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.

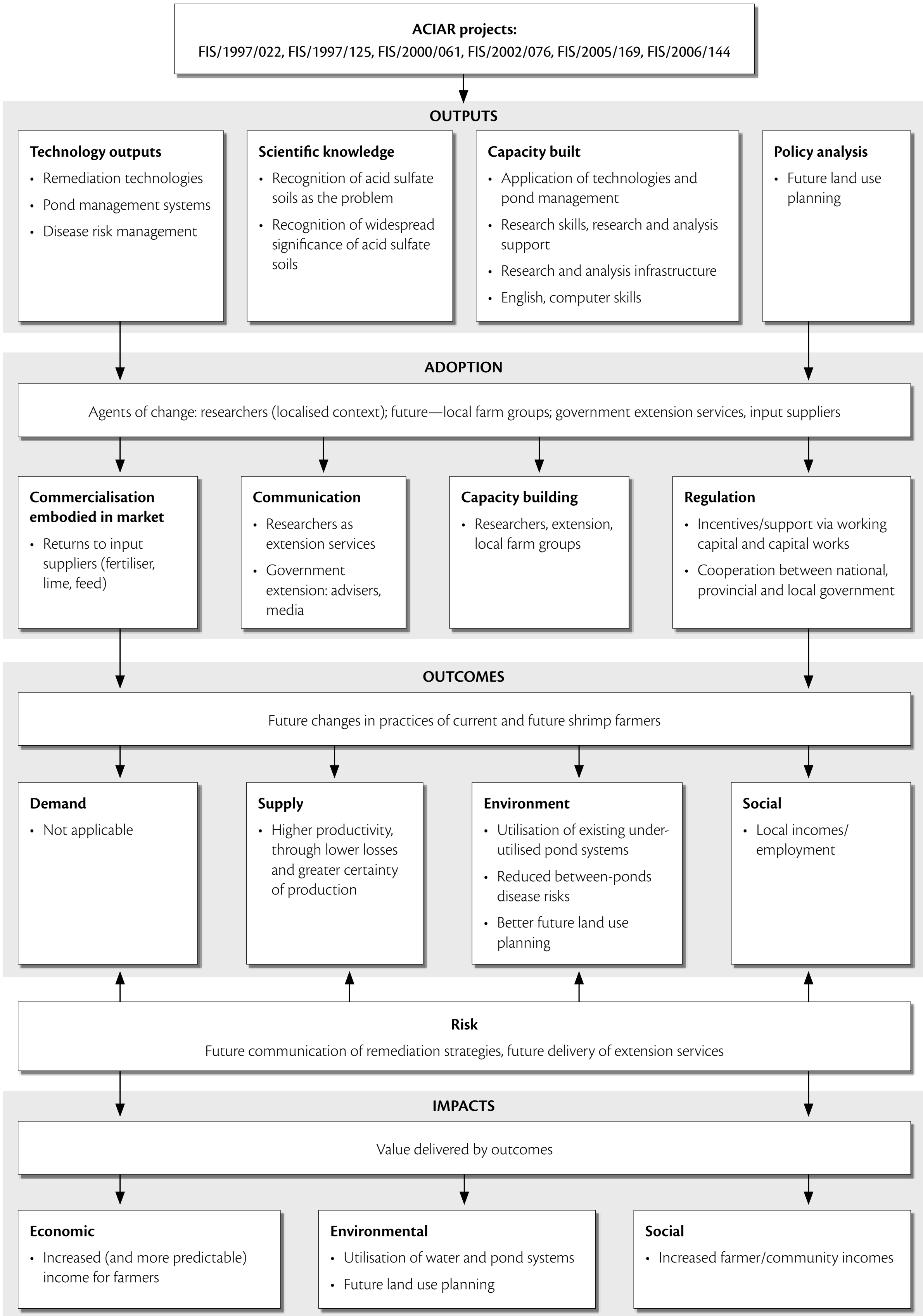

Figure 7. Tambak remediation and shrimp farming in Indonesia: results frame chart

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.

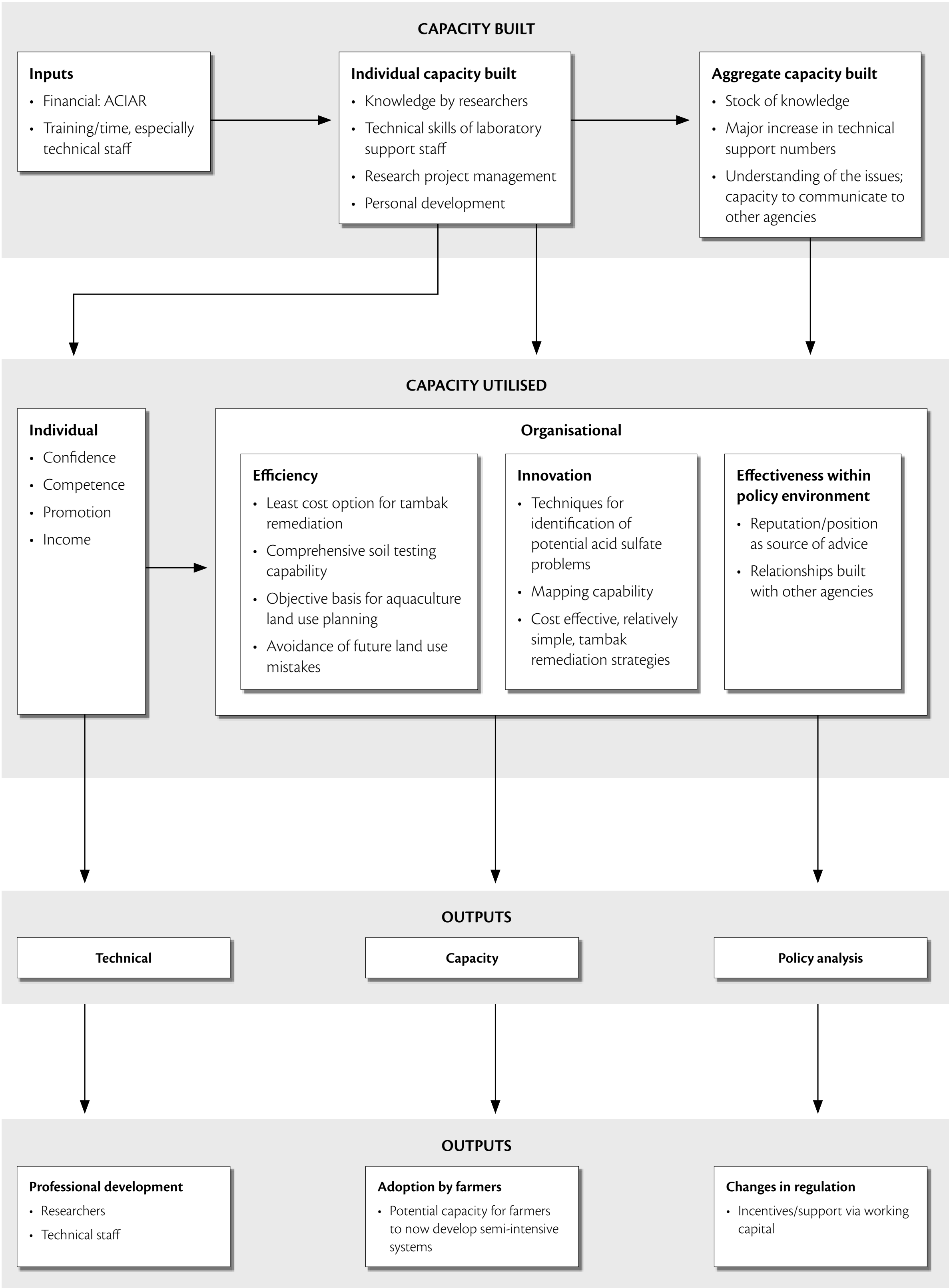

Figure 8. Summary of capacity building in the ACIAR projects on tambak remediation and shrimp farming in Indonesia

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).

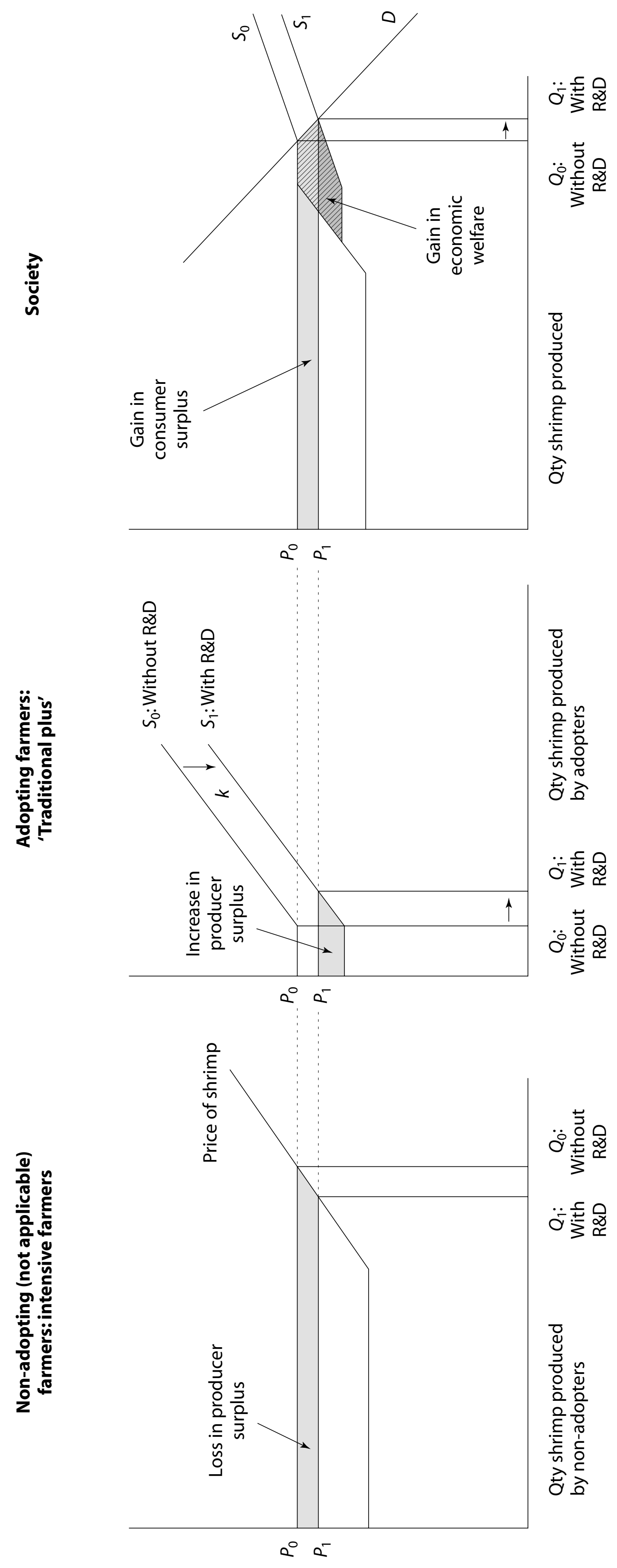

Figure 9. Measurement of consumer and producer surplus due to adoption of tambak remediation technology

- 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.

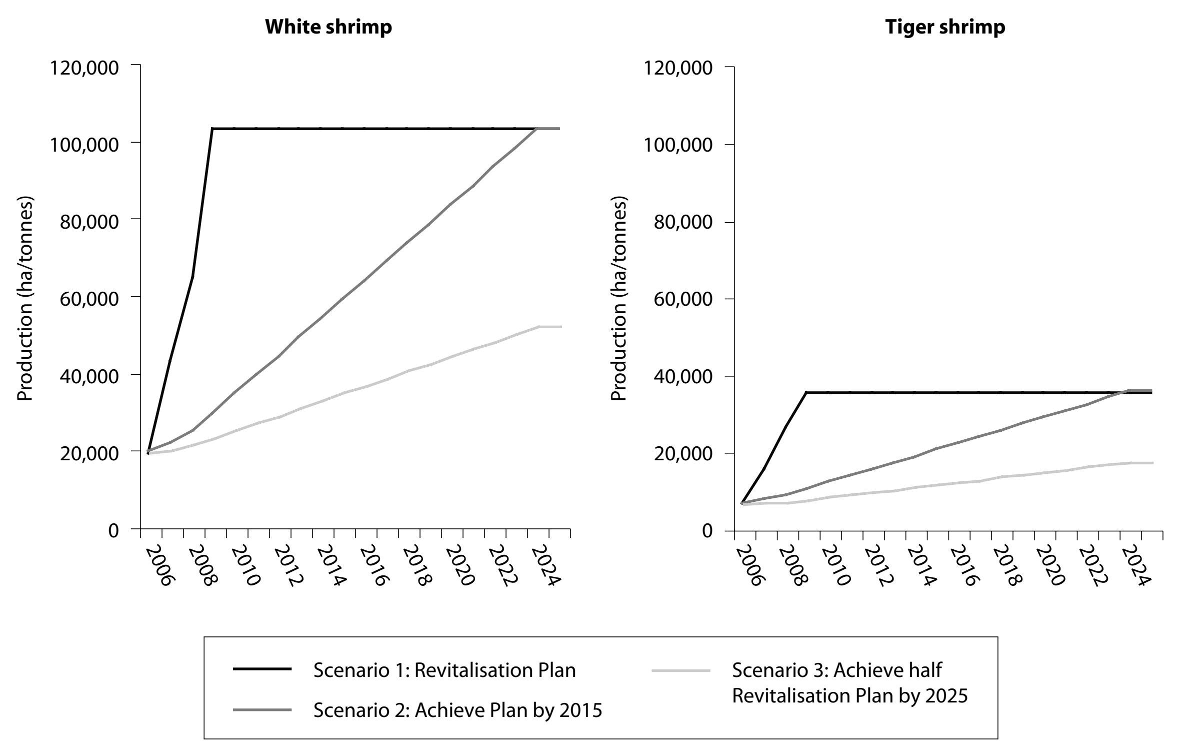

Figure 11. Adoption scenarios: tambak remediation

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

IMPACT ASSESSMENT SERIES <CONTINUED>

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