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AQUACULTURE ASIA

Fires affect Victorian trout farms

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Mangroves in Thailand

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Access and benefit sharing

I have previously written about how (rare) cases of 'biopiracy' have triggered a reaction by governments, many of which now require 'benefit sharing' for use of genetic resources. To enforce this regime, some have introduced legislation, permits, fees and other regulatory requirements to access genetic resources within their jurisdiction, hence the new hot topic 'access and benefit sharing' (ABS) for genetic resources.

It hasn't always been this way. For most of human history genetic resources were considered the common heritage of mankind: anyone could use them. When people spoke of 'access' it was generally in the context of making sure that everyone *had* access.

Enter intellectual property rights. In 1961 the *Convention for Protection of New Varieties of Plants* was established. This convention provides a framework for giving plant breeders intellectual property rights to new plant varieties they develop. It also sets out reasonable usage rights for farmers, such as the right to replant seed saved from their own crops. Importantly, it also allowed people to use protected varieties as the starting point for developing other unique varieties, thereby facilitating innovation. The convention has been widely used as a model for national legislation on 'plant breeders rights' in many countries. The convention was arguably a good thing, but patent law aside it was also the first major step in the erosion of what may be considered the 'genetic commons'.

In 1992 states asserted sovereign rights over genetic resources with the adoption of the *Convention on Biological Diversity* (CBD). This marked the end of 'open access' to genetic resources, as the convention mandated regulatory processes to ensure informed consent and sharing of benefits (the aforementioned fees and permits, and the inevitable legal agreements and royalties). Put simply, you can't just take genetic resources anymore, you have to ask permission. You have to explain (to the government) what you are going to do with them. And you have to agree to share the benefits, whatever they may be, with the state and/or some of its citizens.

Then the trade people got involved. In 1994 the WTO *Agreement on Trade-related Aspects of Intellectual Property* (TRIPS) was established. TRIPS sets minimum requirements for the property rights in member states, including for plant breeder's rights. Section 23(b) concerns the patentability of genetic resources and access and benefit sharing issues. Discussion regarding this provision is ongoing, but one of the more contentious issues has been whether or not the origin of genetic materials should be declared in patent applications (presumably as a prelude to states demanding compensation for patents generated from genetic materials sourced within their jurisdiction). Efforts are underway to try and make TRIPS complementary to the CBD.

One of the consequences of the CBD was that it also bound the genetic resources used in agriculture. Since the beginning of human civilisation the development of agriculture has been underpinned by the exchange and transfer of plant and animal genetic resources. The free transfer of genetic materials remains a critical component in the development of new varieties to this day. In recognition of the importance of genetic exchange to agricultural development, the *International Treaty on Plant Genetic Resources for Food and Agriculture* was brokered in 2004. This treaty essentially facilitates open access to and exchange of key agricultural plant species among participating states, i.e. it effectively allows exceptions to the CBD.

While the international framework for the management of plant genetic resources is reasonably well developed, unfortunately no equivalent instruments exist for animal genetic resources, particularly for aquaculture. A second point that may be made is that most of the international instruments relevant to access and benefit sharing of genetic resources to date essentially aim to protect the intellectual property rights of breeders (or in the case of wild resources, the traditional owners and/or the state). In doing so, most ABS arrangements fundamentally *restrict access* to genetic resources. The *International Treaty on Plant Genetic Resources for Food and Agriculture* is a notable exception as the only measure that actually improves access.

So where to from here? Aquaculture is bound by the CBD, like everything else, but there are no instruments for the open exchange of aquatic genetic resources, and this is stifling research. Consider a scientist that wants to do (say) a population genetic study of an economically important fish species. The data may have considerable economic value if the government uses it to implement better fisheries management, but that benefit will accrue to the *fishers* in the first instance. The scientist doesn't 'make money' out of such research personally (and will probably struggle to cover the laboratory costs) but guess who has to pay the fee?

Sadly, some governments also seem to take the view that if the research proposal doesn't demonstrate an immediate economic return (e.g. most conservation research), they aren't interested. However, restricting scientific access to genetic resources is not in anyone's best interest. It does not aid conservation as it denies the scientific studies required to characterise genetic resources and to develop effective plans to manage them. Neither does it improve benefit sharing; it inhibits the extraordinarily intensive research and development required to identify and develop useful pharmaceuticals and other compounds. So if we are really serious about access and benefit sharing, we need to set up a system that *encourages* research to conserve and develop aquatic genetic resources. Otherwise what benefits will there be to share?

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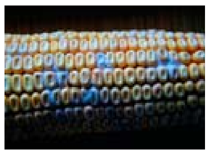

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GLOBALG.A.P. standard in Thai shrimp farms: Mission (im)possible?

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Shrimp aquaculture in Thailand

For years, the shrimp aquaculture industry has played an important role in the socio-economic situation in Thailand. The generation of foreign revenue of the industry was US$ 2.1 billion in 2007[1] and the direct and associated industries engaged at least 1 million people[2]. As a result, the sustainability of the shrimp industry is extremely important to the country. A great effort has been made mainly by Department of Fisheries and associated institutions to maintain high levels of productivity as well as to defend the leading position of Thailand in global markets. Over a long period of development, Thai shrimp farms have continually improved production systems and kept up with fluctuating situations (i.e. unfavourable weather conditions, decreasing prices, increasing and stricter requirements from importing countries).

Certification in shrimp aquaculture

Various certification schemes have been introduced to the shrimp industry, both national (e.g. Thai Good Aquaculture Practice (GAP), Code of Conduct for Responsible Shrimp Aquaculture (CoC), Bangladesh Shrimp Seal of Quality (SSoQ)) and international levels (e.g. Aquaculture Certification Council (ACC), Organic Certification and The Global Partnership for Good Agriculture Practices (GLOBALG.A.P.). These schemes are based on concerns for sustainability and are driven by market requirements. Each scheme has a different emphasis, including aspects on food safety, food quality control, environmental management, social responsibility and animal welfare. However, consumers expect certification to provide useful decision-making information for their purchases and do not wish to be confused by a multitude of certificates providing certification for different aspects of shrimp products[3,4,5].

Producers, on the other side, expect that certification requirements will create neither advantage nor disadvantage in marketing systems and be practical in terms of technical and economic implications[6]. Added to that, the development of certification criteria in many cases involves little or no participation of stakeholders, particularly at the farm level. Furthermore, there is no clear governance system along the supply chain from local producers to overseas buyers and consumers[7]. The financial requirements of certification application and procedures are a great concern for shrimp producers - especially among small-scale farmers whose technical and financial capacities may be not sufficient to apply for the certification[8,9,10].

Situation in Thailand

In order to sustain their business and prolong their livelihoods, shrimp stakeholders in Thailand, especially processors and farmers, are now under pressure to adapt their production systems and pond management practices to comply with different certification requirements. One of their major concerns is that there is no clear mechanism to influence price setting policies of certified shrimp, for those who must carry the burden of higher production costs in order to join the certification schemes. Nor is there a system to fairly distribute benefits to different stakeholders throughout the shrimp supply chains. As a consequence, small-scale shrimp farmers may have less access to markets. The farmers therefore require the responsible authority to give them guidance on how to manage their farms and implement farming practices so as to comply with both national and international certification schemes[2].

Example of a shrimp farm in Thailand (photo taken in the South of Thailand, October 2008).

Among various certification schemes for shrimp products, the recent emergence of GLOBALG.A.P. (previously known as EurepGAP) standards initiated by EU retailers has drawn attention and concern in Thailand as yet another standard to comply with. Although Thailand contributes 30% to the global shrimp production, the market share of Thai shrimp in the EU is only 3%[11]. However, the EU accounts for 37% of global shrimp consumption. On a more positive note, GLOBALG.A.P. could be viewed as a marketing strategy to increase market access in EU countries.

A study on adaption strategies in Thailand toward GLOBALG.A.P.

In order to research the current compliance levels vis-a-vis the newly launched GLOBALG.A.P. standard, a study was conducted by the Fisheries & Environmental Science of Kasetsart University with technical and financial support of the National Metrology Institute of Germany (PTB) in cooperation with German Technical Cooperation (GTZ). The gap analysis has led to the evaluation of likely consequences as well as management strategies. Eighteen shrimp farms were sampled from different farm types (7 small single farms; 6 medium single farms; and 5 small/medium, group farms, covering both inland and coastal farms) in the Central, East and South of Thailand. The sample represented more or less typical shrimp farming practices in the country. The studied farms were audited clause-by-clause against the GLOBALG.A.P. criteria and suggestions on corrective actions were also identified.

Discussion with the farmers at one studied farm (small group farm) in Samut Sakorn province.

Current compliance level

The farm auditing indicated that the farms studied presently comply with nearly half of the GLOBALG.A.P. criteria with no significant difference among different farm sizes. In general, the current compliance level of the farms in the Aquaculture Base Module is highest (47-52%), followed by the Shrimp Species Module (44-46%), the Social Module (43-45%) and the All Farms Type Module (22-27%). The comparison of compliance levels of each module among different farm types showed a similar result in the all farms, aquaculture base and shrimp species modules, except that the farm groups perform better in the social module. This is attributed to the national labour laws in Thailand, which cover many of the criteria found in the social module, such as working hours, minimum wages and working conditions. The high compliance level in the shrimp species module also is credited to the implementation of Thai GAP which is the minimum requirement for processors. This national certification scheme covers, among many others aspects, hatchery management (water supply, post-larvae quality inspection, broodstock source), shrimp health monitoring, including the traceability records and sanitary control of facilities throughout the supply chain[12].

Non-compliance areas and corrective actions

Non-compliance areas were found mainly in the all farms and aquaculture base modules. In the all farms module, these are related to the identification of environmental, health and safety as well as hygiene risks whereas the most critical areas of the aquaculture base module were the procedures to deal with customer complaints and product recall. As a result of the study, suggestions on corrective actions have been proposed. The most remarkable measure being to develop a farm management system that can identify, manage and minimise risks with regard to environmental, health & hygiene and food safety aspects. The farming operation and management practices must be documented in order to monitor for better planning and management. Capacity building activities should be conducted to introduce and educate farmers as well as associated stakeholders (i.e. hatcheries, feed mills, harvesting operators, and processors) to generate an understanding of the GLOBALG.A.P. standard. Only then will full compliance be possible. On-site technical services may be necessary especially for the pioneer farms applying for GLOBALG.A.P.

Farmers and local experts' perspectives

Nearly 50% compliance with the GLOBALG.A.P. standard of all farm types is a good starting point. Small scale farmers in particular are concerned about the costs related to implementation and certification processes. Furthermore, there is no incentive for them to adopt the standards as no premium price is guaranteed. Most importantly, they are apprehensive whether markets will demand GLOBALG.A.P.-certified shrimps. Moreover, as some have their own code of practices it is doubtful whether buyers (i.e. wholesalers or retailers) will take GLOBALG.A.P. into account for pre-selecting their suppliers. Added to that, local experts feel that Thai GAP/CoC should be recognised by buyers to some extent.

International consultant's perspective

The shrimp sector in Thailand, like many other agricultural crops elsewhere around the globe which are an integral part of today's global supply chains, is two-sided. Its participation in global supply chains opens new opportunities and exposes it to new challenges at the same time. The challenges mainly deal with costs for upgrading production facilities and book keeping efforts. However, this should be seen as an investment in order to stay in the business instead of as a hindering factor. Local responsible authorities play a crucial role here. Awareness raising is needed to help farmers understand that this is about sustainability of the sector as a whole and where the health and safety conditions of farmers themselves and people working in the sector can be improved immensely; shrimp product quality can be improved as well while negative impacts on the environment and human health will be minimised. Nevertheless, an often observed problem is that intangible benefits can hardly be seen in the short term. A lot of effort is still required by both demand and supply sides. If (small) farms organise to reach the critical mass and manage efficiently, farmers will be quite surprised by the economies of scale that will result.

Transparent channels of market information need to be established, illustrated by the success of many countries in Africa exporting agricultural products to EU markets.

On the demand side, it seems that retailers expressed a great interest in GLOBALG.A.P.-certified shrimps during the recent GLOBALG.A.P. Summit in Cologne. This is like long awaited raindrops during a drought. It also holds true especially when knowing that some big Japanese retailers are considering using GLOBALG.A.P. standards as a purchasing requirement. Last but not least, the Department of Fisheries (DoF) has worked hard over the last years in developing and enforcing Thai GAP/CoC for shrimp farming. Considerations to have Thai CoC and GLOBALG.A.P. benchmarked will certainly contribute significantly to achieving the target of increasing market share of Thai shrimp export in EU markets.

Concluding remarks and way forward

The introduction of a GLOBALG.A.P. standard in shrimp aquaculture, in addition to many others, emphasises the growing trend in market requirements in terms of sustainability. To enhance market opportunities in EU, it seems possible for Thai farms to join the GLOBALG.A.P. standard by improving farm management systems, including record keeping. The ease of understanding the GLOBALG.A.P. standard (i.e. a guidebook of standard interpretation) and guidance on implementation (i.e. user manual) as well as the compromising of orders and prices are most critical to promote the standard adaptation. Buyers (i.e. retailers) are seen as the most powerful players along the whole supply chain, and thus the requirement of GLOBALG.A.P. standard in their purchasing specification will be the driving force of GLOBALG.A.P. standard application. At the same time, it is essential to convey the message through certified products to end consumers who will hopefully take that into account when purchasing shrimp.

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The Victorian trout industry & the bushfires

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With seemingly endless floods in Queensland and “end of the world” firestorms in Victoria destroying homes, infrastructure and jobs estimated at more than a billion dollars, climate change has taken on a startling new meaning. It must be becoming frighteningly obvious to even the least environmentally aware in the community that we are going to have to change the way we go about our daily lives and produce our food.

The Australian aquaculture industry recently experienced a worst case scenario of just how devastating the changes to the climatic patterns can be.

The Sydney rock oyster is world famous for its succulent sweetness. It is the oldest aquaculture sector in Australia and operates in the estuaries along the New South Wales (NSW) coast. It is a major employer and brings $35 million a year to rural NSW.

In mid February some parts of the coast received half their annual rainfall over seven days with a mid event peak of 150 mm in 24 hours. The rivers rose steadily. When the peak rainfall hit the rivers broke their banks and brought down huge volumes of swirling brown floodwater carrying trees and branches that swept everything before them.

The full extent of the damage won’t be able to be fully assessed until late autumn. The cyclone season has been running later than normal over the last few years and their impact has been more extreme. Although NSW is south of the storm zone, the rainfall events that follow the cyclones have been severely flooding the coastal reaches.

Trouble on the way. All photos courtesy of Mark Fox, Yarra Valley Salmon.

NSW Farmers' Association Oyster Committee Chair Mark Bulley said it was too early to tell the extent of the damage to the industry at this stage. "Some oyster farms have been under freshwater for seven to ten days. We had a neap tide so there was not a lot of seawater pushing up into the estuaries. The oysters won't feed in freshwater so they can get stressed. Once the spring tides come back and the rivers return to normal we'll get an idea of where we stand. It's only by going over the farms after we're back to full saline conditions that we will know the full extent of the damage".

Infrastructure damage was varied. Mark said a lot depended on the amount of debris that came down with the floodwaters. "In some cases oyster rafts were broken away from their moorings by the build up of logs and debris".

The NSW Farmers' Association has called a meeting of industry representatives and invited a range of government authorities to see what can be done for the industry in the most affected areas. Mark said "we prepare as much as possible for the worst case scenario and then you hope for the best. These are the rules when it comes to working with nature".

Oysters farms south of Sydney missed the rain event and were able to remain open. The worst areas hit were on The Mid North Coast from the Hastings River north to the Nambucca River.

While the NSW coast was being inundated, Victoria was suffering from the reverse effects of climate change. Rainfall in the southern parts of Australia has been well below average. Over the last 12 years Victoria has received 20% less rainfall than normal and the government is busy building a desalination plant to keep the capital of 3.5 million people supplied with potable water.

This situation has worsened the bushfire threat to a region that is already prone to destruction from uncontrollable outbreaks of wildfire.

The bushfires that ravaged Victoria recently have placed enormous pressure on the rainbow trout sector, which has been the backbone of the Victorian aquaculture industry since its establishment in the late 1970's. Trout farmers have continuously produced more than half the value of the aquaculture industry in that state and the growers there have stayed abreast of global industry trends.

Situated in the upper valleys of the Great Dividing Range, the industry is based on stream diversion from the Goulburn River and its tributaries. The fires have burnt out at least four of the 10 farms in the area and the others are faced with diminished water quality.

The fires severely impacted on water quality in the catchment, resulting in heavy losses in downstream farms.

The industry employs 200 people in a semi remote region and supplies Melbourne and Sydney with fresh rainbow trout at very affordable prices. Production is just under 1,700 t/ per year worth over $12 million. It has been a model aquaculture industry with an unblemished environmental record.

The south east of Australia is, along with Southern France and California, one of the world's most bushfire prone regions. The debate on global warming and its influence on climate change is polarising communities everywhere. Climate change or no climate change, the facts are that rainfall in Victoria has been below average now for 12 consecutive years and heat waves have become not only more frequent, but also lasting longer and are more extreme.

When in late January temperatures peaked at 45°C and remained over 40°C for four days the state shrivelled. Ten days later the temperature again soared, to 46°C. At the same time a north westerly wind developed with gusts up to 100 kph. It only took one spark and the whole state went up in flames. (Sadly, some of the fires were deliberately lit). Embers were carried by wind miles ahead of the main front and cut off escape roads. In the late afternoon the wind swung around to the southwest and the fire storm changed direction. Over 200 people died and whole towns were wiped out in the inferno.

The trout industry was in the midst of the firestorm. In the shock of the aftermath it is not clear when the farms that were destroyed will be able to rebuild. The industry relies on the clear mountain streams for its water source. The catchments for these streams are now just beds of ash and carrion. Fire retardant chemicals are used in Australia and the extent of their impact is another unknown the industry will have to deal with.

Government and industry are preparing to meet to determine what can be done to get the industry back on its feet. Fisheries Victoria's Aquaculture and Inland Fisheries Manager, Anthony Forster, said the Department of Primary Industries (DPI) was monitoring the effect of the fires on a number of fish farms.

"While the full extent of the impact is not yet known, it is clear a number of fish farms were located in fire affected areas where significant infrastructure and stock loss occurred.

DPI is working with the Victorian Trout Association to identify the extent of the impact, understand the key issues facing industry and how it may be able to assist with recovery".

While the task ahead is indeed daunting, the trout industry is rallying. The Meggitt family has been farming at Goulburn Valley Trout since 1989. Edward Meggitt said, "The trout industry does anticipate supply problems going forward. We hope to meet as an industry when the immediate threat has passed to evaluate exactly where we stand and what is the most appropriate course of action.

“We do hope that our customer base, suppliers and government stand by our industry and support us through this trying time”.

Aquaculture, being more environmentally sensitive than most food sectors, is more vulnerable to climate change than say the pig and poultry sectors. Meeting that challenge is going to place a huge strain on existing aquaculture industries. From the above it can be seen just how devastating climate change can be. It may turn out to be that Australia is the guinea pig in this instance.

However, there is no escaping the fact that the weather is becoming more extreme and more unpredictable. Singapore based Jim Rogers, founder of the Rogers International Commodity Index in a recent interview with George Negus of SBS’s Dateline said that the best thing to be in at the moment was farming. Let’s hope he’s right.

Postscript: At the time of going to press the Queensland coast from Cairns to Maryborough was being lashed by Category 5 cyclone Hamish. This monster storm is 400 km wide and with winds over 200 kph and inundating rainfall, the prawn and barramundi aquacultures in the region face devastation at worst, long interruptions to services and production at best.

Disposing of mortalities resulting from the fire.

Peter Edwards writes on

Rural Aquaculture

Dr Edwards is a consultant and Emeritus Professor at the Asian Institute of Technology in Thailand where he founded the aquaculture program. He has over 30 years experience in aquaculture education, research and development in the Asian region. Email: pedwards@inet.co.th.

Small-scale aquaculture in the Ayeyarwady Delta, Myanmar

During my visit to Myanmar in September last year (see my column in Aquaculture Asia Volume XIII, Number 4, pp.3-12), I was only able to spend one day in the Ayeyarwady Delta, briefly visiting two villages with small-scale fish farms. Four months before my visit last May, Cyclone Nargis had moved across the delta for over two days with a 3-6 m high storm surge of seawater and wind speeds up to 250 km/hour, causing widespread death and destruction. Rohu had been farmed in both villages, in ponds or in rice/fish integrated systems, but the fish had been washed away by the cyclone and the aquaculture facilities damaged.

The extent of occurrence of small-scale aquaculture in the Ayeyarwady Delta is unknown. Government support has concentrated on the large scale commercial aquaculture sector and had neglected to document the contribution that aquaculture made to rural society prior to Nargis. However, it seemed too much of a coincidence that the only two villages I was able to visit on my previous trip both had small-scale aquaculture, implying that it was much more prevalent than commonly assumed. This March I was invited by Zaw Zaw Han, Chairman of the local NGO, Ever Green Group - Social Enterprise Partnership for Development, to make a longer visit to assess the role that small-scale freshwater fish culture might have played in the livelihoods of Nargis affected farming households before the cyclone. We spent five days visiting farms in the township of Kungyangon, Yangon Division, and the townships of Bogale, Dedaye and Pyapon in Ayeyarwady Division with the aim also to identify possible donor-funded project activities in small-scale aquaculture to help to re-establish and secure the livelihoods of farmers previously raising fish and possibly those of potentially new entrant aquaculture farmers.

Official assessment and monitoring

The Tripartite Core Group (TCG) comprising representatives from the Government of Myanmar, ASEAN and the United Nations carried out a needs assessment through a survey of 108 communities impacted by Nargis (Post-Nargis Periodic Review 1, December 2008) and subsequently monitored 40 villages (Post-Nargis Social Impacts Monitoring, January 2009). The questionnaires used to assess the impact of Nargis asked 'what are the three main sources of household income at this time'… as well as '….. before Cyclone Nargis', and included 'aquaculture (shrimps, prawn, crabs, etc.)' as a possible livelihood option. However, the data in the reports do not include aquaculture for any of the surveyed households, possibly partly because freshwater fish culture was not specifically mentioned in the questions although the text states that 'the people of the Delta and rivers traditionally engage in a diverse range of fisheries activities from deep sea fishing to aquaculture in ponds'.

Delta villages have diverse occupations. Most villages have a mix of farmers and fishers, with agriculture dominating in some villages, fishers in other villages. Landless labourers make up a high proportion of people in most villages, often at least 50%. According to the TCG assessment report, relief and recovery assistance had reached even the most remote villages. Food aid had reached all surveyed communities although a high proportion of households still had inadequate shelters with only plastic, tarpaulin or canvas roofs and walls.

Farmed freshwater fish on the market in Pyapon township, striped catfish and rohu.

However, livelihoods had been disrupted with agriculture, fishing and livestock suffering heavy losses which may take households several years to recover from. People lost assets and savings which has reduced their capacity for self recovery and increased indebtedness. According to the TCG monitoring report, today's challenges are different as the people need assistance to re-start their livelihoods. There is 'the need for much greater support for recovery of livelihoods in order for cyclone-affected populations to regain the level of self-sufficiency that they had prior to Cyclone Nargis'.

However, relief and recovery are interconnected. The slow pace of livelihoods recovery means that many people do not have sufficient resources to buy food; food insecurity still exists, especially for the poorest people within villages. Livelihoods recovery has been slow because of the immense damage as well as insufficient aid. There has been a major reduction in crop yields, loss of livestock and disruption of fishing. Landless labourers are particularly affected as fewer casual labourers are being employed by large farmers who lost their assets and have been unable to recapitalise. Many large-scale farmers who lost their assets now only differ from the poor in their ownership of land which they are having difficulty using as they did before the cyclone.

A commercial-scale fish farm converted from rice fields in a village in Dedanaw township.

A major concern is the increasing debt burden of villagers. Before Nargis credit drove the Delta economy with better-off farmers and fishers who had collateral borrowing money from moneylenders in nearby towns at 5-10%/month and marginal farmers and fishers and landless labourers without collateral borrowing money at 10-20%/month. Although these high interest rates stifled capital accumulation and thus stunted the development of village economies, paying back debt was not normally a problem before the cyclone. Villagers are now, however, concerned about being able to service their debts and falling into a vicious debt trap as they have lost their assets. During the TCG surveys they repeatedly gave livelihoods assistance as their top priority. As villagers already face such a serious problem of indebtedness, the TCG recommended that cash injections should be in the form of grants rather than loans or micro-credit.

A small-scale farm couple with their rice-fish system in a second village visited in Dedaye township.

Revisting the villages

Dedanaw Village

The farmer, Hla Min and his wife, Kay Thi Aung in Dedanaw village in Kung Yangon Township, Yangon Division, who I interviewed last September, had now rebuilt their house but still have insufficient money to restart aquaculture to renovate their ponds, and to purchase seed and feed. They had been raising fish for six years before Nargis washed away the rohu stocked in their three 500 m^2 ponds which were now derelict and partially filled with mud and weeds. Their 1.2 ha of land is not suitable for growing paddy and the husband is a seasonal worker on neighbouring rice farms and a bus conductor. They used to buy 2.5 cm fingerlings of rohu but the season before Nargis had nursed fry for 5-6 months to 5 cm before releasing them into another pond for grow-out which took another 1 year. Fish had been fed with boiled broken rice mixed with rice bran and manually made into balls to feed the fish. Partially harvested rohu led to a production of 300 kg, ranging in size from 0.5-1.2 kg which they sold for about US$1/kg, a significant contribution to their household income.

Zaw Zaw Han, Chairman of the NGO Ever Green (right) and Htin Aung Kyaw, an AIT alumnus currently working for the Myanmar Fisheries Federation (left), guided me into the Delta.

Farmer Win Oo in Thee Gone Lay village next to the trench in his rice field.

Most of the 740 households in Dedanaw Village are rice farmers. As the local authorities in Kung Yangon Township do not allow even domestic water supply reservoirs to be built in the village rice fields, if rice farmers are to build a fish pond then it would need to be constructed on the relatively limited land surrounding the households. This would also be the only option for the landless to build a pond. This may be feasible as we observed a poor household excavating a nearby area for soil to raise the level of the land immediately beneath and surrounding the land. Hla Min and his wife expressed willingness to help to teach some of the other households with sufficient land near their houses to farm fish and possibly form a village fish farmers group.

Thee Gone Lay Village

During my previous visit to this village in Dedaye Township, Ayeyarwady Division, I was unable to see any aquaculture facilities as the village was still flooded, with all cultured fish washed away, but was told that two farmers had been culturing fish in integration with rice. During this most recent visit I interviewed both these farmers, Win Oo and Myint Aung, and was able to see their integrated systems which comprised trenches in their rice fields. Although both farmers with rice/fish systems are better-off farmers who each own a small village rice mill, one of the two rice mills had not been put back into operation because Nargis had caused a major decline in rice production in the village. The two farmers had also not restocked their trenches with fish as they were short of money. Current rice/fish integrated systems in the Delta should be studied to see if they would provide a model that could be more widely disseminated to help to improve small-scale farming household welfare. Both farmers said that many villagers would be interested in raising fish in their rice fields, which the local government allows, if they had money to get started.

Both Win Oo and Myint Aung reported that rice/fish culture is more profitable than farming rice alone. Win Oo has constructed a 7 m wide, 0.5 m deep trench for 100 m along one side of his 10 hectare rice field for integration with the monsoon rice crop. He learned how to raise fish seven years ago from a friend, a large-scale fish farmer in another village. He stocked 2,000 of 5.0-7.5 cm fingerlings purchased from his friend. The fish were fed only rice bran as he believes that it is not necessary to use fertiliser. Survival was 80% and the fish of 1.0-1.6 kg were sold in the village and a local town. These are relatively large sized for a system integrated with rice, possibly because the trench approaches a pond in dimensions.

Landless labourers in Thee Gone village about to leave the village take up temporary work elsewhere.

Myint Aung has an 8 m wide, 0.5 m deep trench around his 0.6 hectare rice field in which he stocked 30,000 of 5 cm fingerlings bought from a seed trader. Fish were able to swim into the rice field as the water was 10 cm deep there during the dry season when a short stem variety of summer rice was grown and was about 1 m deep in the rainy season when a long stem variety of rice was grown during the monsoon rice crop. Fish were again only fed rice bran but the rice field was fertilised with chemical fertilisers, leading to green water in the system. Myint Aung reported that he only used to get 30 baskets of rice per acre but with integration with fish he got 50 baskets of rice per acre as well as fish. He got about US$2,000 gross return from selling fish compared to a total of $700 for rice ($400 for the summer rice crop and $300 for the monsoon rice crop). As fingerlings cost $750 and rice bran $700, the net return on the fish was $550.

Thee Gone Lay village has 60 households, 30 of which are rice farmers with the remaining households being landless labourers and fishers, although many rice farmers catch fish after rice harvest. Rice holdings range in size from 1.0-1.5 up to 24 ha but are mostly 4.0-8.0 ha. Fifteen of the rice farming households also have small multi-purpose ponds near their houses for washing clothes and bathing, 4 or 5 of which had also been stocked with fish before Nargis.

I interviewed two of these farmers. Tun Win had learned to farm fish six years ago. He used to stocked 250 rohu and in a 150 m^2 pond which he obtained from a seed trader. Partial harvesting provided fish for domestic consumption and sale in the village, with about 25 fish remaining at final harvest. Before Nargis he sold fish for $0.90/kg but the price had gone up after the cyclone to $1.25/kg. After Nargis he had not renovated and restocked the pond because he had no money.

A rice mill damaged by Nargis in Thee Gone Lay village.

Myint Aung who also had a rice/fish system described above had a 450 m^2 pond. The year before Nargis he had stocked tilapia which he had travelled to Twantey near Yangon himself to purchase. The fish were again washed away by Nargis although he found some of the tilapia in the rice fields which he restocked in his pond.

Brackishwater aquaculture

Nargis cause major loss of life in Byat Kwal Gyi Village in Bogale Township near to the southern tip of the Delta, with only 50 survivors in 100 households from a pre-cyclone population of 650 people from 200 households. There are now only 18 rice farming households with the remaining being fishers and seasonal labourers. The former village headman (he and his entire family lost their lives) had been raising tilapia for two years, nursing in a small pond in the village with grow-out in a 2.4 ha fish pond constructed far away in his rice field. He fed the fish with rice bran. The fish were sold for almost $1/kg in the village and in Bogale Town. Rather surprisingly the villagers said they found tilapia as well as rohu to be more tasty than marine fish, indicating that freshwater fish probably find a ready market even in the lower Delta where brackishwater and marine fish are plentiful.

Four of the villagers had constructed small crab ponds on the river bank to fatten crabs before Nargis. Female crabs 130-160 g in size are purchased from fishers for about $0.25-0.30/ crab and are stocked for about 2 weeks and fed with small fish twice a day costing $0.30/kg until they develop eggs after which they are sold for $0.50/crab. Other villagers would like to fatten crabs which are abundant but have insufficient money.

I also visited a middleman in Hline Bone town in the south of the Delta which used to be surrounded by villages in which crabs were fattened. Male crabs sold for $1.2/kg but females for $4.0/kg. They were sent to Yangon and then mostly exported to China. Most of the crab fishers who caught crabs and the collectors who used to stock female crabs individually in small cages perished in the 5-6 m storm surge as the villages in this area had about a 60% mortality rate. There used to be 20 collectors who fattened crabs in small cages before Nargis but there were none during my visit. While the town suffered little damage during the cyclone, crab fattening had not yet restarted.

Small-scale aquaculture in the Delta

Prevalence

Small-scale inland aquaculture, defined as a third sub-system in a family-level rice dominated farm with buffalo for ploughing and small numbers of scavenging pigs and poultry, appears to be widespread in the townships visited in the Ayeyarwady Delta. Rohu and sometimes catla, common carp and tilapia are grown in small ponds near the farmer's house, and in integrated rice/fish systems as well as in ponds constructed in rice fields ranging in size from 0.2-2.0 ha based on farmer interviews. Fish are fed rice bran either solely or mixed with boiled broken rice. Fertilisation is neither practiced nor understood as in large-scale carp culture although one farmer interviewed previously integrated 500 chickens with fish in 1.2 ha of ponds constructed in the rice field before they were washed away by the cyclone; this farmer drained his three ponds to irrigate his rice which eliminated the need to purchase fertilisers for the rice.

A borrow pit in Dedanaw village that could possibly be developed into a small fish pond.

The flooded rice-fish system belonging to farmer Myint Aung in Thee Gone Lay village.

Proposed project intervention

It is proposed that the small ponds near the households in the two above villages be renovated and the farmers provided with seed and feed for a growing season to enable them to restart aquaculture which is currently constrained by lack of money. As existing fish farmers in both villages expressed a willingness to form a fish farmers club to help each other through a donor funded initiative. Other farmers expressing an interest in raising fish and with land available should be included and provided with a pond, seed and feed. This proposed project would be based mainly on existing local knowledge and experience and would thus be highly likely to succeed. Fish seed is readily available in at least some parts of the Delta as there are more than 200 fish hatcheries in Ayeyarwady and Yangon Divisions; and villagers reported purchasing fingerlings from seed traders travelling in water filled boats.

It is also proposed that farmers be taught to raise fish in a more cost effective way. Rice bran should be used to supplement high-protein natural plankton food produced by

Excavated soil from the borrow pit being used to raise the level surrounding a house in Dedanaw village.

pond fertilisation rather than as the rather poor sole feed as is current practice. There is heavy demand for rice bran to feed poultry and pigs and to a lesser extent buffaloes so use of fertilisers would take some of the pressure off the rice bran for use as a fish feed. Chemical fertilisers would be required as village livestock comprise buffaloes with nutrient-poor manure and scavenging pigs and poultry.

Farmer Hla Min and his wife and son in their newly constructed house in Dedanaw village.

It is also suggested that consideration be given to at least partially integrating ducks with fish by enclosing them at night on a fish pond so that at least some of their manure may provide natural food for fish.

The TCG recommended, as discussed above, that assistance should be provided to large as well as to small-scale farming households as most also require assistance to restart their livelihoods. It is the larger farmers who hire the large numbers of landless in the villages as seasonal labourers who cannot benefit directly from farming either crops or fish.

Rice/fish integration

It is also proposed that a research study be carried out on rice/fish integration in the Delta to assess the production and profitability of rice and fish grown separately and integrated. The Government is concerned about growing sufficient rice for national food security but experience elsewhere as well as from one of the farmers interviewed indicates that rice production is increased through integration with fish. Furthermore, as discussed in my previous two columns on Myanmar, diversification of small-scale rice-dominated farms through conversion of a small area of rice field to a fish culture facility would help to increase the welfare of poor farming households by providing fish for domestic consumption as well income through sale of some of the fish; and it would provide fish for local rural and urban populations. Farmers reported preferring freshwater to marine fish. But the supply of fresh marine fish is also low in the dry season as observed during the visit in township markets where dried marine fish predominated with a small amount of carp, silver catfish and tilapia being sold which had been imported from large commercial farms in Tawantey near Yangon.

The history, status, and future prospects of monosex tilapia culture in Thailand

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Origins

Since its adoption for aquaculture Nile tilapia (*Oreochromis niloticus)* has proven popular for its ease of culture, robustness, palatability, and tolerance of a range of environmental conditions. The fishes' reproductive behaviour was originally seen as one of its most valuable characteristics, making it unnecessary for small-scale farmers to repeatedly purchase hatchery produced seed, and contributed to its promotion and distribution for rural development purposes throughout the tropics. The sub-optimal growth and low or variable size (and market value) which mixed-sex populations of tilapia frequently exhibited acted as a constraint to the species commercial development however, leading to efforts in the 1970's to produce all-male fry in order to circumvent the problem. Despite the obvious promise of such a technical breakthrough no suitable technology for reliably producing all-male tilapia at a commercially viable scale and cost emerged until the mid 1980s. Development of hapa-based broodstock management, which allowed for collection of tilapia eggs and yolk-sac larvae of a uniform age, proved the key to ensuring consistently high (~99%) levels of male fish following the application for 21 days of feed treated with 17-α methyltestosterone. This breakthrough occurred as a result of doctoral research initiated at the Asian Institute for Technology (AIT) in 1984 as part of an EU funded project on the intensification of septage-fed aquaculture systems.

AIT staff immediately recognised the wider implications of the technology and began to increase production of monosex fry for use in experimental trials, and for sale to forward-thinking commercially oriented fish farmers in Central Thailand who were also quick to grasp the potential of all-male tilapia. Word of the benefits spread rapidly among this group following the publication of articles in local popular media, and the Institute began promotion monosex seed to small-scale farmers in NE Thailand as part of its development focussed extension activities there, as a result of which it expanded hatchery production to a peak of two million per month in early and mid 1990's. AIT also worked closely with the Thai Department of Fisheries (DOF) to institutionalise adoption of the technology from the late 1980's, and established a short course training program for monosex hatchery production as part of its remit for disseminating development focussed research outputs. Short courses attracted more than 100 participants from the public and private sector both locally and internationally but their efficacy initially proved somewhat limited, prompting key staff to seek to extend impacts to the private sector through mentoring and support for, and partnership with, private hatcheries.

Development of the hatchery sector

The first informal partnership began in 1987 with the provision of advice and training to a charitable foundation in Udorn Thani. This facilitated the establishment of a monosex tilapia hatchery to provide a source of income with which the foundation could fund its other rural development activities. Former employees of the foundation operate a hatchery on a similar basis at a different location in Udorn Thani to this day.

Feeding red tilapia in riverine cages, Ang Thong Province.

1991 saw the birth of a more formal joint venture with an existing hatchery, Rom Sai Farm in Ayutthaya, under which AIT personnel oversaw the construction and operation of a monosex production facility. This was a significant development, increasing the availability of all-male seed in Central Thailand at a key point in the technology's uptake, but technical and management difficulties ultimately put an end to the collaboration.

In 1993 Manit Farm, a large shrimp and tilapia growout farm in Petchaburi, which had been an early adopter of all-male tilapia seed, established a monosex hatchery of its own after its demand for seed exceeded the production capacity of the AIT hatchery. Again, there were close ties to AIT, and Manit Farm recruited an ex-AIT staff member who had worked at Rom Sai Farm to be its hatchery manager. Manit Farm continues to operate successfully today and is one of Thailand's leading monosex tilapia seed producers. A year later, in 1994, the farm's hatchery manager left to establish his own monosex tilapia hatchery and growout business, Boonholme Farm in Khon Kean, which remains one of Northeast Thailand's foremost seed producers and largest pond-based growout farm.

A subsequent joint venture between AIT, a subsidiary company of Cargill, and two local entrepreneurial investors resulted in the startup of Nam Sai Farm in Prachinburi Province in 1994. The company was headed by the former AIT-employed hatchery manager from the earlier venture in Ayutthaya under an agreement by which AIT would provide technical support and expertise for a six year period, receiving a royalty fee from the Cargill subsidiary for each fish produced. Following the end of this arrangement Nam Sai continued as one of the largest monosex hatcheries in the country.

Charoen Phokpand (CP), the Thai agro-industrial giant, initiated commercial production of all-male tilapia seed in 1995 following several years of experimentation. Again, a fairly direct line of technology transfer can be traced to AIT, with CP staff attending short course training there and AIT alumni joining the company's aquaculture division, but close personal ties played a less critical role than in the earlier start-ups. CP now operates five tilapia hatcheries around the country and produces more all-male tilapia fry than the country's next three largest monosex hatchery operators combined.

From the late 1990's onwards the number of monosex hatcheries in Thailand proliferated (to well in excess of 20 at present), as farmer demand for sex-reversed fry increased and knowledge of the necessary hatchery management techniques, once confined largely to individuals associated with the early development of the technology at AIT, became more widely accessible. Knowledge transfer through DOF officers came to play an increasingly important role; mainly by consultancy and advice given unofficially as part of close relationships between hatchery operators and DOF staff. At least three monosex hatcheries were established in this manner, most notably Bor Charoen Farm in Chachoengsao, which is now one of the largest, and certainly the most technologically advanced in the country. In other instances ex-staff of hatcheries including Nam Sai and CP left to start businesses of their own, and several fry agents who had established a customer base by nursing and selling fingerlings for cage culture used this as an entry point into hatchery production.

Although DOF produces small numbers of monosex fry at fisheries research stations throughout the country for use in extension activities and for sale to small-scale farmers and nursing co-operatives it's most significant contribution by far, aside from the unofficial role described above, has been the provision of high quality broodfish to hatchery owners. At present only four hatchery operators possess the capacity to develop broodstock independently, with the vast majority of the remainder reliant on the government run Aquatic Animal Genetics Research and Development Institute for this service.

The ability to produce all-male tilapia fry has revolutionised the profile of the species' production and consumption in Thailand in the last 15 years, bringing about huge changes in productivity, profitability, value, and diversification. The following sections describe associated developments in two distinct sectors; pond and cage culture.

Pond culture

Thai tilapia production has increased, almost exponentially, from an officially recorded 22,800t in 1990 to 203,700t in 2005[1]. This growth can by no means be exclusively attributed to monosex; the advent of improving transport and communications, greater access to agricultural by-products for use as feeds and fertilisers in pond culture, and the increasing size and affluence of urban markets, being critical factors[2]. However, the existence of tilapia capable of quickly, reliably, and cost efficiently reaching larger sizes (400g-1kg; as opposed to the 250-350g at which mixed sex tilapia were typically harvested) has radically altered the species' utility to farmers and led to major shifts in marketing strategies and consumer preferences.

Production of cyprinid species – once the mainstay of greenwater polyculture systems that predominated in Thailand – has, with the exception of silver barb (*Barbodes gonionotus*), all but stagnated over the same period. This far slower rate of growth can be substantially attributed to the progressive dominance of monosex tilapia in pond polycul-

Table 1. Name, location, date established, knowledge acquisition pathway, and estimated average monthly fry sales for monosex tilapia hatcheries in Thailand.

Hatchery Name	Province	Date est.	Knowledge Acquisition	Monthly fry sales†
Rom Sai	Ayutthaya	1990	AIT assistance	<1m
Isan Aquatics*	Udorn Thani	1991	AIT assistance & training	2m
Manit*	Phetchaburi	1993	AIT staff	8m
Nam Sai*	Prachinburi	1994	Ex-AIT staff	10m
Boonholme*	Khon Kean	1994	Ex-AIT staff	3m
CP*	Ayutthaya, Samut Sakorn, Nakorn Sawan, Kalasin, Ubon	1995	AIT training & alumni, research	30m+
Chiang Mai Patana*	Chiang Mai	1998	AIT alumni	2m+
Bor Charoen*	Chachoengsao	2001*	DOF (personal connection)	10m
Jam Nong	Chiang Rai	2003	DOF (personal connection)	5m
Wiboon	Kalasin	2003	DOF (personal connection)	4m
Uthai*	Ayutthaya	2003	Ex-NS staff	<2m
Winit*	Mukdahan	2004	Ex-AIT staff	<100,000
Nam Sai branch*	Nakorn Pathom	2005	NS training	3.5
Prasit*	Suphanburi	2005	DOF (personal connection)	>2m
Wanida*	Amnatcharoen	2006	NS/Uthai/DOF	1m
Pung Thai	Prachinburi	2007	Ex-NS customer & CP nursery	?
Noli ‡	Nakorn Pathom	?	?	?
? ‡	Phetchaburi	?	Ex-CP staff	?
Thep ‡	Sakon Nakorn	2003	DOF short course	?
? ‡	Nong Kai	2003?	DOF	?
Watcharin ‡	Suphanburi	2007?	Ex-NS customer & CP nursery	?

*Notes: *Hatcheries visited during the course of the research that informs this article; †Average monthly fry sales as reported by operators and/or estimated on the basis of comments by key informants; ‡ Hatcheries reported by informants, the present status of which we were unable to confirm.*

ture. Greenwater polyculture systems in central Thailand are now typically comprised of around 90% monosex tilapia, with assorted carp species (which attract a somewhat lower market value) stocked to fill vacant ecological niches in the pond in order to help maintain water quality.

Farmers stocking monosex tilapia in ponds tend to pursue one of two broad production and marketing strategies. The first, more traditional, system is generally practiced by smaller and medium scale farmers (with holdings in the order of 20-100 rai), in which growout periods of around 8 months facilitate production of tilapia averaging 400-500g. These fish are stored on ice upon harvest, and distributed to fish markets in Central, and to a lesser extent, NE Thailand, and attract a farmgate value in the order of Bt18-20/kg.

Larger farms (100 to >1,000 rai) typically focus on the production of tilapia averaging upwards of 600g. Total growout cycles can last 12-13 months, with partial harvest (thinning out for sale or restocking in other ponds) occurring on two or three occasions, allowing remaining fish to rapidly gain weight. Formulated pellet feeds may be fed during the later stages of growout to assist fattening. Fish are placed in aerated tanks upon harvest for distribution to local markets where they are sold live to demonstrate product freshness to consumers. Large live tilapia attract a considerably higher farmgate price than their dead counterparts (~Bt30/kg).

Production in this manner has become increasingly common in the last five years and now accounts for perhaps 40% of the output of pond culture from the Central region, but is generally only practiced by farmers with sufficient knowledge, experience and space to carefully manage all aspects of growout and staggered harvesting, and with sufficient capital to enable them to defer returns on investment for a year or more. A great many of these originate from a handful of districts in southern Bangkok and Samut Prakan province where commercially oriented pond culture has been widely and successfully practised for over 30 years. These entrepreneurial individuals have expanded operations into provinces including Prachinburi, Nakorn Nayok, Chachoengsao and Ratchaburi where affordable land and labour are more readily available than inside the heavily urbanised Bangkok Metropolitan Region.

Cage culture

The development of pond culture post-monosex can be seen a largely organic affair, resulting from a gradual evolution led by innovative farmers and actors in the marketing chain, and confined primarily to provinces in central Thailand where abundant water, land and feed resources exist. In contrast, the origins of cage-based tilapia culture (which now accounts for perhaps 30% or more of the total output of Thai tilapia) can be traced directly to the research, development and marketing activities of a single corporate entity; CP. The dominant force in Thai agro-industry, CP was already the prime mover in the country's shrimp industry and a major supplier of feed for walking catfish (*Clarius* sp.) culture at the point when monosex hatchery production techniques emerged. Initially focussing on production of tilapia for a buoyant export market, CP began experimenting with the development of saline tolerant strains of hybrid (*Oreochromis sp.*) red tilapia for culture in vacant shrimp ponds on the upper Gulf of Thailand. Although these efforts ultimately proved unsuccessful, in part due to the slow growth of tilapia under these conditions, the company switched its attention to the application of these research outputs to the domestic market.

The enhanced feeding efficiency of monosex over mixed-sex tilapia (FCRs for cage culture averaging around 1.4 and 1.8 respectively), and the larger size and, hence, value attainable, made the prospect of production based exclusively on formulated diets an economically viable possibility for the first time. Adapting the existing concept of cage-based culture to suit its needs, the company launched a concerted marketing strategy based on a shrewd assessment of regional fish consumption preferences, with the ultimate goal of expanding its market for aquatic feeds.

The company promoted sales of live tilapia through television advertisements, endorsements from high profile chefs, product dumping in markets at below production cost, and the engagement of restaurants and caterers providing set meals at festivals and celebrations. CP's marketing in central Thailand revolved primarily around a red strain of tilapia (named pla tabtim by the King of Thailand), reflecting a need to differentiate the product from smaller, dead, pond-produced Nile tilapia commonly considered by Thai consumers to be of low quality due to the frequent occurrence of off-flavour. In the N and NE of the country, where pond raised tilapia are far scarcer and live fish are highly sought after, large live Niles proved more compatible with local tastes.

Farmers must share the river with many other users.

Cage culture of both red and Nile tilapia (based on a contract farming system under which feed and fry produced by the company are supplied to farmers through a network of affiliated dealerships which buy back and market live fish when they attain at a weight of 600g or more) expanded dramatically as a result. Cage-raised fish are now by far the most significant source of tilapia in markets in the northern part of the country, whilst in the central region cage production is limited almost exclusively to red strains. The extent of this division is illustrated by CP's hatchery output, around one third of which is red and marketed largely in Central provinces, with the remaining two thirds of Nile tilapia fry destined primarily for growout in cages in rivers and reservoirs in the N and NE. This live marketing of fish may also have had unforeseen spill over effects on the development of pond culture, setting a precedent from which the increasing popularity of live pond-produced tilapia described above followed.

CP's initiative (which is better viewed as an exercise in astute marketing than a major technical advance) has radically influenced the scale and form of tilapia production in Thailand. However, the system - which transfers risks associated with distribution of feed, seed and final product on to its dealerships and, ultimately, cage farmers, allowing the company to pursue capital accumulation via the profitable feed production arm of the business – is typically a less secure proposition for end users than independently developed pond-based production strategies.

That CP now controls perhaps 60% of the production system it created around 10 years ago testifies in part to the less than charitable practices of certain dealerships working under the company (among a range of complaints voiced by farmers, a failure to honour agreements pertaining to the farmgate value of harvested fish and excessively high input costs are some of the most common). The remainder of the market is divided up between several feed companies operating similar 'integrated' informal contract systems and farmers producing and marketing fish on an independent basis.

The future of cage-based tilapia production looks increasingly uncertain however; the open nature of cage systems and their location in water bodies impacted by multiple users rendering them vulnerable to a range of adverse environmental factors including pollution episodes, low water levels and/or flow rates (particularly in rivers and reservoirs in the NE), annual flooding events and highly turbid water and, perhaps most critically, disease.

Based on anecdotal reports it appears that the incidence of disease in cage-raised tilapia has become increasingly more severe in the last two years. Annual outbreaks of *Streptococcus* during the hot dry season have occurred regularly for some time, but these appeared to have been augmented recently by serious parasitic infections and a new and particularly virulent pathogen, possibly *Microsporidium* which was apparently responsible for very substantial mortalities in April and May of this year.

Current trends and future directions

Cage-based tilapia production now appears increasingly unsustainable from the farmer's perspective in light of progressively more severe disease problems and water quality and availability issues coupled to the rapidly rising cost of commercial feeds. The alternative, which several particularly well informed interviewees suggest is likely to occur within the foreseeable future, is a comprehensive shift from cage culture in multi-use water bodies to intensive cage-based production in aerated ponds; the latter requiring greater capital investment but far being less vulnerable external environmental pressures. A small number of farmers already practise similar culture techniques, nursing Nile tilapia to 200-300g at high density in greenwater before transferring to cages in ponds for rapid fattening on high quality pellet feeds. White shrimp (*Litopenaeus vannamei*) and giant freshwater prawn (*Macrobrachium rosenbergii*) are also stocked in these ponds at low density to provide an additional high value crop.

Numerous other tilapia farmers have also begun stocking shrimp and/or prawn as an additional species and, inversely, it is now commonplace for inland shrimp and prawn farmers to stock tilapia in their systems. In both instances this development appears to be a response to declining profit margins (in the case of tilapia farmers this is due to inflationary pressure on feedstuffs which modest increases in the market value of the fish had been unable to make up for), and has the added benefit of providing some measure of biological control through the removal of detritus and uneaten feeds.

Record prices for Thai rice earlier this year have also brought about some unexpected changes. In one district of Nakorn Pathom, and almost certainly in other areas, a number of small-scale but marginally successful tilapia farmers have, temporarily at least, abandoned pond culture in favour of rice production which is, under normal circumstances, a far lower income activity. In addition it appears that associated increases in the value of rice bran, the most widely used supplementary feed among farmers operating traditional greenwater growout, have made the substitution of low protein formulated feed an economically viable alternative pond input due to the trade-off in reduced growout periods which it facilitates. Whether these trends are likely to continue if rice prices return to more normal levels is open to question, but they underline clearly the intimacy with which fish culture in Central Thailand is bound to other agricultural activities.

Recorded tilapia exports from Thailand are currently fairly meagre (5,128 t in 2006). This figure may under-represent the real volume, considering that national statistics for total tilapia output almost certainly under-report total annual output. However, the likely prospects for expansion of export-led tilapia production remain uncertain. Whilst there may be potential for expansion of Thai exports given the species' ever greater importance as an internationally traded commodity, Thai producers apparently experience difficulties in competing with those in China for a variety of reasons which may include comparative advantages in the cost of feed production and labour, Chinese government export subsidies, and total production volumes. Perhaps the most significant reason for the failure of the sector to expand to date is that domestic consumption has kept pace with production increases. This has meant that local market values are currently comparable to those for export, providing little incentive to producers to pursue these more demanding markets. However, as production continues to expand and intensify, facilitating the production of greater volumes of consistently large, high quality fish, better capitalised Thai producers may ultimately find it advantageous, and even necessary, to enter the global marketplace in order to dispose of their product.

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Mangroves of Nakhon Si Thammarat Province in southern Thailand: Species diversity, community structure and current status

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Mangroves are one among nature's amazing creations, for the reason that these plants are supremely equipped to survive and perform in the harsh inter-tidal zone of the coast where sea meets land. It is reported that 60-75% of the coastline of the Earth's tropical region is lined with mangroves. Thailand's coastline extends over 2815 km, of which 1878 km are around the Gulf of Thailand. Nakhon Si Thammarat (NST) Province borders part of western shoreline of Gulf of Thailand and it is one of the major areas of mangroves around this shallow sea. Relatively large areas of mangroves still remain along the coasts of Surat Thani, Songkla, Samut Sakorn and Chantaburi Provinces that border Gulf of Thailand. Coastline of NST borders Pak Panang bay which receives the largest volume of freshwater from Pak Panang river and lesser amounts from Bang Chak, the Pak Nakhon, and the Pak Phaya rivers. The flow of water in the Pak Panang river, which is 110 km long and drains an area of approximately 100 km^2 is controlled by a barrage built at the river mouth[1].

Nakhon Si Thammarat receives about 2000 mm of annual rainfall of which 50% is received in less than three months, from November to January with north east monsoon. The mean annual temperature is 27.2°C with 83% relative humidity. A semi diurnal tidal pattern prevails with a range that does not exceed 1 m.

Research on reconciliation of multiple demands on mangrove ecosystems of the EU-Funded MANGROVE project jointly carried out by Universities of Essex, Kasetsart, Wageningen, Mulawarman, Vietnam National, Network of Aquaculture Centres in Asia-Pacific and Stockholm Environmental Institute, is based on three villages, i.e. Ban Kong Khong (close to the largest area of mangrove in the mouth of Pak Panang river), Ban Pak Nam Pak Phaya (area with abandoned shrimp ponds and re-plantation occurs to some extent and Ban Talad Has (area where mangrove planting / afforestation is done on mud-flats).

Structure of mangrove ecosystems at study sites in Nakhon Si Thammarat

The structure of mangrove vegetation is characterised in terms of species richness, diversity, tree/stem density, species and stand basal area, frequency of occurrence of constituent species, plant/stand height, above ground biomass and canopy volume/leaf area index. These parameters can either be measured in sample (representative) areas, i.e. from demarcated plots or using plot-less methods. Qualitative assessment of vegetation structure often uses species richness, plant height and apparent zonation of plants.

Figure 1: Location of study sites and distribution of mangroves in Nakhon Si Thammarat Province, Thailand.

Mangrove plant diversity

Plant species that are exclusive to the inter-tidal mangrove habitats are known as true mangrove species while those that occur in mangrove and other wetland habitats are called the mangrove associated species. A total of 87 true and associated mangrove plant species belonging to 41 families are recorded to occur in Thailand[2]. Five families of mangroves, Rhizophoraceae, Avicenniaceae, Combretaceae, Palmae and Sonneratiaceae, are the dominant around the country.

The true mangrove species, i.e species that are exclusive to inter-tidal areas, that occur in the study area include, *Acanthus ebracteatus*, *A. ilicifolius, Aegiceras corniculatum*, *Avicennia alba*, *A. marina*, *A. officinalis*, *Bruguiera cylindrical*, *B. gymnorrhiza*, *B. hainessi*, *B. parviflora*, *B. sexangula*, *Ceriops decandra*, *C. tagal*, *Heritiera littoralis*, *Kandelia candel*, *Lumnitzera littorea*, *L. racemosa*, *Nypa fruticans*, *Rhizophora apiculata*, *R. mucronata, Scyphiphora hydrophyllaceae*, *Sonneratia alba*, *S. caseolaris*, *S. ovate*, *Xylocarpus granatum* and *X. mollaccensis*. The common mangrove associated species, i.e. species that occur in localities outside the inter-tidal zone, are *Acrostichum aurem*, *A. speciosum* (ferns), *Caesalpinia sp. Clerodendron inerme*, *Derris trifoliate*, *Hibiscus tiliaceus*, *Oncosperma tigillarium*, *Phoenix paludosa*, *Premna integrifolia*, *Rapanae porteriana*, *Scolopia macrocama* and *Thespesia populnea*[3].

Distribution of mangrove species within a mangrove area depends largely on availability and distribution of seeds/ seedlings, tolerance of species for inundation as well as soil salinity and thus resulting zonation of species. Three distinct zones can be identified in mangrove areas of Nakhon Si Thammarat, i.e.

- Water-front zone that consists of *Avicennia marina*, *A. alba* and *A officinalis*[4]. Stature varies from a few meters to 10 m in height.
- Rhizophora zone - *Rhizophora mucronata* and *R. apiculata* dominated zone occurs hinterland to the *Avicennia* zone and along rivers and creeks with a mean height about 8 m.
- Mixed species zone - These mangrove forests mostly consist of mixed species including *Bruguiera cylindrica*, *Ceriops tagal*, *Excoecaria agallocha*, *Ficus sp*., *Heritiera littoralis, Hibiscus tiliaceus*, *Intsia bijuga*, *Xylocarpus granatum*, and *X. moluccensis* situated behind the water-front zones.

Figure 2: Mangroves of Pak Panang estuary in Nakhon Si Thammarat Province.

Mangrove areas around Ban Pak Nam Pak Phaya in Ta Sak Sub-district of Mueang District were converted to shrimp ponds during the height of the shrimp farming industry in the 80s and early 90s, most of which are now being abandoned due to rising production costs and declining demand for the commodity. Mangroves occur as a thin belt of less than 10 m in width along the small rivers that drain this area and they are composed mainly of *Rhizophora apiculata*, *R. mucronata*, and *Avicennia alba* which are 7-10 m tall. Mangroves in the periphery of the abandoned ponds were found to be consisted of trees with low stature (3-4 m) and dominated by pioneer species such as *Avicennia marina*, *A. alba*, *Rhizophora apiculata* and *R. mucronata* mixed to a lesser extent with species such as *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Heritiera littoralis*, *Aegiceras corniculatum* and associated species such as *Thespesia populnea*, *Premna integrifolia* that occupy the area interior to the water-front zones. Tidal circulation in these areas does not occur uninterrupted due to the presence of sluice gates of the abandoned shrimp ponds.

Least disturbed mangroves occur in Pak Panang estuary and Ban Kong Khong village is situated in the proximity of this mangrove area (Figure 2).

Mangrove fauna

A total of 607 species of fish belonging to 87 families have been recorded from estuarine waters of Thailand. These include 30 elasmobranch species and 577 teleost species among which gobies (Eleotridae and Gobiidae) are the most diverse groups of fish in Thai estuaries. The Ariidae, Plotosidae, Mugilidae, Sciaenidae, and the Polynemidae mainly inhabit the estuaries, but the nurseryfish (Kurtidae) are restricted to mangrove canals. More than 90 species are commercially important for small-scale coastal fisheries and in the local economy. Around 40 species are well known in the global aquarium trade. In the past decade, species diversity has drastically decreased owing to loss of habitats (over 55% of mangrove areas have been claimed by deforestation, shrimp ponds and settlements), overfishing and pollution. There are 75 threatened species, (8 endangered; 67 vulnerable and near threatened). Two alien species introduced for aquaculture, *Oreochromis mossambicus* and *Poecilia sphenops*, flourish mainly in the inner Gulf of Thailand[5].

Trajectory of change in mangrove extent

The extent of mangroves estimated for NST in 1975 has been 155 km^2 (15,500 ha)[6] and it has reduced to 13,000 ha in 2005[7]. The major reason for dwindling mangrove extent in the province is attributed to their conversion to shrimp farms. Between 1961 and 1996, Thailand lost around 20,500 km^2 of mangrove forests, or about 56% of the original area, mainly because of shrimp aquaculture and other coastal developments[4].

According to Ongsomwang et al.[7], 1,594.48 ha mangrove areas of NST were converted to shrimp farms, while 662.17 ha were turned into agricultural land during the period 1990-2005.

Moreover, 3,223.21 ha of agricultural land too have been converted to shrimp ponds and 484.94 ha into human settlements. Approximately 14,500 ha of land have been converted to shrimp ponds and it is more than the total area of mangroves lost during the same period (Table 1). This is simply due to the fact that Thai shrimp farmers prefer to

Table 1: Extent of land-use types in Nakhon Si Thammarat in 1990 and 2005 (Ongsomwang et al, 2007)

Land use	Extent in 1990	Extent in 2005	Change
Settlement area	2,096.96	2,477.65	380.70
Terrestrial forest	8, 303.38	7,800.82	-502.56
Mangrove forests	14,078.13	12,999.19	-1,078.94
Agricultural land	35,699.71	34,079.28	-1,620.43
Shrimp farms	11,802.26	26,235.65	14,433.40
Water body	109,602.85	109,377.40	-225.45
Abandoned land	29,986.13	18,718.10	-11,268.02
Miscellaneous area	245.41	126.72	-118.69
Total	211,814.82	211,814.82	

locate their ponds away from inter-tidal zone of mangroves and in the supra-tidal areas where drying the pond and cleaning the bottom is less cumbersome, a practice that is effective in preventing diseases, the main cause of income loss from the enterprise. Approximately 30% of the shrimp production in Thailand comes from the freshwater areas, some of which are located 200 km from the sea[8] and culture technology is expected to improve in order to accommodate intensive culture in relatively a small extent of land.[7]

Organic shrimp farming is the latest spinoff of shrimp industry where shrimps are cultured extensively without any inputs such as artificial feed, antibiotics etc. which demand larger tracts of land to maintain organic shrimp farms. Currently it is restricted to one locality in Chanthaburi Province, nevertheless if the demand escalates this culture will be expanded to other areas and the easily acquired mangrove lands could be the target.

Barbier and Cox[9] report that mangrove conversion is determined by the returns to shrimp farmers, (i.e. the price of shrimp), the input costs to farming shrimp (e.g. feed price and wages) and the "accessibility" to mangrove areas. In addition, exogenous influences, such as income per capita, population growth, and in-migration (i.e. the number of shrimp farms) also are important factors in this context. Kongkeo[8] however, substantiates that Thai shrimp industry, dominated by small-scale farmers has managed to maintain high annual production due to the fact that Thai farmers readily move away from mangrove areas and adopt intensive farming methods with closed or less water-exchange systems in the supra-tidal areas, through which they have managed to substantially reduce the incidence of diseases. Use of concentrated seawater or freshwater as the culture medium too has contributed to lower the incidence of viral infections on cultured shrimps.

Although statistics are not available, substantial extent of inter-tidal land exists as abandoned shrimp ponds. The "Green Carpet" project, supported by KEIDANREN Conservation Fund (KNCF) and Japan Fund for Environmental Conservation (JEC) in collaboration with the Thai Union for Mangrove Rehabilitation and Conservation has planned to replant about 1000 ha of abandoned shrimp ponds in Nakhon Si Thammarat Province within 5 years. *Rhizophora mucronata*, *Rhizophora apiculata*,*Ceriops tagal* and *Bruguira cylindrical* have been used in the plantations and the former two species have shown the best growth rate and 75-90% survival rate[10]. Also they have shown that general soil conditions, i.e. organic matter and total nitrogen contents, pH, cation exchange capacity (CEC) and phosphorous content have improved over a period of three years after planting.

Thai shrimp farmers thus provide a mangrove-friendly paradigm of shrimp culture and it is timely that Southeast Asian Nations, particularly Indonesia, that harbours the largest extent of mangroves in the region, deliberate adequately and adopt policy measures to promote intensive shrimp farming in supra-tidal areas which requires relatively low extent of land than extensive farming in mangrove areas that is encouraged at present.

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Induced breeding of pacu (*Piaractus brachypomus*) in captivity with pituitary extract

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Pacu *(Piaractus brachypomus*), a native fish of South America recently introduced as an alien species into India via Bangladesh. A tendency has been observed among the fish breeders of Bengal to raise seeds of alien species, principally those that are carnivorous. Besides breeding individual species, the fish breeders are also interested in conducting hybridisation programmes between Indian major carps and exotic species, as they are largely unaware of the genetic consequences of such activities.

Pacu were probably introduced in India in 2003 or 2004, and leading hatchery owners soon started culture in captivity to raise broodstock for commercial breeding programmes. Pacu attain maturity at 3+ years in age with a stocking density of 2,000-2,500 individuals/ha. They are normally stocked at the ratio of 1 pacu : 3 Indian major carps when polyculture is undertaken.

Some farmers reported that polyculture gives better results than monoculture. During brood stock management the fish are fed with oil cake, boiled rice and grains, peas and fishmeal at 5% of total biomass per day. Compared to other food ingredients, fishmeal and groundnut oil cake offer better growth and maturation. One to two days before breeding is intended to take place, feeding is stopped. Mature male and female fishes are induced with pituitary extract. The first does for females is typically 2 mg/kg body weight, with a second resolving dose administered four and a half to five hours later, at 10-12 mg/kg body weight. At the time of the second female injection, the males are also given a single resolving dose of 2 mg/kg body weight. After injection the fish are kept in hapa, and they are stripped some five to six hours later. Injected fish may also be kept in cement cisterns, with induced fish producing a characteristic vibrating sound on the walls of the cistern.

The eggs are stripped out in trays and the milt and eggs mixed with a feather and the addition of water. The ratio of males : females for stripping is usually 1:1 or 1.5:1 depending on the maturity and density of the milt.

Environmental factors play an important role with regards to both the dose of inducing hormone required and stripping. When temperature is greater, i.e. 34-35°C, then both the dose requirement and stripping time is less. Again, for better fertilisation a congenial environment is needed. The fertilised eggs are transferred successfully into two hatching jars in 48 hours and in between the hatchlings are kept in hapa. As the yolk is absorbed the hatchlings become longer. From the 3rd day onwards the hatchlings are ready for sale.

For nursery management the spawn or hatchlings are stocked in the nursery pond, prepared beforehand, at the rate of 150,000 individuals/ha. The span are fed with artificially prepared feed made from groundnut oil cake, rice polish, soybean dust and also on zooplankton. Generally 2 kg of

The pacu, Piaractus brachypomus.

feed/ha is given daily at this stocking rate. Within 8-10 days the spawn develop into fry, which are transferred to rearing ponds. A 3 ha pond is ideal for rearing and stocking density is usually around 100,000 individuals/ha. The fry are fed with artificial food at the rate of 5 kg/ha per day made from groundnut oil cake, sunflower oil cake and fish meal, and also with boiled rice and Canadian peas.

Future prospects

Pacu was probably introduced into the farming sector of Bengal no more than five years ago. At this stage two to three leading farmers have already standardised the captive breeding and culture techniques for this fish. At the fingerling stage, the fish possess an alluring shining colour with a tint of blood red around the ventro-anterior region of the trunk. At maturity, the colour becomes more subdued with some round spots appearing throughout the body. The overall colour is dark in nature with a shape similar to that of a pomfret.

A great demand for spawn and fry from Midnapore and 24 Parganas (south) districts of the state. Demand is greater from Chennai, Kerala and Andhra Pradesh. The fish seed cultivators of these regions also supply mature fish to Bihar, Uttar Pradesh, Bangladesh and Pakistan where people are very much fond of this fish, as it possesses a lot of meet with less spines. The characteristic pomfret-like shape is considered an attractive quality amongst consumers.

Pacu have already established a place in the farming sector of Bengal and a good number of freshwater hatcheries are likely to be converted into Pacu hatcheries in the near future.

Fumonisins - mycotoxins of increasing importance in fish!

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Fumonisins are a group of recently discovered mycotoxins which belong to the family of Fusarium toxins. The contamination of feedstuffs with mycotoxins poses a serious threat to the health and productivity of animals and cause great economic losses. In the USA, the annual losses caused by mycotoxins in grain production are estimated at 900 million dollars[1]. Dependent on type of animal, sex, age as well as the nutritional and health condition of the animal, fumonisins cause different clinical symptoms. Additionally, the occurrence of several mycotoxins in feed is very likely and can amplify the toxic effects of the individual toxin (synergistic effect).

Fumonisins are mainly produced by *Fusarium verticillioides* (syn. moniliforme) as well as by *Fusarium proliferatum* (see Figure 1) and they occur predominantely in maize and maize-based feeds[2]. In 1988 they were first identified and isolated and so far there are 28 fumonisin analogues known[3,4]. Fumonisins are divided into four groups: Serial A, B, C and G. With regard to their toxicity the B-type fumonisins represent the most important ones[5]. In naturally contaminated food and feed fumonisin B1 represents about 70% - 80% of the total fumonisin content[6].

Fumonisins are very polar and water soluble compounds. Unlike other mycotoxins they have a long chain structure. Chemically they are polyhydroxyl alkylamines esterified with two carbon acids, i.e. tricarballylic acid (TCA). The four common members of the type B fumonisins differ by presence and position of the free hydroxyl groups respectively[7]. The one-sided or bilateral elimination of TCA results in partial hydrolyzed fumonisin or hydrolyzed fumonisin (HFB_1).

Fungal colonisation and growth and/or mycotoxin production are influenced by a variety of factors. Optimum conditions for fumonisin production are temperatures between 10°C and 30°C with a water activity (amount of free available water) of 0.93 aw[8].

A recently published survey about the occurrence of mycotoxins in Asia initiated by BIOMIN GmbH together with Romer laboratories in Singapore reported that 58% out of 960 feed

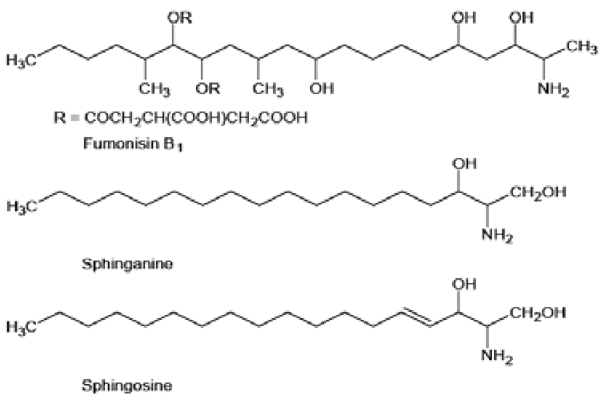

Figure 2: Structures of sphinganine, sphingosine and fumonisin B1.

Figure 1: Fusarium proliferatum contaminated maize (Source: Chamber of Agriculture, Styria, Austria).

raw material samples were contaminated with fumonisins. The highest level of fumonisins detected was 14.7 mg/kg in a corn sample from China[9]. In Europe, the maximum level of fumonisin was 3.1 mg/kg in a sample of soybean meal from Southern Europe[10]. Table 1 gives examples on high concentrations of fumonisins in maize.

Toxicity

Fumonisin toxicity is based on the structural similarity to the sphingoid bases; sphingosine and sphinganine (see Figure 2). They are inhibitors of sphinganine (sphingosine) N-acyltransferase (ceramide synthase), a key enzyme in the lipid metabolism, resulting in a disruption of this pathway. This enzyme catalyzes the acylation of sphinganine in the biosynthesis of sphingolipids and also the deacylation of dietary sphingosine and the sphingosine that is released by the degradation of complex sphingolipids (ceramid, sphingomyelin and glycosphingolipide)[11]. Sphingolipids are basically important for the membrane and lipoprotein structure and also for cell regulations and communications (second messenger for growth factors)[12].

As a consequence of this disruption many bioactive intermediates are elevated, others reduced. The main points are:

- Rapid increase of sphinganine (sometimes sphingosine).
- Increase of sphinganine degradation products like sphinganine 1-phosphate.
- Decrease of complex sphingolipids.

Free sphingoid bases are toxic to most cells by affecting cell proliferation and inducing apoptosis or necrotic cell death[13,14]. The accumulation of sphinganine is associated with hepato- and nephrotoxic effects[15]. Complex sphingolipids are important for cell growth regulation and also cell-cell interactions. The accumulation of free sphingoid bases in the serum and urine are a useful biomarker for the exposure of fumonisins[16].

The importance of fumonisins as toxic agents in fish is still poorly understood as there have been only a few studies published. In several experiments, fumonisins are documented to be toxic for fish.

In an experiment, one-year and two-years old channel catfish were fed diets containing *Fusarium moniliforme* from maize to contain FB_1 at 20, 80, 320, and 720 mg/kg during 10 weeks and 14 weeks, respectively[17]. It was reported that dietary levels of FB_1 of 20 ppm or above are toxic to one-year and two-year channel catfish fish fed with 20 mg/kg. FB_1 did not show differences in mortalities but weight gain was significantly decreased by 15% compared to the control group. Additionally, liver lesions were noted. In another study with catfish consuming *Fusarium moniliforme* maize containing fumonisins, an increase of the Sa:So ratios in serum, liver, kidney and muscle were found at ≥10 mg FB_1/kg after 12 weeks[18]. Catfish has also been fed with FB_1 from *Fusarium* cultured maize[19]. Eight groups of 20 catfishes were fed 0, 0.7, 2.5, 5.0, 10.0, 20.0, 40.0 or 240.0 mg FB_1/kg feed, respectively, for 12 weeks. At concentrations of 40 mg FB_1/kg feed, weight gain and feed consumption were decreased and also histological changes were detected.

Results reported by Tuan *et al.*[20] demonstrated that feeding FB_1 at levels of 10, 40, 70 and 150 mg/kg feed for 8 weeks affected growth performance of Nile tilapia fingerlings. In this experiment the mortality was low and histopathological lesions were not observed. Fish fed diets containing FB_1 at levels of 40 mg/kg or higher had decreased average weight gains. Haematocrit was decreased only in tilapia fed diets containing 150 mg FB_1/kg. The ration between free sphinganine and free sphingosine (Sa:So ratio) in liver increased at a 150 mg FB_1/kg in the fish feed.

Although research studies revealed that FB_1 is toxic to tilapia and channel catfish by suppressing growth and/or causing histopathological lesions, this fish survived mycotoxins levels up to 150 ppm. Reduction on the percentage of survival of channel catfish was observed for diets containing 240 ppm FB_1[21].

Adverse effects of fumonisin contaminated diets have also been reported in carps. One year carps indicated that signs of toxicity can be observed with 10 mg FB_1/kg feed[22]. In these experiments scattered lesions in the exocrine and endocrine pancreas, and inter-renal tissue, probably due to ischemia and/or increased endothelial permeability were reported. In one-year old carp, consumption of pellets contaminated with 0.5 and 5.0 mg FB_1 per kg body weight resulted in a loss of body weight and alterations of haematological and biochemical parameters in target organs[23].

Counteracting

Prevention measurements describe all the steps to counteract mycotoxins during the growth of the grain as well as during harvesting or storage. On the field all management practices which maximise plant performance and reduce plant stress can substantially decrease mycotoxin contamination. This includes pre-harvest practices like fertilisation, proper crop rotation, avoidance of pests, optimal crop density and high quality seeds. In addition, appropriate harvest time as well as optimal storage conditions like temperature or humidity control are important[24]. All these prevention measures can only reduce but not eliminate the risk of mycotoxin contamination. Therefore successful detoxification procedures after harvest are essential. They can be classified into three categories: physical, chemical and biological methods.

The efficacy of physical treatments depends on the level of contamination and the distribution of the mycotoxins in the grain. Additionally, the results obtained are often uncertain and associated with high losses. Various chemicals (bases, oxidizing agents, different gases etc) have been tested for their ability to detoxify mycotoxins but only a limited number of them are shown to be effective against them without reducing nutritive value, palatability of the feed or producing toxic by-products. For achieving adequate decontamination results several parameters like reaction time, temperature and moisture have to be monitored. Due to their uncertain and uneconomic results, the practical application of physical and chemical treatments is very limited.

Adsorption

Adsorbent agents are added to the feed and bind mycotoxins during digestion in the gastrointestinal tract resulting in a reduction of toxin bioavailability. Adsorption of mycotoxins requires molecule polarity and also a suitable position of the functional groups. Due to this fact only a few mycotoxins can be adsorbed efficiently without affecting essential feed ingredients. This method is especially used to counteract aflatoxins, however in the case of fumonisins it's only of limited success. In a study, different adsorbents were tested for their potential to bind FB_1. An effective adsorption of FB_1 was described with activated charcoal and cholestyramin in vitro. However, activated charcoal is a very unspecific adsorbent and binds valuable nutrients as well; therefore these results could only be confirmed for cholestyramin in vivo[25]. Avantaggiato *et al.*[26] from the Institute of Science of Food Production (ISPA) and the National Research Council (CNR), Bari, Italy, found out that among the commercially available feed additives Mycofix® Plus from BIOMIN GmbH showed good results with adsorption rates of 100% and 77% of 2 µg/ml and 20 µg/ml FB_1, respectively.

Biotransformation

Fumonisins are natural toxins, and therefore they are biodegradable by natural metabolic pathways. Compared to adsorption of mycotoxins by clay, microbial biodegradation has the advantages of being highly specific and irreversible. Several microbial strains which are capable of fumonisin biodegradation were previously isolated, and the genes encoding fumonisin detoxification enzymes were identified[27,28,29]. BIOMIN GmbH has a long standing expertise in the application of specific microbes for mycotoxin biodegradation in the gastrointestinal tract of animals[30]. Recently, BIOMIN GmbH scientists isolated and characterised new fumonisin-metabolising bacterial strains[31]. Some of these isolates were found to be active in the gastrointestinal tract of animals. One of the strains with the highest technological potential belongs to the family of the Sphingomonadaceae and was called MTA144. It degrades fumonisins by first cleaving off tricarballylic acid side chains, and subsequently catabolising the rest of the molecule into non-toxic products. Development of a novel feed additive for fumonisin detoxification based on this strain - whose efficacy was proven in vitro - is in progress. Nevertheless in vivo trials are necessary to prove its efficacy in the animals.

Conclusion

A number of experiments reported that fumonisins are toxic for fish and the main target organs are liver and kidney. Although careful selection of raw materials, maintaining good storage conditions for feeds and raw materials, there is still a potential risk of mycotoxin contamination. As a result of their different structures mycotoxins can cause various toxic effects in animals. Therefore, there cannot be only one effective strategy against mycotoxins. Whilst adsorption is very efficient for aflatoxins, this method is quite limited for other mycotoxins and only a feed additive which combines adsorption and biotransformation will lead to success.

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Microsatellite DNA markers, a fisheries perspective Part 1: The nature of microsatellites

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Many new classes of Polymerase Chain Reaction (PCR) -based genetic markers have been developed over the last decade. Of these, microsatellite markers are widely regarded as one of the most useful identified so far[1,2,3]. The significance of microsatellite markers derives from their abundance in the genome, single locus nature, simplicity of assay, high levels of allelic diversity, mendelian inheritance, co-dominance and selective neutrality. Microsatellites are defined as tandem arrays of short DNA sequence motifs of 1-6 base pairs in length. This structure has lead to a number of alternative names such as short or simple tandem repeats (STRs), simple sequence repeats (SSRs), simple sequence length polymorphisms (SSLPs) and variable number tandem repeats (VNTRs)[4]. These are represented as small arrays of repeats with lengths ranging from somewhere around a dozen up to a few hundred base pairs, with many being less than 100 base pairs in total length. Microsatellites are abundantly distributed across the genome, demonstrate high levels of allele polymorphism and can easily be amplified with PCR. These features provide the underlying basis for their successful application in a wide range of fundamental and applied fields of biology and medicine. In the field of fisheries and aquaculture, microsatellites are useful for characterisation of genetic stocks, broodstock selection, constructing dense linkage maps, mapping economically important quantitative traits and identifying genes responsible for these traits and application in marker assisted breeding programmes[5].

Genomic distribution

Microsatellites are ubiquitous in prokaryotes and eukaryotes, present even in the smallest bacterial genomes. The existence of microsatellites in eukaryotic genomes has been known since 1970[6]. In vertebrates these microsatellite loci can be found both in protein coding and non coding regions[7]. However, it has been demonstrated that the presence of microsatellite repeats is much higher in non coding DNA sequences[8]. Microsatellites can be described based on the number of nucleotides in the repeat motifs, with terms such as dinucleotide, trinucleotide and tetranucleotide.

Microsatellites can also be described by the term perfect, imperfect and compounds, which refer to an uninterrupted stretch of identical repeats, a repeat sequences in which there are one or more interruptions and repeat made up of two or more adjacent tandem repeats respectively. The majority of microsatellites (30-67%) found in the genome are dinucleotides. In the genome of vertebrates, the repeat $(AC)_n$ is most common, followed by $(AT)_n$. In total, higher order microsatellite classes such as tri-, tetra-, penta- and hexanucleotides are about 1.5 fold less common in the genomic DNA of vertebrates than dinucleotides[7]. Di and tetranucleotide motifs are mostly clustered in non coding regions. In vertebrates, they are distributed 42- and 30- fold less frequently in exons than in intronic sequences and intergenic regions, respectively. The dimeric microsatellite motifs present within expressed sequences are highly unstable, while in non-coding regions most dinucleotide repeats present as long stretches, probably due to the high tolerance of non-coding DNA to mutations[9].

Dinucleotide microsatellites are found in both exons and introns of a variety of fish species. Intronic dinucleotide microsatellites have been detected in the growth hormone gene of Nile tilapia, barramundi, Japanese flounder, and Japanese puffer fish[10]. Dinucleotide repeats have been described within genes of variety of fish species, including channel catfish[11], Atlantic salmon[12] and zebrafish[10]. Trinucleotide motifs are found in both coding and noncoding genomic regions with a high frequency[13]. In all vertebrates, (G+C) rich motifs are the most common among trinucleotides. These repeats are dominated in exons, whereas they are less common in intronic sequences[7].

Evolution and mutation models of microsatellites

Two models such as DNA polymerase slippage and unequal recombination over in meiosis have been suggested to explain microsatellite generation and evolution. Of these, strand-slippage replication appears to be the predominant mode at microsatellites[14]. Strand-slippage is speculated to occur primarily during lagging strand synthesis[4]. For example, it may involve the slippage of the newly synthesized DNA strand upon dissociation of a polymerase complex. This slippage creates a transient bulge which upon DNA repair would be either removed or lead to the elongation of the repeat[4]. Alternatively, the formation of a transient bulge in the template strand may lead to the shortening of the repeat. Slipped strands mispairing during DNA replication likely to represent the predominant mutational mechanism for microsatellites[15]. Non reciprocal recombination (gene conversion) also plays in genetic instability of some microsatellites including triplet modifs[16]. Gene conversion mechanism were found to be involved in the differentiation and evolution of paralogous sequences (duplicated loci within the species) in members of the family salmonidae, which was derived by tetraploidization.

There are three types of models of mutation that have been proposed to describe variations at microsatellite loci, which include stepwise mutation model (SMM), K” alleles model and the infinite alleles model (IAM). The SMM model holds that when microsatellites mutate, they only gain or lose one repeat and this implies that two alleles that differ by one repeat are more closely related than alleles that differ by many repeats. The genetic distance statistic that uses this model is called RST, it is generally the preferred model when calculating relatedness between individuals and population sub structuring[17]. The K" Alleles Model holds that a microsatellite can mutate into any one of "K" alleles randomly. The IAM model predicts that mutation will lead only to new allelic states and may involve any number of repeat units, the statistic that uses this model is called FST[18]. More precise estimates of population size and structuring events would be possible assessing which model provides a better fit to microsatellite data. The yearly work on mutation models showed that the SMM more accurately predicted the type of variation commonly observed at microsatellite loci. Studies in human families apprised that most mutations led to new alleles which differed from the parental allele by only one or two repeat units. Thus, it is suggested that SMM provides the best fit to the microsatellite data available at this time. However, in fishes particularly from rainbow trout, it has been observed that the IMA gave a consistently better fit than the predictions of SMM to microsatellite variability data using uninterrupted microsatellite loci[19].

Microsatellite markers

The existence of variability in the microsatellite loci is a common phenomena, this variability consists of length polymorphisms caused by changes in the number of repeat units in the microsatellite array. The most likely change is the gain or loss of single repeat units, which suggests that microsatellite repeats are changing in the stepwise fashion. The observed mutation rates range from 10-3 to 10-6 event per locus per generation[8,20] which is several orders of magnitude greater than that of regular non repetitive DNA[21]. This higher rate of mutation at microsatellite loci causes hyper variable marker locus with many alleles. The allelic state at a particular microsatellite locus can be visualized by the analysis of length variation seen in PCR products. Because the regions flanking the microsatellites are generally conserved within a species, primers in these flanking regions can be used for PCR amplification and the products screened for size variation on polyacrylamide gels[22]. As microsatellite alleles are co-dominant they will be seen as one or two bands after PCR amplification representing homozygous or heterozygous states respectively. Microsatellites are being used as genetic markers in many living organisms, including agriculturally important species and in species of taxonomic interest or conservation concern.

Limitations

Microsatellites have proved to be versatile molecular markers, particularly for population analysis, but they are not without limitations. A major drawback to the use of microsatellite markers is that it is necessary to know the sequence of DNA flanking the various tandem repeats in order to design appropriate PCR primers. Unless the DNA sequence for the particular organism is readily available, it is necessary to create and screen a genomic DNA library in order to locate microsatellite loci[2,22].

Genotyping with microsatellite (especially those with dinucleotide repeats) is often complicated by the presence of stutter bands. The stuttering at dinucleotide microsatellite loci can often occlude adjacent alleles. The stutter bands are caused by polymerase slippage during PCR amplification, which results in secondary products containing one or more repeat units less than the primary allelic band. Stutter bands can sometimes equal the intensity of the primary band, making it difficult to accurately characterize genotypes, particularly in population studies where the accurate scoring is essential for parentage determination and family reconstruction from wild populations[11]. This problem is exacerbated in microsatellite loci that have large microsatellites, as the level of stuttering is generally higher in microsatellites with large repeated arrays. One possible approach to avoid this problem is to select tetranucleotide loci instead of dinucletide. A second method for reducing the potential scoring difficulties is to use dinucleotide loci with a reduced product size (<120)[23].

Functions

Although microsatellites are usually considered to be evolutionarily neutral markers, some microsatellites have been proven to have functional significance by critical test in various biological events in several organisms[21].

Chromatin organisation

Microsatellites play an important role in chromosome organisation as they are capable of forming a wide variety of unusual DNA structures with simple and complex loop folding patterns. For example, a hairpin formed by fragile X repeats (CCC)n and the bipartite triplex formed by (GAA)n / (TTC)n, have shown simple loop folding, and such triplex structures may have important regulatory effects on gene expression[24]. In many species, the centromeric and telomeric region of chromosomes is composed of numerous tandem repeats that affect the organisation of the centromere and telomere. Long microsatellites with mono-, di-, tri-, and tetranucleotide motifs are highly clustered in the centromeric regions of tomato, arabidopsis and sugar beet. In fishes, satellite sequences enriched by AT-dinucleotides have been found in the centromeric DNA of various gobiid species[25].

Regulation of DNA metabolic process

Numerous microsatellite and microsatellite DNA have been proposed as hot spots for recombination[26]. Dinucleotide motifs are preferential sites for recombination events due to their high affinity for recombination enzymes. Some microsatellite sequences, such as GT, CA, CT, GA and others, may influence recombination directly through their effects on DNA structure[28]. Microsatellites may affect DNA replication. In rat cells DNA amplification is arrested within a specific fragment which consists of a $d(GA)^{27}$ $d(TC)^{27}$ tract. It is found at the end of an amplicon, and in conjunction with the inverted repeat, may serve as an arrest site for DNA replication in-vivo[29].

Regulation of gene activity

Microsatellite occurrence in coding regions seems to be limited by non-perturbation of the reading frame. In many cases, microsatellite repeat numbers appears to be a key factor for gene expression and expression level. Some genes can only be expressed at a specific repeat number of microsatellites and some genes can be expressed within a narrow range of microsatellite repeat number, and out of this range gene activity would be turned off[21].

Part 2 of this article "Applications of microsatellite markers in fisheries" will follow in the July-September issue.

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Asia-Pacific Marine Finfish Aquaculture Network

Magazine

Formulated feed for tiger grouper grow-out

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Tiger grouper, *Epinephelus fuscoguttatus*, is a carnivorous fish that grows faster than either humpback grouper (*Cromileptes altivelis*) or coral trout (*Plectropomus* spp). However, industry development of this fish has been faced with several challenges, paramount of which has been a lower market price of cultured fish compared to wild-caught tiger grouper. The reasons given by the buyers for the low price paid for cultured tiger grouper are that fish fed on commercial pelleted feeds have a different taste and relatively poor survival during transport from farm to market compared to wild fish. The validity of these claims has not been rigorously tested. An additional impediment to industry development has been the high and increasing cost of trash fish, which has been the traditional source of feed for culturing marine fish, including groupers.

Because of the decreasing price paid for tiger grouper, farmers must find ways to reduce production costs or turn to farming other, higher-value species. Feed is one of the biggest cost component in rearing tiger grouper and total reliance on feeding trash fish has many problems. Most important are poor feed conversion (as much as one third to one half of the trash fish is not actually consumed by the cultured fish), its variable nutritional composition, its susceptibility to spoilage because of inappropriate handling practices, risk of disease introduction and significant downstream environmental pollution[1]. Moreover, increasing competition between human and aquaculture usage of low value fish (i.e. so called trash fish) is not only increasing its price to the farmer but also impacting on the often poor fishing villages, where low value fish may be the most important source of protein for people.

For the above reasons, there was an urgent need to develop cost-effective and high performing compounded feeds that had less reliance on using trash fish and which would have lower environmental impacts. It was recognised that grouper previously fed on trash fish would not readily take a dry compounded (pelleted) feed and thus development of a moist feed acceptable to the fish was an important aspect of our feed development work. There was also a need to test the validity of the market's perception that cultured tiger grouper were less desirable than wild caught fish. This article outlines the work that was carried out by the Research Institute for Coastal Aquaculture, Indonesia to address these issues. This research was part of a collaborative project funded by

Figure 1. Above: Manual mincing of trash fish, dry ingredient mix and oils. Below: Close up of ingredients and mixture.

the Australian Centre for International Agricultural Research: Project FIS/2002/077: "Improved Hatchery and Grow-out Technology for Marine Finfish in the Asia-Pacific Region". The work entailed a controlled sea cage experiment and an on-farm study as an active extension mechanism to gain adoption of rearing tiger groupers on compounded feeds. A

Figure 2. Homogenous mixing of all ingredients.

taste panel assessment was commissioned in Hong Kong to compare the eating quality of cultured groupers fed either trash fish or compounded moist and dry feeds.

Comparison of moist and dry compounded feeds and trash fish

Methods

In this controlled sea cage experiment, five diets were compared when fed to juvenile tiger grouper over a 20-week growing period. Three of the diets were moist diets that examined the effect of reducing the amount of trash fish from a maximum of 50% (on a dry matter basis) to zero; the fourth diet was a commercially manufactured dry pelleted grouper feed and the fifth diet was trash fish (Table 1). The critical chemical composition of these diets is shown in Table 2 while Table 3 gives the cost of these diets.

The making of the moist pelleted diets followed standard procedures: dry ingredients were thoroughly mixed together in a planetary mixer and fish oil slowly added while mixing continued. Trash fish was minced by passing it through a meat mincer several times and then mixed in with the other ingredients. For Moist P3 diet where no trash fish were used, sufficient water was added to form a dough of approximately 50% dry matter content. The dough was cold extruded through the meat mincer with the size of the die plate being varied in accordance with the increasing size of the fish being fed. The freshly prepared moist feed was either fed directly or held in a refrigerator for not more than 24 hours. These manufacturing procedures are illustrated in Figures 1 to 4.

Fish for the experiment had been hatchery reared at the Gondol Mariculture Centre and transferred as fingerlings to RICA's floating net cages at Awerange Bay, South Sulawesi. The fish were acclimated in a floating net cage for a couple of months. During the acclimatisation, the fish were trained to accept moist and dry pelleted feeds. A total of 240 fish were stratified by weight into three groups of average weights of 234±11.3, 269±11.6 and 318±16.6 g. Five fish from each group were randomly sampled for determination of initial whole body chemical composition. The remaining 225 fish were equally distributed (15 fish/cage) within size groups to 15 net cages of 1 x 1 x 2 (depth) m. Throughout the experiment, diets were carefully fed twice daily to apparent satiety.

Figure 3. Manual preparation of noodle (pellet strands) by cold extrusion.

At the conclusion of the 20-week feeding period, three representative fish from each netcage were sacrificed to determine the chemical composition of the fish. A further two fish from each cage or six fish from each treatment were collected randomly and were sent to Hong Kong for independent tast panel assessment.

Results and discussion

Except for the Moist diet P3 (which contained no trash fish) where fish survival was 80%, survival of fish on all other diets was excellent, 91 to 98%. However, there was no significant ($P > 0.05$) difference in fish survival between treatments. Fish grew well on all diets with final weights ranging from 628 to 714 g and significantly lower ($P < 0.05$) only for fish fed Moist diet P3. Specific growth rate (SGR), feed conversion ratio (FCR, on as-fed and dry matter basis) and protein efficiency ratio (PER) of the fish are shown in Figure 5. The fish fed Moist diet P1, commercial diet (Dry P) and trash fish had high and relatively similar ($P > 0.05$) SGR, FCR (as dry matter) and PER whereas these productivity measures were significantly worse for fish fed Moist P3; values for fish fed Moist Diet P2 were intermediate.

Poorer growth and FCR of fish fed Moist Diet P3 may be due to poor feed binding compared to the other moist pellet feeds, and consequently, resulted in high amounts of feed wastage. Moreover, Moist Diet P3 also contained a higher inclusion of soybean meal compared to the other two moist diets. Since soybean meal has a lower essential amino acid quality than fishmeal[2,3,4] and also contains anti-nutritional factors such as anti-trypsin and high phytic acid[5,6], these factors may have contributed to the poorer performance of fish fed the Moist diet P3. However, Rachmansyah et al.[7] reported that soybean meal could be used in diets for humpback grouper, *Cromileptes altivelis*, at inclusion rates of up to 24% in plant based diets as fishmeal replacements without adverse effect provided the feed was supplemented with 0.075% phytase.

Although there were large differences between diets in the as-fed FCR, this difference was mostly due to differences in dry matter content of the diet (Table 2). When expressed on a similar dry matter basis, diets Moist P1, Dry P and trash fish all had similar FCRs which were significantly better than fish fed Moist Diet P3; DM FCR of fish fed Moist Diet P2 was intermediate.

Table 1. Formulation of the pelleted (P) moist diets (% dry matter) & trash fish.

Ingredient	Moist P1	Moist P2	Moist P3	Trash fish
Trash fish[1]	50	25	0	100
Local fish meal	25	30	50	0
Poultry offal meal	0	20	20	0
Shrimp head meal	5	5	5	0
Soybean meal	5	5	15	0
Rice bran	3	3	0	0
Wheat flour	8.5	9.0	6.5	0
Fish oil	1.5	1	1.5	0
Vitamin premix[2]	1.5	1.5	1.5	0
Vitamin C	0.02	0.02	0.02	0
Mineral premix[3]	0.5	0.5	0.5	0

1. Mostly pony fish; 2. Vitamin mix provided (mg/kg diet): Thiamin-HCl, 29.6; riboflavin, 29.6; Ca-panthothenate, 59.3; niacin, 11.9; pyridoxine-HCl, 23.7; biotin, 3.6; folic acid, 8.9; inositol, 1185; p-aminobenzoic, 29.6; astaxanthin, 88.9; menadione, 23.7; calciferol, 11.3; µ-tocopherol, 118.5; ascorbic acid, 888.8; cyanocobalamin, 0.6; choline-HCL, 5485.5.; 3. Trace mineral provided (mg/kg diet): $FeCl_3.4H2O$, 553,3; $ZnSO_4$, 33,3; $MnSO_4$, 22.5; $CuSO_4$, 7,0; KI, 0.5; and $CoSO_4.7H_2O$, 0,3.

Table 2. Chemical composition (dry matter basis) of the feeds.

Analysis	Moist P1	Moist P2	Moist P3	Dry P1	Trash fish
Crude protein (%)	47.4	48.9	50.4	50	55.2
Digest. CP %	43.3	43.3	43.3	?	52.5
Dig. energy (kJ/g)[2]	16.1	16.0	15.1	?	18.6
Total lipid (%)	10.8	11.6	11.4	10.5	10.8
Ash (%)	18.9	16.0	15.3	13.6	21.6
Fibre (%)	3.9	3.6	3.5	2.5	1.2

1. This was a commercial dry pelleted diet specified for grouper grow-out.
2. Derived from digestibility data determined for similar ingredients in previous experiments and estimated for trash fish assuming 100% digestibility of protein.

Table 3. Dry matter (DM) content of the feeds as fed, and cost on an as-fed and DM basis.

Attribute	Moist P1	Moist P2	Moist P3	Dry P1	Trash fish
Feed DM (% as fed)	56	54	49	92	25
Cost (US$/kg as DM)	1.07	0.77	0.66	1.09	1.67
Cost (US$/kg as fed)	0.60	0.42	0.32	1.00	0.42

1. This was a commercial dry pelleted diet specified for grouper grow-out.

The initial and final whole body chemical composition of fish is shown in Table 4. No significant differences were observed between diets for any of the analysed components. However, over the course of the 20-week experiment, there was a uniform increase in lipid content of about 2.5% above that of the initial fish for all diets. It is interesting to note that although the five diets varied considerably in protein and energy contents (Table 2), the fish were able to accommodate these differences in nutrient supply, probably through moderation of appetite, to end up with almost identical final body composition. There is evidence that fish do have considerable homeostatic capacity to maintain whole body chemical composition within reasonably normal limits[8].

The least expensive feeds on an as-fed basis were Moist Diet P3 (US$ 0.32/kg) and trash fish (US$ 0.42/kg) while the most expensive was the commercial diet, Dry P (US$ 1.00/kg). However, when compared on a similar DM basis, the trash fish was the most expensive (US$ 1.67/kg) with the commercial Dry P and Moist P1 diets being the next most expensive (US$ 1.09/kg and 1.07/kg, respectively); the least expensive diets were Moist P2 and P3 (US$ 0.77/kg and 0.66/kg, respectively). These feed costs are based on the ingredient cost for the moist diets without any account of including an on-farm manufacture cost. However, the commercial Dry P diet was the actual cost of the diet as landed in South Sulawesi. When the feed cost to produce 1 kg of fish weight gain was calculated (Table 5), the most expensive feed was trash fish (US$ 2.77/kg fish gain), the least expensive was Moist P2 (US$ 1.72/kg fish gain) while Moist diets P1 and P3 and the commercial Dry P diet were all very similar (US$ 1.98, 1.90 and 2.00/kg

Table 4. The whole body composition[1] of tiger grouper fed different feed types.

Variable	Initial fish	Test diet				
		Moist P1	Moist P2	Moist P3	Dry P	Trash fish
Dry matter %	29.1	30.7±0.74[a]	30.9±0.81[a]	31.4±0.69[a]	31.4±0.58[a]	30.5±0.95[a]
Crude protein %	16.8	16.8±0.51[a]	17.3±0.24[a]	17.1±0.13[a]	17.3±0.14[a]	16.9±0.22[a]
Total lipid %	5.7	8.3±0.32[a]	8.1±0.54[a]	8.1±0.44[a]	8.3±0.64[a]	8.2±0.81[a]
Ash %	4.7	4.2±0.251[a]	4.4±0.40[a]	4.7±0.35[a]	4.7±0.24[a]	4.4±0.09[a]

1. Expressed on a wet basis. a. Means in the same row with the same superscript letter do not differ (P >0.05).

Table 5. Feed cost based on feed conversion ratio (FCR) to produce 1 kg of tiger grouper fed different type and formulation in floating net cage.

Variable	Test diet				
	Moist P1	Moist P2	Moist P3	Dry P	Trash fish
FCR (as-fed basis)	3.30	4.13	5.90	1.99	6.64
Feed price (US$/kg as fed)	0.60	0.47	0.32	1.00	0.42
Feed cost to produce 1 kg of tiger grouper (US$/kg fish)	1.98	1.72	1.90	2.00	2.77

Figure 4. Formulated feed being fed to tiger grouper.

fish gain, respectively). It must be recognized that these cost calculations do not take into account any differences in fish survival between diets. With the exception of Moist diet P3 where fish survival was low (80%), survival on all other diets was high (91-98%) and not significantly different. Looking at level of pellet production cost, practical use, feed stability and environmental compatibility, commercial pellet was more beneficial compared to other meals. However, if tiger grouper have not been adapted to accept dry feeds, it may be necessary to feed a moist diet to help fish to accept dry pellets[9].

Eating quality of the cultured fish as determined by an independent taste panel in Hong Kong is summarised in Table 6. Fish fed Moist P2 tended to have better eating quality than fish fed other feeds, while the least attractive was fish fed Moist P3. It is difficult to relate differences in eating quality to chemical composition of the fish given the similarity for all diets (Table 4). However, fish fed Moist P2 had the highest protein and lowest lipid content compared to fish fed other feeds and whether this combined to produce fish with better eating quality is difficult to assess. Fish fed Moist P3 were noticeably thinner than those fed other diets and particularly those fed Moist P2. The taste panellists also commented that fish fed Moist P2 were superior in overall eating quality than grouper from Thailand and Taiwan. However, this was a very subjective opinion and no information was given about the condition of the fish that that opinion was based on. Overall, the eating quality of fish fed Moist P2 and P1 diets, the commercial Dry P and trash fish feeds was rated highly while only the fish fed Moist P3 was considered to be of inferior quality.

This study demonstrated that feeding Moist diets P1 and P2 and the commercial Dry P diet were equally good in rearing tiger grouper to market size and of excellent eating quality; surprisingly, fish fed the trash fish were not rated as highly while those fed Moist P3 were considered to be of inferior quality. In terms of feed cost to produce 1 kg of tiger grouper fish, the the Moist P2 feeds was the least expensive but it has a high handling/manufacturing demand on the farmer's time. The commercial Dry P diet, though slightly more expensive than Moist P2, this extra cost could be more than offset by the convenience of continuity of supply, ease of storage and handling and least environmental impact. However, if tiger grouper have previously been fed on trash fish, they will only accept dry feeds after several days and possibly weeks of adaptation. This conditioning to dry feeds can be hastened by

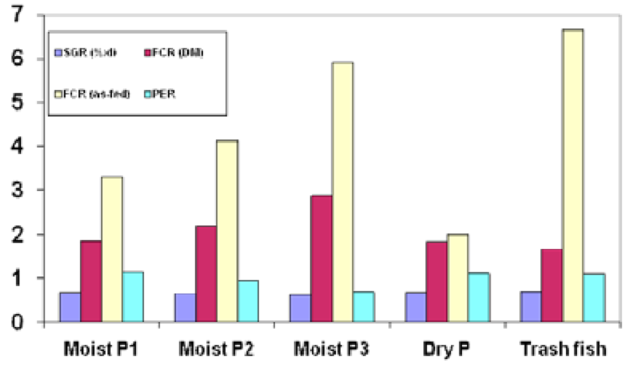

Figure 5. Specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) of tiger grouper fed different feed types.

Figure 6. Commercial grouper farm at Labuange Bay used for on-farm evaluation of different feeds fed to tiger grouper.

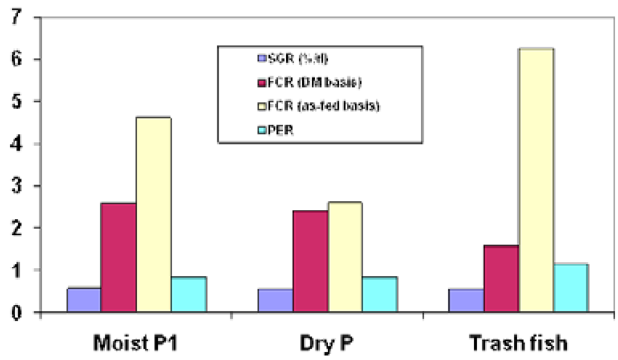

Figure 7. Specific growth rate (SGR), as-fed and dry matter (DM) feed conversion ratio (FCR) and protein efficiency ratio (PER) of tiger grouper fed different feed types during an on-farm trial.

using moist feeds as an interim feeding practice, allowing the fish time to adjust to pellet feeding without any setback in the growth of the fish. Either of the Moist P1 or P2 diets would be ideal as transition or change-over feeds.

Table 6. Taste panel assessment of cultured tiger grouper fed different feeds.

Variable	Test diet				
	Moist P1	Moist P2	Moist P3	Dry P	Trash fish
Odor	Fresh Seaweedy	Strong Fresh Seaweedy	Fishy odor	Light fresh Seaweedy	Fishy odor
Flavor	Light fresh Sweet	Strong Fresh Sweet	Loss of flavour	Some loss of sweetness	Loss of flavour
Texture	Some loss of moistness Slightly dry	Very moist and smooth	Very dry and tough	Moist and smooth	Dry and tough

Table 7. The whole body chemical composition[1] of tiger grouper fed different feed types in the on-farm study.

Variable	Initial fish	Test diet		
		Moist P1	Dry P1	Trash fish
Dry matter %	31.2	30.7±0.90[a]	31.7±0.24[a]	31.5±0.85[a]
Crude protein %	16.4	17.1±0.64[a]	16.9±0.15[a]	17.0±0.69[a]
Total lipid %	6.8	8.2±0.45[a]	8.0±0.18[a]	7.8±0.66[a]
Ash %	4.0	3.8±0.02[a]	3.9±0.024[a]	3.7±0.24[a]

1. *Expressed on a wet basis.*
2. *This was a commercial dry pelleted feed.*
a. *Means in the same row with the the same superscript letter do not differ (P >0.05).*

On-farm comparison of feeding trash fish or compounded feeds

The objective of this study was to evaluate the feeding of a moist feed, a commercial dry feed and trash fish to tiger grouper on a commercial grouper farm. The farm was situated at Labuange Bay, Barru Regency at South Sulawesi (Figure 6).

Methods

Three of the feeds that had been examined in the controlled seacage experiment, namely Moist P1, Dry P and trash fish were compared in this on-farm study. These feeds were made as described for the controlled seacage study and their formulation, chemical composition and cost are shown in Tables 1 to 3, respectively. Tiger grouper were blocked into two size groups of 240±22.7 g and 305±33.6 g and within these groups were randomly allocated to seacages of 2 x 2 x 2.5 (d) m at a stocking rate of 80-83 fish per cage. There were two cage replicates per treatment. The fish had been on the Labuange Bay farm for several months and were accustomed to being fed pelleted feed. During the 16-week study, fish were fed to apparent satiety once daily. At the conclusion of the experiment, a representative sample of three fish was taken from each cage to determine whole body chemical composition.

Results and discussion

Fish survival during the experiment was 94-98% and did not differ between treatments (P >0.05). Other productivity measures (Figure 7) also did not differ between treatments. The SGR of the on-farm grouper averaged 0.56%/day, which was lower than that seen with the same feeds in the controlled seacage experiment where SGR averaged 0.68%/day. Previous studies have shown tiger grouper of 165-263 g to grow at 0.66-0.72%/day[10] while smaller fish of 27 g start weight grew at 1.50-1.59%/day[11]. Although expressing growth as SGR reduces the effect of fish size to some extent, it does not fully compensate for the relative change in metabolic demand as fish increase in size[12].

As expected, the as-fed FCR of fish fed trash fish was much worse than for the other diets that had a higher concentration of dry matter. When compared on a similar dry matter basis, fish fed the trash fish had significantly better FCR than all other diets with the Moist P1 diet being significantly worse than all other diets.

The initial and final whole body chemical composition of representative fish is shown in Table 7. There were no significant treatment differences. However, during the course of the experiment, there was a uniform increase in body lipid from 6.8% to ±8%.

Using the same feed costs as for the controlled seacage experiment (Table 3), the feed cost to produce 1 kg fish weight gain in the on-farm study is shown in Table 8. Essentially, there was no difference in the tiger grouper production cost between the three feed types although the Moist P1 diet was slightly more expensive US$2.78/kg fish gain compared to US$2.62-2.63/kg fish gain for the commercial dry pellet and trash fish. Based on these results, the commercial dry pellet diet is the best to use because of its storage and handling advantages.

Conclusions

The on-farm experiment has demonstrated that tiger grouper fed the commercial dry pellet diet used in this work grew equally as well as fish fed trash fish and with an equivalent per kg fish production cost. Because of the practical handling and positive environmental benefits of feeding a dry pelleted feed, we see no reason why trash fish should continue to be relied upon as the sole source of feed for culturing grouper.

It is recognised that tiger grouper previously fed trash fish may not readily accept a dry pellet diet and may show little or no growth during this period of adaptation. This set back can be avoided by using a moist diet as a transition between feeding trash fish and dry pellet. The moist feed can be easily made on-farm using simple and inexpensive equipment. Our work has shown that our Moist P2 formulation (Table 1) that contained 25% trash fish (on a DM basis) and 75% of readily available dry ingredients was readily accepted by tiger grouper that had previously been fed only trash fish. In our controlled seacage experiment, fish fed Moist P2 survived and grew equally as well as those fed trash fish. Moreover, the feed cost of this moist diet to produce 1 kg fish gain was 60% less expensive than feeding the trash fish (US$ 1.72 versus 2.77/kg gain, respectively).

An independent taste panel assessment of the eating quality of tiger grouper fed the moist, commercial dry or trash fish feeds examined in the controlled seacage experiment found all diets to be highly acceptable. Fish fed the moist diet that contained no trash fish (Moist P3) was considered to be slightly inferior to those fed other diets but this may have been due to these fish being thin and smaller than the other fish.

We recommend that tiger grouper should be fed a good quality commercial dry pelleted feed if only because of its positive environmental benefits over that of feeding trash fish. However, our controlled and on-farm experiments have shown that the commercial dry pellet feed is equally as cost-effective in rearing tiger grouper as feeding trash fish.

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New book: Freshwater prawns: Biology and farming (2nd ed.)

The farming of freshwater prawns has developed very rapidly since 2000. Significant advances in techniques and an expansion in global demand for prawns continue to stimulate the growth of this industry, which has a global farm-gate value exceeding US$ 1.76 billion. This book is not merely an update of the first edition, published in 2000, but has been completely rewritten to incorporate all the most recent information available. This landmark publication therefore is a compendium of information on every aspect of the farming of freshwater prawns. A comprehensive review of the status of research, development and commercial practice, the book is intended to stimulate further advances in the knowledge and understanding of this important field.

An extremely well-known and internationally-respected team of 44 contributing authors have written cutting edge chapters covering all major aspects of the subject. Coverage includes biology and taxonomy; hatchery and grow-out culture systems; nutrition, feeds and feeding; genetics; size management; commercial developments around the world; post-harvest handling and processing; marketing; economics and business management; and sustainability. Although the focus of the book is on the giant river prawn *Macrobrachium rosenbergii*, information is also provided on other commercially significant species, including *M. nipponense* (whose global farmed output already equals that of *M. rosenbergii*), *M. malcolmsonii* and *M. amazonicum*. Contributions to the book have been collated and edited by Michael New, Wagner Valenti, Jim Tidwell, Lou D'Abramo & Narayanan Kutty, all widely known for their work in this area.

The comprehensive information in biology and farming of freshwater prawns will give an important commercial edge to anyone involved in the culture and trade of freshwater prawns. Available from Wiley, ISBN: 978-1-4051-4861-0, 552 pp.

NACA Newsletter

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NORAD funded project on climate change initiated

The inception workshop of the NORAD funded project *Strengthening Adaptive Capacities to the Impacts of Climate Change in Resource-poor Small-scale Aquaculture and Aquatic Resources-dependent Sectors in the South and South-east Asian Region* was held at the NACA Secretariat, Bangkok, Thailand from 19-20 March 2009.

Representatives from NORAD, project partner institutions (Akvaplan-niva ÅS, Tromso, Norway; Bioforsk - the Norwegian Institute for Agricultural and Environmental Research, Ås, Norway; Faculty of Fisheries, Kasetsart University; NACA), national project focal points from case study implementing countries (Indonesia, India, Thailand, Vietnam, Philippines and Nepal); and regional and international organizations (FAORAP SEAFDEC and DPI Fisheries Victoria, Australia) participated in the inception workshop. The workshop participants discussed and agreed on implementation approaches and methodology, developed work plan for country case studies, identified and agreed on roles and responsibilities, developed monitoring and reporting schemes, decided on future project meetings, and developed strategies for dissemination of project findings to a wider audience in the region.

This project is in line with the advocacy to strengthen adaptation capacities of relevant economic sectors, communities and households to climate change impacts. The project focuses on the small-scale aquaculture and the related sectors that consist largely of poor people who depend on aquatic resources for their livelihoods. The project will assess the impacts of climate change on small scale aquaculture sector (environmental, socio-economic and institutional) in selected study areas in five countries. The focus will be on specific farming sectors in the south and south-eastern Asian region, and mapping the farmers' perceptions and attitudes towards climate change impacts and their adaptive capacities to address these impacts. The project will develop future scenarios based on the current trends, assess the potential adaptive measures for different aquatic farming systems and prioritise better practices, suggest Codes of Practices and improved methodologies for such systems.

The project aims to establish guidelines, frameworks and tools for policy and action programs of governments, development assistance agencies, non government organisations, and farming communities that will increase the resilience and enhance adaptive capacities of resource-poor, small-scale aquaculture farmers and those dependent on aquatic resource for livelihoods, to the impacts of climatic changes. It will provide information for investments in research, technology development and transfer, public education, training, infrastructure and systems, markets, financial and other support services for the small-scale aquaculture farmers and aquatic resource users who are poor, most of all provide strategies to small scale farmers to maintain their resilience in the wake of climatic change impacts.

The project activities have been divided into five work packages in order make it convenient for project management and also assign responsibilities to each partner. Each work package will be focusing on main project issue, but will be addressing several sub-tasks that are linked to the main issue in the particular work package. The five work packages are as follows:

- Assessment of impacts of climate change on small-scale aquatic farming systems and the potential contribution of these systems to GHG emissions.
- Risk perceptions, attitudes and risk management behaviour, status of resiliency, adaptive capacities and adaptation strategies of small-scale farmers.
- Developing adaptive solutions and scenario-building of the changes on the resources and livelihoods options of poor and small aquaculture house-holds, and the risks and opportunities presented by climate change.
- Policy and analysis and adaptation strategy development.
- Project coordination, results dissemi-nation and follow up action.

The three-year project will be coordi-nated by NACA. For more information contact Dr CV Mohan, email: mohan@enaca.org, or visit the project web page at:

http://www.enaca.org/modules/inland-projects/index.php?content_id=8

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http://www.enaca.org/modules/newsletter.

Market chains and biosecurity of 'low-value' aquaculture commodities

The international trade in cultured finfish is currently dominated by freshwater species, of which the Vietnamese tra catfish (*Pangasianodon hypophthalamus*) and tilapias collectively exceed commodities such as salmonids. In addition, there is a growing trade in species such as rohu (*Labeo rohita*), both internationally and regionally. All these species are relatively low valued compared to, for example, salmonids and some shell fish. The growing trade in these "low value high volume" cultured species, increase in production and associated processing facilities and service sectors have begun to contribute significantly to the economies of the producing countries. The trade is also providing new livelihoods to many thousands of people, further contributing to food security and poverty alleviation in the region. For example, the processing industry for tra catfish and rohu in Vietnam and Myanmar alone are estimated to provide over 100,000 livelihood opportunities, mostly for women, empowering impoverished households and rural communities.

Rohu heading for the processing line, Myanmar.

FAO and NACA convened a workshop on *Market chains and issues associated with biosecurity of low-valued cultured commodities in Asia* in Siem Reap, Cambodia from 23-26 February 2009. The objectives of the workshop were to identify the crucial issues related to the marketing, quality and certification-associated issues surrounding relatively low-valued fish, including biosecurity and health. The workshop also sought to develop a plan of action for sustaining the trade of these commodities and to provide necessary guidelines to governments of the required legislative and or policy changes to achieve these objectives.

The workshop was opened by the Hon. Vice Minister and Secretary of State for Agriculture, Forestry and Fisheries, H.E. Chan Tongyves, and was graced by the Vice-Governor, H.E. Chan Sophal, Siem Reap Province, the Director General of the Fisheries Administration, H.E. Nao Thuok, and FAO representative for Cambodia, Mr. Ajay Markanday.

Representatives from nine NACA member countries (Cambodia, China, Lao PDR, Myanmar, Thailand, Vietnam, India, Indonesia and Bangladesh) participated in the workshop and made country presentations and case studies relevant to the theme of the workshop. Three senior professional officers from FAO (FIIU) and two professional officers from NACA participated.

A total of 26 presentations were made at the workshop. The presentations and the ensuing discussions focused on the following thematic areas:

- Marketing and value chains of low value cultured fish.
- Fish products from low valued cultured fish.
- Bio-security and human health issues associated with the consumption of low value fish and their products.
- Nutritional value of low value cultured fish.
- Diseases of low value cultured fish and development of better management practices for important low valued cultured commodities.
- Consumption patterns of fish globally and in the region.

The workshop identified important R&D issues for taking follow up activities to support the sustainability of the sector in the Lower Mekong Basin countries. Important R&D issues identified during the workshop included:

- Need for further work on food safety and public health issues associated with fish borne zoonotic parasites (FZP) (e.g. fish borne trematodes such as liver fluke) in most countries of the region, particularly where fish is consumed in raw condition or as various fermented products (e.g. fish paste).
- Need for further work on serotyping of *Salmonella* associated with low valued cultured fish and their products.
- Need for developing better management practices for low value cultured fish in order to address the food safety and fish health issues.
- Need for developing better handling, transportation and processing practices to counter human health related issues and reduced post harvest handling losses, which is presently estimated between 30-40%.
- Need to improve market chains in respect of low valued cultured fish and to popularize the nutritional benefits of consumption of low valued commodities.

In the region low valued fish are transformed into many products, such as fermented fish, fish paste etc. These are traditional practices that have remained unchanged and unimproved over the years. As such there is need to investigate the efficacies of conversion of wild caught and cultured indigenous freshwater fish to major fishery products in Asian countries.

FAO and NACA will work together to follow up on some of the recommendations relevant to the Lower Mekong Basin Countries. Comprehensive documentation of the status of the associated market chains, nutritional value and health hazards pertaining to production and consumption of cultured low-value finfish will also be prepared in the form of a forthcoming FAO Fisheries Technical Paper.

The workshop also included a half-day field visit to the Greta Lake (Tonle Sap), when the participants were able to observe a variety of aquaculture and fishing activities, household processing of aquatic products which provided the opportunity to interact with small-scale aquaculture farmers.

Global Conference on Aquaculture 2010

The 28th Session of the Committee on Fisheries of the FAO, attended by 113 member governments and 84 inter-governmental and international non-governmental organizations, has endorsed the convening of a Global aquaculture Conference to be held 9-12 June 2010 in Bangkok, Thailand. The conference will be jointly organised by the FAO Department of Fisheries and Aquaculture, NACA and the Thai Department of Fisheries will host the conference. The suggestion to hold a Global aquaculture Conference follows a decision of the NACA Governing Council at its 19th meeting held in Kathmandu in March 2008. For more information email the Conference Secretariat at: aqua-conference2010@enaca.org, or download the first announcement brochure from:

http://library.enaca.org/AquaMillennium/plus10/millennium-plus-10-1.pdf

Extending information and technical services to aquaculture farmer groups in Aceh

The Aceh Aquaculture Communication Center (AACC) has been newly established by the Regional Centre for Brackishwater Aquaculture Development (BBAP) at Ujung Batee, Aceh Besar District of NAD with assistance from the ADB funded ETESP-fisheries project. The communication centre is a new resource to support the future development of aquaculture in Aceh, and will be one of the supporting structures for a network of Aquaculture Livelihood Service Centres (ALSC) providing a better interactive technical advisory service, such as disease diagnosis, information, and training services, for farmers. The centre has equipment to produce posters and brochures, as well as a disease diagnosis laboratory next door.

More Aquaculture Livelihood Service Centres are currently under development in Bireuen District and scheduled to be completed by the end of the month to provide various services to groups of aquaculture farmers in Aceh who will own and run the network of centres.

The communication centre is located at the BBAP at Ujung Batee, and five technical staff are working there. The centre has a growing network of collaborating agencies from Aceh, Indonesia, and other regional organizations to exchange information, news, and extension materials.

The centre is establishing an information system and fully interactive website called Jaringan Petambak Aceh (Network of Aquaculture Farmers in Aceh) that provides practical information and materials for aquaculture farmers, covering market information, extension materials, business directories and others developed based on the needs identified by participation of the farmers themselves.

ETESP-Fisheries will further assist BBAP for development of operational practices for the new communication centre, in cooperation with partners in ACIAR, FAO other agencies in Aceh and farmer stakeholder groups.

The AACC concept is new, but together with the ALSC is expected to continue to provide necessary information and technical services to aquaculture farmers in Aceh to maintain and expand their livelihoods in this economically important rural sector in Aceh.

The communication centre is supporting farmers to get back in business.

Giant Prawn 2011, Quingdao, China

Giant Prawn 2011, a landmark technical conference on the culture of freshwater prawns, will be held as an important component of the annual conference and exhibition of the World Aquaculture Society, World Aquaculture 2011, which will be held in Qingdao, China, 6-10 June 2011.

The predecessor of this event, Giant Prawn 1980, was a pioneer meeting organised by Michael New and held in Bangkok through the auspices of the Thai Department of Fisheries with support from FAO, IFS and the Rockefeller Foundation. That meeting was confined to the culture of the giant river prawn *Macrobrachium rosenbergii* and attracted 159 participants from 33 countries, plus about 200 Thai freshwater prawn farmers.

In 1980 the global production of farmed freshwater prawns was a mere 1,300 tonnes per year. Now, thirty years later, it exceeds 450,000 tonnes per year, with a farm-gate value exceeding US$ 1.8 billion.

Giant Prawn 2011 will encompass the rearing of several freshwater prawn species, including the giant river prawn (*M. rosenbergii*), the Oriental river prawn (*M. nipponense*), the monsoon river prawn (*M. malcolmsonii*) and the Amazon river prawn (*M. amazonicum*).

China is the largest producer of farmed freshwater prawns, with a total output of over 300,000 tonnes per year of giant river and oriental river prawns, and conducts significant research on the biology and rearing of these species. Qingdao is therefore an ideal location for this event. Several other Asian countries are also major producers, including India, Thailand, Bangladesh, Vietnam and Taiwan Province of China.

The programme for Giant Prawn 2011 is currently being developed by Michael New, with his many friends and colleagues working in this field. It is anticipated that, like its predecessor, Giant Prawn 2011 will be a single session event held over several days and will include review papers on important topics such as genetics, size management, health management, nutrition, hatchery and grow-out management and marketing, as well as submitted papers.

The meeting will therefore provide a unique opportunity for all those involved in freshwater prawn research and production to share knowledge and meet with their colleagues. It is also an opportunity for those interested in becoming involved in freshwater prawn farming to gain the latest information in this field.

Further details about Giant Prawn 2011 can be obtained from Michael New, OBE (email: new.macrobrachium@yahoo.co.uk).

New publications

Alien species in aquaculture and biodiversity: A paradox in food production

De Silva, S.S., Nguyen, T.T.T., Turchini, M., Amarasinghe, U.S. and Abery, N.W.

Abstract

Aquaculture is seen as an alternative to meeting the widening gap in global rising demand and decreasing supply for aquatic food products. Asia, the epicenter of the global aquaculture industry, accounts for over 90% of the global aquaculture production quantity and about 80% of the value. Asian aquaculture, as with global aquaculture, is dependent to a significant extent on alien species, as is the case for all the major food crops and husbanded terrestrial animals. However, voluntary and or accidental introduction of exotic aquatic species (alien species) is known to negatively impact local biodiversity. In this relatively young food production industry, mitigating the dependence on alien species, and thereby minimizing potential negative impacts on biodiversity, is an imperative for a sustainable future. In this context an attempt is made in this synthesis to understand such phenomena, especially with reference to Asian inland finfish, the mainstay of global aquaculture production. It is pointed out that there is potential for aquaculture, which is becoming an increasingly important food production process, not to follow the past path of terrestrial food crops and husbanded animals in regard to their negative influences on biodiversity.

Published in AMBIO 38(1):24-28. 2009.

Aquatic ecosystems and development: Comparative Asian perspectives

Schiemer, F., Simon, D., Amarasinghe, U.S. and Moreau, J. (eds.)

This book is the principal output of the EU-funded FISHSTRAT project on a holistic approach to sustainable reservoir and lacustrine fisheries in three tropical Asian countries. It explains the broad research context and the project's origin and rationale of the research The study linked three diverse disciplines, namely limnology, fisheries and socio-economic development. The importance of such holistic, catchment-oriented approaches to research and management is increasingly widely recognised.

The five water bodies studied were Minneriya, Udawalawe and Victoria reservoirs in Sri Lanka, Ubolratana reservoir in Thailand's Khon Kaen Province, and Lake Taal, a natural volcanic lake south of Manila on Luzon Island, the Philippines. They were selected in order to represent a wide range of productivities and trophic structures of fish communities, and also a variety of direct and indirect impacts from human activities in their respective catchment areas. This enabled us to understand better the impact of limited biological productivity upon commercial fish yields as well as the extent of any unexploited fish populations.

The volume provides a comprehensive overview of the principal research findings and policy conclusions, structured broadly in line with our objectives and the implications of our interdisciplinary and comparative methodology.

The remaining 22 chapters following this Introduction are divided into six sections, on the basis of coherence and progressively increasing degrees of interdisciplinary integration and comparative analysis.

Section A (Chapters 1-4) provides general descriptions of physical, hydrological and catchment characteristics of the water bodies in the three countries, as the foundation for the more detailed analysis that follows. The key conditions for understanding the limnological processes are set by the overall catchment characteristics, its human utilisation and the seasonality of the monsoonal climate.

Section B (Chapters 5-9,) examines comparative aspects of the aquatic ecosystems, focusing successively on phytoplankton; the regulation of phytoplankton primary production; microbial aspects of carbon dynamics and the detrital food chain; the effects of seasonality on zooplankton populations and status; and the production, biomass and productivity of copepods and cladocerans.

In Section C (Chapters 10-14) the focus shifts to fish ecology. The important themes covered include; the innovative use of hydro-acoustics for assessing fish stocks; feeding ecology of fish assemblages; ecomorphological correlates of diet; selective feeding of small zooplanktivorous pelagic fish species; and a modelling approach to daily feeding patterns and food consumption in certain fish populations.

Section D (Chapters 15-18) addresses fisheries and aquaculture, analysing capture fisheries; population dynamics of non-exploited and under-exploited fish species; population dynamics of commercially important species; and the status and significance of aquaculture. Chapter 18 also examines the socio-economics of aquaculture, thereby providing a useful bridge to Section E (Chapters 19-20) on socio-economics, which comprises detailed surveys of the social economy of fish and fishing in littoral communities, and of fish trading and marketing.

Finally, Section F (Chapters 21-23) attempts to bring together the principal findings and conclusions from each disciplinary area and part of the investigation, in order to offer a holistic analysis as the basis for more appropriate policy and management guidelines for the promotion of sustainable resource utilisation.

Chapter 23 assesses the overall contribution of the study, summarising and explaining the principal findings and conclusions, and exploring the implications for sustainable resource utilisation and management.

The book may be ordered from Margraf Publishers / Backhuys Publishers, visit www.margraf-publishers.eu or email inbox@margraf-publishers.com. ISBN: 978-3-8236-1530-9.

Macrobrachium: The culture of freshwater prawns

By New, M.B., Nair, C.M., Kutty, M.N., Salin, K.R. and Nandeesha, M.C.

The book is a compilation of information on the global farming of the freshwater prawn with special emphasis on the industry in India. In India, the annual production increased from 500 tonnes in 1996 to 43,000 tonnes in 2006. It is a large industry with nearly 6,200 tonnes exported from India alone, with a value of US$ 56 million.

Based on research and commercial experience over the past decade, the book outlines the developments in the industry in India. It provides technical information on the biology and culture of the prawn. The authors have planned the book as a reference book for industry, from academicians, policy makers to investors. It is also a manual in freshwater prawn farming which will be useful for the farmer.

The Book is modestly priced at US$ 25 + P & P overseas and Rs. 750 + P & P within India. The profit from the sales and the royalties received will be donated to Aquaculture without Frontiers (AwF), a global NGO working for the promotion of Aquaculture as a means of rural livelihood. Copies are available from Dr. C. Mohanakumaran Nair, Professor & Head (Aquaculture), Kerala Agricultural University, College of Fisheries, Kochi 682506. Kerala, India. Email: naircm@hotmail.com.

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