REDUCING FISH LOSSES DUE TO EPIZOOTIC ULCERATIVE SYNDROME —
An *ex ante* evaluation

ACIAR Project 9130

Centre for International Economics
July 1998

ACIAR is concerned that the products of its research are adopted by farmers, policy-makers, quarantine officials and others whom its research is designed to help.

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

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Contents

1. Summary

The Australian Centre for International Agricultural Research (ACIAR) project no. 9130 established causes and control measures for epizootic ulcerative syndrome, a major killer of wild and cultured fish. The project cost $1.7 million dollars and, based on conservative assumptions, could yield net benefits (in present value terms) of $56 million. These significant benefits are a result of the importance of fish production in Australia, Indonesia and Thailand, both as a commercial crop and a source of subsistence income.

These benefits are based on the assumption that the knowledge obtained from the project is actually adopted by fish producers and others. There is no guarantee of this, and the results should be interpreted in that light. This also suggests that ACIAR could achieve high leverage from funds devoted to increasing rates of adoption.

2. The Project

ACIAR project no. 9130, *Improving Fish Production in Freshwater Aquaculture and in Estuaries by Reducing Losses due to Epizootic Ulcerative Syndrome*, commenced in 1993, was completed by 1996 and subsequently extended, reflecting the recommendations of the review committee.

The project combined a number of research streams and involved a multi-disciplinary team. It included research in epidemiology (the study of disease transmission), mycology (the study of fungi), pathogenesis (the study of disease development), ecology, and soil and water chemistry. The project also included training and extension activities.

2.1 Background to the Problem

Epizootic Ulcerative Syndrome

Epizootic Ulcerative Syndrome (EUS) is a pathogenic, invasive fungal infection of Asian and Australian freshwater and estuarine fish. EUS causes skin ulceration and death in both wild and farmed freshwater fish populations. Figure 1 shows how EUS has spread across the Asia–Pacific in a relatively short time.

Figure 1. Outbreaks of Epizootic Ulcerative Syndrome (1970–92).

Data source: ACIAR (1997).

EUS causes seasonally recurrent losses in over 30 species of commercially important cultured and wild fishes, both in freshwater and estuaries (ADB/NACA 1991). The large skin ulcers render fish unmarketable and fish mortality rates are often high during EUS outbreaks.

The need for Research and Development

Prior to the commencement of the project, the relationship between causal agent(s), environment, transmission mechanism, predisposing factors and susceptible fish species was not adequately understood. As a result, control and prevention methods were not available.

The Asian Development Bank (ADB) has identified EUS as one of the most serious fish diseases in the Asia–Pacific region**.** As regional governments and associated organisations are actively promoting aquaculture at the small-holder level (as a means of improving nutrition and rural incomes), the need for a practical EUS control measure was significant (ADB/NACA 1991).

2.2 Objectives of the Project

The project had two research objectives (in order of priority):

- to develop practical, cost-effective, environmentally acceptable control and prevention measures for EUS in pond and rice–fish culture systems—measures applicable at the smallholder level throughout South-East and South Asia; and

- to identify the major causal factors for EUS in estuarine fish, with particular reference to the possible role of run-off water from acid sulphate soil areas.

It was believed that satisfying the first objective would significantly reduce fish losses attributable to EUS in the main freshwater aquaculture systems of South-East and South Asia, thereby improving nutritional intake and income of smallholders and their families. It was hoped that the second objective would facilitate the identification of cost-effective and environmentally acceptable land management practices that could reduce EUS prevalence and enhance estuarine fishery sustainability.

2.3 Outcomes of the Project

An independent review of the project in January 1996 (ACIAR 1996) found that:

> The research resulted in numerous significant findings and achievements relating to understanding the epidemiology and pathogenesis of epizootic ulcerative syndrome, and provided significant directions for cost effective and environmentally acceptable control and treatment mechanisms.

In concluding their assessment of the project, the independent reviewers considered that the project had fulfilled its objectives, namely to:

> … develop practical, cost effective, environmentally acceptable control and prevention measures for EUS in pond and rice–fish culture systems, applicable at the small-holder level throughout Asia, and to identify the major causal factors for EUS in estuarine fish, with particular reference to the role of run-off water from acid sulphate soils.

The research carried out in the project established:

- that the onset of EUS was associated with exposure to acidic water, rainfall events, decreased salinity and decreased water temperatures;
- a causative role for a pathogenic species of the fungus *Aphanomyces* and demonstrated a high level of similarity between isolates of the fungus from different countries;
- the growth and environmental requirements for the causative agent, providing possible control and treatment measures;
- that successful invasion and establishment of EUS within fish requires tissue (epithelial) damage, a susceptible fish species and appropriate environmental conditions;
- the modes of infection and identification of the role of sub-lethal acid exposure and consequent tissue damage in rendering fish susceptible to fungal invasion; and
- an initiating role of acid run-off from acid sulphate soils in the development of EUS.

The project achieved its main objectives, particularly in developing practical and cost-effective measures of control and prevention. The review team considered that chemical treatment of culture ponds with lime to raise pH or with salt to raise salinity may afford protection and treatment against EUS. However, it was recognised that these control measures may not be appropriate in all situations and that further tests were required to validate the control measures.

The review report also recommended an extension of the project to complete and validate some of the research. The extension work was carried out (primarily in the Philippines) and verified that one of the proposed EUS treatments is effective.

3. The Potential Socioeconomic Impacts

The major economic impact of this research will be to reduce the losses in fish production which result from the disease. The economic impact therefore depends upon the importance of fisheries in the countries concerned and on the impact that EUS would continue to have in the absence of control measures.

3.1 Importance of Fisheries to Australia, Indonesia and the Philippines

The South-East and South Asia population is growing rapidly and fish products are a customary source of animal protein for most people in the region. By 2010, fish supplies will need to increase by an estimated six million tonnes in order to maintain current consumption levels (FAO 1996). The effect of economic growth on incomes and domestic demand means even higher volumes of fish products will be needed.

Marine fishery resources are generally already being fully utilised and offer few opportunities for increased production, so it is unlikely that future demands for fish products will be met from significant increases in marine fish production. Aquaculture and inland fisheries may provide the answer to future fish production needs, but it is these fisheries that are most at risk from EUS. Table 1 provides selected statistics for the fishery industries of Australia, Indonesia and the Philippines.

Table 1. Fishery summary statistics 1995[a]

			Australia	Indonesia	Philippines[b]
Production volumes					
Freshwater	– Aquaculture	'000 t	13	575	919
	– Wild	'000 t	6	386	972
Marine	– Aquaculture	'000 t	13	na	na
	– Wild	'000 t	194	3 275	893
Total			226	4 236	2 784
Production values					
Freshwater	– Aquaculture	A$m	80[b]	621	1 760
	– Wild	A$m	42	417	1 389
Marine	– Aquaculture	A$m	316	na	na
	– Wild	A$m	1 262	3 539	1 210
Total			1 700	4 578	4 359
Industry employment			na	na	1.8
Growth in production 1994–95					
Freshwater	– Aquaculture	%	2.1	1.8	5.7
	– Wild	%	– 31.6	4.4	–2.1
Marine	– Aquaculture	%	4.5	na	na
	– Wild	%	1.3	6.3	3.9
Total			0.2	5.5	2.3
Fishery contribution to gross domestic product		%	0.4	1.7	4.4
Fishery contribution to employment		%	na	na	6.6

[a]Values for Australia are for the financial year 1995–96.
[b]Freshwater aquaculture value includes some marine products such as culture of oysters, mussels and seaweeds.
na = not available

Source: Statistik Indonesia (1996); Philippine National Statistical Coordination Board; Asian Development Bank; Centre for International Economics (CIE) estimates; ABARE (1997); Brown et al. (1997).

Australia

The quantity and value of wild fish being caught has not changed substantially in recent years. In contrast, the quantity and value of aquaculture has increased markedly over the past six years (75 and 76 per cent, respectively). Australia's aquaculture industry has become a very important supplier of seafood to both Australian and overseas markets. Australia is in a good position to sell quality seafood to these markets as our aquatic environments are clean and a variety of different species can be farmed here.

Relative to Indonesia and the Philippines, the Australian fishing industry is very small, approximately 5 per cent of Indonesian and 8 per cent of Filipino fishing production volumes. In addition, the Australian fishing industry does not contribute significantly to gross domestic product (GDP) (Table 1).

Indonesia

Although fish constitute an important part of the diet of Indonesians, the sector accounted for only about 1.7 per cent of GDP in 1995. Much of the fishing industry's potential has not been fully realised as the industry continues to rely on traditional methods and equipment. With the assistance of the World Bank, United Nations Development Programme (UNDP), Food and Agriculture Organisation of the United Nations (FAO) and individual donor countries, the Indonesian government is introducing a number of measures, including a motorisation program for traditional vessels, to increase fish production. Nearly three quarters of export revenue from fishing comes from shrimps that are exported mainly to Japan.

Over the 20 year period 1975–95, annual growth in total fish harvest was approximately 6 per cent.

Philippines

The Philippines has extensive fishing resources, both marine and inland, with the largest area of developed estuarine fish ponds in South-East Asia. Production in the fishing sector has risen strongly in recent decades and the sector now accounts for approximately 4 per cent of GDP and employs 1.8 million workers. Annual fisheries production is about 2.8 million tonnes. The major exports are shrimp and prawns.

3.2 Impact of Epizootic Ulcerative Syndrome

EUS has the potential to financially decimate those who rely on fishing for income. In addition, and perhaps more importantly, EUS outbreaks threaten food security for subsistence fishers and subsequently people's physical health, as fish are an important source of animal protein for people in many countries of South and South-East Asia.

The tangible effects of EUS, such as fish losses, are quantifiable where data permits. However it is extremely difficult to measure and assign a monetary value to the effects of inadequate nutrition culminating in malnutrition as well as public concern over health risks associated with consuming local water products.

EUS may have other, indirect effects that may not be realised or observed for decades to come. EUS has the potential to pose a threat to aquatic biodiversity (for example, declining fish biomass) and cause irreversible ecological damage. It is extremely difficult to place an economic value on biodiversity. If EUS adversely impacts on aquatic biodiversity and ecology, the effects may not eventuate for many years. It is unclear whether lost biodiversity will impose a cost on future generations, or whether scientific advances will circumvent the problem. For these reasons the impact of EUS on aquatic biodiversity and ecology is not considered in this report. However, this may pose a real and significant cost in the future.

An accurate assessment of the effects of EUS on fish yields, prices, incomes of those working in fishing industries and nutritional intake is difficult to make owing to insufficient data and poor documentation of EUS outbreaks. The reported losses in Table 2 provide an insight into the potential financial impact arising from an EUS outbreak.

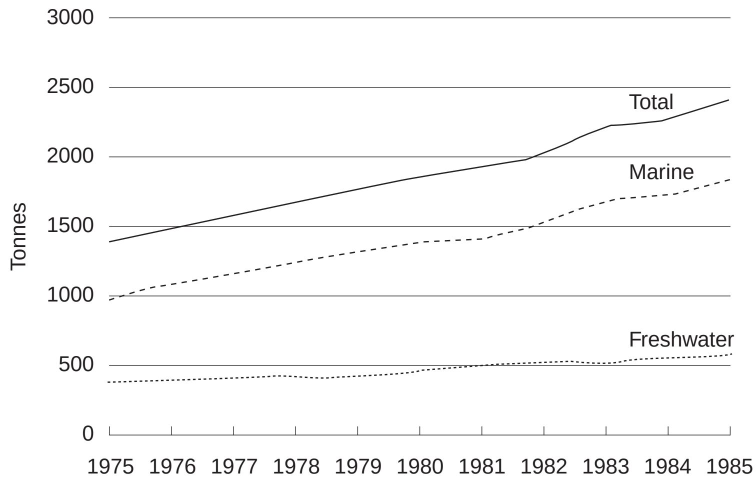
Table 2. Reported fish losses attributed to Epizootic Ulcerative Syndrome (EUS).

Country	Year	Fish type	Fish with EUS (%)	Value (A$m)
Australia (east coast)	Annually	Estuarine	10	1.0
Bangladesh	1988–89	Pond carps	28	4.2
	1989–90	Cultured freshwater	na	3.0
Nepal	1989	Major carps	17	1.7
Indonesia	1980	Cultured freshwater	na	2.5
Thailand	1982	Cultured freshwater	na	10.9
na = not available.				

Source: ACIAR (1993; 1997).

Findings of EUS researchers suggest that the disease imposes a significant economic and social cost. Researchers have reported fish infection rates in EUS affected ponds of between 20 and 80 per cent (ACIAR 1997). From Table 2 we see that, in 1980, EUS in Indonesia was estimated to be responsible for a loss in the fish harvest equivalent to $2.5 million. However, looking at fish production over the period 1975–1985 (Figure 2), the EUS outbreak in 1980 did not appear to have a marked impact on Indonesian fish production. The total fish harvest was largely unaffected in 1980 and the immediately preceding years.

Figure 2. Indonesian fish production from 1975 to 1985.



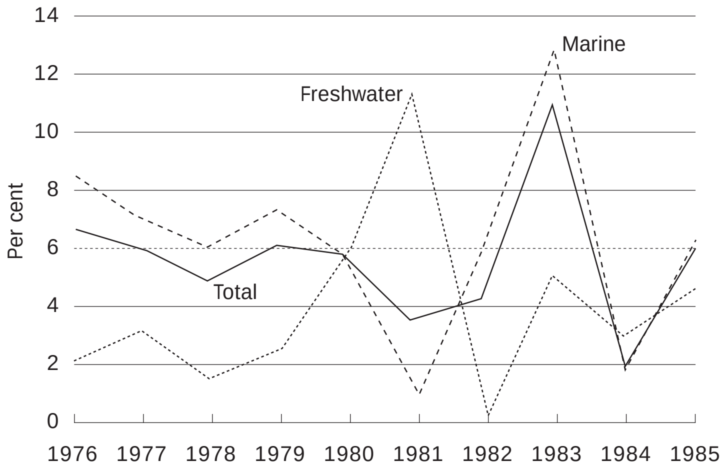
Data source: Statistik Indonesia (1996).

Despite Indonesian fish production volumes remaining (largely) unchanged, of particular importance is the change in rate at which the harvest grew in the EUS affected year(s). Figure 3 plots the change per year in fish harvest over the period 1976–85. Two things are immediately apparent:

- the growth rate in fish production varies widely between years; and
- the effect of the 1980 EUS outbreak on the fish harvest growth rate does not look substantially different to what happened in 1983 when no outbreak was reported.

The second observation raises the possibility that EUS outbreaks may not be the only adverse environmental occurrence that restricts the fish harvest from growing over time. When deciding on the rate at which the fish harvest will be assumed to grow at in the future (the base case scenario), occurrences such as that which occurred in 1983 need to be taken into consideration. For this reason, average per annum growth in fish harvest over an extended period (for example, 1975–95 for Indonesia) is used to determine the base case annual fish harvest.

Figure 3. Growth rate of Indonesian fish production from 1976 to 1985.



Data source: Statistik Indonesia (1996).

3.3 Fish Species at Risk From Epizootic Ulcerative Syndrome

Not all fish species are susceptible to EUS. Subsequently, not all of the fishery production reported in Table 1 is at risk from EUS. In addition, the figures in Table 1 reflect harvest of a wide range of aquatic species. For example, of the 26 000 tonnes of aquaculture harvested in Australia in 1995–96, only 13 000 tonnes were fish—the remainder comprising crustaceans, molluscs, crocodiles, and so on. As only fish are at risk from EUS, it is inappropriate to use the figures reported in Table 1 to perform the benefit–cost analysis. Table 3 shows the fish harvest that is potentially at risk from EUS.

Table 3. Fish production at risk from Epizootic Ulcerative Syndrome[a].

		Australia[b]	Indonesia	Philippines[c]
Production volumes				
Freshwater – Aquaculture	'000 t	3	575	735
– Wild	'000 t	4	386	972
Marine – Aquaculture	'000 t	10	na	na
– Wild	'000 t	118	3 275	893
Total		135	4 236	2 600
Production values				
Freshwater – Aquaculture	A$m	24	621	1 408
– Wild	A$m	10	417	1 389
Marine – Aquaculture	A$m	99	na	na
– Wild	A$m	311	3 539	1 210
Total		443	4 578	4007

[a]Numbers may not add due to rounding. [b]Values for Australia are for the financial year 1995–96.
[c]Freshwater aquaculture value includes some marine products such as culture of oysters, mussels and seaweeds.
na = not available

Source: Statistik Indonesia (1996); Philippine National Statistical Coordination Board; Asian Development Bank; Centre for International Economics estimates; ABARE (1997); Brown et al. (1997).

Obviously, fish losses will depend in part upon the species of fish being cultured and the susceptibility of that species to EUS. The numbers reported in Table 3 refer to the total fish harvest. These figures are modified to take into account the fact that not all fish are susceptible to EUS. In addition, the share of the fish harvest that is at risk from EUS is likely to decline in the future for two reasons.

- Natural selection in the presence of EUS will favour EUS resistant fish species. These species will, over time, dominate the aquatic environment. Hence, the share of the fish harvest that is at risk from EUS can be expected to diminish over time.

- Fish farmers can be expected to culture EUS resistant fish species as a means of reducing their losses. However, it needs to be acknowledged that it is typically the EUS susceptible fish species that are the most valuable (for example, snakeheads). Individual farmers would need to assess the relative benefits of culturing low value EUS resistant fish compared with high value EUS susceptible fish.

4. Benefit–cost Analysis of the Project

4.1 Evaluation Methodology

- First, a base case scenario is specified. The base case depicts expected fish harvests and EUS-associated fish losses over the time period 1997–2027. The base case represents a business-as-usual situation where the disease is unabated and allowed to run its course.
- Second, an alternative scenario is derived where the research and development (R&D) associated with project no. 9130 is assumed to be effective in reducing EUS related fish losses.
- Third, the difference between the base case and alternative scenarios is quantified and assigned a monetary value for each year over which the project is evaluated. These monetary values are then discounted and summed. The discounted value of the project costs are then subtracted from the benefits, yielding a net present value (NPV) for the project.

A NPV greater than zero infers that the benefits arising from the project, bearing in mind the assumptions made, are greater than the cost of the project.

4.2 Key Assumptions

In order to carry out the benefit–cost analysis several key assumptions have been made. The sensitivity of the NPV to these key assumptions has been investigated by varying (some) key parameters and observing the effect on the NPV. The outcome of the sensitivity analysis is presented later in this report (Table 6).

Table 4 shows the key assumptions made and the values assigned to the associated parameters. In concordance with the ACIAR guidelines for calculating net benefits, these assumptions are on the conservative side.

There are a variety of sources for the estimates presented in Table 4. The key sources for each of these are as follows.

►►►► (1) The literature (including ACIAR 1993 and 1997) refers to varying fish susceptibility to EUS. Mr R. Callinan (NSW Fisheries, personal communication) confirmed that fish susceptibility was contingent on fish species and also commented that presence of EUS would select in favour of EUS resistant fish species, thereby decreasing fish at risk from EUS over time. As there is no definitive value, we have used a range of values here.

►►►► (2) Depends on (1). As (1) is variable, so therefore is (2).

Role of (1) and (2) is to gauge sensitivity of the net benefit estimate to assumptions about the sensitivity of fish to EUS.

Table 4. Key assumptions and parameter values.

Assumption	Associated parameter values
■ (1) Starting fish EUS susceptibility rates	Variable, three starting values are used in the sensitivity analysis: 80, 60 or 40 per cent of the freshwater fish harvest is initially assumed to be at risk from EUS. Five per cent of the marine fish harvest is assumed to be at risk from EUS.
■ (2) Rate at which EUS susceptibility changes over time	Variable depending on the starting and final susceptibility rates chosen. In the sensitivity analysis freshwater fish EUS susceptibility is assumed to decrease by 0.95, 1.34 or 2.28 per cent per annum (respective to starting and final EUS susceptibility rates). Marine fish EUS susceptibility is not assumed to change over time.
■ (3) Fish losses due to EUS	Five per cent of the freshwater fish harvest is assumed to be lost due to EUS (basecase). One per cent of the marine fish harvest is assumed to be lost due to EUS (base case).
■ (4) Project no. 9130 reduces fish losses attributable to EUS by :	Variable, a range of rates reflecting the effectiveness of the EUS control and prevention technique in reducing fish losses attributable to EUS has been used in the sensitivity analysis.
■ (5) Adoption rate	Variable, in the sensitivity analysis the full extent of the control and prevention technique in reducing fish losses is felt after ten years.
■ (6) Rate at which fish harvest grows over time	Freshwater fish harvest grows in all countries at a rate of 2 per cent per annum. Marine fish harvest grows in all countries at a rate of 1 per cent per annum.
■ (7) Per annum decrease in fish harvest growth rate	Freshwater fish harvest growth rate assumed to fall by 5 per cent per annum. Marine fish harvest growth rate assumed to fall by 10 per cent per annum.

Table 4. (cont'd) Key assumptions and parameter values.

Assumption	Associated parameter values
■ (8) Initial susceptible fish harvest production volume	1995 freshwater and marine harvest volumes used.
■ (9) Initial susceptible fish harvest production value	1995 freshwater and marine harvest values used, converted into Australian dollars.
■ (10) Value of 1 tonne of fish	Calculated for each country for freshwater and marine fish using 1995 fish volumes and values.

Source: Refer to text discussion.

▶▶▶▶ (3) The (available) literature typically reports extensive fish losses attributable to EUS. Due to poor and inadequate data collection, the reported EUS-related fish losses are difficult to verify and quantify. Where data exists, the results are typically drawn from a small sample and extrapolated to the entire population. EUS-related fish losses are reported to be around 10 per cent of the annual fish harvest. Because of the uncertainty surrounding the true impact of EUS, a conservative estimate of its affect has been used in the benefit–cost analysis.

▶▶▶▶ (4) There is little data on the success of the identified EUS control and prevention technique in reducing EUS related fish losses. Hence, the benefit–cost analysis uses a range of conservative success rates.

▶▶▶▶ (5) To date there is no data on the uptake rate of the identified EUS control and prevention techniques. It is unlikely that these techniques will be immediately adopted. To account for this, a gradual uptake rate has been incorporated into the benefit–cost analysis.

▶▶▶▶ (6) This is based on past fish harvest volume growth, adjusted to reflect the potential for growth in the future.

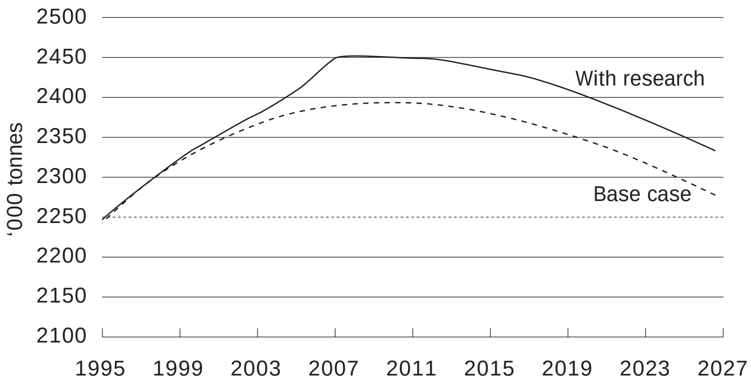
▶▶▶▶ (7) This reflects future potential of resources with the marine environment almost fully utilised, hence a largerdecrease in fish harvest growth rate per annum than that for the freshwater environment.

▶▶▶▶ (8) and (9) and (10). These are derived from published statistics for 1995, the latest year for which common data are available for all countries.

4.3 Baseline and Alternative Scenarios

Figure 4 shows the harvest of EUS susceptible fish under the baseline and 'with research' scenarios which EUS-related fish losses are reduced as a result of the R&D conducted in the project. The difference between these two lines is the value of the benefits of the project.

Figure 4. Illustration of baseline and 'with research' scenarios.



Data source: Centre for International Economics estimates.

Figure 4 is presented for illustrative purposes only and is based on the assumption that 80 per cent of the freshwater fish harvest is susceptible to EUS in 1997, falling to 60 per cent susceptibility in 2027. The R&D associated with the project is assumed to reduce fish losses attributable to EUS by 50 per cent. The chart shows that in 2005, for example, under the baseline 2 380000 tonnes of fish are harvested, but with the research 2406000 tonnes are harvested. The difference is the value of the research.

The shape of the lines in Figure 4 illustrates two key assumptions. The base case harvest of susceptible fish increases and then declines, reflecting the reduction in the proportion of fish susceptible to EUS over time. The increasing divergence between the two lines reflects the gradual adoption of the control technologies.

4.4 Benefits of the Project

To derive the benefits arising from project no. 9130, the increase in useable fish harvest arising from the R&D conducted in the project is calculated for each year and then valued.

4.5 Costs of the Project

The costing of project no. 9130 is shown in Table 5. Initially, ACIAR assigned $669 262 to the project, followed by three further funding allocations resulting in total project costs of $1.6 million.

Table 5. Total funding for project no. 9130 (A$ 1992).

Contributing organisation[a]	Year 1 1993	Year 2 1993–94	Year 3 1994–95	Year 4 1995–96	Total
ACIAR	189 789	210 384	162 280	106 809	669 262
ACIAR extend funding	0	29 757	22 078	24 700	76 535
Indonesia	39 300	79 300	89 200	47 900	255 700
Philippines	19 015	38 030	38 030	19 015	114 090
NSW Department of Fisheries	49 492	89 785	89 785	44 892	274 354
NSW Department of Agriculture	13 196	26 393	26 393	13 196	79 178
University of NSW	2 875	4 250	2 750	1 375	11 250
Queensland Department of Primary Industries	19 568	39 920	41 428	21 133	122 103
Total	333 235	517 819	471 998	279 020	1 602 072
ACIAR contribution (%)			57	46	39

[a]The NSW Department of Fisheries was the commissioned organisation for the project. The NSW Department of Agriculture, University of NSW and the Queensland Department of Primary Industries were collaborating institutions.

Source: ACIAR (1993).

4.6 Net Benefits of the Project

Table 6 shows the NPVs obtained from the benefit–cost analysis under different assumptions about susceptibility of fish to EUS and the success of project no. 9130 in reducing fish losses attributable to EUS.

Table 6. Net present values under different assumptions: 1996 (A$m, assumes 5 per cent real discount rate)

Fish harvest susceptibility			Fish losses attributable to EUS reduced by (%)						
Freshwater		Marine	10	25	33	50	66	75	90
Initial	Final								
80	60	5	136	316	410	608	791	894	1055
60	40	5	97	224	290	430	559	532	752
40	20	56	130	168	249	324	365	435	

Source: Centre of International Economics estimates.

Using the most conservative assumptions about fish susceptibility to EUS and the success of project no. 9130 in reducing fish losses attributable to EUS, the project is still estimated to have a NPV of $129 million.

5. Qualifications and Conclusions

Project no. 9130 cost $1.7 million (1996 dollars). Under the most conservative assumptions, the NPV of potential benefits from the project are valued at $56 million (1996 dollars). The NPV of the project remains positive even when the project reduces current EUS losses by only 0.1 per cent. This occurs for two reasons. First, the project is not costly; and second, the value of fish lost due to EUS is very large. Hence, only a small fraction of the fish lost need to be protected from EUS in order for the project to have a positive NPV.

The NPV is dependent on the assumptions made concerning the rate of growth in fish harvests, the susceptibility of fish to EUS, fish losses attributable to EUS and the success of project no. 9130 in reducing those fish losses. The assumptions made in this benefit–cost analysis are conservative. Based on these assumptions, project no. 9130 was clearly cost-effective and represented a prudent expenditure decision.

The calculated benefits of the project refer to the value of fish saved as a result of applying the disease mitigation technique(s) developed. For subsistence fishers, the change in welfare (or consumer surplus) is approximated by the value of fish saved. If, as a result of EUS, subsistence fishers do not harvest the required quantity of fish, they must purchase the shortfall at market prices. Hence, if there are only subsistence fishers, the change (increase) in welfare is equivalent to the value of fish saved.

In the case of commercial fishers, the gain in producer surplus best estimates the gain arising from the R&D. This is because the change in producer surplus reflects the change in returns to the factors of production used in fish harvesting (quasi-rents). The change in value of fish harvest simply reflects market prices.

As the value of fish saved is greater than the change in producer surplus, using the value of fish saved overstates the benefits that accrue to commercial fishers. Estimating the change in producer surplus requires detailed knowledge of the demand and supply schedules for fish products.

As this information is not available, the change in fish harvest value has been used as a proxy for the benefits arising from the R&D.

The R&D carried out in project no. 9130 resulted in the identification of an effective control and prevention technique for EUS that is applicable at the smallholder level. However, the identification of a control and prevention technique does not infer that the technique will be adopted and used by those for whom it was developed. Obviously, the greater the uptake rate and application of the identified treatment mechanism, the greater the NPV of the project. For example, if application of the identified EUS mitigation technique is such that EUS losses are reduced by 50 per cent as opposed to 33 per cent, the NPV of the project is increased from $290 million to $430 million.

The role of the adoption rate in determining the NPV of the project has possible implications for future ACIAR funding. The returns (in terms of NPV) may be greater from supporting programs aimed at increasing the uptake of the identified EUS control and prevention technique as opposed to funding R&D into other areas. Extension work providing fish farmers with advice on EUS prevention, control and related public health aspects may yield greater returns than pioneering R&D in another field.

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Appendix

Table A.1 Sample benefit–cost analysis[a] for 1996 (A$ millions).

Period	Year	Research costs		Benefits					Totals		
		Nominal $	1996 $	Australia	Indonesia		Philippines		Gross benefits	Net benefits	NPV
				1996 $	Rupiah 1996	1996 $	Peso 1996	1996 $	1996 $	1996 $	1996 $
1	1993	0.33	0.36							–0.36	–0.36
2	1994	0.52	0.55							–0.55	–0.53
3	1995	0.47	0.50							–0.50	–0.45
4	1996	0.28	0.29							–0.29	–0.25
5	1997	0	0	0.01	426	0.24	12	0.59	0.84	0.84	0.69
6	1998	0	0	0.01	534	0.30	15	0.74	1.05	1.05	0.82
7	1999	0	0	0.01	668	0.37	18	0.93	1.31	1.31	0.98
8	2000	0	0	0.02	836	0.46	23	1.16	1.64	1.64	1.17
9	2001	0	0	0.02	1046	0.58	29	1.45	2.05	2.05	1.39
10	2002	0	0	0.03	1306	0.72	36	1.81	2.56	2.56	1.65
11	2003	0	0	0.04	1631	0.90	45	2.25	3.19	3.19	1.96
12	2004	0	0	0.04	2035	1.13	56	2.81	3.98	3.98	2.33
13	2005	0	0	0.06	2538	1.41	69	3.50	4.96	4.96	2.76
14	2006	0	0	0.07	3163	1.75	86	4.36	6.18	6.18	3.28
15	2007	0	0	0.09	3940	2.19	108	5.42	7.69	7.69	3.88
16	2008	0	0	0.09	3897	2.16	106	5.35	7.60	7.60	3.66
17	2009	0	0	0.09	3852	2.14	105	5.29	7.51	7.51	3.44
18	2010	0	0	0.08	3806	2.11	104	5.22	7.41	7.41	3.23
19	2011	0	0	0.08	3759	2.08	102	5.14	7.31	7.31	3.04
20	2012	0	0	0.08	3711	2.06	101	5.07	7.21	7.21	2.85
21	2013	0	0	0.08	3663	2.03	99	5.00	7.11	7.11	2.68
22	2014	0	0	0.08	3613	2.00	98	4.92	7.01	7.01	2.52
23	2015	0	0	0.08	3564	1.98	96	4.85	6.91	6.91	2.36
24	2016	0	0	0.08	3513	1.95	95	4.77	6.80	6.80	2.21
25	2017	0	0	0.08	3463	1.92	93	4.70	6.70	6.70	2.08
26	2018	0	0	0.08	3412	1.89	92	4.62	6.59	6.59	1.95
27	2019	0	0	0.08	3361	1.86	90	4.54	6.49	6.49	1.82

Table A.1 (cont'd) Sample benefit–cost analysis[a] for 1996 (A$ millions).

Period	Year	Research costs		Benefits					Totals		
		Nominal $	1996 $	Australia	Indonesia		Philippines		Gross benefits	Net benefits	NPV
				1996 $	Rupiah 1996	1996 $	Peso 1996	1996 $	1996 $	1996 $	1996 $
28	2020	0	0	0.08	3310	1.84	89	4.47	6.38	6.38	1.71
29	2021	0	0	0.08	3259	1.81	87	4.39	6.27	6.27	1.60
30	2022	0	0	0.07	3209	1.78	86	4.32	6.17	6.17	1.50
31	2023	0	0	0.07	3158	1.75	84	4.24	6.06	6.06	1.40
32	2024	0	0	0.07	3108	1.72	83	4.16	5.96	5.96	1.31
33	2025	0	0	0.07	3057	1.70	81	4.09	5.86	5.86	1.23
34	2026	0	0	0.07	3008	1.67	80	4.01	5.75	5.75	1.15
35	2027	0	0	0.07	2958	1.64	78	3.94	5.65	5.65	1.08
			1.51	0.76		19.00		46.87	66.63	–	55.97

[a]Based on assumptions from the bottom row of Table 6 and assuming that fish losses are reduced by 10 per cent.

Source: Centre for International Economics estimates.