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# Aquaculture in Papua New Guinea

Status of freshwater fish farming



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Edited by Paul T. Smith

Australian Centre for International Agricultural Research  
Canberra 2007

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## Foreword

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Although freshwater fish farming began in Papua New Guinea in the 1960s with the introduction of carp and trout species, aquaculture is still a developing industry. Substantial bottlenecks have impeded its progress and the spread of its nutritional and financial benefits to rural communities. Because of ACIAR's strong support of the development of aquaculture in the Asia–Pacific region, it is keen to identify the impediments and implement strategies for substantially improving the opportunities for fish farmers in PNG.

This monograph is the result of an ACIAR project which aimed to determine the status of inland aquaculture in PNG and prioritise the key researchable issues. The publication summarises the findings of the project. It also provides the reader with a comprehensive account of the history of aquaculture and fish stock enhancement programs in PNG, supported by a CD of 177 unpublished reports.

Importantly for the development of fish farming in the lowlands and warm regions of the highlands, in late 2002 a genetically improved farmed strain of tilapia (GIFT) was bred at the Highlands Aquaculture Development Centre at Aiyura and Eastern Highlands Province Government began distributing it throughout PNG. The characteristics of this fish suggest that it should help overcome the bottlenecks that occur with fingerling production of

trout and carp. Nevertheless, the study reveals that there are difficulties caused by high mortality rates during fingerling transport, uncontrolled breeding in ponds, slow growth and deformities of fish. This indicates that farmers need assistance in making fish feed, managing broodstock and implementing animal husbandry.

Already the results reported here have been used by ACIAR to further support the aquaculture industry in PNG through a suite of projects. Those projects focus on increasing fingerling supply, improving training of farmers and extension officers, producing better fish feed with local ingredients, running trials with the GIFT strain in cages in Yonki Reservoir, and developing hatchery techniques for indigenous species. The follow-on project has determined the causes of high rates of mortality during transport of GIFT fingerlings, and survival rates have improved from 5–20% to 80–100%. This book provides researchers, farmers, extension officers and NGOs in inland fish farming with a valuable resource.



**Peter Core**

Director

Australian Centre for International  
Agricultural Research

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## Preface

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Papua New Guinea is a remarkable and spectacular country, with natural beauty, rich mineral resources, biological diversity and vibrant cultures. Mountain ranges run the entire length of the main island, with peaks as high as 5,000 m forming the backbone of this largely undeveloped, tropical paradise. The nation's 5.6 million people speak more than 800 distinct languages. Because 87% of the population are smallholder farmers, food security has been a major focus of governments since independence in 1975. Fish is recognised as a source of high-quality protein, and two types of international programs have been implemented to substantially support the development of aquaculture in PNG. During 1995–2001 the Japan International Cooperation Organisation expanded the facilities at the Highlands Aquaculture Development Centre and provided training to farmers with the wokabaut skul (a field-based workshop program for regional areas). In addition, freshwater fish stocks in the Sepik and Ramu Rivers were supplemented from 1987 to 1997 when the Food and Agriculture Organisation of the United Nations introduced a range of new species in two programs.

PNG is a neighbour to many of the leading aquaculture nations in the Asia–Pacific region; hence, it is well located to share in the benefits that modern aquaculture provides. Out of a sense of curiosity and in search of collaboration, the present study started in August 2000 with a pilot project funded by the University of Western Sydney. Officers from Eastern Highlands Province Government (EHPG), National Department of Agriculture, and Livestock and National Fisheries Authority took me on the first of many wonderful journeys. The enthusiasm, good humour, friendship and commitment of the officers and farmers of PNG were the inspiration for developing a proposal that was accepted by the Australian Centre for International Agricultural Research (ACIAR).

In October 2001 the key representatives in aquaculture in PNG were brought together for the first time at a stakeholders' workshop at Aiyura, Eastern Highlands province. That is how the study began, and this is the report on its findings. Hopefully, it can assist the aquaculture industry fulfil its potential and achieve benefits in the areas of health and welfare for the people of PNG.

Paul T. Smith, PhD  
Project Leader  
University of Western Sydney



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This study was possible because of the goodwill and assistance of the farmers, NGOs and government officers of PNG. More than 300 farmers participated in the study and their contributions are gratefully acknowledged. Grant support was provided by the Australian Centre for International Agricultural Research, Fisheries Research Institute (grant numbers FIS/2001/034 and FIS/2001/083) and the University of Western Sydney (grant numbers 2000/067, 2001/018, 2003/015, 2004/033, 2005/043).

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### Commissioned organisation

University of Western Sydney (UWS)

### Collaborating institutions in PNG

Highlands Aquaculture Development Centre (HAQDEC)

National Fisheries Authority (NFA)

National Department of Agriculture and Livestock (NDAL)

University of Papua New Guinea (UPNG)



The First Stakeholders Workshop for Aquaculture in PNG, 15–19 October 2001. The workshop was held at the National Agricultural Research Institute (NARI) in Aiyura, Eastern Highlands province, and participants were: (standing, left to right) Kine Mufuape, Micah Aranka, Avini Vera, Ursula Kolkolo, Awepstar Seka, Ian Middleton, Pukah Kohun, Ian Quartermain, Ian Mopafi, Nephion Tarapi, Bire Bino, Joe Zogoro, Kaupa Kia, Paul Smith; (middle row, left to right) Igu Yawane, Augustine Mobiha, Eric Langelet, Bernard Maladina, Dr Nime Kapo (NAQIA vet), David Busin; (front row) Charlie Avende.

## Acronyms and abbreviations

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ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
CIS	Correctional Institution Services (government prisons)
DAL	Department of Agriculture and Livestock (there are both national and provincial DALs)
DASF	Department of Agriculture, Stock and Forestry
DFMR	Department of Fisheries and Marine Resources (former name of NFA)
DO	dissolved oxygen
DPI	Department of Primary Industries Fisheries
EHP	Eastern Highlands province
EHPG	Eastern Highlands Province Government
ENB	East New Britain province
ESP	East Sepik province
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FISHAID	Fisheries Improvement through Stocking Higher Altitudes for Inland Development—a fish stock enhancement program carried out by FAO and DFMR–NFA during 1993–97 (Project No. PNG/93/007)
GIFT	genetically improved farmed tilapia ( <i>Oreochromis niloticus</i> )
GIS	geographical information system
HAQDEC	Highlands Aquaculture Development Centre based at Aiyura and first established in 1954 under DASF
JICA	Japan International Cooperation Agency
NACA	Network of Aquaculture Centres in Asia–Pacific
NADMAC	National Aquaculture Development and Management Advisory Committee
NAQIA	National Quarantine Authority
NARI	National Agricultural Research Institute
NCD	National Capital District
NDAL	National Department of Agriculture and Livestock
NFA	National Fisheries Authority

- NGO** non-government organisation (In PNG many of the NGOs involved in aquaculture are small groups formed by Papua New Guineans with a shared interest in assisting this and other rural industries. They are often linked to and partially supported by Christian churches and missions.)
- OISCA** Organisation for Industrial, Spiritual and Cultural Advancement—a training organisation in Rabaul, East New Britain
- PDAL** provincial Department of Agriculture and Livestock
- PIP** public investment program
- PNG** Papua New Guinea
- SHP** Southern Highlands province
- SPC** Secretariat of the Pacific Community
- SRFSEP** Sepik River Fish Stock Enhancement Project—a program carried out by FAO and DFMR during 1987–93 (Project No. PNG/85/001)
- UPNG** University of Papua New Guinea
- Unitech** University of Technology
- UWS** University of Western Sydney
- WHP** Western Highlands province
- WNB** West New Britain (province)



The genetically improved farmed tilapia (GIFT) strain of *Oreochromis niloticus* was first distributed from the Highlands Aquaculture Development Centre, Aiyura, to fish farmers in October 2002. This fish is overcoming chronic production bottlenecks because of its ability to grow rapidly and produce fingerlings in earthen ponds.

## Glossary

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**Halpim long pis fama** help for fish farmers—a training and extension program started by the new ACIAR project in 2006 (pidgin English)

**Kina** the unit of currency in PNG—there are about 2 kina to the Australian dollar (as of June 2006)

**Mapinfo** computer software mapping package for geographic presentation of data

**Nupela fama** used here to describe new fish farmers, who have not harvested yet (pidgin English)

**Nupela lik lik fama** used here to describe fish farmers with some experience, who have harvested once (pidgin English)

**Olpela fama** used here to describe experienced fish farmers in PNG (pidgin English)

**Province** PNG is divided into 19 provinces and each province is divided into districts

**Sol pis** salted fish (pidgin English)

**SPSS** computer software statistical package for data management and analysis

**Tok pisin** pidgin English

**Toea** a subunit of currency in PNG—there are 100 toea in 1 kina

**Wokabaut skul** Walkabout School—a program run by HAQDEC which operated from 1997 to 2001. Officers ran field-based workshops in regional areas throughout PNG to extend information and train fish farmers. Similar programs were run by the Lutheran Development Service, starting in the late 1980s

**Worldfish Center** a worldwide research and development organisation (previously ICLARM—International Center for Living Aquatic Resources Management)

**Yonki Reservoir** a reservoir formed after the construction of the hydroelectricity dam across the Upper Ramu River in 1991 (elevation 1,300 m). Yonki Reservoir is the largest lake in the highlands of PNG (2,200 ha)



Map of Papua New Guinea showing provinces and the key cities and towns associated with freshwater fish farming



The future of fish farming and all other enterprises in PNG depends on education of children like these at A1 fish farm near Goroka, EHP.

# Chapter 1

## Summary

*Paul T. Smith, Augustine Mobiha, Jacob Wani, Kine Mufuape,  
Ursula Kolkolo, Peter Minimulu and Johnney Soranzie*

## Introduction

The start of rural aquaculture in Papua New Guinea (PNG) can be traced back to 1954 when the Department of Agriculture, Stock and Forestry established the Highlands Aquaculture Development Centre (HAQDEC) and soon afterwards constructed four fish ponds at Aiyura. The principle reason for introducing aquaculture was, and still is, to increase protein consumption in the diet of people in the highlands. The secondary aim has been to provide a means for smallholder farmers to earn cash income and develop a new commercial industry.

More than 25 exotic fish species have been introduced to PNG, mostly for fish stock enhancement. This started on 1 December 1949 when Sir Hudson Fysh introduced rainbow trout (*Oncorhynchus mykiss*) from Australia for release in streams in the highlands. Fish stock enhancement of the Sepik–Ramu River Basin was substantially expanded by the Food and Agriculture Organisation of the United Nations (FAO), with two large programs being conducted from 1987 to 1997.

Three fish species have been successfully incorporated into smallholder farms in inland PNG. Common carp (*Cyprinus carpio*), which was first introduced in 1958–59, has been the most widespread in distribution and arguably the most successful fish for smallholder farmers. Rainbow trout was first farmed commercially at Kotuni in 1973 with imported eggs. In the 1990s Mrs Betty Higgins was the first to successfully spawn trout at her farm in the foothills of Mt Wilhelm in Simbu (Chimbu) province.

Since then trout have been sporadically farmed by smallholder farmers in the cool regions throughout the highlands. More recently, on 18 May 1999, the genetically improved farmed strain of tilapia (GIFT) (*Oreochromis niloticus*) was brought to quarantine at HAQDEC from the Philippines and on 23 October 2002 the first batch of fingerlings was officially released to farmers. GIFT is now rivalling carp as the farmers' preferred species because of its rapid growth rate and ability to breed in ponds.

Two international agencies have contributed to the development of aquaculture in PNG: FAO and the Japan International Cooperative Agency (JICA). In the late 1980s FAO, with the PNG Government, developed plans for substantially expanding HAQDEC's pond and hatchery facilities at Aiyura. In the mid 1990s the work was undertaken by JICA with the cooperation of National Fisheries Authority (NFA) and its predecessor, the Department of Fisheries and Marine Resources (DFMR). Training of farmers was boosted in a variety of regions in PNG by running the wokabaut skul during 1997–2001, with help from Eastern Highlands Province Government (EHPG). Distribution of carp fingerlings increased dramatically from 36,729 in 1990 to a peak of 258,731 in 1999. Following this peak, fingerling supply slipped back because of infrastructure problems, severe cuts to financial assistance and reduced technical support at HAQDEC. As a result, in 2004 total fingerling distribution from HAQDEC was 43,559 (20,768 carp and 22,791 GIFT). However, some of these problems have since been addressed, resulting in a slight increase in total fingerling distribution to

55,476 in 2005 and further improvements in the first half of 2006.

With this background, it was timely to analyse the rural aquaculture industry in PNG. A number of questions immediately spring to mind. What are the characteristics of the average smallholder fish farm in terms of factors such as number of ponds, pond dimensions, fish species, water source, stocking density, feed, fertiliser and experience of farmer? How many farms are there? Where are they located? What are their problems? What are their plans?

The current study of rural aquaculture in PNG was carried out from 2001 to 2006 and the findings are described in this book. The principle objective was to determine the status of inland, pond-based aquaculture with particular emphasis on freshwater smallholder farming. Survey data was collected between December 2001 and 1 March 2003 with surveys in tok pisin (pidgin English) of farms, hatcheries, markets and institutions. Outputs from hatcheries and trends in farming were monitored from 2001 to 2006. In addition, secondary data was collected from unpublished and published reports. All available unpublished reports written in the period from 1950 to 2005 were scanned and indexed, and copied onto the accompanying CD for easy access and rapid distribution (inserted in the back of this monograph).

The findings of the study were presented in tok pisin to stakeholders at nine workshops held between 2003 and 2005 in Eastern Highlands province (EHP), Morobe province, Western Highlands province (WHP), East New Britain province (ENB) and East Sepik province (ESP). The feedback from farmers and

participants at the workshops was used to identify the constraints and needs of smallholder farmers.

## Fingerling production—results of the hatchery survey

---

A total of 19 hatcheries were surveyed, of which only four had substantial levels of production. HAQDEC at Aiyura in EHP is the major hatchery in PNG for fingerling production of common carp, the GIFT strain and Java carp (*Puntius gonionotus*). It distributes fingerlings throughout the country. The Erap Aquaculture Centre, located in the lowlands near Lae in Morobe province, produces GIFT fingerlings and distributes them to farmers mainly in Morobe province. The Lake Pindi Yaundo Trout Hatchery in Simbu province, owned and managed by Mrs Betty Higgins, was the major source of trout fingerlings and eyed eggs from the mid 1990s until 2002. After closing down for a while, it is now operational again. Smallholder trout farmers currently rely on obtaining fingerlings from advanced farmers or catching wild trout fingerlings to stock their ponds. As for coastal aquaculture, Bismark Barramundi Farm in Madang province produces barramundi, selected marine fish and crustaceans.

Most of the small-scale hatcheries had basic facilities and fed broodstock with cooked sweet potato (kaukau). Under these conditions their production was very low. Fish hormones were absent from all inland hatcheries, including HAQDEC, in PNG throughout the period from late 2002 to May 2005, so natural spawning was practised and production of fingerlings was low.



The cost of fingerlings varied according to size and species of fish. Generally, carp fingerlings sold for 20 toea each (PNG kina 0.20) and GIFT fingerlings for 30 toea. Of the 19 hatcheries surveyed during 2001–03, 68% produced common carp, 21% produced rainbow trout and the remaining 11% produced common carp and either rainbow trout or tilapia. The release of the GIFT strain from quarantine in late 2002 resulted in a reduced reliance of farmers on central hatcheries for fingerlings, with smallholder farmers now being suppliers of GIFT fingerlings.

## Findings of the farm survey

Some 313 fish farms participated in the survey, which covered 12 provinces. From data on fingerling distribution, there are 5,418 known active fish farms in PNG. However, there are probably between 10,000 and 15,000 farms with fish ponds that require supply of fingerlings and training. Most surveys were carried out in the four provinces that are dominant in purchasing fingerlings from HAQDEC: Morobe province (33.2%), WHP (26.5%), EHP (22.7%) and Simbu province (8.9%). Common carp was the main species cultured at the farms, being the sole species in 90.4% of farms and farmed with other species in 7.7% of farms. The average respondent could be described as a small-scale agricultural farmer who is a married male with  $3 \pm 2$  children and is  $35 \pm 11$  years of age. There are principally three types of fish farmers in PNG:

- *nupela fama*—the new farmer who has not yet harvested a crop (45–55% of farmers)

- *olpela lik lik fama*—established farmers who have less than 1,000 fish in ponds and have harvested at least one crop (40–45% of farmers)
- *olpela fama*—pioneer farmers who have more than 1,000 fish, have considerable infrastructure and sell to restaurants and town markets (5% of farmers).

Respondents strongly (86.9% of cases) identified fish farming as a means of obtaining cash income and improving family nutrition. Farmers became aware of fish farming by the following means: other farmers (26.8%), their own interest (20.8%), non-government organisation (NGO) networks (13.1%) and officers from the Department of Agriculture and Livestock (DAL) (10.5%). Farmers rated the assistance they received from institutions and organisations as either ‘nil’ or ‘very low’. Most respondents (72.2% of cases) had not received any prior training. Some 7.0% of farmers received training from wokabout skul, 6.4% at HAQDEC and 5.1% from NGOs.

The capital costs for setting up a fish farm were generally regarded as very high by 43.7% of farmers and high by 21.7%. Farmers were interested in expanding their fish farming activities, with 70% having a high or very high intention to construct more ponds. The main limitations to starting up commercial or small-scale fish farming activities were supply of fingerlings, financial viability and availability of marketable species.

Only 4.2% of farms kept daily records of farm activities (i.e. observations, feeding or water conditions). The source of fingerlings for 90.4% of farms

was hatcheries and HAQDEC was the major supplier of fingerlings. Some 4.8% of farms received free fingerlings from another farmer, 1.3% caught wild fingerlings, 0.3% purchased wild fingerlings and 1.0% purchased large fish as broodstock. Most respondents did not have carp or trout hatcheries in their locality. The stocking density for all farms averaged 3.8 fish/m<sup>2</sup> (median 1.4 fish/m<sup>2</sup>). Many farms appeared to have been unable to obtain fingerlings.

Mean survival rates were in the range 85–95% for carp and tilapia, and 75–85% for trout. The main water sources were streams or creeks (69.3% of farms), underground springs (17.6%) or a combination of water sources. Some 43.8% of farms used a flow-through system. The discharge of water from the ponds was mainly to a river or stream (82.7% of responses). Only 6.4% of farms discharged onto agricultural land and 1.6% discharged onto fallow land. Pond management practices carried out between each crop were mainly for the purpose of leaving water in the pond (35.3% of farms).

The main type of feed used was either kitchen leftovers and vegetables (64.2%), or kitchen leftovers and live feed such as worms and termite nests (21.7%). In less than 10% of farms, manufactured pellet feed was used in combination with other home-based feeds. No fertiliser was used in 59.1% of farms. In cases where fertiliser was used, organic animal manure was the most common form (33.2%).

Carp was sold at an average weight of 0.8 kg, while all other fish were approximately 0.3 kg. The average age of carp at harvest was 16 months, while

for trout it was 10 months and for tilapia 5 months. Average prices for table-size fish were: carp K7.9, trout K12.6 and tilapia K2.5. Most farms (e.g. 80% of carp farms) had not yet made any sales. Some 43.7% of farmers had consumed some of their own fish, and home consumption of farmed fish accounted for 39% of the harvest. The main buyers of farmed carp were local villagers and farmers, with minor sales at street markets. Trout was sold to restaurants, hotels, town markets, supermarkets and town workers. Tilapia was sold to villagers, town dwellers and other farmers. The average price paid for fingerlings was K0.39±0.91.

Coffee was a substantial cash crop for respondents, providing an average percentage of 34% of farm income. Income from vegetables, betel nuts and fruit averaged 20% of farm income. Time spent working on the fish farm was generally a family effort. The father/male carried out 50% of the work, the mother 21%, children 20% and others 9%.

The average number of ponds per farm was 3.25 (median 2 ponds) and the total area of ponds averaged 141 m<sup>2</sup> (median 60 m<sup>2</sup>). Some summary statistics for water quality for the 313 farms were (mean ± standard deviation): water temperature: 22.0±3.5 °C (median 21.1 °C); depth of ponds: 51±38 cm (median 46 cm) and Secchi visibility depth: 63±76 cm (median 25 cm).

The average number of family members living with the farmer was between five and six, although up to 18 people were recorded. The average distance of the ponds from the farmhouse was 287 m (median 70 m). The main soil type was loamy clay (37.4% of farms). Some 93.6%

of farms had earthen ponds, and 5.4% of farms used concrete to construct or partly construct walls.

The most common reasons for failure of neighbouring fish farms were vandalism and theft, lack of help or extension, shortage of fingerlings and water supply problems. The respondents identified the most significant issues for development of fish farming and commercial success of fish farms as:

- improved training and advice
- improved fingerling supply
- better financial support
- improved feed
- better supply of equipment and materials.

## Key issues for inland pond aquaculture—priorities of the workshops

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At a major project workshop of stakeholders held in Goroka in May 2003, participants in a priority setting exercise were organised into groups that represented the three categories of farmers identified by the surveys: new farmers (*nupela fama*), established farmers (*olpela lik lik fama*) and experienced, pioneer farmers (*olpela fama*). The participants examined and prioritised the key issues identified in the surveys. In addition, at the regional workshops held in 2003–05, participating farmers contributed opinions and assisted in refining priorities and actions for the key issues. The results of the prioritising exercises are summarised in Table 1.

**Table 1.1**

Summary of key issues that received a high rank from the three categories of farmers

<b>Areas for action and research</b>			
<b>Issues of high priority</b>	<b>Olpela fama (experienced, pioneer farmers)</b>	<b>Olpela lik lik fama (established farmers)</b>	<b>Nupela fama (new farmers who have not yet harvested)</b>
1. Improving fingerling supply	Improve fingerling supply, improve survival of GIFT in transport, re-establish trout fingerling supply, establish decentralised distribution centres, improve training, restart wokabaut skul	Reduce mortality rates of fingerlings during transport to farmers, establish decentralised distribution centres	Improve fingerling supply, reduce mortality rates during transport, establish decentralised distribution centres, establish farmer associations and improve networking
2. Improving nutrition and growth	Research high quality locally made feed for various species to avoid high cost of imported feeds, improve poor broodstock nutrition	Research a formula to make farm-made feeds with local ingredients for various species	Survey local ingredients for feeds, research a formula for farm-based and commercial feed using local ingredients
3. Identifying appropriate species and methods for farming in different regions	Conduct comparative growth studies (especially with GIFT at various altitudes), training and extension at demonstration farms	Introduce training on integrated farming and use of fertilisers, improve broodstock of GIFT and carp	Conduct trials at demonstration farms, reintroduce better broodstock of carp and GIFT
4. Developing farming strategies for new species	Perhaps trial indigenous species—but resolve problems with current species first	Research nutrition and breeding with new species (not high priority)	Improve existing broodstock, reintroduce Chinese carp species, research new species
5. Improving marketing strategies	Introduce better training in fish processing, value-adding and developing market standards	Train farmers on marketing a quality product, improve roads and infrastructure	Train farmers on value-adding and planning of harvest, e.g. for Christmas and New Year
6. Improving communication of research findings to the industry	Introduce better extension and training services in local languages, build farmer associations and networking	Establish database on aquaculture, carry out research and publish findings, restart wokabaut skul	Research using local conditions and communicate results to farmers with demonstration farms



The view of the Markham Valley from the highlands of Papua New Guinea

# Chapter 2

## Introduction

*Paul T. Smith and Kine Mufuape*

## Background on fish species in Papua New Guinea

Some 86.8% of the 5.6 million inhabitants of PNG are farmers or live a rural lifestyle, and more than 2.0 million live in the highlands (>1,400 m above sea level). Published data shows that most of the population lives at a subsistence level, with an average GDP per capita of US\$622. Malnutrition is a major concern and the average life expectancy at birth is 57.2 years (WDIO 2006). PNG is a signatory to the FAO agreement on food security, and freshwater aquaculture is recognised as a means of meeting the needs of the population. Importantly for inland fisheries in PNG, census data shows that 95% of the inland population live within 2 km of freshwater rivers and 70% live within 0.5 km.

Freshwater fish is much sought after by inland people and there is a real need for improved fisheries resources to meet the existing and future protein requirements of the PNG people. Villagers have traditionally obtained food by agriculture and hunting, and a proportion of villagers regularly fish in inland waters to supplement their diets. Three groups of native freshwater species are favoured by village people: eels, freshwater prawns and catfish. Relevant information on each group is briefly described below.

There are five indigenous species of eel in PNG according to Allen (1991), and they are highly prized. The Indian short-finned eel (*Anguilla bicolor*) is found in the northern rivers, particularly the Sepik and Ramu Rivers, but it is also endemic to other lowland rivers and mountain

tributaries. The giant long-finned eel (*A. marmorata*) is found in regions in the south-east, near Port Moresby, in lowland rivers and in upland tributaries. The Pacific long-finned eel (*A. megastoma*) is found in coastal streams and pools as well as inland from Popondetta and in the north-west around Wewak. The Pacific short-finned eel (*A. obscura*) is found in various types of streams and localities, including Port Moresby, Embi Lake near Popondetta, Madang, Sepik River and near Jayapura. The marbled eel (*A. reinhardtii*) is found in a few localities including Dinawa and the Upper Saint Joseph River.

Ursula Kolkolo (pers. comm.) stated that 18 different species of freshwater crustaceans had been identified in studies of waterbodies in PNG. Experience in Australia and other countries with *Macrobrachium* spp. and redclaw suggests that they may be candidates for pond aquaculture in PNG.

Native catfish is a delicacy in PNG and farming those species also offers potential.

In an attempt to increase fish stocks, more than 25 exotic species of fish have been introduced to PNG since 1949 (Coates 1986). By the early 1990s, some 11 species showed potential for aquaculture or were found in rivers and lakes in PNG. These include African tilapia (*Oreochromis mossambica*), walking catfish (*Clarias batrachus*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), bighead carp (*Aristichthys nobilis*), climbing perch (*Anaba testudineus*), snakehead (*Channa striata*), mosquito fish (*Gambusia affinis*), guppy (*Poecilia reticulata*), brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*). Of these species, tilapia became an important food source

for people along the Sepik and Ramu Rivers (Allen 1991), and common carp, tilapia and trout became common in rivers in the highlands. However, grass carp and bighead carp do not appear to have survived. Local fishermen are able to catch the introduced species, but complain that indigenous species of fish have declined in recent times (Smith and Kia 2000).

An ambitious stock enhancement program occurred in PNG during 1993–97 under the Food and Agricultural Organisation of the United Nations (known as FISHAID, FAO Project No. PNG93/007). There was also an earlier fish stock enhancement project by FAO (Zwieten 1990) in the Sepik River in 1987–93 (known as SRFSEP, FAO Project No. PNG/85/001). The FISHAID project introduced nine new species to the freshwater rivers of

PNG (Coates 1997) with the: ‘immediate objective to improve the naturally poor fish stocks of the Sepik–Ramu basin by stock enhancement’ (FAO 1997).

The fish species and numbers that were released into the Ramu–Sepik river system were: 173,111 of *Tilapia rendalli* (redbreast tilapia), 37 of *Osphronemus goramy* (giant gouramy), 27,750 of *Puntius gonionotus* (Java carp), 70,309 of *Schizothorax richardsonii* (snow trout), 29,827 of *Tor putitora* (golden mahseer), 11,224 of *Acrossocheilus hexagonolepis* (chocolate mahseer), 14,511 of *Colossoma bidens* (pacu) and 160,511 of *Prochilodus marginatus* (curimbata). Another fish, *Barilius bendelesis* (lesser baril), arrived without notice and was not solicited by the project, so the 150 fish of this species



Common carp and tilapias caught in Yonki Reservoir, EHP, by a fisherman in November 2005

were destroyed without stocking. Two species, *Labeo dero* (minor carp) and *Trichogaster pectoralis* (snakeskin gouramy), were intended for the enhancement program but were not imported.

The reports on the project make a number of interesting conclusions (FAO 1997; Pullin et al. 1996; Zwierton 1990), including the following:

the major problem faced during the project ... related solely to government policies and priorities. During the course of the project, involvement with the country's on-going aquaculture (ie village pond culture) programme was minimal. This was unfortunate as the FISHAID project was an aquaculture based project ... The lack of access of the FISHAID project to existing aquaculture facilities, and staff, was a significant planning omission. Several extremely valuable stocks of fish ... imported at significant expense by PNG ... were reared almost to breeding age in order for PNG to become self-sufficient in its programmes. Due to lack of support from the aquaculture programme, at the closure of the project the future of these stocks was bleak. Many, in fact, were dumped in the Ramu River by necessity.

Sagom (1995), the officer in charge of HAQDEC, was critical of the FISHAID project because he considered that: a) more technical staff should have been put on the project, b) the roles of the FISHAID project and of HAQDEC should have been combined with the aim to research and develop aquaculture in PNG (Sagom 1995), and c) the project lacked an extension program, which, among other things, should have taught village

fishermen how to catch the fish that had been released into the rivers and streams by the project.

The current study observed that introduced fish have had a substantial impact on the country's biodiversity and the village people. Anecdotal stories of problems are common. For example, snow trout (*S. richardsonii*) causes vomiting when the roe is eaten and there is talk that some children have died. This species is very numerous in the rivers and it cleans stones by scraping the surfaces. As a result, many villagers have complained of injuries suffered as a result of slippery stones as they wade across streams. The pacu (*C. bidens*) is a relative of the piranha and it was introduced to eat nuts and berries that float down rivers. It is nicknamed the 'ball-cutter' by the villagers because on occasions it has bitten off the testicles of bathing men.

At the inland markets, villagers complain that there are no longer any native fish species being sold. Fishermen believe that introduced species have reduced the numbers of native fish as well as changing the inland fishing industry. For instance, in the Sepik River the once prosperous tilapia fishery has been decimated by predatory fish feeding on tilapia fry. Anecdotal evidence from local people indicates that the introduced 'ball-cutter' and 'rubber-mouth' species are responsible. Further, a common complaint is that the small, intramuscular bones of some introduced fish cause problems when the fish are consumed.

On a positive note, *Tor putitora* (golden mahseer) is breeding in Yonki Reservoir, providing a new fisheries resource for smallholder fishers. A thorough survey



of the distribution and abundance of introduced species would be helpful. It should include studies of both benefits for villagers and impacts on biodiversity of native fish stocks.



Specimens of golden mahseer (*Tor putitora*). Fish weighing approximately 5 kg were caught by net in Yonki Reservoir at night in February 2006 and sold the next morning at a roadside market for K25. Female fish had roe and are descendants of broodstock released by the FISHAID project of FAO in the mid 1990s.

Prior to 1990, common carp and rainbow trout were raised in earthen ponds in smallholder farms in the highlands. The number of freshwater fish farms in PNG grew rapidly in the 1990s and now small-scale fish farming is a significant form of agriculture in PNG. This development was sparked by the expansion of ponds and hatchery facilities at HAQDEC at Aiyura and improvements in methods for producing fingerlings of common carp (*Cyprinus carpio*). Distribution of fingerlings of common carp increased

from 13,288 to 64,147 in the early 1990s (Sagom 1995) and then to 258,731 in 1999 (Mufuape 2000).

The improved results were achieved largely through the financial and technical assistance of the Japan International Cooperation Agency (JICA). In June 1996 JICA entered into a 4-year collaboration with HAQDEC, providing equipment, machinery, pond construction, office buildings, training, vehicles and technical expertise under the direction of Dr Kyoshi Matsuda (EHPG 1996; HAQDEC Newsletter 1998; Wani 1998). Also, during that period, National Fisheries Authority transferred responsibility for aquaculture development to the Eastern Highlands Province Government. When that program ended, assistance was renewed for a further 2 years and Mr Kuma Chiaki of JICA arrived from Japan in May 2000 to replace Dr Yamazaki. In 2003–05 Dr Yada was the Japanese representative.

HAQDEC has been the main supplier of carp fingerlings to fish farms in PNG, although there are a few small-scale carp hatcheries in inland PNG. The only significant trout hatchery is the Lake Pindi Yaundo Trout Farm near Mount Wilhelm, which breeds and distributes fingerlings of rainbow trout to smallholder farmers, mainly in Simbu province. Mrs Betty Higgins set up the Pindi Yaundo Trout Farm in 1993, and in 1997 she was able, for the first time in PNG, to successfully produce eyed trout eggs and fingerlings. Trout culture is restricted to farms at altitudes >1,600 m above sea level and, because trout is a relatively delicate fish, high mortality rates of fingerlings often occur during transport. Also, successful culture requires a feed with a high protein content and a year-round supply of fast-flowing clear water.

In 2000 data on fingerling distribution by HAQDEC and Lake Pindi Yaundo was used to estimate that 60,000 kg of carp and 10,000 kg of trout were produced each year (Mufuape 2000). Most of this production was either consumed by the families of farmers or sold at the local markets. From records at HAQDEC, it appeared that there were approximately 5,000–6,000 fish farms in inland PNG and that most of these farms combined fish ponds with other forms of agriculture (Smith and Kia 2000). Those estimates were based on the supply of fingerlings by HAQDEC, which sold them for K0.10 each (at the farmgate) on a cost-recovery basis to inland and coastal provinces. From the distribution data, Mufuape (2000) estimated that 77% of farms purchase less than 50 fingerlings at a time. Larger purchases were made by the national Department of Livestock and Agriculture (NDAL) for on-selling to small farmers. Mufuape (2000) calculated that there were approximately 5,000 families in the highlands who each had one or two fish ponds that grew 50 fish to 500 g. He argued that fish farming can make a considerable contribution to meeting the requirements of food security in rural subsistence communities. However, there was very little data on pond management practices, feeding, fish growth or survival rates. Also, the extent to which farmers integrated fish farming with subsistence agriculture was not known (Smith and Kia 2000).

In May 1999 GIFT (also known as 'super' tilapia) were brought in from the Philippines through the GIFT Centre and quarantined at HAQDEC until fingerlings were released to farmers on 23 October 2002. The officers at HAQDEC were pleased with the performance of GIFT in experimental ponds, and farmers reacted

very positively to the new fish because of its superior growth rate and ability to breed in their ponds. The introduction of the GIFT species to the various climates of PNG needed to be nurtured and its performance monitored. Unfortunately, there were only a handful of officers at HAQDEC, NDAL or NFA who had any technical expertise to provide training and extension to this blossoming industry.

A major limitation to the growth of aquaculture, and particularly trout farming, in PNG has been the cost of importing processed feed and fishmeal. However, two fish canneries and fish loining plants have recently been established in Lae and Madang, and these now provide a source of local fishmeal and fish oil for incorporation into locally produced diets. Although a cheaper, locally processed diet is now available, it has a high fibre content and 10% less protein than the imported pellets. Betty Higgins and other trout farmers have tested their own feed formulations with limited success. With respect to carp, JICA, in collaboration with HAQDEC, investigated the composition of diets and their impact on feed conversion for pond culture and for cage culture at Yonki Reservoir. Farmers have also tested local fertilisers such as chicken manure and coffee waste, as well as their own feeds (Smith and Kia 2000).

## Objectives of the study

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The problems with development of freshwater pond aquaculture are probably more apparent in PNG than in other countries because: a) PNG does not have a cultural history of fish farming and its indigenous fish species have not been successfully farmed, b) it has a mountainous landscape which severely hampers transport and infrastructure, and c) it is a developing country which has many competing needs since gaining independence in 1975.

Nevertheless, farmers in PNG are enthusiastically driving the development of the industry and are capable of benefiting substantially from the 'Asian experience' in aquaculture. To this end, this study was undertaken in order to determine the status of fish farming and the needs, constraints and plans of farmers. The study aimed to prioritise R&D issues so that research donors such as the Australian Centre for International Agricultural Research (ACIAR) can target their assistance.

The study developed during meetings and site visits in 2000 (Smith and Kia 2000), in which the following main issues were identified:

- food security and the needs of the inland people, who comprise most of the population of PNG
- increased fingerling production and full utilisation of introduced fish species such as carp, tilapia and trout
- the need for cheap and productive fish feeds and improved techniques in animal husbandry

- training and extension work for fisheries officers and farmers.

It was considered that for government agencies, research providers and service sectors to provide appropriate training, develop ancillary industries and target the delivery of resources, the first step should be to determine the status of the industry and its needs. Appropriate policies for management and sustainable development of inland pond aquaculture could then be based on accurate and comprehensive information on the structure of the industry, animal husbandry techniques, the degree of integration with agriculture, and the socioeconomic and environmental impacts.

## Activities and survey methods

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The approach was to employ and train two full-time technical assistants to work at HAQDEC with the main aim of carrying out a detailed survey of pond aquaculture in inland PNG. Also, a comprehensive literature survey was carried out in which 177 reports were collected, scanned and indexed (see CD in the back of this monograph).

The survey provided data on farm location, farming experience, stocking information, pond management, feed use, growth rates, production results and water sources. It also identified constraints, needs and problems such as transportation of fingerlings, disease, feed, sediment, water quality and post-harvest marketing. To validate farmers' responses to the survey questions, the technical officers made direct observations and measurements during the farm interviews (see below). The survey team usually

consisted of the two technical officers, a senior member of the project team, a local industry representative who acted as a guide, the local provincial DAL officer and a driver. Police officers also accompanied the team during some field trips.

Four types of questionnaires were developed—for surveying fish farms, hatcheries, institutions and markets.

In October 2001 the number of farms in each province was estimated from the available data at HAQDEC and from knowledge of the most experienced aquaculture officers in PNG (Table 2.1). The aim was to survey a representative number of sites from each province, and the main provinces were in the highlands: EHP, Simbu and WHP.

**Table 2.1**

The plan for surveying aquaculture in Papua New Guinea. At the start of the survey period in October 2001, the number of active farms in each of the 19 provinces was estimated and a plan was made for surveying a representative number of farms, hatcheries, markets and institutions in each province.

Province	Estimated number of active farms	Plan of the number of survey sites			
		Farm	Hatchery	Market	Institution
Eastern Highlands	1,500	63	3	7	6
Simbu	2,000	65	1	6	6
Western Highlands	1,000	63		6	8
Enga	180	30		3	2
Southern Highlands	200	35		4	3
Morobe	300	30		6	3
Madang	60	8		3	2
East Sepik	35	10		3	3
West Sepik	25	8		2	2
Oro	15	3		2	2
Milne Bay	5	2		2	1
Central	7	3		3	2
Gulf	0				
Western	50	12		3	2
Bougainville (North Solomons)	3	2		2	1
New Ireland	3	2		1	1
East New Britain	20	6		3	2
West New Britain	12	5		3	1
Manus Island	3	3		1	1
National Capital District	0			1	1
<b>Total</b>	<b>5,418</b>	<b>379</b>	<b>4</b>	<b>68</b>	<b>61</b>

The questionnaire began with an introduction to ACIAR and the purpose of the survey. In almost all cases, the farmers, hatchery operators and institutions were willing to answer the questions and in turn ask questions themselves. Sellers at markets were more reluctant to spend time answering survey questions.

The farm and hatchery surveys were carried out while travelling through areas where common carp, trout and tilapia were known to be cultured (from data on fingerling distribution). The market survey was carried out at supermarkets, open markets, roadsides, hotels and lodges. Institutional surveys were carried out with schools, missions, hospital and medical centres, governments, NGOs, youth groups and community groups.

The format for the questionnaires is summarised in Table 2.2. Some questions

required straightforward responses (e.g. 'Number of years farming?' or 'How would you describe your intention to construct more fish ponds?'), with the answer selected from five choices ranging from very high to very low. Other questions required data to be added to a table (e.g. species of fingerlings, number of fingerlings, price of fingerlings, source of fingerlings for specific years).



Technical officer Mr Kaupa Kia interviewing a smallholder farmer and family. Most interviews became a community event.



Technical officer Mr Kaupa Kia measuring pH in a fish pond in Simbu province

<b>Table 2.2</b>				
Summary of key issues that received a high rank from the three categories of farmers <sup>a</sup>				
<b>Section</b>	<b>Farm</b>	<b>Hatchery</b>	<b>Institution</b>	<b>Market</b>
A	Background information (10)	Background information (10)	Background information (10)	Background information (10)
B	Type of activities carried out at the farm (9)	Type of activities carried out at the hatchery (5)	Type of activities carried out by the institution (3)	Type and source of fish (11)
C	Farmer's opinions about the influence of agencies and institutions on the farm (2)	Hatchery's opinions about the influence of agencies and institutions on the hatchery (2)	How do they regard the influence of their activities? (2)	Processing of fish (2)
D	Observations about fish farms in local surrounding area (2)	Observations about fish farms in local surrounding area (2)	Observations about fish farms in local surrounding area (2)	Market preferences and opinions about farmed fish (1)
E	Opinions about fish farming (2)	Opinions about fish farming (2)	Opinions about fish farming (2)	Comments (1)
F	Farm details and information (2)	Comments (2)	Comments (2)	Questions for buyers and sampling (3)
G	Comments (2)	Photographs	Photographs	Photographs
H	Measurements of farm parameters (18)			
I	Photographs			

<sup>a</sup> The number of questions for each section of the survey is shown in brackets.

For farm surveys a total of 18 parameters were measured at each farm. Three water quality parameters were taken: temperature, dissolved oxygen (DO) and pH. In the case of farms with more than two ponds, the average readings were recorded. Turbidity or pond clarity was measured by dipping a long stick into the water and measuring the depth at which the brightly coloured end of the stick disappeared or became invisible (Secchi visibility depth). The type of water source and exchange process was recorded.

The number of ponds were recorded and pond lengths and widths were measured with a tape measure. Pond depth was measured with a calibrated stick, and average depth was recorded for farms with more than one pond.

The type of soil at each fish farm was recorded and the clay content was estimated. The surrounding vegetation of the fish farm was recorded as grassland, forest, gardens or a mixture of all these types. The number of fish stocked in the

ponds was recorded as well as the distance of the ponds from the house, road and market.

GPS readings were recorded at each survey location. The GPS variables were longitude and latitude readings in degrees and minutes to three decimal points, for example 05°50.764' S and 144° 58.329' E. The altitude (height above sea level) was recorded in feet and converted into metric units. The GPS instrument used was a GARMIN GPS 12. Photos were sometimes taken of the ponds and farm set-ups.

In the case of the market survey, photos were sometimes taken of the type of food items and other goods displayed at the market at the time of the survey. For the roadside markets, especially at Yonki Reservoir, samples of prepared fish were bought and comments were recorded on its taste, saltiness, moisture content, freshness and the ratio of meat to bone.

At the end of each questionnaire, the farmers usually discussed their problems and were given advice by the officers. Farmers usually wanted help with technical issues relating to feeding, fingerling supply, slow growth of fish and water quality. These issues were recorded.

The database from the farm survey included data for 298 parameters (variables) from 313 farms (cases) and was statistically analysed with SPSS quantitative data analysis software. The other three surveys had much fewer cases (less than 20) and the databases were analysed for ranges, averages and trends.



Technical officer Mr Micah Aranka taking DO (dissolved oxygen) readings at Mr Peter Gundil's carp hatchery in Simbu province

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Dr Akhteruzzaman (centre), an aquaculture expert from Bangladesh, helps with training of NGOs, farmers and hatchery operators at the hatchery workshop held by HAQDEC at Aiyura in November 2005. From left to right: Siwi Kuman (owner of Distribution Centre Simbu province), Arnold Andiken (Simbu adviser), Matthew Ten (WHP), Paul Homate (farmer in EHP), Dr Akhteruzzaman (holding carp), Rudy Artango (farmer in Morobe province) and Chris Mondo (Simbu province).

## Chapter 3

### Building infrastructure and capacity in aquaculture

*Johnney Soranzie, Jacob Wani,  
Kine Mufuape and Paul T. Smith*

## History of aquaculture in Papua New Guinea

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Blichfeldt (1975) described the introduction of trout and attempts to stock highland rivers in PNG:

The first introduction has been recorded by Sir Hudson Fysh in 'Round the Bend in the Stream' and took place on 1st December, 1949, when 20,000 Brown Trout Fingerlings were flown up direct from Boggy Creek Hatchery near Oberon in N.S.W. in a D.C. 3 to the Airstrip at Nondugl via Port Moresby. These were put into the river at Nondugl in W.H.D. and allegedly also in tributaries of the Wahgi River, but apparently 'they did not do too well and disappeared

That was also probably the first attempt at pond culture of fish in PNG because according to Schuster (1951):

... the fishes were partly released in streams and partly in a pond on the Agriculture Station. During a visit to Nondugl there was no evidence of the trout. With a sufficient supply of animal food and a favourable temperature of the water, conditions are suitable for trout, but the chance that the streams of the Hagen mountains will become good trout waters is minimized by the many floods during the wet season. The muddy water of the floods is a danger to all types of fish accustomed to clear water.

The Division of Agriculture, Stock and Fisheries (DASF), which had been established in 1954 during the time of Australian colonial administration of PNG,

selected aquaculture as an important part of a program to provide protein and combat malnutrition in communities, particularly in remote, rural areas. DASF officers encouraged people to construct ponds and culture fish for their own consumption. Many fish ponds were constructed and stocked with fingerlings supplied free of charge by DASF. Also, several fish ponds were established by DASF at various locations in the country to train farmers, propagate fingerlings and distribute freshwater fish species such as *Tandanus* sp., *Puntius gonionotus*, silver carp, bighead carp and common carp. Research on the growth and feeding habits of each of these fish species was undertaken by the DASF research staff.

The Bomana fish ponds at Port Moresby were established to research freshwater catfish and the Javanese carp, but were closed down in the 1960s when the freshwater biologist in charge of the project left the country (Sagom 1995).

The Dobel fish ponds, on a 12-acre (5 ha) site 3 miles from Mt Hagen, WHP, were constructed in the period 1954–62. A total of 10 ponds were constructed and eight species of fish were trialled (Anon. 1962; Buckwell 1960). *Tilapia mossambica* was the first to be tested in 1954 and it performed poorly because of uncontrolled, rapid breeding and small size of fish at harvest (Anon. 1962; Buckwell 1960). In 1959 giant gouramy (*Osphronemus goramy*) and snakeskin gouramy (*Trichogaster pectoralis*) were trialled but they showed low growth and the climate of the highlands was found to be too cold for them to reproduce. Apparently, giant gouramy did well in Rabaul, reaching 3.5 lbs (1.5 kg) in 15.5 months (Anon. 1962). Ten fingerlings of

golden carp (*Cyprinus carpio flavipinnis*) arrived from Taronga Park Aquarium, Australia, in August 1959. They grew to 3 lbs (1.4 kg) in 15 months and produced 700 fingerlings. Although the growth and early reproduction was promising, the DASF officers were concerned that the golden colour may attract predatory birds at farm situations. Seven fingerlings of Cantonese carp (*Cyprinus carpio cantonosa*) arrived in 1960 and grew to 3 lbs (1.3 kg) in 18 months. Although they spawned on numerous occasions, the survival of the fry was low.

Three other carp species were also introduced in 1960 and trialled at the Dobel fish ponds—Japanese carp, mirror carp and silver carp. The fish were fed and reportedly did well on kaukau (sweet potato). An inspection of the contents of the digestive tracts of *Tilapia mossambica* revealed that it mainly consisted of kaukau (Buckwell 1960). However, Filewood (1967) reported that kaukau had very little food value for carp and it required 30 lbs of kaukau to produce 1 lb of carp. He suggested that better native feeds were insects (which could be attracted by night lights over ponds or insect traps), earthworms, offal, blood, spoiled cereal and kitchen scraps. Farmed fish also performed well on peanut meal and coffee cherry beans (Buckwell 1960). Work ceased at Dobel when the fish did not provide the growth required by the project staff, and the ponds were filled in with earth in the 1970s (Sagom 1995).

Only the Aiyura ponds with common carp survived from those early days. Common carp was introduced to Aiyura and the highlands in 1958–59 by the colonial administration. By 1967–68 the Department of Primary Industries

Fisheries (DPI) reported that there were 7,000 fish ponds in Wagi Valley alone (Mufuape 1999). Common carp also became widely distributed in natural rivers and was accepted by highlanders.

Nevertheless, by 1970 the colonial government considered that development of carp farming should be abandoned. Mufuape (1999) suggested that the main reason was that the colonial administration lacked the technical capacity to run a carp hatchery. Also, carp is a pest in Australia so the colonial administrators recommended that vegetable production should be the focus for inland communities and that fish from the coast should be distributed inland. Consequently, use of the four ponds at Aiyura Fisheries Station was discontinued.

However, the interest of farmers remained high. Under the independent Government of PNG, the program for the development of carp farming was revived during the 1980s and the Aiyura Centre was re-established in 1983 by DFMR. Petrus Sagom was appointed as the officer in charge in 1984 and the Aiyura Carp Breeding Station was renamed the Highland Aquaculture Development Centre (HAQDEC). Prior to this time, the number of carp fingerlings distributed from Aiyura was 2,000–5,000 per year to areas within the highlands region. However, with the establishment of HAQDEC, this production increased to approximately 10,000 carp fingerlings per year (Sagom 1995).

Returning to the history of trout farming, after the first introduction of trout in 1949 trout hatcheries were established to facilitate a stock enhancement program for highland rivers. In the 1970s Southern

Highlands province (SHP) was the most developed with respect to inland fisheries. Trout was well established in the rivers and the trout hatchery in Mendi, SHP, produced approximately 350,000 fingerlings from eggs imported from Australia (Haines and Keller 1979a). The local councils purchased the fingerlings for K20 per 1,000 and released them into streams. After a number of attempts at pond aquaculture with rainbow trout by highland farmers, the Kotuni Trout Farm in Goroka, EHP, was established in 1973 and became the first successful trout farm in PNG. It produced 10 tons per year until it closed in 1984. The Lake Pindi Yaundo Trout Farm in Simbu province produced up to 5 tons per year, and in 1996 successfully produced trout fingerlings from its own broodstock, for the first time in PNG (Wani 1998). It was able to supply local small-scale trout farms until it closed down in 2002–03 because of feed problems, compensation claims and deteriorating roads. It reopened operations in 2005–06.



Rainbow trout, which were used as broodstock, at the Lake Pindi Yaundo Trout Farm and Hatchery. This hatchery is the main source of trout fingerlings for the highlands of PNG.

## Expansion of HAQDEC

Following the resumption of activities at the Aiyura fisheries station in 1984, DFMR sought technical assistance from FAO to cope with the increasing demand for carp fingerlings and to train officers. FAO provided engineer plans for the expansion of the facilities at HAQDEC, and in 1990 DMFR and DPI launched a public investment program (PIP) for expansion of Aiyura. In 1991 DFMR sought assistance from JICA to expand the fish farming facilities at Aiyura according to the design from FAO (Map 3.1) and using funding from the PNG Government and JICA. During the construction stage, the centre's activities were jointly run by three staff: a JICA aquaculture expert Dr Kiyoshi Masuda, scientific officer Mr Jacob Wani and regional development officer Mr Paul Murri of the Resource Branch (Wani 1996). Under their leadership, 40 fish ponds with a total pond area of 2.33 ha and a small multi-species hatchery were completed by the end of 1996 (Wani 1997). Other improvements included the building of a 2.0 ha reservoir pond, a carp hatchery, a research laboratory, an office building, an intake drain measuring 2 km, a quarantine area and miscellaneous storage areas; and the acquisition of two vehicles.



Pond at HAQDEC, Aiyura, in 2006. Happas are set up to hold GIFT fingerlings.



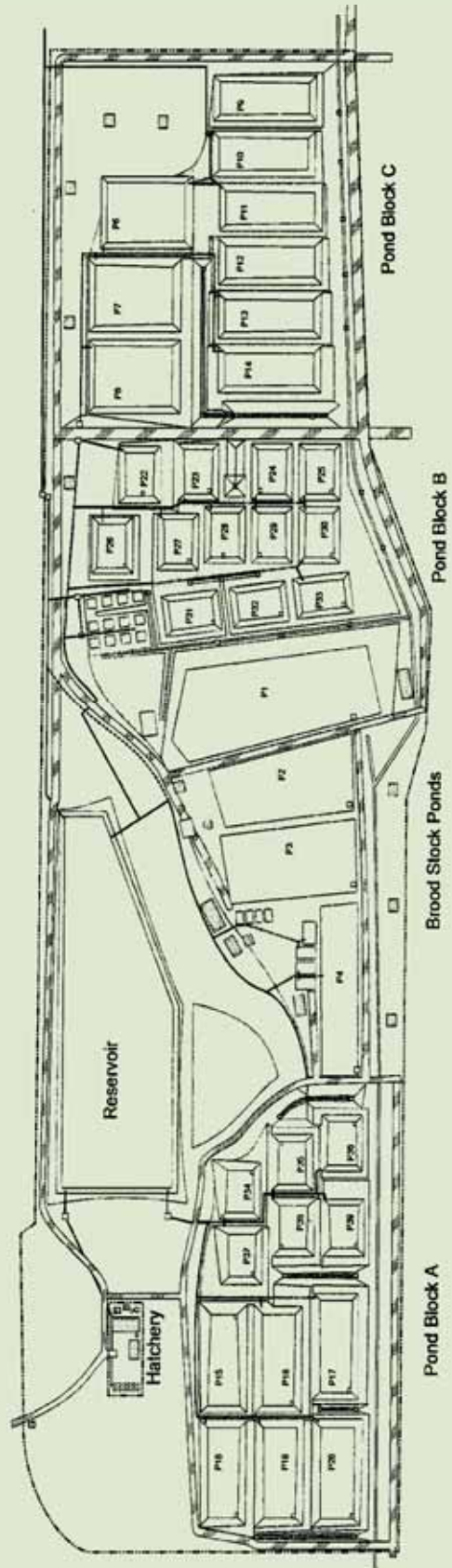
A pond at HAQDEC used to raise common carp



Broodstock tanks, spawning tanks and plankton ponds at the common carp hatchery at HAQDEC, Aiyura



The water storage reservoir at HAQDEC, Aiyura, in the dry season. The water supply is seasonal and the water level falls to low levels during the dry period from April to September each year.



Plans of the construction of ponds and hatchery facilities at HAQDEC in Aiyura (Wani 1997)

In 1996, with changes in the Organic Law on Provincial Governments, the DFMR was restructured, changing its focus to facilitation, advisory, planning and policy making. Also, according to the 1994 Fisheries Act, DFMR became the National Fisheries Authority (NFA). As a consequence of these changes, NFA transferred the functions of HAQDEC at Aiyura to the Eastern Highlands Province Government. In 1997 NFA, EHPG and JICA signed a tripartite agreement to allow EHP to be the host province for HAQDEC. Ian Mopafi of EHPG was the project manager and Jacob Wani of NFA was the officer in charge prior to the transfer of HAQDEC to EHPG. Kine Mufuape of EHPG became the officer in charge of HAQDEC in April 1998. In 1999 NFA officially handed HAQDEC to EHPG. JICA continued to provide technical support to aquaculture farmers and experts came from Japan to provide technical training in hatchery operations and farming. During the period of change in government administration and donor technical support, the facility was the main source of carp fingerlings and the training centre for farmers.

## Wokabout skul and extension programs

There have been a small number of very important aquaculture training and extension programs that have encouraged farmers to commence fish farming. In the 1960s, under the colonial administration, farmers in Morobe province were asked by DASF officers to dig fish ponds without any clear instructions. 'Many people dug deep holes similar to toilet

pits, filled them with water and stocked fish' (Soranzie 2005). According to eye witnesses, agricultural extension officers flew in on helicopters and dropped off plastic containers filled with small fish for farmers to stock their ponds or pools of water. Farmers were not given information on how to feed or cook fish so many ponds were left unattended—farmers thought that the fish would eat mud and drink water (Soranzie 2005).

There was a revival of aquaculture in Morobe province in 1987–89 when the Lutheran Development Service (LDS) carried out a training program. At first the focus of the project was to develop small-scale coastal mariculture in Morobe province but, because of strong demand, the focus moved to inland pond aquaculture (Soranzie 2005). In the early 1990s the extension and training program under Johnney Soranzie travelled to Lutheran Church members in EHP, Simbu province, WHP, SHP and Madang province.

In the highlands Petrus Sagom was the officer in charge at HAQDEC from 1984 to 1994. Under his leadership and with the assistance of two technical officers, the aquaculture program focused on training and extension at the subsistence level. Consequently, integrated farming was encouraged using a combination of chickens and/or ducks with common carp.

Following the expansion of HAQDEC in the mid 1990s, JICA funded approximately three training courses per year during 1997–2004. Training for fish farmers was principally through the wokabout skul, which was funded by JICA and run by officers of HAQDEC. It travelled to a number of locations in PNG and trained farmers, government officers,



vocational officers and prison officers. It started in 1996 with 30 farmers and, in the period 1996–99, some 10 training sessions had been held with 318 people in the highland and inland areas of many provinces (Mufuape et al. 2000).

During 2000–06 the Asian Development Bank (ADB) funded fish farmer training courses in Morobe province and EHP. ADB makes contracts with advanced farmers or experienced officers who then train fish farmers at locations that are central to village communities (Solato 2005). Also, ACIAR projects commenced training programs for smallholder fish farmers in 2005.



Feed trials by officers of HAQDEC under JICA's supervision were carried out with cages of common carp in Yonki Reservoir (1998–2001).

## Cage culture

Yonki Reservoir is the largest highland water body in PNG, measuring 2,000 km<sup>2</sup>. It was set up to provide electricity to the highland provinces as well as Morobe and Madang provinces. Trials of cage culture with common carp and tilapia species commenced in Yonki Reservoir in 1998 under the direction of JICA. In 2002 GIFT fish were trialled with more

success and in 2003 the Yonki Fish Farmers Association was formed. The first training of farmers on cage culture of GIFT fish was carried out by officers of EHPG in 2004 (Solato 2005; Vira 2004). In 2006 NFA, ACIAR and the Secretariat of the Pacific Community (SPC) commenced a research project on cage culture at Yonki Reservoir to investigate the growth rate of GIFT with trial feeds.

It should also be mentioned that Haines and Keller (1979b) reported complaints from highland provinces that the disappearance of eels from rivers is possibly due to the dam at Yonki Reservoir, which they claim is preventing the migration of eels. There are methods for overcoming this type of problem and they should be implemented.

## Institutional infrastructure and capacity

Management of aquaculture in PNG is shared by various government departments. The Fisheries Management Acts of 1994 and 1998 established NFA as a corporate entity with a focus on fisheries management and development through policy development, facilitation and advisory roles (Wani 2004). Also, NFA was made the lead organisation for aquaculture; however, responsibilities for performing activities such as research, extension, training and fingerling production fall to other government departments (NDAL and the National Agricultural Research Institute (NARI), provincial governments, NGOs and other stakeholders. In 2003 NFA established a national body, the National Aquaculture Development and Management Advisory



Research and extension facilities for cage culture at Yonki Reservoir

Committee (NADMAC), consisting of 10 members to provide advisory support to the managing director of NFA.

Wani (2004) reported that there are only eight officers directly involved with aquaculture in government agencies in PNG. He points out that most of these officers have limited or little aquaculture training. Until recently the four universities and colleges in PNG had no aquaculture curriculum. In 2003 the University of Papua New Guinea introduced aquaculture as part of its biology program for undergraduates and the University of Technology in Lae is linked with village aquaculture programs.

HAQDEC is the main facility in the highlands and the aquaculture facility at Erap is the main lowland aquaculture facility. Both facilities provide training, fingerlings and extension to farmers. The facility at Erap mainly caters for Morobe and other coastal provinces. Also, NDAL has an aquaculture facility at Goroka which carries out feed research and fingerling distribution to highland provinces.

In 2004 a collaborative project by ACIAR, NFA and Ok Tedi Mines commenced in Western province. The project is trialling indigenous fish species in a new hatchery that was constructed in Tabubil, and aims to train technicians and farmers in hatchery techniques.

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