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Brackishwater Integrated Farming Systems in Southeast Asia

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Abstract

Integrated aquaculture-agriculture systems are more common in fresh water than in brackish water. Nevertheless, southeast Asian countries already have considerable research and experience in brackishwater integrated farming systems. In the Philippines, the effects of animal wastes on water quality and production of fish have been studied: chicken wastes on the mixed culture of milkfish *Chanos chanos,* tilapia *Oreochromis niloticus,* and shrimp *Penaeus indicus;* chicken and cattle manures on *P. monodon* and *Artemia;* and swine wastes on tilapia *O. mossambicus.* In Indonesia, about 60 hectares of fish farms have crops (pumpkin, spinach, cassava, maize, and chili) or livestock (cattle, goat, sheep, chicken, and duck) grown on the dikes of milkfish ponds. In Vietnam, culture of the giant prawn *Macrobrachium rosenbergii, Scylla serrata* and marine shrimps has been integrated with coastal rice farming. Aquaculture-silviculture is a flourishing venture in Vietnam and Indonesia and gaining ground with experimental sites in Thailand and the Philippines. The seaweed *Gracilaria* has been cultured with fishes and shrimps in Taiwan, Vietnam, Thailand, and the Philippines. The production of *Artemia* cysts and biomass has been integrated with salt-making and fish or shrimp farming in the Philippines and Thailand. Production inputs and outputs from these integrated farming systems vary widely and socioeconomic information is nil. It is imperative to conduct follow-up research and evaluation of each system in terms of production and socioeconomics.

Introduction

The continuous population growth and demand for food dictate that farm lands be used more efficiently and productively. Integrated farming improves farm productivity and profitability by: (1) growing species that could coexist and share water or land space, (2) growing species that could supply each other's production inputs, and (3) effectively using idle or available land, water, farm labor, and facilities. Use of land and water resources both for aquaculture and agriculture or forestry is one way to increase farm efficiency, productivity, and profitability.

Freshwater integrated farming systems (FIFS) usually consist of two or three commodities: a fish or crustacean, a plant crop, and one or other species of livestock. There is a great diversity of aquatic species, livestock, crops, and even forest products that can be included in FIFS. Figure 1 shows the sharing of space by fish, crops, and livestock and the flow of materials produced and used in the different components of an integrated farming system. As the number of species in a system increases, so does the technical knowledge that is required. The culture conditions in an integrated system must be modified to allow harmonious coexistence of species and thus satisfy the concept and objective of integration.

Diverse FIFS have been documented in various parts of the world and significant advances have been achieved in many of them (Pullin and Shehadeh 1980, Hopkins and Cruz 1982, de la Cruz et al. 1992, Haller and Baer 1992, Jeney 1992, Lin and Lee 1992, Mukherjee et al. 1992). The greatest scope for further development of integrated crop-livestock-fish farming is in the humid tropics and this is also where the need is greatest (Edwards et al. 1988). A technology information kit on farmer-proven integrated agriculture-aquaculture has been put together by IIRR-ICLARM (1992) for extension purposes.

The integrated aquaculture-agriculture systems in freshwater environments can also be developed in brackish water especially in Southeast Asia, which has more than 781,892 hectares of brackish water ponds: 276,442 in Indonesia, 222,907 in the Philippines, 189,000 in Vietnam, and 72,796 in Thailand (see country papers, this volume), 18,665 in Taiwan, 1,975 in Hongkong, and 107 in Singapore (de la Cruz 1983). In addition to existing ponds, Southeast Asia has considerable areas of brackishwater ricefields and tidal flats that could be tapped for integrated aquaculture, agriculture, and forestry.

Brackishwater integrated farming systems (BIFS) could be a mix of crops thriving concurrently or alternately in brackish water and fresh water, in brackish water throughout, or in marine to brackish waters. BIFS could be of three types: (1) aquaculture-agriculture, (2) aquaculture-silviculture, and (3) brackishwater and marine polyculture.

This paper reviews the status of BIFS in Southeast Asia and includes similar research done elsewhere in Asia for the lessons they provide. Only Indonesia, the Philippines, Thailand, and Vietnam have had experience or at least research in both integrated aquaculture-agriculture and aquaculture-silviculture. Taiwan has pioneered in integrating marine seaweeds, particularly *Gracilaria* sp., with fishes or shrimps in brackishwater ponds.

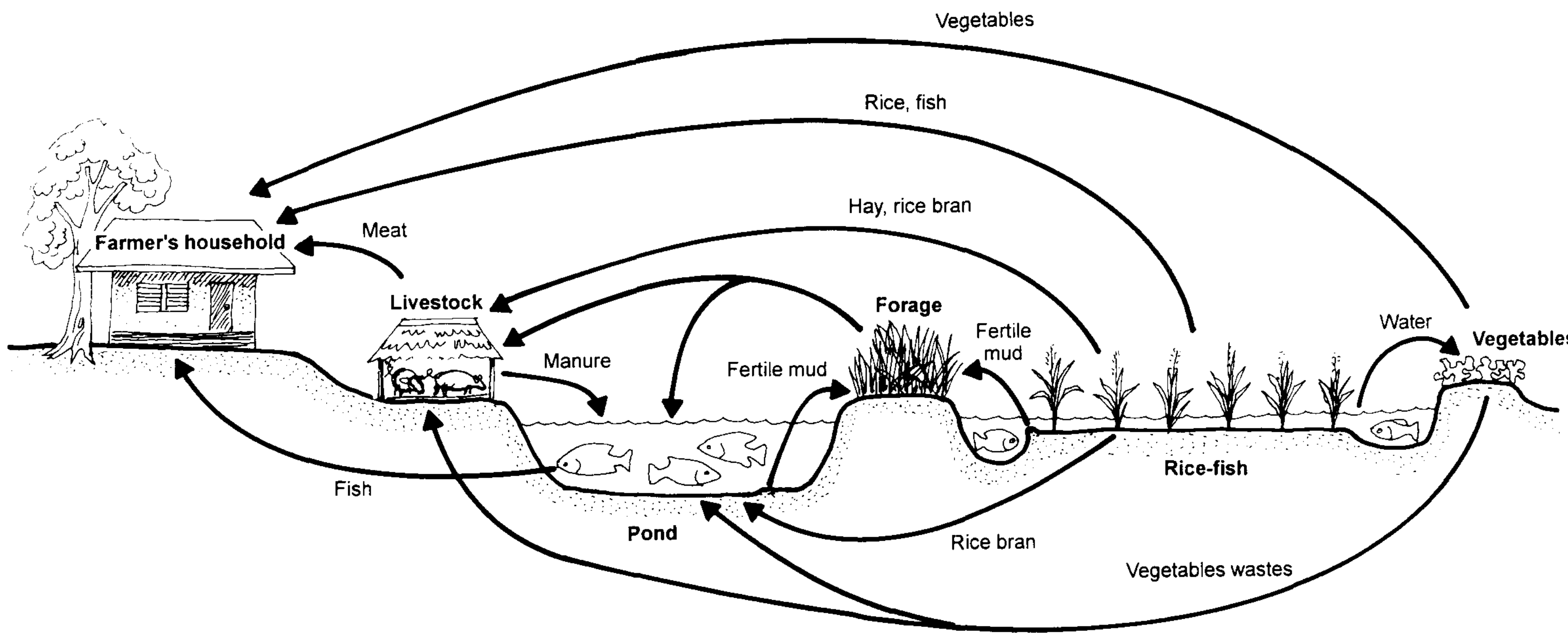


Fig. 1. Integrated fanning of plant crops, livestock, and fish. Arrows show flow of materials (inputs and outputs).

Brackishwater Aquaculture with Agriculture

Tilapia with swine

Tamse et al. (1985) studied the use of piggery waste effluents (from biogas digesters) in fish ponds. They determined the duration of fermentation necessary to produce a nutrient-rich slurry. The highest nutrient levels were observed on the 14th to 17th week of fermentation at temperatures of 25-30°C. The levels in mg/1 were: total phosphorus 1,100-1,300; available phosphorus 17.2-21.9; total nitrogen 3.9-5.2; and dry matter 9.2-13.2.

The optimum dose and frequency of application of slurry for the production of all-male tilapia *Oreochromis mossambicus* was determined in twenty 40-m^2 ponds (Tamse et al. 1985). Production of tilapia significantly increased to 545 kg/ha when slurry was applied 5x a week, and to 469 kg/ha when slurry was applied 2x a week. Ponds that received slurry once a week had net production of 316 kg/ha and those without slurry had 372 kg/ha.

White shrimps, milkfish, and Nile tilapia with poultry

Pudadera et al. (1986) evaluated the feasibility and profitability of integrating broiler chicken with shrimp and fish in 1,000-m^2 ponds. Broiler chickens (180/pond) were housed in the middle of the ponds for one culture period and these supplied manure to a mixed culture of Nile tilapia *Oreochromis niloticus,* white shrimp *Penaeus indicus,* and milkfish *Chanos chanos.* Tested for production were combinations of 50,000 white shrimp, 2,000 milkfish, and either 5 000, 10 000, 15 000, or 20 000 tilapia per hectare. Net production after a 120-day culture period were: tilapia 337-670 kg/ha, shrimp 192-284 kg/ha, milkfish 75-117 kg/ha, and broiler chickens 1,810-2,170 kg/ha. The highest tilapia production (670 kg/ha) was obtained at the stocking rate of 15,000/ha. However, it was at this stocking density that yields were lowest for shrimp (192 kg/ha) and milkfish (75 kg/ha). Thus the total productions (680-936 kg/ha) were not significantly different among the treatments.

The highest net earnings were obtained at the tilapia stocking density of 15,000/ha. The lowest earnings were obtained at 20,000/ha due to higher inputs of juveniles but lower net production and smaller harvest size. The economic analysis indicated a 16% return on investment for the integration of 1 800 broiler chicken, 50 000 white shrimps, 2 000 milkfish, and 10 000-15 000 tilapia per hectare.

Tiger shrimps with cattle, poultry, and brine shrimp

Ogburn et al. (1986) studied the integrated production of cattle and poultry with the tiger shrimp *Penaeus monodon.* Various ways of manuring were tried in developing the system. One way was to add manure during pond preparation and shrimp grow-out. Another way was to wash manure from a cattle-fattening shed into shrimp ponds. A third way was to apply liquid manure to 'kitchen ponds' where natural food (the brine shrimp *Artemia* and the cyanobacterial mat 'lablab') could be grown.

Organic manure applied during pond preparation (prior to stocking) stimulated the growth of 'lablab'. However, pond water quality deteriorated towards the end of the culture period.

Plankton analysis showed excessive blooms of nanno- and picoplankton that were not utilized by the shrimps.

The kitchen pond produced 40 kg/day *of Artemia* and 'lablab' through the daily addition of manure (dry weight 100 kg/ha) during a three-month period. An area ratio of 1 kitchen pond to 5 shrimp ponds resulted in shrimp production of 200-400 kg/ha-crop. A combination of 'lablab' and medium-quality feed pellets increased production to 700-1,000 kg/ha-crop, where stocking density was 30,000/ha and survival was 60-70% after 130 days. Feed costs were significantly reduced. The advantages of using an *Artemia*-lablab' kitchen pond were discussed by Ogburn et al. (1986).

Milkfish with chili, maize, cassava, spinach, and pumpkin

Integrated farming in brackishwater farms is being encouraged as a way to improve farmers' income in Indonesia, where the average farms are small: 1.42 hectares in Central Java, 2.41 hectares in West Java, and 3.62 hectares in East Java (Manik and Tiensongrusmee 1979). A study was conducted in Pati District, Central Java where about 60 hectares of ponds were operated under two integrated systems: fish with agricultural crops and fish with livestock.

Due to rains, old pond dikes have reduced salinity. In Bakalan Village, the salt content of dikes is below 1 ppt and it is possible to grow agricultural crops. The dikes of most ponds are wide and suitable for growing farm crops such as chili *Capsicum annum,* pumpkin *Legenaria leucantha,* spinach *Amaranthus* spp., cassava *Manihot utilissima,* and maize *Zea mays.* These crops are grown in November-April. Among these crops, chili commands a good price and provides high returns to the farmers. A two-hectare pond in the Pati District could provide net returns of about Rp 310,000 (US$1 = Rp 625) from milkfish culture and one crop of chili a year. The returns may be further increased to Rp 1,940,500 per year with a system that combines shrimps, milkfish, and two crops of chili a year (Manik and Tiensongrusmee 1979).

Milkfish and shrimp with sheep

Sheep, goats, and chicken are also raised with fish in Pati, Central Java. In Langenhardjo village, a farmer operating a 4-hectare fish-sheep farm (out of his 15-hectare fish farm) was able to increase his sheep stock from seven females and one male in 1975 to 75 sheep in 1979. About 40 male sheep could be sold each year and the remaining herd could provide about 100 kg of manure each month for the ponds. The net returns from an integrated system with milkfish, shrimp, and sheep was about Rp 395,625/ha-year (Manik and Tiensongrusmee 1979).

Fish, prawns, and shrimps with rice

Various combinations of coastal rice with shrimps and fishes have been reported from Vietnam with the corresponding farming schedules. The Mekong Delta has about 2,000,000 hectares of ricefields, 41% of the total ricefield area in the country. The freshwater prawn *Macrobrachium rosenbergii* and other shrimps and fishes are produced in ricefield aquaculture systems, rivers, canals, and brackishwater areas in the Mekong Delta (Mai et al. 1992, Lin and Lee 1992).

Three types of integrated farming systems dominate in the Mekong Delta (Mai et al. 1992). One is year-round rice with freshwater prawn or fish, e.g., in Thanh Loc in Thot Not District and Cai Con and Mang Ca in Phung Hiep District. Another is year-round rice with brackishwater shrimp or fish, e.g., in Giong Co in My Xuyen District. A third system is rice rotated about every six months with shrimp or fish, e.g., in Long Thoi Commune, Nha Be and Duyen Hai Districts. Examples of integrated cropping patterns and yields are shown in Table 1, and an example production calendar in Figure 2.

Table 1. Cropping patterns and production of rice with shrimp or fish in Vietnam during the wet and the dry seasons. Modified from Mai et al. (1992).

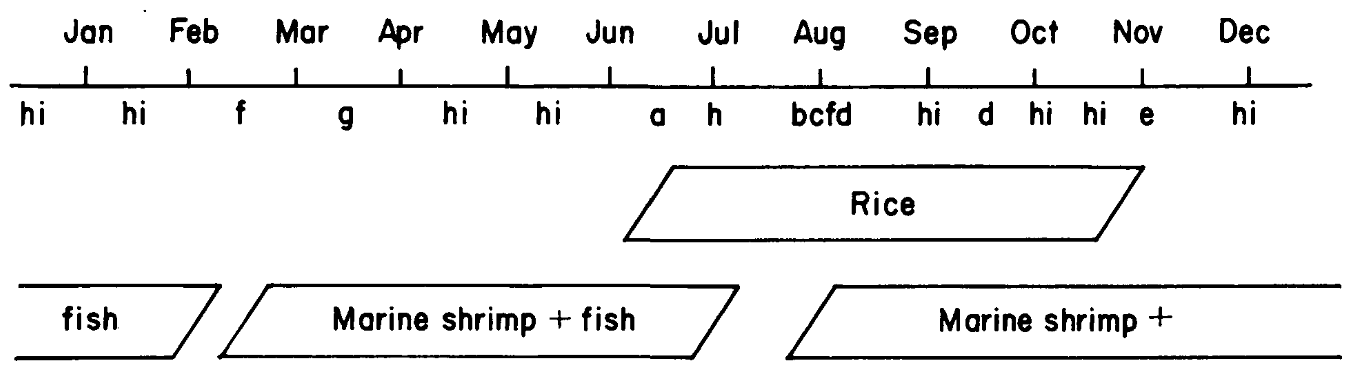
Cropping patterns	Rice yield (t/ha) wet	dry	Shrimp & fish yield wet	dry
WSR-fallow	2.4			
(WSR+F+S)-(F+S)	2.4		S 2-2.5 kg/day, F 15 kg/day	S 2.5-3 kg/day
WSR-DSR	5.2	5.7		
(WSR+S)-(DSR+S)	5.2	5.7	S 187 kg/ha	
(WSR+F+S)-(DSR+F+S)	5.2	5.7	F 214 kg/ha	
WSR-DSR	3.9	4.0		
WSR-TR	3.9	3.5 TR		
(WSR+S)-(TR+S)	3.9	3.5 TR	S 79 kg/ha	
(WSR+S)-(DSR+S)	3.9	4.0	S 48 kg/ha	

DSR dry season rice; WSR wet season rice; TR traditional rice; F fish; S shrimp

In the third system, rice is grown during the wet season when freshwater is available and shrimp or fish is cultured when the rice paddies turn brackishwater (Le 1992). When salinity remains lower than 10 ppt in the dry season, farmers can raise a second crop of *Macrobrachium* without rice. Where salinity is 10 ppt or higher, marine shrimps (Penaeidae) migrate into tidal flats at spring tides. Farmers use fallow ricefields to trap and grow shrimps. Data collected from 55 rice-prawn farms in Duyen Hai District indicated that 55% had yields of 100-300 kg/ha-crop and 23% had yields of more than 300 kg/ha-crop (Le 1992). Farmers with prawn yields lower than 100 kg/ha had net benefits less than US$400/ha-crop. Yields of more than 300 kg/ha netted higher than $1,000/ha-crop (Le 1992).

Mudcrabs with rice

Fanners in Vietnam also collect juveniles of the mudcrab *Scylla serrata* and stock them in fallow ricefields or backyard ponds 300-500 m^2 in size (Le 1992). There are two systems: molting-crab culture and crab fattening. In molting-crab culture, four pairs of walking legs are removed from small crabs less than 100 grams. Crabs molt 13-25 days after leg removal. The



- a Seeding of rice (soaking, incubating, broadcasting)
- b Land preparation (plowing, puddling, levelling)
- c Transplanting of rice
- d Fertilizer application
- e Harvesting of rice
- f Excavating/reexcavating of trenches
- g Tidal water coming in and retained at about 30cm above field level
- h Repeated harvesting of shrimp
- i Repeated harvesting of fish

Fig. 2. Fanning calendar for rice and shrimp or fish farming in Giong Co Hamlet, Tham Don Village, My Xuyen District, Hau Giang Province, Vietnam. From Mai et al. (1992).

appropriate salinity range is 8-25 ppt so farmers engage in molting-crab culture in the dry season. In crab fattening, large but thin crabs >100 grams are fed well in earthen ponds fenced with nipa fronds or bamboo. Farmers engage in crab fattening mainly from August to November.

Fanners can get 50-70 kg of soft-shelled crabs from 100 kg of hard-shelled crabs in 300-500 m^2 ponds. Net income from soft-shelled crabs can reach US$50-70/month, 5-10x that from hard-shelled crabs. From fattened crabs in a 300-m^2 pond, the net income is $100-150/month, 3x more than for thin crabs. More information about mudcrab culture is given by Le (1992).

Shrimps with rice: the 'pokkali'and 'bhasabadha' systems

Ghosh (1992) reported on integrated culture of coastal rice with marine shrimps and fish in West Bengal, Kerala, Goa and Karnataka in India. During the monsoon, coastal rain-fed fields are planted with rice; during the summer months when salt content is high, the fields are used for fish farming. The 'pokkali' system involves the trapping of shrimps such as *Metapenaeus dobsonii, M. monoceros, Penaeus monodon, P. indicus, P. semisulcatus* from the tidal water that entered the ricefields. Lately, the system has been modified to include selective stocking of desired shrimp species.

The ricefields are desalinated after the shrimp crop in time for the rice crop. The 'pokkali' plots have crisscross trenches to quickly drain the runoff water and wash away the surface salts from the shrimp culture phase. The topsoil is scraped to better remove the salts and is then heaped away from the plots. After these heaps have been washed by the rain, the desalinated soil is again spread over the rice plots. With the 'pokkali' system, production amounts to 785-2,135 kg/ha-year (80% shrimps), whereas traditional plots normally produce 500-600 kg/ha-year of aquatic crops (Ghosh 1992).

A slightly different farming system, the improved 'bhasabadha', involves selective stocking of fishes (tilapia, mullets, and others) and marine shrimps. Production from the 'bhasabadha' system could be 600-1,000 kg/ha-year. The return on capital investment could be 29% in the traditional 'pokkali' and 56% in the improved 'bhasabadha' systems (Ghosh 1992).

Tilapia with alfalfa

In Kuwait, fresh water is a very precious commodity used solely for household consumption and brackish water is used for limited agriculture. Some farmers are currently engaged in a pilot BIFS using alfalfa *Medicago sativa* with tilapia *Oreochromis spilurus* (EM Cruz, personal communication). The system involves flow-through of brackish irrigation water (7-12 ppt) into concrete or fiberglass tanks (10-50 m^3) with tilapia. From the fish tanks, nutrient-enriched water is then released to fields (5-10 hectares) of alfalfa used as forage for sheep and cattle.

Aqua-silviculture: Fishes and Shrimps with Mangroves

Marginal coastal sites such as denuded and overexploited mangrove areas and unproductive or abandoned fishponds can be made productive and economically profitable through the integration of aquaculture with silviculture, the harmonious co-existence of fishery species and mangrove trees in a semi-enclosed system. This integrated multi-use system mimics the natural mangrove forests and swamps that protect the coasts, maintain ecosystem integrity, and provide various goods. Aqua-silviculture may help solve the conflicting interests between the coastal fishery and forestry sectors and can provide both ecological and economic stability Beukeboom et al. 1993).

Aqua-silviculture is in its early stage of development. The layout or design of this farming system varies in different places. The system usually consists of 1/4 pond area for shrimps or fishes and 3/4 forestry area for planted trees. The ponds are deeper than the planted area. Water is controlled such that both the ponds and the trees are inundated. During the first 3-5 years, the planted trees are in the seedling or sapling stage and the ponds can be used for fish production. In the next 5-10 years, the mangrove saplings (2-10 cm in diameter) and trees (>10 cm in diameter, 5 meters high) limit light penetration into the water and the production of natural food. The trees may be thinned or pruned and the wood used as fuel, posts or low-cost housing materials, and the leaves as forage for livestock.

Vietnam

The shrimp-mangrove integrated system in Vietnam is the most developed in southeast Asia (MJ Phillips, personal communication). The very southern part of the Mekong Delta lost large areas of mangroves during the Vietnam War (1966-1975). In Ngoc Hien District in Minh Hai Province, about 44,918 hectares were destroyed and 24,700 hectares of these were replanted with *Rhizophora* (Le 1994). There are now several thousand hectares of shrimp-mangrove integrated farms operated by the local government and allocated to farmers as the so called 'State Forestry-Fisheries Enterprises.' Each household receives 5-10 hectares of land, of which 70-80% is meant for *Rhizophora* planted at 20,000 trees per hectare and 20-30% is for shrimp farming, canals and dikes (Ngo 1993, Nguyen 1993). Annual production of shrimp is about 250 kg/ha during the first two years, then declines to 100-170 kg/ha after the fifth year of production. The decline is due to limited light penetration due to the dense canopy and poor water quality due to decaying leaves. The loss in shrimp revenues is compensated by income derived from thinning and harvesting of trees.

The economic returns from shrimp-mangrove systems in Vietnam have recently been surveyed. The systems are extensive as far as shrimp is concerned but those with 40-60% mangrove cover are the most economically efficient in terms of shrimp yields (MJ Phillips, personal communication). If the revenues from timber and secondary forest products are added, a higher percentage of the mangroves within the pond area may be justified. The shrimp-mangrove system has been widely accepted by fisher-farmers, who are looking into various ways to increase yields. Aqua-silviculture has reduced the disorderly clearing of mangroves for shrimp production, restored some of the destroyed mangroves, and created new job opportunities (Nguyen 1993).

Indonesia

Aqua-silviculture began with 15-hectare and 25-hectare pilot projects in 1986-1987 in Ciasem Pamanukan and Cikiong Sub-Forest Districts (Sastroamidjojo 1993). Since 1990, the system has spread throughout West Java, where each family is allocated 5 hectares, of which 80% is for mangrove forests and 20% for ponds. The ponds are generally the traditional kind and the species cultured are milkfish, tilapia, and assorted shrimps. There are about 25,000 hectares of mangrove forests with traditional ponds yielding 30,200 tons of fish each year and providing livelihood to at least 5,000 families. Improved aqua-silviculture designs or models are presently under experiment (Sastroamidjojo 1993).

Thailand

About 173 hectares of mangrove forest in Kung Krabaen Bay were distributed to 104 families. Of the 1.6 hectares given to each family, 1 hectare was for shrimp pond, 0.5 hectare was for mangrove trees, red tilapia, grouper, and a settling pond, and the rest for ditches and dikes (Chantanee 1993). Benefits came in the form of more mangrove trees planted, entrapment of sediments and organic matter, and improved incomes (about 5x greater). Farmers' production of shrimps averaged 3,762 kg/ha valued at Baht 247,000/year per family (Chantanee 1993; US$1= Baht 25).

Philippines

There are about ten aqua-silviculture sites in the provinces of Quezon, Oriental Mindoro, Negros Occidental, Bohol, Cagayan, and Guimaras (SR Baconguis, personal communication). Milkfish is the main species stocked. Other species cultured are shrimps, crabs, tilapia, and siganids. A newly established site in Oriental Mindoro grows mixed species in ponds with natural seeding. The trees planted are *Rhizophora* spp., *Avicennia* spp., and *Nypa fruticans.*

Aqua-silviculture in the Philippines has shown varying degrees of success, ranging from poor to good harvest of shrimps and fishes, up to 3.24 t/ha of milkfish and 3.17 t/ha of tilapia per year (SR Baconguis, personal communication). Poor harvests were due to poaching, typhoons, and lack of skill in pond management

Brackishwater-Marine Aquaculture Systems

Gracilaria with fish or shrimps in ponds

Extensive cultivation of *Gracilaria verrucosa, G. gigas,* and *G. lichenoides* is done in brackishwater ponds in southern Taiwan. About 5,000-6,000 kg of the seaweed are seeded per hectare of pond, at the bottom 50-80 cm deep (Chiang 1981). Pond water is maintained 30-40 cm deep most of the time, but is reduced to 20-30 cm when water temperature falls below 10°C and increased to 50-60 cm at >32°C. Frequent exchange of water is necessary to maintain the salinity at 10-20 ppt and to provide nutrients for the seaweed. When needed, urea is applied at 3 kg/ha or fermented pig or chicken manure is used at 120-180 kg/ha. The seaweed is harvested every 30-35 days; annual yield (dry) is about 16-43 tons/ha (Chiang 1981). Milkfish stocked at 1,000/ha increase production and also control the competitors of *Gracilaria* — the green algae *Enteromorpha* and *Chaetomorpha* (Lin et al. 1979, Chiang 1981). Milkfish will consume *Gracilaria* when the other algae are gone, so the large juveniles must be harvested and small ones stocked anew (Chiang 1981).

Tiger shrimp at 10,000-20,000/ha or mudcrab at 5,000-10,000/ha can be stocked with seaweed for additional income (Gomez 1981). *Gracilaria* species have been grown successfully with tiger shrimp, mudcrab, and milkfish in brackishwater ponds in the Philippines, Thailand, India, China, and elsewhere (Gomez and Azanza-Corrales 1988). In Thailand, fish farmers harvest the *Gracilaria* that grows on the polyethylene net and bottom of cages stocked with the seabass *Lates calcarifer*. Total yearly production of seaweed and fish is 50-100 kg per 10 m^2 cage (Tachanavarong 1988). *Gracilaria* culture has been carried out in shrimp pond effluents (Chandrkrachang et al. 1991).

In China, an experiment on mixed culture of *Gracilaria tenuistipitata* and *Penaeus monodon* was conducted to develop new methods to prevent shrimp diseases (He et al. 1990). *Gracilaria* absorbs the abundant ammonia in shrimp ponds. Through photosynthesis, abundant oxygen is produced, oxidation of organic matter is accelerated, ammonia and hydrogen sulfide are reduced, and water quality is improved. The stress factors are reduced, and so are the levels of fungi, parasites, and pathogens. Polyculture of shrimp with *Gracilaria* increased shrimp production by 76% (He et al. 1990).

Artemia and salt with fish or shrimp

The integration of fish, shrimp, *Artemia,* and salt is now a well established venture in Thailand. Annual per hectare production is about 23 kg wet *Artemia* cysts, 8 300 kg wet *Artemia* biomass, 62 tons salt, and 1 125 kg fish and shrimp (Tarnchalanukit and Wongrat 1985).

In the Philippines, several experiments on the culture of *Artemia* in salt ponds have proven it feasible (Santos et al. 1980, Jumalon et al. 1986). The monthly per hectare production from these trials were 7.45-20 kg dry *Artemia* cysts and 2-7 tons wet *Artemia* biomass, and 100 tons salt (Jumalon et al. 1986, 1987). Salt and *Artemia* are produced during the dry season in ponds with salinities higher than 90 ppt; fish or shrimps are produced during the wet season in ponds with much lower salinities.

Discussion

The review revealed that BIFS in southeast Asia are a fertile area for research and development. In Indonesia, the integrated system is aquaculture-based and additional income accrues from farm crops. In Vietnam, the integrated system is agriculture-based and additional income comes from fish crops. Integrated agriculture-aquaculture and aqua-silviculture have had visible impact in Vietnam and Indonesia. The systems developed in Vietnam seem to be promising, expanding rapidly, and socially acceptable to farm households. Indications are positive that the potential of ricefield aquaculture and aqua-silviculture systems are being realized in Vietnam. The extent of development or adoption of integrated agriculture-aquaculture in Indonesia, however, is not clear as follow-up reports are not available.

The scale of operation or size of the fish farm is an important consideration in establishing an integrated system. A fully integrated farm usually involves huge operation and capitalization and as such is not feasible for small farmers. For BIFS to be appropriate and sustainable technologies, the research, development, and dissemination of BIFS should focus on small-scale coastal fish farms, more or less adapting the Indonesian experience. In inland areas that are predominantly agriculture-based, there is much to learn from the Vietnamese and Indian experiences.

The studies done so far on BIFS in the Philippines are still experimental. Concerted follow-up research should focus on improving production efficiency. Research must determine optimal pond design and water management schemes, ascertain the quantity and quality of manure in relation to the potential production of selected aquatic species cultured with agricultural crops or livestock, and find ways to reduce pollutants (e.g., non-use of pesticides and pre-treatment of manure before use in ponds).

In aqua-silviculture, more research is needed on the proper spacing, density of trees, felling of trees, water level regulation, and other variables and techniques. Productive and compatible aqua-silviculture models must be developed, taking into account pond engineering and management, the appropriate species to be cultured, and the socioeconomic characteristics of coastal communities.

The polyculture systems in brackishwater and marine environments can be improved. Screening of more marine species for culture in brackishwater should continue. For example, in China and Korea, seaweeds are integrated with mollusks and sea cucumbers; in Japan, seaweeds are grown with fish in cages (MJ Phillips, personal communication).

BIFS could still be developed in both theory and practice. Experiences and research done on BIFS must be collated to assess the state of the art and identify the necessary research to facilitate its further development. Along with the technology generation and development of BIFS, socioeconomic studies must also be made. Socioeconomics data help identify the location and the conditions under which a given BIFS would prove viable.

The increase in human population and thus the demand for freshwater necessitate the use of other types of water for food production. Southeast Asia is fortunate in that freshwater is still available for agriculture and aquaculture. Nevertheless, there are localized or seasonal shortages of freshwater throughout the region. In the Gulf countries, Kuwait for example, freshwater is so valuable that it is purely for household use. In southeast Asia, we must now start to integrate agriculture and brackishwater aquaculture to conserve freshwater and improve the livelihood and income of coastal communities.

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