

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 of 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 founda-



Feeding red tilapia in riverine cages, Ang Thong Province.

tion 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.

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 2005¹. 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 factors². 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*	Udon 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 Khai	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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References

- DOF. 2007. Fisheries Statistics of Thailand 2005. Department of Fisheries, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.
- Belton, B. and D. C. Little. 2008. The Development of Aquaculture in Central Thailand: Domestic Demand versus Export-Led Production. *Journal of Agrarian Change*. 8 (1): 123-143.