Shrimp Farming in the Asia-Pacific: Environmental and Trade Issues and Regional Cooperation

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Abstract

Production of farmed shrimp has grown at the phenomenal rate of 20-30% per year in the last two decades. The leading shrimp producers are in the Asia-Pacific region while the major markets are in Japan, the U.S.A. and Europe. The dramatic failures of shrimp farms in Taiwan, Thailand, Indonesia and China within the last five years have raised concerns about the sustainability of shrimp aquaculture, in particular intensive farming. After a brief background on shrimp farming, this paper reviews its environmental impacts and recommends measures that can be undertaken on the farm,

country and regional levels to promote long-term sustainability of the industry. Among the environmental effects of shrimp culture are the loss of mangrove goods and services as a result of conversion, salinization of soil and water, discharge of effluents resulting in pollution of the pond system itself and receiving waters, and overuse or misuse of chemicals. Recommendations include the protection and restoration of mangrove habitats and wild shrimp stocks, management of pond effluents, regulation of chemical use and species introductions, and an integrated coastal area management approach. Regional cooperation is needed in research and information sharing, and trade in supplies and equipment.

The contribution of farming to global shrimp production has dramatically risen from a mere 6% in 1970 to 26% in 1990 (FAO, 1993). In terms of value, this has meant a 16-fold increase from US$300 million in 1980 to $7 billion worth of cultured shrimp by 1993 (Rosenberry, 1993). Annual growth rate of farmed shrimp has been 20-30% in the last 20 years (Table 1). In contrast, increases in commercial landings of shrimp have stabilized at 2-3% yearly due to the full or close to full exploitation of most wild stocks and high fuel costs. However, the recent failures of shrimp crops in Taiwan followed by China and Indonesia have raised concerns about the sustainability of shrimp aquaculture. This paper will a) give a background of the shrimp farming industry, b) review the different shrimp culture systems, c) evaluate the environmental impacts of shrimp farming, and d) recommend actions to promote long-term sustainability in the industry including suggestions for regional cooperation.

I. BACKGROUND

In 1993, more than 600,000 mt of shrimp were harvested from around 960,000 ha of ponds worldwide (Table 2). Close to 80% came from Asia while Latin America accounted for more than 20% of total production. Except for Ecuador, the top countries producing more than 20,000 mt each are all in Asia (Fig. 1).

As a highly prized seafood delicacy, shrimps and prawns are a cash crop grown mainly for the affluent export (and urban) markets. From farms in Southeast Asia, East Asia, South Asia and South America, shrimp are exported to the major markets in Japan, the USA and Europe (Fig. 2). Domestic consumption accounts for only 5-20% while foreign markets absorb 80-95% of total farmed production (Rosenberry, 1991). Often, products rejected for the export market due to small size, bacterial load, or chemical residue levels are shunted to local markets.

Asia has been called the cradle of aquaculture where the culture of fish in fresh water probably began about 500 B.C. and in brackishwater ponds later in 1400 A.D. From Java in Indonesia, brackishwater culture spread to the Philippines and other Southeast Asian countries (Hora and Pillay, 1962). Traditional shrimp culture has been characterized by low- density stocking of wild fry (entering ponds during passive tidal water exchange or purchased from fry collectors) generally in polyculture with fish. Modern shrimp farming can be traced directly to M. Fujinaga of Japan who laid the groundwork for hatchery technology with his pioneering research on the spawning and larval rearing of kuruma ebi, scientifically known as Penaeus japonicus in the 1930s. The availability of shrimp seed as commercial hatcheries were established throughout the region in the 1970s and 1980s coupled with marketing of formulated feeds and the active support of governments and private sector set the stage for the industry take-off in the 1980s (Fig. 1).

Shrimps and prawns are swimming crustaceans that inhabit the warm marine waters of the tropics and subtropics. Belonging to the Family Penaeidae, their complex life history starts in nearshore waters where ripe females spawn eggs which hatch into free-swimming larvae. These metamorphose through a series of stages into postlarvae which move toward nursery habitats along the coastline and estuaries. Here they develop further into juveniles and subadults until they undertake the reverse migration to offshore waters where they spawn and remain until they die. This life cycle is

typical for most penaeids although a few species are able to complete the cycle in purely marine or estuarine water.

Among 300 species of penaeid shrimp known worldwide, only a few dozen are commercially important in capture fisheries. Table 3 lists these species, their common names and origin. Among the leading cultured species, the giant or black tiger prawn Penaeus monodon has increased its share in global production from 33% to 56% and the Ecuador white shrimp P. vannamei from 14% to 19%, whereas the Chinese white shrimp P. chinensis has declined from 28% to 6% in the last five years (Rosenberry, 1989, 1990, 1991, 1992, 1993).

II. SHRIMP FARMING

The culture of shrimp is basically a two-step process composed of a broodstock-hatchery phase for producing seed or postlarvae and a grow-out phase usually in earthen culture ponds for ongrowing of fry to marketable size. (Sometimes a nursery for rearing of postlarvae to larger juveniles is incorporated.) When the industry is highly developed, specialization includes producers or manufacturers of farm equipment, algal feeds, formulated feeds, spawners, nauplii and services (for pond cleaning, harvesting, etc.). Total capitalization of the Ecuadorian shrimp industry in 1990 was $1.66 million comprising 1,422 farms ($1,419,100), land sales ($120,200), 75 packing plants ($44,100), 120 export companies ($38,700), and 55 hatcheries ($133,300), not including some 1,700 shrimp-associated enterprises (Aiken, 1990). These enterprises employed around 100,000 persons including 32,000 artisanal fishermen (fry collectors), 41,000 workers in shrimp farms, 1,600 in hatcheries and 5,800 in processing plants (Hirono, 1989). Around 114,000 persons were employed in 19,000 Thai shrimp farms in 1991 (FAO/NACA, 1994) and shrimp processing plants in India absorbed some 500,000 skilled personnel.

Because of the volumes of shrimp harvested and amounts of water utilized, it is the grow-out phase that generates most of the profits, and problems, in shrimp aquaculture. Grow-out or farming systems for shrimp are classified into four categories--traditional, extensive, semi-intensive and intensive-- characterized by increasing stocking rates supported by corresponding feed and water management inputs (Table 4). Traditional culture with stocking rates below 10,000 fry/ha (<1/sq m) often in polyculture with fish, and average production not exceeding 500 kg/ha/yr depends completely on natural food and tidal flushing. Supplemental wet or dry feeds and pumping are used only occasionally in extensive culture and more regularly in semi-intensive farming as densities increase to 10,000-30,000/ha (1-3/sq m) and 30,000-100,000/ha (3-10/sq m), respectively. In intensive ponds where fry are stocked at 10-30/sq m or more, feeding and water management are completely dependent on formulated pellets, pumps and aerators. Average yearly production is 0.6-1.5 mt, 2-6 mt and 7-15 mt, respectively for extensive, semi- intensive and intensive culture (Table 4).

According to Hirasawa (1985), intensive farming is characterized on a per kilogram basis by low fixed cost because of high productivity per area, but high variable cost mainly for feeds and water quality maintenance. Profitability depends on market price and production costs. If market prices are favorable, intensive farming remains profitable from the sheer volume of production; once prices drop, so does profitability. Semi-intensive farms will survive because of relatively higher productivity at lower production costs. Using 1987 data from Philippine farms, Posadas (1988) found that intensive farms had higher profitability compared to semi-intensive farms on a per hectare basis but a lower profit per kilogram. Similarly, a more recent study (Auburn University, 1993) showed that low-density (2/sq m) culture gave higher income per kilogram but lower profit per hectare than high-density (above 10/sq m) farms in the Philippines. In Indonesia, gross and net profits increase with intensification of culture but so does breakeven price (Chamberlain, 1991). Therefore intensive and semi-intensive farms can only remain profitable at selling prices of $4.37/kg and $3.28/kg,

respectively.

III. ENVIRONMENTAL EFFECTS OF SHRIMP FARMING

The environment affects aquaculture just as aquaculture impacts on the environment. Two events in 1993 illustrate the first relationship in the case of shrimp culture--the crash of Chinese farms particularly in the north due in part to increasing levels of industrial pollution around the Gulf of Bohai (Anon., 1993a) and the Taura syndrome in Ecuador (Anon., 1994). In the latter, massive mortalities in pond shrimp were apparently caused by fungicides used in banana plantations.

This paper will focus on the on the enviromental effects of shrimp farming. These effects include the loss of mangrove goods and services, soil and water salinization, over- exploitation of wild stocks and destruction of natural seed resources, the abuse of chemicals, and species introductions. Some of these factors have been implicated in the "boom-and- bust" pattern where peaks of production are followed by sharp declines with losses valued at $187 million in Taiwan in 1987 and $750 million in China in 1993 (Fig. 1).

A. Mangroves - Mangroves are characteristic features of protected areas along tropical and subtropical coastlines (38oN to 40oS latitude) (Chapman, 1984) which total 160,000 sq km (Saenger et al., 1983). Since most of the cultured penaeid species are found at these latitudes, it follows that existing mangroves or former mangrove areas now converted to salt beds, agricultural land, etc. are presenttly under the greatest threat of conversion to shrimp (and fish) ponds.

A good example of this mangrove-to-pond conversion is apparent from the Philippine experience of a decrease in mangroves from approximately 500,000 ha in 1920 (Brown and Fischer, 1920) to 132,500 in 1990 (Auburn University, 1993) matched by an increase in ponds from 61,000 ha in 1940 to 223,000 ha in 1990 (Fig. 3). During the 1951-1988/1990 period, approximately half of mangrove loss of close to 280,000 ha could be attributed to pond development (Fig. 4).

Similarly, 50% of over 171,000 ha of mangroves lost in 1961-1987 in Thailand and most of the mangrove loss of 30,000 ha between 1969 to 1987 in Ecuador was due mainly to shrimp pond construction (Aksornkae, 1988; Olsen and Figueroa, 1989). Around 10,000 ha of the Sunderbans mangrove areas on the border shared by India and Bangladesh have been converted into shrimp ponds (Anon., 1993b).

Among other factors, the earlier conversion of mangroves to aquaculture ponds in the 1950s and 1960s can be traced to the pervasive belief that wetlands are wastelands and to financing from such multilateral institutions as the International Bank for Reconstruction and Development (Siddall et al., 1985) and the Asian Development Bank (Primavera, 1993).

The varied goods provided by mangroves include fuel (firewood, charcoal); construction (roof shingles, timber, beams, poles); fishing (poles, floats); agriculture (fodder, lime); paper production; drugs and beverages (vinegar, alcohol, medicines); household items (furniture, glue); textile and leather products (dyes, tannins); forage for livestock; and food products mainly fish, crustaceans and molluscs (Saenger et al., 1983; Hamilton and Snedaker, 1984). In addition to this wide array of products, mangroves act as a buffer zone providing coastal protection during typhoons and storm surges, reduce shoreline and riverbank erosion by stabilizing sediments, and control of pollution by removal of nutrients, suspended solids, heavy metals and toxic hydrocarbons (Saenger et al., 1983; Hamilton and Snedaker, 1984; Phillips, 1994).

Rough valuation efforts give maximum figures of over $11,000/ha/yr from forestry and fisheries products (see references in Primavera, 1993) and $277,00/sq km (=$2,770/ha) for artisanal fisheries in mangroves and associated lagoons and estuaries (Gedney et al., 1982). Because conventional

financial analysis usually includes only marketed goods (e.g. fish and crab catches) and ignores non-monetized benefits such as traditional medicines and storm protection (Hamilton and Snedaker, 1984), such figures will tend to underestimate the full value of mangroves. Kapetsky (1987) has estimated an annual yield worldwide of 751,000 t of fish, shrimps and crabs from coastal lagoons and estuaries and 175,000 t of molluscs (meat weight) from openwater area associated with mangroves supporting more than 460,000 coastal fisherfolk. For example, the Matang Mangrove Forest Reserve in Malaysia provides direct and indirect livelihood to a work force of 2,400 people in the forestry industry and 10,000 in fisheries (Ong, 1982).

Nevertheless, local populations lack formal titles or property rights to traditionally exploited mangrove resources so that the conversion of mangrove swamps into fish/shrimp culture ponds transforms multiple- use, multiple-user resources to a single-purpose resource (Bailey, 1988). Employment of local people in shrimp farms is often limited to low-paying jobs such as laborers and guards while technical and managerial positions are reserved for outsiders because shrimp farming is capital- rather than labor- intensive (Aksornkae et al., 1986). Funds invested in pond culture are generated from outside the community so profits also leave the community. The economic benefits of shrimp culture did not trickle down to the residents of two coastal villages in Panay Island, central Philippines but remained with the farmers, entrepreneurs and traders (Amante et al., 1989). Instead of improving living standards and village welfare (in terms of housing, property ownership, availability of electricity, toilet facilities and water supply), shrimp farming brought about social displacement and marginalization of fishermen. Shrimp culture in Ecuador has also led to multiple use right conflicts, loss of valuable cultural sites, and increased difficulty in resource management aside from reduced occupational diversity in coastal communities and inequitable allocation of benefits (Epler, 1992).

B. Salinization of soil and water - The release of salt water from shrimp ponds has caused salinization of agricultural lands--45,000 ha of once productive rice and also shrimp farms in central Thailand have become an ecological desert (Briggs, 1993). The breaking of coastal embankments in the search for sea water has led to salinization of rice lands and a drop in rice production from 1.7 t to 0.5 t in the last 10 years in Khulna, Bangladesh (Anon. 1993b).

A basic feature of the intensive shrimp farming technology developed in Taiwan was the requirement of brackishwater salinity of 15-25 ppt for the rearing of P. monodon (Liao, 1987; Chiang and Kuo, 1988) achieved by pumping large volumes of underground water--29,000 to 43,000 cu m in intensive culture vs. 11,000 to 21,430 cu m in semi-intensive farming for each ton of shrimp produced (Phillips et al., 1991). With the emptying of groundwater aquifers, salinization has occurred due to intrusion of sea water direct from the coast or from pond discharge of salty water. Either way, the saline contamination of ground water results in reduced water supplies for domestic and agricultural purposes as experienced in Thailand and the Philippines (Macintosh and Phillips, 1992; Primavera, 1993; Briggs, 1993). Continuous extraction of ground water eventually led to land subsidence of up to 2 m and more in Taiwan (Chen, 1990).

Ironically, the 15-25 ppt requirement for intensive P. monodon ponds that has caused so many ecological, financial and social problems is proving to be more mythical than real with the production of tiger shrimp at full strength sea water of 30-35 ppt in Thailand and the Philippines (Kongkeo, 1988; Primavera, 1993).

C. Feeds and pollution - Because it relies mainly on natural food and tidal water exchange, extensive culture in ponds places minimal stress on the environment (aside from the major loss of habitats in the case of mangrove-based ponds). Evidence of such sustainability is the centuries' old culture of milkfish in tambak in Indonesia and the Philippines.

In contrast, intensive farms need large amounts of feeds to support high densities of shrimp, and flush correspondingly high loads of wastes into coastal waters. Estimates based on digestibility coefficients and feed conversion ratios show that only 17% by dry weight of total feeds applied to a pond is harvested as shrimp; 15% is not consumed, 20% becomes fecal material and another 48% goes to energy utilization, metabolites and molted shells (Fig. 5). Pond wastes consist of solids (excess food, feces, plankton, bacteria) and dissolved matter (e.g. ammonia, urea, carbon dioxide and phosphorus) (Table 5). Levels of nitrogen, phosphorus and other water quality parameters are generally higher in effluent than inflowing water (Macintosh and Phillips, 1992).

Nutrient budgets for intensive shrimp ponds in Thailand have been constructed by Briggs and Funge- Smith (1994). Ninety-two percent of nitrogen is supplied by feeds but harvested shrimp account for only 21% of total nitrogen output compared to 31% in sediments, 22% in effluent water and 13% drained during harvest. Phosphorus (51% from feeds, 21% from fertilizer and 26% from old pond sediment) is transformed less efficiently--84% in sediments, 10% lost during regular exchange and harvest, and only 6% becomes shrimp biomass.

Although the pollution potential of shrimp pond effluents is minimal compared to domestic or industrial waste water (Macintosh and Phillips, 1992), problems arise because of the large volumes of water discharged from intensive farms compounded by the high concentration of farm units in areas with limited water supplies and inadequate flushing. Intensive shrimp farming as practised in Taiwan and parts of Southeast Asia has been unsustainable because discharge of effluents has exceeded the assimilative capacity resulting in pollution not only of receiving waters but inside the ponds as well. The production of nearly 58,000 t of shrimp from a strip of land in southeastern Thailand measuring 40 km long and 2 km wide in 1992 resulted in he addition of around 4.1 t of nitrogen, 0.4 t of phosphorus and 11 t of biological oxygen demand daily to nearby coastal waters (Briggs, 1993).

At present, 25-50% of total world production of formulated shrimp feeds consists of fish meal and to a lesser extent, shrimp meal, squid meal and fish oil (Tacon, 1993). By the year 2000, shrimp farms in Asia will need 1.1 million mt of compound feeds which in turn will use up 20% of total world supply of fish meal and fish oil compared to only 14% in 1990 (Tacon, 1993). Because these raw materials are also used for livestock feeds and human consumption, prices of poultry feeds and chicken have increased in Thailand, and domestic food fish have been diverted to shrimp feed manufacture in India and Malaysia (New and Wijkstrom, 1990).

D. Chemicals - A whole suite of antibiotics and other chemotherapeutants have been used to prevent or control a multitude of bacterial, fungal and viral diseases in shrimp hatcheries and farms. Other chemicals are also applied as disinfectants, water and soil conditioners, pesticides and fertilizers (Table 6). The prophylactic use of antibiotics at low doses to prevent the occurrence of disease has become widespread in the Philippines and other tropical countries (Brown, 1989; Baticados and Paclibare, 1992). The rampant use of antibiotics in shrimp hatcheries in the Philippines and Thailand has led to the development of drug-resistant bacteria (Baticados and Paclibare, 1992; Nash, 1990). Such high levels of antibiotic use in hatcheries have been associated with the perception of some farmers that wild fry are sturdier than hatchery ones. Weak postlarvae produced by hatcheries were among the factors responsible for the 1988 collapse of Taiwanese farms (Lin, 1989).

Antibiotics and other chemicals used in aquaculture may be toxic not only to the targetted pathogen or pest but also to nontarget populations such as the cultured species, wild flora and fauna, and human consumers. After finding unacceptable levels of oxytetracycline and oxolinic acid in farm-raised shrimp from Thailand in late 1990, the Japanese government initiated a compulsory inspection program for Southeast Asian shrimp (Rosenberry, 1991) in compliance with the 1959 Food Sanitation Law. In response, the Thai government and private sector developed guidelines and

a monitoring program that resulted in significant reduction of antibiotic residues in exported shrimp (Kungsuwan, 1992 in Macintosh and Phillips, 1992). Unfortunately, such regulations did not extend to domestic supplies--8.4% of a total of 1,461 samples of P. monodon obtained from open markets in Thailand between October 1990 and October 1991 tested positive for oxytetracycline and oxolinic acid with levels above prescribed limits (Saitanu et al., 1994). Oxytetracycline, furazolidone, erythromycin and kanamycin have been found to be health hazards associated with digestive disorders, allergies; the widely-used antibiotic chloramphenicol can cause anemia, stomatitis, etc. in humans (Schnick, 1991). Even malachite green has been implicated as a carcinogen.

Widespread chemical use in Philippine hatcheries has caused mortalities and morphological deformities in shrimp larvae (Baticados and Paclibare, 1992). The toxicity of some drugs limits their use as therapeutants for shrimp diseases.

E. Seed - Traditional low-density ponds in Asia rely mainly on wild-caught fry because seed requirements do not exceed 10,000/ha (Table 4). The preference for P. monodon has led wild fry collectors to wastefully discard the larvae of other prawn and fish species which are much more abundant (Motoh, 1981; Silas, 1987). The loss of mangrove habitats, mostly converted to ponds, has been implicated in the decline in abundance of wild shrimp larvae, the stocking material for most farms in Ecuador (Twilley, 1989).

Semi-intensive and intensive farms require hatcheries to provide the millions of postlarvae required for stocking. Majority of giant tiger prawn hatcheries in Asia depend on either mature females (spawners) or immature broodstock caught from the wild (Primavera, 1985).

Subtropical countries like Taiwan and China which farm the tropical P. monodon have resorted to importing spawners and broodstock from other countries (Weidner and Rosenberry, 1992), whether legally or otherwise, to supplement inadequate local supply. Without extensive imports of live tiger prawns from Southeast Asia, the Taiwanese prawn industry would never have taken off--wild spawners imported from 1976 to 1982 fetched prices of up to $2,000 apiece (Liao, 1989). Yearly imports from Malaysia totalled 40,000 spawners from 1979 until the Malaysian government banned exports in 1983 (Chin, 1988). Thus Taiwanese hatcheries had to shift to broodstock using the eyestalk ablation technique (Primavera, 1978) with imports of immature females ranging from 70,00 to 160,000 yearly during the 1982-1986 period (Chin, 1988). When the industry collapsed in 1987, excess fry (and possibly their pathogens) from Taiwanese hatcheries were being exported in reverse to Southeast Asian farms (Primavera, 1993).

F. Introduction of exotic species - Movements within the natural geographic range of a species such as those of P. monodon broodstock and fry described in the previous section are called transfers while those outside native ranges of a given species constitute introductions.

Among hundreds of penaeid species described worldwide, less than a dozen exhibit fast growth rates and captive breeding, among various criteria required for culture. The growing interest in shrimp farming has been accompanied by numerous transfers and introductions of adults and larvae of these preferred species, mainly the Indo-Pacific P. monodon and the Eastern Pacific P. vannamei, to and from culture facilities all over Asia and Latin America. Lightner (1990) has constructed a shrimp (and pathogen) transfer network based on shipments of shrimp broodstock and postlarvae for commercial and research purposes outside their normal geographic range over two decades (Fig. 6). A major concern associated with species introductions is the spread of viruses and other pathogens--out of 24 worldwide occurrences of shrimp viruses, Lightner and Redman (1992) reported that 9, possibly 10, were due to introductions.

Acute mass mortalities behind the 1993 collapse of the shrimp crop in China may have been

triggered by one or more viruses (Anon., 1993a). The greater disease resistance of the introduced species P. monodon, P. japonicus and P. vannamei compared to the native P. chinensis underscores the possible role of newly introduced viruses in these mortalities (Anon., 1993a). Viral diseases affecting cultured penaeids in Israel are believed to have been introduced through importation of the non-native shrimp P. monodon and P. stylirostris (Colorni et al., 1987).

In addition to pathogens, introductions of aquatic species may lead to habitat changes, competition and predation, and genetic interactions with native species (Sindermann, 1993).

IV. RECOMMENDATIONS

To achieve long-term sustainability, the shrimp farming industry will need to seriously consider its effects on the environment. To assess the impacts, and improve environmental management, of coastal aquaculture development, FAO recommends the protection of resources and environments required for such development (Barg, 1992). This may include strengthened efforts in planning and management of coastal aquaculture development, integrated coastal area management (ICAM), implementation of the Environmental Impact Assessment (EIA), monitoring of pollution, and environmental legislation, among others.

For shrimp culture, these measures include management of pond effluents, regulation (of species introductions, chemical use, etc.), ICAM, and rehabilitation of wild habitats and populations. Because shrimp is a product traded mainly in international markets and the cultured species are common to countries within a region, these actions will need regional and international cooperation.

1. ICAM - The over-all goal of ICAM or ICZM (integrated coastal zone management) is to ensure optimal sustainable use of coastal natural resources, perpetual maintenance of high levels of biodiversity and real conservation of critical habitats by coordinating the initiatives of various economic sectors toward long-term optimal socio-economic outcomes including resolution of conflicts (Clark, 1992). In addition to aquaculture, the multiple uses of the coastal zone include urban settlement, industrial development, waste disposal, ports and marine transportation, fisheries, forestry and tourism. For mangrove areas in particular, priority zones for the following activities can be designated (Bird and Kunstadter, 1986): a) preservation-conservation for biodiversity and ecological functions including natural exchanges and storm buffer, b) sustained yield of fisheries and silviculture, c) reforestation areas, and d) conversion to culture ponds, salt beds, etc. preferably on previously altered sites.

An Environmental Impact Assessment should be required to ensure compliance with site selection criteria that include not only standard grow-out parameters such as salinity and land elevation which treat the farm as an isolated unit but also the potential effects of the environment (e.g., industrial pollution sources affecting shrimp culture) and vice-versa (e.g., capacity of receiving waters to dilute or absorb effluents from shrimp ponds). Zoning guidelines should prevent the concentration of farm areas as seen in Taiwan and the Gulf of Thailand where levels of pond effluents eventually exceeded the "carrying capacity" of the environment. Siting ponds inland will spare mangrove areas but jeopardize land and water through salinization whereas location in the intertidal mangrove zone does not cause salinity problems but is destructive of mangroves.

2. Protection and restoration of mangrove habitats and wild stocks - Integrated coastal management programs should address the question of how much mangrove vegetation should be left undisturbed in order to maintain such functions as storm protection, and nutrient/particulate export to nearshore communities. Remaining mangroves should be conserved and existing legislation that prohibits further conversion and requires greenbelts should be enforced. Abandoned ponds should be allowed to regenerate back to mangroves by breaking down dikes. Large-scale reforestation should be undertaken in severely degraded areas. Many lessons can be learned from the experience of

Bangladesh where a total of 120,000 ha have been afforested since 1966 to protect and stabilize coastal areas from severe cyclone damage (Saenger and Siddiqi, 1993). The planted species include Sonneratia and Avicennia whereas many rehabilitation projects depend solely on Rhizophora species because of convenience in obtaining propagules. (Ironically, some 10,000 ha of the natural mangrove forest in the Bangladesh Sunderbans have been converted to shrimp ponds [Anon., 1993b]).

These mangroves can be managed for silviculture and give annual income up to $11,000/ha/yr (see references in Primavera, 1993). Integration of forestry, fisheries and aquaculture in mangroves can also be seen in the tambak tumpang sari of Indonesia (Naamin, 1986) and traditonal mangrove-shrimp ponds in Vietnam. Moreover, nutrients produced by shrimp farms can be absorbed by mangroves--2.4-7 ha of mangroves for nitrogen wastes and 3-22 ha for phosphorus for each hectare of shrimp pond (Robertson and Phillips, 1994). Some forms of aquaculture are also compatible with mangroves-- stake, raft and bottom culture of oysters and other shellfish; fish culture in pens, cages and rock mounds (also called brush park fisheries); and seaweed culture.

Conservation of wild shrimp stocks should cover not only juveniles through preservation of mangrove nurseries but also adults through restocking programs such as those for P. japonicus in Japan (Uno, 1986) and P. chinensis in China (Liu et al., 1991). The ban on collection of wild P. chinensis broodstock for hatchery purposes during their spawning migration (Liu, 1990) enhances recruitment and increase in wild catches. (The same species, P. chinensis, is important for both capture and culture fisheries in China, unlike other countries.)

3. Management of pond effluents - Intensive culture has been recommended as an alternative to extensification which exploits wide mangrove areas. However, such intensification can only be viable if pollution levels in effluents are minimized and salinization of outlying areas prevented.

Reduction of wastes means proper site selection, pond design and husbandry--pond preparation, water management and feeding. Since most of the nutrients in effluents come from feeds, feeding management should consider appropriate nutrient requirements, feeding strategies and improved water stability of pellets. Control of nutrient and solid loadings can be accomplished through biological (polyculture with mussel or seaweed) and physical (sediment and oxidation ponds) treatment.

Ecological concerns over chemical use in aquaculture can be addressed by disallowing the prophylactic use of antibiotics, setting up strict guidelines for use of chemicals, establishing withdrawal times and permissible residue standards, development of probiotics and vaccines, and banning the use of drugs important in human health. On the other hand, it has also been argued that excessive and misguided restrictions placed on the use of drugs could become a threat to the health of the cultured animals as much as the pathogens (de Kinkelin and Michel, 1992).

4. Legislation and regulation - For shrimp culture to be sustainable, there is a need to regulate pond effluent disposal, chemical use, groundwater extraction as well as mangrove conversion, if appropriate controls are not yet in place. Toward this end, the following measures apply the principles of conservation, amelioration, prevention and protection: a) preventive - government authorizations (licenses, permits), EIAs and regulation (quality standards or permissible levels); b) enforcement - criminal prosecutions, and c) economic incentives/disincentives - effluent charges (the polluter pays principle), user charges (e.g., for sea water or ground water), grants or subsidies, e.g., low- interest loans to encourage more environment-friendly operations (Van Houtte in FAO/NACA, 1994). There may be some complications, however, in cases where farms are state-owned as in China and Vietnam.

As a result of the 1990 shrimp crop failures in the Gulf of Thailand, legislation was set in place to ban the release of salt water into public freshwater resources or other farming areas and the flushing of mud or silt from shrimp farms into natural water sources or public areas, to set a maximum biological oxygen demand in effluents, and to require treatment and sedimentation ponds for farms greater than 8 ha (Briggs and Funge-Smith, 1994). Nevertheless, to what extent these measures are implemented remains uncertain (I. Baird, Mangrove Action Project, pers. comm.). Self-regulation by the industry may be more effective than government regulation (Bailey, 1992). Based on the Ecuador experience in promulgation and enforcement of laws and policies relating to shrimp culture and mangroves, coastal management policies in developing countries should take into account the local social and political economy rather than copy integrated coastal zone management models designed for developed countries with a stable middle class (Meltzoff and LiPuma, 1986).

Resource use fees should be commensurate with economic rents, defined as total revenue minus all costs excluding the lease fee (Evangelista, 1992). For example, the economic rent of ponds converted from mangroves in the Philippines ranges from P515/ha to P3296/ha, way above the present pond lease fee of P50/ha (Evangelista, 1992). The imposition of such fees would replace reliance on bureaucratic red tape and administrative discretion and reduce the amount of corruption that characterizes the allocation, management and regulation of natural resources such as mangroves (World Bank, 1989).

V. REGIONAL COOPERATION

The major venues for regional cooperation, particularly among producing countries, are in research and information networking and regional trade. (Other recommended actions for national governments, non-governmental organizations, and at the farm level are enumerated in Briggs, 1993 and FAO/NACA, 1994.)

1. Research and information network - Collaborative research efforts are needed especially on valuation of mangroves and delineation of greenbelt areas, impacts of exotic species on biodiversity, common methodologies for evaluating environmental impact, disease-free broodstock and healthy seed, nutrient requirements of species and quality standards for feeds, assessment of impacts of drugs and chemicals (Briggs, 1993; FAO/NACA, 1994). Regional cooperation is also needed in the generation of data to hasten the worldwide marketing of drugs. Mechanisms for this include regional or universal acceptance of guidelines for mammalian safety and environmental studies for aquaculture drugs, acceptance of protocols for studies on aquatic species, willingness to develop regulations and registration requirements for aquaculture drugs, and acceptance of codes for aquaculture (Schnick, 1992).

The information network will include exchange of technicians and sharing of technology (e.g. mangrove reforestation in Bangladesh, mangrove silviculture in the famous Matang Forest of Malaysia and shrimp restocking programs in Japan) among countries in the Asia-Pacific. Patenting of technology runs counter to the principle of information sharing and patents are not always awarded to those who develop the technology. The case of eyestalk ablation, first observed and documented by a French scientist (Panouse, 1943) will illustrate this point. Since it was first used to induce ovarian maturation in P. monodon broodstock in Indonesia and the Philippines in the 1970s (Santiago, 1977), the ablation technique has become a universal procedure used in hatcheries worldwide (Primavera, 1978, 1985). Yet a U.S. enterprise applied for, and was granted, a patent for the technique in the 1980s.

2. Regional trade in equipment and supplies - The export of equipment and supplies for hatchery and grow-out operations from countries with more advanced technology will hasten the development of shrimp culture among such latecomers as India and Vietnam, provided the practice is not made an excuse for dumping obsolete products. Trade in shrimp spawners, broodstock and fry should also be

allowed only if legal prohibitions in the respective importing/exporting country are not violated. This brings to mind the rampant smuggling in the 1980s of P. monodon spawners and broodstock mostly from Malaysia and the Philippines to Taiwan in spite of a ban on exports of live shrimp instituted by these countries to protect local hatcheries. Countries should agree on health standards for quality control of marketed shrimp to minimize residue and disease problems. Importations of foreign shrimp species should follow strict procedures such as the EIFAC/ICES Code of Practices (Turner, 1988) which incorporate a stringent review mechanism to evaluate the validity of introductions, potential for transfer of diseases and parasites, and ecological benefits/risks.

Smuggling of shrimp can also be minimized--approximately 75% of 1987 shrimp exports from Peru valued at $12 million actually came from Ecuador with traders taking advantage of the differences in currency exchange rates (Aiken, 1990). The resulting capital flight is a serious problem because it extracts investment capital which developing countries like Ecuador sorely need (Meltzoff and LiPuma, 1986).

3. Price volatility - Prices for exported shrimp are highly volatile. The 1989 decline in international prices for shrimp could be traced to reduced demand after the death of the Emperor in Japan, one of the major shrimp markets. Conversely, high prices in 1992-1993 resulted from the large-scale failure of shrimp crops across China and Indonesia leading to a shortage of supplies. In this connection, the formation of a cartel among major producing countries to control prices and production has been suggested by Liao (1992). Another approach to address the problem of price volatility is the development of domestic markets.

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