

Report to the Overseas Development Administration

DEVELOPMENT OF STRATEGIES FOR SUSTAINABLE SHRIMP FARMING

Research Project R4751

**STATUS, PROBLEMS AND SOLUTIONS FOR A SUSTAINABLE
SHRIMP CULTURE INDUSTRY WITH SPECIAL REFERENCE TO
THAILAND.**

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Guidelines for planning the development of sustainable aquaculture have recently been proposed (Barg, 1992). These involve first an understanding of the environmental and socio-economic significance and impacts of such development in integration with existing and proposed coastal aquaculture development and management plans. This requires the proper formulation and implementation of environmental impact assessments, site selection criteria and a suitable legal framework in support of aquacultural development. Onto this framework should then be promoted environmental farm management practices including training and extension of techniques for suitable land use, species production, waste management, feeding practices, chemical use and product quality (Barg, 1992).

In Thailand, as in other countries, this sequence of development has not been followed. This is due to various reasons, including lack of governmental regulation on the expansion of aquacultural development together with a general ignorance of its environmental and socio-economic consequences. Intensive shrimp farming as practised in Thailand thus provides a perfect example of the unsustainable development of such an aquacultural system. The following is a brief history of the Thai shrimp farming industry, its successes and failures, and the lessons that it has provided for the future of the world industry.

2.1 THE HISTORICAL DEVELOPMENT OF THE THAI SHRIMP CULTURE INDUSTRY

2.1.1 CONDITIONS FOR DEVELOPMENT

As of 1991, Thai shrimp production ranked fifth in the world after China, the United States, India and Indonesia. Since the early 1980s the capture industry of Thailand has stagnated at the level of 100,000t yr⁻¹. The main reason for this has been the ratification by Thailand in 1981 of the 200 mile exclusive economic zone in the Gulf of Thailand, limiting her catch to the Thai-operated parts of the Gulf and the Andaman Sea on the west coast. This limitation on the fishing grounds led Thailand to put special emphasis on shrimp culture development in coastal areas. Thailand had many advantageous and sometimes unique features favouring such development. These included 2,600 km of coastline, a lack of typhoons or cyclones, ideal and un-fluctuating water temperatures and good soils and terrain for pond construction (Ferdouse, 1990; Liao, 1990; New, 1991; Menasveta, 1992).

2.1.2 INTENSIFICATION

Thailand had in fact been culturing penaeid shrimp for several decades, but exclusively by extensive polyculture methods (<10 shrimp m⁻² with no supplementary feeding) using finfish, *Penaeus merguensis* and other 'low value' penaeid species which yielded only 180 kg ha⁻¹yr⁻¹ or less. Then during the 1970s the government supported the development of freshwater prawn (*Macrobrachium*) farming. When that industry reached the point where supply exceeded demand and the market price was pushed down, the government assisted the conversion of *Macrobrachium* to penaeid hatcheries. These hatcheries concentrated on producing *P. monodon* (due to its large size and rapid growth rate) for subsequent intensive pond culture. Intensive culture of *P. monodon* as practised in Thailand uses hatchery-reared seed, stocked at anything over 20 shrimp m⁻², supplementary feeding usually consisting of high-protein, formulated pellets and pump-assisted water exchange. Thus, from about 1986, with the help of Taiwanese technicians, heavy private investment and tax and other incentives from the government, Thailand began to farm *P. monodon* intensively along the northern edge of the Gulf of Thailand from Samutsongkram to Chon Buri (Figure 1). With these techniques, the production rate increased to an average yield of 1 t ha⁻¹crop⁻¹ by 1988 and 2 t ha⁻¹crop⁻¹ by 1992, production occasionally reaching as high as 6 t ha⁻¹crop⁻¹ with 2-3 crops per year. Capitalising on the crash of the Taiwanese industry from 80-100,000t in 1987 to 30,000t in 1988 and only 9,000t in 1990 (Table 1)

and the consequent increase in shrimp prices, Thailand's production of cultured shrimp rose sharply from 18,000t in 1986 to 93,000t in 1989 and up to 163,000t in 1992 (Table 1). The industry was then worth approximately £ 600-800 million in foreign exchange (Sheeks, 1989; FAO, 1992; Fast, 1992; Menasveta, 1992; Anon., 1992a,b,c; Anon., 1993a,b).

From the beginning of the intensive shrimp farming industry, first in Taiwan and later in Thailand, it tended towards overexpansion. This was because, despite the high initial investment cost, the first harvest could be obtained within four months, three crops could be obtained yearly and potentially high profit margins could be realised with, at first, no end in sight (Chong, 1990). Thus, once intensive culture was adopted, land prices rose and forced new investors into ever-increasing intensity to pay back the spiralling investment costs. This was further aggravated due to high operating costs and strong market competition until there was no simple alternative to increasing intensity (Sheeks, 1989).

2.1.3 LAND USE

The 16,500 shrimp farms in central, south and eastern Thailand are now 85 per cent intensive, with only 15 per cent still being farmed in the traditional extensive ways (Anon., 1992b,c; Lohawathanakul, 1992). Of these farms 14,000 (80 per cent) are small-scale operators each with 1-2 ponds from 0.5-1 ha in size (Anon., 1992b). The expansion in shrimp culture has seen the area of land utilised by shrimp farmers double from 40,000 ha in 1985 to 80,000 ha or 0.15 per cent of the natural land area in 1992 (Figure 1, Table 1). This has meant the wholesale conversion of salt and extensive shrimp ponds to intensive ponds as the high-producing *P. monodon* culture practices were adopted, and the conversion of mangrove, rice paddy and other coastal lands into new highly-productive shrimp farms (Ferdouse, 1990; Liao, 1990; New, 1991; Menasveta, 1992; Anon., 1993b; Stanley, 1993).

2.1.4 ASSOCIATED INDUSTRIES

Due to the rapid expansion and initial success of the intensive shrimp culture industry, and in addition to the farmers themselves, business prospects and employment opportunities have been generated for many people in associated industries. The growing requirements of the burgeoning shrimp culture industry have stimulated the creation of infrastructure and capital investments, and have spurred economic growth in many areas as the industry has diversified and specialised, as it did in Taiwan. These support industries include the capture and supply of wild broodstock by fishermen, the hatchery production of nauplii and shrimp seed, nursery operations, shrimp farming equipment, live and pelleted feed and chemical production, distribution and sales, pond harvesting and cleaning industries, processing and cold storage plants and exportation companies. At present in Thailand there are about 30 large hatcheries and at least 1,000 backyard hatcheries and nurseries. Post-larval production is at least 2 billion yr⁻¹ and increasing. Shrimp feed production is estimated at least 100,000 t yr⁻¹. Shrimp processing plants have the present capacity to produce block frozen shrimp at 40,000 t yr⁻¹ from 70 processing plants and cold-storage facilities. The government is trying to promote these latter businesses since they are still inadequate to process the ever increasing amounts of shrimp being produced (Ferdouse, 1990; Liao, 1990; New, 1991; Anon., 1992b; Menasveta, 1992).

2.1.5 INITIAL PROBLEMS AND RESPONSE

Warning signs for the sustainability of the Thai shrimp culture industry became evident in late 1988/early 1989, when the farm gate price of farmed shrimp in Thailand decreased sharply from a high of £ 6.50-8 kg⁻¹ to only £ 2.50-4 kg⁻¹ for 30 kg⁻¹ size shrimp. This was due to many factors including: First, the poor market caused by the rapid expansion of production throughout Southeast Asia without any regard to marketing due largely to the price increase when Taiwan lost its production. This was combined with the slow Japanese market due to the death of Emperor Hirohito

and hence an over-supply of shrimp onto the world market in relation to the demand. The slow market was further aggravated at the time of the major harvest following the dry season at the end of 1988. Second, the lack of processing facilities to cope with the increased volume of shrimp produced. The unprocessed shrimp then had to be sold locally, which brought down the shrimp prices markedly. Thirdly, higher production costs, due mainly to feed cost increases. At that time, shrimp production costs on the intensive farms rose to £ 3.4 kg⁻¹, slightly higher than the market price for shrimp. Further complicating the situation at that time, the Thai shrimp feed industry also ran out of high quality fish meal (Ferdouse, 1990; Liao, 1990; New, 1991; Malasaidh, 1992; Menasveta, 1992; Quarto, 1992; Wallace, 1992; Anon., 1993b).

As a result of these problems the Thai government took action. The Department of Fisheries proposed limiting shrimp farming to 80,000 ha nationwide in order to maintain production at 100-300,000t annually, the Department of Fisheries, the Department of Trade and Commerce, the Shrimp Farmers Association and the Shrimp Exporters Association arranged shrimp exhibitions and cooking demonstrations from June 1989 to boost domestic demand for *P. monodon*. The governments' Board of Investment also facilitated the construction of more processing and cold storage facilities in order to hold shrimp until the market price recovered. Finally, the Commerce Ministry reduced electricity costs and allowed the tax-free importation of 100,000t of high quality fishmeal and encouraged 12 major feed producers to reduce feed prices by 12.5 per cent for direct sales to farmers through cooperatives and groups. During this time there were allegations of collusion amongst the big companies in the industry to control prices. Nevertheless, the action initially had the desired effect and in 1992, approximately 163,000t of *P. monodon* were produced in Thailand (Table 1) worth some £ 600-800 million in foreign exchange when exported to Japan, USA and Europe (Chong, 1990; Ferdouse, 1990; Liao, 1990; Niemeier, 1990; New, 1991; Fast, 1992; Fast & Lester, 1992; Malasaidh, 1992; Menasveta, 1992; Quarto, 1992; Wallace, 1992; Anon., 1993a,b).

2.1.6 PRODUCTION CRASH

Until recently, the impact of aquaculture on the environment (especially in the Third world) had been neglected. In the case of both Taiwan and Thailand, shrimp farming speculators (encouraged by the government incentives in Thailand) invested heavily in coastal property and began to generate quick profits. However, the over-exploitation of coastal areas, industrial pollution, improper site selection (particularly with regard to water supply and discharge), mis-management and self-pollution combined with a 'get-rich-quick' mentality that over-stressed the ecology of the intensive shrimp ponds and resulted in many people being forced into bankruptcy. Thus, the sudden wealth for some investors came at a high environmental and social price that finally led to the crash of these intensive culture industries after only 2-4 years. Taiwans' shrimp culture industry crashed completely in 1988 and that of Thailand along the north coast of the Gulf of Thailand (Figure 1) crashed in 1990 after just two growout seasons (Chua, 1993). The crash in Thailand resulted in the central regions' production falling from 70 per cent to just 20 per cent of the countries' total, with 80-90 per cent of the farms around Samut Sakhon going bankrupt in 1989-90 (McClellan, 1991; Chua, 1993; Phillips, Kwei Lin and Beveridge, 1993). Water/sediment quality and disease problems have persisted even though the production has stopped and the central region is now only managing to produce small quantities of shrimp by decreasing stocking densities and recirculating pond water through reservoirs and filters (Pomlerd Chanratchakool, AAHRI, pers. comm., 1993).

2.1.7 MIGRATION SOUTH

Since the crash in central Thailand, most of the farmers have either stopped production, going into other businesses or migrating to already overcrowded Bangkok, or moved south to farm new areas. This has left behind 45,000 ha of once productive rice and then shrimp farming land as an ecological

utilising recirculation and integrated culture techniques (Anon., 1991a,b; Lin, Ruamthaveesub & Wanuchsoontorn, 1991; Pornlerd Chanratchakool, AAHRI, pers. comm., 1993). Determining baseline information, followed by monitoring of the effects of specific development activities will help to quantify the synergistic relationships between aquaculture and the environment and assist the development of a truly sustainable industry (Ferdouse, 1990; Liao, 1990; Anon., 1991a; New, 1991; Malasaidh, 1992; Masae & Rakkheaw, 1992; Menasveta, 1992).

2.1.9 POTENTIAL LOSS

Without such measures, the industry in southeast Thailand will surely collapse. This will leave the government of Thailand in the situation of having to consider allowing expansion of shrimp culture in the currently mangrove-covered areas in western Thailand on the Andaman Sea (Figure 1), something which they have already legislated against. Alternatively, they will have to face the loss of thousands of hectares of formally productive land, the majority of an industry which earned £ 600-800 million in foreign exchange in 1992 and the basis for the business prospects and opportunities for thousands of people in allied industries. In Taiwan, the disaster of 1988 had a pervasive impact throughout the industries' service sectors and millions of dollars were lost (Chua, 1993). By 1989, 70 per cent of the countries' hatcheries had gone out of business, processing plants were desperately looking for business from other countries, feed companies were being forced to go abroad as were aquacultural production and investment companies of all types (Sheeks, 1989). Then in 1992 70 per cent and in 1993 90 per cent of Taiwans' *P. monodon* farms were again wiped out by disease. Taiwan therefore currently relies almost entirely on imported shrimp to meet its domestic market needs (Anon., 1993c). The crash in central Thailand's shrimp production in 1990 amounted to an estimated loss of £ 18.4 million (Phillips *et al.*, 1993). In 1992, due to a combination of environmental deterioration and high operating costs, shrimp production in the Philippines declined by about 50 per cent to 25,000t (Anon., 1992d, 1993c). 50-60 per cent of the processing plants on Javas' north coast closed since they had nothing to process, and disease and environmental problems are also currently affecting China and Ecuador (Anon., 1993c).

2.1.10 THE WAY AHEAD

What is necessary now is a reassessment of the goals of shrimp farming and a thorough understanding through research of the culture systems best suited for achieving these goals in a sustainable manner. This must ultimately involve cost-benefit analyses, including estimates for socio-economic and environmental damage, in the light of the long-term prospects for a downward trend in shrimp prices and hence the necessity for reducing production costs. Shrimp culture systems (and the countries that employ them) that produce shrimp competitively and consistently on the world market will become dominant (Anon., 1991a; Fast & Lester, 1992).

2.2 DETAILS OF THE PROBLEMS ENCOUNTERED

2.2.1 INTRODUCTION

The problems facing the Intensive shrimp culture industry as expressed in Thailand are manifold. They began with difficulties in marketing, storage and rising production costs which may, and to some extent have been solved by suitable government legislation on the restriction of shrimp culture activities. However, there are a host of other problems which are not so easily solved. These problems, as seen in the Thai situation began with the mis-management (due both to ignorance and greed) of the intensive shrimp pond ecosystem which lead in turn to stress, disease and mortality. This mis-management was compounded by the fact that in suitable coastal areas all available land was converted

to shrimp ponds resulting in an overstressing of the local resources, particularly in terms of water supply and discharge. The other main consequence of this poor site selection and management was a deterioration in the environment surrounding the shrimp farms from the construction of, and the wastes generated by the ponds, including organic materials, phytoplankton, chemicals, drugs and salt.

The high short-term profits obtainable and the rapid proliferation of intensive shrimp culture in Thailand also lead to land use and socio-economic conflicts. These included the conversion of salt, rice and other agricultural land as well as mangrove and other marginal land into shrimp ponds and the displacement of previous tenants and landowners. This situation then proved to be financially, ecologically and socially disastrous when the shrimp culture industry crashed in 1990 south of Bangkok leaving 45,000 ha of unproductive land in its wake (Figure 1). A large number of shrimp farmers moved on from these devastated areas and began the industry anew in the southeast of Thailand from 1989/1990. This area is now also beginning to lose production. The Thai shrimp farming companies and consultants (just as did the Taiwanese ones after the collapse of their own industry in 1988) are now beginning to approach and advise the governments and private companies of other developing nations.

The repeated use of the techniques that destroyed the industry in Taiwan and central Thailand are beginning to shake the industry in southern Thailand, Indonesia and the Philippines, and still further expansion is imminent both within Thailand and in other countries. What is now required therefore, is an examination of the factors contributing to the decline of this industry and the implementation of techniques capable of preventing a repetition of previous mistakes. The following is a breakdown of the major problems faced by the industry in Thailand, the solutions proposed and the research work necessary for the rectification of this situation.

2.2.2 ECOSYSTEM MIS-MANAGEMENT

a) Intensification

Intensive shrimp farming relies on the provision of large numbers of hatchery-reared seedstock, large amounts of high-quality pelleted feeds and intensive management of water and sediments in ponds stocked at high densities. Such intensive aquaculture is relatively new to most countries, but may be carried out at up to 50 shrimp m⁻² successfully with proper management (Pomlerd Chanratchakool, AAHRI, pers. comm., 1993). It is not shrimp farming *per se* that damages the environment but ignorance combined with human greed manifested as overstocking ponds at 3-4 times the recommended maximum of 20-30 shrimp m⁻² (Anon., 1991a,b; Anon., 1992b; Csavas, 1990; Stanley, 1993). It has been found that inorganic and organic nutrient concentrations increase with increased intensity ie stocking density and biomass (Pruder, 1992, Briggs, 1993a,b). Following the collapse of the Taiwanese industry Dr Liao I-Chiu formed a task force and identified a number of areas where mis-management had contributed to the collapse. These included: rapid high temperature larval rearing leading to poor quality seed, cumulative deterioration of ponds, excessive stocking density, poor feed quality, indiscriminate use of antibiotics and chemicals leading to lowered resistance to stress and disease, poor water quality, incompetent management and lack of hygienic practices (Liao, 1990). Dr Liao stressed that the mortalities were due to the combined effects of environmental stress leading to disease in an ever-worsening cycle. There was a technology gap between hatchery and pond grow out and an illusory belief in the power of chemicals to remedy the situation (Nash, 1988; Sheeks, 1989; Anon., 1990a). It is now quite clear that these lessons were not learned and that Thailand's industry has suffered from precisely the same set of problems.

Traditional extensive shrimp farming as practised in Thailand and other Asian countries relied on wild shrimp being trapped in fish/shrimp ponds and ongrown without major inputs at up to 10 shrimp m⁻².

Intensive shrimp farming was started in central Thailand by large, well qualified and experienced companies, facilitated by Taiwanese and Thai government-funded advances in hatchery and feed technology and advice from Taiwanese technicians and consultants. With the advent of this new industry many small-scale farmers began intensive shrimp farming themselves at densities of 30 shrimp m^{-2} within very restricted locations. Despite many warnings and good advice from the large companies and the Thai government through its fishery stations, these farmers, due to a combination of ignorance and greed, started farming shrimp at densities of up to 100 shrimp m^{-2} . Stocking shrimp at these densities will probably never be sustainable, but requires the adoption of complex management procedures to stand any chance of success. These management changes, specifically, those of adequate pond construction, maintenance and fertilisation, controlled stocking, adequate water quality exchange and management and effective treatment of disease were not adopted by the small-scale farmers. Unfortunately, the virgin ponds were able to support the high levels of shrimp biomass held under such super-intensive cultivation and production rates of as much as 25 t $\text{ha}^{-1}\text{yr}^{-1}$ for up to three years were recorded (Anon., 1989).

The high production rates achieved encouraged the rapid proliferation of the industry until it occupied almost all of a strip of land stretching from the shoreline to up to 4 km inland for more than one hundred kilometres (Figure 1). This land was centred around the mouths of a series of rivers and inter-connecting canals coming from highly populated, urban industrial centres of Thailand, on the northern edge of the already polluted Gulf of Thailand. Such crowding of shrimp farms into areas, often poorly supplied with good quality seawater, leads to the overstressing of the coastal environment. In 1987, immediately prior to the first crash in Taiwan's shrimp culture industry, she was producing 56.7 t of crustaceans per kilometre of coastline. Following the crash, however, production fell to 19.4 t km^{-1} in 1990 (Csavas, 1993). In comparison, Thailand's production increased from 13.5 to 37.1 t km^{-1} over the same time (Csavas, 1993). Thailand's industry in the central region then collapsed in 1990, indicating that these levels of production may not be sustainable. Figures for the Ranote/Hua Sai region of southeast Thailand reveal that this region produced nearly 1,500 t km^{-1} of shrimp in 1992 (ODA, unpublished report). The declining shrimp pond productivity currently experienced in this area is not therefore surprising. The problems encountered are probably due to the general pollution and deteriorating environmental conditions resulting from this intensity of culture (Phillips *et al.*, 1993).

b) Pollution

Over 3 years of intensive shrimp culture a combination of huge quantities of both organic and chemical effluent was emitted from the ponds into either the rivers and canals serving as both water supplies and outlet channels to extensive areas of ponds, or directly into and back out of the Gulf, where they combined with industrial pollution being brought by these rivers into the Gulf from Bangkok. The ensuing rapid and unregulated deterioration of water quality in the shrimp farming areas led first to acute stress in the shrimp and then to the proliferation of shrimp bacterial and viral diseases which quickly resulted in shrimp mortality during 1989/90. The final disease organism quoted as being responsible for this loss (as it was in Taiwan) was MBV or the monodon baculovirus. However, this organism is only really pathogenic due to the already highly-stressed condition of the shrimp (Nash, 1988; Anon., 1991b; Fegan *et al.*, 1991). With the onset of these conditions it rapidly became uneconomic to farm shrimp in these areas leading to the abandonment of 90 per cent of the ponds and environmental degradation, a situation which remains largely unchanged to this day. This same syndrome happened first in Taiwan (Lin, 1989; Sheeks, 1989; Anon., 1990a; Liao, 1990; Chua, 1993), then in central Thailand (Ferdouse, 1990; Liao, 1990; Anon., 1991a; New, 1991; Malasaidh, 1992; Menasveta, 1992; Quarto, 1992; Chua, 1993; Phillips *et al.*, 1993) and is now being noticed in south-eastern Thailand (Ferdouse, 1990; Liao, 1990; Anon., 1991a; New, 1991; Malasaidh, 1992; Menasveta, 1992; Anon., 1993a; ODA, unpublished report, 1993), Indonesia (Kakorkin & Sunaryanto, 1993), the Philippines (Liao, 1990), Sri Lanka (Phillips *et al.*, 1993) and Bangladesh (Anon., 1993c).

pond organisms (which subsequently bloom and crash, stressing the shrimp), but the majority first lowers the water and sediment quality of the ponds and then, as the ponds are flushed (particularly on harvest), the environment. Subsequently there is more stress on the shrimp, thereby decreasing their performance and increasing their susceptibility to disease and mortality (Anon., 1991c,d; 1993a; Lin *et al.*, 1991; Macintosh & Phillips, 1992). The intensity of the shrimp farming operations, with particular regard to feed quantity, quality and digestibility must therefore be considered carefully so as to minimise pollution of both the pond and ultimately the immediate environment.

d) Stocking density

In conformation of the advice of the government fishery stations and scientists, the largest shrimp farming company in Thailand, Charoen Pokphand (CP) have found that stocking at relatively low density is a much better path to a sustainable industry (Anon., 1992b). They conducted a series of pond trials at two stocking densities: 25 and 107 shrimp m^{-2} and found maximum profitability to be achieved at the lower density. This was because costs for shrimp seed were less, while growth and survival were better leading to increased gross income and profit at the lower density. Survival was 99 per cent compared to 32 per cent and the value of the shrimp increased at low density due to their bigger size (27 compared with 57 kg^{-1}). Gross profit was £ 14,000 compared to £ 6,000. For intensive shrimp farming, they recommended an optimal biomass of 500-800 g m^{-2} . If this figure rose to between 800 and 1,200 g m^{-2} , problems started occurring, and at $>1,200 \text{ g m}^{-2}$ the ecosystem was impossible to manage (Anon., 1992b). These figures mean that if the ponds are stocked at 100 shrimp m^{-2} , once the shrimp reach about 10g in size ie. after about two months, problems with the shrimp pond environment can be expected. Indeed, that is precisely the time when both bacterial and viral diseases do begin to become serious under intensive culture conditions (Anon., 1992e). It seems clear that stocking densities of up to 100 m^{-2} cannot now be sustainable. Furthermore, although densities of up to 50 m^{-2} can be used successfully if site selection and pond management are conducted properly, the number of poorly managed farms per unit area that have been in production in Thailand have resulted in these densities also becoming unsustainable. Without severe restrictions on land use, reducing stocking densities to below 30 m^{-2} is therefore vital for the development of a sustainable industry (Anon., 1990a; 1991a,b, 1992b).

2.2.3 DISEASE

a) Antibiotics

As a result of the intensification of shrimp culture activities, producers, both at the hatchery stage and during growout, are under intense pressure to maintain production. In a six month survey of eight hatcheries in the Gulf of Thailand, the Andaman Sea and Malaysia, 95 per cent of the larvae produced were found to be affected with MBV (Lin, 1989). It had already been discovered in Taiwan that the production of shrimp larvae in hatcheries effectively 'sterile' due to the continual use of antibiotics resulted in post-larvae that were unable to cope with the pond environment and to antibiotic-resistant strains of bacteria. This may also have played its part in the downfall of the Taiwanese industry (Anon., 1989; Brown, 1989a; Lin, 1989).

Despite the efforts of experts and government agencies to reduce the misuse of antibiotics and the so-called 'probiotics' (other bacterial treatments), the calls went unheeded as farmers tried desperately to avoid massive mortalities caused by an increasing number of diseases. The diseases also became more problematic due to both deteriorating water and sediment quality and to the proliferation of antibiotic resistant pathogens resulting from the indiscriminate and prophylactic use of various drugs (encouraged by the chemical companies) in shrimp hatcheries and ponds (Brown, 1989, Chua, 1993). This then may lead to complications with disease treatments, antibiotic accumulation in wild animals

and disruption of the natural bacterial decomposition processes and hence the ecological structure of benthic microbial communities (Chua, 1993).

The Japanese then discovered antibiotic residues in imported cultured shrimp from Thailand in 1991 and Indonesia in 1992 and threatened a ban on shrimp imports. The immediate result of this announcement was a 27 per cent drop in price for Thai shrimp (Brown & Higuera-Ciapara, 1991). The Thai government acted quickly (as indeed it was forced to), introducing monitoring systems at shrimp farms and processing plants. In March 1991 16 per cent of the monitored farms had residues, but this had figure dropped to zero by July 1991. In the processing plants a figure of 4.2 per cent detectable residues in early 1991 dropped to zero by early 1992. Two thirds of the processing plants by that time had the necessary equipment (Fitzgerald, 1991; Anon., 1993d). However, the Japanese Ministry of Health and Welfare continued to inspect shrimp imports from the Philippines, Thailand and Indonesia for antibiotic residues into 1992 (Anon., 1992f) as it was still concerned about antibiotic abuse.

Thus, in 1992 the Asian Shrimp Culture Council (ASCC) called for the setting up a drug residue standard for the cultured shrimp industry to match those in force for most other farm-raised products. The ASCC said that it was time for shrimp farmers, processors and government agencies from exporting and importing nations to meet and agree on maximum acceptable limits, and for consumers to be educated and informed that a certain residue is acceptable and safe for human consumption (Anon., 1992f).

b) Viral diseases

As has been stated, the mis-management of the intensive shrimp pond ecosystem leads to stressed shrimp which are then less resistant to fighting off potentially pathogenic diseases. It is now understood that MBV, the infamous viral disease which has been blamed for the demise of both the Taiwanese and central Thai shrimp industries, as well as other opportunistic diseases including *Vibrio* bacteria and protozoa, are not particularly pathogenic if the shrimp are healthy (Nash, 1988; Lin, 1989; Sheeks, 1989; Anon., 1990b; Csavas, 1990; Anon., 1991b; Fegan, Flegel, Sriuraitana & Waiyakruttha, 1991; Timothy Flegel, pers. comm., 1993). It is instead, the combination of ecosystem mis-management and environmental degradation leading to stress that is the root cause of most shrimp diseases (Lin, 1989) and disease losses can be diminished by ensuring optimal conditions for growth and monitoring shrimp health continuously (Lin, 1989; Anon., 1992c,g; Fegan *et al.*, 1991).

Unfortunately, a new shrimp virus, the most pathogenic of all penaeid viruses, now known as YHDBV (the yellowhead disease baculovirus) has appeared in Thailand. YHDBV first appeared in eastern and central Thailand in 1990 where it is still a problem. It has now spread south, where it is causing severe losses on shrimp farms. In the south it was reported first in Pakphanang in early 1992 (Figure 1) and then moved down to Songkhla Lake in 1993 (Anon., 1992c; Timothy Flegel, Aquastar, pers. comm., 1993). There are collaborating researchers of the fish Disease Research group working on it at the National Institute of Coastal Aquaculture and at the Natural Resources Department of the Prince of Songkhla University in Thailand. Mortalities can rise to 100 per cent in 3-5 days and is transmitted through the consumption of infected carcasses, usually 50-70 days into the culture cycle (Anon., 1992c; Fegan, 1993). YHDBV was estimated to be responsible for £ 21 million worth of lost production in Thailand in 1992 (Timothy Flegel, pers. comm., 1993). The disease in southern Thailand is now a big threat and many farmers are afraid to stock in case they succumb to the disease and as a consequence many ponds are presently empty (Fegan, 1993). The shrimp harvest in Thailand consequently declined by more than 10 per cent for the first time in five years in the first quarter of 1993 (Anon., 1993a). There are currently no chemicals available to treat this virus, but both Aquastar and the Asian Shrimp Culture Council recommend that sanitation on farms should be regarded as a priority and that stocking densities should be kept within manageable limits, thus maintaining a

healthy, stress-free environment for the shrimp (Anon., 1992c; Fegan, 1993). This type of prevention should become the major form of disease control for the intensive shrimp culture industry to avoid repetition of the problems that have hampered its sustainability to date.

2.2.4 ENVIRONMENTAL DETERIORATION

a) Water/sediment quality

Ecosystem mis-management leads to poor water and sediment quality in the shrimp ponds, stress, disease, shrimp mortality and then to environmental deterioration. Intensive aquaculture invariably has the greatest environmental impact (New, 1991; Phillips *et al.*, 1993). The sub-lethal effects of self-pollution may however, be more important than the more obvious fish kills as seen through aquacultural waste-enhanced toxic algal blooms in Japan, North America and Europe. The main problem lies with the effluent from the intensive shrimp ponds (Quarto, 1992). The huge volumes of seawater necessary for intensive farming must be disposed of which leads to the contamination of the ponds themselves, as these pollutants are flushed from and then returned to the ponds, the surrounding land, groundwater and the seacoast. The list of pollutants is a long one and includes organic matter from shrimp metabolism and uneaten food, potentially pathogenic micro-organisms, pharmaceuticals (including antibiotics often used for treating human diseases), dead and live vaccines, toxic chemicals, phytoplankton and suspended inorganic solids (Lin, 1989; 1992; Liao, 1990; Wang, 1990; New, 1991; Primavera, 1991; Anon., 1992f; Quarto, 1992; Phillips *et al.*, 1993). In time, the intensively operated and often badly-managed shrimp ponds poison themselves as the seawater used becomes contaminated, weakening the shrimp production until finally the ponds are closed since suitable water for a meaningful water exchange is no longer available (Csavas, 1990; Quarto, 1992). This has recently been seen to occur within two to four years in both Taiwan and Thailand.

Currently, almost nothing is known about how shrimp farms affect either their own water and sediment quality or that of their surroundings, particularly with regard to the carrying capacity of the ecosystem for shrimp farms over the long term (New, 1991; Anon., 1992g; Barg, 1992; Macintosh & Phillips, 1992; Pruder, 1992; Chua, 1993; Phillips *et al.*, 1993). This aspect has therefore been the subject of the main thrust of the current ODA research project. The research conducted has been aimed at modelling the nutrient budgets of shrimp farms of varying age, intensity and levels of management (Briggs, 1993a,b; Funge-Smith, 1993a,b). With the figures generated a greater understanding of nutrient flows through intensive shrimp farms will be obtained. It should then be possible to recommend sensible legislation in order to prevent environmental deterioration and self-pollution before such problems succeed in limiting the intensive aquaculture industry themselves.

For the conditions found in southeast Thailand, the total production of wastes from intensive shrimp farms, including that found in the sediments, has been estimated at 46.1 kg of total organic matter (TOM), 3.1-4.2 kg of total nitrogen (N) and 0.9-1.1 kg of total phosphorous (P) $\text{ha}^{-1}\text{d}^{-1}$ (Anon., 1991c, Lin *et al.*, 1991; Phillips *et al.*, 1993). This compares with initial data analysis from the ODA project, based on a seawater use of 6,700 m^3 per tonne of shrimp produced (ODA, unpublished report), which revealed that nutrient loadings in the discharge water of intensive shrimp farms in southern Thailand increased by an average of 1.2 kg of N, 0.1 kg of P and 3.1 kg of B.O.D. $\text{ha}^{-1}\text{d}^{-1}$ over that found in the influent water (Briggs 1993a,b). In the Ranote/Hua Sai areas of southeastern Thailand, a strip of land less than 40 km in length and 2 km in width containing 3,520 ha of shrimp ponds, nearly 58,000t of shrimp were produced in 1992 (ODA, unpublished report, 1993). This area of land thus added approximately 4.1 t of N, 0.4 t of P and 11 t of B.O.D. daily to the immediate coastal waters. In addition to this, substantial quantities of shrimp pond sludge (1,500 m^3) (Briggs 1993a,b; Briggs & Funge-Smith, 1993), phytoplankton (22t) and TOM (122t) (Anon., 1991c, Lin *et al.*, 1991) was produced daily suggesting that the industry is having a deleterious effect on the coastal environment.

The quantification of the rates of nitrification from intensive shrimp farms in Thailand are in opposition to previous reports which have stated that the discharge of pond effluent is not in itself a serious environmental threat (Chua *et al.*, 1989), but that poor stock quality and spreading disease are more serious issues (Pruder, 1992). The general lowering of water and sediment quality in areas of intense shrimp farming activity due to the rates of discharge now occurring are almost certain to affect the health of the stock being cultured as the shrimp farms pollute their own water supplies (Boyd & Musig, 1992). The evidence for this occurring is in the repeated crashes of the Taiwanese industry and the crash in central Thailand and declining productivity of shrimp ponds in southern Thailand, the Philippines, China and Indonesia (Sheeks, 1989; Anon., 1992d; Anon., 1993c).

The treatment of shrimp farm effluents offers an obvious (though largely as yet unpractised) method of reducing their impacts on water and sediment quality in the environment and ultimately on the farms themselves (Macintosh & Phillips, 1992; Phillips *et al.*, 1993). In the Western world, mechanical, physical and/or biological methods are required for reducing the impact of farm wastes on the environment due to strict government legislation (Macintosh & Phillips, 1992). Lately in Thailand, the draining of shrimp pond sludge into canals or the sea has been prohibited due to its effects on coastal water quality. This material is then dumped on the pond banks or into empty ponds or 'waste' land. However, the increasing amounts of solid wastes produced are becoming difficult to dispose of due to lack of space. The various methods which are used in attempts to maintain water and sediment quality within shrimp ponds are reviewed in this ODA research project (Briggs, 1993a,b,c; Funge-Smith, 1993a,b). In addition, novel methods of reducing the impacts of shrimp farm wastewater on the environment (as yet unrequired under Thai law) have also been reviewed and have been the subject of research efforts during this ODA research project (Briggs, 1993a,b; Funge-Smith, 1993a,b; Briggs & Smith, 1993).

b) Competition for resources

The rapid growth of the intensive shrimp farming industry in Thailand has resulted in intense competition for valuable and increasingly scarce coastal resources. The industry in Thailand at present utilises about 80,000 ha of land or 0.15 per cent of the natural land area (Anon, 1993a). This area consisted of 10,000 ha of former mangrove forests, 40,000 ha of former rice paddy and 30,000 ha of other land (Quarto, 1992; Anon., 1993d; Vibulsreth & Aschbacher, 1993).

(i) Mangroves

Being close to brackishwater supplies and on level terrain, mangrove forests are often used for shrimp farming despite their acid-sulphate soils and high clearance and maintenance costs. When requisitioned for shrimp farms they are cleared and the once balanced and highly productive ecosystems disrupted. This loss is tragic because these ecosystems (like most wetlands) provide a wide variety of significant environmental goods and services that sustain social and economic structures and activities (Singh, 1987; Csavas, 1988; Folke & Kautsky, 1992). There is also the argument, expressed by some conservationists, that the mangrove ecosystem is already highly productive and it is questionable whether its use for shrimp culture (particularly using extensive systems) is a "better" use of the resource (Singh, 1987; Barg, 1992; Primavera, 1992). Outside investors, who do not have intimate contact with these ecosystems, cannot perceive their true sustainable value and construct new shrimp ponds regardless of the loss of that resource. When these ponds begin to lose production, the farmers move to new areas and ever more mangroves disappear. Replacement of a mangrove habitat by shrimp culture transforms a multi-user/use coastal resource into a privately-owned, single-purpose (and often unsustainable) business (Pollnac, 1992).

Extensive polyculture techniques have utilised large areas of mangroves in Thailand for many years.

It was not until the intensification of shrimp culture in mangrove areas in the 1980s however, that many of these areas were turned into wasteland. The farmers are now beginning to move their operations to western Thailand on the coast of the Andaman Sea (Figure 1) which is still largely mangrove forest (80 per cent of Thailand's mangrove forests) and supports a rich fishery. Concern over mangrove forest destruction was documented in 1986 by the FAO who recommended research to determine the compatibility of forestry and other sustainable uses with fisheries and aquaculture. They also emphasised the need for proper site selection for aquaculture in mangroves in order to limit its impact on mangrove ecosystems (Indo-Pacific Fishery Commission, 1986). Unfortunately, the mangroves have suffered at the hands of influential people with millions of pounds at stake. The land grabbing is backed by the policy makers who share the money gained from the illicit land deals and the boom of shrimp farming (Quarto, 1992). Thailand has lost a total of 203,000 ha of mangroves since 1961. This is a 52 per cent reduction from the original figure of 368,000 ha in 1961 to just 176,000 ha in September 1992. This latter figure comprises just 0.3 per cent of the total land area. This reduction includes approximately 10,000 ha of pristine forest lost in the last 10 years to the growing intensive shrimp culture industry (Anon., 1993d; Vibulsreth & Aschbacher, 1993), but 65,000 ha altogether from the initial use of mangroves for logging or traditional extensive culture which has subsequently been intensified (Phillips *et al.*, 1993; Pullin, 1993).

The Thai government has at last recognised the importance of preserving the pristine mangrove forests. Thailand is therefore now using remote sensing by satellite to track its loss of mangroves and to provide the methodology for a cost-effective, reliable, timely and effective information gathering system for sensible mangrove planning and management. They have combined this with government legislation, when in 1991, they announced a zoning policy to preserve mangrove forests. The Department of Forestry has adopted control over mangrove use in the south west of Thailand and all farmers must leave the forest by 1994. However, there has so far been no firm enforcement and the conversion of mangroves to shrimp ponds goes on (Figure 1). In addition, zoning is difficult since the forests have never been clearly demarcated (Malasaidh, 1992). If many of the shrimp farmers are forced to cease shrimp production in southeast Thailand due to declining productivity, the pressure on the government to allow shrimp farming in the south-west's extensive mangrove forests will be intense. The commitment of the Thai government and the effectiveness of their policies will then be given a severe examination.

The example of Thailand is not unique and similar events are taking place in other areas of the world. In Indonesia, most of the 300,000 ha of land being cultured for shrimp in 1991 was ex-mangrove land. If the development proceeds "as planned" more than 1 million ha of mangrove area will be converted to shrimp ponds with devastating effects on coastal fisheries (Newkirk, 1991). By 1985, Java had lost 70 per cent of its mangroves, Sulawesi 49 per cent and Sumatra 36 per cent (Csavas, 1988). In the Philippines a similar scenario exists where mangrove forests have shrunk from 448,000 ha in 1968 to 110,000 ha in 1990 which has led to the destruction of a resource responsible for nutrient export and as a breeding and nursery ground for many marine organisms, and hence to the marginalisation of subsistence fishermen and the erosion of shorelines (Singh, 1987; Liao, 1990; Primavera, 1991, 1992; Barg, 1992; Padilla & De Los Angeles, 1992; Pollnac, 1992; Chua, 1993; Phillips *et al.*, 1993). A positive correlation between mangrove/intertidal area and shrimp capture landings has been reported by various workers (Singh, 1987; Primavera, 1991), while the erosion of shorelines due to loss of mangroves buffering against wind and wave action has also been a problem in the Pakphanang region (Figure 1) of southern Thailand (Stephan Flos, CORIN, pers. comm., 1993). Bangladesh too, is investing heavily in shrimp culture. Its production has risen from 1,000t in 1980 to 18-25,000t in 1992, earning the country more than £ 68 million in foreign exchange in 1991. However, environmentalists say the new industry has led to the impoverishment of peasants and is at the expense of mangrove forests and farmland. About 10,000 ha of the Sunderbans mangrove forest on the India/Bangladesh border have been cleared for shrimp ponds to date (Anon, 1993e). In Vietnam, the total mangrove

forest area is estimated at 409,000 ha. During the first half of the 20th century, the Mekong Delta alone had 250,000 ha of mangroves, but war, defoliation and uncontrolled exploitation, largely by aquaculture ventures, had reduced this area (despite reforestation) to less than 100,000 ha by 1986 (Quynh, 1992).

(ii) Agricultural land

Conflicts between competitors for the same resources, in this case land and water, are common in Thailand and began as poorly-planned shrimp farming started to expand into the rice farming areas and salinate the groundwater and crop-land. The rice farmers protested and demanded compensation, but received only death threats brought about by greed on one side and impoverishment on the other, exacerbated by inadequate governmental control. In Thailand, where conflicts between rice and shrimp farmers are common, the price of the life of a protesting rice farmer is said to be just 20 kg of shrimp (New, 1991). Under these conditions the farmers then had to sell their land to the shrimp farmers or begin shrimp farming themselves. This was appealing due to the huge profits being made by the virgin industry and initially at least, the ex rice farmers obtained high profits. The farmers who remained trying to earn money from rice or livestock however, continued to suffer problems of salinisation of soils and reduced quantities of good quality freshwater and are now often losing money, with the result that local food production is decreasing.

Unfortunately, few of the ex rice farmers had any training in intensive shrimp farming techniques and they mis-managed the ponds leading to reduced productivity and in many cases bankruptcy (New, 1991; Malasaidh, 1992). Approximately 40,000 ha out of the total 9.6 million ha of rice paddies in Thailand (Anon., 1993d) have been replaced by shrimp farming and vast areas more have had their productivity reduced because of salinisation caused by shrimp farm effluents. Yet in freshwater, rice production can actually be enhanced by rotation or integration with aquaculture (New, 1991). A lot of people have got hurt and many increasingly claim that shrimp farming has not been good for Thailand (Liao, 1990; New, 1991; Newkirk, 1991; Primavera, 1991, 1992; Malasaidh, 1992; Masae & Rakkheaw, 1992; Pollnac, 1992; Wallace, 1992; Stanley, 1993).

Other countries are also facing these same problems. Agricultural farmers in Bangladesh say that shrimp ponds have made their water salty. The production of rice has fallen from 1.7 to 0.5 t ha⁻¹yr⁻¹ and the yield of fruit and vegetables has dropped in the last 10 years in Khulna, one of the major shrimp farming areas (Anon., 1993e). Shrimp farmers, in their search for salt water, have also been breaching coastal embankments built with aid money from the World Bank and the Dutch government to control floods and stop tidal waves. This has led to flooding of farmlands with seawater that renders them useless for cultivation (Anon, 1993e). In the Philippines problems with brackish or salt-water expelled from shrimp ponds has also resulted in saline irrigation water, with negative consequences for rice and other agricultural endeavours (Liao, 1990; Primavera, 1991).

Khao San Roi Yot National Park in central Thailand has now also been ruined by shrimp farm pollution so that many investors have moved south to start new operations in Ranong and elsewhere. This place is home to many influential people who have spoken out on the issues and received only death threats. In July 1992 this area suffered from water quality problems, but even today, farms are still being constructed there. Also the farmers are encroaching on the national park area and draining freshwater from the wetlands of the park leading to conflicts with the Forestry and Irrigation Departments (Fahn, 1993).

(iii) Freshwater resources

Fresh ground water is another casualty of intensive shrimp farming operations. As ever more intensive

farms are built, the underground freshwater resource is becoming overutilised and the water table is getting deeper. Among the consequences of such abuse are land depression, low freshwater levels and seepage of seawater into springs and deep wells (Primavera, 1991; Barg, 1992; Masae & Rakkheaw, 1992; Phillips *et al.*, 1993). In the absence of official statistics, Primavera (1991) estimated that roughly 6,600 m³ of freshwater were required for diluting a 1 m deep pond one hectare in area over a four month cycle. One of the pioneering shrimp farms established in southeast Thailand was that of the Aquastar Corporation. They set up operations in 1987 in the Ranote area (Figure 1) due to the extensive underground freshwater aquifer present in that area (Brown, 1989b). However, with the overuse of that resource, mixing freshwater with marine to create the ideal brackish salinities for shrimp culture, the water table started to sink. This created problems for local people in terms of irrigating their crops, watering their livestock and in obtaining unpolluted supplies of drinking water. Aquastar then desisted from this practice and began growing the shrimp in full-strength seawater since they found that the shrimp could grow almost as well as in brackishwater with a few management changes. The other independent shrimp farmers (or 'wildcatters' as they are known locally) however, who began farming adjacent coastal areas following the success of Aquastar, are still drawing on the groundwater resource leading to further conflicts with local people (Niemeier, 1990; Daniel Fegan, Aquastar, pers. comm., 1992).

(iv) Marine environment

Dr Surapol Sudara of the Marine Science Department, Chulalongkorn University in Bangkok has stated that the build-up of dissolved organic matter from metabolites and decomposition of uneaten food and shrimp faeces cast into the sea from intensive shrimp farming operations has also caused considerable harm to the coastal environment and its marine life (Quarto, 1992). It has also killed coral reefs and created toxic algal blooms offshore (Stanley, 1993) and resulted in fish death and foul-smelling water in many wetland areas (Masae & Rakkheaw, 1992).

(v) Land cost

The price of coastal land itself, in the light of the increasing intensity of shrimp production all over the world, has increased dramatically during the past decade. This is because when productivity increases, land value increases, resulting in the need for higher productivity in an ever-increasing spiral. At the same time, the willingness to lease land out for others to farm decreases so that small producers have more difficulty paying advance rent in cash. These smaller producers also have a greater potential for failure than bigger operators, who end up taking over when the small farmers go bankrupt (Pollnac, 1992). In Thailand, land prices in the shrimp farming belt increased tenfold from £ 270 to £ 2,700 ha⁻¹ between 1985 and 1989; the price of coastal land in Songkhla province reaching £ 5-14,000 ha⁻¹ recently (Brown, 1989b; James Hanson, Aquastar, pers. comm. 1992). The value of this land can only persist as long as the intensive shrimp culture is successful. Once it fails, the land is worthless to both outside investors and, more importantly, to the local population.

The problems involved with environmental deterioration leading to conflict for resources are therefore of paramount importance. These problems must be examined as closely as possible in order to optimise husbandry techniques, to better understand the effects of intensive culture on the environment and to allow the establishment of sensible and enforceable legislation in order to assist the development of sustainable shrimp farming inside an overall coastal resources plan (Lin, 1989; New, 1991; Anon., 1992g; Masae & Rakkheaw, 1992).

(vi) Feedstuffs

A final aspect of resource competition is seen in terms of the demand intensive shrimp culture makes

on raw materials for feed production. Feeds account for 40 per cent of the total operational costs in semi-intensive systems and 55-60 per cent in intensive ones (Csavas, 1990; Primavera, 1992). Because the rest of the operational costs, made up largely of labour, energy and seed are difficult to economise on, feed costs and feeding efficiency should be closely examined. Similar to the situation with poultry, shrimp feeds started out relying on fish meal as their major protein source. Shrimp farming consumed 180,000t of fishmeal in 1988 (Phillips *et al.*, 1993). Shrimp feeds have yet to minimise fishmeal inclusion and there is potential (as with poultry) and indeed the necessity, to reduce dependence on this finite and increasingly expensive resource, particularly in diets for semi-intensive culture. In intensive systems there are environmental limits to the substitution of fish meal since food utilisation efficiency may decrease with higher inclusion rates of plant proteins in the diet. This would increase waste production, endangering the environment. In semi-intensive systems however, a small increase in waste production is less critical and a slower growth rate may be acceptable if a significant saving in feed costs is achieved. It has also been pointed out that in tropical semi-intensive systems, the economically optimal protein level is significantly lower than the biological one. In addition, if systems become less intensive, significant savings can be made through the use of farm-made feeds rather than expensive, factory-made, compound feeds (Csavas, 1990; Michael New, pers. comm., 1993).

Nutritional research is therefore needed in order to minimise feed costs (as has already been accomplished for poultry and some finfish species) by reducing dependence on valuable marine protein sources and targeting dietary formulations at specific culture systems with regard to optimal performance in terms of shrimp growth, feeding efficiency, protein use, environmental impact and profitability (Fast & Lester, 1992). Work in the previous ODA research programme on shrimp culture was concentrated on answering some of these questions, and the most promising aspects of this work have been carried on into the lifetime of the current project (Fox, Brown & Briggs, in press). Work on sparing dietary protein through the increased dependence on lipid and carbohydrate has produced encouraging results (Briggs and Brown, in prep.). The use of feeding attractants to enhance the palatability of shrimp diets, particularly those containing low levels of marine proteins has also shown promise in laboratory-scale trials (Hartarti, 1991; Hartarti & Briggs, 1993; Dimitriou, 1993). The use of alternative protein sources such as shrimp head meal has also shown potential in reducing the dependence on fish meal (Fox, 1993; Fox, Blow & Brown a.b, in press). Finally, work is still in progress assessing the potential of seaweed (*Gracilaria sp.*) meal in shrimp diets to further integrate the use of seaweed/shrimp polyculture systems (Briggs, 1993 a,b; Briggs and Funge-Smith, 1993).

2.2.5 SOCIO-ECONOMICS

a) Small-scale versus industrial production

Another problem in the development of the intensive production of luxury species such as marine shrimp is the question of who are the beneficiaries of such industries. Typically, the already rich and powerful investors have the advantage due to their capital-rich and influential status giving them easier access to permits, credit, subsidies and imported technology (Csavas, 1990; New, 1990; Primavera, 1991; Masae & Rakkheaw, 1992). Often, the potential of the industry to earn foreign exchange is of more importance to governments than the livelihood and welfare of poor coastal communities. In southern Thailand, although shrimp farming does contribute significantly to the local economy, the ownership of shrimp farms is unequal among different socio-economic groups (Masae & Rakkheaw, 1992). Due to its requirement for high monetary investments, poor groups, including rice farmers and fishermen generally have smaller farms than outside investors including businessmen and government service employees (Masae & Rakkheaw, 1992). Thus, commercial aquaculture can negatively affect the poor coastal communities, through resource competition, altered familial work patterns, increased unemployment and the degradation of living standards, electricity, land and water resources and nutrition.

In Southeast Asian countries, the low wage rates are important in maintaining shrimp farming profitability. This, however, is a self-propagating system, because by removing the sources of livelihood (local fisheries, rice paddies and other sources dependant on the mangrove swamps) many people become desperate for work. Since the work on shrimp farms is unskilled and there are relatively few jobs as a result of its poor employment-to-investment ratio, heavy competition inevitably drives the wage rate down. Thus the economic success of the big companies does not trickle down to the traditional users of coastal resources, who are largely bypassed by the development process (Csavas, 1990; Newkirk, 1991; Primavera, 1991, 1992; Pollnac, 1992; Anon., 1993b,c; Chua, 1993; Csavas, 1993). Kee-Chai Chong, an FAO Economist therefore maintains that in many developing countries, small farmers have not benefitted from shrimp farming in any significant manner (Chong, 1990). Fishing and growing rice have been replaced by shrimp culture, communal resources privatised and fishermen, rice farming tenants and landless workers have been displaced. Small-scale farmers who generate income through selling their shrimp crops do not necessarily have better-nourished families because the extra revenue is often spent on non-food items. Families actually reduce intake in order to sell more and may even have to sell the whole crop at once in order to repay loans incurred for expenditure on farm inputs and other items. Indeed, most aquaculture producers in Asia are entrepreneurs. Small-scale fishermen and agricultural and livestock farmers, who are the most populous groups, are generally not yet widely involved (New, 1991; Primavera, 1991, 1992; Stanley, 1993). One of the few exceptions to this rule is that of contract farming pioneered by Aquastar and now also taken up by CP in Thailand (Brown, 1989b).

In the case of shrimp culture in Thailand, the land used is often owned originally by small-scale rice farmers before being converted into ponds in which to culture shrimp. This culture is occasionally carried out by the farmers themselves, but more frequently the land is either sold or contracted out to entrepreneurs or large businesses, leaving the families to migrate to other areas. Often, in the absence of a government licensing system, this decision is forced on the rice farmers since their agricultural activities soon begin to deteriorate from the salty wastes of the adjacent shrimp farms. Rice farmers earning only £ 54 yr⁻¹ growing rice, once converted to shrimp farming were reported to make £ 5,400 yr⁻¹ in 1991, while Aquastar reckon that average income has increased from £ 270-540 (£ 130-260 ha⁻¹) to £ 4-8,000 yr⁻¹ (£ 2-4,000 ha⁻¹) for their contract farmers (James Hanson, Aquastar pers. comm., 1988; Brown, 1989b; Niemeier, 1992; Wallace, 1992). Aquastar also maintain that most of their contract farmers make a similar amount of money from their first shrimp crop as they would from ten years of farming rice on the same area of land (Timothy Flegal, Aquastar, pers. comm., 1992). Results from a survey carried out in 1992 by the Coastal Resources Institute of the Prince of Songkhla University in southern Thailand showed that the average cash income per household increased from £ 1,300 yr⁻¹ for rice farmers and £ 1,600 yr⁻¹ for fishermen to between £ 9-12,000 yr⁻¹ when the family began shrimp farming (Masae & Rakkheaw, 1992).

The independent shrimp farmers, without the backup provided to the contract farmers, do not possess the necessary skills to manage intensive shrimp farms and have constructed farms without suitable site selection and/or water control structures. This ignorance, combined with the application of 'get-rich-quick' policies over huge areas has resulted in many of these farmers (making up 80 per cent of Thailand's current shrimp farms) going bankrupt within 2-4 years. The government has been slow to enforce regulations such as mandatory treatment of waste water that may curb the excesses of these short-sighted producers and save the industry from self destruction (Stanley, 1993). Meanwhile, their polluted lands, occupying large areas of central, south and eastern Thailand are now unable to raise either shrimp or rice. This leaves the communities devastated without a local food source, high unemployment and the unproductive, abandoned land (Lin, 1989; Fitzgerald, 1991; New, 1990, 1991; Newkirk, 1991; Anon., 1992d; Wallace, 1992; Stanley, 1993). This in turn forces the farmers to either to start again (if, as is rarely the case, they can afford it) on virgin land or to move to the slums of Bangkok to earn their living.

It may be that the larger, stronger companies and contract farmers (if they are not dragged under by the wildcatters) will take over when the smaller farms have gone out of business due to poor water quality, disease and slipping prices due to the competitiveness of the world market. The bigger farmers generally have more experience and money invested and consequently have farmed less intensively and minimised the deleterious effects on the environment within the constraints of farming the same areas as the wildcatters (Anon., 1992d; Malasaidh, 1992). These larger companies, the Charoen Pokphand group, Aquastar, Unicord and Nichirei together already produced approximately 40 per cent of Thailand's farmed shrimp in 1991 (Fitzgerald, 1991). This may maintain Thailand's shrimp production for a while, but may also only widen the gap between rich and poor.

Despite the fact that Bangladesh has a relatively younger shrimp culture industry, producing 18,000t extensively from 120,000 ha at just 0.15 t ha⁻¹ in 1992, the country is already facing similar problems to Thailand. Traditional farmers have complained that since shrimp earn dollars, the government has allowed rich businessmen to farm shrimp without regard to the environment or the local peoples' livelihood. A survey by M. Haq of Dhaka University shows that nearly 75 per cent of all the shrimp farmers are rich people from outside the region with little interest in long-term local development. These people move into the area and push out the local rice farmers often with the help of the police and violence. In the Sarkhira area of Khulna, nearly 1.2 million peasants have lost their land to shrimp ponds which now occupy 55 per cent of the Khulna's land area and they have had to migrate to the cities to look for jobs. While 50 workers are required for the cultivation of 40 ha of rice, the same land area under shrimps requires only 5 people. Faced with a wall of apathy from the government, Haq has asked the World Bank and UNDP which have funded the development of Bangladesh's shrimp industry to review their policy (Anon., 1993b,e).

b) Culture systems

In the currently mature phase of the world shrimp culture industry, characterised by falling prices and decelerating growth, it is crucial to select the culture system that will provide optimum profitability, while remaining sustainable. With the world's shrimp suppliers now showing signs of matching current demand, production costs in relation to market price will be of major importance (Csavas, 1988, 1990; Primavera, 1991, 1992; Fast & Lester, 1992). Since 1989, when the world shrimp market price for 30 kg⁻¹ size collapsed from £ 6.50 kg⁻¹ in July 1988 to between £ 4 kg⁻¹ in January and £ 2.50 kg⁻¹ in July 1989, prices have stagnated at between these two levels and show no promise of returning to their former level. The large, vertically integrated farmers such as the contract farmers can withstand these prices since their production costs were only £ 2-2.6 kg⁻¹ in 1990. The smaller producers however, must pay higher prices for feed and post-larvae and have production costs of about £ 3 kg⁻¹. With few financial resources, such farmers cannot survive if prices do not rise again. In the light of continuing low prices, high production costs and disease problems, high technology, high production cost shrimp farms may not have a long lifespan (Csavas, 1988, 1990; Ferdouse, 1990; Liao, 1990; Niemeier, 1990; New, 1991; Fast, 1992; Fast & Lester, 1992; Menasveta, 1992; Anon., 1993b).

Economic analysis has shown that while all systems from traditional extensive to super intensive remain profitable under static market conditions, only semi-intensive systems can easily survive a 20 per cent fluctuation in inputs and/or market price (Csavas, 1988, 1990; Chong, 1990; Primavera, 1991, 1992). This same decrease would drive all of the intensive ventures (which are operating with a high profit per unit of culture area, but with a narrow profit margin per volume) and extensive culture (due to its low production) into the red. Intensive operators paid no attention to this problem when the prices were high because they merely wanted to maximise their profits and return on capital. But with more competition and lower prices, the lower profit per kilogramme of shrimp sold will put intensive producers at a disadvantage. Semi-intensive culture, which has less environmental impact, should thus be encouraged through research into the critical parameters of optimised shrimp pond dynamics

management and through the reduction in dependence on intensive systems, with all of their inherent drawbacks, through the institution of new policies and the implementation of existing guidelines (Csavas, 1988, 1990; Primavera, 1991, 1992; Fast & Lester, 1992; Macintosh & Phillips, 1992).

It is clear from the above discussion that socio-economic factors must be taken into account when assessing the benefits of such intensive aquaculture operations. The development of sustainable shrimp farming will require that the real price of shrimp production, including those of impairment, degradation and destruction of the ecosystem and environment (which may frequently be irreparable) be taken into serious consideration (Chong, 1990). These are costs that never appear on any farm ledger and which are difficult to estimate, but which are essential in gauging the full impact of these production systems.

2.2.6 EXPANSION TO OTHER COUNTRIES

a) Taiwanese expansion

From 1986 to 1990 a large number of Taiwanese shrimp farming technicians and consultants were called in to advise on the development of the Thai shrimp culture industry. Unfortunately, they recommended techniques and practices identical to those used in Taiwan until the collapse of its industry in 1988. The adoption of Taiwanese techniques, already shown to be unsustainable, in combination with all of the above mentioned factors, resulted in the Thai crash of 1990. This occurred despite the fact that Professor Chen of the National Taiwan University had spelt out the likelihood of shrimp farming following a similar pattern in Thailand as it did in Taiwan to the shrimp farmers and government of Thailand at a meeting in Bangkok in 1989. The Taiwanese farmers themselves only started producing shrimp again in 1990 by a combination of lowering stocking densities and switching to disease-resistant species, only for the industry (this time using *P. japonicus* and *Parapenaeus longipes*) to crash again in 1992 and once more in 1993 (Anon., 1992c,d; 1993c).

One of the most worrying aspects of this scenario is that due to the financial success of shrimp production in Taiwan and Thailand, other developing countries are asking them for help in developing their own industries. The Taiwanese government now has a newly-identified role in shrimp farming as a research and development centre and a supplier of progressive technology and investment capital through joint-venture partnerships (Liao, 1992). Disregarding the role of Taiwanese technology in the demise of Thailand's shrimp industry, the Taiwanese government is now funding a feasibility study for a relocation project that would encourage Taiwanese farmers to establish operations abroad and avoid high production costs and environmental degradation in Taiwan (Anon., 1993f). Presumably the Taiwanese government feel that it is better to pollute the environment of other countries for its own economic gain. The countries targeted so far include many in Latin America, desirable due to their low production costs and proximity to the huge American market, Australia because of its considerable natural resources and other Southeast Asian countries due to their low labour costs (Anon., 1993f).

b) Thai expansion

In Thailand, due to the continuing decline of the shrimp farming areas in central and eastern Thailand, Thai entrepreneurs, larger companies and even the government are beginning to expand their own operations to other developing countries. The Charoen Pokphand Group (CP) began shrimp farming in Thailand in 1986 and are now the largest shrimp farming company in the world. The company is also the leading shrimp feed producer in Indonesia where it promotes semi-intensive shrimp farming (Lohawathanakul, 1993). They are now expanding into China, Turkey and soon into Indochina (Anon., 1992h; Hjul, 1992; Lohawathanakul, 1993). They will operate an experiment in Danang Vietnam in 1993 as the first step in a long term plan to establish an integrated shrimp breeding, growing,

processing and export project in Vietnam. They will initially take over the site of a failed joint venture with an Australian company. If the experiment and the technology transfer is successful, the Deputy Minister for marine products Dr Huynh Cong Hoa said that they could cooperate further, going slowly and firmly. He also said that UNDP had already advised Vietnam about the problems of large-scale intensive shrimp farming in mangrove areas, but that they would use only available farms sites without expanding further into mangrove areas (Lohawathanakul, 1993). Vietnam may already have up to 200,000 ha of extensively-farmed shrimp ponds using methods of trapping and holding or rotation with rice. These systems rely of wild post-larvae and may produce up to 42,000 t yr⁻¹ currently at an average production of just 0.2 t ha⁻¹yr⁻¹. However, recently, a number of joint venture shrimp farming projects have been initiated with foreign-based companies including CP. Over £ 0.7 million is being invested to develop over 2,000 ha of ponds as well as some feed plants and hatcheries (Liao, 1990; Anon., 1992h; Anon., 1992i; Anon., 1992j; Quynh, 1992; Anon., 1993g,h; Donald Macintosh, Stirling University, pers. comm., 1993).

Despite the results of their own research proving the benefit of low stocking densities (Anon., 1992b), CP have already begun testing their feeds and technology on an intensive shrimp farm in Mexico operated at 70-80 shrimp m⁻² with 'encouraging' results (Anon., 1993f). The Thai government too participated in a fact-finding mission on shrimp farming led by the Thai ambassador to establish ties allowing Thai companies access to the Mexican shrimp farming and feed industry. (Villarreal, 1992). The Thai government, under Commerce Minister Uthai Pimchaichon, now intend to use Mexico as a production base for products it exports to the western hemisphere and has asked them to cut their taxes on imported shrimp feeds, a move which would lower the farmers production costs and benefit a Thai-Mexican shrimp farm project (Anon., 1993f). It seems that the lessons from Taiwan and Thailand have yet to be heeded (Chong, 1990). The expansion of intensive shrimp farming technology must proceed cautiously and with integrity (if at all), bearing in mind the plethora of problems unrestricted culture can produce. Only with more knowledge and appropriate extension and regulation, based on thorough research, can such culture be prevented from recombining with short-sighted greed and affecting new areas with its inherent problems.

2.3 THE SOLUTIONS PROPOSED

2.3.1 NON-GOVERNMENTAL ORGANISATION SOLUTIONS

a) Environmental management

Due to the growing concern of non-governmental organisations (NGOs) and the general public over the decline of the intensive shrimp farming industry and the environment, and in the light of non-existent or ineffective government legislation, pressure is mounting for the government to clean up and promote sustainable shrimp farming. Environmentalists have long wanted to see grass-roots concerns over the coastal ecology transformed into effective regulations (Malasaiddh, 1992). Economic policies and environmental trends are closely linked. Economic policies that enhance living standards can also improve the quality of the environment, but in some countries the pursuit of development has had the opposite effect (ADB, 1990). For development to be sustainable, these negative environmental consequences must be addressed. Environmental problems undermine the goals of development (World Bank, 1992) and policies which promote intensified use of coastal resources are deemed unsustainable.

A broad view of economic policies pertaining to coastal resources must be taken since the rate at which these resources are utilised is undoubtedly influenced by factors emanating from outside the immediate environment. If resources are already under extreme pressure, the wrong set of policies will only exacerbate the situation (Padilla & De Los Angeles, 1992). Thus, policies with a sound scientific

basis are necessary to optimise sustained benefits of renewable resources. Initially, subsidies and incentives may be required, but when the resources become depleted, conservation and protection measures are warranted. In all cases, the costs and benefits of policies should be carefully evaluated. Economic policy reform may be insufficient for sustainable development of coastal resources. Poverty, which is endemic to fishing communities and which forces marginalised labour into the fishery, further increases the burden on coastal resources. However, poverty alleviation may not significantly improve the exploitation of coastal resources as long as they are open-access. This problem may only be transformed by resource pricing under community management which can facilitate exclusion policies and the enforcement of rules to rationalise coastal resource use (Padilla & De Los Angeles, 1992).

The United Nations Conference on Environment and Development (UNCED) held in June 1992, recognised these problems and world governments agreed to a Commission for Sustainable Development to carry on the work of UNCED beginning in 1993. The conference maintained that the marine environment -including the oceans and all seas and adjacent coastal areas- formed an integrated whole that is an essential component of the global life support system, and a positive asset presenting opportunities for sustainable development. Under Agenda 21 they set forth the rights and obligations of States and provided the international basis upon which to pursue the protection and sustainable development of the marine and coastal environment and its resources. It was now, said the UNCED, up to governments to translate these global objectives into their own national policies and practices (Anon., 1992k). At the same conference, various NGOs met and proposed a set of "alternative treaties" to the main UNCED recommendations. Recognising the same problems, the NGOs pledged to collaborate on achieving 1. support for fishing communities and 2. the conservation and protection of aquatic ecosystems. In addressing these concerns, among the areas that they particularly highlighted ensuring were:

1. That fisheries were managed from an ecosystem perspective utilising integrated management principles which take into consideration of human activities leading to degradation of aquatic ecosystems and the environment, such as unsustainable aquaculture;
2. That successful management of aquatic environments should have the full and meaningful participation of all interests including locals, women, environmentalists, development experts and scientists;
3. That a precautionary approach be taken in making decisions that affect aquatic environments, including the use of environmental impact assessments;
4. That, following a comprehensive ecosystems approach, all existing technologies that protect aquatic ecosystems be implemented, the development of others be encouraged and that technologies determined to be harmful to the aquatic environment be restricted or eliminated;
5. That, recognising the need to enhance knowledge of aquatic ecosystems, support for research programmes be encouraged to increase our understanding of the relationships between aquatic organisms and their environment, and which determine ecologically appropriate fishery yields; and
6. That public and private sectors were pressurised to make the transition to sustainable culture and to direct their resources to the research and development of sustainable culture methods.

The long term objectives of aquacultural development, in line with sustainable growth must be integrated into the framework of coastal area planning and management, itself within the countries' national policy. The purpose of management guidelines for the development and environmental management of coastal aquaculture must be to minimise its adverse effects either through preventative

measures in the planning stage or through mitigating and regulatory measures when the culture practices are already in operation (Chua, 1993). The first stage of this process in Thailand has been neglected. 80,000 ha of coastal land have been developed for shrimp farming in the absence of any integrated coastal development plan. Thus, environmental management guidelines are now necessary to assist the industry on the path to sustainability. Mitigating and regulatory measures are required for:

1. Wetland conservation i.e. replanting mangroves,
2. Control of drug abuse,
3. Species transfers,
2. Maintaining optimal feeding regimes,
3. Removal of organic sediments,
3. Reduction in nutrient loading,
3. Removal of suspended solids loads,
4. Licensing to aid regulation of farm size and their distribution,
5. Education and training,
6. Research to provide the basis for environmental management (Chua, 1993).

b) Intensive shrimp culture management

Dealing more specifically with shrimp farming, the Thai Fishery and Frozen Products Association in Bangkok presented a brochure on the Thai shrimp farming and environmental protection policy at Sea Fair '92 in California, USA. They recommended the following procedures for reducing the environmental problems caused by shrimp farms:

1. Stop constructing shrimp farms in mangroves,
2. Restrict the use of drugs and other chemicals during growout,
3. Register all shrimp farms with the government,
4. Locate intake pipes >240 m offshore,
5. Use deep, wide drainage canals that double as settling basins,
6. Pump the final effluent >150 m offshore,
7. Reduce BOD in the discharge water to <10 mg l⁻¹,
8. Encourage shrimp farming cooperatives that disseminate information on good environmental policies (Anon., 1992I).

The Asian Shrimp Culture Council (ASCC) as early as 1991, detailed the problems facing the intensive shrimp culture industry in southern Thailand and called upon the government administration and businessmen to consider improving the cost-benefit relationship of intensive farming, taking into account all long-term environmental implications and specifically to immediately legislate on:

1. Zoning for suitable culture systems for specific land-use types,
2. Enforcement of regulations for hatchery and farm registration to control farm size, quality of shrimp produced and quality of effluent water,
3. Provision of a suitable seawater irrigation system for shrimp farming (Anon., 1991a).

Similarly, the Taiwanese scientists, led by Dr Liao I-Chiu and Professor Chen of the National Taiwan University drew up a list of recommendations to help prevent the crash that they suffered in 1988 from occurring elsewhere. These included:

For the farmers:

1. Clean the ponds out between cycles,

2. Choose only healthy seedstock.
3. Control the use of drugs.
4. Maintain low stocking density.
5. Maintain good water and sediment quality.
6. Check feeding rate properly by use of feeding nets.
7. Sterilise the ponds and water after viral infections.
8. Report disease outbreaks immediately.
9. Diversify culture practices.

For the government and public:

1. Legislate stricter regulations for farmers.
2. Register and certify all farms.
3. Develop qualified extension workers and scientists.
4. Legislate drug laws and penalties for infractions.
5. Modernise the shrimp farming infrastructure.
6. Maintain feed quality standards (Lin, 1989).

In a similar situation to Thailand, it has been stated that for the Philippine shrimp industry to survive the pending downward trend in shrimp prices, both the government and the private sector must act immediately to decrease stocking densities, improve cost effectiveness, largely by lowering feed tariffs, setting up government subsidies and improving infrastructure, and set up trade missions for market diversification (Primavera, 1992). To sustain the industry, the government should focus on resource management. Target culture areas should be identified and rational regulations on mangrove use developed. Groundwater and seawater use must be regulated and their pollution prevented. Wild stocks of shrimp must be protected. This programme will require, as in Thailand, enforcement of existing laws, promulgation of new legislation and a continued research and technology dissemination effort (Primavera, 1992).

Dr Sudara of Chulalongkorn University in Bangkok says that the Government has an extremely short-sighted policy. There has never been any comprehensive planning which takes into account the relationship between the total area and the number of ponds allowed by the government. The development of shrimp farming should harmonise with the environment. For the industry to develop sustainably there must be increasing regulations due to concern for the economic costs of mismanagement and for the environmental impact of unlimited expansion. There is already significant government regulation in most countries concerning effluent treatment, sea and freshwater use, protecting wetlands, indigenous wild stocks (in terms of broodstock capture limitation and the importation and culture of exotic species), inspection of harvested shrimp, government-funded support services and education and training (Fast & Lester, 1992; Hopkins, 1992). Also smaller farmers, run by already impoverished farmers may end up losing out to bigger, better trained and equipped ones (Malasaiddh, 1992). In addition, almost nothing is known about how shrimp farms affect their surroundings, particularly with regard to the carrying capacity of the coastal ecosystem for shrimp farms over the long term (Anon., 1992g; Phillips & Macintosh, 1992; Phillips *et al.*, 1993) and the groundwater supplies (McClellan, 1991). The shrimp farmers themselves are now calling on the government to restrict development and insist on buffer zones between farms (New, 1990). The Yad Fon (raindrop) Association, the Wildlife Fund of Thailand and the Southern Branch of the Coordinating Committee on Rural Development, in the absence of any enforceable government legislation are helping to organise coastal fishermen and farmers to prevent such environmental destruction (Quarto, 1992). Collectively, the shrimp industry should work out ways to police itself by not only limiting, through licensing, the proliferation of the number of farms and areas in production but also farm size and production intensity (Chong, 1990).

c) Contract farming

Proponents of the contract farming system such as Aquastar maintain that this system may offer a better way of ensuring sustainability. This is because it is very difficult to enforce any regulations placed upon shrimp farming activities. Uncontrolled expansion of small-scale and highly intensive shrimp farming by inexperienced operators without the knowledge or finances to utilise suitable water control devices has shown to be detrimental to the environment and the industry itself. By organising these farmers into units large enough to be able to afford the investment in the infrastructure necessary for sustainable culture, the benefits of small operators working for themselves may be retained and the problems of self-pollution and environmental impact may be avoided (Brown, 1989b; Harry Hoogendorn, Aquastar, pers. comm., 1990). Aquastar's technology is also now being exported to other countries including India (Anon., 1993c). However, the question for the small farmers is often whether to accept this dependence on the centre or to sell their farmland to a wealthy entrepreneur, usually an outsider, and take his chances in the city (Csavas, 1990).

d) Disease

In terms of disease, in 1992 the Asian Shrimp Culture Council called for the setting up a drug residue standard for the cultured shrimp industry to match those in force for most other farm-raised products. The ASCC said that it was time for shrimp farmers, processors and government agencies from exporting and importing nations to meet and agree on the maximum limits acceptable, and for consumers to be educated and informed that a certain residue is acceptable and safe for human consumption (Anon., 1992f). Then in April 1992 at a conference on the Diseases of Cultured Penaeid shrimp in Asia and the United States hosted by the Oceanic Institute from Hawaii, the importance of the spread of pathogens (especially viruses) via the uncontrolled movement of shrimp stocks was highlighted. This problem requires widespread adoption of quarantine regulations and increased usage of specific pathogen-free (SPF) stocks (Anon., 1992f). At that same conference, the need for improved husbandry techniques, particularly in intensive culture was also reinforced since many serious diseases are caused by opportunistic organisms and disease losses can be prevented by ensuring optimal conditions for growth and by monitoring shrimp health continuously (Anon., 1992f).

Despite all of the well-intentioned plans and initiatives suggested by NGOs, scientists and some of the farmers themselves, due to the general apathy of shrimp farmers who are interested only in realizing maximum profit in minimum time, for a sustainable industry to develop it is imperative for the government to take sustained, meaningful, enforceable, integrated and environmentally-sound action in the planning and development of shrimp farming before the resources are lost for everyone for ever.

2.3.2 GOVERNMENT LEGISLATION, ENFORCEMENT AND EFFECTS

a) Environmental management

According to the Thai government, to protect its increasingly threatened coastal environment and natural resource base, Thailand has begun to formulate an integrated coastal resource management plan including cabinet resolution, legislative action and the seventh National Economic and Social Development Plan, running from 1992-1996. The plan recognises that local governments, NGOs and key economic sectors must cooperate in formulation, testing and eventual success of coastal policy implementation. The national priority coastal issues in the policy development plan (first established in 1980) consist of the protection of water quality, tourist amenities, critical coastal habitats and near-shore fisheries resources and the development of a sustainable mariculture industry. The government insists that these policies set specific guidelines for the sustainable use of coastal resources. The Office of the Natural Environment Board (ONEB) devises the policies. The coastal and marine resources

agencies responsible for their implementation and enforcement include the Department of Fisheries, the Royal Forestry Department, the Department of Mineral Resources, the Land Development Department, the Tourism Authority of Thailand and the ONEB. Unfortunately, there is no one single national agency responsible for the coastal management of both marine and coastal areas. Thus, although the implementation of strategies through intersectional cooperation has been presented as a major objective, the ONEB admit that it is rarely achieved. In addition, constraints encountered in implementing the plans include planning constraints, lack of public participation, insufficient institutional capabilities and budget, and perhaps most damning of all, ineffective or non-existent laws and no commitment to law enforcement (Tabucanon, 1991).

As long ago as 1991, the previous Thai government had announced a zoning policy to preserve mangrove forests and the Department of Forestry had adopted control over mangrove use in the southwest of Thailand. However, there has been no firm enforcement (Dr. Surapol) so its effectiveness is unknown and zoning is difficult since the forests have never been clearly demarcated (Malasaidh, 1992). In addition, shrimp farmers are continuing to cut down mangroves in western Thailand, despite the deadline for their removal at the end of 1993. Dr Suraswadi of the Fisheries Department has urged shrimp farm operators to cooperate in conserving mangroves to avoid pressure from international groups. He consulted with the Thai Development Research Institute (TDRI) who insisted that shrimp farming was important for the economy of the country and must be developed. Dr Suraswadi has also promised to cooperate with the Forestry Department to prevent mangrove destruction and assist with the construction of irrigation facilities in Ranote. He also said that advanced technology would be employed in order to boost productivity and that research would be conducted into how to develop shrimp farming and make it ecologically sustainable (Anon., 1993g).

In 1993, the Harbour Department Waterways Transport Inspection Division Chief has stated that large quantities of seawater were being used on shrimp farms and the cost of desalinating this water was as much as that of tap water purification (Anon., 1993h). Therefore, because of this cost and the ecological impact of waste water, the Environmental Impact Assessment Committee of the ONEB would propose that the government impose a tariff on the use of seawater which would go into a fund to be created for state agencies such as the Fisheries Department to restore marine life to the sea. The rate of the fee was yet to be worked out. In addition, polluters would face an undisclosed fee for damage done to ecology (Anon., 1993h).

b) Intensive shrimp culture management

The current regulations pertaining to shrimp farming announced by the Deputy Minister of Agriculture and Cooperatives, Mr Arch Taolanon in November 1991 (Taolanon, 1991) due to intense pressure from all parties involved, comprised:

1. All shrimp farms to register with the government between January 1st and June 30th, 1992 without charge.
2. All registered farms of over 8 ha to have waste water treatment or sediment ponds of not less than 10 per cent of the total size of their farms.
3. A limit of 10 mg l⁻¹ biochemical oxygen demand (BOD) in all shrimp farm effluents.
4. A ban on the flushing of mud or silt from shrimp farming areas into natural water sources or public areas.
5. A ban on release of salt water into public freshwater resources or other farming areas.

These regulations were also endorsed by the King of Thailand in 1991 (Anon., 1991e). In this Royal Decree it was stated that the underlying reasons for the proclamation were so that the government would be able to better oversee the industry, prevent their lands from being encroached upon and to

support the shrimp farming business to produce standard output. It was also aimed at properly controlling waste water treatment systems and the use of drugs and chemicals in shrimp farms to avoid adverse effects on consumers and the environment. It was also expected that the government would obtain data for use in planning shrimp farming, production and marketing (Anon., 1991e).

Also in 1991, the Director General of the government Department of Fisheries Dr Plodprasop Surawadi added a regulation on shrimp farming in mangrove areas stating that there would be no new mangrove destruction or government loans to farmers planning farming on mangrove sites and that all existing farms located on mangrove areas must leave by the beginning of 1994.

These laws were to be enforced by the Regional Fishery Stations of the Thai government, with fines imposed for infringement (Kanit Chaikam, NICA, pers. comm., 1993). The government, in conjunction with aid money from the Canadian International Development Agency (CIDA) has also implemented a three year project in Kung Krabaen Bay (one of the first areas to crash in 1990) to transfer technology and management programmes to Thai scientists to aid the situation. In addition, the government has organised seminars aimed at raising environmental awareness among local residents (Malasaidh, 1992). The government was also going to provide support with funds from the rich farmers to build pumps to pass waste-water through water treatment facilities and pump in clean seawater from the Gulf of Thailand to the central areas, but did not succeed in doing so before the industry in that location collapsed (Malasaidh, 1992; Anon., 1992i).

c) Disease management

In terms of disease, the Thai government acted quickly, introducing monitoring systems for antibiotics at shrimp farms and processing plants in response to a threatened ban on shrimp exported to Japan in 1991 (Anon., 1993c). However, residues are still being found as revealed in the announcement by the Japanese Ministry of Health and Welfare in 1992 saying that it would continue to inspect shrimp imports from Thailand, the Philippines and Indonesia for antibiotics (Anon., 1993c). Thus, as voiced by the ASCC in 1992, the government still needs to meet with shrimp farmers, processors and foreign governments and agree on acceptable drug residue limits, and to educate consumers that a certain residue is acceptable and safe for human consumption (Anon., 1992f).

The Thai government has also initiated the establishment of the International Commercial Aquaculture Research Institute (ICARI) on the campus of the Prince of Songkhla University in southern Thailand. This institute is to be created by eight equal-share founders including the National Science and Technology Development Agency of Thailand, the University and a minimum of six aquacultural companies. The purpose of the institute will be to promote, through research and development, the long-term profitability and sustainability of the aquaculture industry. The establishment of the institute will be supported by donations and grants from governmental and international agencies. Initial aims will concentrate on the production of specific pathogen free (SPF) captive broodstock for the production of high quality, disease-free larvae as a prerequisite for long-term industry stability and high, efficient production. Later, various other issues such as environmental and rearing problems will also be investigated (Anon., 1993c).

Similar to the Thai situation, the government of the Philippines are studying several measures designed to prevent environmental deterioration and assist the long term and integrated planning and harmonious development of the shrimp farming industry. These measures include: setting of ecologically-based limits to freshwater wells for shrimp culture through a locally-based licensing system; conversion from highly intensive to semi-intensive systems; raising species which thrive on pure seawater to obviate the requirements for freshwater; cost-effective methods of removing pollutants, treating shrimp culture waste and reuse of water and even the lay-out of industrial zones (Liao, 1990).

d) Policy effectiveness

Clearly, the governments' mangrove policy is very difficult to enforce and hence open to corruption. The requirements for wastewater treatment/settlement ponds at only the larger shrimp farms is unenforceable due to their number and the lack of government manpower and authority to penalise offenders (Kanit Chaiyakam, NICA, pers. comm., 1992). In addition, the larger farms are generally operated more sustainably than the small farms due to their greater knowledge and level of investment, so that the smaller 'wildcatters' who are still not required to treat their effluents, will remain the major source of pollution. The governments' claim that their regulations will limit drug and other chemical waste discharges is also unfounded since no checks are done on the levels of such chemicals in waste water from any size of farm. Furthermore, the ban on flushing of polluted water to the sea is enforceable only through local cooperatives which is often carried out violently. Lastly, the limit on effluent BOD is also unenforceable, as well as being ineffective, since increased water exchange would limit the concentration, but not the total volume of BOD discharged.

The upshot of the excessive and ineffective bureaucracy and the impotent policies, which are yet to be enforced, is that shrimp farming has been allowed to escalate out of all proportion without any limitation whatsoever. Indeed, Mr Kijar Jaiyen, Deputy Director of the Department of Fisheries has admitted that the government had been ineffective when it came to preventing pollution from shrimp farms and that there was as yet no mechanism for forcing the shrimp farmers to do anything. He stated that the best and most permanent way to solve the problems was in extension of suitable farming techniques to the farmers (Stanley, 1993). This view has subsequently been subscribed to by scientists (Fast & Lester, 1992).

Such extension surely begins with research work done to establish the most effective means of combatting the various problems associated with the intensive shrimp culture industry. This research should also take into account the recommendations of the NGOs working in the field, the effects of the existing government legislation and the applicability and enforceability of any new recommendations. This is precisely the sort of research which is being conducted and disseminated by the current ODA project (Briggs, 1993a,b,c; Briggs and Funge-Smith, 1993; Funge-Smith, 1993a,b).

2.4 RESEARCH WORK REQUIRED FOR SUSTAINABILITY

Research work conducted by government Fishery Stations, Universities and private companies has already begun both in Thailand and other countries in attempts to find solutions to some of the more pressing sustainability problems associated with intensive shrimp culture. In Thailand, as in many other Third world countries, the important step of regulating the development of aquacultural activities to prevent inappropriate use and overexploitation of coastal resources has been neglected. Thus, Thailand is now in the position of having to deal with a situation which should not have been permitted to develop. The only solution, short of closing down huge areas of shrimp farms is thus in the development, promotion and enforcement of environmentally-sound farm management practices (Barg, 1992, Chua, 1993). Initial research has therefore focused on defining the most effective management strategies to ensure the sustainability of the shrimp farming industry. The establishment by the Thai government of the International Commercial Aquaculture Research Institute should also assist the development of sustainable shrimp culture techniques. This research will initially be directed towards the production of disease free seed and go on to tackle environmental and husbandry problems (Anon., 1993c).

Environmental management techniques are mainly concerned with providing a suitable habitat in which the animals can be cultured sustainably without polluting either themselves or their environment. These

In attempting to identify the reason for the loss in production in Taiwans' shrimp ponds in 1988, it was found that by conditioning water before stocking and employing ecological management principles i.e. polyculture with fish, up to 10 t ha⁻¹ production could be achieved from ponds yielding nothing from shrimp monoculture (Chiang, Chien, Liu & Kuo, 1990). Polyculture of seaweeds (*G. fisheri*) between the net cages used for Asian seabass (*Lates calcarifer*) culture has achieved both nutrient reduction and production rates of seaweed equal to 106 t ha⁻¹yr⁻¹ (Chaiyakam & Tanwilai, 1992b). At a current value for seaweed of at least £ 0.5 kg⁻¹ for agar production (Suwalee Chandkrachang B.R.U., pers. comm., 1993), *Gracilaria* production has the potential to add £ 52,500 ha⁻¹ onto the gross income of seabass farming, while simultaneously maintaining water quality. Problems concerning salinity, epiphyte and predator levels however, require further research before such integration can be reliably achieved on a large scale (Chaiyakam & Tanwilai, 1992b). Other trials under field conditions in aquacultural ponds have shown that *Gracilaria* can remove nutrients effectively and grow rapidly under the right conditions (Fralick, Huguenin & Lapointe, 1981). At an average production rate of *Gracilaria* in ponds of 30 t ha⁻¹yr⁻¹, and assuming 5 per cent of the dry weight as nitrogen, potential nutrient removal is in the order of 4.1 kg N ha⁻¹d⁻¹ (Fralick *et al.*, 1981). For the conditions found in southeast Thailand, the total production of nitrogen from intensive shrimp farms, including that found in the sediments, has been estimated at 3.1-4.2 Kg N ha⁻¹d⁻¹ (Anon., 1991c, Lin *et al.*, 1991; Phillips *et al.*, 1993). This compares with the average increase in water-borne nutrient loadings of about 1.2 kg N ha⁻¹d⁻¹ on discharge from intensive shrimp ponds in southeast Thailand (Briggs 1993a,b; Briggs & Funge-Smith, 1993). If seaweed were to be cultured within settlement ponds, an area 30 per cent of the pond area would therefore be required to absorb all of the water-borne nitrogenous wastes produced (Briggs & Smith, 1993). Current research under the ODA project is aimed at examining the short and long term ability of *Gracilaria* to reduce nutrient loadings from shrimp pond waste water under field conditions, and the value of *Gracilaria* meal in shrimp diets.

Use of biological treatment techniques like these will distance the industry from the now common and increasingly problematic monoculture systems (characterised by high levels of stress and inefficient resource use) and realign it with traditional extensive methods which more closely mimic natural ecosystems. The management of intensive shrimp farming for short-term profits does not recognise the interrelationships between resource use, environmental impacts and ecosystem maintenance. These factors are now clearly fundamental for aquaculture development. Such integrated systems require less resource input, have less effect on the environment and are hence more sustainable economically, socially and ecologically. The fact that integrated systems, using principles of ecological engineering have been in existence for hundreds of years testifies to their sustainability (Folke & Kautsky, 1992). Such integration techniques are thus clearly in need of further research under both tank and field conditions to more fully assess their potential in alleviating environmental problems and promoting sustainability (Macintosh & Phillips, 1992; Phillips *et al.*, 1993). This will therefore be an area of concentrated effort over the remainder of the current ODA shrimp culture research project.

2.4.2 PHYSIO-CHEMICAL TECHNIQUES

Other methods of environmental management use various management procedures including chemical and physical treatments of ion-exchange, buffering, settlement and filtration. These areas too, have been subject to some research, but have still to have their efficiency and/or cost effectiveness confirmed for shrimp farming (Beveridge, Phillips & Clarke, 1991; Macintosh & Phillips, 1992), particularly due to the high flow, low concentration of wastes from such systems (Barg, 1992). For example, work on the current ODA research project has failed to find any benefit to using zeolites in shrimp ponds as ion-exchangers to reduce levels of toxic metabolites (Briggs, 1993a,b,c). This runs counter to their almost ubiquitous use by at least 50 per cent of farmers in the Ranote and Hua Sai areas of southeast Thailand, where a £ 1.2 million annual industry currently exists (ODA, unpublished report; Briggs, 1993a,b,c). In contrast, the use of settlement ponds comprising 10 per cent of the pond

area have been shown effective at reducing suspended solids and total nitrogen and phosphorus loadings to the environment (Briggs, 1993a,b).

Effective manipulation of the environment to favour production and reduce pollution requires an understanding of basic physical, chemical and biological processes in shrimp pond dynamics. There are wide variations in and limited knowledge of these processes in intensive shrimp ponds. Research is particularly needed on phytoplankton dynamics, water and effluent management, sediment chemistry and deposition and nutrient flow from fertilisation and feeding (Fast & Lester, 1992). In addition, almost nothing is known about how shrimp farms affect their surroundings, particularly with regard to the carrying capacity of the ecosystem for shrimp farming over the long term (Anon., 1992d; Phillips & Macintosh, 1992). Long term baseline studies, modelling and simulation techniques are therefore necessary to be able to reveal how shrimp farms are affecting their own ecosystem and the environment as a whole. This knowledge will enable the prediction of how suitable planning, siting and management changes may assist sustainability and what the impact of a certain area of shrimp ponds will be on the environment. This approach would also facilitate the integration of shrimp culture into an overall coastal resource management strategy (Boyd, 1986; Beveridge, Phillips & Clarke, 1991; Macintosh & Phillips, 1992). Other potential management practices that may help reduce effluent discharge include careful draining on harvest, the use of settlement ponds and treatment ponds prior to release of heavily-polluted water, rigorous pond sediment treatment regimes and the optimisation of feeding strategies, including the use of low pollution diets, to reduce feed wastage (Boyd & Musig, 1992; Macintosh & Phillips, 1992).

2.4.3 FUTURE TECHNIQUES

Finally, Dr Liao of the Taiwan Fisheries Research Institute and others have suggested that to be able to develop a truly sustainable shrimp culture industry, research work needs to be carried out in the following areas:

1. Increasing the number of species, strains and hybrids being commercially cultured to aid genetic manipulation and improvement,
2. Hatchery and grow-out techniques to lower production costs and assist product competitiveness on world markets,
3. Work on optimum nutritional requirements for each species of cultured shrimp and the development of feeds with optimal food conversion efficiency and low pollution,
4. Quarantine procedures and preventative measures to combat disease problems,
5. Product quality improvement i.e by live transport,
6. In-vitro cell and tissue culture to aid research procedures,
7. Novel or innovative biological techniques,
8. Long-term integrated planning to counteract profit-oriented development which is exacting a high social and environmental cost,
9. Stock-enhancement or sea-ranching programmes to boost natural populations (Supawewat, 1984; Liao, 1990, 1992).

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Figure 1: The main shrimp farming areas of Thailand.

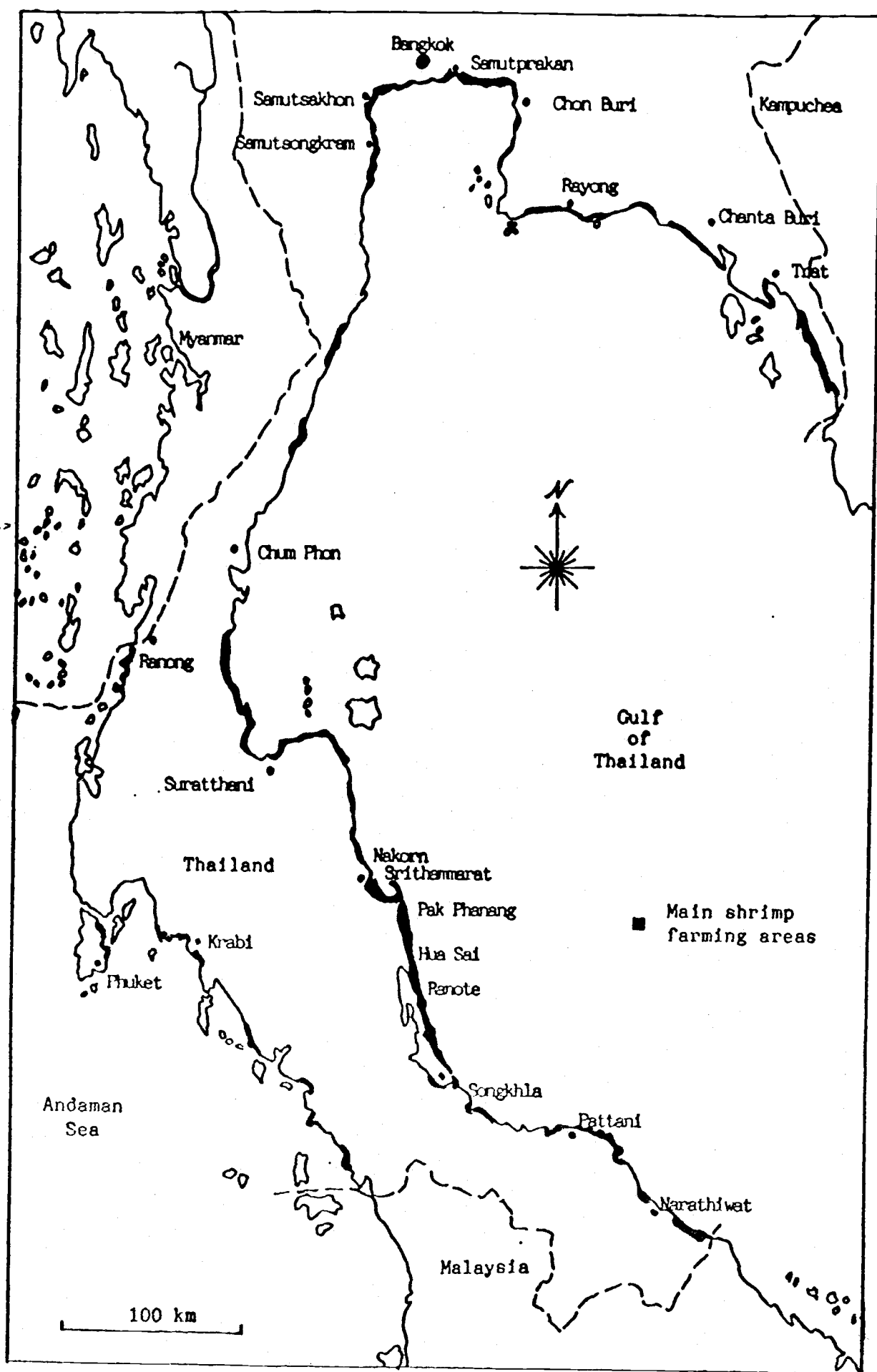


Table 1: The production of cultured shrimp from 1984 to 1993.

STATISTIC : DATE	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Total world shrimp production by culture in metric tonnes (t)	162,646	210,088	297,893	482,174	548,562	567,231	599,807	690,000	721,000 *	744,000 *
Total Thailand shrimp production (t)	13,007	15,840	17,886	23,566	55,633	93,496	120,906	153,377	163,000 *	170,000 *
Thailand production of <i>P. monodon</i> (t)	170	106	897	10,544	40,774	81,492	105,028	137,241	151,700 *	161,500 *
Proportion of Thailand shrimp production as <i>P. monodon</i> (%)	1.3	0.7	5.0	44.7	73.3	87.2	86.9	89.5	93.1 *	95.0 *
Total area of shrimp ponds in Thailand (ha)	36,791	40,768	45,367	51,139	56,911	62,684	68,456	74,228	80,000 *	85,000 *
Production rate of shrimp in Thailand (kg/ha)	354	389	394	461	978	1,492	1,304	1,482	2,038 *	2,000 *
World production of <i>P. monodon</i> (t)	47,672	55,726	89,384	147,856	154,564	197,896	223,040 *	300,000 *	335,000 *	370,000 *
Proportion of world <i>P. monodon</i> production from Thailand (%)	0.4	0.2	1.0	7.1	26.4	41.2	42.0 *	45.7 *	45.3 *	43.7 *
Taiwanese production of <i>P. monodon</i> (t)	10,755	16,715	44,387	78,548	30,603	16,672	8,570	12,000 *	19,500 *	17,550 *
Proportion of world <i>P. monodon</i> production from Taiwan (%)	22.6	30.0	49.7	53.1	19.8	8.4	3.4	4.0 *	5.8 *	4.7 *

* = estimate

Table 2: The world production of *P. monodon* in 1990 by country.

Country	Production (t)
Australia	577
Fiji	7
Indonesia	59,000
Italy	2
Malaysia	1,275
Myanmar	1
Pakistan	38
Philippines	47,591
Saudi Arabia	51
Seychelles	15
Solomon Is.	5
Sri Lanka	700
Taiwan	8,750
Thailand	105,028
World Total	223,040