Survey of Tilapia-Shrimp Polycultures in Thailand

Tenth Work Plan, New Aquaculture Systems/New Species Research 3A (10NSR3A)
Final Report

Yang Yi
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
School of Environment, Resources and Development
Asian Institute of Technology
Pathumthani, Thailand

Kevin Fitzsimmons
Department of Soil, Water and Environmental Science
University of Arizona
Tucson, Arizona, USA

Abstract

The survey on tilapia-shrimp polyculture was conducted in Thailand and Vietnam from March through June 2002. The survey conducted in Thailand was to assess the current status of farmers' practice of tilapia-shrimp polyculture, while the survey conducted in Vietnam was to find out why Vietnamese shrimp farmers do not grow tilapia in shrimp ponds. In twelve provinces of Thailand, 61 farmers who culture fish in their shrimp farms were selected and interviewed using a structured checklist and open-ended type of questionnaires. In the Mekong Delta of Vietnam, university researchers, local shrimp farmers association and local government fisheries staff, and shrimp farmers were interviewed.

Results showed that three versions of tilapia-shrimp polyculture—namely simultaneous, sequential, and crop rotation systems—are practiced by Thai shrimp farmers. Among all interviewed farmers, 42.6% use a simultaneous polyculture system, while percentages of farmers using sequential and crop rotation systems are 34.4 and 6.6%, respectively. The remaining 16.4% of farmers stock fish in reservoir ponds and use a monoculture system for shrimp. Among the farmers who adopt the simultaneous tilapia-shrimp polyculture system, 76.9% released tilapias directly into shrimp ponds, and 23.1% stocked tilapias in cages suspended in shrimp ponds. Tilapia-shrimp polyculture is practiced in a wide range of salinity levels from 0 to 30%. Tilapias used in the polyculture include red tilapia (Oreochromis spp.), Nile tilapia (O. niloticus), and Mozambique tilapia (*O. mossambicus*).

The survey revealed that shrimp production and economic returns from the two simultaneous polyculture systems and in sequential polyculture systems were higher than those in their respective shrimp monoculture systems practiced before. Also shrimp production and economic returns from these polyculture systems were higher than those in the crop rotation polyculture system and in the currently practiced monoculture system. Many farmers responded that tilapia-shrimp polyculture could improve water quality in shrimp ponds, reduce diseases, and reduce the use of chemicals. In the direct style of tilapia-shrimp polyculture, about 40% farmers believed tilapias compete for feed with shrimp, while the remaining 60% were not aware of such feed competition. The major reasons given by Vietnamese shrimp farmers for not growing tilapia in shrimp ponds are that tilapia would compete for the costly shrimp feeds, water quality in shrimp ponds was good enough and there was no need to use tilapia to improve water quality due to low shrimp stocking density, and added tilapia might bring dissolved oxygen down thus adversely affecting shrimp growth.

It can be concluded from the survey that polyculture of shrimp with tilapias may provide an alternative approach for shrimp farming, which could ultimately lead to a more sustainable shrimp industry. However, further research is needed on the merits for converting from shrimp monoculture to polyculture with tilapia.

Introduction

Shrimp ponds have been abandoned in many parts of the world due to diseases, poor management, and environmental degradation. Tilapia production, supplemented with low densities of shrimp, in abandoned shrimp ponds may provide an opportunity to develop a sustainable aquaculture system that will support local inhabitants who have not benefited from the shrimp boom in many parts of the world. Polyculture, or crop rotation of shrimp and tilapia, may be the modern equivalent to the Chinese polyculture of carp. Tilapia production in former shrimp ponds (with and without shrimp) has increased rapidly in many countries including Thailand, the Philippines, Honduras, Mexico, Peru, and the inland desert of Arizona, USA.

Farmers in several locations around the world appear to have demonstrated that tilapia and shrimp can in fact be grown together. There are several technical questions to be answered regarding optimal salinities, stocking densities, feeding rates, disease and parasite infestations, cost-benefits, and environmental impacts of tilapia-shrimp polyculture. These would be the first replicated trials and technical evaluation of tilapia-shrimp polyculture.

Shrimp aquaculture has been devastated in many countries due to a mix of disease outbreaks and decreasing yields. The progression of shrimp aquaculture has followed a familiar pattern throughout the tropics. Initially, farms are constructed in the most appropriate areas. These locations are characterized by good soils with proper pH, appropriate levels of clay, silt, and sand, proper elevation, good access to clean water, and convenient disposal of wastewaters to a location that keeps wastes from being cycled back into the farm. These farms, if managed well, tend to be very profitable. This early success leads others to imitate the process as best they can. This has led to a "gold rush" attitude where excessive numbers of farms are built, often in ecologically fragile areas, especially mangrove forests. From a practical point, mangrove forests, in general, are poor sites for shrimp farms. They do not have the proper soils, there is usually poor access to water and inadequate drainage due to low elevation, and they are especially susceptible to storm damage.

A related phenomenon is overstocking of an existing farm. After the initial success of a farm, the managers often assume they can increase yields and profits by stocking more shrimp and feeding more heavily. This may work for one or two crops, encouraging even more stocking. But inevitably the producer overshoots and a disease outbreak occurs because the animals have been overstocked and are stressed under the available environmental conditions in the pond.

In most cases the farm managers react by increasing water flow through the farm or adding mechanical aeration. These do in fact address the problem but also increase operating expenses and environmental impacts. Added to this situation is the fact that the ponds must be properly maintained and the pond soils managed between crops. Many farms do not properly maintain their infrastructure or their pond environments. When multiple farms in one area reach this stage, there tends to be an environmental overload. The effluent from one farm becomes the supply water for another. The receiving environment cannot process the nutrient rich effluents, leading to eutrophication, and diseases are spread by water transfer, birds, and other vectors. Excessive pumping of water can lead to saltwater intrusion and depletion of freshwater aquifers. Farms that had been wildly profitable with little management, suddenly require more investment and sophisticated management for lower levels of profit. Some farms make the investment to operate in a more sophisticated and sustainable manner, while many others just abandon the farm. In many countries the governmental oversight, environmental regulation, and protection have been inadequate to avoid this serious ecological damage.

A related problem has been one of land tenure. In many instances investment groups have come in and gained control of coastal lands and hired local inhabitants. These people are usually happy to have the employment and appreciate the infrastructure (roads and electrification) that often accompanies the farm. However, when these farms fail, the local inhabitants are often left with no jobs and environmental damage that impairs their ability to return to artisanal fishing or small-scale agriculture. Common environmental damages include salinization of soils, saltwater intrusion, loss of breeding areas for marine species, eutrophication, and changes in the water flow through estuaries.

One technique that has been tested to utilize abandoned shrimp ponds is to convert the pond to tilapia production. There have been several variations of tilapia production including rearing in seawater, brackish water, and fresh water. Some have attempted polyculture with shrimp and some are using a crop rotation of tilapia and shrimp (Fitzsimmons, 2001).

In nature tilapias are omnivores. Young tilapia graze on algal and bacteria films scraping most hard surfaces with tongue and teeth. As they grow they also become effective filter feeders of phytoplankton and predators of zooplankton. Larger tilapia are less effective filter feeders but begin to graze heavily on macrophytic algae and aquatic plants. In extensive farming situations, tilapia filter feed on algae, prey on zooplankton, and scrape films from any hard surfaces in the pond. In intensive farming, most nutrition is derived from pelleted feeds, although fish will continue to spend time scraping algal and bacterial films from all surfaces.

In nature, shrimp feed first on phytoplankton and then zooplankton during larval stages. As juveniles and adults, they are omnivores and detritivores. Their natural behavior is to search the bottom substrates for decaying plant and animal material. They also constantly pick up sand grains and pieces of organic matter and graze off the algae and bacteria, drop the grain or particle, and go onto the next item. In farmed settings shrimp feed on pellets and natural productivity in the pond. Research by Samocha et al. (1998) has demonstrated that shrimp can be reared in systems with little water exchange, taking advantage of the natural abilities of shrimp to thrive in conditions with high bacterial loading so long as dissolved oxygen levels and other water quality factors are maintained.

There are several variations of tilapia-shrimp polycultures—simultaneous, sequential, and crop rotation. In the simultaneous instance, the fish and shrimp are grown together in a pond or raceway; in the sequential case the water is moved from one growing unit to another; and the crop rotation alternates between tilapia and shrimp. There appear to be distinct advantages with each of these systems.

In a polyculture setting, tilapia and shrimp can utilize different niches. In extensive farming, tilapia can filter feed on phytoplankton and zooplankton in the upper water column. Shrimp spend most of the time in the pond bottom grazing on bacterial films on the substrate and on the detritus settling from above. This detrital matter consists of dying algae cells and fecal matter from the tilapia. In a more intensive farm receiving pelleted feeds, the tilapia monopolize the feed, especially if it is a floating feed. However, some feed particles always get to the bottom where the shrimp will consume it. More importantly, the fecal matter from the tilapia contributes to the detrital rain that supports the shrimp. Macrobrachium-tilapia polyculture reduces the yield of prawns compared to monoculture, but increases total yield of fish and prawns (Garcia-Perez et al., 2000). A similar effect may occur with brackishwater polyculture of tilapia and shrimp (Yap, 2001). Anggawa (1999) reported that yields of shrimp increased when tilapia were stocked into existing shrimp ponds. The suggested stocking rate was 20 to

Table 1. Study areas and distribution of interviewed farmers in Thailand.

Regions	Provinces	Number of Interviewed Farmers
Central area (inland, not connected to the sea)	Ayutthaya	1
	Nakhonpathom	2
	Ratchaburi	2
	Suphaburi	2
Central area (inland, connected to the sea)	Chachoeangsao	19
	Phatchaburi	4
	Prachinburi	5
	Samutprakarn	5
Eastern area (coastal)	Chonburi	3
Southern area (coastal)	Nakhon Si Thammarat	5
	Songkhla	3
	Suratthani	10
Total		**61**

Table 2. Percentages (%) of the status, gender, and age of farm operators (N = 61).

Gender/Age	Farm Operation by		Total
	Owner	Manager	
Men			
20-29 years old	1.6	1.6	3.2
30-39 years old	21.3	3.3	24.6
40-49 years old	8.2	0	8.2
50-59 years old	8.2	0	8.2
>60 year old	3.3	0	3.3
Unknown	21.3	13.1	34.4
Subtotal	63.9	18.0	81.9
Women			
20-29 years old	0	0	0
30-39 years old	3.3	0	3.3
40-49 years old	6.6	0	6.6
50-59 years old	6.6	0	6.6
>60 years old	1.6	0	1.6
Unknown	0	0	0
Subtotal	18.1	0	18.1
Total	**82.0**	**18.0**	**100**

25 g fish m^{-2}, and the fish size at stocking of 50 to 100 g. The use of all-male fish was needed to control reproduction. Fish were stocked when the shrimp biomass was at least 80 g m^{-2} (for 3 to 4 g shrimp) or 150 g m^{-2} (for 5 to 6 g shrimp). Tilapia harvest biomass was 40 to 50 g m^{-2}, and shrimp survival was 70%.

From the disease aspect, tilapia seem to provide advantages in several ways. Growers in Ecuador have reported that tilapia will consume dead or moribund shrimp in polyculture ponds. Cannibalism is one of the primary vectors for transmission of shrimp diseases. Tilapia, which do not appear to be susceptible or carriers of these viruses, disrupt cannibalism as a mode of transmission. Tilapia also consume small crustaceans in shrimp ponds. These crustaceans are of concern as potential vectors. Having tilapia directly in the ponds or alternating with shrimp in a crop rotation can be effective for reducing crustacean populations. Bacterial infections also may be impacted by polyculture. Vibrio and most other bacterial pathogens common in shrimp culture are gram negative while waters that have been used for fish culture tend to be predominated by gram positive bacteria. Using water from a fish culture pond seems to reduce the prevalence of luminous Vibrio bacterial infections in shrimp ponds (Yap, 2001). Growers in Asia and South America have provided anecdotal reports that shrimp production increases due to higher survival in some of these polyculture systems; however, carefully controlled and replicated trials are needed to better study these systems and confirm the results. There may also be physical factors that improve shrimp survival and growth in polyculture and crop rotations. Tilapia disturb bottom sediments to a greater degree than shrimp, both in foraging and nest building activities. This may be beneficial in several ways. Disturbing the bottom could improve oxidation of the substrate and interrupt life cycles of shrimp pathogens and parasites. It could also release nutrients into the water column that could improve algae blooms. However, it is also possible that these activities may be detrimental. Disturbing bottom sediments could negatively impact water quality by lowering dissolved oxygen (DO) levels, increasing turbidity from sediments, and reducing algae blooms, decrease the ability to remove fish and shrimp, and most certainly increase the need to repair pond bottoms between crops. This particular aspect would require close attention and careful experimentation to gain a clear understanding.

The purposes of this study were to:

1) Investigate which shrimp ponds have been abandoned; where, how many, what size, and what water source;
2) Identify the causes of abandonment and/or low production;
3) Identify which farms have been converted to tilapia culture and/or tilapia-shrimp polyculture;
4) Determine which species or strains of tilapia and shrimp are used;
5) Determine what salinities are used in the culture system;
6) Identify who are operating the ponds;
7) Determine the inputs and outputs of the system;
8) Determine whether farmers use fertilizers, pelleted feeds, and aerators;
9) Investigate what parasite problems have been encountered and what has been the most successful treatment;
10) Investigate which diseases have been encountered;
11) Assess the economic benefits of polyculture;
12) Assess whether these tilapia and shrimp will be marketable as "green" products; and
13) Determine what additional follow-up information the farmers would like to have.

METHODS AND MATERIALS

The survey was conducted in Thailand and Vietnam during March through June 2002 to investigate the current practice of tilapia-shrimp polyculture. In Thailand, the survey was done in four major shrimp production areas, namely the central inland area, central estuarine area, eastern coastal area, and southern coastal area, covering 12 provinces (Table 1). In the central inland area, some farmers practice shrimp culture in low salinity water diluted from hypersaline water, while the water sources for shrimp farms come from the tidal, river, and estuarinal waters in the central estuarine provinces and from the tidal seawater in the eastern and southern areas. In Vietnam, the field survey was conducted in shrimp farming areas of the Mekong Delta.

For the study in Thailand, the first step of the survey was to identify the farmers who have already tried tilapia-shrimp polyculture by contacting farmers' associations, community leaders, and private sectors. The second step was to contact the identified farmers through phone calls to gather preliminary information regarding their culture systems to ascertain whether they were suitable for the purposes of the study and their availability. The third step was to interview the selected 61 farmers using a structured checklist and open-ended type of questionnaires. The questionnaires consisted of farmers' backgrounds, tilapia-shrimp polyculture systems, pond and water management, feed and feeding management, parasite

Table 3. Land ownership and use in farms (N = 61).

	Own	Rent	Partially own*
Land ownership (%)	63.9	24.6	11.5
Farm size (ha)	30.7±9.9	13.2±4.0	55.7±26.3
Use of land (%)			
Shrimp ponds	15.9	25.1	23.9
Fish ponds	13.6	11.3	17.9
Water storage ponds	16.5	30.5	24.2
Effluent treatment ponds	19.5	15.8	26.3
Others	34.5	17.3	7.7
Mean pond size (ha)			
Shrimp ponds	0.6±0.0	0.6±0.1	0.5±0.1
Fish ponds	0.7±0.2	1.3±0.7	2.9±1.5
Water storage ponds	1.4±0.5	1.5±0.4	9.1±6.9
Effluent treatment ponds	5.4±2.3	1.1±0.0	10.1±5.8

*Partially owned land is a combination of owning and renting.

Table 4. Causes of low or collapsed shrimp production that led to shrimp pond abandonment (N = 61).

Causes of low/collapsed production	Percent (%)
Disease outbreak	45.6
Low quality of shrimp seeds	15.8
Weather change	7.0
Pollution of water and soil	5.3
Low quality of shrimp and pollution of water and soil	5.3
Disease outbreak and pollution of water and soil	3.5
Disease outbreak and low price of shrimp	1.8
Disease outbreak and low quality of shrimp	1.8
Disease outbreak and poor management	1.8
Disease outbreak, poor management and low quality of shrimp seeds	1.8
Disease outbreak, low quality of shrimp seeds and pollution of water and soil	1.8
Weather change and low quality of shrimp seeds	1.8
Weather change, low quality of shrimp and pollution of water and soil	1.8
High stocking density	1.8
Lack of knowledge and experience on culture	1.8
Low salinity and algae bloom	1.8
Total	**100**

Table 5. Considerations for farmers to use tilapia-shrimp polyculture (N = 61).

Considerations	Percent (%)
Improve water quality	49.5
Reduce nutrients in effluent	22.6
Reduce disease outbreak	11.8
Culture tilapia as by-product from shrimp culture	4.3
Use tilapia as an indicator of water quality	2.2
Culture tilapia to cover investment loss due to low shrimp prices	2.2
Reduce gas production at pond bottom	1.1
Increase natural food and provide good species of plankton	1.1
Increase natural food and provide good species of plankton/reduce investment/cover investment loss due to low shrimp prices	1.1
Control algal bloom in shrimp ponds due to culture in low salinity	1.1
Tilapia can help to reduce parasites such as *Zootamnium* sp	1.1
Tilapia can control plankton	1.1
Tilapia can consume wastes in shrimp ponds	1.1
Total	**100**

and disease problems, harvest and production, economic returns, and other information.
For the study in Vietnam, a preliminary survey was conducted through contacting Vietnamese researchers involved in shrimp research, and it was found that there was no tilapia grown in shrimp ponds in Vietnam. Thus, a field trip was conducted in the Mekong delta to interview researchers at Can Tho University, local shrimp farmers' associations, local government fisheries staff, and shrimp farmers to find out why Vietnamese shrimp farmers do not practice tilapia-shrimp polyculture.

MS Excel® was used to store all the data and to generate tabular and graphical representation of different types of data.
A partial budget analysis was conducted to compare economic benefits of different tilapia-shrimp polyculture systems.

RESULTS

Farmers' Backgrounds

Thai shrimp farms are mainly operated by farm owners, which accounted for 82% of the interviewed farmers, and only 18% of farms are run by professional managers (Table 2). Men dominate the Thai shrimp culture industry with men making up 81.9% compared to 18.1% for women (Table 2). All professional managers are men, and no women are hired as professional managers (Table 2). Among the interviewed farmers, 27.9% have run the farms for 1 to 5 yr, 44.3% for 6 to 10 yr, 26.2% for 11 to 15 yr, and only 1.6% for more than 16 yr.

As for land ownership, 63.9% of interviewed farmers own the farm land, 24.6% rent farm land from other peoples, and 11.5% own a part of the farm land and rent the rest from other people (Table 3). Farm size is largest for the farmers who both own and rent the land, intermediate for those who own the land, and lowest for those who only rent the land (Table 3). The average land rental for the small ponds (3 to 4 ha in size) is Baht (Bt) 14,720 ± 5,764 ha^{-1} yr^{-1}, while that for the large ponds (> 10 ha in size) is Bt 20,313 ± 8,885 ha^{-1} yr^{-1}.

In shrimp farms the land is delineated into water storage ponds, shrimp ponds, fish ponds, effluent treatment ponds, and other (house/building/garden). Compared to the farmers who either fully or partially own the land, farmers who rent land use the largest percentage of land for shrimp ponds and water storage ponds, and smaller percentages for fish ponds and effluent ponds (Table 3).

Causes Leading to Abandonment of Shrimp Ponds

Among the interviewed farmers, 93.4% have experienced low or collapsed shrimp production, and only 6.6% never have such problems. Of the farmers who experienced low or collapsed shrimp production almost half (45.6%) attributed such problems to disease outbreak whereas low quality of shrimp seeds (15.8%) was also a significant factor (Table 4).

Many farmers have temporarily abandoned their shrimp ponds by either leaving the ponds empty or shifting to other activities such as fish culture. Based on the opinions of all interviewed farmers, the causes leading to abandonment of shrimp ponds are disease outbreaks (57.4%), low production (26.2%), losing money (high investment cost and low shrimp price) (16.4%), low quality of shrimp seeds (16.4%), external pollution (13.1%), acidic soil (4.9%), poor management (6.6%), and high culture risk (1.6%).

Tilapia-Shrimp Polyculture

Approximately 26.2% of the interviewed farmers have been operating tilapia-shrimp polyculture for less than 1 yr, 18.0% for 1 to 2 yr, 14.8% for 2 to 3 yr, 9.8% for 3 to 4 yr, and 31.2% for more than 4 yr. Most farmers attributed the reasons for tilapia-shrimp polyculture to improving water quality (75.4%), reducing nutrients in effluents (34.4%), and reducing disease outbreak (18.0%) (Table 5).

Three major tilapia-shrimp polyculture systems, namely simultaneous, sequential, and crop rotation, were found during the farm survey in Thailand. Among all interviewed farmers, 42.6% use a simultaneous polyculture system, while percentages of farmers using sequential and crop rotation systems are 34.4 and 6.6%, respectively, and the remaining 16.4% stock fish in reservoir ponds and use a monoculture system for shrimp.

Table 6. Stocking and harvesting data in the simultaneous tilapia-shrimp polyculture with tilapia stocked directly in shrimp ponds.

Case	Salinity (ppt)	Shrimp stocking		Tilapia stocking				Shrimp production (kg/ha/crop)	Shrimp size (g/pcs)	Fish production (kg/ha/crop)	Fish size (g)	Culture period (months)
		Density (pcs/m²)	Size (PL)	Species	Density (fish/m²)	Size (cm)	Timing (DASS)*					
1		31.0	14	Nile	0.09	1	28	3,125	20.0	228	250	4
2	0-5 (20%)	31.3	15	Nile	0.02	1	28	7,793	25.0	1,289	n.a.	4
3		31.3	15	Red	0.02	3	28	3,646	16.7	156	n.a.	4
4		43.6	17	Nile	1.25	4	56	5,000	15.4	3,125	333	4
5		36.1	16	Nile	0.03	7.5	84	7,813	25.0	60	200	3.5
6	6-10 (20%)	46.9	18	Red	0.02	5	56	4,688	18.5	n.a.	n.a.	3.3
7		50.0	15	Nile	1.56	1	28	4,688	22.2	1,172	200	4
8		46.6	15	Nile+Mozambique	n.a.	n.a.	56	5,000	19.6	n.a.	n.a.	4
9		10.4	11	Red+Milkfish	3.1	2.5	0	2,813	35.7	13,203	500	4
10		37.5	15	Red	0.02	2	56	5,000	n.a.	n.a.	n.a.	4
11		34.4	15	Red	0.02	2	56	5,625	n.a.	n.a.	n.a.	4
12	11-20 (35%)	62.5	16	Red	0.03	n.a.	28	7,500	18.2	n.a.	n.a.	5
13		45.0	16	Nile+Mozambique	n.a.	10	45	5,000	25.0	n.a.	n.a.	4
14		35.0	15	Nile+Mozambique	0.5	10	56	6,250	25.0	n.a.	n.a.	3
15		47.0	12	Red	0.01	6.3	56	4,735	16.7	75.8	800	3.5
16		62.5	15	Red	0.03	1	45	6,094	18.9	n.a.	n.a.	4
17		37.5	15	Red	0.01	2.5	20	6,875	26.3	125	500	4
18	21-30 (25%)	42.5	15	Nile+Mozambique	0.01	10	42	5,938	23.3	n.a.	n.a.	4
19		45.0	15	Red	0.01	17	56	6,250	n.a.	n.a.	1,000	4
20		37.5	17	Red+Mozambique	0.01	15	28	3,688	20.8	n.a.	n.a.	3.5
Mean		40.7±2.6	15±0.3		0.37±0.19	5.6±1.2	43±4.2	5,376±326	22±1.2	2,159±1,420	473±104	3.9±0.1

*DASS – days after stocking shrimp.
Red = red tilapia; Nile = Nile tilapia; Mozambique = Mozambique tilapia.

Table 7. Stocking and harvesting data in the simultaneous tilapia-shrimp polyculture with caged tilapia in shrimp ponds.

Case	Salinity (ppt)	Pond size (ha/pond)	Cage (m²/pond)	Shrimp stocking		Tilapia stocking				Shrimp production (kg/ha/crop)	Shrimp size (g/pcs)	Fish production (kg/ha/crop)	Fish size (g)	Culture period (months)
				Density (pcs/m²)	Size (PL)	Species	Density (fish/m²)	Size (cm)	Timing (DASS)*					
1	0-5 (33%)	0.64	4 x 25	47.0	15	Red	40.0	12	0	5,078	16.7	1,094	752	4
2		0.96	105	5.2	15	Red+Nil e	23.8	n.a.	0	3,438	n.a.	208	833	4
3	6-10 (17%)	0.64	100	62.0	20	Nile	10	n.a.	0	6,250	16.7	3,906	333	4
4	11-20 (17%)	0.40	105	6.3	12	Red	28.6	1	0	>2,500	n.a.	2,000	800	4
5	21-30 (33%)	0.40	2.3	37.5	15	Red	6.7	7.5	28	5,000	21.7	38	1,000	3.5
6		0.56	15	45.0	15	Red	2.0	15.0	28			On-going		
Mean		0.60±0.01	71±20	33.8±9.5	15±1		18.5±6.0	9±3	9±6	4,942±516	18.4±1.7	1,449±707	744±111	3.9±0.1

*DASS – days after stocking shrimp.
Red = red tilapia; Nile = Nile tilapia.

Table 8. Stocking and harvesting data in the sequential tilapia-shrimp polyculture.

Case	Shrimp pond					Fish pond						Water exchange (times/shrimp cycle)	
	Salinity (ppt)	Area (ha)	Density (pcs/m²)	Cycle (mo)	Production (kg/ha/crop)	Salinity (ppt)	Area (ha)	Species	Density (fish/m²)	Cycle (mo)	Production (kg/ha/crop)	Shrimp to fish	Fish to shrimp
1		0.48	43.8	3.8	5,625	0-5	0.48	NT	2.19	9	8,571	1	8
2		1.2	33.3	3.8	5,625	0-5	1.20	NT,SB,RO,CC,MR	4.7	12	13,461	1	8
3		2.08	62.5	4	5,625	0-5	0.32	NT	3.13	12	n.a.	n.a.	n.a.
4		1.6	46.9	3.8	2,917	0-5	4.8	NT,SB,RO,CC,MR	1.04	8	3,750	76	76
5		0.96	46.9	4.3	n.a.	0-5	0.96	NT,RT,SB,RO,CF	n.a.	n.a.	n.a.	n.a.	n.a.
6		0.4	46.9	4	4,688	0-5	0.16	NT,CF	0.06	4	n.a.	16	16
7	0-5 (62%)	2.4	31.3	4	3,750	0-5	1.2	NT,SG	n.a.	12	n.a.	n.a.	12
8		1.68	14.3	3.5	3,571	0-5	3.2	RT	2.34	12	6,250	n.a.	n.a.
9		3.84	31.3	5	4,375	0-5	0.96	RT	0.06	7	3,125	n.a.	n.a.
10		0.34	34.4	4	5,938	0-5	0.34	RT	0.63	6	n.a.	15	15
11		3.84	31.3	4	3,646	0-5	9.6	NT,SB,RO,CC,MR	3.13	10	5,208	15	15
12		1.6	62.5	4	5,313	0-5	1.6	NT,SB,SH,MR	n.a.	n.a.	n.a.	n.a.	75
13		0.72	n.a.	3.5	8,125	0-5	0.16	RT	n.a.	5	n.a.	n.a.	5
14		2.4	25.0	4	5,000	0-5	1.92	RT	3.1	4	n.a.	n.a.	n.a.
15	6-10 (19%)	0.72	25.0	3.8	1,458	0-5	1.2	NT	n.a.	8.5	n.a.	8	8
16		4.8	62.5	3.3	4,063	0-5	0.48	NT,RT	0.63	7.5	7,500	10	10
17		0.96	62.5	4	5,924	6-10	0.32	NT,CF,SG	n.a.	12	n.a.	n.a.	1
18		2.24	34.4	3	6,250	0-5	2.72	NT,CF	1.25	12	n.a.	n.a.	4
19	11-20 (19%)	0.96	31.3	3.5	2,188	0-5	1.60	NT,RT,SE,RO	n.a.	10	3,125	5	11
20		1.76	43.8	3.8	2,188	0-5	0.80	RT	0.19	n.a.	n.a.	7	7
21		4.8	46.9	4.3	4,375	6-10	2.72	NT	0.77	3	313	9	9
Mean		1.9± 0.3	40.8± 3.1	3.9± 0.1	4,532± 362		1.7± 0.5		1.66± 0.39	8.6± 0.7	5,700± 1,282	15±6	18±6

Note: NT = Nile tilapia; RT = Red tilapia; SB = Silver barb; SE = Seabass; CF = Hybrid catfish; CC = Chinese carps; RO = rohu; SH = Snakehead; MI = mrigal; SG = Snakeskin gourami.

Table 9. Stocking and harvesting data in the crop rotation tilapia-shrimp polyculture.

Case	Shrimp pond					Fish pond					
	Salinity (ppt)	Area (ha)	Density (pcs/m^2)	Cycle (mo)	Production (kg/ha/crop)	Salinity (ppt)	Area (ha)	Species	Density (fish/m^2)	Cycle (mo)	Production (kg/ha/crop)
1	0-5 (25%)	0.85	29.5	4	2,621	0-5	4.16	NT,SE,SB,RO,JA	n.a	8.5	4,128*
2	6-10 (50%)	0.53	46.9	4	3,314	0-5	1.6	NT,SE	9	18	4,735
3		0.26	62.5	4	2,813	0-5	0.8	RT,CF,SB,SE	2	11	n.a.
4	10-20 (25%)	2	50.0	4	4,688	0-5	n.a.	NT	1	4.5	2,813*
Mean		0.91±0.38	47.2±6.8	4±0	3,359±466		2.19±1.01		4.0±2.5	11±3	3,892±567

Note: NT = Nile tilapia; RT = Red tilapia; SB = Silver barb; SE = Seabass; CF = Hybrid catfish; RO = rohu; JA = Jalamed.
* supplemental feeds were given to fish.

Table 10. Comparison of shrimp production (kg/ha/crop) between before and after using polyculture, and between monoculture and polyculture.

Current culture systems	Before using polyculture (monculture)	After using polyculture (polyculture)
Simultaneous system		
Direct polyculture	4,169±733 (n=8)	5,376±326 (n=20)
Cage-cum-pond	4,167±1,667 (n=2)	4,942±516 (n=4)
Sequential system	3,648±890 (n=5)	4,532±362 (n=20)
Crop rotation system	----	3,359±466 (n=4)
Monoculture	3,524±331 (n=10)	

Simultaneous Polyculture System

Two types of simultaneous polyculture were observed. Among the farmers who adopt this system, 76.9% released tilapias directly into shrimp ponds, and 23.1% stocked tilapias in cages suspended in shrimp ponds. These two types are practiced in all ranges of salinity between 0 and 30% (Tables 6 and 7). In this polyculture system, all farmers culture Penaeus monodon, and 8.3% culture both Penaeus monodon and Penaeus vanamei, while three tilapia strains are cultured, namely Nile tilapia (Oreochromis niloticus), Mossambique tilapia (O. mossambicus), and red tilapia (Oreochromis spp.) (Tables 6 and 7).

In direct polyculture, shrimps were stocked at high densities (average of 40.7 pieces m^{-2}) ranging from 31.0 to 62.5 pieces m^{-2}, and tilapias were stocked at low densities (average of 0.37 fish m^{-2}) at least 20 d after stocking shrimp (Table 6). However, in most cases, stocking densities of tilapias were less than 0.10 fish m^{-2}. In one case (9), shrimps were stocked at 10.4 pieces m^{-2}, while red tilapia and milkfish (Chanos chanos) were stocked at a density of 3.1 fish m^{-2}, resulting in very high fish production of more than 13 t ha^{-1} in four months. From Table 6, it is difficult to assess the role of tilapia in shrimp ponds due to controversial results from different farmers; however, it can be seen that it is better to stock large size tilapia at the later part of the culture cycle. In this system, a very important issue is whether tilapias compete for expensive shrimp feeds with shrimps. Less than half of the farmers (40%) observed such feed competition, while 60% were not aware of this feed competition.

In the cage-cum-pond polyculture system, four 25-m^2 cages were placed in different locations of a shrimp pond of 0.64 ha in surface area in case 1, while only 1 cage ranging from 2.3 to 105 m^2 was suspended in one pond with surface area between 0.40 and 0.96 ha (Table 7). In four out of six cages, tilapias and shrimps were stocked at the same time, while tilapias were stocked 28 d after stocking shrimps in the other two cases. The stocking densities of both shrimps and tilapias varied largely, ranging from 5.2 to 47.0 pieces m^{-2} and from 2.0 to 40.0 fish m^{-2}, respectively. The highest production of both shrimp and tilapia was achieved in a 0.64-ha pond with shrimp stocked at 62.0 pieces m^{-2} and Nile tilapia at 10 fish m^{-2} in a 100-m^2 cage at 6 to 10% salinity (Table 7).

Sequential Culture System

In this system, all cultured shrimps were P. monodon, and shrimps were stocked at different densities ranging from 14.3 to 62.5 pieces m^{-2}, giving largely varied production from 1,458 to 8,125 kg ha^{-1} per crop (Table 8). In fish ponds, tilapia species (Nile tilapia and red tilapia) were in polyculture with several other species, including hybrid catfish (Clarias macrocephalus Í C. gariepinus), snakeskin gourami (Trichogaster pectoralis), rohu (Labeo rohita), sea bass (Lates calcarifer), silver barb (Puntius gonionotus), snakehead (Channa striata), Chinese carps, and mrigal (Cirrhinus cirrhosus) (Table 8). The highest fish production was 13,461 kg ha^{-1} in a one-year cycle with supplemental feeds.

Salinity in shrimp ponds ranged from 0 to 20%, while salinity was 0 to 5% in most fish ponds (Table 8). Nutrient-rich water in shrimp ponds was pumped into fish ponds for culturing fish. After treated by fish, water in fish ponds was pumped back to shrimp ponds to compensate for the water loss due to evaporation and seepage. The frequency of water exchange between shrimp and fish ponds ranged from 1 to 76 times per shrimp crop (Table 8).

Crop Rotation Culture System

Four interviewed farmers (6.6%) have practiced the crop rotation style of tilapia-shrimp polyculture. The average pond areas for shrimp and fish culture were 0.91 and 2.19 ha per farm, respectively (Table 9). All farmers culture P. monodon and tilapias (50% for red tilapia and 50% for Nile tilapia). One farmer cultures Nile tilapia in the monoculture system, while the other farmers polyculture Nile tilapia or red tilapia with several other fish species, including silver barb, sea bass, rohu, hybrid catfish, and jalamed (Table 9). Average stocking densities of shrimp and fish were 47.2 pieces m^{-2} and 4.0 fish m^{-2}, respectively. Average production of shrimp and fish was 3,359 and 3,892 kg ha^{-1} per crop, respectively (Table 9).

Comparison of Shrimp Production between Polyculture and

Monoculture Systems

Shrimp production has increased after using simultaneous and sequential tilapia-shrimp polyculture systems, compared to the production from the previous monoculture system. The production from both the simultaneous and sequential tilapia-shrimp polyculture systems was also higher than that from the current monoculture system. For the crop rotation system, data of the previous monoculture system are not available, thus no comparison could be done. However, the shrimp production from the crop rotation system is similar to that from the current monoculture system. The highest shrimp production was achieved in the direct polyculture system, intermediate in the cage-cum-pond system and sequential system, and lowest in the crop rotation system (Table 10). The highest increase of shrimp production is 29.0% in the direct polyculture system, followed by 24.2% in the sequential system and 18.6% in the cage-cum-pond system. It is surprising that feed conversion ratio (FCR) is low in the two simultaneous systems and sequential systems—that is, 1.49 in the direct polyculture, 1.92 in the cage-cum-pond polyculture, and 1.32 in the sequential system—compared to 2.04 in the crop rotation system and 2.40 in monoculture.

Water and Pond Management

Sources of Saline Water and Water Treatment

Nearly half of the interviewed farmers (42.62%) buy hypersaline water and dilute in fresh water. This is the normal practice in inland shrimp farms in Thailand, and only 3.28% farmers dissolve salt in fresh water for shrimp culture. Other farmers directly pump saltwater from estuary or tidal river (34.43%) or from the sea (18.03%), and only 1.64% farmers pump saltwater from the established irrigation canal by the Thai Department of Fisheries.

Some farmers (34.4%) treat the water in reservoir ponds using chemicals, and the remaining 65.6% farmers do not use any chemicals to treat the water. The commonly used chemicals are synterex (29.0%), chlorine (25.0%), iodine (16.7%), potassium permanganate (12.4%), lime (8.3%), formalin (4.2%), and probiotic (4.2%).

Farmers usually treat pond water using different chemicals including chlorine (156.4 kg ha^{-1}), probiotic (216.7 kg ha^{-1}), cyanide (1,047.2 kg ha^{-1}), benzalkonium chloride (BKC) (463.1 kg ha^{-1}), potassium permanganate (6.3 kg ha^{-1}), zeolite (137.5 kg ha^{-1}), synterex (12.5 kg ha^{-1}), iodine (6.3 kg ha^{-1}), kokowoaf (6.3 kg ha^{-1}), and dolomites (312.5 kg ha^{-1}) prior to stocking shrimp. When farmers believe that water quality decreases or disease outbreak in shrimp ponds occur during the culture period, they apply different types of chemicals including lime (95.6 kg ha^{-1} per time), disinfectant (5.2 kg ha^{-1} per time), antibiotic (31.3 g kg^{-1} feed per time), probiotic (48.8 kg ha^{-1} per time), teaseed cake powder (20.0 kg ha^{-1} per time), zeolite (195.3 kg ha^{-1} per time), chlorine (1.5 kg ha^{-1} per time), iodine (2.1 kg ha^{-1} per time), and formalin (25.0 kg ha^{-1} per time). About 44% farmers have reduced the usage of chemicals after adopting the tilapia-shrimp polyculture system, while about 56% farmers said there is no change in the usage of chemicals compared to their previous monoculture system.

Water exchange is a common practice in shrimp culture. Seven reasons for water exchange were given by the interviewed farmers:

1) Improve water quality (38.2%);
2) Improve water quality and stimulate shrimp to eat and molt (18.2%);
3) Stimulate shrimp to eat and molt (10.9%);
4) Maintain water level (10.9%);
5) Improve water quality and maintain water level (9.1%);
6) Maintain water level and stimulate shrimp to eat and molt (1.8%); and
7) Take out sediments, mud, and feces from the pond (7.3%).

Only 3.6% farmers do not exchange water because they use the close-culture system. The average frequency of exchange water is every 17 d, and the average amount of water exchanged is 13.2 cm each time. About 28% farmer apply lime/probiotic at 307.6 kg ha^{-1} per time during exchange water.

During harvest, farmers discharge water from shrimp ponds into fish/tilapia ponds (37.5%), drainage canal (37.5%), sedimentation ponds (19.4%), ricefields (1.4%), and wetland (1.4%).

Aerators

Aerators are commonly set up in shrimp ponds. All interviewed farmers use aerators in shrimp ponds. Four types of aerators were observed during the farm visits: paddle wheels (81.3%), pipe-style diffusers (14.7%), air jet (2.7%), and plate-style diffusers (1.3%).

Pond Preparation

Different types of soil have been found in the visited shrimp farms. They are clay soil (73.8%), silt/clay soil (6.6%), silt/sand clay soil (6.6%), clay/loam soil (4.9%), silt/clay loam (4.9%), sand clay soil (1.6%), and loam soil (1.6%).

There are several methods to deal with pond sediments. The first one is to dry ponds until cracking and remove top-layer mud mechanically (54% farmers); the second is to flash bottom slurry out right after harvesting shrimps (29%); and the third is to dry ponds and then till/plow bottom mud. Pond bottom mud is usually used to repair pond dikes. Prior to filling ponds, lime and teaseed cake powder are applied at 1,978.3 kg ha^{-1} and 108.6 kg ha^{-1}, respectively.

Shrimp Stocking and Sampling

Farmers stock shrimps 17 ± 1 d after filling water to ponds. About 55.7% of farmers directly release shrimp PL to ponds, while 44.3% of farmers nurse shrimp PL for 7 ± 1 days in hapas setup in shrimp ponds prior to releasing to the open pond water.

During the culture period, most farmers (93.3%) sample shrimps regularly to estimate growth and survival, and the remaining 6.7% do not sample shrimps during the entire culture period. Sampling methods used by farmers are: cast net (58.9%), feeding trays (23.2%), and both (17.9%).

Fertilization, Feed, and Feeding

Table 11. Partial budget analysis to compare increased profit from shrimp ponds alone between direct and currently used cage-cum-pond style of simultaneous tilapia-shrimp polyculture, sequential tilapia-shrimp polyculture and crop rotation tilapia-shrimp polyculture and their respective previous monoculture (unit: US$/ha/crop).

Item	Farmers Using Direct Polyculture		Farmers Using Cage-Cum-Pond Polyculture		Farmers Using Sequential Polyculture	
	Previous Monoculture (n=8)	Current Polyculture (n=18)	Previous Monoculture (n=2)	Current Polyculture (n=4)	Previous Monoculture (n=5)	Current Polyculture (n=18)
Income from shrimp	19,553	25,213	19,543	23,178	17,109	21,255
Income from fish	----	1,209	----	2,768	----	----
Added income (A)	----	6,869	----	6,403	----	4,146
Cost for feed	4,597	6,311	5,920	7,024	3,563	4,429
Cost for fish seed	----	104	----	112	----	----
Added cost (B)	----	1,818	----	1,216	----	866
Increased profit (A-B)	----	5,051	----	5,187	----	3,280

Table 12. Partial budget analysis to compare increased profit from shrimp ponds alone between different tilapia-shrimp polyculture systems and monoculture system found in the current survey (unit: US$/ha/crop).

Item	US$ ha^{-1} per crop				
	Current Monoculture (n=4)	Direct Polyculture (n=18)	Cage-cum-pond Polyculture (n=4)	Sequential Polyculture (n=18)	Crop rotation Polyculture (n=3)
Income from shrimp	16,523	25,213	23,178	21,255	15,754
Income from fish	----	1,209	2,768	----	----
Added income (A)	----	9,899	9,423	4,732	-769
Cost for feed	6,270	6,311	7,024	4,429	5,048
Cost for shrimp seed	1,632	1,628	1,352	1,632	1,888
Cost for fish seed	----	104	112	----	----
Added cost (B)	----	141	586	-1,841	-966
Increased profit (A-B)	----	9,758	8,837	6,573	197

Approximately 79% of farmers fertilize ponds prior to stocking shrimps, while the remainder (21.3%) do not apply fertilizers. The reasons for not fertilizing ponds are: fertilizers make phytoplankton bloom rapidly (22.2%); there is sufficient nutrients in wastes accumulated in pond bottom (11.1%); pond soil is good (11.1%); water is very green (11.1%); using water from fish ponds (11.1%); never use fertilizers (11.1%); shrimp feeds can produce natural food (green water) (11.1%); and do not want to increase nitrogen in the shrimp pond (11.1%).

Two types of feed used for shrimps are fresh feed and pelleted feed. About 86.6% of farmers use dry pelleted feed only; 1.7% use fresh feed only; and 11.7% use both. The types of fresh feeds include trash fish, Moina, fish meal, and egg, which are used alone or in different combinations.

During nursing in hapas, shrimps are fed daily at 9 ± 2 kg per million shrimp larvae. During the first 2 to 3 weeks of culture, shrimp are fed four times daily with pelleted feed at an average rate of 1.3 ± 0.1 kg per 100,000 shrimps.

During the rest of culture the period, farmers use feeding trays to adjust daily feed ration. Farmers' practices are as follow:

- If the remaining feed in feeding trays is more than 50%:
  - a) reduce feed amount (10.5% of farmers);
  - b) stop feeding for one day (2.6%);
  - c) stop feeding for one time and continue to feed shrimps at the same rate (5.3%);
  - d) stop feeding for one time and decrease feed amount by 5 to 10% (5.3% farmers);
  - e) stop feeding for one time and decrease feed amount by 10 to 20% (23.7%);
  - f) stop feeding for one time and decrease feed amount by 20 to 30% (15.8%); and
  - g) stop feeding for one time and decrease feed amount by more than 30% (36.8%).
- If the remaining feed in feeding trays is about 30%:
  - a) reduce feed amount by 5% (38.5% of farmers);
  - b) reduce feed amount by 10 to 20% (53.8%); and
  - c) reduce feed amount by more than 20% (7.7%).
- If the remaining feed in feeding trays is about 10%:
  - a) not adjust feed amount (50% of farmers);
  - b) reduce feed amount by 5% (21.4%);
  - c) reduce feed amount by 20% (21.5%); and
  - d) increase feed amount by 20% (7.1%).

Other factors considered in adjusting feed rations are: water color (26.9% of farmers), molt cycle (26.9%), high temperature (17.9%), low dissolved oxygen (14.9%), disease (7.5%), and water pH (6.0%).

The feeding schemes between daytime and nighttime are 1:1 (1.8% of farmers), 2:1 (1.8%), 2:2 (10.5%), 3:0 (1.8%), 3:1 (33.3%), 3:2 (43.9%), 4:1 (3.5%), 4:2 (1.8%), and 5:2 (1.8%).

During the entire culture period, average feed inputs to shrimp ponds are 8,528 ± 533 kg ha^{-1} per crop (n = 18) in direct polyculture and 9,492 ± 1,095 kg ha^{-1} per crop (n = 4) in the cage-cum-pond culture of the simultaneous system; 5,990 ± 549 kg ha^{-1} per crop (n = 18) in the sequential system; 6,821 ± 514 kg ha^{-1} per crop (n = 3) in the crop rotation system; and 8,473 ± 501 kg ha^{-1} per crop (n = 4) in the monoculture system.

Diseases

Table 13. Sources of information on shrimp culture and further information needs of the Thai shrimp farmers.

Item	Percentage of Farmers (%)
Sources of information	
Salesmen from commercial companies	27.5
Neighbors	21.7
Magazines	18.8
Other farmers' experiences	17.4
TV programs	5.8
Seminars and training workshops	2.9
Radio programs	1.4
Bosses	1.4
DOF (Department of fishery)	1.4
Both salesmen from commercial companies and farmers' experiences	1.4
Further information needs	
Shrimp marketing	47.1
Culture techniques	40.0
Shrimp, feed, sediment, and water management	8.6
Sources of good quality of shrimp seed	1.4
Shrimp research	1.4
Services of shrimp health	1.4

Shrimp farmers have experienced serious problems from the disease outbreak for many years. The most serious diseases of shrimp are yellowhead and whitespot. About 43% of farmers who adopt the tilapia-shrimp polyculture system said that the outbreak of these two diseases has decreased, while 36.1% of farmers said there is no change. However, 1.6% of farmers said that the outbreak of these two diseases has increased. The remaining 19.7% of farmers could not answer this question.

Farmers (37.7%)said that parasite diseases have decreased, while 27.9% of farmers have not observed any change and 34.4% of farmers could not answer this question. The dominant parasite species found by farmers is Zoothamnium spp. About 55.7% of farmers have found this parasite in their polyculture systems, while the remaining 44.3% of farmers could not answer this question.

When shrimps are observed to be infected by yellowhead and whitespot viruses, farmers have no methods to treat shrimps with any medicines or chemicals, and they just harvest shrimp ponds as soon as possible. For parasite diseases, farmers use the following methods to treat pond water or ease the problem: exchange water (36.7% farmers), BKC (30.0%), O land (6.7%), formalin (6.7%), teaseed cake powder (3.3%), potassium permanganate (3.3%), probiotic plus pinapple (3.3%), lucea (3.3%), exchange water combined with using BKC (3.3%), and just removing infected shrimps (3.3%).

Partial Budget for Polyculture Systems

To conduct partial budget analyses, several assumptions are made due to limited data available. The first is to assume that feed conversion ratio, shrimp stocking density, pond inputs except feed, and unit prices of all revenue and cost items are the same before and after adopting different styles of tilapia-shrimp polyculture systems. The second is that unit prices of all revenue and cost items for pond inputs except feed are the same among all farms of different culture systems. The costs of hapas used for nursing shrimp larvae and cages used for confining tilapia are ignored. Under the above assumptions, the following results are presented.

All farmers adopting both simultaneous and sequential tilapia-shrimp polyculture systems have enjoyed increased profits ranging from US$3,280 to 5,187 ha^{-1} per crop, compared to their respective previous monoculture system (Table 11). The increased profit is higher in the two simultaneous systems (direct polyculture and cage-cum-pond polyculture) than in the sequential system (Table 11). Compared to the current monoculture system, the two simultaneous systems and the sequential system have produced large increased profits ranging from US$6,573 to 9,758 ha^{-1} per crop, while the crop rotation polyculture system has only a marginal increase of profit (Table 12). Again, the increased profit is higher in the two simultaneous systems than in the sequential system (Table 12). In the simultaneous tilapia-shrimp polyculture system, the direct polyculture style has produced higher profit than the cage-cum-pond style (Table 12).

Sources and Further Information Needs by Farmers

Farmers' information on shrimp culture comes mainly from commercial companies (31.1% of farmers), their neighbors (24.6%), magazines (21.3%), and other farmers' experiences (17.4%), while only a few farmers obtained the information from government agencies (Table 13). Further information needed by farmers is shrimp marketing (54.1%) and culture techniques (45.9%) (Table 13).

Reasons for No Tilapia-Shrimp Polyculture in Vietnam

The major reason given by shrimp farmers for not growing tilapia in shrimp ponds is that they thought tilapia would compete for the costly shrimp feeds. In Vietnam, shrimp farming is commonly practiced in extensive and semi-intensive rotation culture with rice. Due to low shrimp stocking density (5 to 10 pieces m^{-2}), farmers believed that water quality in shrimp ponds was good enough and there was no need to use tilapia to improve water quality. Most small-scale farmers did not use any aerators in shrimp ponds, thus they also worried that tilapia would lower dissolved oxygen in shrimp ponds and adversely affect shrimp growth.

DISCUSSION

Traditionally, marine shrimp culture in Thailand was undertaken in extensive coastal sites, which were reliant on natural seed and feed (Lin, 2000). The widespread intensive farming of black tiger shrimp, Penaeus monodon, began in 1988 and 1989 after the catastrophic collapse of the shrimp industry in Taiwan due to disease outbreak. Shrimp production has increased from 30,000 metric tons in 1987 to the present 250,000 metric tons. However, it has not been plain sailing for the Thai shrimp industry. Production stagnated during the late 1990s, however, since then Thailand has recently rebounded with production now estimated at 250,000 metric tons in 2000 (Kongkeo, 2001).

During this survey farmers were asked whether they had experienced a decline in their shrimp production, 93% said they had. It was found that this often resulted in farm closures, although sometimes only temporarily. For instance in Chachoengsao Province, farmers had to abandon their ponds because of disease problems; however, they returned and resumed shrimp culture after a short period. This is mainly driven by the high economic return of shrimp farming. Forty percent of the farmers surveyed said that disease was the major cause of reduced or collapsed production. Results from this survey also showed that environmental degradation, specifically deteriorated water quality, was also a serious problem. Production setbacks were also blamed on poorer quality of shrimp seeds with weaker, less disease-resistant shrimp strains being sold.

The majority of shrimp farms in Thailand belong to small-scale independent operators. Recent statistics show that small-scale farms comprise of approximately 80% of the various-sized intensive shrimp farms throughout Thailand (Lin, 2000). In this study large-scale commercial farmers were interviewed as well as small family-run farms. The area ratio of fishponds to shrimp ponds was almost 1:1, and this clearly showed that fish-shrimp polyculture systems are presently gaining in popularity.

About 75.4% of the interviewed farmers said that tilapia can improve the water quality, and 34.4% believed that tilapia can reduce nutrients in pond effluents. This shows that Thai farmers understand the potential or efficiency of tilapia, and thus, shrimp-tilapia polyculture could sustain shrimp production for them. Tian et al. (2001a) investigated the water quality in a closed polyculture system containing Chinese penaeid shrimp (*Penaeus chinensis*) with Taiwanese red tilapia (*O. mossambicus Í O. niloticus*) and constricted tagelus (Sinonovacula constricta). They found that bacteria and organic matter were significantly reduced in the polyculture system compared to monoculture. In addition, nitrogen and phosphorus levels were measured in the sediments of the polyculture enclosure and found to be 39.76 and 51.26% lower, respectively, than those of monoculture sediments. These results indicate that tilapia are useful in improving water quality in shrimp ponds. Tian et al. (2001b) also reported that the best stocking rates were 7.2 shrimp m^{-2}, 0.08 tilapia m^{-2} and 14 tagelus m^{-2} in the polyculture of Chinese penaeid shrimp, Taiwanese red tilapia, and constricted tagelus. Compared to the above results, Thai farmers stock shrimps at much higher densities. Overstocking makes management more difficult and is not sustainable in the long run.

Wang et al. (1998) also found that the optimum stocking density of Chinese penacid shrimp and Taiwanese red tilapia was 6 shrimp m^{-2} and 0.32 tilapia m^{-2} (126.3 g in size), and shrimp growth and survival rates at all three tested stocking densities did not differ significantly among treatments. In comparison, the farmers interviewed in the present study stocked tilapia with average sizes of 3 to 6 cm in length. Therefore tilapia stocked by these farmers might be too small to affect any improvement in the pond environment. The farmers were reluctant to stock large fish since they thought that large fish might eat shrimps. Guo-Chang (1989) found that tilapia fry and fingerlings (1 to 9 cm) are strong predators on other fish and are known to be cannibalistic if food is in short supply; however, no evidence of shrimps preyed by tilapias was found. Anggawa (1999) reported that yields of shrimp increased when tilapia were stocked into existing shrimp ponds. The suggested stocking rate was 20 to 25 g fish m^{-2} and fish size at stocking of 50 to 100 g. The use of all-male fish was needed to control reproduction. Fish were stocked when the shrimp biomass was at least 80 g m^{-2} (for 3 to 4 g shrimp) or 150 g m^{-2} (for 5 to 6 g shrimp). Tilapia harvest biomass was 40 to 50 g m^{-2}, and shrimp survival was 70%. These results seem to indicate that tilapia and shrimp can cohabit the same pond peacefully without an established predator-prey relationship.

Shrimp production and survival in the simultaneous and sequential polyculture were higher than those in monoculture in the present study. Gonzales-Corre (1988) found that total yield from polyculture was better than that from monoculture in the polyculture of P. monodon with Nile tilapia in brackish water. Similarly, Tian et al. (2001b) reported that survival and net yield of shrimp in a polyculture system were higher by 3 to 16% and 5 to 17%, respectively, than those in monoculture, due probably to better water quality in the polyculture system.

Gonzales-Corre (1988) reported that tilapia were found to compete with shrimp for food. Saelee (2002), who conducted studies on the polyculture of P. monodon and Nile tilapia in low salinity water, found that FCR of shrimp from polyculture was approximately equal to 2 and was higher than that in monoculture (about 1.6) and concluded that tilapia-shrimp polyculture is technically feasible but may not be economically attractive. One way of circumventing the problem of tilapia competing with shrimp for expensive pelleted feed is by culturing the tilapia in a cage. In the present study, however, FCR of shrimp in polyculture was found to be lower than that in monoculture.

Most of the farmers from the central provinces that were interviewed bought hypersaline water, which was then delivered to their farms by tanker. The majority of farmers interviewed in Chachoengsao Province had previously cultured fish and rice but converted to shrimp farming because of higher profit from farming shrimp. However, disease outbreaks, low shrimp prices, high investment, and so on have led many of the farmers to culture fish along with shrimp to safeguard their investment. They said that with shrimp and fish products they can make additional money and cover losses of investment that may arise in shrimp monoculture systems. The farmers from the southern provinces that were interviewed said they were not that interested in fish production from their shrimp ponds for sales. They had problems with high salinities during the dry season when it proved difficult to culture shrimp in very high salinities (> 30%), which led to increased incidences of disease. Tilapia were seen to improve water quality and thought to reduce occurrences of disease, so they were introduced to the shrimp ponds. Red tilapia and Mozambique tilapia were the favored species. The most favorite tilapia strain among the surveyed shrimp farmers was red tilapia. The farmers said that red tilapia grew faster and could fetch a high price in the market. However, some farmers in the central provinces stocked solely Nile tilapia because they cultured their shrimp in low salinity waters (0 to 5%). Another reason given for choosing Nile tilapia was that it was easier for them to find seed of this species in hatcheries compared to red tilapia.

One farmer in Petchaburi Province polycultured milkfish with shrimp with the purpose of using milkfish to improve water quality in shrimp ponds and clean up waste from the pond bottom more efficiently than using tilapia. However, Baylon (1996) reported that polyculture of shrimp with milkfish resulted in ponds with water having significantly higher phytoplankton content compared to monoculture, but no significant differences existed in biological oxygen demand, total suspended solids, phosphate, nitrate, and ammonia contents of pond water between polyculture and monoculture. Baylon (1996) also undertook a crop rotation experiment to determine the effect on sediment quality of shrimp ponds by culturing milkfish immediately after shrimp harvest. The results showed that sediment sampled from the ponds where milkfish had been cultured had a decrease in organic matter for three ponds only, while the phosphorus content decreased in only two ponds. Tian et al. (2001a) reported that most varieties of tilapia are omnivorous in feeding habit and are mainly filter feeders, thus they are capable of improving water quality in ponds (Diana et al., 1991; Ruan et al., 1992, 1993; Zhang et al., 1999).

The present survey showed that the use of chemicals for shrimp culture was reduced in polyculture compared to monoculture. If such polyculture systems could be optimized to eliminate the use of chemicals in the tilapia-shrimp polyculture, the resultant tilapias and shrimps then could be marketed as "green" products and thus benefit both producers and consumers.

Therefore, polyculture of shrimp with tilapias may provide an alternative approach for shrimp farming that could ultimately lead to a more sustainable shrimp industry. However, further research is needed on merits for converting from monoculture to polyculture of shrimp.

ANTICIPATED BENEFITS

The results of this survey will hopefully provide fresh insight and information relating to tilapia-shrimp polyculture in Thailand. The findings will be shared through workshops and regular publications and regional training courses. This information may also be beneficial to both commercial shrimp producers and small-scale shrimp farmers in other countries.

ACKNOWLEDGMENTS

The authors wish to acknowledge all the Thai shrimp farmers involved in the survey. Special thanks are extended to Potjanee Nadtirom and Vinit Tansakul of the Asian Institute of Technology for conducting the field survey and data analysis. The authors also wish to thank the staff of Charoen Pokphand Co. Ltd. for their support in the field survey, especially Surachai Jarudamrongsak and Umpon Kijjariyapum.

LITERATURE CITED

Anggawa, A., 1999. Polyculture of shrimp and tilapia in east Java. American Soybean Association (ASA) Technical Bulletin AQ47-1999.

Baylon, C., 1996. Polyculture and crop rotation in brackish-water shrimp ponds: Effect on soil and water quality. Aquaculture Research and Sustainable Development in Inland and Coastal Regions in South-East Asia. International Foundation for Science EC DGXII of the European Union, University of Can Tho, Vietnam, pp. 160–167.

Diana, J.S., D.J. Dettweiler, and C.K. Lin, 1991. Effects of Nile tilapia (Oreochromis niloticus) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis in brackish water ponds. Can. J. Fish. Aquat. Sci., 48:183–189.

Fitzsimmons, K., 2001. Polyculture of tilapia and penaeid shrimp. Global Aquaculture Advocate, 4(3):43–44.

Garcia-Perez, A., D. Alston, and R. Cortes-Maldonado, 2000. Growth, survival, yield and size distribution of freshwater prawn, Macrobrachium rosenbergii, and tilapia, Oreochromis niloticus, in polyculture and monoculture systems in Puerto Rico. J. World Aquacult. Soc., 31(3):446–451.

Gonzales-Corre, K., 1988. Polyculture of the tiger shrimp (Penaeus monodon) with the Nile tilapia (Oreochromis niloticus) in brackish water fish ponds. In: R.S.V. Pullin, T. Bhukaswan, and K. Tonguthai (Editors), Proceedings of the Second International Symposium on Tilapia in Aquaculture, Manila, Philippines, pp. 15–20.

Guo-Chang, G., 1989. Polyculture of Tilapia with Shrimp in China. NAGA, Bangkok, Thailand, 17 pp.

Kongkeo, H., 2001. Current status and development trends of aquaculture in the Asian region. In: R.P. Subasinghe, P.B. Bueno, M.J. Phillips, C. Hough, S.E. McGladdery, and J.R. Arthur (Editors), Aquaculture in the Third Millenium. NACA/DOF/FAO, Bangkok, Thailand, pp. 267–293.

Lin, C.K., 2000. Development of shrimp farming and environmental sustainability in Thailand. SUISANZOSHOKU, 48(2):267–272.

Ruan, J., K. Rong, S. Wang, and Q. Liu, 1992. Effect of Nile tilapia on plankton community and primary productivity of freshwater microcosms. Chinese J. Appl. Ecol., 4(1):65–73.

Ruan, J., Q. Liu, S. Wang, and K. Rong, 1993. Effect of tilapia on nutrient levels of freshwater microcosms. Chinese J. Appl. Ecol., 4(4): 404–409.

Saelee, W., 2002. Shrimp-tilapia polyculture in low salinity water. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.

Samocha, T., A. Lawrence, and D. Pooser, 1998. Growth and survival of juvenile Penaeus vannamei in low salinity water in a semi-closed recirculating system. Isr. J. Aquacult./Bamidgeh, 5(2):55–59.

Tian, X., D. Li, S. Dong, G. Liu, Z. Qi, and J. Lu, 2001a. Water quality of closed polyculture of penaeid shrimp with tilapia and constricted tagelus. Chinese J. Appl. Ecol., 12(2):287–292.

Tian, X., D. Li, S. Dong, X. Yan, Z. Qi, G. Liu, and J. Lu, 2001b. An experimental study on closed-polyculture of penaeid shrimp with tilapia and constricted tagelus. Aquaculture, 202(1–2):57–71.

Wang, J., D. Li, S. Dong, K. Wang, and X. Tian, 1998. Experimental studies on polyculture in closed shrimp ponds: I. Intensive polyculture of Chinese shrimp (Penaeus chinensis) with tilapia hybrids. Aquaculture, 163(1–2):11–27.

Yap, W.G., 2001. The lowdown on world shrimp culture II. INFOFISH International, 2001(3):20–27.

Zhang, H., D. Li, and Y. Wang, 1999. The impacts of tilapia polyculture in shrimp ponds on the structure of plankton communities. Journal of Fisher. Sciences of China, 6(4):114–116.

Cite as: [Author(s), 2004. Title.] In: R. Harris, I. Courter, and H. Egna (Editors), Twenty-First Annual Technical Report. Aquaculture CRSP, Oregon State University, Corvallis, Oregon, [pp. ___.]