Peter Edwards writes on

Rural Aquaculture

Promoting small-scale inland aquaculture in Papua New Guinea

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Papua New Guinea (PNG) comprises the eastern half of the world's largest tropical island with a total land area approaching 500,000 km^2 and is located to the north of Australia. Almost 90% of the population are subsistence farmers living in fertile highland valleys at altitudes between 1,500-2,500 m. Malnutrition is widespread with about 35% of children underweight. The isolation of communities caused by the mountainous terrain led to the evolution of more than 800 languages and some of the more remote human groups were only discovered in the 1930s. The mountainous landscape also severely hinders the development of infrastructure, including roads, and therefore constrains farmers attempting to grow fish from obtaining institutional support; seed, fertiliser and feed; and marketing fish surplus to household needs.

Small-scale fish ponds constructed in a valley with banana and sweet potato crops in the foreground.

While PNG does not have a tradition of fish farming, it has a unique indigenous system of agriculture based on root crops and not on cereal crops as in most other parts of the world, and on the exploitation of wild sago palm. New Guinea is also an early agricultural pioneer, one of only half a dozen places on Earth with independent development of agriculture. Recent dating of residues of taro and banana in soils and on stone tools indicates that they were planted, tethered in plots, and canals dug to control the flow of water about 10,000 years ago. However, it is uncertain how important agriculture was then relative to hunting, fishing and foraging and it may have only played a minor role as these indigenous plants are also distributed in the wild. Some of the other staples farmed today, root crops such as sweet potato and yam, vegetables and pigs were introduced into New Guinea much later.

I was delighted to be invited by the Australian Centre for International Agricultural Research (ACIAR) to join a team last October to review a project on the promotion of small-scale aquaculture in PNG. As I have spent most of my professional career on integrated aquaculture, I was most curious to see how small-scale aquaculture could be developed in PNG. Much of the traditional inland aquaculture in Asia is integrated with agriculture and animal husbandry using on-farm or locally available farm by-products as these were the only resources available to feed fish before the manufacture of inorganic fertilisers and formulated feed.

Background

The severely denuded landscape in heavily populated areas is no longer rich in mammals and birds, and rivers and streams in most areas are too small to be important for fishing, so animal protein is in short supply. There are several types of traditional food production systems in PNG based on root crops, and mixed vegetable gardens with traditional crops such as sugar cane interplanted with introduced vegetables like cabbage and onion. Pigs store the energy of surplus root crops and provide an important source of animal fat and protein in the diet; but pig meat is perishable and once a pig is slaughtered it must be eaten without delay, usually at community-level feasts.

The development of aquaculture is a government priority in PNG to provide badly needed protein for a rapidly expanding population.

Young boys on a fish farm, potential future fish farmers.

High population growth, currently over 2%, is having an adverse impact on the age old agricultural systems as well as the ability of families to raise sufficient numbers of pigs for food because of declining per caput availability of land. Ecological stability is threatened by a trend to reduce the fallow period required to regenerate soil fertility in the shifting cultivation or swidden method of farming in which crops are grown in cleared and burnt secondary forest; and there is a trend towards permanent cultivation of crops. Agricultural productivity is increasing, but also decreasing soil fertility and increasing erosion threaten sustainable crop production. Some communities

Seining a small-scale fish pond.

with better access to outside markets are replacing traditional polyculture of crops with monoculture of cash crops such as coconuts, cacao, coffee, peanuts or rubber which exacerbate these problems as well as increasing risks to natural disasters such as pests and economic risk due to falling produce prices.

Aquaculture is an important priority for the government for food security and poverty alleviation, especially to increase the protein consumption of people in the highlands, as well as a means to earn income. Fish is recognised as a source of high-quality protein, and fish can be eaten frequently as they are small compared to a large pig.

Development of aquaculture

There is limited fish biodiversity in PNG so more than 25 exotic species were introduced into the country over the last 60 years in an attempt to increase fish stocks in rivers, some with value for aquaculture. Inland aquaculture began in PNG in the 1950s with the introduction of common carp (*Cyprinus carpio*) and rainbow trout (*Oncorhynchus mykiss*). Farming common carp as well as Mozambique tilapia (*Oreochromis mossambicus*) were promoted initially in the late 1960s/1970s as a means to alleviate chronic malnutrition in inland areas but they were abandoned due to lack of fingerlings and extension support, problems which are very much prevalent today. Aquaculture activities were reactivated in the 1990s with the assistance of the Japanese International Cooperation Agency (JICA). The Highlands Aquaculture Development Center (HAQDEC) at Ayuria in the Highlands Region was upgraded and the number of farmers building fish ponds grew rapidly through FAO as well as JICA funded programmes.

ACIAR has been providing assistance over the past decade to develop inland aquaculture in the country. Initially a survey was carried out from 2000-2004 to determine the level of pond aquaculture in PNG and to identify constraints (Smith, 2007). This was followed by the current project, commencing in 2005, to address the constraints to more productive small-scale aquaculture identified in the survey, especially through the GIFT strain of Nile tilapia *(O. niloticus)*. GIFT was introduced in 1998 and was quarantined until 2002 at HAQDEC, the largest hatchery in the country. It was introduced in part to lessen the reliance of small-scale farmers on centralised hatcheries for fingerlings as it breeds readily in farmers' ponds, unlike common carp, another species low down in the food chain that was previously promoted by the government.

The survey reported the presence of nineteen hatcheries, although only four had a substantial level of production and 11,000 fish farmers with a combined total of about 1,000 tonnes. Most farmers had two to three small ponds with a total area of 100-200 m^2, about half with flow-through water

One of the families of GIFT tilapia broodstock maintained at HAQDEC.

A pondside training programme.

Large sized GIFT tilapia harvested from Yonki Reservoir.

The seined fish indicating a poor yield of relatively small tilapia of various sizes.

A pelleted feed ingredient grinder (left) and an ingredient mixer (right) at a small-scale feed making centre.

from mountain streams. A majority of farmers did not use fertiliser as the main farmed animal, the pig, is free-ranging which makes it difficult to collect manure to fertilise ponds. The main feeds for fish were kitchen leftovers, waste vegetable leaves, termites and worms. Most farmers were inexperienced and lacked aquaculture training. Farmers reported difficulty in obtaining fingerlings and once stocked, uncontrolled breeding of tilapia and slow growth of fish in their ponds. Traditional experience with raising animals is with pigs which scavenge for much of their food so many farmers believe it is only necessary to stock fish in the pond and let them forage for their own feed in an extensive mode.

Field visit and project review

Overview

We flew north over the mountains from Port Moresby, the capital in Central Province, to Lae in Morobe Province, the lowland project area on the northern side of the island; and later drove up the mountains to Aiyura where HAQDEC is located and Goroka in Eastern Highlands Province. We visited several project collaborating farmers in both the lowland and upland areas, and fingerling distribution and small-scale feed making centres which have been established through the project. We also visited a provincial prison in Goroka where aquaculture is being used to help to rehabilitate low security risk prisoners. As the scheme has considered to be a success it was been introduced into five more provincial gaols.

Five to ten of the 20 collaborating farmers were reported to be successful but the farmers we visited did not appear to have productive ponds although some farmers expressed satisfaction with the 'palm' sized fish they were harvesting for domestic consumption and sale. Most of the farmers had been provided with tilapia fingerlings by the project 2-3 years ago and their ponds contained fairly small and stunted, freely breeding tilapia of various sizes.

GIFT

Visual observation of the five families of GIFT maintained at the HAQDEC indicated that some appear to be of high quality. Large-size tilapia were also observed for sale on the roadside adjacent to Yonki Reservoir, a 2,000 km^2 water body constructed for hydro power and stocked with GIFT, which supports the view that good quality tilapia still exist in the country. However, the founder stock of currently farmed Nile tilapia in PNG are derived from only a few individuals as the original fish introduced from the Philippines suffered from heavy mortality. Such an inbred stock with limited genetic variability may soon suffer from reduced performance so new stocks of GIFT should be reintroduced.

Seed

Decentralised production of tilapia seed, required in PNG because of the mountainous terrain, was taking place at some collaborating farms but was inefficient because of stunting and asynchronous spawning. The ability of tilapia to breed in the pond is considered a positive attribute by small-scale farmers as they can readily produce and sell seed but proper management is needed for good production of both seed and table fish. Introduction of improved tilapia hatchery technology is required for both central and decentralised farmer-level seed production.

Stunting, reduction in size of fish for their age through stress, and the timing of breeding in tilapia, are complex and poorly understood phenomena. In a sense all farmed tilapia may be regarded as stunted because natural populations of Nile tilapia in large African lakes may grow to more than 60 cm and mature when quite old, at least two years of age, while well-fed Nile tilapia in ponds reach a relatively small but acceptable size for small-scale farmers of only 250-350 g and in the relatively short time of only five to six

A fish pond being developed from a sago palm (background)swamp with taro and banana crops in the foreground..

months before they mature. In PNG the tilapia are also stressed even more than in well-managed ponds by poor nutrition, and subsequently breed when much smaller. Many of the 'fingerlings' collected by farmers for restocking their own ponds and for sale directly to neighbouring farmers or indirectly through the four seed distribution centres are likely to be relatively old as well as small, and therefore would breed relatively soon after stocking which would reduce their growth. There is evidence for compensatory growth of stunted fingerlings in some species of fish but this strategy may be counterproductive in tilapia, unless there is demand for out of season fingerlings, because it leads to the early onset of breeding.

Feed

There appeared to be very few materials on-farm that could be used to fertilise the pond or feed the fish as reported earlier in the survey. Feedlot chicken manure was being used by several farmers as raising poultry is a well-established business around Lae in the lowlands. Manure was applied in sacs suspended in the pond but it would be more efficient to fertilise the pond manually with a small amount of manure every few days to develop and maintain a satisfactory level of 'green water' without running the risk of overfertilisation. Not all farmers appreciated that allowing water to continuously flow through the pond would wash out phytoplankton. Farmers reported feeding cassava, papaya and sweet potato leaves but it would be difficult to feed a sufficient amount due to their high water content; also bananas, coconut meal and papaya fruit but these are worth more as human food; and termites but the supply would soon be exhausted. Since feed availability is clearly a major constraint, we recommended that grass carp be reintroduced to capitalise on abundant vegetation, especially underutilised wild grasses and other vegetation, although today the import of exotic species is restricted because of negative impacts of some introduced species. Efforts also being made to develop the culture of indigenous species.

The project was also manufacturing 'farm-made' pelleted fish feed at four feed-making centres as there are so few on-farm feed resources and farmers were asking for pelleted feed although there were problems in obtaining all the ingredients, especially fish meal. A brochure was produced through an ACIAR-funded mini-project on aquaculture feed formulation and how to make simple feeds, store them and feed them to fish (Gonzalez and Allan, 2007). Formulated feed is required for broodstock and nursing fingerlings as well as to demonstrate to farmers how to produce high yields of fish although it is likely to be beyond the limited resources of most small-scale farmers. However, according to Jacob Wani of the National Fisheries Authority, there is a need to develop a commercial tilapia industry in PNG similar to the well-established chicken industry and for this pelleted feed would be required. Small-scale feed production centres may be able to develop sufficient demand for feed to interest the commercial sector to produce and market aquaculture feeds. Small-scale farmers may be able to use the feed economically as a supplementary feed in chicken-manured green water ponds (chemical fertilisers are prohibitively expensive), and only to fatten fish towards the end of the growth cycle.

A holistic and comparative view of feeds is necessary as there are two groups of farmers: subsistence farmers with limited resources for rural food security; and potentially large scale commercial farmers with resources available to purchase inputs, and the capacity to supply urban markets. There is a spectrum between these two and the appropriate technology and its management will vary. A comprehensive assessment of the various types and levels of fertiliser use and feeds, alone and in combination, is required from the perspectives of both small-scale and potentially large-scale commercial farmers.

Credit

Farmers would require access to credit as well as to quality seed and feed and the development of markets to become more commercially oriented. Farmers currently have difficulties accessing micro-credit. NFA has attempted to make credit commercially available but banks lack an appreciation of the financial requirements of aquaculture. A proposed ACIAR micro-project on credit may help to solve this problem.

Conclusions and recommendations

The project has significantly raised awareness of the potential of inland aquaculture in PNG through training 1,500 farmers. Farm numbers are reported, albeit somewhat subjectively, to now exceed 15,000, and to be growing quickly. However, many farmers are inactive, having dug ponds at considerable effort while still waiting for technical advice, fingerlings and feed. There is a question regarding the impact of training on farmer practice as trainees returning to their villages to train others when the technology remains to be sufficiently verified; and that the trainees understand enough of a given technology to be able to implement it on their farms and to disseminate it correctly to others. There is a need to demonstrate that aquaculture can be productive, profitable and eventually sustainable as a private sector enterprise.

Ponds must be provided with adequate nutrition for fish to perform well in hatcheries and grow-out. Synchronous breeding should be used to obtain uniformly young and small-sized fingerlings. Recruitment should be controlled in grow-out ponds to obtain more growth and therefore higher production. The easiest way to achieve this is by stocking young fingerlings with potential for a longer period of growth of four to five months before they start to breed. Monosex culture is not necessary for small-scale aquaculture as fish of at least 250 g can be readily produced in well-managed mixed-sex culture before the onset of breeding. Fish pond biomass should be managed to optimise the use of pond volume and carrying capacity by multi-stage culture: early nursing of fry to produce 2-3 cm fingerlings, advanced nursing of the small fingerlings to produce 20-50 g large fingerlings, and final grow-out to 250-350 g table fish. Ponds must be drained between fish crops as it is not possible to harvest tilapia effectively by seining as they are adept at avoiding capture. Any recruitment may be controlled by polyculture with small numbers of carnivorous fish. Walking catfish (*Clarias batrachus*) and striped snakehead (*Channa striata*) have both been introduced into PNG but are considered to be invasive species. The native Asian seabass (*Lates calcarifer*) will grow in freshwater and could be considered if fingerlings

Many small-scale fish ponds have running water.

could be distributed in inland areas. A broad assessment of the feasibility of how best to integrate aquaculture into the diverse inland farming systems in PNG should be undertaken, although experience to date indicated rather few on-farm resources that can be used as fertilisers or feed. In both lowland and highland project areas, farmers are converting natural sago palm swamps to fish ponds, the economic and environmental impacts of which remain to be assessed. The assessment should cover socioeconomic-farm opportunities as well as potential environmental impacts, and possibly include GIS based technology. Evaluation of appropriate technology and its management for farmers requires consideration of the ability of current and potential farmers to farm fish within their available resource constraints. Future projects should adopt a farming systems research, development and extension framework which involves on-farm testing of technologies and their management, with feedback loops to the researchers who are providing the direction to the farmers.

Highland farmers are responsive to the promotion of aquaculture as their needs for food and income generating activities are great. However, there is greater potential for large-scale commercial aquaculture in the lowland Markham valley as it is flatter, more water is available and land is more readily accessible, and it is close to the major urban market of Lae with a reported significant and largely unmet demand for tilapia indicated by a high retail price of about US$5/kg.

References

1. Smith, P.T. 2007. Aquaculture in Papua New Guinea, Status of Freshwater Fish Farming. Australian Centre for International Agricultural Research, Canberra. 123 pp.
2. Gonzalez, C. and G. Allan. 2007. Preparing farm-made fish feed. ACIAR and New South Wales Department of Primary Industries. 21 pp.

Applying chicken manure in a sack suspended in the pond can lead to over-fertilisation.

Dried feedlot chicken manu pond fertiliser.