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PROJECT DEVELOPMENT ASSESSMENT : GENETIC IDENTIFICATION AND STOCK IMPROVEMENT OF TILAPIA IN MALAYSIA AND FIJI : PROJECT 9206

M Fearn[1], P Mather[2], J Macaranas[2] and M Capra[3]

in association with M Lagribalavu[4], S Nand Lal[4],
E Ledua[4] and T K Mukherjee[5]

Technical editor : Chris Tweddell

1 Project Economist, ABARE (formerly ANUTECH/ACIAR)
2 Project Scientists, Queensland University of Technology
3 Director, CBPM, Queensland University of Technology
4 Department of Fisheries, Ministry of Primary Industry, Fiji
5 University of Malaya, Kuala Lumpur, Malaysia

Australian Centre for International Agricultural Research

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1. INTRODUCTION

1.1 The Project

The ACIAR Fisheries Program is considering a project proposal aimed at investigating the development of tilapia production in Malaysia and Fiji. The proposal has been developed in response to a request by the Fiji Ministry of Primary Industries and as a result of the bilateral consultations between ACIAR and Malaysia. The proposal has been developed as a collaborative effort between the Centre for Biological Population Management (CBPM) of the Queensland University of Technology (Australia), the University of Malaya (Malaysia) and the Ministry of Primary Industries (Fiji).

1.2 Project Objectives

Tilapia are an extremely versatile fish for aquaculture, with high reproductive and growth rates. They are relatively disease free and can be cultured in water of variable quality and salinity. Because of their ability to grow under a range of conditions, they are ideal for subsistence farming, but additionally, are quite suitable for market-orientated production. As such, tilapia production technology appears to be well-suited for adoption by small-scale producers, primarily because the initial capital investments are comparatively low, making their uptake an attractive option.

While tilapia are appropriate for culturing, there are a number of biological characteristics that potentially limit their productivity under conditions quite commonly encountered in aquaculture. These include a tendency towards precocial reproduction and stunting under high stocking regimes and a high reproductive and high survival rate. Technologies have been developed to address these problems. One is to use genetic selection to develop strains with enhanced performance while the other is to manipulate existing stocks with growth promoters, sex reversal agents and altered culture conditions. The genetic approach has proven to be successful in the larger producing countries but is not currently adapted to the conditions of smaller producers such as Malaysia and Fiji. This proposal seeks primarily to improve the culture of tilapia in Malaysia and Fiji by the application of stock improvement techniques, enhancing the existing cultural operations and removing potential constraints on the expansion of tilapia production from aquaculture.

The project objectives can be summarised as:

(i) **To genetically characterise existing tilapia stocks**, strains and hybrids in Malaysia and Fiji.

(ii) **To compare the relative productivity of the existing various Fijian and Malaysian strains** with that of their hybrids with respect to fry production and survival, growth performance, stocking rates, integrated farming systems and potential for heterosis.

(iii) **To evaluate the need for the introduction of new strains/species for Fiji and Malaysia** in respect of potential sources of supply, availability and potential for hybridisation.

(iv) **To enhance expertise in fish culture and stock improvement** in participant nations via exchange and training of personnel.

1.3 Tilapia Production

Table 1 lists tilapia and cichlid production for selected countries of the world. From 1978 to 1989, world production has increased 64%, this growth primarily from countries in South East Asia. While Africa was the main producing region a decade ago, its production has since been variable but showing a declining trend. On the other hand, production from South East Asia has more than trebled during the same period. Philippines tilapia production increased from 6,100 mt caught or cultured to almost 102,000 mt in 10 years from 1979, a factor of 17x or 1,560% (FAO 1991). Other significant producers in the region include Indonesia (46,890 mt in 1989) and Thailand (27,800 mt in 1989). Sri Lanka is also a large producer with 39,700 mt in 1989, displaying a reasonably static level of production over the past decade. On the other hand, Africa's production has been variable, but declining. Currently, the major producers include Tanzania, Madagascar and Kenya. Countries such as Uganda, which has previously been a major producer with a high point of production reaching 90,300 mt in 1978, has seen production decline to only 5,900 mt in 1989. Other producers such as Tanzania and Nigeria have suffered similar falls in production, though not as dramatic. Though the reasons for the dramatic decline are not clear from the data, potentially it could be a result of degrading of the broodstock through inbreeding, disease and poor management practices. Research programs funded by ICLARM are addressing some of these issues. In addition, recent catastrophes such as widespread drought and regional conflicts may also have had a significant impact.

From the production information contained in Table 1, it is noted the two collaborating developing countries are not currently major producers of tilapia. Production from Malaysia has only been reported consistently for the past 5 years with production peaking at 3,300 mt (1988). Production for 1989 was 2,903 mt. Production from Fiji is a result of a small amount of aquaculture and the capture from natural stocks.

1.4 Brief Outline of Production Systems

There are three main systems used to produce tilapia - ponds, cages and pens. Pond culture can be either in brackishwater or freshwater environments, while cages and pens are common in freshwater lakes and reservoirs.

Tilapia produced from brackishwater ponds, in particular the Philippines, are usually as a by-product of milkfish production. Monoculture of tilapia in brackishwater ponds has been growing steadily over the past decade in Asia, but there are still problems of salinity tolerance in such environments. The application of fertilisers to ponds is a common practice. Operators commonly apply inorganic fertilisers such as urea, while organic fertilisers such as chicken manure are also used. Fertilisers are not only used to feed the tilapia directly but also to encourage growth of algae and other organisms which the growing tilapia feed on. Supplementary feeding is also necessary in the pond situation, with rice bran the most common feed used (this usually being in combination with chicken manure). Harvesting does not usually follow a definite schedule with the most common methods being netting, partial draining and netting and total draining. The products are predominantly sold fresh, usually sorted by size but rarely packed in any form. There is a trend to sell fish live, improving the

Table 1: Tilapia and other cichlids (mt whole fresh fish equivalents) Production for South Asia, South East Asia, China and the South Pacific/PNG

Region	Country	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
SOUTH ASIA		16,735	17,422	20,264	29,586	33,319	36,061	30,575	32,743	35,390	36,465	38,012	39,720
	Bangladesh	0	0	0	0	0	0	0	0	0	0	0	0
	Bhutan	0	0	0	0	0	0	0	0	0	0	0	0
	India	0	0	0	0	0	0	0	0	0	0	0	0
	Nepal	0	0	0	0	0	0	0	0	0	0	0	0
	Pakistan	0	0	0	0	0	0	0	0	0	0	0	0
	Sri Lanka	16,735	17,422	20,264	29,586	33,319	36,061	30,575	32,743	35,390	36,465	38,012	39,720
SOUTH EAST ASIA		55,460	44,865	47,343	67,720	61,420	115,724	108,129	117,862	133,095	172,106	173,482	179,240
	Myanmar	0	0	0	0	0	0	0	0	0	0	0	0
	Indonesia	36,667	38,743	38,239	40,920	34,094	43,332	45,619	47,923	43,785	49,800	47,330	46,890
	Kampuchea	0	0	0	0	0	0	0	0	0	0	0	0
	Laos PDR	0	0	0	0	0	0	0	0	0	0	0	0
	Malaysia	0	0	0	0	0	173	4	2,126	1,150	1,366	3,346	2,903
	Philippines	18,793	6,122	9,104	26,800	27,326	60,128	53,203	52,703	69,794	93,593	95,006	101,647
	Thailand	0	0	0	0	0	12,091	7,953	15,110	18,366	27,347	27,800	27,800
	Vietnam	0	0	0	0	0	0	0	0	0	0	0	0
CHINA		0	0	0	0	0	0	0	0	0	0	0	0
	China	0	0	0	0	0	0	0	0	0	0	0	0
	Mongolia	0	0	0	0	0	0	0	0	0	0	0	0
SOUTH PACIFIC/PNG		32	86	2,514	2,514	2,510	2,512	2,520	2,523	2,525	2,526	2,528	2,534
	Fiji	10	46	14	14	10	12	20	23	25	26	28	29
	Papua New Guinea	22	40	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,505
	Western Samoa	0	0	0	0	0	0	0	0	0	0	0	0
	Solomon Islands	0	0	0	0	0	0	0	0	0	0	0	0
	Tonga	0	0	0	0	0	0	0	0	0	0	0	0
	Vanuatu	0	0	0	0	0	0	0	0	0	0	0	0
AFRICA		229,916	231,392	262,598	258,187	236,275	194,908	229,591	184,061	193,464	191,541	214,730	173,515
	Ethiopia	2,500	2,800	3,100	3,500	3,400	3,500	3,700	3,500	3,500	3,500	3,344	2,706
	Kenya	10,616	10,084	10,489	6,518	9,403	9,617	13,013	9,942	10,151	13,293	20,007	19,615
	Malawi	23,215	19,155	24,860	18,644	25,191	19,505	24,147	23,080	21,272	15,694	15,700	15,700
	Mozambique	0	0	0	0	0	0	0	0	0	0	0	0
	Tanzania	21,837	57,200	89,678	95,457	77,017	57,143	49,179	42,722	44,035	44,035	50,480	62,500
	Uganda	90,300	59,410	58,280	58,400	45,640	18,250	52,200	39,550	48,600	49,190	59,270	5,900
	Zambia	0	0	0	0	0	0	0	0	0	0	0	0
	Zimbabwe	0	0	0	0	0	325	473	735	750	750	750	857
	Nigeria	39,656	41,075	29,939	29,909	30,859	39,680	39,702	16,504	17,153	16,492	16,492	17,550
	Madagascar	23,000	23,000	22,837	23,100	23,000	25,200	25,400	26,000	26,000	26,000	26,000	26,000
	Sudan	0	0	0	0	0	0	0	0	0	0	0	0
WEST ASIA/NORTH AFRICA		0	0	0	0	0	0	0	0	0	0	0	0
	Egypt	0	0	0	0	0	0	0	0	0	0	0	0
	Turkey	0	0	0	0	0	0	0	0	0	0	0	0
WORLD TOTAL		320,392	315,565	363,523	390,471	368,542	444,434	478,228	442,009	482,140	535,049	558,076	525,310

Source: ACIAR Information System Database, utilising FAO Data Tapes as source data.

post-harvest quality of the fish. Monoculture of tilapia in freshwater ponds is increasing and follows similar practices to that of brackishwater ponds. Whereas brackishwater culture is usually a by-product with average yields of 100 kg/ha, freshwater culture is a monoculture system with average yields of 1000 kg/ha, with some operators in the Philippines achieving 2t/ha.

Cage culture of tilapia uses inland freshwater bodies such as lakes and reservoirs. Two types of cage culture are used: the floating type and the fixed type. The former is used in deeper water bodies while the latter are more suitable for the shallower lakes. The floating types are made from a floating frame used to suspend the net cages. 'Artificial feeding is normally not practised' with the growth of the fish 'largely dependent on the primary production in the surrounding waters and the management practices applied such as the size of the cage, density of fish and the spacing between cages' (Guerrero 1985). Tilapia culture in fixed cages is common in shallow lakes and is generally more productive than floating cages. Additionally, they are easier to construct and manage. The culture period varies from 4-12 months, depending on the time of year, stocking density, management practices and conditions in the water body. Poor water circulation and lack of natural food result in poor growth and the need to supplement feeding, usually with rice bran. 'Growth rates thus appear to be very dependent upon the lake environment and the extent of cage culture in the vicinity' (Guerrero 1985).

With the increasing difficulty of culturing milkfish in fishpens, operators are converting to tilapia culture. While similar materials and practices to milkfish are applied, the higher stocking rates necessitate the need for supplementary feeding, most commonly with rice bran or pollard (wheat bran). However, even though tilapia growth in pens is much faster than in cages, there are problems of harvesting with very low recovery rates. The problem of harvesting needs to be dealt with more efficiently to ensure the viability of this culture system.

A crucial component of any successful aquaculture system is access to good quality but inexpensive fingerling fry for growing out. Besides self-stocking, hatcheries are the predominant method for supplying growers with high quality fry. The infant nature of hatchery operations is indicated by the diversity of management practices. While an important aspect of the production cycle, they are not the focus of this proposal and the various management practices are not elaborated further.

2. PROJECT ASSESSMENT FRAMEWORK

2.1 Economic Surplus Approach

A basic closed-economy, economic-surplus framework is used for the analysis. This assumes a linear demand and supply curve where the research results in technology that lowers the costs of production, shifting the supply curve down and to the right. The basic framework assumes the supply shift is parallel and demand is static. Benefits of the research are measured by the change in economic surplus.

For details of the basic framework used to assess benefits from research on developing and emerging industries (including diagrammatic representations), reference can be made to Fearn et al. (1994). Since the initial application of a framework to incorporate new and emerging commodities, the theoretical basis has further evolved. These are to be documented in detail in a future working paper and are not considered at length in this document. For the purpose of this analysis however, the basic framework has remained unchanged.

With emerging and new products, it is normal practice to estimate a potential forecast production which is likely to occur at some future point in time coinciding with the availability of research results to producers. As such, any benefits accruing as a result of the research are assumed to also be applicable to the forecast quantity. The estimation of the forecast production is discussed in Section 2.5.

2.2 Application to the Production of Tilapia from Aquaculture

The framework can be readily applied to aquaculture operations such as the production of tilapia. Producers operate under similar economic conditions to those faced by other primary producers such as crop and livestock producers.

It is assumed the research has an impact on the technology used to aquaculture tilapia similar to, for example, the improvement of a wheat variety in a cropping situation. The technology associated with the improvement of tilapia broodstock has a potential impact through reducing the production costs of culturing tilapia. A simple cost analysis is used to estimate the potential research impact where the resulting unit cost reduction is used to measure the change in economic surplus.

The assumed research impacts translate into cost reductions for each country and can be summarised as follows:

(i) **Fiji:**

(a) Increased production through lowering mortality of fingerlings.

(b) Reduced input cost of fingerlings.

With reduced mortality, more fish grow out to a marketable age given the same stocking densities by farmers. The average size of harvested fish is assumed to remain constant. Currently, there is an excess capacity in the production of fry. With the improvement of the quality and survival rates of fry, it is assumed two effects will occur. Firstly, the costs of fry will fall because more are surviving, given the current level of costs. Secondly, with the initial lowering of the costs of fry, combined with an increase in the quality of fry, demand for fry should increase as the industry expands and potential producers recognise that a supply of good quality, inexpensive fry is consistently available. The level of excess capacity will be further reduced, which would also reduce the cost of fry. Therefore, the improvement of the stock can be considered to have a double impact.

(ii) **Malaysia:**

(a) Genetic improvement of broodstock results in increased average size of fish, increasing annual output.

With genetic improvement, a better rate of growth can be achieved as well as a more favourable colour (this being the red tilapias). This would result in an increase in production through improving the growth rate per period such that larger, average-sized fish being grown within the same time period. The survival of fingerlings is already high and remains unchanged as it is not the focus of the research in Malaysia.

The research in both countries is focused on improving characteristics of the broodstock important to that country and considered a constraint to production. The improvement of the quality of fingerlings available to producers is seen as a vital component to the success of any aquaculture system and is equally applicable to the emerging tilapia industry in Fiji and the more established industry in Malaysia.

2.3 Cost Analysis: Assumptions and Estimation

A critical component in estimating the potential research benefits is determining the impact of the technologies on the cost structure for producing tilapia in Malaysia and Fiji. Aquaculture production of tilapia is similar to many crop and livestock enterprises where costs and returns occur in the same period. In addition, there are various types of production systems that can occur, from pond and cage culture to integrated production systems such as fish culture with rice. For this analysis, it is assumed the most appropriate technology applicable to culture tilapia in Malaysia and Fiji is that of pond culture. This is primarily due to the lack of suitable and inexpensive indigenous materials such as cane and bamboo suitable for the construction of cages and pens in Fiji and the availability of ready-made ponds in Malaysia. Therefore, production costs are based on pond-culture cost structures. With the improvement in broodstock, benefits are also likely to occur within other production systems.

Table 2 lists the cost components for culturing tilapia using the current pond technology for Fiji 'with' and 'without' the research while similarly, Table 3 lists cost information for Malaysia. The 'with' research situation in both tables indicates the potential changes in input use, costs and production that may result from the research. For Fiji, this information is based on data supplied by the Department of Primary Industries while the Malaysian cost information is based on data from the University of Malaya (Mukherjee, pers. comm.) in conjunction with information adapted from similar production systems in the Philippines.

For the cost analysis, the following simplifying assumptions were used:

(i) It is assumed that 2 tilapia crops are cultured in Fiji each year and 3 are cultured annually in Malaysia. A 150-day growing period is assumed for Fiji and a 110-day growing period for Malaysia. This is because tilapia culture techniques are already established in Malaysia, while the occurrence of a cooler period during the year in Fiji inhibits fry production and fish growth.

(ii) Ponds are stocked with 12,500 fry per hectare per crop in Fiji and Malaysia, equivalent to 1.25 fry/m^2.

(iii) The cost of fry in Fiji without the research is $0.10 each which falls to $0.06 per piece with the research. The cost per fingerling in Malaysia is $0.05 which remains constant with the research. Fry are assumed to weigh 4 grams when purchased.

Table 2: Cost Analysis for Fiji Tilapia Production (per one hectare/year)

Item	Units		Before Research: Cost ($A)	Before Research: No. of Units	Before Research: Cost per Hectare ($A)	After Research: Cost ($A)	After Research: No. of Units	After Research: Cost per Hectare ($A)
			Capital Cost	Depreciation Allowance	Annual Cost	Capital Cost	Depreciation Allowance	Annual Cost
(1) Fixed Costs								
Pond construction	per ha.		4,000	10%	400	4,000	10%	400
Storage dam for water			400	20%	80	400	20%	80
Storage house (fertiliser/feed)			800	15%	120	800	15%	120
Equipment			400	33%	130	400	33%	130
TOTAL DEPRECIATION					730			730
Land Lease	per ha.				200			200
Pond maintenance	per ha.				100			100
Interest on loan	per ha.				600			600
TOTAL FIXED					1,630			1,630
			Cost per unit	No. of Units		Cost per unit	No. of Units	
(2) Variable Costs								
Fingerlings	no./ha/year		$0.10	25,000	5,000	$0.06	25,000	3,000
Feed	kg/ha/year		$0.40	9,597	3,839	$0.40	11,516	4,607
Organic Fertilizer	kg/ha/year		$0.04	3,000	120	$0.04	3,600	144
Lime	kg/ha/year		$0.32	1,000	320	$0.32	1,000	320
Transport (fertlisers)					180			180
Labour	md/ha/year	(Misc.)	$8.00	16	128	$8.00	16	128
	md/ha/year	(Feeding)	$8.00	23	368	$8.00	28	442
	md/ha/year	(Harvesting)	$8.00	16	256	$8.00	19	307
	md/ha/year	(Selling)	$8.00	8	64	$8.00	10	80
Selling materials	sort & pack				320			320
Truck hire					300			360
TOTAL VARIABLE					10,895			9,887
TOTAL COSTS					$12,525			$11,517
Production	kg/ha/year				3,000			3,600
Unit Costs	$/kg				$4.17			$3.20
Unit Cost Reduction	$/kg							$0.98

[illegible]

(iv) Fingerling mortality in Fiji is assumed to fall 20%, with the number surviving to harvest increasing from 60% to 72%. In Malaysia, survival remains constant at 80%.

(v) Daily supplementary feeding of tilapia occurs in the ponds at a rate of 3-5% of the body weight of the growing fish. Details of the estimated daily feeding patterns assumed for Fiji and Malaysia are listed in Tables 4 and 5. Feed is assumed to cost $A0.40/kg. The feed mix can consist of a variety of ingredients, but usually rice bran, copra meal, meat meal and/or fish meal are the most common used. The mix depends on the availability of each ingredient and their relative cost.

(vi) Without research, the average size of fish harvested is assumed to be 200 grams for Fiji and Malaysia.

(vii) The impact of the research in Malaysia is on fish growth rates, where the increase in production is reflected through an increase in the average size of the fish harvested. The improvement in the growth rate over the same period of culture is assumed to result in a 20% increase in the average size of the fish harvested to 240 grams.

(viii) The research impact on production in Fiji is assumed to occur through an increase in the survival of fingerlings used to stock the ponds. A 20% increase in fingerling survival from 60% to 72% translates into a 20% improvement in production per hectare of pond where 20% more fish are harvested at the same size (ie 200 grams).

(ix) As a result of the perceived changes in production, annual production per hectare for each country is assumed to increase 20% with the research. For Fiji, pond production per hectare per year increases from 3,000 kg to 3,600 kg (or 1,500 to 1,800 kg per crop); while Malaysian production increases from 6,000 kg to 7,200 kg per hectare per year (or 2,000 kg to 2,400 kg per crop).

(x) Annual feed requirements per hectare increase in relation to the increase in production while fertilisers such as manures, lime and superphosphate remain unchanged.

(xi) Fixed costs are included in the cost analysis, consisting of costs for pond construction, pumps, storage houses and other sundry equipment. These are depreciated at varying rates, depending on the expected life of the item. Fixed costs for items with a flow of services over multiple periods are included using the annual depreciation amount. Other annual fixed costs include land lease, pond maintenance and any loan interest.

(xii) Labour is another important cost item with increased labour inputs required

Harvest Weight	200 grams
Growth/Day	1.31 grams/day
Survivability	60%

Feeding Rate (% of BW)	Feed Requirements (kg)
5%	42.0
5%	91.0
5%	140.0
5%	189.0
5%	238.0
4%	268.7
4%	268.8
4%	308.0
4%	347.2
4%	386.4
4%	425.6
4%	464.8
4%	504.0
4%	543.2
4%	582.4
	4798.5

With Research

Fingerling Weight	4 grams
Growing Period	150 days
Stocking rate/ha	12,500 fry/ha
Number Harvested	9,000 fish/ha

Harvest Weight	200 grams
Growth/Day	1.31 grams/day
Survivability	72%

Day	Daily Bodyweight (grams)	No. of Fish Harvested	Total BW (kg)	Feeding Rate (% of BW)	Feed Requirements (kg)
1-10	111.9	9,000	1006.8	5%	50.3
11-20	242.5	9,000	2182.8	5%	109.1
21-30	373.2	9,000	3358.8	5%	167.9
31-40	503.9	9,000	4534.8	5%	226.7
41-50	634.5	9,000	5710.8	5%	285.5
51-60	765.2	9,000	6886.8	4%	322.4
61-70	895.9	9,000	8062.8	4%	322.5
71-80	1026.5	9,000	9238.8	4%	369.6
81-90	1157.2	9,000	10414.8	4%	416.6
91-100	1287.9	9,000	11590.8	4%	463.6
101-110	1418.5	9,000	12766.8	4%	510.7
111-120	1549.2	9,000	13942.8	4%	557.7
121-130	1679.9	9,000	15118.8	4%	604.8
131-140	1810.5	9,000	16294.8	4%	651.8
141-150	1941.2	9,000	17470.8	4%	698.8
					5758.2

Table 5. Feed requirements for Malaysia

Without Research

Fingerling Weight	4 grams	Harvest Weight	200 grams
Growing Period	110 days	Growth/Day	1.78 grams/day
Stocking rate/ha	12,500 fry/ha	Survivability	80%
Number Harvested	10,000 fish/ha		

Day	Daily Fry Bodyweight (cumulative) (grams)	No. of Fish Harvested	Total BW (kg)	Feeding Rate (% of BW)	Feed Requirements (kg)
1-10	138.0	10,000	1,380.0	5%	69.0
11-20	316.2	10,000	3,161.8	5%	158.1
21-30	494.4	10,000	4,943.6	5%	247.2
31-40	672.5	10,000	6,725.5	4%	269.0
41-50	850.7	10,000	8,507.3	4%	340.3
51-60	1,028.9	10,000	10,289.1	4%	411.6
61-70	1,207.1	10,000	12,070.9	4%	482.8
71-80	1,385.3	10,000	13,852.7	4%	554.1
81-90	1,563.5	10,000	15,634.5	4%	547.2
91-100	1,741.6	10,000	17,416.4	4%	609.6
101-110	1,919.8	10,000	19,198.2	4%	671.9
Total Feed Requirements					4360.8

With Research

Fingerling Weight	4 grams	Harvest Weight	240 grams
Growing Period	110 days	Growth/Day	2.15 grams/day
Stocking rate/ha	12,500 fry/ha	Survivability	80%
Number Harvested	10,000 fish/ha		

Day	Daily Bodyweight (grams)	No. of Fish Harvested	Total BW (kg)	Feeding Rate (% of BW)	Feed Requirements (kg)
1-10	158.0	10,000	1,580.0	5%	79.0
11-20	372.5	10,000	3,725.5	5%	186.3
21-30	587.1	10,000	5,870.9	5%	293.5
31-40	801.6	10,000	8,016.4	4%	320.7
41-50	1,016.2	10,000	10,161.8	4%	406.5
51-60	1,230.7	10,000	12,307.3	4%	492.3
61-70	1,445.3	10,000	14,452.7	4%	578.1
71-80	1,659.8	10,000	16,598.2	4%	663.9
81-90	1,874.4	10,000	18,743.6	4%	656.0
91-100	2,088.9	10,000	20,889.1	4%	731.1
101-110	2,303.5	10,000	23,034.5	4%	806.2
					5,213.6

for activities that would vary according to the level of production, in particular, harvesting and feeding. These are valued at $8 per labour-day for Fiji and $15 for Malaysia.

(xiii) Other costs include water charges, pump fuel, selling materials for sorting and packing if required and transport costs for inputs and produce.

2.4 Other Parameter Estimates

For the analysis it is necessary to collect information on other parameters. If this is not available, estimates are required. The other parameters included in the analysis are discussed below.

2.4.1 Supply and demand elasticities

Supply of tilapia is relatively price-responsive, given the short production cycle and flexibility to harvest earlier or later. The supply of tilapia can be considered reasonably price elastic where an estimate of 0.8 has been assumed for the analysis. With production being either for subsistence purposes or for the domestic market (in particular, the fresh market), demand will vary according to the influence of domestic factors such as the price of competing goods (ie other fish species such as milkfish or reef fish, other sources of protein such as beef and chicken), taste and preferences and income levels. In an analysis by Gonzales (1985) on Philippines tilapia marketing in the context of structural demand for protein, the estimated own-price demand elasticity for total fish varied from -1.44 for low income groups to -0.48 for higher income groups, with an own-price elasticity of -1.00 for the average of all income groups. The analysis showed that, while the proportion of income spent on fish did not vary greatly between income groups, the contribution of tilapia to the fish consumed in each household was higher for lower income groups than that for households with higher incomes. However, this may not necessarily be the case for Fiji where quality (ie freshness, especially if sold live) and number of pieces per kilogram are preference aspects that appear to override income influences and substitution influences considering tilapia attracts a price similar to reef fish. For the purpose of this analysis, a demand elasticity of -1.5 is assumed.

2.4.2 Ceiling level of adoption and adoption pattern

Adoption of the proposed technology is assumed to commence in Year 9, which is the sixth year after the proposed completion of the research. Adoption takes four years to reach the ceiling level of adoption, which is 50% for Malaysia and 90% for Fiji. Through discussions with the project scientists, the adoption patterns determined as being representative were as follows: for Fiji, 10% in the first year of adoption (ie Year 9), 20% in the second, 40% in the third and 50% in the fourth and subsequent years; and for Malaysia, 20% in the first, 40% in the second, 80% in the third and 90% in the fourth and subsequent years.

2.4.3 Research costs

The project proposal indicates a total cost of $A757,979 from all sources of funds. The contribution from ACIAR totals $A319,979. The other institutions and the collaborating countries (QUT, Malaysia and Fiji) contribute the remaining $A438,000. The proposed total annual expenditures are $A247,050 for the first year, $A256,064 in the second year and $A254,865 in the final year. Completion is expected in 3 years though the impact of an extension or replacement project could be readily considered in the analysis.

2.4.4 Discount rate

A key issue of cost benefit analysis is expressing future costs and benefits in present day values. This is achieved by discounting the future values using an appropriate discount rate. There are numerous factors affecting the choice of discount rate where no one rate can be practically determined for all uses. However, to maintain a degree of consistency between other ACIAR project development assessments, the benchmark rate recommended by the Department of Finance for use by government organisations in cost benefit analyses has been adopted. This benchmark discount rate is 8% (Dept. of Finance, 1991). This rate is in real terms (rather than nominal terms), meaning that it assumes inflation effects have been removed from the costs and benefits streams.

2.4.5 Price

Price information from SEAFDEC (1990) suggests prices for tilapia vary considerably throughout South East Asia, where trade is generally confined to domestic markets. For Malaysia, the trend in prices appears to be upward, with price increasing from $A1.10/kg in 1984 to $A3.29/kg in 1988. The price assumed for Malaysia in the analysis is $A2.75/kg.

For Fiji, the unit price comparable to reef fish reflects the fact consumers consider fresh tilapia a close substitute to reef fish. Producers usually market the fish directly to consumers, often sold live which enhances the quality of the product. The price assumed in the analysis for Fiji is $A3.50/kg.

2.5 Production and Estimated Production

Current levels of tilapia production in both countries are low where the industries are in early stages of development. In Malaysia, with the emergence of recorded tilapia production in 1983, a rapid expansion of the industry is indicated. Production increased from no recorded production in 1982 to 2,900 mt in 1989 (FAO 1991). This is predominantly from culture activities.

On the other hand, tilapia have existed in Fiji since the 1940s when they were introduced as potential pig food. Deliberate stocking of the natural waterways occurred in the late 1950s and 1960s to provide an alternative protein source. Subsequent introductions from the 1960s were made with aquaculture as the primary motivation. While recorded production has existed in Fiji over several decades, the level has been low and reasonably static with no significant growth indicated. The majority of production has traditionally been sourced from wild captures in natural waterways but the contribution from aquaculture has been increasing in recent years.

Given that production already exists in the collaborating countries even though the industries are still emerging, application of the conventional framework would be most appropriate to determine potential research benefits. However, consistent with previous approaches and the emerging status of the industry, some minor alterations would be necessary, most notably the level of production considered applicable on which the research innovations have an impact. If development is consistent with the trend in other Asian countries, it is reasonable to expect an expansion of production over time for reasons other than through research innovations. Two reasons most apparent for an increase in supply over time are:

(i) A change of environment (political, social, physical) that enhance factors affecting the learning curve of potential producers for adopting the existing technology. Most notable would be an improvement in the information available to potential producers.

(ii) Substitution effects because of changing price relativities, for example, between tilapia and other competing protein sources such as other fish species, chicken and other meats.

By the time the research is expected to have an impact, production potentially would have expanded, therefore it would be desirable to incorporate the potential level of production into the assessment. To accommodate these emerging industries, country experts were asked to provide forecasts of the potential production likely to occur when the research results become available.

In Malaysia, Liong et al. (1988) identified 8,000 ha of land and 17,500 ha of mining pools suitable for development of aquaculture (not necessarily tilapia alone though). However, this is further qualified where the development of such areas is not without constraints, identifying the 'lack of good quality broodstock' as a major limitation with freshwater finfish culture. Information from the proposed project leader in Malaysia indicates a similar potential area of 20,000 ha.

For Fiji, estimates of the potential area of ponds is based on land currently considered unproductive and on irrigation areas previously devoted to rice production. The available land considered to be non-productive with no agricultural activities is approximately 1,200 ha. In addition, with the relaxation on rice imports, subsidised production of rice has ceased and several rice irrigation schemes have not been utilised for up to 3 years. It has been suggested pond construction on these areas is considered a suitable option given the availability of water already. The approximate area available is 300 ha.

While the estimated areas may be suitable for aquaculture production, it is unlikely that all of the area will be devoted to ponds. It was therefore assumed an area of 2,000 ha will be devoted to ponds in Malaysia and 200 ha in Fiji. This includes the current area of production.

Given the potential for expansion in an emerging industry such as tilapia culture, it is necessary to consider two base cases. Firstly, the proposal is assessed using **current production**, and secondly using **forecast production**. The two base cases would utilise the same assumptions in relation to the costs analyses and other parameters, but the potential benefits would be applied to different levels of production. For each base case, the level of production benefits applicable are:

(i) **Base Case 1 (current production)**

Fiji	26 mt
Malaysia	2,000 mt

(ii) **Base Case 2 (forecast production)**

Fiji	600 mt
Malaysia	12,000 mt

Production forecasts for Base Case 2 are estimated using forecast area and potential production per hectare after the research.

3. RESULTS OF BASE CASE ASSESSMENTS

The base case is the situation considered most likely to exist as determined by the project scientists. The analysis therefore assesses the most likely research impact on the base case which, for the tilapia proposal, is a 20% increase in fish output per hectare. However, by using a forecast production in the analysis to incorporate the developing aspects of the industry, it is necessary to estimate the results of two base cases. Each base case uses a different industry level supply (Q_{so}) as estimated in the previous section while all other parameter estimates remain unchanged. The estimation of the annual and total net benefits and reporting of the results are summarised in the following sections.

3.1 Estimation of Annual Benefits

Annual benefits resulting from the research are estimated using the following standard economic surplus formula:

$$AB = kQ_{so} + \frac{e_d e_s k^2 Q}{2P(e_s + e_d)}$$

where:

AB	is the annual benefits
k	is the unit cost reduction
Q_{so}	is the quantity supplied before research
e_d	is the price elasticity of demand
e_s	is the price elasticity of supply
P	is the price before research

The unit cost without the research is $A4.17 per kg for Fiji and $A2.86 per kg for Malaysia. With the research, the impact on the production costs results in a unit cost reduction (k) of $A0.98/kg and $A0.30/kg for Fiji and Malaysia respectively. These estimates of k are used in conjunction with the estimates of production, adoption levels and the elasticities of supply and demand to estimate the annual benefits accruing as a result of the research.

For current levels of production, annual benefits with 100% adoption total $A0.026m for Fiji and $A0.613m for Malaysia. Where production is likely to expand, a forecast estimation of production is used, resulting in annual benefits of $A0.611m for Fiji and $A3.677m for Malaysia (with 100% adoption). As it is unlikely all producers will adopt the technology, therefore, at maximum adoption the annual benefits for current production are $A0.024m for Fiji and $A0.306m for Malaysia where the level of maximum adoption is 90% and 50% respectively. With forecast production, annual benefits are $A0.550m and $A1.839m.

3.2 Flow of Costs and Benefits

Table 6 indicates the flow of costs, the adoption pattern for each country and the subsequent flow of benefits and total net benefits from the research. Costs are estimated to occur for the first three years, with Table 6 indicating the breakdown of costs between each contributor. After the completion of the project, there is a 6-year lag before any benefits start accruing. The cost and benefit flows are assumed to occur over a 30-year time period.

3.3 Net Present Value and Internal Rate of Return

The Net Present Value (NPV) and the Internal Rate of Return (IRR) are used as indicators of the financial suitability of a proposal for funding. The NPV is the value of the future flow of net benefits discounted to current dollar terms using a predetermined discount rate which, in this case, is 8%. The IRR is the discount rate necessary to result in a net present value of zero. In other words, it is the interest rate that would need to occur for the value of the net benefits in current dollars to equal zero.

For the proposal, Base Case 1 results indicate a NPV of $A0.92m and an IRR of 15%. For Base Case 2 using forecast production, the NPV for the project is estimated at $A10.7m, with an IRR of approximately 34%.

4. SENSITIVITY OF RESULTS

Because of the uncertainty of parameter estimates used in the development assessment, a standard component is the inclusion of an analysis of the sensitivity of research benefits to variations in key parameters which have an important impact on the results. As it is not feasible to test the sensitivity of all parameters, a subset of those parameters highlighted with the assistance of the project scientists as being significantly influenced by the research or having a major impact on the level of benefits are selected.

For the tilapia proposal, the key parameters tested for their sensitivity to variation include:

(i) Yield of fish per hectare, where the base cases assume a 20% increase in output.

(ii) Lag period before adoption commences, with adoption currently assumed to commence in year 9, 6 years after the proposed completion of the research.

(iii) Maximum level of adoption assumed, currently 50% of producers for Malaysia and 90% of producers for Fiji.

Table 6: Cost Benefit Flows for Tilapia Stock Improvement Proposal

Year	Research Costs					Annual Level of Adoption		Annual Research Benefits (current production)				Net Benefit Stream	Annual Research Benefits (forecast production)				Net Benefit Stream
	ACIAR	Comm. Organis.	Malaysia	Fiji	Total	Fiji	Malaysia	Fiji		Malaysia			Fiji		Malaysia		
								100% Adoption	Expected Adoption	100% Adoption	Expected Adoption		100% Adoption	Expected Adoption	100% Adoption	Expected Adoption	
	($m)	($m)	($m)	($m)	($m)	(%)	(%)	($m)	($m)	($m)	($m)	($m)	($m)	($m)	($m)	($m)	($m)
IRR	0.5											15%					34%
NPV	0.08											$0.92					$10.73
PV	0.273	0.122	0.103	0.152	0.651			0.146	0.115	3.377	1.455		3.368	2.650	20.265	8.728	
Total	0.320	0.141	0.120	0.177	0.758			0.583	0.490	13.482	6.251		13.446	11.307	80.895	37.506	
1	0.091	0.057	0.040	0.059	0.247							(0.247)					(0.247)
2	0.115	0.042	0.040	0.059	0.256							(0.256)					(0.256)
3	0.114	0.042	0.040	0.059	0.255							(0.255)					(0.255)
4												0.000					0.000
5												0.000					0.000
6												0.000					0.000
7												0.000					0.000
8												0.000					0.000
9						20%	10%	0.026	0.005	0.613	0.061	0.067	0.611	0.122	3.677	0.368	0.490
10						40%	20%	0.026	0.011	0.613	0.123	0.133	0.611	0.244	3.677	0.735	0.980
11						80%	40%	0.026	0.021	0.613	0.245	0.266	0.611	0.489	3.677	1.471	1.960
12						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
13						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
14						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
15						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
16						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
17						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
18						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
19						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
20						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
21						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
22						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
23						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
24						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
25						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
26						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
27						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
28						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
29						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389
30						90%	50%	0.026	0.024	0.613	0.306	0.330	0.611	0.550	3.677	1.839	2.389

(iv) Forecast production used for base case 2, where this is currently 12,000 mt for Malaysia and 600 mt for Fiji.

With the variation of parameters that have an impact on the cost analysis, other parameters in the cost analysis such as labour inputs and feed requirements would also have a relative change. In the assessment, such adjustments are automatically accounted through the use of spreadsheets. In particular, adjustments are necessary with the variation of the potential yield per hectare, where increasing output is one of the primary aims of the broodstock improvement program.

It is also important to assess the potential impact of changes to the forecast level of production, especially since the forecast is for 10 years hence especially if the production changes that have occurred in Africa and Asia over the past decade can be used as a guide. Due to the inherent dangers involved with forecasting, this is probably the most uncertain parameter included in the analysis. The difficulties involved with forecasting are numerous where the likelihood of error increases dramatically the further into the future the forecast is considering. This allows too many uncertainties to occur to be able to make any forecast with confidence. It was therefore important to assess the impacts on the analysis if forecast targets were not achieved.

A standard inclusion to almost all sensitivity analyses is the variation in the lag period before adoption and the maximum level of adoption. These traditionally are seen as having a major impact on the present value of benefits. Changing the period when benefits come on stream alters the discounting factor used to calculate the present value of benefits. For example, the longer the benefit stream is delayed, the lower the discounting factor used, which would subsequently result in a lower present value of benefits. Conversely, reducing the lag has the opposite effect where benefits in the earlier years have a much higher weighting due to the higher discounting factor.

Table 7 presents the results of the sensitivity analysis completed on the selected parameters considered to be important.

As identified by the project scientists, the focus of the research is on the yield of fish per hectare, therefore it is important to assess the impact of variation from achieving the expected gains. The sensitivity analysis shows this to be crucial in the success of the project, in particular in relation to the base case using current production levels. This indicates that at least a 10% yield increase is necessary to have a positive NPV and an IRR that is greater than the discount rate. With the forecast production, there is a greater degree of flexibility with the yield increase achieved as a result of the research. However, this does not mean that it is not important, considering these estimates are based on forecast production. For example, the sensitivity analysis indicates that if potential yield only increases by half that suggested by the scientists for the base case, the estimated NPV is almost 50% lower.

The lag period before adoption of the research and the subsequent accrual of benefits is also an important parameter as indicated by the results of the sensitivity in Table 7. For example, if the period to the commencement of adoption is extended by 4 years, where adoption starts in Year 13, the NPV in base case 1 will fall by 57% and 36% in base case 2 using forecast production. For base case 1, the IRR falls further from an already marginal rate while, with base case 2, the IRR is still acceptable but the fall has been significant, thus indicating the importance of the lag period.

It would not be unreasonable to expect a delay in adoption, especially since the industry is emerging and the flows of inputs and outputs have not been fully established. Factors that may hinder adoption could include the availability of information to producers, especially if the institutional capacity for extension is weak; or the infrastructure capacity is unable to support the expansion of the industry. For example, with the increased demand for pond construction, there may be insufficient capacity to dig ponds for a rapid expansion; hatchery capacity may be unable to supply the initial demand of new producers with the new broodstock; or the feed mill capacity to provide suitable feed supplements could be insufficient. It is important to consider such possibilities given the importance of lag on the benefits accruing from the research.

However, given the nature of tilapia culture, which is amenable to various cultural practices and environments, the lag period also has the potential to be shorter than suggested in the base case analyses. Again, it is important to note the rapid expansion in Asia as possible evidence of this. The sensitivity analysis assessed the impact of shortening the lag period by two years, the results of which suggested a substantial increase in the level of benefits.

The maximum level of adoption does not appear to be as crucial as the other parameters as indicated by the sensitivity though its importance should not be discounted. While reducing the level of potential adopters, the resulting fall in NPV and IRR is not as dramatic. Significant reductions in the number of adopters need to occur before major declines in the indicators are noted.

The overriding component of the analysis is the use of forecast production. An acceptable rate of return is based on the presumption that forecast levels of production are achieved. If this is not the case, as noted previously; the returns from the research are based only on current production which are shown to be low and result in marginal returns. Therefore, it is important to assess the impact of achieving production lower than the forecast level. Table 7 indicates the impact of not achieving the expected expansion in the industry by the time the research results become available. For example, if only half the number of hectares are developed into tilapia ponds, then the net present value of benefits falls to $A5.0m and the IRR to 27%.

Overall, the sensitivity analysis indicates that, when using forecast production, the potential variability does not have a dramatic detrimental impact on the results. However, if forecasted production levels are not achieved, small variations in the selected parameters deteriorate further the already marginal results.

5. SUMMARY COMMENTS

While the two countries selected for the project are currently minor producers of tilapia, the scientists proposing the research have indicated the potential for production to expand. The recent rapid expansion in other regions, notably Asia, suggests this presumption is not unreasonable, especially with the suitability of tilapia as a fish to culture under variable conditions using basic techniques that make it conducive to rapid and widespread expansion.

Table 7: Sensitivity Analysis of the Tilapia Stock Assessment Proposal

Parameter	Change in Parameter			Current Production		Forecast Production	
				NPV ($m)	IRR (%)	NPV ($m)	IRR (%)
Base Case				0.93	15	10.7	34
Yield/ha	5% increase			−0.15	6	3.8	24
	10%			0.24	10	6.3	29
	15%			0.60	13	8.6	32
	20%			0.92	15	10.7	34
	30%			1.51	17	14.5	38
	40%			2.02	19	17.8	40
Lag	7 th year			1.27	17	13.1	43
	9			0.93	15	10.7	34
	11			0.65	13	8.7	29
	13			0.40	11	6.9	25
	15			0.19	9	5.4	21
	17			0.01	8	4.1	19
Maximum Adoption	% Change from Base	Fiji %	Malaysia %				
	0%	90%	50%	0.92	15	10.7	34
	−10%	81%	45%	0.78	14	9.7	34
	−20%	72%	40%	0.63	13	8.6	32
	−30%	63%	35%	0.47	12	7.6	31
	−40%	54%	30%	0.32	11	6.5	30
	−50%	45%	25%	0.16	10	5.3	28
Estimated Production (mt)		Fiji		Malaysia			
		(ha)	(mt)	(ha)	(mt)		
		50	150	500	3,000	2.2	20
		100	300	1,000	6,000	5.0	27
		150	450	1,500	9,000	7.9	31
		200	600	2,000	12,000	10.7	34

If such a development pattern following the Asian example can be accepted, then it is not unreasonable to treat tilapia culture in Malaysia and Fiji as rapidly emerging industries for the purpose of the assessment.

The estimated unit cost reduction for both countries appears favourable. However, with current levels of production low, the subsequent estimation of potential research benefits using the standard framework results also in low returns. Any capacity for the industry to expand is disregarded in this framework. Subsequently, the returns on the proposed research are marginal, though sensitivity analysis indicates these estimates to be relatively stable.

Given the potential for the industry to expand, it is not unreasonable to incorporate into the assessment a second-base case using forecast production instead of current production. The results from this base case indicate a higher potential return to the research. However, it must be stressed that these returns are based on forecast production, where any long-term forecasting activity has a high degree of uncertainty. Therefore, the acceptability of the proposal is dependent on accepting the forecast production and the inherent level of uncertainty associated with it. Given the importance of incorporating forecast production in the analysis, the impact of lower forecast production levels were assessed. These indicated that acceptable returns were still achievable.

Under the regime of forecast production, the proposal can be considered acceptable.

There are other considerations that should be noted, though not explicitly incorporated in the analysis. These include:

(i) Acceptability of tilapia production as a viable alternative to other activities.

(ii) The importance of alternative protein sources, to both subsistence producers and other consumers, and as a potential substitute for declining reef resources.

(iii) The human-capital building aspects of the research, not only for scientists and institutions in Fiji and Malaysia, but also for Australian scientists involved with the proposed research.

(iv) The detrimental impacts of widespread aquaculture, such as the externalities created (ie the environmental impacts such as raising the water table, pollution and other wastes and impacts on ecologically sensitive areas such as coastal wetlands).

(v) Given the assumption of forecast production that can potentially occur through factors other than research innovation, the notion that by just doing the research, there is a potential to enhance the expansion of the industry through increased awareness and the availability of information cannot be totally discounted, even if the scientific success of the project was marginal.

However, given the assumptions of the assessment, if the forecast levels of production are achieved, the proposal indicates returns in the medium to high category.

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