it appears that other nations would not have supported the catch monitoring work. Australian officials report a continuing reluctance by Japan and others to support the monitoring work in Indonesia.

It seems reasonable to conclude that, without the Australian support and carriage of the work, Indonesia would not have attained membership.

Table 1. Commission for the Conservation of Southern Bluefin Tuna (CCSBT) quota allocations (tonnes), 2007–09

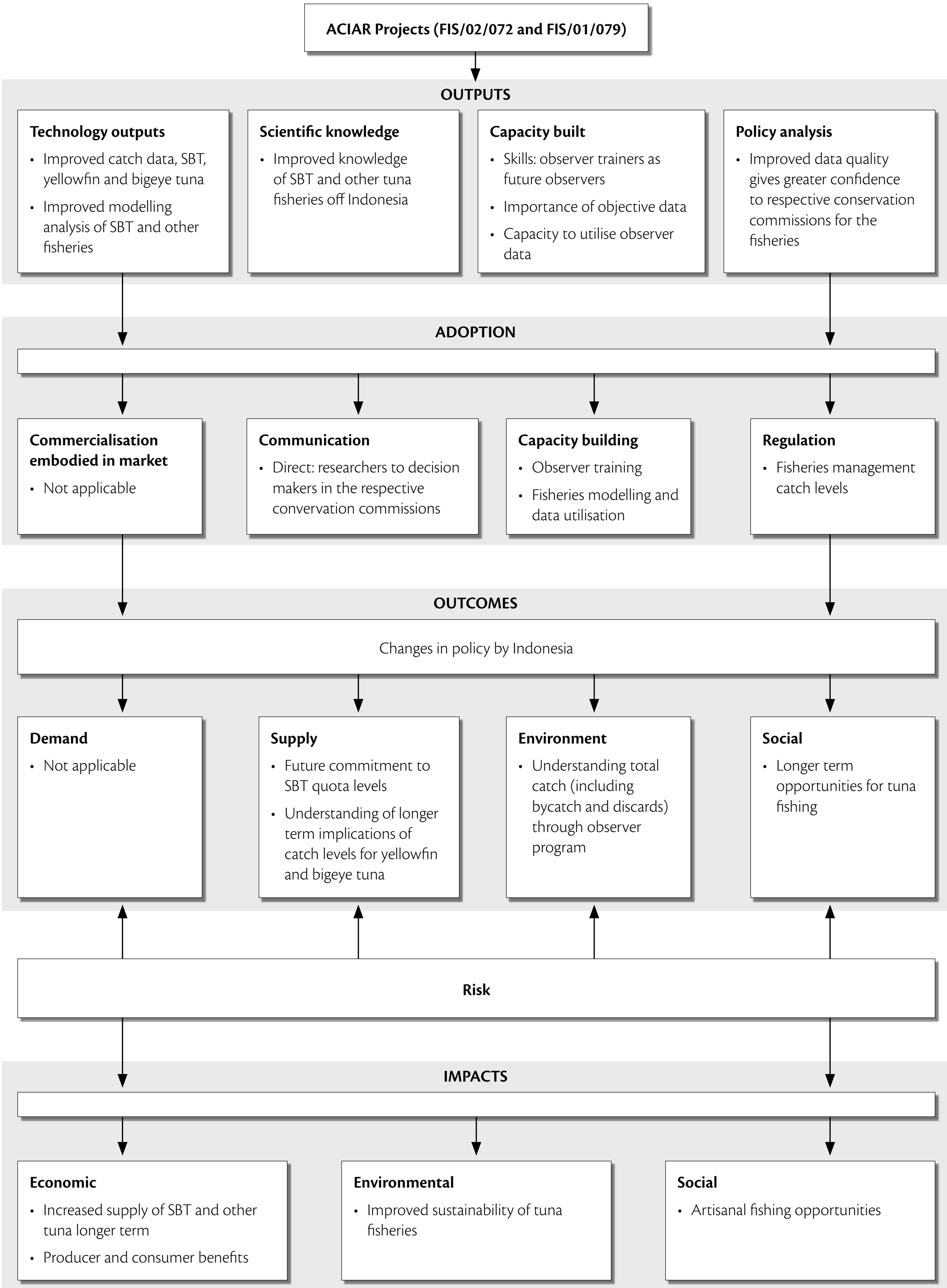
Country	Quota
Australia	5,265
Japan	3,000
Republic of Korea	1,140
Fishing entity of Taiwan	1,140
New Zealand	420
Cooperating non-members and observers	
Indonesia	750
Philippines	45
South Africa	40
European Union	1
Total	*11,801*

Note: The CCSBT usually sets the global total allocated catch (TAC) annually, and the quotas are then allocated among member countries and non-members countries and observers. Following the release of a report by an independent international panel, which suggests southern bluefin tuna catches may have been substantially under-reported over the past 10–20 years, the CCSBT has reduced the annual TAC for the fishery for 2007–09 by 3,115 tonnes to 11,801 tonnes. This major reduction has been in the quota allocated to Japan.

Source: CCSBT

8 Most of Australia's SBT quota is caught for subsequent farming.

5.6 Assessment framework



5.6.1 Costs

These are the costs of developing and applying the improved catch and associated information to management of SBT in Indonesian waters, as follows:

- ACIAR R&D project costs
- other Australian costs in support of Indonesian SBT monitoring, estimated at $150,000 for the past 3 years, with this level of funding continuing in the future, but funded by the CCSBT
- R&D project and continuance of the observer program costs incurred by the Indonesian parties, principally in kind, estimated at $75,000 per annum
- investment by Japan through the Overseas Fisheries Cooperation Foundation, estimated to be around $150,000, assuming that this continues into the future.

5.6.2 Benefits

Economic welfare gains: producer and consumer surplus

The ACIAR investment has contributed to Indonesia being better able to monitor its tuna fishing and provide higher quality catch and other data relevant to modelling the tuna fisheries. With more reliable modelling of the tuna fisheries, management and sustainability of the fisheries can be improved. These outcomes are probable for all three fisheries—SBT, the Indian Ocean tuna fisheries and the western and central Pacific Ocean tuna fisheries. For the respective fishing industries, fishing costs will be lower (per unit of catch) since there will be more fish to catch in the future. For tuna consumers, more fish are supplied to the market than otherwise and prices are lower. The respective gains to producers (producer surplus) and consumers (consumer surplus) are shown in Figure 6.

Estimating the gains in economic welfare is complicated by the biological aspects of fisheries, especially recruitment and subsequent population changes. A proper analysis thus requires an integrated bioeconomic approach. Campbell and Kennedy (2007) have developed a bioeconomic model for the SBT fishery and results from that model have been used to estimate the contribution that the ACIAR investment might be expected to have upon the economic welfare of SBT fishers and tuna consumers.

The analysis by Campbell and Kennedy suggests significant economic gains from the quota arrangements under the CCSBT, relative to no harvesting (see Box 1). While the authors modelled other scenarios, the key issue is the likely economic gain if Indonesia remained outside of the CCSBT and continued to fish at historical levels. If it did, and continued to fish at these levels on an open-access basis, the total catch for all nations would then be about 8% more than the CCSBT quota level. Indonesia would lose its producer surplus, and the losses to the other fishing and consumer interests could be argued to be about 8% less than with full membership of the CCSBT.

However, Indonesia is much more important because, historically, Indonesia fishers have fished in the SBT spawning ground. CSIRO researchers say that the SBT has no other known spawning ground outside of Indonesia waters. Australia and the other CCSBT members have sought for many years to encourage Indonesia to become a member.

The gains from reduced Indonesian fishing are thus much more important than implied by the reduction in tonnage of fish. Without improved knowledge of the fishery and associated management through the CCSBT, it is possible that the fishery would collapse. Thus, the benefit of Indonesian membership (and its reduced fishing effort) could be responsible for a significant proportion of the benefits generated by the CCSBT quota management arrangements.

For this analysis the key issue is the extent to which the ACIAR work has enabled full membership of the CCSBT and thus the subsequent gains to fishers and consumers of a more sustainable SBT fishery. Before the ACIAR (and other) involvement, Indonesia was being strongly encouraged to join the CCSBT and thus commit to the commission's objectives. It had been admitted as an associate member which, in part, meant that Indonesia committed to reducing its catch and implementing a catch monitoring system with its costs met by other CCSBT members. Thus, Indonesia had an established port-based catch monitoring system. However, this had a number of limitations, especially given the large number of ports that could potentially be used to land fish. The trial observer program established with the ACIAR funding has enabled Indonesia to become a member (since a more rigorous catch monitoring system was established).

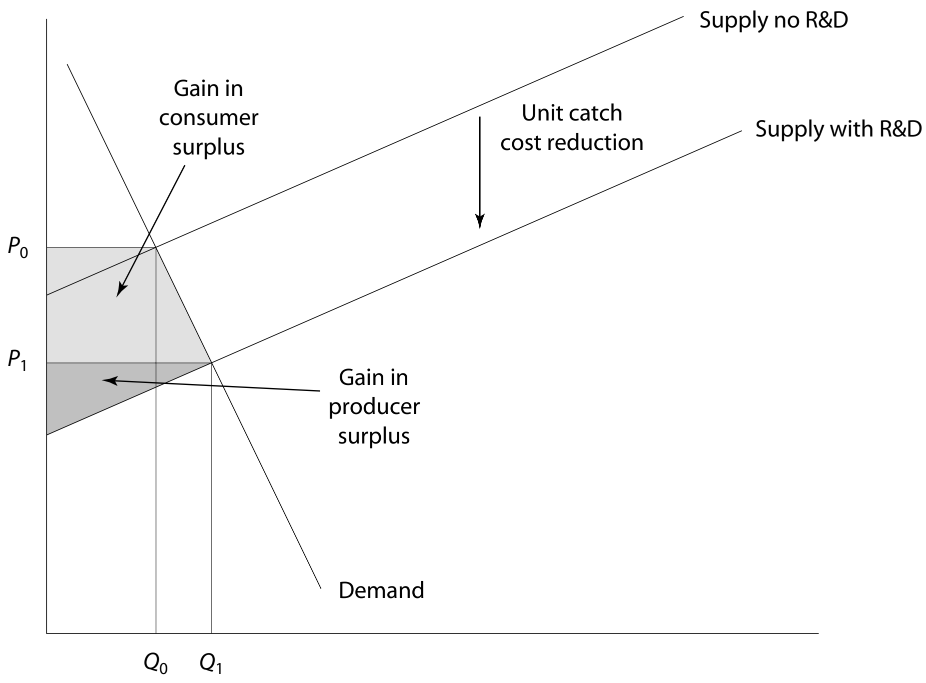


Figure 6. Gains in economic welfare from research and development on southern bluefin tuna (world market)

Thus a significant proportion of the benefits of Indonesia's membership of the CCSBT can be attributed to the ACIAR investment in developing the trial observer program and establishing a scientific modelling base through CSIRO involvement. In the absence of ACIAR funding, Indonesia or others would have had to fund the investment. This may have eventuated, albeit somewhat later. The key nature of the ACIAR-funded investment suggests that at least a quarter of the gain from CCSBT quota arrangements can be attributed to the ACIAR investment and to other investment associated with enhancing the quality of data and analysis of Indonesian SBT catch.

If this were the case the benefits from Indonesian membership of the CCSBT and associated better management of the SBT fishery would total around $1,140 million in present value terms, assuming that Indonesia was able to profit from higher prices as a result of reducing its catch (Table 2). These benefits are assumed to be highly likely to accrue given the recently established membership of Indonesia.

Most of this gain ($924 million) accrues to Japanese, Korean and Taiwanese consumers since the reduced catch (the aim of the quota arrangements) ensures a longer term supply of SBT to the benefit of these consumers who place a high value on SBT. However, other nations, including Australia, also benefit. The profit gain to Australian and New Zealand fishers is estimated at $30 million, with another $170 million to Japanese, Korean and Taiwanese fishers. The benefit to Indonesia, in terms of producer surplus accruing to Indonesia fishers, is estimated at close to $10 million, as Indonesia is the predominant fishing interest among the other nations fishing the stock.

5.6.3 The investment return

The ACIAR investment (which represents around 15% of the total investment—recognising that achieving the benefits will require continued extensive R&D and fisheries modelling by the CCSBT and Indonesia) is calculated to deliver potential benefits totalling $168 million in present value terms, since the benefits are still to accrue (Table 3).[9] This yields a benefit:cost ratio of 180 and an internal rate of return of 210% (Table 4).

[9] In the absence of detailed year-to-year expected benefits, the temporal flow of benefits has been assumed to equal an annuity delivering the same present value.

Box 1. The bioeconomic model of Campbell and Kennedy (2007): assumptions and findings based on Commission for the Conservation of Southern Bluefin Tuna quota levels for 2005–06

The key assumptions in the Campbell and Kennedy bioeconomic model are:

- The three fishing groupings which cover the interests and characteristics of the stakeholders in the SBT fishery are: ANZ (Australia and New Zealand); JKT (Japan, Korea and Taiwan) and IPSA (Indonesia, The Philippines and South Africa).

  For simplicity it is assumed that each group continues to fish in its current grounds and to sell its catch in the Japanese market: the latter assumption implying no consumer impacts outside of Japan.
- Fishing costs are set at a fixed fraction of the market price.
- Each fleet's catch may attract a different market price per unit of weight because of differences in the size of fish or other perceived quality differences.
- Own price elasticities of demand are 1 (given the absence of information about responses in market prices); i.e. a 1% rise in price leads to a 1% fall in demand.

Summary results of the Campbell and Kennedy analysis, noting that additional model runs were reported by the authors but are not reported here.

CCSBT quotas. With all parties, members and non-members, observing the CCSBT quotas and assumptions of low levels of recruitment, the fishery does not generate catches to the quota level. At the more optimistic stock recruitment (h = 0.8), the 20-year stock was estimated at just 29,400 tonnes. The conservation aim is not met. The economic outcomes (producer surplus and consumer surplus, compared with no harvesting) were reported as follows (converted to real 2007 values). The total benefit was estimated at $4.5 billion (net present value (NPV) over 20 years, 5% discount rate) with most of the benefit accruing to Japanese consumers, since without quotas the fishery would crash and there would be very little supply. The Campbell and Kennedy analysis showed that if fishing by those outside of the CCSBT continued to harvest on an open-access basis the fishery would likely collapse as the breeding rate would be substantially reduced.

ANZ	IPSA	JKT			NPV ($m)
Producer surplus (PS) ($m)	PS ($m)	PS ($m)	Consumer surplus (CS) ($m)	Total ($m)	
120	40	680	3,696	4,376	4,550

Table 2. Gains from Indonesian membership of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) ($m, net present value (NPV) 20 years[a])

		Australia, New Zealand[c]	Indonesia, Philippines, South Africa	Japan, Korea and Taiwan			Total
		Producer surplus (PS)	PS	PS	Consumer surplus	Total	
All parties observe CCSBT quotas		120	40	680	3,696	4,376	4,550
Gain from Indonesian membership[b]	25%	30	10	170	924	1,094	1,137

a NPV is calculated at a 5% discount rate.

b This is the proportion of benefits resulting from Indonesian membership of the CCSBT (assuming that, in the absence of Indonesia, the quota arrangements would be ineffective in sustaining the fishery) that has been attributed to the ACIAR and other investment in developing better catch monitoring and maintaining that monitoring into the future.

c This estimate of the ANZ producer surplus may be conservative. It is reported that the permanent transfer of this quota is valued at around $100/kg. Based on the ANZ quota of 5,685, the quota value would then total $570 million. As ABARE (2007) notes, however, the value a holder places on a unit of quota is related to the holder's perception of the current and future profits of the fishery. This makes quota values an important indicator of the profitability of a fishery. For a seasonal lease in 2004–05, estimates of the price of SBT quota were over $10 a kilogram. For a permanent transfer, which is permitted, estimates are above $100 a kilogram.

5.6.4 Sensitivity

The estimated economic benefit of the ACIAR investment relies heavily on the quantitative assessment of the gains from Indonesian membership of the CCSBT (and the contribution to more sustainable management of the SBT fishery) and the importance of the ACIAR investment in helping achieve Indonesian membership.

The values used in the above assessment are likely to be at an upper level in terms of the gains from Indonesian membership (since some gains would have accrued from continuing associate membership). However, they are more likely to be conservative in terms of the importance of ACIAR's investment (since the value of a credible scientific catch monitoring system is likely to be more evident in time rather than at the start).

If the gains from Indonesian full membership are about $2,200 million (about half rather than the quarter estimated above) and the ACIAR investment is credited with contributing 15% of that gain the total benefits from the ACIAR investment would still be of the order of $336 million in present value terms.

5.7 Benefit flows (economic, environmental and social)

Aside from the direct economic benefit to Indonesia from becoming a member of the CCSBT, there are three other groups of benefits.

- There are broader ecological benefits, for example for other fish species, through improving the SBT stock levels. However, it is difficult to be definite about the effect.
- Relations with Australia are further improved, since the SBT fishery is important to the Australian fishing industry. Reliable stock assessments are essential for predicting future recruitment to the populations and, in turn, for predicting the future resources available to the Australian SBT industry (primarily tuna farming). Most SBT now harvested in Australian waters is used as an input into SBT farming in South Australia, with the gross value of SBT aquaculture production in South Australia totalling $156 million in 2005–06.

Table 3. Time profile of cost and benefit flows from ACIAR's and other investments in Indonesian tuna fisheries

	ACIAR investment			DAFF[a]	Indonesia	Japan	Other (CCSBT[b])	Total nominal	CPI	Total real costs	Benefits	Net benefits (IRR)
	FIS/2001/079	FIS/2002/074	Total									207%
2002	82,582		82,582					82,582	1.15	94,777	–	–94,777
2003	111,124		111,124					111,124	1.12	124,587	–	–124,587
2004			–					–	1.09	–	–	–
2005	15,048	179,637	194,685	150,000	75,000	150,000		569,685	1.06	605,621	–	–605,621
2006		179,637	179,637	150,000	75,000	150,000		554,637	1.03	571,044	–	–571,044
2007		179,637	179,637	150,000	75,000	150,000		554,637	1.00	554,637	–	–554,637
2008		179,637	179,637		75,000	150,000	150,000	554,637	1	554,637	94,112,279	93,557,642
2009					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2010					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2011					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2012					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2013					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2014					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2015					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2016					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2017					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2018					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2019					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2020					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279

Table 3. (continued)

	ACIAR investment			DAFF[a]	Indonesia	Japan	Other (CCSBT[b])	Total nominal	CPI	Total real costs	Benefits	Net benefits (IRR)
	FIS/2001/079	FIS/2002/074	Total									207%
2021					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2022					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2023					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2024					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2025					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
2026					75,000	150,000	150,000	375,000	1	375,000	94,112,279	93,737,279
NPV	192,441	636,984	742,073	408,487	987,225	1,974,450	1,812,798	5,006,084		5,072,330	1,137,377,083	1,131,027,559

a Department of Agriculture, Fisheries and Forestry, Australia
b Commission for the Conservation of Southern Bluefin Tuna

Table 4. Summary of returns on ACIAR's and other investments in tuna fisheries in Indonesia

	All R&D investment			ACIAR investment
Present value (PV) of benefits ($m)	1,137		PV of benefits ($m)	169
PV of costs ($m)	6		PV of costs ($m)	1
Net benefits ($m)	1,100		Net benefits ($m)	168
Benefit:cost ratio (BCR)	179		BCR	179
Internal rate of return (IRR) (%)	210		IRR	210

- There are social benefits for Indonesian fishing communities. In the absence of joining the CCSBT it is probable that Indonesian SBT fishing would have continued, with local sales of SBT. CCSBT membership (and the lead into membership) has meant higher SBT prices than otherwise and higher incomes for the Indonesian fleet. Both commercial (longline) and artisanal (smallholders) fishers work within the Indonesian exclusive economic zone and it is expected that both sectors will benefit from the actions of the CCSBT.

The project has, in addition, developed a better understanding of other tuna species. Following a review of tuna fisheries in eastern Indonesia, the report on which is forthcoming, some of that focus is now towards assisting Indonesia to establish monitoring programs for all gear types (both industrial and artisanal) catching tuna in the Indian and western Pacific Oceans and other waters in the eastern sector. The results of the monitoring, combined with all other available information, suggest that Indonesia's longline fisheries are in an 'unhealthy state'. Catches of the key target species (yellowfin and bigeye, as well as SBT) have continued to decline over many years. The potential benefits for better understanding, and subsequent better management of these other species for ecological and economic benefit, have not been quantified in this analysis.

5.8 Lessons

Management of fisheries requires reliable, credible, catch monitoring data. Developing the dataset takes time. The observer program, data collection systems and fisheries modelling developed during the project have enabled Indonesia to be accepted as a member of the CCSBT since the observer program had been developed jointly with CSIRO Australia. In the absence of an agency with acknowledged expertise and experience in the field, the observer program would have had little credibility.

6 Impact assessment: remediation of extensive shrimp farms (tambaks)

6.1 Context of the research

The initial ACIAR project (FIS/1997/022, *Remediation and management of degraded earthen shrimp ponds in Indonesia and Australia*) focused on techniques for remediation of degraded shrimp ponds. Subsequent projects have extended the research findings in three directions: first, a focus on land capability assessment and suitability for activities such as shrimp farming (FIS/2002/76); second, an extended investment in disease control programs and better on-farm management practices (initially FIS/1997/125 and subsequently FIS/2000/61 and FIS/2005/169); and finally, capacity building, especially in Aceh following the 2004 tsunami (FIS/2005/028 and later FIS/2006/02 and FIS/2005/09). These later projects are still current.

The principal focus of this analysis is FIS/1997/022 since the work in that project has been completed and the results are potentially benefiting farm-level production and policy at the national level. However, the other ACIAR projects noted above have also contributed to these and other outcomes.

Details of the investments by ACIAR and other agencies in these projects are given in Table 5.

Figure 7 gives an overview of the project outputs, outcomes and impacts.

6.2 Project details

Project FIS/1997/022: *Remediation and management of degraded earthen shrimp ponds in Indonesia and Australia*

Collaborating countries: Indonesia

Commissioned organisation: University of New South Wales, Australia

Project leader: Dr Jesmond Sammut

Collaborating institutions:

- Australian National University
- Research Institute for Coastal Fisheries, Indonesia
- University of Western Sydney, Australia
- Research Institute for Coastal Fisheries, Indonesia
- University of Hassanudin, Indonesia
- NSW Department of Primary Industries, Australia
- Assessment Institute for Agricultural Technology, Indonesia
- Central Research Institute for Fisheries, Indonesia

Project duration: 01/07/1998–30/06/2001

Project extension: 01/07/2001–30/06/2005

- ACIAR research program manager: Mr Barney Smith

Table 5. Research and development investments ($) in shrimp farming research projects in Indonesia: 1989–99 to 2010–11

		ACIAR budget	Australian agencies	Indonesian partners
FIS/1997/022	Remediation and management of degraded earthen shrimp ponds in Indonesia and Australia	851,129	1,207,200	464,100
FIS/1997/125	Integrated disease control programs for prawn farms in Indonesia and Australia: a pilot study	190,982	221,556	20,920
FIS/2000/061[a]	Development and delivery of practical disease control programs for small-scale shrimp farmers in Indonesia, Thailand and Australia	557,101	666,194	47,921
FIS/2002/076	Land capability assessment and classification for sustainable pond-based aquaculture systems	767,063	410,994	117,884
FIS/2005/169	Improving productivity and profitability of smallholder shrimp aquaculture and related agribusiness in Indonesia	1,046,590	1,046,590	319,012
FIS/2006/144[b]	Strengthening regional mechanisms to maximise benefits to smallholder shrimp farmer groups adopting better management practices (BMP)	19,298	–	–
Total[c]		3,432,163	3,552,534	969,837

[a] Indonesian share of total 50%

[b] Indonesian share of total 25%

[c] Total equals sum of budget allocations, not adjusted for year of payment

Source: ACIAR project records

6.2.1 Background

Acid sulfate soils (ASS) are pyrite-bearing sediments that cause moderate to severe soil acidification when excavated or drained. ASS commonly occur in coastal lowlands and are often responsible for low yields from shrimp ponds and recurrent total crop failure in the Asia–Pacific region and parts of Africa and South America. In Indonesia more than 80% of extensive farming systems have been developed in ASS, leading to significant economic losses and environmental degradation. Accelerated soil erosion and subsequent increases in sediment accumulation rates also degrade shrimp ponds. Accumulated sediments pollute the pond environment, increase farm management costs and may cause high sediment loads in farm discharge waters.

Past studies on sediment management in shrimp farming have focused on pond bottom management and have ignored the physical and chemical properties of dyke soils. Similarly, soil properties and chemical processes have been poorly described or not appropriately considered in site selection criteria, remediation strategies or in the assessment of pond productivity problems. In ASS-affected ponds, iron, aluminium and low pH cause mortality and poor growth rates in shrimp, reduce available phosphorus and beneficial algal blooms, and degrade the quality of shrimp. Accumulated sediments may contain appreciable concentrations of metals weathered and/or eroded from the pond walls or liberated from within the dyke as a result of strongly acidic conditions. Standard pond preparation and management strategies do not adequately deal with soil acidification and erosion, leading to lower yields and, in the case of ASS-affected ponds, high abandonment rates.

The present study developed low-cost methods to control soil processes to reduce soil acidification, metal contamination, erosion and subsequent sedimentation. Remediation and management strategies were underpinned by fundamental research on soil–water processes in dyke and pond bottom materials. Field and laboratory studies described soil and water interactions that affect pond water quality and shrimp health.

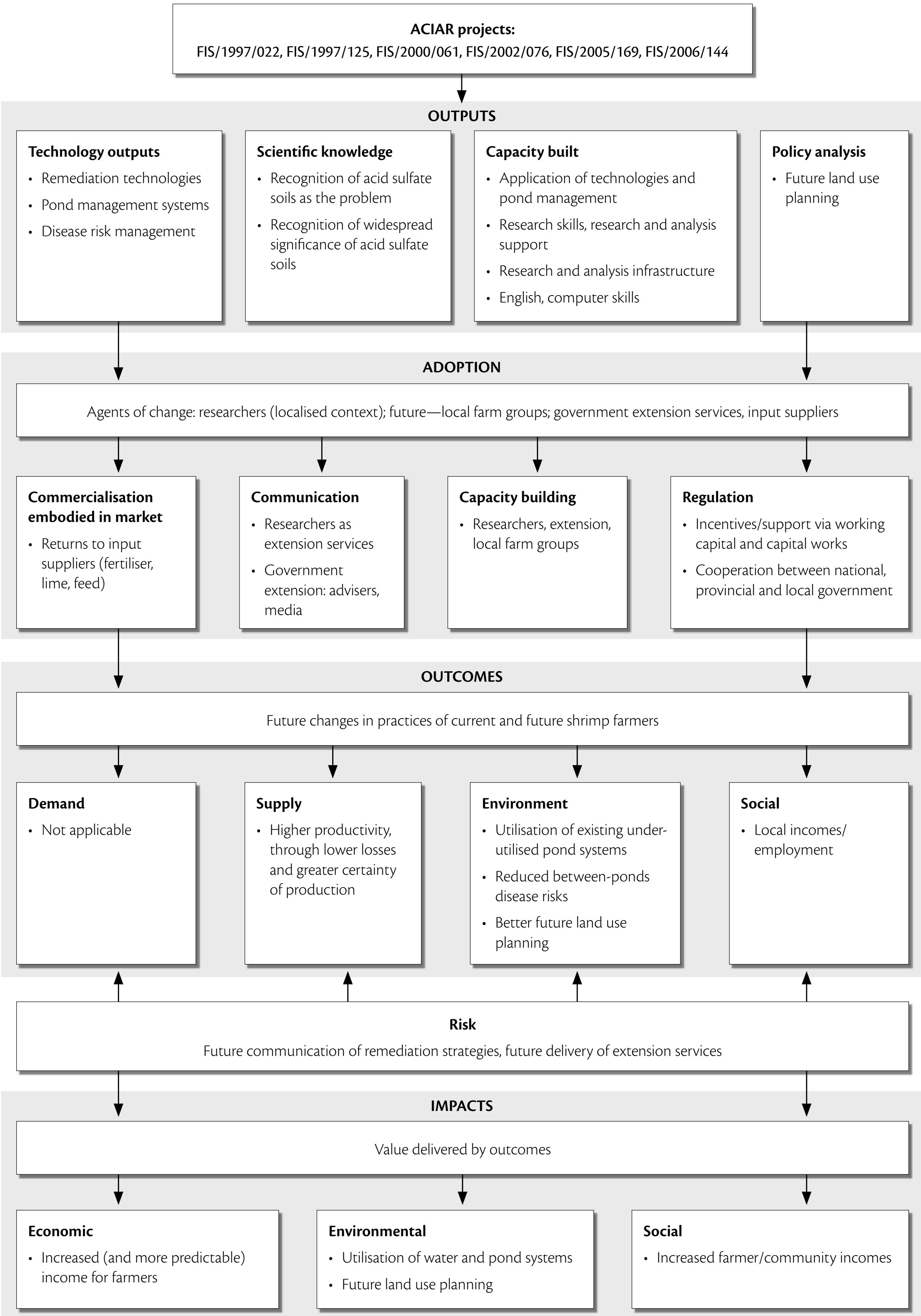


Figure 7. Tambak remediation and shrimp farming in Indonesia: results frame chart

Field experiments were used to improve and manage soil quality, reduce contamination of pond waters by metals and eroded materials, and to stabilise dykes. The project also developed site selection criteria and models for coastal mapping and land capability assessment to facilitate coastal planning and environmental decision-making in the shrimp farming industry.

The overall objective of this project was to develop low-cost technology to remediate and manage ponds affected by ASS, soil erosion and sediment accumulation in Indonesia and Australia. The specific objectives included to:

- develop and assess cost-effective, low technology methods of treating and managing soil acidification associated with disturbance of ASS
- assess methods of ameliorating and conserving erodible soils on pond walls, pond bottoms and effluent canals using low-cost technology, settlement ponds and vegetation
- model iron accumulation in pond bottom sediments and develop management strategies to minimise iron leaching and deposition in intensive ponds
- undertake training of collaborating researchers and to extend findings of the project to farmers in Australia and Indonesia.

6.2.2 Achievements

Soil remediation and management

The project has developed low-cost technology to remediate and manage ASS in extensive (tambak) shrimp production systems. The strategies include more efficient liming based on different liming materials and application methods, improved pond bottom and dyke preparation, restoration of problematic dykes, improved water management and more efficient fertiliser application.

Yields have been dramatically improved in ponds that were once low yielding or abandoned (Table 6). Shrimp[10] growth rates, colour, shell condition and overall quality have also been improved as a result of the modified pond management strategies. In the experimentation sites the remediation of pond bottom soil resulted in a doubling of shrimp survival, a 290% increase in production and better feed-conversion ratios.

10 The main species farmed are white shrimp (*Litopenaeus vannamei*) and black tiger shrimp (*Penaeus monodon*). For convenience the latter is referred to as tiger shrimp in this report. These crustaceans are usually referred to as prawns in Australia.

Table 6. Production of tiger shrimp (*Penaeus monodon*) in farm experimental ponds in Luwu Regency, South Sulawesi

Variables	Remediation of bottom soil	
	Without	With
Stocking density (pieces/m^2)	8	8
Initial weight (g/piece)	0.08	0.08
Final weight (g/piece)	9.7	18.02
Duration of culture (days)	98	98
Survival (%)	27.52	57.46
Production (kg/400 m^2)	8.54	33.13
Feed-conversion ratio	2.32	1.23

Source: Rangka (2007)

Milkfish, seaweed and juvenile shrimp production in net enclosures were tested as alternatives to higher risk shrimp monoculture in severely degraded ponds. These production systems were developed for farmers operating in severely acidic soils that are too costly to remediate. The production systems can be run separately or as polyculture.

The chemical processes that cause soil acidification and metal contamination were rigorously studied in Australia. The work showed that the dyke soils are a more significant source of acid and metals than the pond bottom, which is often the focus of management. The work demonstrated that metal hydrolysis accounts for most of the mineral acidity generated in pond soils and must be factored into the net acid-generating capacity of ponds. The findings of this study were used in Indonesia to test the effectiveness of modified management strategies for dyke soil. Iron accumulation can be substantially reduced by reducing soil acidification in the dyke and using open-weave mesh to trap iron flocs as they form at the boundary between the dyke wall and the water.

Soil conservation strategies were tested in Australia. The work showed that acid- and salt-tolerant species can dramatically reduce soil erosion from dyke walls. Vegetation decreased splash erosion, rills and wave erosion by reducing the erosivity of water and the erodibility of the pond soils. Dyke wall slumping is controllable through compaction of the dyke walls, water level management to balance dyke and pond water forces, and the use of gentler slope angles.

The effects of metals and low pH on post larvae and maturing shrimp were described, enabling more effective assessment of shrimp farmed in ASS-affected ponds. The research identified iron as a cause of recurrent shrimp and fish mortalities that farmers had erroneously attributed to 'unknown' diseases.

Biological, physical and production indicators of ASS were identified and integrated into simple site-assessment techniques for farmers. These enabled farmers to identify causes of production problems without the need for expensive interventions from consultants. Furthermore, the identification of ASS at the farm level has helped farmers to select the most appropriate, low-cost methods to remediate their soils.

Site selection criteria were developed with a greater focus on soil limitations than previously considered. This research was extended under FIS/2002/076 to include a suite of environmental factors that had been ignored in past site selection guidelines.

Sampling equipment was designed to more accurately sample dyke and pond bottom soil (pore water) and the pond water column. This new approach to sampling has improved on-farm assessment of soil and water quality problems, leading to better management strategies.

Capacity building and training

The original project and subsequent extensions have contributed to substantial capacity building in research capability, the stock of knowledge about ASS, and technical support for ASS assessment and mapping. In time, the knowledge and technical mapping outputs will improve the capacity of local government and communities to make more informed land use decisions. An overview of the nature of, and outcomes from, the capacity building is presented in Figure 8.

Specific activities that contributed to capacity building included:

- a workshop conducted during project launch in 1998 to train project team members and collaborating researchers on field methods to assess and collect ASS, and in laboratory analysis to determine actual and potential acidity, pyrite concentration and a range of other physical and chemical properties of ASS
- a workshop on the applications of geographic information systems (GIS) and remote sensing to land capability assessment in coastal aquaculture (held at the University of New South Wales (UNSW) in 1999)
- a workshop on remote-sensing techniques and laboratory management (held at UNSW in 2001)
- a soil and water laboratory established to support project activities—the laboratory is now used by other projects and also provides services to other organisations
- a computer mapping facility with capability in GIS and remote-sensing applications
- a one-day seminar on the project theme conducted in May 2002 at the Research Institute for Coastal Aquaculture in Maros.

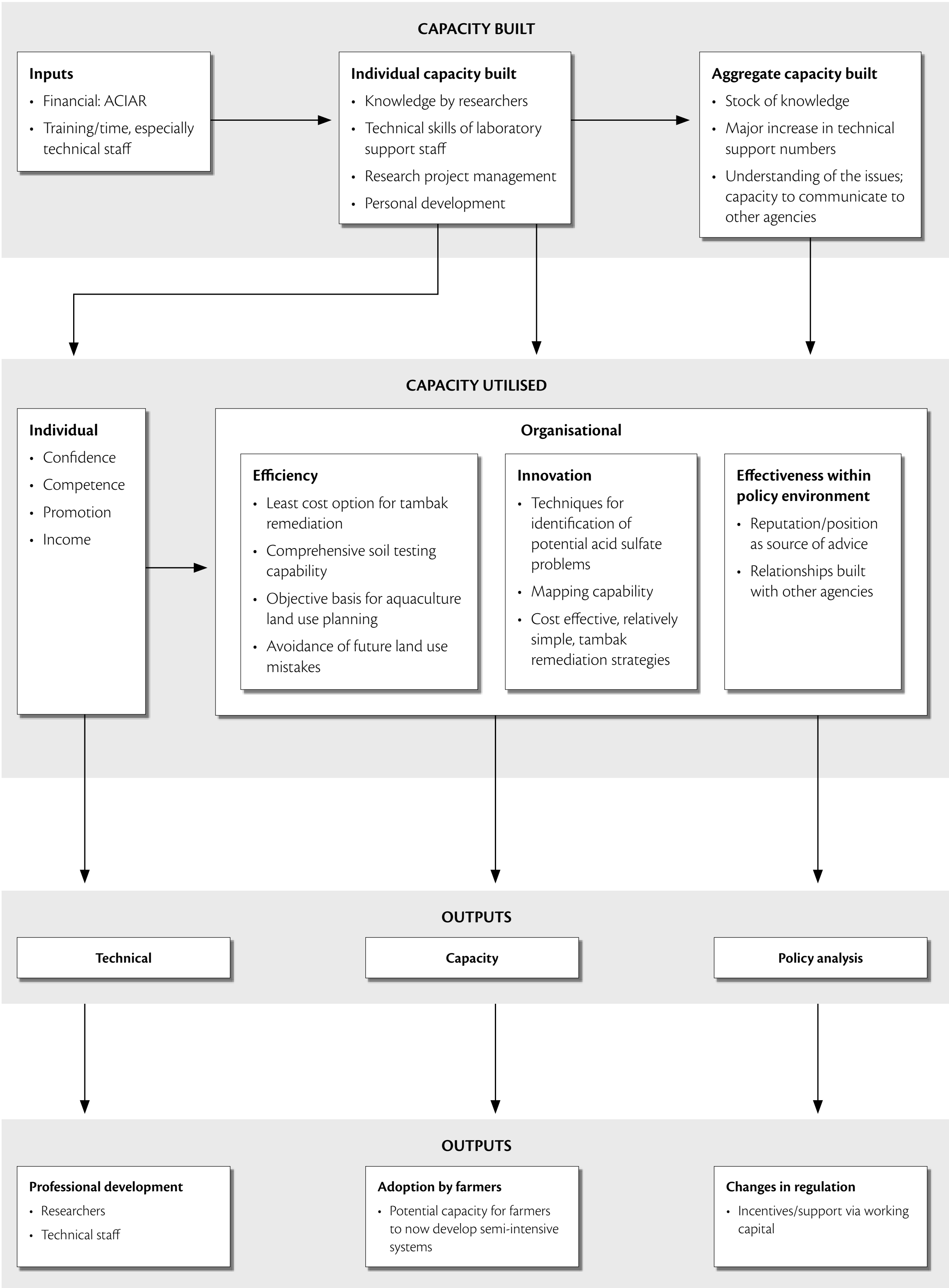


Figure 8. Summary of capacity building in the ACIAR projects on tambak remediation and shrimp farming in Indonesia

Extension

Extension materials developed during the project included:

- a demonstration site at Sinjai, established to promote alternative farming technologies and to demonstrate soil remediation strategies
- an ASS educational video in VHS and VCD format which explains in technical and non-technical terms soil processes, remediation strategies and pond management protocols
- posters and brochures to educate farmers and extension officers on pond management, ASS treatment methods and field identification of ASS.

The project has used participatory research to involve farmers in field trials, as a strategy to develop adoption. Researchers have also undertaken roadshows and conducted field days to promote the findings.

6.3 Benefits of the project

Two broad groups of benefits can be attributed to the project:

- Successful strategies for the remediation of tambak ponds. These strategies are being implemented and their development underlies the proposed expansion of traditional shrimp aquaculture in Indonesia's Revitalisation Plan for Aquaculture. These benefits are quantified in detail in the next section.
- Development of mapping techniques that identify ASS and will enable a more informed basis for future land use planning across Indonesia and, in particular, potentially avoid the significant costs that have resulted from failed aquaculture and other developments in areas characterised by ASS. The prospective nature and extent of these benefits is discussed in a later section.

6.3.1 Approach to estimating welfare changes

The standard approach used in ACIAR impact assessment studies for assessing the economic impact of projects, namely gains in economic welfare measured as changes in consumer and producer surplus, has been applied. These changes in welfare (economic surplus) have been estimated using a partial equilibrium economic model. The advantages of this approach are that it reflects values above prices paid by consumers (consumer surplus), as well as producer surplus (the difference between the price that producers are willing to supply at and the market price), it prevents double counting and it identifies the distribution of benefits between producers and consumers. The approach can be used to estimate research impacts since it enables examination of the impact of changes in producer costs, producer responses to lower costs, and subsequent flow-on benefits to consumers through lower prices.

To simplify the analysis, the population of shrimp farmers in each year has been divided into those who have adopted the remediation technology, those to whom it is not applicable, namely intensive system producers, and those who have not yet adopted the technology. Disaggregation of the supply into these different populations enables the (economic) welfare gain to be measured as a parallel shift in the supply curve, greatly simplifying the analysis and data requirements, but still providing an appropriate measure of the research benefits.[11]

The demand and supply analysis for traditional shrimp farms, with and without the remediation R&D technology, is shown in Figure 9. The same analysis applies for tiger shrimp.

The following are key points for the analysis:

- For each year the white shrimp and tiger shrimp industries can be divided into:
  - traditional farm tambaks adopting the remediation technology resulting from the ACIAR R&D (this area of tambak comprises the area farmed by both new adopters in that year and those farmers who were using the technology in the previous year; that is, the cumulative area of tambaks now using the technology)

[11] There is a rich literature on partial equilibrium analysis for benefit–cost analysis; see, for example, Alston and Pardey (2001).

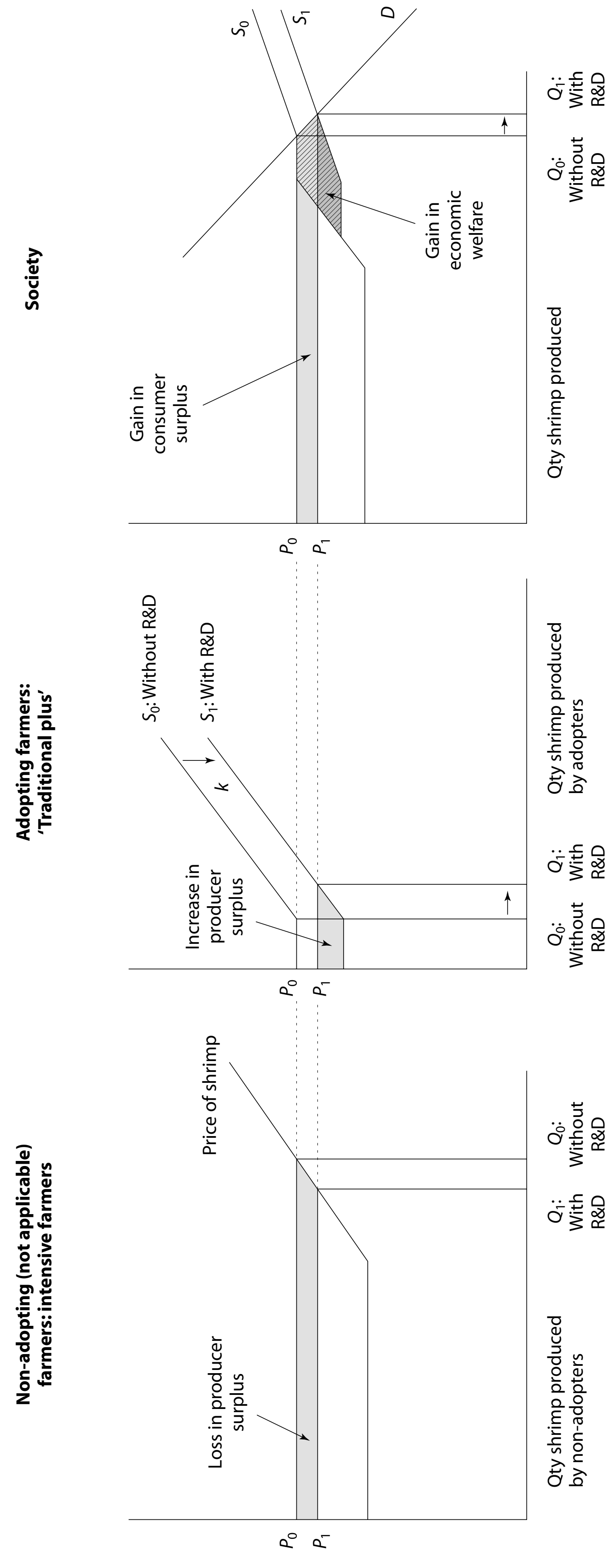


Figure 9. Measurement of consumer and producer surplus due to adoption of tambak remediation technology

- potential adopters; that is, tambaks which could re-enter shrimp production in the future as a result of the ACIAR R&D but are currently not producing shrimp
- existing tambak or semi-intensive operators who have managed to tackle the ASS issues independently of the ACIAR-funded R&D and are currently suppliers of shrimp
- industry participants for whom the remediation technology is not applicable—in particular, intensive operators who have developed other means of managing the ASS problem (higher volume pumping direct from ocean water)—and are currently suppliers of shrimp.

- Discussions with government officials and industry indicate that over the past decade the supply of shrimp from traditional farms in the ASS affected areas has been very small. Most of the tambaks that could be used for white shrimp or tiger shrimp either lie idle or are used for limited fish production. These ponds were all used for shrimp production several decades ago before the impact of disease. This long period of no production illustrates the importance of understanding the host–pathogen–environment interaction. Where there is no white spot disease virus, there is no major problem, except in sites where ponds in ASS areas that have been dug deeper to accommodate shrimp.

- Applying the R&D (in concert with biosecurity-related BMP implementation) increases productivity on these traditional farms by enabling more shrimp to be grown and harvested from a given pond area, thus lowering production costs per unit of supply (by k, in Figure 9).

- The prospect of remediation leads to production of Q_1 by these farms. It is assumed that these farms do not currently produce shrimp (and have not done so for some time).

- This additional shrimp production pushes down the price of shrimp in the market, to the benefit of consumers. The price falls from P_0 to P_1 for both white shrimp and tiger shrimp. Prices to *all* farmers fall: both the adopters and non-adopters. The net gains to adopting farmers are reduced (that is, lower prices take away some of the gains from adopting the R&D). Non-adopting farmers face lower prices and, by definition, have not benefited by the productivity gain. However, these lower prices benefit consumers.

The total increase in welfare is the sum of the net welfare gains to producers in both the adopting and non-adopting segments of the white shrimp and tiger shrimp industries and to shrimp consumers.

Given the measurement scheme outlined in Figure 9, the information required to measure the welfare benefits of the R&D in each year is thus:

- initial price and quantity (P_0 and Q_0) in the respective groups (adopting and non-adopting) for white shrimp and tiger shrimp

- Q_1 for the adopting farmers—this is the exogenously determined level of adoption in each year and includes the new adopters in that year plus those who were using the remediation technology in the previous year

- price elasticity of the demand (ή) and supply (έ) functions at the initial price and quantity in the respective groups

- a shift supply due to the adoption of the R&D (k) and the extent to which current shrimp farming is not economic; that is, the supply shift needed for farming to become attractive.

The welfare benefits over time comprise the benefits in each year, reflecting:

- welfare gains from existing adoption, plus that arising from new adoption[12]

- the rate of adoption of the technology due to factors such as its promotion and demonstration of its cost savings, which encourage farmers to adopt the technology

12 The modelling for each year was treated as an independent event. The quantity supplied in each year equals Q_1 in year 1 — the additional supply resulting from increased adoption arising from extension investment, local farmer groups and so on. The impact of technology change (k) was applied to the total quantity and thus reflects technology impact on existing adopters (since the start of the program) and new adopters in each year.

- a shift in supply due to adoption of the technology (*k*)—that is, the cost reduction
- discounting of future benefits and costs to reflect the opportunity cost/social cost of investment. ACIAR employs a standard 5% discount rate.

Initial quantity and price

In 2005 the quantity of shrimp produced in Indonesia totalled around 300,000 tonnes. Around two-thirds were white shrimp and one-third tiger shrimp.[13] The majority, in both cases, was supplied from intensive and semi-intensive farms (estimated at 75%), the balance from traditional tambak. However, about 75% of the farmed area is traditional tambak.

The net area of tambak aquaculture is around 430,000 ha (net of pond banks and waterways). The main areas are in Sulawesi (32%), Java (32%) and Sumatra (20%) (Figure 10).

Dyspriani (2007) reports Widiyanto stating that in 2006 more than 50% of shrimp tambaks were no longer operational due to shrimp disease, price fluctuations and generally low prices. Non-operational tambaks are used for salt ponds, industry, seaweed aquaculture and paddy fields. Further, Pahlevi (2007) reports that there is potential for 1.22 million ha of aquaculture in brackish water, of which about 40% is currently being used or at least developed in terms of established infrastructure.[14]

Under MMAF's aquaculture revitalisation plan, additional areas of traditional, semi-intensive and intensive production are proposed (Table 7). The main emphasis is on 'traditional plus' farms especially in terms of area.[15]

In 2005, white shrimp and tiger shrimp prices were 38,000 Rp and 50,000 Rp (per kilogram), respectively.[16]

Price elasticities of demand and supply

Indonesia is a significant world producer of both white shrimp and tiger shrimp. About 60% of Indonesian shrimp production is exported.[17] The main export markets are Japan (60%), the USA (17%) and the EU (12%). Increased exports are a major emphasis in the industry revitalisation plan.

Indonesia competes directly with shrimp from other South-East Asian countries for the US, Japanese and EU markets. Major world exporters of white shrimp and tiger shrimp are Thailand, India and Vietnam. While these export markets are not limited in the sense of quantitative restrictions, there are new requirements regarding residues (such as maximum levels of antibiotics) for product shipped to Japan and the EU that could limit export opportunities for shrimp. Significantly, the remediation technology enables production without the use of antibiotics since the disease risks are addressed directly through use of good quality water and disease-free fry.

World shrimp aquaculture has been rising, especially since 2000. Trade has also increased, with world production now about equal to world trade. However, world prices (in US$ terms) have fallen from the peak in the mid 1990s, and particularly since 2000, as production growth (mainly from China, but for domestic consumption) has exceeded growth in demand (Josupeit 2007).

The export demand elasticity facing Indonesian shrimp farmers, tambak and intensive alike, is likely high. In 2002, Indonesian exports of shrimp from aquaculture represented 6.5% of world exports and a slightly higher proportion of world shrimp aquaculture production (around 11% in 2002 and 9% in 2003) (Josupeit 2004).

---

13 MMAF (2005, p. 5)

14 This general context suggest that there are likely to be gains from drawing together and extending current and past ACIAR investments to ensure that past mistakes are not repeated and future government funding is well targeted.

15 Dyspriani (2007) describes the tambak system as follows: 'Traditional tambak uses little or no fertilisation and no supplementary feeding with the low production costs (US$1–2/kg live shrimp). Biomass rates are below 10,000 fry/ha (10 fry/m^2). Traditional plus (extensive) shrimp farmers use fertiliser to grow plankton as a source of shrimp feed, and sometimes they use supplemental feeds and water pumping with the densities between 10,000–30,000/ha (10–30 fry/m^2).' Most of traditional (plus) farmers use a polyculture method by cultivating shrimp with milkfish, tilapia, or seaweed. The method is easier, cheaper and profitable economically. If the harvest of shrimp fails, the shrimp farmers can still harvest the other products. By using milkfish, tilapia and seaweed, the water quality of tambak also can be improved without using the waterwheel. The milkfish and tilapia can mix water to generate oxygen by moving their fins, while seaweed can absorb pollutants.

16 MMAF (2005, pp. 410–415)

17 MMAF (2005, pp. 28–30)

Figure 10. Principal areas of shrimp production in tambak ponds in Indonesia. Source: Dyspriani (2007)

Table 7. Area and production targets for white shrimp and tiger shrimp in Indonesia, 2006–2009

	Area targets (ha)	Yield (tonnes/ha)	Implied production targets (tonnes)
Traditional plus[a]	138,013	1	138,013
Semi-intensive	13,067	5	65,335
Intensive	3,904	30	117,120
Total	154,984		320,468

[a] 'Traditional plus' covers extensive traditional shrimp farming with remediation including liming, fertiliser and other practices consistent with the BPM guidelines (see Dyspriani 2007)

Source: MMAF (2005), p. 54

Recent econometric analysis of the shrimp market in the USA and the EU suggests that the elasticity of demand for product imported from Asia is between −1.8 for the USA and around −0.5 for the EU (Poudel and Keithly 2008). On this basis an approximate export demand elasticity facing Indonesia would be −18 for product shipped to the US and −5 for product destined to the EU. For the purposes of this analysis, the more conservative (in the sense of lessening the price impacts of additional shrimp production) export demand elasticity of −5 has been used.

The substantial underutilisation of the existing tambaks suggests that the adoption levels and supply response by farmers, for both white shrimp and tiger shrimp, could be quite high. The tambak ponds are already constructed, together with inlet and outlet water channels. While it can be argued that the current systems are potentially 'part of the problem', since they limit disease control, they are nevertheless in place and additional investment is not required. However, other factors are likely to limit supply response. They include bad past experiences with shrimp monoculture; uncertainty of the success of the technology, given continuing disease issues in some experimental situations; and some upfront investment and working capital requirements for tambak farming using the remediation technologies. A further factor is the recent price rises for fertiliser, feed and fuel, in the absence of increases in product prices. In this context the traditional 'set up and forget' and harvest whatever results will continue to have attraction. Economic studies of supply elasticities confirm that there is a low response to changes in prices. Analysis by the WorldFish Center (2004) reports a supply elasticity for Indonesian aquaculture of 0.28, the lowest supply elasticity of major South-East Asian aquaculture producers.

Productivity increase

Remediation of bottom soil in tambaks has been shown to increase the survival rate of tiger shrimp from 27% to 57%, resulting in a production increase from 8.5 kg/400 m^2 of pond to 33 kg/400 m^2 (see Table 6), a rise of around 290%.

These results were achieved in experimental sites. As the researchers involved acknowledged[18], and the income comparison between the experimental sites and farmers' subsequent attempts showed, farm performance is typically less than that implied by experimental results (Table 8). Nevertheless, these results reflect a single year's experience of the farmers as they sought to follow the pond remediation process undertaken by the researchers. Now that BMP advisory material has been developed and the farmers involved have a better understanding of the disease control issues, there are indications that future performance will improve. Even so, there was substantial discussion and guidance by the researchers involved, suggesting that, in some respects, use of the 'farmers' attempts' for the purposes of inferring production increases by other farmers in other areas may be more appropriate than use of the researchers' results.

While it is unlikely that the experimental results will be achieved generally by farmers adopting the technology, it is reasonable to expect that around 60% of the experimental performance should, in time, be achievable (compared with 40% reported from the trial results). That level of production and yield is much the same as that reported and used by MMAF for its shrimp budgets (MMAF 2005). This would imply an income gain of Rp4 million per cycle, or an increase in income of about 100% compared with the 'before remediation' situation, implying a cost reduction in producing tiger shrimp of about 50%.

Unfortunately, comparable data for the before and after gains for remediation of ponds used in white shrimp production are not available. Discussions with researchers suggest that the main emphasis of future production will lie with tiger shrimp as the capacity of traditional farmers to compete with semi-intensive and intensive white shrimp farmers will be more challenging. Hence, there has been less comparative analysis for white shrimp. For the purposes of the current analysis it has been assumed that the remediation technology and BMP could lead to a unit cost reduction of at least 30% in traditional tambak white shrimp farming. This is significantly lower than that used for tiger shrimp but is likely realistic in representing the relative attractiveness for farmers of using the remediation technology for tiger shrimp rather than white shrimp production.

Further gains in production and income could be achieved if farmers changed from traditional tiger shrimp farming to a semi-intensive system involving pumping and aeration as well as higher stocking rates and associated higher feeding. Ministry budgets show that semi-intensive tiger shrimp production systems are about twice as profitable as the traditional system (with pond remediation).[19] RICA researchers suggest that the improvement in confidence that has accompanied application of the remediation practices by traditional farmers will lead to greater interest and entry into semi-intensive systems. Such a shift will depend upon the extent to

18 The researchers noted: 'The income was greater in the demonstration period because RICA team members were more diligent than the farmers in terms of disease screening and soil management. RICA was also prepared to invest more than the farmers to manage the system and farmers exercised caution by stocking less'.

19 Some care is needed in interpreting the implications of these budgets since they suggest that production and income equivalent to or higher than that achieved in the experimental sites is possible.

Table 8. Farm income impacts of pond remediation technology (Research Institute for Coastal Aquaculture (RICA) experiments, Sinjai Regency, South Sulawesi)

	Before	**During (RICA experiment)**	**After (farmer attempts)**
Items	Per cycle	Per cycle	Per cycle
Culture method	Polyculture	Monoculture	Monoculture
Duration of culture (days)	110	100	120
Pond area (ha)	0.2–3.0	0.4–1.0	0.4–1.0
Stocking density (pieces/ha)			
Tiger shrimp fry	10,000	20,000	15,000
Milkfish fry	750	6,700	1,700
Operational cost (Rp) :			
Tiger shrimp	1,100,750	4,250,000	1,141,000
Milkfish	700,750	810,300	1,156,000
Total	1,801,500	5,060,300	2,297,000
Average gross income (Rp)	5,751,500	18,385,300	7,628,250
Average net income (Rp)	3,950,000	13,325,000	5,331,250
Increase in net income relative to 'Before' (Rp)		9,375,000	1,381,250
Increase in net income relative to 'Before' (%)		237	35

Source: Rangka (2007)

which farmers are able to achieve higher production performance in their traditional ponds with the use of the remediation practices. However, for the purposes of this analysis, a shift toward semi-intensive production has not been included. To that end, the analysis is a conservative representation of potential developments.

Adoption and encouragement of shrimp farming

The potential for higher farm income through remediation of (mostly) currently idle ponds (apart from limited milkfish production) will provide a significant incentive for farmers to re-enter shrimp farming. The extent to which adoption occurs is a major factor for assessing the impact of the project. Without significant adoption the gains from the remediation technology will not be realised.

Farmers' capacity to re-enter the industry or expand their current production will be encouraged by local and broader developments. These include MMAF's aquaculture revitalisation plan.

The revitalisation plan has important implications for the adoption of the remediation technology since the plan both recognises the importance of the remediation technology and provides support for extension and other approaches to encourage or facilitate adoption.

The plan includes the following operational policies (MMAF 2005, p. iv):

- Put to use and maximise the potential of brackish water ponds (tambak) and freshwater ponds
- Optimising and capacity building of fish hatcheries, both government and public hatcheries
- Facilitating the development of partnerships
- Importing broodstock of the white shrimp strain that is certified as 'specific pathogen free' and domestication of broodstock to produce stock that is 'specific pathogen resistant'

- Applying standards and certification as well as controlling seed quality
- Providing intensive support/capacity building through dissemination activities and establishing demonstration ponds. Dissemination is to be carried out by taking advantage of existing fisheries extension officers and technical field staff, technical support officers both from the central technical implementation units and local technical implementation units and through recruitment of technical extension staff as required.
- Coordination with relevant institutions in the fields of spatial planning, financing, market development, environmental control security and others.

Future markets for the additional production of shrimp and other aquaculture species were not detailed in the revitalisation plan. This is of some concern since the plan implies an overall 80% increase in white shrimp and tiger shrimp production.[20]

Within the plan the target growths for white shrimp and tiger shrimp in the 'Traditional plus' production systems are substantial—approaching a total of more than 25,000 ha per annum (Table 9). 'Traditional plus' farms are projected to account for 43% of the total production increase outlined in the plan.

Table 9. 'Traditional plus' shrimp farm area (ha) and implied production targets (given a typical 1 tonne/ha/year production level)

	White shrimp	Tiger shrimp
2006	19,118	6,842
2007	23,542	8,575
2008	21,680	10,955
2009	38,330	8,970

Source: MMAF (2005, p. 54)

An issue is the production levels expected after 2009. The investment and capacity development in infrastructure and farmers in achieving the forecast production growth to 2009 can be expected to maintain production beyond 2009. It is probable that it would continue to increase, especially if farmers moved to adopt semi-intensive production systems.

Given this level of increase, which is of the order of 15% per year, there are questions as to whether it is likely and whether the resources to enable this rate of development are available.

The plan outlines that disseminating knowledge of the technologies to enable the future development of shrimp farming, as well as the other areas of aquaculture development, is important. It shows that these responsibilities will lie with the central government technical implementation units (UPT) and local technical implementation units (UPTD) operated by the Fisheries and Marine Services at the provincial and local levels. The plan also recognises that historically the institutional aspects of extension services have not worked well, limiting the flow of information from the UPTs to farmers, a view shared by researchers and farmers. It is intended that the UPT themselves will become involved in extension work to farmers. In this regard it is worth noting that a key element of the success in achieving the rehabilitation of tambak ponds in East Sulawesi was the direct involvement of the researchers in extension. However, the cost involved in encouraging and supporting researchers to undertake extension can be significant. Thus, there is a continuing major question mark over whether there are sufficient staff to achieve the 'extension' role that is envisaged in the plan.

The plan calls for substantial capacity building for farmers, particularly through using the group (*kelompok*) approach, since that approach utilises existing social networks and makes greater use of the limited government extension services.

The plan also recognises the importance of promoting aquaculture development within the whole marketing chain, including input supply systems as well as product markets and market requirements.

The action plan to deliver this capacity building is outlined to comprise:

- organisation for implementing the revitalisation plan
- institutional strengthening of fish-farmer groups
- higher level education for people involved in technology development

20 MMAF (2005, p. 50): a production increase from 300,000 tonnes in 2006 to 540,000 tonnes by 2009, an increase of about 15% per year.

- training in aquaculture techniques for technical extension offices and staff
- field schools for fish and shrimp farmers
- capacity building for fish-farmer groups
- distribution of information concerning the application of aquaculture technology.

These strategies will require a major financial investment by MMAF and they may well involve considerable change within the respective agencies. The plan proposes expenditure over 4 years totalling Rp3 trillion.[21] Of this investment, Rp95 billion is for rehabilitation of brackish-water systems, which relates directly to development of white shrimp and tiger shrimp production. White shrimp and tiger shrimp production are expected to benefit from the proposed investment in hatchery optimisation, the operational taskforce, the establishment of the development service centres (UPP), technical extension officers (TPT) and working capital stimulus for community and backyard hatcheries. In addition the plan outlines that investment will be sought from local government budgets. ACIAR project managers and researchers report an increasing interest from provincial and district governments implementing parallel BMP programs as long as the ACIAR BMP projects demonstrate some success. Further, the Director General Aquaculture, during a recent visit, asked the Governor of South Sulawesi to provide increased support to aquaculture in the province.

This proposed investment in support services over the period 2006–09 is detailed in Table 10. Other investment, such as input supplies and banking sector support through working capital, are significant costs but are costs that are recovered through purchase/payments by farmers. In contrast, the central and local government investments contribute to the plan's achievement but are not reflected in farmers' costs.

Given the issues associated with financing for traditional farmers, the extension requirements and provision of information generally (including demonstration sites), it has been estimated that around 60% of the government investment will be directed at the traditional farms. This is higher than the 43% proportion of production attributable to traditional farms, but reflects the greater inputs needed to achieve the level of production increase sought.

A question is the extent of government investment after 2009 to maintain or increase projected production levels. Maintaining projected production levels beyond 2009, even at 2009 levels, will require a continuing investment by the government, since much of the investment relates to support for demonstration units, financial support and extension. These are likely to be continuing costs given exit and entry of farmers to the industry and continuing changes in technology applicable to traditional farms. Most of the government support for tambak remediation under the revitalisation plan reflects financial support to purchase inputs; working capital for future input purchases will still be required after the initial years of the plan to achieve the output levels suggested in the plan. Thus continued investment and input purchases will be required, whether provided by the government, local groups or individual farmers. It has been estimated that 60% of the proposed government investment in 2009 will be required in subsequent years. The measured net benefits of the revitalisation plan explicitly allow for these near term and longer term input purchases and infrastructure.

A review of the history of past programs and the underlying approach adopted in this revitalisation plan has been undertaken by Dyspriani (2007). Key observations that have relevance for the current assessment, future R&D and development of traditional aquaculture farming in Indonesia are summarised in Box 2. They suggest that promoting adoption of the remediation technology will not be without its challenges. As Dyspriani (2007, p. 27) observed:

> Factors (leading to the low utilisation of tambak areas) are related to operational management and socio-culture of shrimp farmers. They include technical constraints, lack of knowledge and capital, high shrimp operational costs and low shrimp prices.
>
> Technical constraints are related to the inability of shrimp farmers to apply appropriate technology that determines the quantity and quality of shrimp. When shrimp farmers open a tambak, they do not consider the area selection, design and lay out of the tambak, irrigation canals, and carrying capacity of environment. They use lower quality shrimp seed. They only have

21 MMAF (2005, p. 194)

Table 10. Government investment (Rp billion) to support revitalisation: total and 'Traditional plus' white shrimp and tiger shrimp farming

	2006	2007	2008	2009
Demonstration units	2.70	5.40	10.80	21.60
Financial support	13.50	27.00	54.00	108.00
Training	1.35	2.70	5.40	10.80
Business meetings	0.68	1.35	2.70	5.40
Field visits	0.68	1.35	2.70	5.40
Supervision	0.27	0.54	1.08	2.16
Extension	2.43	4.86	9.72	19.44
Financial support for backyard hatcheries	1.35	2.70	5.40	10.80
Development of hatcheries (operating costs)	4.60	4.60	4.60	4.60
Tambak rehabilitation	13.50	13.50	13.50	13.50
Share of local government budgets (5% allocated to shrimp)	1.78	2.28	2.62	3.68
Share allocated to 'Traditional plus' farmers (%)	60	60	60	60
Total for 'Traditional plus' white shrimp and tiger shrimp farming	25.7	39.8	67.5	123.2

Source: MMAF (2005, pp. 198–199)

experience through learning by doing. If the problem occurs during the production process, they have to solve the problems by themselves or by exchanging information and technology among themselves to find a solution.

Against this background three broad scenarios of adoption have been examined.

The first (Table 11) reflects the production objectives set out in the plan: an 80% increase in production between 2005 and 2009, and maintenance of 2009 production levels post 2009. This might be termed the optimistic scenario since is requires a substantial investment by government and farmers and suggests a substantial increase in production in a short period.

The second presents a more conservative scenario and reflects the view, endorsed by discussions with governments officials, researchers and industry, that implementation will take longer. This delay reflects both resource constraints in promoting the technology and the underlying risks faced by traditional farmers when an up-front working capital investment is required to make changes. Also, there are issues concerning the availability of farmers since many of the previous generation of shrimp farmers are now working at other jobs, given the very limited income that can be derived from tambaks. This scenario examines the implications of taking 15 years (i.e. to 2025) to achieve the plan's suggested production increase.

The third scenario examines the implications of a much more conservative outcome: the increased utilisation of existing tambak ponds takes longer and the production increase is about half that proposed under the plan, even with the investment proposed under the plan. This scenario reflects a situation where there is little impact of government extension or other advisory services. Rather there continues to be localised adoption of the technology reflecting the continued influence of researchers and individual extension and advisory personal—the widespread national adoption of the revitalisation strategy essentially fails to materialise. It could be argued that such a situation reflects, in essence, what has been happening up until 2005.

The implications of these three scenarios for shrimp production are shown in Figure 11.

Box 2. Governance and organisation of the program for the revitalisation of shrimp production in Indonesia: key points from the study by Dyspriani (2007)

Many types of institutions and organisations will need to be involved to achieve the goals of the plan — R&D, extension institutions to disseminate the technology, service-providing institutions (banks, financing institutions, *koperasi*, fisheries associations), private industries (industries related to production, processing, and marketing), fish-farmer groups and NGOs.

In order to implement appropriate technological packages and innovations in local areas, the Director General Aquaculture is supported by 12 technical implementation units (UPT). The UPT coordinate and cooperate with the Brackishwater Aquaculture Development Centre (BPBAP) and local technical implementation units (UPTD), operated by the ministry at the provincial/district/city level. The UPT and UPTD are supported by technical support officers (TPT). (The UPT and UPTD are the local institutions available/used to disseminate technology, and TPT are counsellors of a sort.)

The extension service (UPT), which plays an important role in giving information to shrimp farmers related to technology, has not been functioning properly. UPP has the responsibility to provide services for the members, for example in the procurement and distribution of production equipment and supplies, the arrangement and channelling of finance, and to provide advice and guidance to members of fish farmer groups.

Besides those institutions, some existing professional and commercial societies and associations play a key role as partners with the government and entrepreneurs in the field of aquaculture. They include: the Indonesian Fisheries Society (MPN); the Indonesian Aquaculture Society (MAI); the Indonesian Shrimp Commission (ISC); Shrimp Club Indonesia (SCI); and the Fisheries Entrepreneurs Association (Gappindo), along with all the Associations under its auspices such as Indonesian Seaweed Association (ARLI), Indonesian Cold Storage Association (APCI), and Indonesian Association of Shrimp Feed Producers (APPUI).

Support for the plan will also come from the local governments in East Java and South Sulawesi and from fishery associations. For example, local government (MFO) in East Java has established a relationship with one local bank to give credit to small-scale shrimp farmers.

Shrimp farmers have organised themselves too. A group might consist of 2–10 people. Within the group, they share knowledge, information and technology to improve the shrimp productivity by learning from each other.

In general, small shrimp farmers are the members of *koperasi,* which are small local organisations. *Koperasi* typically only provide credit (for production) and do not provide other assistance, such as advice and marketing. On the other hand, the formal organisations of shrimp farmers, such as Indonesian Shrimp Commission and Shrimp Club Indonesia do not have representatives from small-scale shrimp farmers.

The KCD (Dinas Branch Office) is necessary to provide counselling, but the local counsellors have limited capacity. (KCD is a field extension agent (counsellor), providing service in agriculture, fishery and forestry sectors. There is no specific job description.) They do not have specific skills and knowledge about shrimp tambak aquaculture and they cannot give assistance regularly, because they are generalists.

Adoption issues are also complicated by the way tambaks are managed and therefore the way in which farm decisions are made. Tambak areas vary between 0.5 ha and 15 ha, and one shrimp farmer can have 1–15 tambaks. For the shrimp farmers who do not have tambaks, they rent tambaks or work as labour. Those who do not have sufficient capital to pay for the operational costs, such as feed, fertiliser, shrimp fry, often enter into partnership agreements with traders or processors by using the *Bapak Angkat* approach. Some make partnerships with integrated shrimp farming industries by using the 'plasma-nucleus concept'.

The preliminary perception of the program is that the small scale shrimp farmers are not ready to improve shrimp technology and tambak infrastructure and to shift from windu [tiger shrimp] to vannamei [white shrimp], because they have limited capital and knowledge. Therefore, the operational policy to develop organic tiger shrimp in polyculture with other species could be the best option for the small-scale shrimp farmers to maintain their livelihood, increase their income and create long term sustainability.

Table 11. Benefit calculations: white shrimp (Scenario 1)

Scenario	Impacted area				Adopters		Non adopters		Total	
		P_0	K	Z	Q_0	Q_1	Q_0	Q_1	Q_0	Q_1
1	ha/tonnes	$/ tonne	%	%	ha/ tonnes	ha/ tonnes	ha/ tonnes	ha/ tonnes	ha/ tonnes	ha/ tonnes
2006	19,118	$4,535	40	2	–	19,118	202,000	202,000	202,000	221,118
2007	42,660	$4,449	41	2	19,118	42,551	202,000	200,853	221,118	243,404
2008	64,340	$4,359	42	2	42,551	63,974	200,853	200,778	243,404	264,753
2009	102,670	$4,283	42	3	63,974	101,967	200,778	199,796	264,753	301,763
2010	102,670	$4,163	44	0	101,967	101,112	199,796	199,094	301,763	300,207
2011	102,670	$4,167	44	0	101,112	101,143	199,094	199,858	300,207	301,001
2012	102,670	$4,165	44	0	101,143	101,127	199,858	199,063	301,001	300,190
2013	102,670	$4,167	44	0	101,127	101,144	199,063	199,890	300,190	301,034
2014	102,670	$4,165	44	0	101,144	101,127	199,890	199,029	301,034	300,156
2015	102,670	$4,167	44	0	101,127	101,144	199,029	199,925	300,156	301,070
2016	102,670	$4,165	44	0	101,144	101,126	199,925	198,993	301,070	300,119
2017	102,670	$4,167	44	0	101,126	101,145	198,993	199,963	300,119	301,108
2018	102,670	$4,165	44	0	101,145	101,125	199,963	198,953	301,108	300,079
2019	102,670	$4,168	44	0	101,125	101,146	198,953	200,004	300,079	301,150
2020	102,670	$4,165	44	0	101,146	101,124	200,004	198,911	301,150	300,035
2021	102,670	$4,168	44	0	101,124	101,147	198,911	200,048	300,035	301,195
2022	102,670	$4,164	44	0	101,147	101,123	200,048	198,865	301,195	299,988
2023	102,670	$4,168	44	0	101,123	101,147	198,865	200,097	299,988	301,244
2024	102,670	$4,164	44	0	101,147	101,122	200,097	198,815	301,244	299,937
2025	102,670	$4,168	44	0	101,122	101,148	198,815	200,149	299,937	301,297

Table 11. (continued)

P_1	ΔP	Producer surplus adopters (R&D and government plan)	Producer surplus non-adopters (R&D and government plan)	Total producer surplus (R&D and government plan)	Consumer surplus (R&D and government plan)	Total surplus (R&D and government plan)
$/ tonne	%	$m	$m	$m	$m	$m
4,449	−2	35	−17	17	17	35
4,359	−2	73	−18	55	20	75
4,283	−2	111	−15	96	19	114
4,163	−3	173	−24	149	32	181
4,167	0	184	1	185	−1	183
4,165	0	183	0	183	1	183
4,167	0	184	0	184	−1	183
4,165	0	183	0	183	1	183
4,167	0	184	0	184	−1	183
4,165	0	183	−1	183	1	183
4,167	0	184	1	184	−1	183
4,165	0	183	−1	183	1	183
4,168	0	184	1	184	−1	183
4,165	0	183	−1	183	1	183
4,168	0	184	1	184	−1	183
4,164	0	183	−1	182	1	183
4,168	0	184	1	184	−1	183
4,164	0	183	−1	182	1	183
4,168	0	184	1	185	−1	183
4,164	0	183	−1	182	1	183
NPV		2,072	−69	2,003	80	2,084

Table 11 presents the estimated surplus calculations for scenario 1 for the ACIAR and government investment outlined in the revitalisation plan.

6.3.2 Other economic benefits: improved land use planning

The historical context of the ASS impact on shrimp aquaculture suggests that a better understanding of soils and land use options will be important in the future development, particularly new development, of aquaculture in Indonesia.

The revitalisation plan recognises the issue of spatial planning. It notes the potential for conflicts of interest between sectors in the absence of explicit spatial plans for an area. It notes the issue of frequent overlap between shrimp culture and other activities that impact negatively on aquaculture and that 'aquaculture activities are frequently sacrificed in order to protect the interests of other sectors, such as tourism, residential development or mining'.

In this context the understanding of the ASS issues and the capacity for mapping potential 'at risk' areas for the development of aquaculture, and more broadly the development of other activities, such as rice or forestry, is a potentially significant benefit of the project. Mapping, followed by land use planning and biosecurity considerations, can potentially avoid substantial investment in engineering works, development of new industry infrastructure, and migration of people when there in no likelihood of successful development. Further, as is evident in much of the tambak areas affected by ASS, such planning could avoid the subsequent costs of remediation.

The experience of recovery in Aceh is indicative of the potential for mistakes to continue to occur. The limited understanding of ASS in the redevelopment of tambaks in Aceh meant that inappropriate engineering works were repeatedly undertaken. The inherent limits of such work in ASS (for example, slopes of walls, soil disturbance, inlet and outlet water systems) were not recognised, mainly because the limited depth of soil testing that had been undertaken did not identify the areas as ASS.

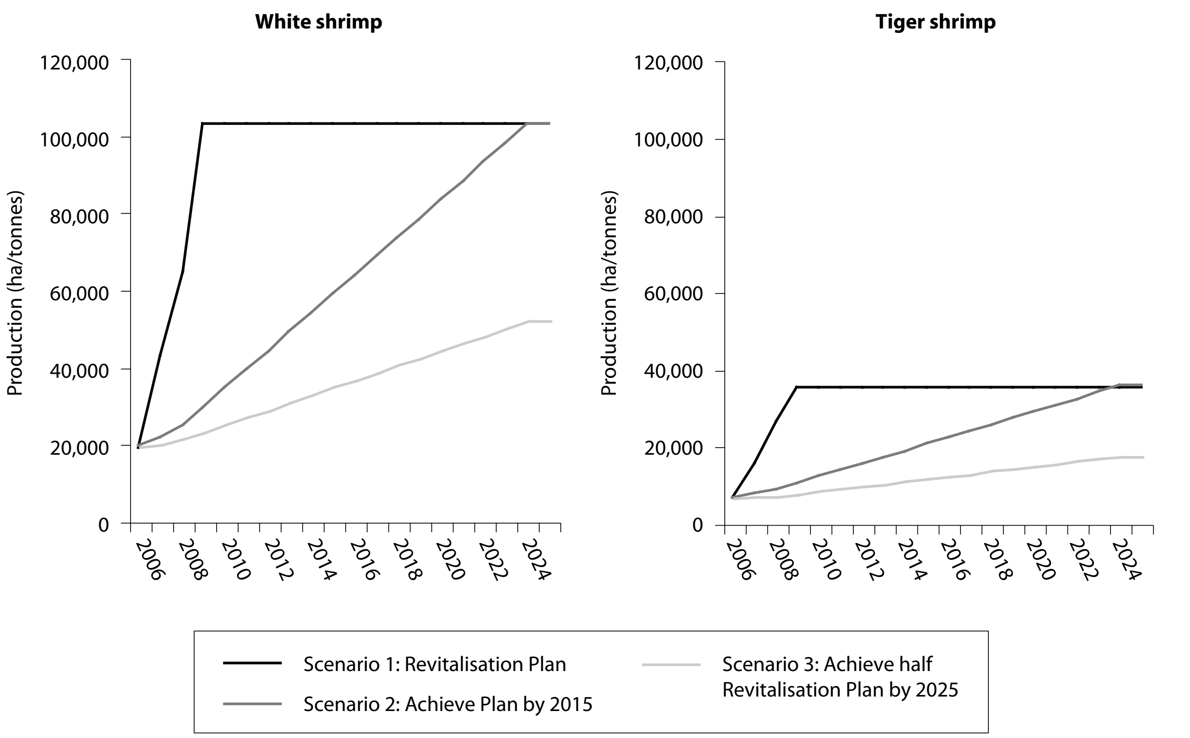


Figure 11. Adoption scenarios: tambak remediation

It has not been possible to quantify as part of this assessment the extent and costs of mistakes that could have been avoided, or the potential for future avoidance. The interest and support being shown by local government in South Sulawesi and requests to the researchers from other local government bodies elsewhere in Indonesia suggest that the gains from the better understanding of ASS will influence future land use planning. However, it is somewhat premature to quantify these benefits since there is little information concerning the gains from such planning and the possible extent of adoption and compliance. That said, the benefits of the mapping technology now being developed, combined with adherence to its analyses in future planning, potentially offer annual savings of many millions of dollars.

The projects have also had significant impacts for Australia. The work in Indonesia prompted closer examination of the reasons for fish kills and aquaculture decline along the east coast of Australia. Drawing on the Indonesian work, ASS were identified as a contributing factor. Changes in land use and land use planning, including the requirements for development, have followed. However, the impacts of these changes have not been quantified here.

6.3.3 Analysis

Data summary

Summary data are presented in Table 12.

Net benefits attributable to the ACIAR investment

The estimated welfare impacts of the availability of the remediation technology, net of the investment proposed and projected by the government and input purchase costs of farmers, are summarised in Table 13. These are the impacts of the gains from the use of remediation technology at the farm level, given the three scenarios of adoption of an expansion in 'Traditional plus' white shrimp and tiger shrimp production under the revitalisation plan, which can be attributed to the R&D in total and ACIAR funded R&D. ACIAR R&D (Table 5) is calculated to have contributed 41% of total R&D costs (calculated on a real, net present value basis) and the benefits of the R&D have been apportioned on this basis.

In the absence of the technology it is concluded that none of the possible scenarios of adoption would have eventuated. This is a reasonable approach since, in the absence of the remediation technology, the income gains at the farm level from pursuing aquaculture would have been negligible, and promotion of an expanded white shrimp and tiger shrimp tambak industry would not have proceeded.

Under all scenarios, the estimated welfare gains are substantial. Most of the gains accrue to farmers using the remediation technology. Gains to consumers through lower prices are small since the impact on product prices of additional white shrimp and tiger shrimp production from the traditional farming sector is small, given the

Table 12. Summary data: benefit analysis (all scenarios)

Data		White shrimp		Tiger shrimp	
		Adopters	Not applicable/ non-adopters	Adopters	Not applicable/ non-adopters
Total production 2005		202,000		98,000	
Estimated Q_1	*t*	19,118	202,000	6,842	98,000
P_0	*Rp*	38,000		50,000	
	A$/kg	$4.50	$4.50	$6.00	$6.00
ed (–ή)		–5	–5	–5	–5
es (έ)		0.3	0.3	0.3	0.3
Increase in income	%	40		30	
k	*$/kg*	$1.80		$1.80	

demand conditions in the market, i.e. the much more substantial production from intensive productions systems and the high price elasticity of demand.

The measured returns and investment return on the ACIAR investment are higher if the revitalisation plan achieves its objectives in the next few years. The longer it takes to achieve the production levels, the lower the benefits and investment returns given the lower production levels in each year and the opportunity cost of the funds invested in the project (i.e. the discount rate).

The investment returns are much lower if future production levels are significantly lower than those implied in the revitalisation plan objective.

It is unlikely that scenario 1 will eventuate, given the adoption levels required in a short time. The longer time period inherent in scenario 2 is more reasonable. However, given the resource issues involved, including the skills of farmers, there is the question of whether the suggested level of production, as outlined in the plan, would be achieved by 2025. Some weighting

Table 13. Economic welfare changes attributable to adoption of tambak remediation technology (A$m): 1998–2025, present values: scenarios 1, 2 and 3

	All R&D investment	ACIAR investment
Scenario 1: Adoption: revitalisation plan target achieved by 2009		
Present value (PV) of consumer surplus ($m)	20	8
PV of producer surplus ($m)	1,980	823
PV of total surplus ($m)	2,000	831
PV of R&D costs ($m)	10.7	4.5
Net present value (NPV) ($m)	1,989	826
Benefit:cost ratio (BCR)	186	186
Internal rate of return (IRR) (%)	72%	72%
Scenario 2: Adoption: revitalisation plan target achieved by 2025		
PV of consumer surplus ($m)	10	4
PV of producer surplus ($m)	790	328
PV of total surplus ($m)	800	332
PV R&D costs ($m)	10.7	4.5
NPV ($m)	789	328
BCR (ratio)	74	74
IRR (%)	35%	35%
Scenario 3: Adoption: half revitalisation plan target achieved by 2025		
PV of consumer surplus ($m)	0	0
PV of producer surplus ($m)	90	37
PV of total surplus ($m)	90	37
PV of R&D costs ($m)	10.7	4.5
NPV ($m)	79	33
BCR (ratio)	8	8
IRR (%)	10%	10%

Table 14. Estimated return to the ACIAR investment in tambak remediation

	Total R&D investment	ACIAR investment
Present value (PV) of consumer surplus ($m)	7	3
PV of producer surplus ($m)	551	229
PV of total surplus ($m)	558	232
PV of R&D costs ($m)	10.6	4.4
Net present value ($m)	547	227
Benefit:cost ratio	52	52
Internal rate of return (%)	26	26

therefore has to be given to scenario 3. Adopting an overall conservative approach suggests a 66% likelihood of scenario 2 and a 33% likelihood of scenario 3. The net investment return implied by this approach is summarised in Table 14.

The analysis suggests that the return to the ACIAR investment will be substantial, if white shrimp and tiger shrimp production in the traditional tambak ponds increases.

Investment analysis

Analysis of the investment returns shows that, if the production gains can be achieved and the costs are limited to that outlined above, the return on investment will be very high.

Other impacts

The project can be expected to have important social and environmental benefits.

Abandoned ponds leave farmers with no income (or a much reduced income) from aquaculture. Higher incomes can be expected to lead to higher employment in the coastal regions characterised by tambak production systems.

In the absence of remediation, the existing pond system is likely to gradually break down. There are limited other uses for the ponds as currently structured. Rice production is not generally now feasible although some of the areas previously grew rice. The brackish-water source, high levels of acid sulfate impact and the fact that the ponds have been dug deeper for shrimp production are key constraints. Typically, there is no topsoil within the ponds in which to establish rice crops, even though some salt-tolerant varieties have been developed.

7 Conclusions

ACIAR, together with investment by Australian research agencies and partner agencies in Indonesia, has made a significant investment in fisheries in Indonesia. This investment, begun in the late 1980s, has the potential to bring substantial benefits to Indonesia, Australia and, more generally, other countries, especially for consumers of fish sourced from Indonesia. Further, the common property issues associated with wild fisheries management and the inter-nation aspects of these fisheries means that, from both a commercial and environmental perspective, R&D investments which help improve fisheries management will typically provide benefits beyond national borders.

Key observations of the ACIAR investment in fisheries Indonesia include the following:

- ACIAR's investment has traversed a wide range of fisheries and fishing activities. This impact assessment has provided an overview of the diversity of projects and the linkages between them.
- Workshops and scoping studies were used to identify the key problems, R&D strategies and partnership arrangements (in R&D and to facilitate implementation) and from these activities specific R&D projects have been developed. Not surprisingly these processes have meant that delivering R&D outputs has taken time.
- In many areas the R&D has required a substantial 'Indonesianisation'. Generally it has not been possible to take Australian or other R&D findings or management practices and apply them to the Indonesian situation. For example, data collection techniques and approaches to capture fisheries have been applied, but the R&D outputs rely upon application in the Indonesian situation to then identify possible and appropriate management strategies. Equally, some technology solutions, such as in the remediation of tambaks, are not necessarily overly complex in themselves, but they do require a full understanding of the farm management decision-making context and attitudes to risk. As the ACIAR projects have shown, these are issues that will need to continue to be attended to in the future.
- To date, much of the capture fisheries R&D has focused on information collection, analysis and modelling to help with subsequent fisheries management. This work has relatively long lead times in terms of impacting upon fisheries management and the realisation of subsequent commercial and environmental benefits. While there have been some impacts to date, much of the potential benefit of this work has yet to be realised.
- Adoption of R&D outputs remains a key issue in many project areas. In the context of aquaculture, adoption will be in the near-term set of issues that a number of projects will need to address. These issues are recognised by researchers and agencies alike but, nonetheless, it will take a concerted focus to ensure that R&D findings are translated into outcomes that benefit Indonesia.
- Directly and indirectly the ACIAR projects have led to a substantial increase in the capacity of Indonesian researchers and agencies to formulate and undertake R&D, to apply R&D findings to other areas (other issues and regions) and to generally provide support services for R&D as well as government operations. By way of illustration, the ACIAR projects focusing on acid sulfate soils have led to further projects focused on land use planning and the associated capacity for soil assessment locally in the project areas (Sulawesi) as well as more generally across Indonesia.

- Combined with the work of other agencies, the ACIAR projects have helped better understand the fickle nature of many of Indonesia's fisheries and the fact that the fisheries resource base is not as resilient to historical levels of fishing as had been believed in the early 1990s. However, developing (and more importantly implementing) the management regimes that will be needed to handle over-fishing problems will be challenging. IUU fishing remains a key issue.

The two project areas examined in this impact assessment have shown high rates of return on the investment made by ACIAR and the associated research and partner organisations. The salient points are:

- The contribution that the ACIAR investment has made to the data collection and modelling of the SBT fishery in Indonesia, thus enabling and facilitating Indonesian membership of the CCSBT. It is estimated that the projects will yield benefits of around $168 million (NPV) over the next 20 years. This represents a return on investment of 180:1, and a rate of return of some 210%. In addition, the past and continuing R&D can be expected to deliver significant benefits from better management of the yellowtail and bigeye tuna fisheries which are facing much the same challenges as the SBT fishery.
- In aquaculture the ACIAR project investment is estimated to yield substantial future benefits as the Indonesian Government pursues revitalisation of the aquaculture industries. Without the ACIAR project R&D, and its demonstrated applicability, the traditional tambak shrimp-farming sector would continue to languish. The estimated benefits from restoring production in village tambaks, net of the investment that the government will make to assist farmers, is $547 million (NPV over 20 years). This represents a return of 52:1 (BCR) or 26% (IRR). In addition, the investment can be expected to have significant payoffs in other areas. In particular, the land use suitability mapping that has been developed by the project teams will enable better land use planning and investment based on land use capability, thus potentially avoiding the mistakes of the past, in respect of both aquaculture and other land use activities, including cropping. The tambak remediation R&D also demonstrates the gains from capacity building. Although not quantified, the knowledge of the issues associated with acid sulfate soils meant that a rapid response to the problem of tambak reconstruction in Aceh was possible, albeit recognising the difficulties of initially gaining acceptance by the agencies involved in the reconstruction in Aceh.

Although these two project areas have illustrated the potentially high returns that can be achieved from fisheries R&D in Indonesia some caution is required in drawing generalisations.

In respect of the SBT analysis the ACIAR investment was certainly a key factor in achieving Indonesian membership CCSBT. However, the key drivers for Indonesian membership were international as well as Indonesian. The benefits for SBT-consuming countries, and for SBT fishing interests such as Australia, meant that the R&D output could be used within the existing management framework of the CCSBT. That circumstance will not necessarily apply in all circumstances as the rationale for the projects on IUU fishing demonstrates.

The return to the investment in remediation of the tambaks reflects the underlying situation that much of the area of tambaks lies idle. The engineering costs of developing the ponds and associated water inflow and outlets are sunk costs. They do not have to be incurred to realise the gains from remediation of the tambaks and there is no alternative use in sight for much of the tambak area. Ordinarily these engineering and opportunity costs would limit the investment returns. Thus, the estimated investment return from this area of aquaculture is unlikely to be replicated in other areas of Indonesian aquaculture.

In summary, the ACIAR investment in fisheries in Indonesia has shown high rates of return in the two project areas examined in detail. There has been a substantial investment in other projects. Some of these are nearing the point where the potential returns will be realised.

References

ABARE (Australian Bureau of Agricultural and Resource Economics) 2007. Fisheries status report, October 2007, p. 66. ABARE: Canberra.

ACIAR (Australian Centre for International Agricultural Research) various years. ACIAR activities in fisheries and aquaculture. ACIAR: Canberra.

Alston J.M. and Pardey P.G. 2001. Attribution and other problems in assessing the returns to agricultural R and D. Agricultural Economics 25, 141–152.

Campbell H.F. and Kennedy J.O.S. 2007. Alternative futures for southern bluefin tuna. International Journal of Global Environmental Issues, 7, 240–254.

Campbell H.F., Kennedy J.O.S. and McIlgorm A. 2002. Conservation and optimum utilization of southern bluefin tuna. P. 18 in 'Eleventh biennial conference of the International Institute of Fisheries Economics and Trade, Victoria University, Wellington, New Zealand, 19–22 August 2002'. At: <http://oregonstate.edu/Dept/IIFET>.

CCSBT (Commission for the Conservation of Southern Bluefin Tuna) 2006. Report of the thirteenth annual meeting of the Commission, October 2006. At: <http://www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_13/report_of_CCSBT13.pdf>.

— 2007. P. 33 in 'Report of the fourteenth annual meeting of the Commission, Canberra, Australia, October 2007'. At: <http://www.ccsbt.org/docs/pdf/meeting_reports/ccsbt_14/report_of_CCSBT14.pdf>.

Dyspriani P. 2007. Governance and the study of shrimp revitalization program in Indonesia. Masters thesis in international fisheries management, Norwegian College of Fishery Science, University of Tromsø, May 2007. At: <http://www.ub.uit.no/munin/bitstream/10037/1008/3/thesis.pdf>.

Josupeit H. 2004. An overview on the world shrimp market, 2004. At: <http://www.globefish.org/files/SHRIMPMadrid_171.pdf>.

— 2007. Aquaculture trade and prices, May 2007. At: <http://www.globefish.org/files/12_Josupeit_wild_aquaculture_445.PPT>.

Jusuf G. and R. Dahuri R. 1999. The impact of the economic crisis on Indonesia's fishery sector. Ch. 15 in 'Indonesia's economic crisis: effects on agriculture and policy responses', ed. by R. Stringer, S. Bahri, M.S. Pasaribu and P. Simatupang. Centre for International Economic Studies Indonesia Working Papers 99.23. CIES: Adelaide. At: <http://www.adelaide.edu.au/cies/papers/iwp9924.pdf>.

MMAF (Ministry of Marine Affairs and Fisheries) 2005. The revitalization of aquaculture 2006–2009. MAFF: Jakarta.

Pahlevi, R.S. 2007. Current status and future trends in aquaculture in Indonesia, ACIAR Consultation Jakarta, 21 February 2007. At: <http://www.aciar.gov.au/system/files/node/766/Current+status+and+future+trends+in+aquaculture+-+Reza+Shah+Pahlevi+(Ministry+of+Marine+Affairs+and+Fisheries).ppt>.

Poudel P. and Keithly W. Jr. 2008. Analysis of United States and European Union import demand for shrimp. Paper to the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, 2–6 February 2008. At: <http://ageconsearch.umn.edu/bitstream/123456789/30326/2/sp08po12.pdf>.

Rangka 2007. Production of tiger shrimp (*Penaeus monodon*) in farm experimental ponds in Luwu Regency, South Sulawesi. Research analysis, unpublished.

WorldFish Center 2004. Disaggregated projections on supply, demand and trade for developing Asia: preliminary results from the ASIA FISH model. At: <http://oregonstate.edu/dept/IIFET/Japan/proceedupdates/306.pdf>.

Appendix. Benefits and costs: tambak remediation

	ACIAR costs	Australian R&D organisations	Indonesian partner organisations	Total	Present value (PV) producer surplus	PV of consumer surplus	PV of total surplus	Net benefits
	$	*$*	*$*	*$*	*$m*	*$m*	*$m*	*IRR (%)*
	2,989,562	3,304,628	901,323	7,195,514				72
1999	602,531	732,044	208,318	1,542,893				–2
2000	274,162	552,172	204,896	1,031,231				–1
2001	488,457	680,413	213,236	1,382,105				–1
2002	227,960	220,593	13,770	462,323				–0
2003	110,938	215,494	11,140	337,572				–0
2004	199,770	155,357	8,988	364,114				–0
2005	34,778	–	–	34,778				–0
2006	354,669	108,746	25,996	489,411	4	2	5	5
2007	413,183	319,160	54,040	786,383	42	6	48	47
2008	479,591	427,831	139,205	1,046,627	70	3	74	72
2009	389,034	388,289	117,403	894,726	96	10	106	105
2010	177,899	177,899	70,294	426,092	173	–1	172	172
2011	51,189	51,189	33,031	135,409	172	1	172	172
2012					172	–1	172	172
2013					172	1	172	172
2014					172	–1	172	172
2015					172	1	172	172
2016					172	–1	172	172
2017					172	1	172	172
2018					173	–1	172	172

Appendix (continued)

	ACIAR costs	Australian R&D organisations	Indonesian partner organisations	Total	Present value (PV) producer surplus	PV of consumer surplus	PV of total surplus	Net benefits
	$	*$*	*$*	*$*	*$m*	*$m*	*$m*	*IRR (%)*
2019					172	1	172	172
2020					173	–1	172	172
2021					172	1	172	172
2022					173	–1	172	172
2023					172	1	172	172
2024					173	–1	172	172
2025					172	1	172	172
NPV	4,464,471	4,934,976	1,345,994	10,745,441	1,980.0	20.0	2,000.0	

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce, D. (2002)	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner, R. and Bauer, M. (2002)	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod, R. (2003)	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
23	McLeod, R. (2003)	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036

No.	Author(s) and year of publication	Title	ACIAR project numbers
25	Brennan, J.P. and Quade, K.J. (2004)	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen, J.D. (2004)	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren, M. (2004)	Acacia hybrids in Vietnam	FST/1986/030
28	Harris, D. (2004)	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
29	Lindner, R. (2004)	Impact assessment of research on the biology and management of coconut crabs on Vanuatu	FIS/1983/081
30	van Bueren, M. (2004)	Eucalypt tree improvement in China	FST/1990/044, FST/1994/025, FST/1984/057, FST/1988/048, FST/1987/036, FST/1996/125 and FST/1997/077
31	Pearce, D. (2005)	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce, D. (2005)	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere, D. (2005)	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009, LWR2/1996/143
34	Pearce, D. (2005)	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer, D.A. and Lindner, R. (2005)	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner, R. (2005)	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
37	McLeod, R. (2005)	Management of fruit flies in the Pacific	CS2/1989/020, CS2/1994/003, CS2/1994/115 and CS2/1996/225
38	ACIAR (2006)	Future directions for ACIAR's animal health research	
39	Pearce, D., Monck, M., Chadwick, K. and Corbishley, J. (2006)	Benefits to Australia from ACIAR-funded research	FST/1993/016, PHT/1990/051, CS1/1990/012, CS1/1994/968, AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
40	Corbishley, J. and Pearce, D. (2006)	Zero tillage for weed control in India: the contribution to poverty alleviation	CS1/1996/013
41	ACIAR (2006)	ACIAR and public funding of R&D. Submission to Productivity Commission study on public support for science and innovation	
42	Pearce, D. and Monck, M. (2006)	Benefits to Australia of selected CABI products	
43	Harris, D.N. (2006)	Water management in public irrigation schemes in Vietnam	LWR2/1994/004 and LWR1/1998/034
44	Gordon, J. and Chadwick, K. (2007)	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004 and LWR2/1998/034
45	Turnbull, J.W. (2007)	Development of sustainable forestry plantations in China: a review	
46	Monck M. and Pearce D. (2007)	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060

No.	Author(s) and year of publication	Title	ACIAR project numbers
47	Fisher, H. and Gordon, J. (2007)	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore, C., Gordon, J., and Bantilan, M.C. (2007)	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968
49	Fisher, H. and Gordon, J. (2007)	Minimising impacts of fungal disease of eucalypts in South-East Asia	FST/1994/041
50	Monck, M. and Pearce, D. (2007)	Improved trade in mangoes from the Philippines, Thailand and Australia	PHT/1990/051 and CS1/1990/012
51	Corbishley, J. and Pearce, D. (2007)	Growing trees on salt-affected land	FST/1993/016
52	Fisher H. and Gordon J. (2008)	Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts	AS2/1994/023
53	Monck M. and Pearce D. (2008)	The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology	AH/1997/115
54	Monck M. and Pearce D. (2008)	Impact of improved management of white grubs in peanut-cropping systems	CS2/1994/050
55	Martin G. (2008)	ACIAR fisheries projects in Indonesia: review and impact assessment	FIS/1997/022, FIS/1997/125, FIS/2000/061, FIS/2001/079, FIS/2002/074, FIS/2002/076, FIS/2005/169 and FIS/2006/144

ACIAR Impact Assessment Series 55

ACIAR fisheries projects in Indonesia:
review and impact assessment





Part of Australia's development
assistance program

www.aciar.gov.au