Development, Environment and Shrimp Aquaculture: The Emerging Challenge of Inland Low-Salinity Shrimp Culture in Thailand

by

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ABSTRACT

Farm-raised marine shrimp are Thailand's most important agricultural export, earning $US 2.4 billion annually in revenues for the government. Thailand's experience with intensive shrimp culture spans almost two decades. First generation marine shrimp farms, located mostly in coastal areas, have given way to a second generation of shrimp farms located in freshwater and brackishwater areas. The success of these second generation farms is attributed to the discovery by farmers that they can successfully cultivate a marine species of shrimp under low-salinity conditions. The nature of this innovation, referred to as inland or low-salinity culture, has greatly increased the potential for establishing shrimp cultivation much further from the coast than previously believed possible. While there are still many coastal shrimp farms, the most significant industry expansion since the mid 1990s has occurred in the irrigated floodplain and delta of Thailand's central plain. The output from low-salinity shrimp culture in freshwater areas now accounts for a large and rising proportion of total Thai production, and is a significant component of world production.

This dissertation investigates the development of low-salinity shrimp culture in Thailand. The key findings were the firsthand documentation of the factors contributing to the development of low-salinity shrimp farming in freshwater environments. This study documents the innovations in hatchery and farming techniques, examines the development of the saltwater infrastructure required to sustain inland shrimp ponds, and identifies the land and water management challenges associated with low-salinity culture from both the government and producer perspective. The methodology adopted to achieve the research objectives consisted of secondary data review, farm and key informant surveys utilizing semi-structured interviews, informal interviews and discussions, and statistical description and analysis. The research was completed during four separate field investigations totaling ten months over an eight-year period from 1997 to 2004. Recommendations are offered to improve the environmental management of low-salinity shrimp culture.

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GLOSSARY

Selected Thai Terms

Amphur: District or administrative unit beneath the province.

Baht: Thai currency unit, equivalent to approximately 5 cents.

Changwat: The province; the largest administrative unit below the nation in modern Thailand.

Kamnan: Thai official governing the tambon, or group of villages, directly under the amphur in administrative hierarchy.

Muban: A village or community.

Nai Amphur: District officer.

Padi: Unprocessed rice or rice growing in the field.

Phuyaiban: Term for the elected head of the village or muban.

Rai: Thai unit of land area measurement – there are 6.25 rai per hectare. One rai is equivalent to 0.16 hectares.

Tambon: Thai term for commune or group of villages under the leadership of the kamnan.

Terminology

Aquaculture: is the farming of aquatic organisms in inland and coastal areas, involving intervention in the rearing process to enhance production and the individual or corporate ownership of the stock being cultivated.

Aquatic: all encompassing term used to describe marine, brackish and freshwater environments.

Brackish water: coastal or inland waters with a salinity level ranging from 1 to 16.5 parts per thousand (ppt).

Broodstock: A group of mature fish that is kept separate and used for producing fry, also: mature fish retained at a hatchery to produce eggs and young. The term can include younger fish eventually to be used as spawners but not yet mature. May be used for eggs or juveniles from which subsequent generations will be produced.

Crustacean: marine shrimp, freshwater prawns and crabs.

Development: A process through which women and men, with varying degrees of external support, increase their options for improving their quality of life.

Eyestalk Ablation: Most of the broodstock require unilateral eyestalk ablation in order to induce successful spawning. The ablation removes the source of an inhibitory hormone(s) that blocks the reproductive system of the female. Although this method may succeed in inducing spawning, the female is considerably stressed which may result in deteriorating egg quality and trigger off pathogenesis of otherwise dormant pathogens.

Farmer: A person who works a piece of land devoted to raising crops or livestock.

Fresh water: inland waters with a salinity level below 1 ppt.

Mariculture: cultivation of any plant or animal species exclusively in marine waters.

Marine water: coastal or oceanic waters with a salinity level greater than 16.5 ppt.

Nauplii: A crustacean larva having three pairs of locomotive organs (corresponding to the antennules, antennae, and mandibles), a median eye, and little or no segmentation of the body.

Salinity: Concentration of dissolved salts in seawater. Salinity measured by grams of solids contained in 1 kilogram of seawater (parts per thousand or ppt, grams/kilogram). Full strength seawater is around 35 ppt.

Shrimp: marine or brackish water forms of the families *Penaeidae* or *Palaemonid* (e.g., *Penaeus monodon*).

Shrimp vs. prawn: FAO has attempted to establish clear-cut distinctions for these terms where "prawns" refer to freshwater creatures, while shrimp refer to their marine and brackish water relatives. Common usage has often resulted in reference to large shrimps as "prawns" and to small shrimp as "shrimp" regardless of the salt content of their habitat. The latter applications are deeply embedded in the common and scientific usage.

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CHAPTER 1

INTRODUCTION

1.1 Nature of the Problem

Aquaculture is one of the fastest growing food production systems in the world. With stagnating yields from many capture fisheries and increasing demand for fish and fishery products, expectations for aquaculture to increase its contribution to the world's production of aquatic food are very high (see, for example, FAO, 2002). According to FAO statistics, aquaculture's contribution to global supplies of fish, crustaceans and molluscs continues to grow, increasing from 3.9% of total production by weight in 1970 to 27.3% in 2000. Worldwide, the aquaculture sector has increased at an average compounded rate of 9.2% per year since 1970, compared with only 1.4% for capture fisheries and 2.8% for terrestrial farmed meat production systems (FAO, 2002). Global aquaculture production currently accounts for more than 25% of all fish consumed by humans (FAO, 2002). Rapid growth in aquaculture, referred to by some analysts as a Blue Revolution, is in many ways analogous to the Green Revolution in terrestrial agriculture. Just as the Green Revolution was acclaimed as the means to end world hunger, the Blue Revolution is said to hold the promise of increasing local incomes and assuring the availability of affordable protein to the poor in the developing world (Coull, 1993; Kelly, 1996; Weber, 1996). Since the late 1980s, a primary component of the Blue Revolution has been the integration of aquatic species and ecosystems into the global agricultural food system (Stonich et al., 1997).

The intensification and industrialization of terrestrial agriculture is not a new phenomenon. Agro-industries have long been in the forefront of important shifts in spatial, institutional, and technological organization of world agriculture (Watts, 1994).

Recently, however, attention has shifted to the production of aquatic commodities. Aquatic culture is also intensifying in large part due to the fact that the world's oceans are no longer able to supply adequate amounts of seafood to meet demand (Jackson et al., 2001; Ellis, 2003a). Aquaculture is now considered by many analysts to be essential in order to supplement supplies in order to meet demand (Muir, 2001; FAO, 2002).

In developing economies, the growth of aquaculture is one response within the food production sector to the forces of globalization and trade liberalization. It has generated significant debate over the social and environmental impacts of globalization and the industrialization of agriculture in global agro-food systems (FitzSimmons, 1986; Watts, 1990). While many species are cultured, the development of the shrimp farming industry in many tropical-developing economies has shifted rural producers towards increased market orientation and commodity trade instead of local use. Commodity trade remains the most significant generator of foreign exchange for many tropical countries. Like many other agricultural and natural resource products, shrimp have become more of a high-value trade commodity. Shrimp farming is also concentrated in the developing world while the majority of farmed shrimp are exported to three principal consumer markets in the developed world, namely the United States, Europe and Japan. In producer nations, shrimp often rank among the top exports. In consumer nations, there has been a steadily increasing demand for shrimp (Gujja and Finger-Stich, 1996). International demand for shrimp is contributing to the shift from the culture of low- (economic) value traditional food species, previously supplying domestic markets, to the intensive culture of high-value aquatic species, such as shrimp that cater to lucrative international export markets (Hotta, 1996). Over the last three decades, marine shrimp farming has been transformed from a subsistence activity into a large-scale agro-industry producing 30% of the shrimp traded in expanding world markets (FAO, 2002).

Shrimp farming has evoked critical international concern owing to the extensive role that it plays in transforming coastal landscapes and livelihoods in tropical developing nations. Although many types of aquatic species are cultured commercially, shrimp are the most important sector of the global aquaculture industry in terms of value. In 2002, the world's shrimp farmers produced roughly 2,130,984 tonnes of shrimp worth an estimated $US 10.8 billion (FAO, 2005b). National governments and multilateral aid agencies often promote shrimp farming on the basis that it can play an important role in replacing the declining wild capture fisheries (Coull, 1993), enhancing the income and employment opportunities for coastal communities (Suraswadi, 1987), strengthening local food security (Williams, 1997; Tacon, 2000), and generating significant foreign exchange (Siregar, 2000). Shrimp farming has been one of the driving forces behind the large increase in shrimp trade during the late 1980s and early 1990s. The subsequent growth of the shrimp industry in tropical and subtropical coastal areas of Asia and Latin America has been referred to as an "aquatic gold rush." The term "aquatic gold rush" is derived from three factors: the high-value of the product; the largely unregulated entry of producers into the industry; and the fact that the rapid pace of development shrimp aquaculture has often outpaced regulatory efforts.

Industry promoters contend that the overall impacts of shrimp farming are largely positive (Huisman, 1990; Hempel and Winther, 1997; Lem and Shehadeh, 1997; FAO, 1998a; Phillips, 1998; Kutty, 1999). The contribution of shrimp farming to foreign exchange, employment earnings, and income diversification are seen as offsetting any problems associated with shrimp farming (Phillips and Barg, 1999). Other analysts, however, have expressed concern over the social, economic and environmental impacts of shrimp farming that are off-loaded onto the rural poor (Boontrigrugsa, 1990; Khor, 1995a; DeWalt, P. et al., 1996; Gujja and Finger-Stich, 1996; Yadfon Association, 1996; Ahmed, 1997; Stonich et al., 1997). There is now growing uncertainty over the long-term sustainability of intensive production systems (Fegan, 1996; Primavera, 1998) and intense debate over the appropriateness of shrimp aquaculture development (Bailey and Skladany, 1991; Kelly, 1996; Gronski, 1997). In short, shrimp farming is a highly controversial activity at local, national and global levels.

Controversy over shrimp farming development is particularly acute in Thailand, a leading producer of farmed shrimp, currently supplying around 22% of the world trade in shrimp (GLOBEFISH, 2004). Farmed shrimp contribute over 70% of Thailand's annual shrimp production and exports garner $US 2.4 billion in foreign exchange earnings (Department of Fisheries, 2005). Shrimp represent 3.5% of total exports of goods and services (Department of Fisheries, 2005). The importance of shrimp to Thailand's economy, however, has been overshadowed by persistent and intractable social and environmental impacts (Phantumvanit and Sathirathai, 1988; Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996; Yadfon Association, 1996; Stevenson, 1997). Recurring 'boom-and-bust' cycles, attributed to widespread disease epidemics and large fluctuations in the farm gate price for shrimp, have left many rural small holders indebted and without a resource base on which to reconstruct their livelihoods. There is growing evidence that marine shrimp farming has not benefited the majority of the residents of coastal communities (Funge-Smith, 1993; Flaherty and Karnjanakesorn, 1995). These concerns notwithstanding, shrimp farming in Thailand continues to be a growth industry. Farmed shrimp production has remained high and is supported by the expansion of shrimp farming into new inland production areas.

Until recently, the operational requirements of shrimp farming confined shrimp pond development to a narrow band of land along the coast. With coastal shrimp farming practices coming under increased criticism because of mangrove destruction, and concerns with pollution and disease, the shrimp industry has endorsed "sustainable" shrimp farming practices (Phillips and Macintosh, 1996; FAO, 1997a; FAO, 1999b; Yap, 1999). Although the extent to which mangrove destruction by shrimp farming has slowed down is open to debate (Menasveta, 1997b), recent innovations in shrimp culture technology are raising new land and water management concerns (Flaherty and Vandergeest, 1998). During the early 1990s, low-salinity shrimp farming, which relies on salt water trucked in from the coast, facilitated the establishment of marine shrimp farms in predominantly wet rice growing areas much further from the coast than previously believed possible (Flaherty and Vandergeest, 1998). By 1998, inland shrimp farming was reported as occupying approximately 22,455 ha in 23 provinces (Land Development Department, 1998), and accounting for between 50 to 60% of Thailand's farmed shrimp exports (Limsuwan, 1998). In 2002, it was reported that 70% of the shrimp produced in Thailand, or about 300,000 metric tonnes (MT) a year, was produced from farms using low-salinity conditions (Limsuwan et al., 2002).

The rapid expansion of low-salinity shrimp farming into the rich farmland of Thailand's central region came under intense public and governmental scrutiny in 1998. Subsequently, the Thai government banned inland shrimp farming in designated freshwater areas (Arunmart and Ridmontri, 1998; Hongthong, 1998; Inchukul, 1998c).

Concerns remain, however, over the capacity and willingness of the government to enforce the ban (Inchukul, 1998a; Inchukul, 1998b) and the manner in which fresh and brackish water areas have been designated (Bangkok Post, 2000). Vast areas in the central region have been designated as brackish. In the absence of effective regulation, there is potential for serious and even more recalcitrant environmental problems than those being experienced in shrimp farming areas along Thailand's coast. The potential also exists for these impacts to emerge in other shrimp producing nations that emulate Thailand's low-salinity culture practices in their respective agricultural production areas.

The establishment of marine shrimp farming in irrigated wet rice farming areas has the potential to generate both local and regional effects on rice production and environmental quality. The social, economic, and environmental impacts generated by marine shrimp farming in rice producing areas are largely unidentified. This development also raises a number of concerns over the environmental impact of marine shrimp farming in freshwater environments. Many of the concerns over this emergent form of shrimp farming, however, have yet to be investigated. Details on the nature of this innovation are not available, and the farming techniques applied have yet to be fully documented. Additionally, the hatchery techniques and saltwater infrastructure supporting this innovation have not been examined in detail. Given the speed with which low-salinity shrimp farming is spreading into freshwater areas there is an urgent need to develop a better understanding of the factors contributing to the spread of low-salinity culture, and the impacts that it is generating in rural communities. This information will provide a basis for developing appropriate policy responses that support of sound environmental management, which in turn will help ensure the long-term sustainability of shrimp farming.

1.2 Purpose of the Study

Low-salinity shrimp culture is an important innovation in shrimp farming. The purpose of this research is to improve our understanding of the low-salinity shrimp culture innovation, and to determine the implications of this development for rural communities. The specific research objectives are to:

1. Document the integration of shrimp farming into Thailand's national development strategy.
2. Investigate the nature of the low-salinity shrimp culture innovation, including the hatchery, husbandry and operating procedures.
3. Investigate the factors contributing to the rapid adoption of low-salinity shrimp aquaculture in freshwater environments.
4. Document the economic and institutional factors that have facilitated the development of low-salinity shrimp farming in freshwater environments.
5. Identify the ways in which low-salinity shrimp farming is impacting on rural environments and communities.
6. Develop a set of recommendations for policy improvements and better management practices at the farm-level.

The field investigations for this research were completed in several stages - beginning in 1997 and ending in 2004. The results of the 1997 research have been published in several reports (see, Flaherty et al., 1999; Miller et al., 1999; Miller, 1999; Vandergeest et al., 1999a; Vandergeest et al., 1999b; Flaherty et al., 2000; Vandergeest et al., 2001; Flaherty et al., 2002; Miller, 2003).

1.3 Outline of the Thesis

This thesis has seven chapters. Chapter 2 sets the context for this study by reviewing the historical development of marine aquaculture from a global perspective, touching on the interactions between aquaculture, development and the environment. It then focuses on the social, economic and environmental impacts of shrimp aquaculture development in tropical developing economies. Chapter 3 presents an overview of Thailand's natural resources and economy. It documents the government's focus on export-oriented natural resource based development. It discusses the development of marine shrimp farming in Thailand and reviews the emergence of shrimp farming as one of the nation's most important export commodities. Chapter 4 describes the research context and methodology adopted for the field study. Chapter 5 presents the results of a field investigation of inland shrimp aquaculture conducted in the central region of Thailand. It then provides a profile of low-salinity shrimp farming households. Chapter 6 discusses the results in the context of all of the natural resource users: shrimp farmers, rice farmers, fish farmers, orchardists and the village leaders. It also presents a set of recommendations for improvements in shrimp farming policy and farm-level management. Chapter 7 presents the conclusions drawn from the research.

CHAPTER 2

MARINE SHRIMP AQUACULTURE

This chapter reviews the historical development of aquaculture, and presents an overview of global production levels. It then examines the development of marine shrimp aquaculture, describes shrimp culture systems, and reviews global shrimp production levels. The social, economic and environmental impacts associated with shrimp farming are then reviewed.

2.1 Marine Aquaculture

The term "aquaculture" has been defined in a number of different ways – some quite narrow, others broad. For the purpose of this study, the definition provided by the Food and Agriculture Organization of the United Nations (FAO) is quite appropriate:

> Aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated (FAO, 1990).

The practice of aquaculture can be traced to settled civilizations prior to 2000 BC amongst the Japanese, Chinese, Romans, Assyrians, Egyptians and Mayan Indians of South America (Hanfman et al., 1989). Aquaculture may have even more remote roots in the highly organized ancient water-oriented civilizations of the Near East, in which fish were an important dietary component (Bardach et al., 1972). Evidence of oyster culture in East Asia dates to times before the Christian era. In the West, the Romans were probably the first to cultivate oysters (Sasson, 1983). The common carp has been a salient farm stock throughout the history of aquaculture. Over 1000 years ago, the Chinese practiced an advanced form of polyculture with various species of carp on silkworm farms (Ling, 1977; Sasson, 1983). The first written account of fish culture in ponds was by Fan Lee, a Chinese fish farmer, in 476 BC and represents the beginnings of traditional aquaculture (Milne, 1972).

Despite the long history of aquaculture and the development of modern techniques, the majority of aquatic foods for human consumption are still derived from natural stocks. However, the majority of natural stocks are fully utilized, and, in many cases, over exploited (Jackson et al., 2001; Pauly et al., 2003). In addition, the composition of the world fish supply is shifting towards a proportionately higher catch of low value species, hiding the slow but steady degradation of demersal high-value resources (Caddy and Garibaldi, 2000). The expression "fishing down the food chain" is often used to describe the situation where the total weight of fish caught remains constant, but the makeup of the catch in terms of quality deteriorates (Pauly et al., 1998; Sumaila, 1998). Older individuals of a species are much more rare too.

Capture fisheries landings have reached a plateau at around 85 to 95 million tonnes per year (Figure 2.1). The FAO predicts that global capture fisheries production will remain constant at approximately 90 million tonnes per year up to the year 2010. However, with an expected world population of 7 billion at this time, wild fish supplies will be faced with a 19 million-ton shortfall (FAO, 1997b). This deficit arises not only due to increased demand, but also from the concomitant pressures of over fishing, habitat degradation and habitat loss (Williams, 1997). There is a growing consensus that capture fisheries alone cannot meet the nutritional needs of an expanding global population for high quality and affordable animal protein (Ellis, 2003b; Pauly et al., 2003). Therefore, aquaculture is expected to fill the shortfall created by declining capture fisheries.

Early aquaculture practices evolved from subsistence artisanal production. These traditional methods were small-scale, low-intensity, and produced low yields of low value products (Edwards and Demaine, 1997). Like other traditional forms of agriculture and animal husbandry, early practices were practiced much as craft, with knowledge of the methods being transferred from generation to generation, and improvements being achieved through trial and error procedures. Farmers usually focused on ensuring sufficient production to meet domestic needs and switched to income generation once subsistence needs were met. This type of rural aquaculture has long made important contributions to the alleviation of poverty, directly through small-scale household farming of aquatic organisms for domestic consumption or income, and indirectly by providing employment for the poor or low-cost fish for rural and urban consumers (Edwards, 1997). Although these traditional aquaculture methods are still used by many rural inhabitants, modern aquaculture involving more intensive methods is growing in importance.

Ongoing advancement of modern aquaculture is achieved through the introduction of new areas, species, and practices and through increased production from existing systems. After the Second World War, several factors combined to hasten the development of new aquaculture practices. These included international agricultural development programs coupled with the growing population, and capture fisheries decline. Substantive technological improvements such as the development of hatchery techniques and the use of supplemental formulated feeds have allowed producers to dramatically increase aquaculture yields. Improvements in refrigeration technology have also facilitated the distribution of local aquaculture products to new international markets (Muir, 2001; Lebel et al., 2002).

2.1.1 Global Aquatic Production

In response to increasing consumer demand, global aquatic production has increased through advances in fishing technology (i.e., areas and species fished) and by growth in aquaculture (i.e., area and species cultured). Total global aquatic production reached 145.9 million MT in 2002: marine capture fisheries production of 94.6 million tonnes and aquaculture production of 51.4 million tonnes (FAO, 2005b; FAO, 2005c). The production increase of 20 million tonnes over the last decade was mainly due to aquaculture, as capture fisheries remained relatively stable (Figure 2.1). Aquaculture's share of the total aquatic food supply has increased from 11.6% in 1984 to 35.2% in 2002 (FAO, 2005b).

Asia dominates global aquaculture production, with China the leading nation worldwide. In 2002, this region produced over 91% of total aquaculture production by weight, followed by Europe, South America, North America, Africa, and Oceania (FAO, 2005b). Asia's combined production was 46.9 million tonnes and included 91% of mollusks, 87% of crustaceans, 88% of finfish, and most aquatic plants. Although approximately 250 species of finfish, shellfish and crustaceans are farmed commercially, only a dozen or so species account for the bulk of the world's output. By weight, freshwater aquaculture dominates with the harvest of low-value finfish species that are produced mostly for local consumption. In value terms, marine aquaculture dominates owing to the production of high-valued marine species such as salmon and shrimp, which are cultivated for export (Table 2.1). In 2002, the total value of international aquaculture production exports was around $US 60 billion. Although crustaceans contributed around 4% of total aquaculture production by weight (over 2 million tonnes), they represented around 18% in value terms of international trade. This share equates to a dollar value of around $US 10.8 billion.

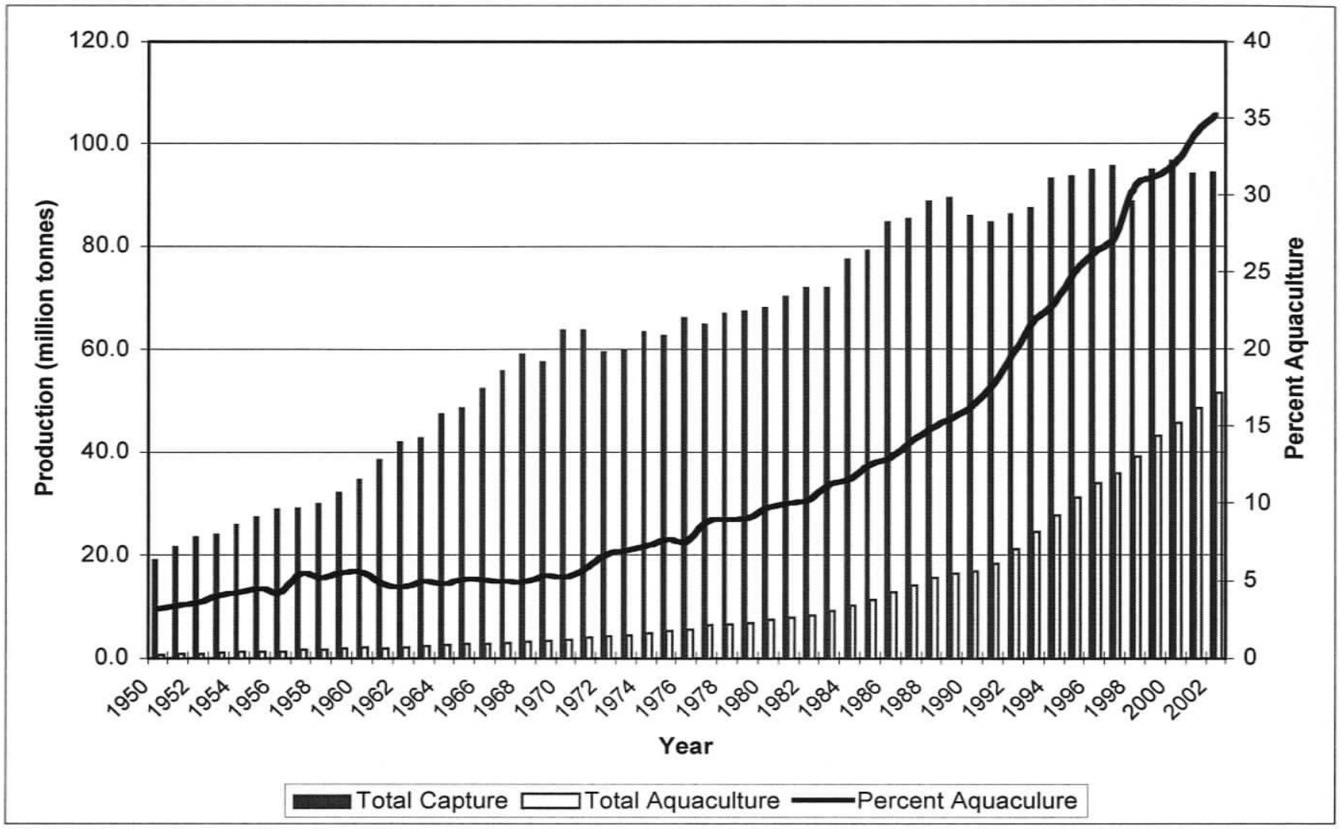
Table 2.1 Global Aquaculture Production and Value, 2002

Species	Production (MT)	Value ($US 1000)
Aquatic Plants	11,587,341	6,188,605
Crustaceans	2,130,984	10,838,545
Diadromous fishes	2,589,898	6,465,170
Freshwater fishes	21,937,653	21,342,839
Marine fishes	1,201,060	4,143,878
Misc. aquatic animals	154,903	495,760
Molluscs	11,784,073	10,511,858
	51,385,912	59,986,655

Source: (FAO, 2005b)

Although aquaculture encompasses a wide variety of culture practices and species, marine shrimp farming has emerged as one of the world's most important, albeit controversial, aquaculture sectors.

Figure 2.1 Global Aquatic Production



Source: (FAO, 2005b; FAO, 2005c)

2.2 Marine Shrimp Aquaculture

The earliest brackishwater farming in Southeast Asia is believed to have originated in Indonesia on the island of Java during the 15th century AD (Ling, 1977). The culture of milkfish (*Chanos chanos*) and other brackishwater species in embanked coastal areas (tambaks) began under the influence of the Hindu rule. In these systems, low walls were built in estuarine areas to close off part of an estuary, with the tidal filling or passive flooding of 'ponds' controlled through simple sluice gates. Desirable seed including juvenile fish and shrimp and other biota, as well as unwanted predators and competitors, were allowed in through the gate with the rising tide. After a few days, the gate was closed, or at least screened to prevent escape, and the impounded animals were grown for some time and then harvested. The harvest generally occurred on a spring high tide by letting the water out through a net at the gate. At harvest, finfish were the property of the pond owner while the shrimp, a by-catch, became the property of the labourers. These traditional extensive culture methods were characterized by low annual yields, typically in the order of 50 to 500 kg per ha (Chamberlain, 1991).

Farmers eventually modified trap and hold systems to eliminate the constraints of low and unpredictable yields of unknown species composition. The pond source water was screened to prevent undesired entrants and the pond was subsequently stocked with specific quantities of a known species. Such modifications were first perfected in Indonesian and Philippine brackishwater ponds with milkfish and various shrimp species (Bardach et al., 1972). Despite the additional labour and skill required for stocking, the farmer gained greater control over survival rates, growth and size at harvest. One important limitation of traditional systems was that they relied upon seed collected in the wild, which could vary widely in amount in different seasons. Over time, trial and error experimentation gave way to scientific research into culture systems supported by captive reproduction and mass propagation of shrimp seed through larviculture in hatcheries. While traditional systems still predominate in some coastal areas of India and Africa (Hein, 2002; Rönnbäck et al., 2002), higher yielding systems are also being introduced at a rapid pace.

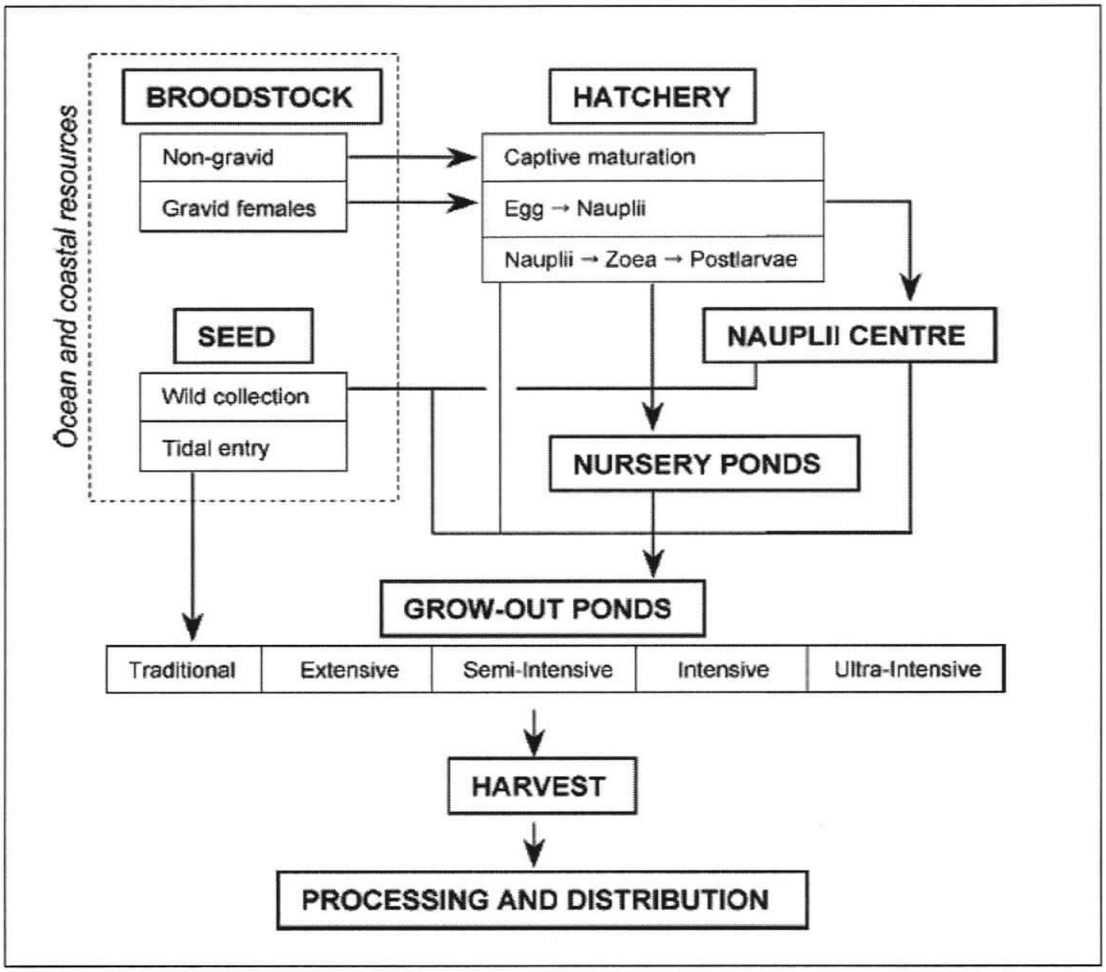
Modern marine shrimp aquaculture resulted from the pioneering research of Japan's Motosaku Fujinaga (published under Hudinaga, 1935; Hudinaga, 1942). In the 1930s, Fujinaga completed the technical groundwork for the captive reproduction and seed production with wild gravid shrimp through larviculture in hatcheries (Shigeno, 1978). Fujinaga's research on the spawning and larval rearing of kuruma prawn, *Penaeus japonicus* was a breakthrough in shrimp culture technology that was not widely recognized or applied until the late 1960s. An important subsequent technological advance occurred when researchers discovered that non-gravid female shrimp could be induced to mature and spawn in captivity by a technique known as eyestalk ablation (Caillouet, 1972; Chamberlain and Lawrence, 1981). Because of this discovery, wild-captured non-gravid female shrimp could be transported to culture areas, and matured and spawned in captivity. This advancement allowed for the provision of a consistent seed supply produced year round on demand, and facilitated the expansion of farming effort to locations outside of the natural range of shrimp species. In the 1970s, the commercial development of hatchery techniques provided the foundation for the rapid progression of marine shrimp culture into tropical coastal areas around the globe during the 1980s (Bray and Lawrence, 1992). The global expansion of shrimp aquaculture continues to rely upon the wild capture of gravid females that are used by hatcheries to produce seed (Beveridge et al., 1997).

2.2.1 Farming Practices

In the wild, the genus Penaeus species have a life cycle where they spawn at sea and after a few weeks the post larval shrimp settles in inshore and estuarine waters (Dall et al., 1990). The nursery ground, which for many species is characterized by the presence of mangroves, is the critical habitat that determines most of the recruitment success to fisheries. After a few months in their nursery grounds, the juvenile shrimp start their emigration offshore to complete their life cycle.

The aquaculture production cycle for marine shrimp is depicted in Figure 2.2. The shrimp post-larvae, or seed that are stocked in grow-out ponds originate from four sources. Naturally occurring wild shrimp seed can be allowed to enter traditional ponds with incoming tidal waters or caught by seed fishermen and subsequently stocked in ponds. Shrimp post-larvae can also be produced in hatcheries, which depend upon the continual inputs of wild-caught gravid female spawners or broodstock that are allowed to mature in captivity. The development from hatched egg to ready-to-stock post-larvae lasts approximately three weeks. In recent years, a nauplii producing industry has emerged in some countries. These operations buy nauplii larvae (1 day old) from hatcheries; grow them into post-larvae, which are then sold to farmers. Shrimp farmers employ a one or two-phase production cycle. With the two-phase cycle, post-larvae shrimp are initially stocked in nursery ponds for a few weeks before they are transferred to grow-out ponds. The use of nursery ponds improves managerial aspects like predator control and feed waste minimization, although the post-larvae suffer increased mortalities when they are harvested for stocking into grow-out ponds. It takes three to six months to produce a crop of market-size shrimp.

Figure 2.2 Aquaculture Production Cycle for Shrimp



Source: (Fast, 1992b)

2.2.2 Shrimp Culture Grow-Out Systems

Shrimp farming is a dynamic industry. New techniques are continually being developed and existing ones modified so as to increase production. These techniques often require higher levels of management and inputs like feed and chemicals. Changes in shrimp culture grow-out systems are reflected in the transition from subsistence extensive culture in trapping-growing ponds with mixed species to the present day intensive monoculture. As with other aquaculture systems, shrimp culture systems are usually classified as traditional or extensive, semi-intensive and intensive – characterized by increasing stocking rates supported by corresponding feed and water management inputs (Pullin, 1989). The classification of shrimp culture systems is based on the relationship between the level of inputs and the corresponding productivity of the culture system. The characteristics of the various marine shrimp culture systems are presented in Table 2.2.

Table 2.2 Characteristics of Marine Shrimp Culture Systems

Feature	Traditional or Extensive	Semi-intensive	Intensive
Pond size (ha)	30 (Traditional); 5+ (Extensive)	1 to 20	0.25 to 2
Stocking rate (No./m^2/crop)	0.1 to 1	3 to 10	15 to 40
Seed source	Wild	Wild/Hatchery	Hatchery
Crops per year	1-2	2-3	2.5-3
Survival (%)	<60	60 to 80	80 to 90
Minimum water depth (m)	<1.00 (Traditional); 0.4 to 1.0 (Extensive)	0.7 to 1.5	1.5 to 2.0
Aerators per hectare	None	4 to 8 units	4 to 8 units
Feed source	Natural (No supplement)	Natural + Supplement	Formulated from Wild Supplies
Feed conversion	0	< 1.0 to 1.5	1.5 to 2.0
Water exchange rate (%/day)	<5	< 5 to 20	10 to 20
Water management	Tidal exchange	Tidal/Aerators	Pumps/Filters
Effluent volume	Large	Smaller	Least
Effluent quality	Acceptable	Poor	Variable
Production (MT/ha/year)	<0.1 to 0.3	0.5 to 2.5	5 to 15

Source: (Fast, 1992b; Saenger, 1993)

Extensive systems are low input systems characterized by low stocking densities, little or no external nutritional inputs, tidal water exchange, and shrimp yields of less than 100 to 300 kilograms per hectare per year. Semi-intensive systems use fertilizers combined with supplemental feeding, intermediate stocking densities, occasional pumping of water and produce yields of 0.5 to 2.5 tonnes per hectare per year. Intensive systems use high stocking densities, formulated complete feeds, aeration and water pumping with yields of 5 to 10 tonnes per hectare per year. Although the above terms are commonly used, there is limited agreement among aquaculturists as to the exact set of conditions that each describes (Weeks, 1992). Several reports provide a detailed discussion of the different shrimp culture systems, including monoculture and polyculture (Apud et al., 1983; Fast and Lester, 1992).

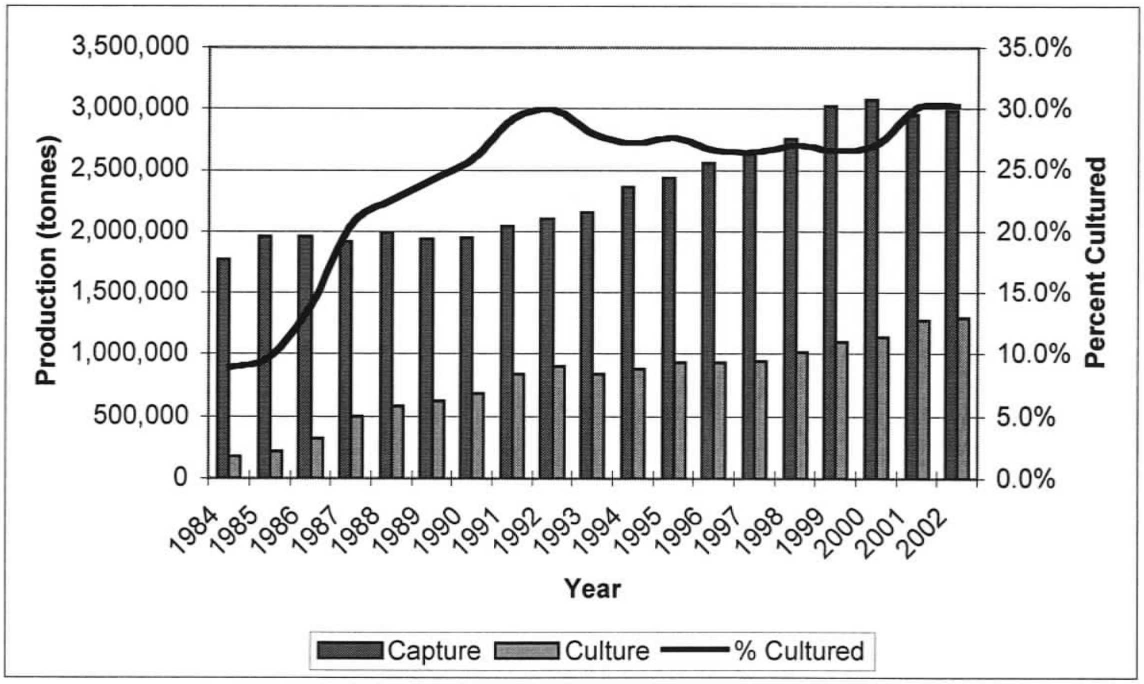
Shrimp culture grow-out systems rely on a small number of key inputs. After the successful development of techniques for the mass production of post-larvae, hatcheries were key to the widespread intensification and expansion of marine shrimp monoculture systems in brackishwater and saltwater environments. By guaranteeing the supply and maintenance of broodstock, hatcheries were able produce fry all year round as long as spawners were available (Kungvankij et al., 1986). Hatchery-bred fry of the same age are almost uniform in size and can be produced in large quantities at any one time. Other infrastructure is also needed. The manufacturers and suppliers of feeds, equipment and chemicals support intensive shrimp culture systems. It also relies upon individuals who are involved in shrimp post-harvest handling, processing, distribution, marketing and trade.

2.2.3 Global Shrimp Production

The capture fishery has traditionally been the major supplier of shrimp to world markets. Although global landings of shrimp from the capture fisheries reached a plateau of approximately 2 million tonnes in 1985, farmed shrimp have kept the world supply expanding. The volumes of wild catch and farmed shrimp and their shares of global shrimp production, for the period 1984 to 2002 are given in Figure 2.3. Between 1984 and 2002, the global supply of shrimp from capture and culture fisheries increased from 1.9 to 4.3 million tonnes. Over the same time-period, cultured shrimp production increased exponentially from 172,178 to 1,292,476 tonnes. In 1984, only 9% of global shrimp production was obtained from aquaculture. By 2002, more than 30% of world shrimp supplies were derived from shrimp farming (FAO, 2005b).

Although 343 shrimp species of economic importance have been identified by the FAO (Bailey-Brock and Moss, 1992), only a few species are traded commercially (Csavas, 1992; Clay, 1997). About 80% of global crustacean production is tropical marine shrimp. Although early research and development for penaeid shrimp farming was conducted on *Penaeus japonicus*, the explosive growth of shrimp farming in the later decades has been associated with the black tiger shrimp *P. monodon*. At present, the black tiger shrimp is the species of choice for producers. The suitability of the black tiger to intensive culture is well documented (Chen, Liu et al., 1989). They have a fast growth rate (Chiang and Liao, 1985; Liao and Murai, 1986), low protein requirements compared to other carnivorous shrimp (Lee, 1971; Deshimaru and Yone, 1978), and possess a high tolerance to stressful culture practices. In 2002, this species comprised almost 44% of the total production. The fleshy prawn *P. chinensis* and the Pacific white shrimp *P. vannamei* contributed 33% and 19% respectively, and *P. indicus, P. stylirostris, P. japonicus, P. merguiensis* contributed the rest (Figure 2.4).

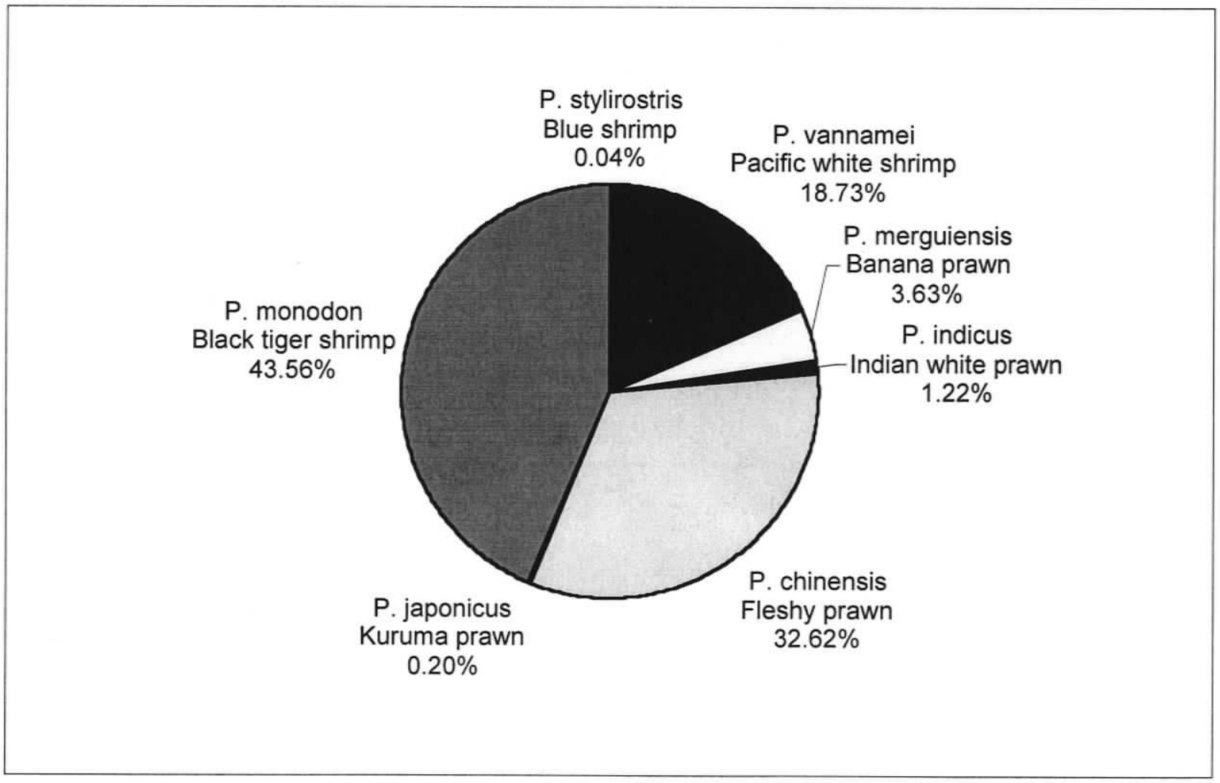
Figure 2.3 Global Shrimp Production



Source: (GLOBEFISH, 2003)

In 2002 (the most recent year for which global data are available) the FAO reported farmed shrimp production for over sixty-seven countries. It is estimated that shrimp production ponds occupy some 864,350 hectares worldwide (FAO, 2005b). In 2002, the six leading producers of farmed shrimp were China, Thailand, Indonesia, India, Vietnam and Ecuador (Figure 2.5). Production is highly concentrated in the tropical and subtropical areas of Asia and Latin America. In 2002, over 75% of total shrimp production came from the top five Asian producers. In Latin America, the top five producers in this region contributed almost 14% of world farmed shrimp production (FAO, 2005b). Thailand was the world's leading producer of farm-raised shrimp from 1993 until 2001. In 2001, China edged out Thailand's production slightly to become the world's leading producer of farmed shrimp.

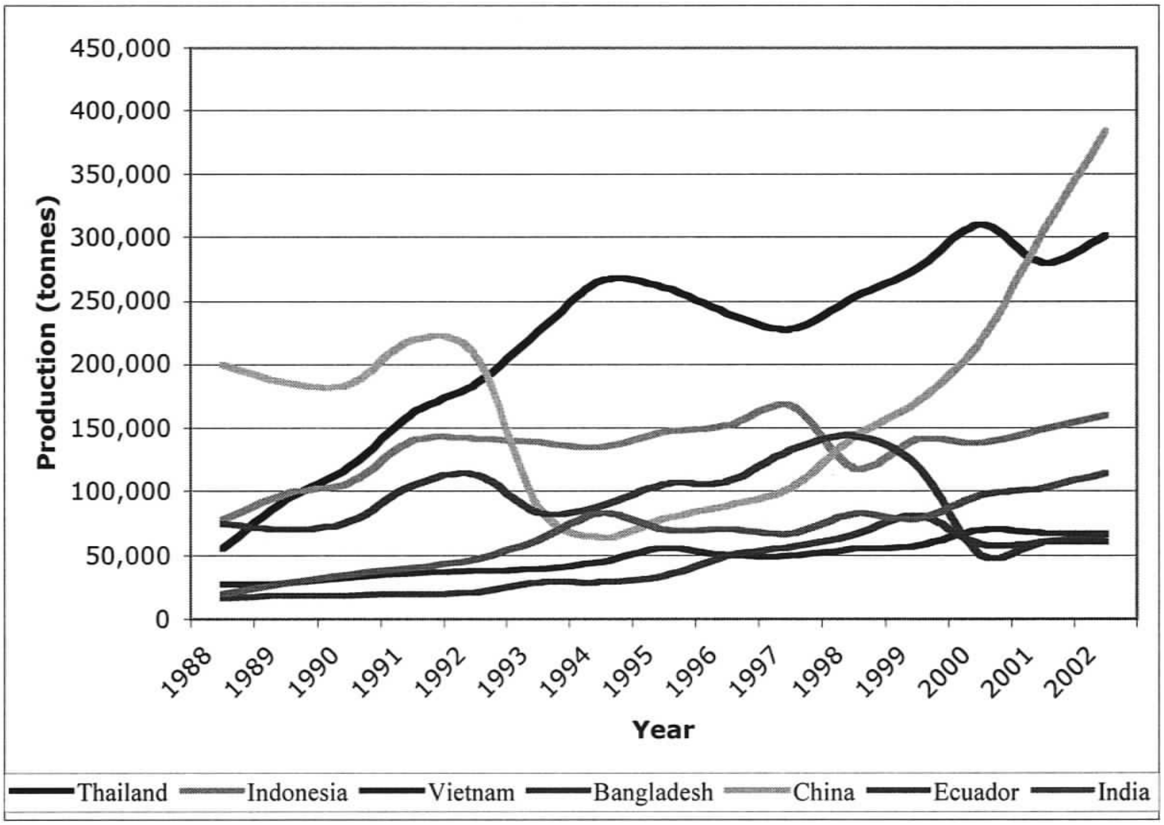
Figure 2.4 Global Shrimp Production by Species, 2002



Source:(FAO, 2005b)

Over the past several years, many shrimp-producing countries in South America experienced a decline in production owing to disease or weather problems. In Asia, cultured shrimp production has also been characterized by a series of outbreaks of disease caused by viral pathogens, which have caused significant losses to the culture industries of most Asian countries over the past decade. These disease outbreaks have not been confined to a single country but have spread throughout shrimp culture regions as a result of transfers of infected stock. It was not until the late 1990s, spurred by the production of imported white shrimp (a non-indigenous exotic species), that Asian (therefore world) production levels have begun to increase again.

Figure 2.5 Leading Producers of Farmed Shrimp



Source: (FAO, 2005b)

The annual production of farmed shrimp is small compared to other farmed species, such as freshwater finfish. However, marine shrimp are the highest value seafood commodity currently flowing through world trade channels (FAO, 2005a). Estimates of the monetary values generated by farmed shrimp production vary widely depending upon the prices and volumes assumed, and the point in the production chain at which they are calculated. The FAO reports that shrimp account for fewer than 20% of the total value of internationally traded fishery products (FAO, 2005a). Because shrimp are high-priced commodities, shrimp consumption is mostly concentrated in the affluent economies of temperate developed countries. Although consumer markets for shrimp are increasing, three dominate globally – Japan, the United States and the European Union (FAO, 2005a). The United States and Japan represent the largest single country markets for shrimp. Overall, however, shrimp imports by the European Union represents the largest market for cultured shrimp. Over the period 1988 to 2001, the total volume of global imports of fresh, chilled, frozen, prepared and preserved shrimp ranged between 1.0 to 1.7 million tonnes (FAO, 2005a). While the total volume of shrimp imports has not increased dramatically, an increasing proportion of the global shrimp trade is comprised of farmed shrimp.

Some analysts have heralded the growth of marine shrimp aquaculture as a development panacea. Marine shrimp aquaculture development has been promoted and subsidized by multilateral lending agencies and national governments as a means to provide employment, strengthen local food security, acquire foreign investment, increase export earnings, and improve the balance of trade (Huisman, 1990; Skladany and Harris, 1995). However, there is growing evidence that shrimp aquaculture development has resulted in serious environmental degradation and generated social and economic injustices in many countries around the world. The following sections discuss the social, economic, and environmental impacts of shrimp aquaculture.

2.3 Social and Economic Impacts of Shrimp Aquaculture

Historically, farmers used traditional methods and local ingenuity to improve their living conditions through low-intensity shrimp aquaculture. Though these systems produced low yields, production was sufficient to meet their domestic needs with any surplus going to markets. Over time, however, shrimp farming has evolved from a low technology activity into a capital and technology intensive industry that is oriented towards international markets. With the adoption of "industrial" shrimp aquaculture many negative social and economic impacts have emerged in local communities (Phillips et al., 1993). This section reviews the key impacts.

2.3.1 Privatization of Resources and Marginalization of Rural Communities

The privatization of common property resources and subsequent marginalization of indigent coastal communities is an ongoing concern associated with the development of intensive shrimp farming. Although shrimp ponds are established in a variety of locations, shrimp farming in mangroves is the most widely publicized example of the negative social and economic impacts of shrimp aquaculture development (Katesombun, 1992; Parks and Bonifaz, 1994; Stevenson, 1997). Mangroves have traditionally supplied a wide-variety of goods and services that have contributed to the well being of coastal communities (Snedaker, 1986; Folke and Kautsky, 1992). For centuries, local populations have lived, fished, and hunted within mangroves, deriving from them valuable commodities such as timber, fuel, thatching and roofing materials, medicine and food (Macintosh, 1998). Unfortunately, the communities dependent upon mangroves have tended to be politically and economically marginal within national society. In many cases what they regard as their traditional rights to local resources has been unknown or ignored by the larger society (Collier, 1978; Bailey, 1988; Bailey, 1989). In most countries, traditional coastal resource users do not hold tenure and the state claims legal ownership to coastal mangroves or undeveloped coastal lands (Bailey and Skladany, 1991). Shrimp aquaculture development has resulted in the transfer of multiple-use common property resources to single-use private property controlled by smaller private interests (Bailey and Skladany, 1991; Clay, 1996). Long-term leases sanctioning large-scale mangrove conversion for shrimp farming development have directly impacted the livelihoods of rural communities depending on mangrove resources (Smith and Pestano-Smith, 1985; Chua, 1993).

The social, economic and environmental impacts of shrimp farming in mangroves or other habitats are difficult to assess. Local residents, small-scale fishers and aquaculturists have been physically denied direct access to mangrove goods and services, or have experienced concomitant losses due to declining catches from fisheries resources associated with mangroves (Turner, 1977; Macintosh, 1982). In Bangladesh, shrimp farming expansion into mangroves led to reductions in fish catches, and declining socioeconomic conditions for traditional coastal fishers (Phillips, 1994b). Thai fishers reported declining catches, linked to restricted access to previously accessible mangrove areas and lagoon fishermen in Sri Lanka reported declining catch rates following the establishment of shrimp farms (OEPP, 1994; Corea et al., 1998). One major impact of resource privatization on local populations occurs when common grazing grounds are converted to shrimp ponds, and the owner then restricts grazing areas by not allowing cattle to pass over the dikes (Deb, 1998).

With the adoption of more intensive shrimp culture systems, shrimp pond development was promoted in an expanded number of locations. Extensive shrimp farms, sugar and coconut plantations, salt farms, paddy fields, nipa palm forests, rubber plantations and orchards have since been converted to intensive shrimp ponds (Chong, 1988; Aitken, 1990; Chong, 1990). Rural communities have experienced many of the negative impacts associated with intensive shrimp aquaculture development, and received few of the benefits (Primavera, 1989; Maybin and Bundell, 1996; Primavera, 1997). As shrimp farming has appeared as a *boon* to a few powerful people in society, it has been a *bane* for a larger section of the coastal community as it broadly ignores and deprives them of their traditional territorial use rights (Deb, 1998).

In Thailand, the privatization of natural resources and the marginalization of rural communities resulting from shrimp farming have been documented in several studies (Briggs and Funge-Smith, 1994b; Miller, 1994; Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996; Gronski, 1997; Boonchoo, undated). Section 3.5 of Chapter 3 discusses the Thai shrimp farming industry in greater detail.

2.3.2 Competition for Land, Credit, and Commercial Products

Until recently, land was not a limiting factor to the expansion of shrimp farming in most countries. The availability of extensive tracks of low cost land was a major reason that shrimp farmers abandoned ponds and shifted to new locations with the onset of disease and/or declining productivity (Gujja and Finger-Stich, 1996). However, the availability of land for further expansion of marine shrimp farming has declined owing to increased competition with urban, industrial, tourism and other uses. Additionally, since shrimp farming relies on the natural environment for water, feed and seed, the expansion of production sites have exacerbated competition with other users of these same resources, notably agriculture and capture fisheries. Consequently, the remaining land suitable for shrimp aquaculture has increased dramatically in price, particularly in coastal and estuarine areas (Dierberg and Kiattisimkul, 1996; Kongkeo, 1997; ADB/NACA, 1998; Kutty, 1998; Kongkeo, 2000). Issues of land tenure and ownership or use of land and water resources are increasingly in the center of discussions on shrimp aquaculture.

In Asia and Latin America, natural resource conflicts are pronounced between displaced groups and outside capitalists. The prevailing land ownership patterns and the power structures in rural areas have created a disposition towards outsider ownership of shrimp farms. Rural inhabitants have determined from experience that outsiders are seldom interested in dialogue with local communities and assume limited responsibility for the environmental impacts (Corea et al., 1998; Stackhouse, 2000). According to Peluso et al. (1994:12), "the outsider may degrade the resource, pulling out when the profits have been extracted. This leaves the community with a resource base that is exhausted, unattractive to other investors, and relatively useless for local livelihoods". In Honduras, conflict has erupted between the dominant larger shrimp farms and coastal communities (DeWalt et al., 1996) and the majority outsider ownership of shrimp ponds in Khulna in Bangladesh is intensifying conflict in the region (Haylor and Bland, 2000). Absentee ownership arrangements with tenant sharecroppers are usually structured so that landowners receive the majority of the profits while tenants are responsible for all of the production costs and risks (Guimarães, 1989). In Sri Lanka, 70% of the medium and large-scale shrimp farmers are outsiders to the district and have acquired land for the sole purpose of shrimp culture (Corea et al., 1998). While semi-intensive and extensive shrimp farms in West Java Indonesia tended to be locally owned, outsiders controlled all of the intensive shrimp ponds (Muluk and Bailey, 1996).

Shrimp pond development has occurred in regions where land prices are relatively low. Subsequent changes in land use have transformed traditional land use activities, or provided opportunities for larger shrimp farming interests to absorb local power and to eliminate the regional and small group benefits from shrimp farming. According to Neiland et al. (1997:25), the methods of land use transfer have included "legal sale of deed, forced sale through harassment, sale following degradation of the land by shrimp farming, and sale after inundating and ruining the land with salt water, and eviction of tenants." Shrimp companies have often purchased or leased low-yielding agricultural land from small and marginal farmers in local communities by offering attractive prices (Bhatta and Bhat, 1998; James, 1998). In some instances, shrimp culture promoters have sweetened the deal by offering to provide opportunities for local communities by financing local amenities and social facilities (Pillay, 1997; James, 1998). Local residents usually come to regret these decisions once they see the high profits generated by shrimp farming (Pillay, 1997).

Shrimp farming development tends to concentrate land ownership among the elites and urban entrepreneurs (Hannig, 1988; Bailey, 1992; Skladany, 1992). Increased demands for ponds located in productive areas have created exaggerated conditions for sale and rent, often not based on net returns but on hypothetical pond productivity (Muluk and Bailey, 1996). With increased land value in shrimp producing regions, smaller landowners have been inclined to sell even if the land is their only source of income. Small-scale shrimp producers are vulnerable, oftentimes forced to migrate to other areas by selling their land to larger producers or leasing to entrepreneurs if there are dramatic changes in the shrimp market (Briggs, 1994; Briggs and Funge-Smith, 1994b; Clay, 1996). In traditionally exploited estuarine areas of India, annual lease rents received from contractors did not account for the losses in rice farming (Bhatta and Bhat, 1998). In Indonesia, shrimp aquaculture development increased the selling prices of shrimp ponds, but also led to higher rent and sharecropping conditions that favoured local elites (Hannig, 1986). While land developed for shrimp farming increases in value for investors, affordability of land becomes an issue for locals and non-shrimp farming interests. In one region in Southern Thailand, land prices per hectare soared from $US 50 to 75 in 1985 to $US 50,000 to 75,000 in 1991 (Boromthanarat, 1995). While the benefits to landholders that sell out are obvious, the situation makes land unattainable for poorer farmers.

Intensive shrimp farming has favoured the entry of multinational corporate investors, land speculators or local elites with capital and the ability to absorb financial risks (Primavera, 1992). In most shrimp producing nations, national and international corporations are involved in the investment, development and operation of shrimp farms (Angell, 1993; Shang et al., 1998). Economies of scale and better management are reported to make large-scale intensive shrimp farms economically viable in the long term (Tokrisna and Benheam, 1995; Shang et al., 1998). Although larger shrimp farms have long dominated in Latin America (DeWalt et al., 1996), the situation in Asia varies. In the Philippines, shrimp production is controlled by a small group of investors and is related to land ownership patterns (Primavera, 1991). In the Philippines, expensive inputs such as fertilizers, pesticides, seed, feed, are purchased exclusively from suppliers outside the locality (Kelly, 1996).

In Thailand, the shrimp industry is dominated by small-scale independent farmers on small parcels of land that are owner occupied (Lin, 1995; FAO, 1997a). Increasingly, however, ownership of the land under production is of less importance. Larger shrimp farming operations are strategically shedding risks associated with production and moving towards controlling the financial and technical inputs of production and into the processing and marketing of shrimp (Barraclough and Finger-Stich, 1996). In Thailand, grow-out disease risks have increased to the point where larger shrimp farming interests prefer to focus on feed manufacturing, processing, marketing, and distribution activities (Goss et al., 2000).

2.3.3 Employment and Labour Patterns

The International Labour Organization does not collect data on employment in shrimp aquaculture. While some Asian governmental agency and FAO reports give crude estimates of overall employment, existing information is usually drawn from data contained in various country reports. Nevertheless, the global shrimp aquaculture sector is reported to directly employ 584,080 people, excluding China and Bangladesh, and

2,019,328 people indirectly (Singh, 1999). Although employment is often cited as a major benefit of shrimp farming, there is limited information on the types and quality of the jobs created in the sector. Discussions usually refer to the direct employment opportunities, neglecting the substantial number of people indirectly employed in the processing, packaging, distribution, and the retail and service sectors. There is general agreement, however, that capital is replacing labour as the key factor of production, with the result that neither extensive nor intensive shrimp production is labour intensive. The shrimp farming industry cannot be viewed as labour intensive considering the small number of people employed per unit of production area, or the limited employment generated per unit of capital investment.

Higher labour absorption is often cited as a positive aspect of intensive shrimp aquaculture development. However, this argument does not take into account the fact that one household or company often controls a larger number of shrimp ponds, so that the distribution of assets and benefits within the community is less equitable than less intensive systems. In traditional pond systems, each household typically owns and manages a single pond. With the shift towards more intensive systems, farm owners often become pond labourers, so that the higher level of labour absorption may not yield positive impacts. Over the long term, shrimp farms directly employ fewer people than other forms of land use, especially labour-intensive agriculture or fisheries (Primavera, 1991; Weeks, 1992; Clay, 1996). Rice farming requires many times more workers than shrimp farming (Maybin and Bundell, 1996). In Indonesia, rice production employed an average of 76 workdays per hectare per crop cycle (Clay, 1996). In the same region, a semi-intensive shrimp farm employed about 26 workdays per hectare, and an extensive shrimp farm about 45 workdays per hectare per cycle (Hannig, 1986). In other types of agriculture, for example, seven to eight labourers are required to maintain a five-hectare sugarcane plot, while only three people are required for a shrimp farm of equal size (Primavera, 1993). Primavera (1993) also reported that in the Philippines, small-scale fisheries have long provided better equity than aquaculture.

Direct employment opportunities for local people in shrimp farming include low-paid work as security guards, pond labourers and part-time collectors of seed (Weeks, 1992). Until recently, significant amounts of unskilled labour were required during shrimp farm construction, pond preparation and maintenance, and at harvest. However, most ponds are now constructed using heavy machinery and, even if ponds are manually excavated, labour requirements diminish once the ponds are established (Bailey, 1988). Typically, higher-paid managerial positions are reserved for non-locals with technical expertise. Although entrepreneurs investing in shrimp aquaculture may hire locals, often they bring their own trusted people resulting in dislocation for locals in areas around the shrimp farms (Saclauso, 1989). In Bangladesh, outsider leaseholders generally do not trust local labourers and prefer to hire their workforce from their own localities (Deb, 1998). In Indonesia, however, outside investors prefer to hire locals, believing that this reduces poaching (Muluk and Bailey, 1996). Generally speaking, shrimp farms usually employ one person per hectare, or between one to two workers for every pond (Saclauso, 1989; Goss et al., 2000).

Wages for unskilled workers in rural communities tend to be low, reflecting the opportunity cost of labour. Although shrimp farming is argued to be productive and profitable, wages paid to resource-poor and occupationally diverse farmers entering shrimp farming do not always compensate for the inability to engage in other income-generating or food-producing activities. The majority of those who find jobs in shrimp farming are hired as unskilled pond labourers and guards, and wage rates are often lower than in rice cultivation (Weeks, 1992). Shrimp farming contributes to low wages by restricting access to local resources, thereby reducing employment opportunities and increasing dependence on seasonal jobs that require few skills (Goss, 2000). While Ecuadorian shrimp farm labourers in harvesting and seeding enjoyed higher wages than agriculture at both the supervisory and unskilled levels (Meltzoff and LiPuma, 1986a), their direct employment is connected to ecological cycles and the perishable nature of the shrimp. Work in shrimp farming requires long and irregular hours and unlike agricultural jobs, employment is seasonal and declining production levels due to disease adversely impacts the economic security of shrimp farm workers (Briggs and Funge-Smith, 1994b). In shrimp producing regions there is increased incidence of under-employment with dependence on seasonal jobs or unemployment (Deb, 1998).

Although there is little official documentation, the majority of people involved in the shrimp aquaculture sector are indirectly employed in hatcheries, feed processing plants, and freezing and cold storage facilities. The processing sector in particular generates thousands of jobs. In Thailand, a typical processing plant employs around 2,000 workers and feed mills employ between 200 and 400 workers (Goss et al., 2000). Waged labour in the feed and processing aspects of the shrimp sector, including social and gender relations, is reported to be similar to other labour-intensive production processes. Jobs are also created in transportation, manufacturing of products such as paddlewheels for pond aeration, containers for shrimp storage and transport, hatchery tanks, water pumps, chemicals for water treatment, and chemotherapeutants for disease control (Jenkins, 1995).

2.3.4 Economic Impacts at the National, Community and Farm Level

Farmed shrimp exports are an important source of income and hard currency in many developing economies. Multinational corporations and international investors are both attracted to and actively pursued by governments to invest in shrimp production in their countries (Clay, 1996). Potential shrimp farming investors are often given preferential access to public lands and water, credits, tax holidays, markets, subsidies, licenses, favorable exchange rates, the right to repatriate money, and the ability to import production inputs tax free (Gujja and Finger-Stich, 1996). According to Smith and Peterson (1982), as funds invested in shrimp aquaculture are from sources outside the community, so profits also leave the community.

The economic impact of shrimp farming on rural communities has been immense. Public income and public spending for shrimp farming is reported to have improved the standard of living of individuals employed by the aquaculture sector and resulted in substantial infrastructure development in previously neglected coastal areas (Csavas, 1994b). In Asia, the reported benefits have included improved electrical, transportation and communication infrastructure (ADB/NACA, 1998). Other analysts, however, have suggested that shrimp aquaculture has widened the gap between local elites and the general population of rural communities in producing regions (see, for example, Angell, 1993; Kent, 1995; Kelly, 1996). Instead of improved living standards and village welfare, shrimp farming has resulted in social displacement and the marginalization of rural communities (Primavera, 1993). The economic benefits of shrimp farming have favoured a minority of farmers, entrepreneurs and traders with wealth, better education and greater political influence (Skladany, 1992). Although shrimp farming is profitable, the profits are usually not earned by those whose interests are threatened and whose immediate needs are income and employment (Bailey, 1989).

Within rural communities, shrimp farming has reinforced income concentration. In Bangladesh, for example, government policies supporting export diversification by intensive shrimp farming have significantly reduced productive opportunities for families (Coote, 1992; Datta, 1995). Although less intensive shrimp farming resulted in economic diversification among the disadvantaged segment of the rural population, primarily people who owned land or had the money to rent land captured the benefits (Guimarães, 1989). Similarly in Latin America, community involvement in shrimp farming in Mexico revealed that the conditions under which aquaculture affected inequality depended upon the economic status of those entering aquaculture (Cruz-Torres, 2000). Meltzoff and LiPuma (1986a) highlight the duality of interests that pervades the Ecuadorian shrimp industry – government officials tasked to oversee the industry are also shrimp producers and exporters with personal economic and political interests.

In Thailand, shifts from rice, salt farming or capture fisheries to intensive shrimp aquaculture produce incomes that are, in the short term, orders of magnitude greater than those provided by previous occupations. In some areas, two and sometimes three crop cycles can be completed in one year if there are no significant disease losses (Patmasiriwat et al., 1998). While the direct benefits of shrimp farming are reflected by net returns, little consideration has been given to the externalities associated with the industry. For example, farm-level profits tend to diminish as production ponds age (Briggs and Funge-Smith, 1994a). Small-scale entrepreneurs entering into shrimp farming often accumulate significant debt to purchase feeds, fertilizers, equipment and medication. Servicing the loan becomes difficult if yields do not meet expectations or if there are crop failures (Lee and Wickens, 1992a). For small-scale producers, pond failure usually results in farm abandonment and outstanding debt. As production sites are abandoned, local populations are often left with neither employment nor access to traditional resources. The wider impacts of abandonment are evidenced by ongoing debt restructuring programs initiated by multilateral agencies in regions previously patronized to develop shrimp aquaculture (MIDAS, 1995; Deb, 1998).

2.4 Environmental Impacts of Shrimp Aquaculture

The type of shrimp culture practiced has the greatest influence on the nature and extent of the environmental impacts (Beveridge, 1984; Braaten and Hektoen, 1991). While extensive shrimp culture systems contribute most to habitat loss, intensive shrimp culture systems contribute more to pollution. The environmental impacts of shrimp aquaculture include increased pressure on natural fish and shrimp stocks, risks from exotic introductions and disease transmission, and the potential loss of biodiversity resulting from destructive fishing practices to supply feed raw materials and incidental losses incurred during broodstock or seed larvae capture. A number of authors have chronicled the many wide-ranging impacts in Asia and in Latin America (see, for example, (Chua et al., 1989; Braaten and Hektoen, 1991; Beveridge and Phillips, 1993; Suvapepun, 1993; Marsden, 1994; Werner, 1994; Samocha and Lawrence, 1995; Clay, 1996; Tookwinas, 1996). The following sections review the main environmental impacts of intensive shrimp aquaculture development.

2.4.1 Habitat Loss and Land Alienation

Shrimp ponds have been developed in many different coastal environments. These include rice paddies, saltpans, coconut and sugar plantations, wetlands and mangrove forests. The most widely reported habitat loss associated with shrimp farming is the conversion of mangrove forests (Meltzoff and LiPuma, 1986b; Bailey, 1988; Flaherty and Karnjanakesorn, 1995; DeWalt et al., 1996; Gujja and Finger-Stich, 1996; Stonich et al., 1997). Globally, as much as 800,000 ha of mangroves have been destroyed for shrimp pond construction (Hogarth, 1999). Over the past few decades, the Philippines has lost 75% of its mangroves, mostly due to coastal aquaculture; while Ecuador, Indonesia, Malaysia, Thailand and other tropical developing nations have lost substantial areas (Snedaker, 1986; Terchunian et al., 1986; Olsen and Arraiga, 1989; Paw and Chua, 1991).

Large-scale destruction of mangroves for shrimp aquaculture has occurred in most countries that farm shrimp. However, it is not always possible to quantitatively separate mangrove loss from shrimp farming and finfish farming (particularly milkfish, *Chanos chanos* (Chamberlain, 1991; Primavera, 1991; Chua, 1993; Ong, 1995). Therefore, the extent of mangrove habitat converted to shrimp farming ponds is the subject of debate (Parks and Bonifaz, 1994; Menasveta, 1997a; Menasveta, 1997b; Sreeraj, 2000). With roughly half of the world's mangrove ecosystems already transformed or destroyed by humans, the incremental cost of mangrove conversion to shrimp ponds is high (World Resources Institute, 1996). While mangrove conversion to shrimp ponds is under increasing scrutiny, encroachment continues to outpace conservation and preservation plans around the world. Shrimp farms are often constructed after the clearance of mangrove forests (Chua, 1993). In Asia and Latin America, most data regarding the extent of mangrove loss only considers existing shrimp farms, while there are no reliable data on shrimp farms that once encroached mangroves and have since been converted to other uses (Kaosa-ard, 1998).

The establishment of a shrimp farm may be a direct replacement of habitat or may involve a gradual process, which sees the habitat area utilized sequentially for several different land uses prior to shrimp farming. Invariably, the accumulated effects of the land use prior to shrimp farming also degrade the habitat. In the case of mangroves, land alienation increases as mangroves are gradually appropriated from their once complex ecological function in a multi-use capacity, and replaced by a single purpose, dominant, land use that subsequently limits all others.

Habitat and land alienation impacts also result from the construction of too many ponds in any one region. The cumulative environmental impacts associated with high densities of shrimp pond development are related to the type of shrimp culture system. Crowding results in reduced larval shrimp supply for extensive farms and effluent disposal problems and increased oxygen demand in semi-intensive and intensive farming regions. Many shrimp ponds are subsequently abandoned when production exceeds the carrying capacity of the local environment, especially in areas where the natural flushing rates of water systems are poor (Lin, 1995). The rehabilitation or conversion of extremely degraded pond areas to other agricultural uses is often difficult and expensive and not economically feasible (Beveridge et al., 1997). Similar to issues related to the extent of habitat loss, the levels of abandonment within shrimp producing nations are difficult to discern as growout ponds are often abandoned temporarily during disease epidemics, or for seasonal and economic reasons (Stevenson, 1997). In Thailand, the mangrove area lost of shrimp farming development has been highly controversial issue (Katesombun, 1992; Dierberg and Kiattisimkul, 1996; Menasveta, 1997a; Huitric et al., 2002).

2.4.2 Pollution

Intensive shrimp farms produce substantial quantities of solid waste that has to be removed from the ponds after harvest. They also discharge large volumes of effluent that includes sediment, water borne suspended solids, dissolved nutrients, and toxic metabolites to surface waters (Burford and Williams, 2001). Solid wastes and effluent are high in inorganic (chiefly clay and silt particles scoured from the pond) and organic material (from shrimp and feed wastes and dead plankton), as well as being anoxic and saline. Pond effluent, discharged during routine water exchange and drainage during harvest, is reported to pollute surrounding water bodies impacting other users of the water body, and even back on the polluting farms (Lin, 1995). The latter condition, referred to as "self-pollution", is common in areas of high farm density and poor water system infrastructure (Braaten et al., 1988; Chen and Shang, 1992; Maybin and Bundell, 1996; Corea et al., 1998).

Concerns regarding the discharge of nutrients, suspended sediments and the chemicals in pond effluent are a recurring theme in shrimp farming. Nevertheless, few countries have accurate data on the quantity of effluent discharges or the total load of the major elements of nitrogen (N) and phosphorus (P) released into the waterways from shrimp farming. Overall, the levels of N, P and suspended sediments in pond effluent are dependent upon rainfall, farm location, season, age of ponds, other activities in the catchments, and shrimp farmer management practices. In a typical intensive shrimp culture system, shrimp feed accounts for most of the N, P and organic matter inputs to the ponds. Approximately 86% of feed inputs (by dry weight) end up as solid waste and only 14% is incorporated into shrimp biomass (Pascual and Corre, 1991; Primavera, 1993; Funge-Smith and Briggs, 1998).

The pollution effects of shrimp farming effluent on the receiving waters vary according to local assimilative capacity. The levels of biological oxygen demand, total suspended solids (TSS) and turbidity increase during the culture period. Since low percentages of N are retained as shrimp biomass, it usually becomes an expensive fertilizer that stimulates the growth of natural biota, particularly the plankton and the microbial communities (Moriarty, 1997; Burford and Gilbert, 1999; Burford and Williams, 2001). Phytoplankton blooms develop which become unstable and have deleterious effects on water and sediment quality. To minimize these effects within the shrimp ponds, managers periodically flush the ponds. The discharge water enters nearby rivers, creeks and estuaries, often without being treated to reduce nutrient and suspended solid loads. This organic pollution is significant compared to other industries because shrimp ponds are often located in restricted areas in close proximity. The discharge of soluble inorganic nutrients, namely N and P, has the potential to cause nutrient enrichment or hypernutrification, possibly followed by eutrophication, the increase of primary productivity of a water body (Smith et al., 1999). Nutrients added to the water column by shrimp farming wastes may alter the composition of natural phytoplankton communities (Takahashi and Fukazawa, 1982), and the related changes in phytoplankton ecology may result in algal blooms that are harmful to local ecosystems (Barg and Wijkström, 1994).

In Thailand, pollution from shrimp farming is a major issue owing to the highly intensive nature of shrimp culture and the large numbers of small farms. According to (Funge-Smith and Briggs, 1998), each tonne of shrimp produced in a Thai intensive culture system required 1.98 tonnes of feed, and added 102 kg of N and 46 kg of P to the environment including overflow and drainage water. (Briggs and Funge-Smith, 1994a) estimated that the effluent water during regular flushing and at harvest could account for 45% of N and 22% of organic matter output from intensive shrimp ponds. Pond sediment, however, is the major sink of N, P and organic matter, and over one production cycle accumulates in intensive shrimp ponds at the rate of almost 200 metric tonnes (dry weight) per hectare (Briggs and Funge-Smith, 1994a). The aggregate of pollution impacts resulting from multiple farms is substantial considering that a typical intensive shrimp farm uses 20 tonnes of feed over a four- to five-month period (Funge-Smith and Briggs, 1998). Briggs and Funge-Smith (1994a) estimate that 40,000 hectares of farms in Thailand will produce over 16 million metric tonnes of dry sediment per year. In other shrimp producing regions, Páez-Osuna et al. (1999) predicted that P and N loads discharged into the Gulf of California from approximately 26,000 hectares of shrimp farms in NW Mexico during 1998 would be 834 and 2,903 metric tonnes respectively. The difference in values between Thai farms and farms in other parts of the world is related to culture intensity – i.e., highly intensive Thai farms produce much higher quantities of waste.

2.4.3 Water Use

Intensive shrimp farming requires large volumes of clean water to support the shrimp, replenish oxygen and remove wastes. Table 2.3 indicates the range of water withdrawal rates reported for some shrimp farming operations. Although water use in terms of production may be low in intensive systems, in absolute terms high rates of water use are characteristic of such systems, as the water quality has to be maintained at a high level even though aeration and other means of improving quality standards are employed.

Several studies have examined water use at Thai shrimp farms. Briggs and Funge-Smith (1994a) documented water use at a coastal brackishwater shrimp farm as part of a nutrient study and Braaten and Flaherty (2000) investigated low-salinity shrimp farming in Chachoengsao province. They reported that shrimp farm consumptive water use rates range between 7,300 to 9,050 cubic metres per hectare per crop. Shrimp farmers must also account for additional freshwater losses to evaporation and seepage, which can reach as much 1% to 3% of the pond volume daily (Kautsky et al., 2000). Of the total water withdrawn by shrimp farms, a varying amount is usually returned to the supply source after being retained during the growout.

Table 2.3 Water resource requirements for shrimp farming operations

Water Requirements	Production (t/ha/year)	Water (m^3/t)*
Extensive ponds	0.3 - 0.8	44,000 - 233,000
Semi-intensive ponds	1.0 - 5.0	7,000 - 70,000
Intensive ponds	3.0 - 8.0	4,000 - 23,000

* Estimated values assume mean pond depth of 1 m during growout, water losses of 1 to 2 cm /day and 350 days production per year.

Source: (Hepher, 1985; Muir and Beveridge, 1987)

Shrimp farmers prefer to reduce the water intake from external sources as much as possible adding less water during the latter stages of growout. Shrimp farmers know that if the water quality in the pond is good, there is no reason to exchange water. In some areas the water quality in supply canals or reservoirs may be lower in quality than the water in the shrimp pond. Under certain conditions, however, the quantity of water use at individual shrimp farms can increase well above the typical requirements. Poor management practices such as high stocking densities and over feeding can necessitate large daily water exchanges to maintain water quality. The practice of flushing the grow-out ponds during disease events also adds significantly to overall water consumption. Whereas many of the traditional or low-intensity aquaculture systems are considered to be 'non-consumptive' water users, intensive shrimp culture systems are considered 'consumptive' water users because they do not simply borrow the water, but consume large volumes of water and return it with a much reduced water quality.

Water use conflicts over saline and brackish water between individual shrimp farming operations in coastal and estuarine areas is infrequent given the easy access to supply for filling the ponds and subsequent water exchange. However, farms in these locations increase concerns related to the removal of estuarine biota in the process of transferring water into the ponds. While it is conceivable that estuarine organisms could be pumped into the ponds and later discharged back to the estuary with effluent, this is not likely to occur and most organisms entrained will perish during the shrimp growout (Hopkins et al., 1995a).

In Thailand, water use conflicts have emerged in locations where freshwater provides a major proportion of the shrimp farm's water supply. The emergence of shrimp aquaculture within irrigated regions may exacerbate existing water supply shortages

(Braaten and Flaherty, 2000). The substantial withdrawal rates from surface irrigation systems by intensive shrimp farming is reported to directly compete for surface freshwater resources that are needed for rice paddy irrigation (Ridmontri, 1998a). In Thailand's Ranot district, which is densely covered with intensive shrimp farms, an average of 33 cubic metres (i.e., 33 MT) of freshwater per day is pumped in for each tonne of shrimp produced (Barraclough and Finger-Stich, 1996). Other studies in Thailand have compared the consumptive water use of shrimp ponds and rice fields, and suggested that conversion from rice farming to shrimp farming would have little impact on water availability for irrigation. However, the large volumes of discharge could have serious environmental implications because small inland waterways have low assimilative capacity and pond effluent is saline (Braaten and Flaherty, 2000).

2.4.4 Chemicals and Chemotherapeutants

Shrimp farmers use a wide range of chemicals including therapeutants (e.g., antibiotics, vaccines), disinfectants, water and soil treatment compounds, algicides and pesticides, plankton growth inducers (e.g., fertilizers and minerals) and feed additives (reviewed in Primavera et al., 1993). Excessive and unwanted use of such chemicals often results in problems related to toxicity to non-target species (cultured species, human consumers and wild biota), development of antibiotic resistance and accumulation of residues (Primavera, 1998; Tendencia and de la Peña, 2001). Constraints to the safe and effective use of chemicals include misapplication, insufficient understanding of mode of action and efficacy under tropical aquaculture conditions, as well as uncertainties with regards to legal and institutional frameworks to govern chemical use in aquaculture (Barg and Lavilla-Pitogo, 1996).

Shrimp farm effluent may contain drug and chemical residues. The environmental impact of chemicals used in shrimp farming remains poorly studied. The potential impacts are exacerbated by the management practice of using chemicals to overcome bad husbandry, especially the increasingly common practice of treating diseased pond water prior to discharge (Liu, 1989; Schnick, 1991; Alderman, Rosenthal et al., 1994; Suwanrangsi, 1995; Thonguthai, 1996; GESAMP, 1997). For example, Thai shrimp farmers are reported to use up to 300 kg of chlorine per ha to treat water discharges (Kongkeo, 1997). Chlorine kills bacteria and viruses, but also the small crustaceans and other invertebrates that could act as vectors for the disease-causing organisms (Boyd, 1996; Dierberg and Kiattisimkul, 1996). The impacts of chlorination have received limited investigation, in spite of widespread use and the potential interactions of chlorine with organic substances that may lead to the formation of halogenated hydrocarbons (Gräslund and Bengtsson, 2001; Gräslund et al., 2002). Formalin and malachite green, which are also widely used in Asian shrimp ponds, are known to be toxic to shrimp nauplii at low concentrations (Castille and Lawrence, 1986), indicating the potential to adversely impact biota in coastal waters when discharged in effluent. Both compounds are also potentially harmful to humans.

Antibiotic use in shrimp farming is of particular concern. Although recommended as a last resort, the abuse of antibiotics and other drugs remains widespread in Southeast Asian and Latin American shrimp culture (Holström et al., 2003). Until recently, efforts to reduce the misuse of chemicals passed unheeded as shrimp farmers used increasing quantities of chemicals in attempting, often unsuccessfully, to avoid disease mortalities. In shrimp hatcheries and grow-out operations, antibiotics such as chloramphenicol, furazolidone, streptomycin, oxytetracyclene, nitrofurazone are commonly applied to treat and prevent disease (Phillips, 1993; Primavera et al., 1993). Studies have shown that antibiotics produce post-larvae that are more disease-susceptible because many will have developed from weak larvae that have been artificially protected from disease (Brown, 1989). The indiscriminate use of antibiotics was a major contributing factor to the collapse of shrimp crops in Taiwan through the development of antibiotic resistant shrimp pathogens (Lin, 1989). It has been suggested that the use of excessively large amounts of antibiotics was partly driven by unscrupulous agents for drug companies who persuaded poorly educated shrimp farmers to buy and use as much of their companies products as possible (see, for example, Hopkins et al., 1995b; Clay, 1996; Gujja and Finger-Stich, 1996).

Major concerns regarding chemical use relate to the development of drug resistant strains of bacteria, the fate of chemical compounds or their residues in the aquatic environment and the longevity of bioactive compounds in animal tissues (Whitely and

Johnstone, 1990; Barg and Wijkström, 1994). Since antibiotics are used prophylactically to treat human diseases, shrimp farm effluent containing antibiotic resistant bacteria or disease organisms represents a potential hazard to hatcheries, other shrimp farms and consumers (Brown, 1989). Prolonged use of antibiotics has been proven to encourage antibiotic resistance in microbial communities (ICES, 1988; ICES, 1989). There is concern that the antibiotic resistance of shrimp pathogens could be transferred to human pathogens (Phillips et al., 1993). Concerns over the transfer of resistance to human pathogens were confirmed when drug-resistant bacteria were detected in the effluent of an intensive culture fishpond in Japan (Aoki and Kitao, 1985; Beveridge et al., 1997). Jacobsen and Berglind (1988) reported the accumulation of oxytetracyclene in the sediments beneath net pens in Norway, and drug resistance has been transferred from a fish pathogen to a human pathogen in vitro (Toranzo et al., 1984). Studies have confirmed that the relative numbers of drug-resistant bacteria increase because of antibiotic use in animal feed, and that resistance can be transferred to human and animal pathogens (Wright, 1990). While most concerns are based on actual observations under specific conditions (Aoki and Kitao, 1985; Jacobsen and Berglind, 1988), evidence remains circumstantial whether human health is threatened even under the continual use of antibiotics in livestock operations over many years (Walton, 1988).

Several of the chemicals used in shrimp farming are carcinogenic and some nations have imposed stringent regulatory measures on the use of chemicals (Schnick, 1991; Thonguthai, 1996; GESAMP, 1997). However, most developing nations where shrimp farming is concentrated have limited regulatory control and routinely use chemicals banned for agriculture and aquaculture in more developed countries (Brown, 1989; Saitanu et al., 1994; Miller, 1996). Since antibiotics are readily available to farmers, the potential residue problem in shrimp products has prompted some producers to implement monitoring programs because contamination could result in human poisonings and have widespread impact on consumer confidence for farmed shrimp products. The emphasis with farm-raised shrimp has been on securing a guarantee that the products contain no chemical residues of concern (Wickramanayake, 2001).

Consumer and occupational health impacts in the shrimp production chain, from the farmers through processors to consumers are not well documented (Weeks, 1992).

Nonetheless, several authors have discussed the human health impacts of aquaculture (see, for example, Bernoth, 1991; Huss, 1991; Phillips, 1993; Guo, 1994; FAO/NACA, 1995). In response to consumer demands, producers have attempted to produce high quality products and to reduce any potential risks to human health (Phillips, 1994a; Rackman, 1995). While most producer nations have implemented quality assurance mechanisms (Aukrust et al., 1995; Otwell and Flick, 1995; Woodhouse, 1995), the number of fishery products classified as sub-standard or of poor quality by importers has been increasing (Hotta, 1996; Ostergard, 2000). Potential consumer health risks are associated with the presence of chemical and biological contaminants in aquaculture products. While the issue of contaminants has been raised in regard to farm-raised salmon and other seafood products, there is little information regarding farm-raised shrimp (Huss, 1991; Huss, 1993; Wilson, 2001).

Occupational health concerns relate to the potential hazard to hatchery and farm workers in the handling of drugs and chemicals and the potential risk of parasitic and bacterial infections during periods of immersion in pond water. Shrimp pond workers routinely handle dangerous drugs and chemicals that are readily available on the market without regulation regarding the procurement, storage, or use. In the water supplies around farming sites, workers may be exposed to endemic pathogens or be at a higher risk of contracting malaria and dengue transmitted through mosquitoes (Guo, 1994). Health hazards to local populations living near or working in shrimp farms include reduced drinking water quality, and the misuse of chemicals has led to toxicity in non-target species and increases in waterborne diseases (Corea et al., 1998; James, 1998).

2.4.5 Salinisation and Salt Water Intrusion

Salinisation is the process whereby the concentration of total dissolved solids is increased and is primarily associated with an increase in the concentration of chloride salts (for example, sodium chloride, potassium chloride) (Symoens et al., 1981; Thornton et al., 1999). Surface freshwater and soil salinisation occurs when land or water systems previously inaccessible by the sea because of elevation are flooded with saltwater or when saline water is unnaturally impounded in ponds for shrimp culture. The direct impact of salinisation of agricultural lands, especially rice paddies, by seepage, discharge and inundation often ruins crops and renders the land unsuitable for agriculture. Often the impacts are indirect, and occur when irrigation canals are contaminated with saline shrimp farm effluent.

The principal impact of salinisation on terrestrial agricultural lands or freshwater aquatic ecosystems relates to the physiological effects of high-salinity waters on the osmoregulatory systems of plants and animals (Thornton et al., 1999). Impounding saline water for shrimp farming reduces the ability of nearby plants to absorb soil nutrients (Csavas, 1995). The retention of saline water for longer periods changes the soil chemistry as the salt percolates into the surrounding soils. The long-time inundation of lands with saline water prevents free nitrogen fixation, and mineralization is halted and the soil fertility drops down within 1 to 2 years (Hart and Nandy, 1990). In Bangladesh, the preparation of rice seedling beds is not always possible because of prolonged stocking of saline water for shrimp farms (Deb, 1998). In some areas salinisation has permanently eliminated the vegetation and trees, and continuous saline water inundation has impeded the growing of vegetables and the rearing of domestic animals and birds, which are important supplementary sources of income for rural peoples.

Groundwater extraction for the freshwater requirements of intensive shrimp farms has resulted in saltwater intrusion of freshwater aquifers and land subsidence. Aquifer salinisation impacts the groundwater supplies of local populations by impairing irrigation and potable water supplies. The force of this impact falls on women who are usually in charge of household water collection (Patil and Krishnan, 1998). In supratidal areas, the release of saline shrimp pond water to adjoining lands and irrigation canals has salinised prime agricultural lands in East Java, Indonesia and in the Negros Occidental, Philippines and other regions (Borjal, 1989; Yap, 1990; Yap, 1999). Shrimp cultivation is reported to have adversely affected rice production in the Khulna region (Rahman, 1999) and 90% of the villages in the Nellore District of India have reported declining paddy yields in plots adjacent to shrimp ponds (Patil and Krishnan, 1998). In many areas, croplands in the immediate vicinity of shrimp ponds have become completely uncultivable due to high levels of salinity. Even croplands situated further downstream could lose as much as 40% of their productivity (NEERI, 1995). Measuring the immediate impacts of salinisation is difficult. However, in places where farmers tried growing rice after years of shrimp production, crop yields have declined substantially (Bhatta and Bhat, 1998).

In southern Thailand, rice farmers either accepted lower yields and increased possibility of crop loss, or abandoned rice farms after shrimp cultivation entered the region (Boromthanarat et al., 1993; Yadfon Association, 1996). Although there are few pond-level salinisation studies of shrimp farming regions, one study from Thailand documented the pattern of salinity spreading from shrimp farms to rice paddies (Maneepong, 1993). When such areas are abandoned, the landscape is barren, salinised and often acidified, making reclamation extremely difficult and costly (Chung-Huang, 1990; Kongkeo, 1997). The continued storage of salt water in shrimp ponds irreversibly increases the rate of salt-water dispersal, altering soil salinity of adjacent croplands (Csavas, 1995).

2.4.6 Loss of Ecosystem Goods and Services

Aquaculture consumes natural resources and relies on ecosystem services, as do agriculture and wild capture fisheries (Naylor et al., 1998). Shrimp farming is a resource-intensive food production system that relies heavily upon ecosystem goods and services (see, for example, Larsson et al., 1994; Kautsky et al., 1997; Folke et al., 1998; Kautsky et al., 1998). Intensive shrimp farming is associated with a high level of use of primary resources. The principal natural resources consumed by shrimp farming are habitat, food, and energy. Issues with regard to the ecological impacts of intensive shrimp farming have been raised and the sustainability of such practices questioned (see, for example, Folke and Kautsky, 1992; Naylor et al., 1998). Analysts have developed the concept of the 'ecological footprint', the total area required to support production on the basis of supply of inputs. Semi-intensive shrimp culture systems require a 'footprint' of between 35 to 190 times greater than the size of the pond area, appropriating about 295 joules of ecological work for each joule of edible shrimp protein produced (Larsson et al., 1994).

The potential impacts of shrimp aquaculture on biodiversity, the totality of genes, species and ecosystems in a region, are multiple (Beveridge et al., 1994). Biodiversity impacts from shrimp farming result from the destruction of habitat and wild fry stocks, alteration of gene pools through the introduction of exotic species and disease by importing non-indigenous animals (see, for example, Welcomme, 1988; Sindermann, 1993; Beveridge et al., 1994; Parks and Bonifaz, 1994; Ross and Beveridge, 1995).

Biodiversity is impacted by the practice of capturing and trading gravid females or wild-caught seed to support intensive shrimp farming. Catches of both are declining in most areas (Silas, 1987b; Silas, 1987a; Abernethy, 1998). Broodstock catch-rates in the Bay of Bengal have declined by 66% over the last five years (Ostergard, 2000). Wild seed harvesting negatively impacts commercially valuable stocks of finfish and crustaceans that depend upon mangroves during juvenile stages of their life cycle (Hamilton and Snedaker, 1984). The bycatch of wild post-larvae harvesters is generally higher than that of shrimp trawlers (Clay, 1996). In India, wild fry harvesters discard an estimated 10-kg of finfish and shrimp larvae of other species for each kg of black tiger post-larvae harvested (Silas, 1987b), and up to 5,000 post-larvae are wasted for every 100 marketable post-larvae captured in Bangladesh (BOBP, 1990). Anecdotal evidence suggests that for each pond raised shrimp, almost a hundred other fish and shrimp are killed (Csavas, 1988; Fast, 1992a; Ostergard, 2000). The negative environmental impacts of wild fry harvesting are likely to be significant given the correlation between mangrove areas and fisheries landings (see, for example, Martosubroto and Naamin, 1977; Turner, 1977; Staples et al., 1985).

The introduction and transfer of species and breeds for shrimp farming may alter or impoverish the biodiversity and genetic resources of the marine ecosystem through breeding, predation, competition, habitat destruction and possibly, through transmission of parasites and diseases (Sindermann, 1993). Regulations restricting the movement of diseased fishes are not new (FAO, 1968), although full recognition of the dangers inherent in transplantation of even apparently healthy fishes has developed slowly and has often been hindered by the aquaculture industry. As demand for broodstock and seed often exceeds local supply, the movement of animals, including exotic strains and species, with and between countries or regions, to overcome resource limitations is common (Hotta, 1996). Risks are exacerbated considering that importing countries do not assess whether imports of diseased live or frozen shrimp threaten native wild populations (Goldburg and Clay, 1998). In Asia, studies on the delineation of the population breeding structure of the black tiger shrimp (*P. monodon*) have shown clear stock differentiation either side of the Malay peninsula, suggesting that Gulf of Thailand populations may have been altered by farm escapes (AADCP, 1994).

Some of the disease problems in the shrimp industry could be prevented. Regulatory agencies in shrimp producing countries, however, have generally not taken precautionary measures to control the spread of pathogens by requiring the treatment of wastes from shrimp processing plants (Goldburg and Clay, 1998). Farmed shrimp pathogens are suspected of being spread from their natural range on the Pacific Coast of Latin America to the Middle East and Asia through transshipment of infected feeds (Bell and Lightner, 1983). Several viruses including the White Spot Syndrome Virus (WSSV) and Yellow Head Virus (YHV), which remain infective in frozen shrimp, have been detected in imported shrimp products (Nunan, 1999; Wang et al., 2000). At the producer level, shrimp farms are prone to a variety of infectious diseases and in waters adjacent to shrimp farms, disease transfer can result from the interbreeding of diseased-farmed shrimp and wild stocks (Hopkins et al., 1995a; Clay, 1996; Gujja and Finger-Stich, 1996). In Taiwan, the WSSV has been detected in approximately 48% of the captured black tiger shrimp broodstock, confirming that the virus is established in the wild populations (Lo et al., 1997).

2.4.7 Feed

The use of so-called "trash fish" or other types of single- or multi-ingredient moist feeds in the aquaculture of carnivorous shrimp places direct pressure on fisheries resources and creates competition for fish protein. At present, 30% of the world fish catch is used for fishmeal, 93% of which goes into poultry and other animal feeds (Naylor et al., 2000). Whereas traditional and extensive shrimp aquaculture systems use the natural productivity in the ponds or in the incoming waters, semi-intensive and intensive production systems are dependent on formulated feeds derived from protein-rich fishmeal that contains amino acids similar to those found in shrimp. These latter systems use two times more protein, in the form of fishmeal, to feed the farmed shrimps than is ultimately harvested (Tacon and Barg, 1998). For marine shrimp, the ratio of wild fish to fed farmed shrimp is 2.81 (Naylor et al., 2000). While fishmeal availability is declining, aquatic animal production is intensifying (Beveridge et al., 1997), leading to what (Wijkstrom and New, 1989) have referred to as the "fish meal trap". Ultimately, fishmeal production undermines efforts to protect wild fish stocks and places human consumers, often, indigent fisher people, and other livestock producers in direct competition with shrimp (Stonich et al., 1997).

In Thailand, marine shrimp farming has benefited from the growth of trawl fishery in the Gulf of Thailand over the last few decades. While total production has not declined substantially, 70% of landings are now suitable only as animal feed (Gujja and Finger-Stich, 1996). Supplies of high quality 'food grade' protein-rich feed are finite and in the absence of alternatives, producers rely upon raw material sources supplied by destructive fishing practices (Tacon, 1994). While alternatives to pelagically derived fishmeal are being investigated, industry analysts have recommended that fishmeal used for shrimp feed made from fish that could be used for human consumption should be reduced and eventually eliminated (Goldburg and Clay, 1998).

2.5 Impact of the Environment on Aquaculture

Shrimp farming is one source of pollutants to the environment; others arise from agriculture and urban and industrial developments. The impacts of the environment on aquaculture are the various types of pollution from urbanization, industrialization and intensification of agriculture (see, for example, Chua et al., 1989; DeWalt et al., 1996; Colburn, 1997). Shrimp ponds located in polluted environments are exposed to a variety of contaminants, some of which are persistent and have the capacity for bioaccumulation.

The effect of rice agriculture on shrimp aquaculture is of particular concern. Shrimp farms are increasingly established in intensively cultivated agricultural regions because of the declining availability of coastal land. Agricultural run-off can contain a variety of agrochemicals. Compared to other agricultural industries, rice farming is a major user of agrochemicals because of the high application rates and the relatively large area of production (Rayment, 1999). There have been numerous cases of pesticide poisonings of aquatic organisms attributed to agricultural runoff (Knox and Miyabara, 1984; Burbridge and Maragos, 1985). In many locations, agrochemicals are routinely detected in run-off or groundwater. When determining the effects of agrochemical contaminants, consideration must be given to not only present agrochemical use, but also to the accumulated residues of agricultural products in agricultural soils or coastal sediments that have not been used for decades. Assessing the ecological impacts of agrochemical contaminants in the environment is extremely difficult. The potential impacts to shrimp crops include direct mortality, genetic or physiological changes or altered behavior patterns (Muirhead-Thompson, 1988). The ecological impacts may not occur for long periods (e.g. decades) and be extremely difficult to detect. Agrochemical products (or their derivatives) are known to occur in the tissue of a variety of fauna including birds, fish and dugong (see, for example, Willis and McDowell, 1982; McDougall et al., 1989; Russell et al., 1996; Haynes et al., 1999; Mortimer and Cox, 1999).

Investigations of the biological effects of surface water pollutants from agriculture on aquatic systems have determined that crustaceans, especially larvae, are more sensitive to low concentrations of pesticides than other marine organisms (Costlow Jr., 1982; Cooper, 1993). Many pesticides, particularly insecticides, are extremely toxic to fish and shrimp, in the parts per billion concentrations (Cope, 1964). Insecticide residues are reported to be important predisposing factors for disease in shrimp at sub-lethal levels (Flegel et al., 1992). Sub-lethal effects on reproduction processes could be anticipated at levels well below the actual toxicity levels (Fast, 1992b). Although pesticides may not cause mortality they may decrease the growth of food organisms that consequently reduces the growth and productivity of shrimp. Pesticides may reduce the viability of offspring, or cause pathological changes in various organs (Eisler, 1972; Mitrovic, 1972). Despite widely acknowledged concerns over increasing levels of agricultural pesticides in aquaculture producing areas, there is a general paucity of information regarding the impact of pesticides on aquatic resources and aquaculture (see, for example, GESAMP, 1991; GESAMP, 1997).

Shrimp crop loss from exposure to agricultural pesticides and fertilizers, sedimentation of canals and water inlets resulting from soil erosion in upland areas due to deforestation and inappropriate agricultural practices have been widely reported (Huang, 1997). In Ecuador, reduced growth rates of juvenile *Mysidopsis bahia* resulted from pesticides applied in the rice paddies of the Guayas River basin (McKenney Jr., 1986). In Latin America, pesticides were reported to be responsible for the shutting down of 12,000 ha of ponds in the Gulf of Guayaquil in the early 1990s (Khor, 1995b), and massive mortalities from Taura syndrome in Ecuador have been attributed to fungicides used in banana plantations (Rosenberry, 1994). In Asia, the crash of Chinese shrimp farms in 1993 was partly attributed to increasing levels of industrial pollution in the Gulf of Bohai (Asian Shrimp Culture Council, 1993).

In Thailand, quantitative field studies recorded that potentially harmful heavy metal and pesticide pollutants were ubiquitous to all water systems regardless of the management precautions or the type of shrimp culture system used (Miller, 1996).

2.6 Challenges and Constraints to Shrimp Aquaculture Development

Globally, the shrimp aquaculture industry faces many formidable challenges and constraints. Some analysts have suggested that the shrimp aquaculture industry will continue to grow, but at a slower rate, and that growth will eventually stabilize (Hall, 2004). Much of the debate over the future of shrimp aquaculture has focused on the long-term sustainability of intensive shrimp farming, and the need for more stringent environmental guidelines and better management practices (FAO, 1998a).

Disease is the most significant factor limiting global shrimp production. Viral and bacterial diseases, together with poor soil and water quality, are the proximal cause of low yields, shrimp mortality and failure (Flegel and Alday-Sanz, 1998; Kautsky et al., 2000; Schuur, 2003). Although poor management of shrimp farms is another determinant, the risk of disease in shrimp farming also increases with culture intensity and high stocking densities (Flegel, 1996). However, viral infection is in fact an unavoidable part of animal cultivation. Highly developed vaccines have regularly controlled such infections in poultry and pig farming. Unfortunately, shrimp, as an invertebrate cold-blooded animal, does not possess specific immune activities required for the production of specific vaccines. After more than ten years of trials, laboratories across the world still have no effective means against shrimp's viral breakout in the field.

Disease problems have devastated shrimp farming in virtually every country where the industry has been established including China, Thailand, Indonesia, and the Philippines (Kongkeo, 1997; Bacère, 2000; World Bank, 2002). One regional study in Asian shrimp producing countries estimated that annual disease losses amounted to $US 1.4 billion (ADB/NACA, 1998). In several countries of Latin America, disease losses are also having a major negative economic impact (Gillespie, 2001). Since 1991, the most striking example of disease and consequential major economic loss in shrimp farming is White Spot Syndrome Virus (WSSV). The spread of WSSV to most of the shrimp farming countries of Asia and the Americas has been attributed by some experts to the uncontrolled international trade in live shrimp for aquaculture purposes and in dead shrimp for processing. Disease epidemics continue to cause significant losses in shrimp production and trade and in some instances have had a significant impact on economic development in shrimp producing countries.

Increasing consumer demand for shrimp has supported the industry's rationale for intensification at every level of the commodity chain including seed stock development, formulated feeds, extension information, and marketing outlets. Despite achieving significant growth rates, the increase in per hectare yields at individual farms is often much lower, highlighting the technical constraints of intensification (Hardjano, 1994). Many of the problems associated with shrimp farming arise not because of shrimp farming in itself, but because of the inherent problems with intensification (Rönnbäck, 2002; Hall, 2004). Due to self-pollution and disease problems, the life span of most intensive shrimp culture systems seldom exceeds 5 to 10 years in Thailand (Flaherty and Karnjanakesorn, 1995; Dierberg and Kiattisimkul, 1996). While there are examples of farms that have been operating for more than 10 years, upon investigation, it is determined that most have not operated continuously and have from time to time been closed or left fallow. In these locations, good site management by the operator can increase farm longevity. More appropriately, farm managers manage the site to reduce the onset of inevitable productivity declines. Regardless, studies show that the longevity of most production sites is linked to the declining productivity in growout ponds. Shrimp pond yields decrease at a rate of 3 to 8% per cycle as wastes gradually reduce the carrying capacity of the receiving environment (Briggs, 1994). Experience has shown that shrimp farmers can do little to circumvent declining productivity. The typical response has been to shift cultivation to new locations with a more favorable environment. Shifting locations also refers to shifting between countries, as cheaper costs of production drive the emergence of new producing countries.

Some analysts suggest that the limits to the coastal shrimp-farming land frontier are at hand in many countries (Dierberg and Kiattisimkul, 1996). In Thailand, and in other shrimp producing nations, most of the coastal areas are currently being utilized and there is little room for further expansion short of continued encroachment upon mangroves, agricultural land and other land uses (Kaosa-ard and Pednekar, 1998). Future expansion of shrimp production will involve a combination of further intensification and the increasing use of marginally productive lands. In Thailand, recurring disease problems in coastal areas and international controversy over the siting of shrimp farms in coastal mangroves have been contributing factors behind the innovation and application of shrimp farming techniques in new environments.

2.7 Low-Salinity Shrimp Farming

In the late 1980s, coastal shrimp farming around the world experienced several major set backs, namely recurring disease and production crashes in coastal areas and international criticism over habitat destruction. During the early 1990s, Thai shrimp farmers shifted attention towards other habitat, often hundreds of kilometers from the coast. Using culture techniques adapted from coastal shrimp farming, producers discovered that it was feasible to cultivate the marine species *Penaeus monodon* (the black tiger shrimp) under mesohaline conditions (3 to 10 ppt – parts per thousand). The rapid expansion of this type of shrimp farming was in part, fueled by the belief that inland areas were devoid of disease problems (Kongkeo, 1997). The emergence of 'low-salinity' shrimp farming, which relies on salt water trucked in from the coast, enabled shrimp farming to expand inland into freshwater areas, notably the irrigated delta of the central region, heart of Thailand's rice bowl (Flaherty et al., 1999).

The widespread adoption of low-salinity shrimp farming has enabled Thai producers to achieve record levels of shrimp production. However, accurate information on the production output from inland shrimp ponds for the whole of Thailand does not exist. Kongkeo (1997) reported that 30% of shrimp production was derived from freshwater areas, and that over 60% of intensive shrimp ponds were located in supratidal areas. Limsuwan (1998) estimated that inland shrimp farming could represent as much as 40 to 50% of the total farmed shrimp production. In 2002, it was reported that 70% of the shrimp produced in Thailand, or about 300,000 MT a year, was produced from farms using low-salinity conditions (Limsuwan et al., 2002). The accuracy of estimates is difficult to verify since farmed shrimp are processed without delineating the farm or region of origin (Miller, 1999). National production figures do not distinguish between coastal or inland shrimp production.

Investigations to determine the total farming area have reported a wide range of estimates; differences resulting from how inland shrimp farming have been defined. Pongnak (1999) estimated inland shrimp farming area to be 32,000 hectares, delineating several types of culture systems, and Tookwinas (1997) estimated that there were only 2,930 hectares of marine shrimp culture ponds in freshwater regions. While the majority of data collection efforts have focused on the central region, marine shrimp culture in freshwater areas is mostly unreported for the whole of Southern Thailand. For example, Tookwinas (1997) estimated that there were only 104 hectares of inland shrimp ponds in the southern province of Nakhon Si Thammarat. Recent observations in the south, however, especially around Songkhla Lake, suggest that the culture pond area greatly exceeds earlier reports (Vandergeest, 2001). Although individual inland low-salinity shrimp farms are small household operations, over 22,000 hectares of pond area were identified in a national inventory of this activity.

The magnitude of inland shrimp farming development may have the potential to detrimentally affect both local and regional soil and water resources. Low-salinity shrimp farming raises concerns regarding potential environmental impacts, and the suitability of conducting this activity within highly productive freshwater agricultural areas. Specific environmental impacts of concern include soil salinization, pollution and water quality degradation as a result of effluent disposal, and water use conflicts with competing activities such as rice farming (Pongnak, 1999; Flaherty et al., 2000).

To date, inland shrimp farming has been subjected to very limited scrutiny. Little is known about the nature of the low-salinity shrimp culture innovation, in particular the husbandry and operating procedures. There is also a limited understanding of the factors contributing to the adoption of low-salinity shrimp aquaculture in freshwater environments. In the absence of this information, the government has not been able to develop effective policies to regulate the development of this activity and minimize its impact. This research gap highlights the need for empirical research that will document the economic and institutional factors facilitating the development of low-salinity shrimp farming in freshwater environments and identify the ways in which low-salinity shrimp farming is impacting on rural environments and communities. Ultimately, this information would allow for the development of recommendations to improve shrimp farming policy and the management practices at the farm-level.

2.8 Summary

Marine shrimp farming is a high-value primary industry in coastal areas of many tropical developing countries. Over the last decade (since 1995) there has been a dramatic increase in the number of intensive culture operations, which has resulted in substantial increases in shrimp production. The rapid growth of the shrimp culture industry, however, has been accompanied by criticisms over its social, economic and environmental consequences.

Thailand is a world leader in shrimp production. Major production crashes and increased coastal pollution, however, has necessitated the need for new farming sites in order to maintain production. During the early 1990s, innovative producers discovered that the black tiger shrimp could be cultivated in a reduced salinity environment away from the coast. The adoption of intensive low-salinity techniques in Thailand's freshwater regions, however, has yet to be fully researched.

The next chapter documents recent economic growth in Thailand and examines the focus on export-oriented natural resource based development. It also reviews Thailand's capacity to effectively manage and regulate the use of natural resources and the inclusion of marine shrimp farming into Thailand's national development plan and the development of low-salinity shrimp farming in Thailand's freshwater rice growing areas.

CHAPTER 3

THAILAND: NATURAL RESOURCES AND DEVELOPMENT

The chapter provides an overview of Thailand's economic development, and outlines how this development has been guided by national economic and social development planning. It then examines the nature of export-oriented natural resource based development, and reviews Thailand's capacity to manage and regulate the use of its natural resource base. A review of the social and environmental impacts of natural resource based development is followed by a discussion on the growth and diversification of export cash crops. The final section introduces Thailand's preeminent cash crop activity since the early 1990s: marine shrimp farming and the development of low-salinity shrimp farming in Thailand's freshwater rice growing areas.

3.1 Trends in the Thai Economy

Thailand has experienced remarkable economic growth over the past 30 years. Since the 1960s, the rapid expansion of the national economy has been sustained by policies encouraging fast-track economic development. Between 1960 and 1985, Thailand's Gross Domestic Product (GDP) expanded more than 18-fold, maintaining an average annual growth rate of 7.5% over the period. Thailand had the world's fastest growing economy from 1985 to 1995, with the World Bank calculating an average annual growth rate of 10% per year over the decade (World Bank, 1997). A World Bank mission facilitated record achievements in the late 1950s, which assisted in developing a blue print for the Thai economy (Bello et al., 1998). The World Bank advised the government to focus on the development of modern infrastructure – telecommunications, irrigation, power and transportation – and recommended that "the government should not only refrain from seeking to increase its industrial participation, but should disengage itself from its present commitments" (IBRD, 1959). Subsequent national economic policies encouraged industrial investment by private firms, and reduced the active involvement of government in ownership and management.

From the mid-nineteenth century to the late 1960s, Thailand's role in the world economy was to supply primary commodities to the global market (Hewison, 1988). Rice, teak, rubber, and tin exports fueled the Thai economy and accounted for between 50 and 90% of all exports. Maintaining dominance in agricultural exports had necessitated substantial infrastructure investments in irrigation and road systems. Aided by foreign donors, development policies pushed the "rice economy" out into the land frontier. While increasing global demand for agricultural goods sustained favorable commodity prices, producers in other countries reached the limits of their land frontiers and shifted focus to manufacturing based production. Thailand's comparative advantage in agriculture, arising mainly from a land surplus, allowed for an extended period of agricultural-export-led growth under import substitution industrialization. Agricultural area doubled in the three decades from 1961 to 1991, from 10.56 million hectares to 21.28 million hectares (Kaosa-ard and Pednekar, 1996). During this period, new land was cleared and planted at the rate of over 300,000 hectares per year. Over 2.5 million new farms powered the economy with agricultural exports increasing at an average rate of 12% per year (Phongpaichit and Baker, 1998). The fast pace of extensive agricultural development was achieved at the expense of the forest cover (Hirsch and Warren, 1998).

During the 1960s and 1970s, the government maintained an inward-looking economic development strategy of import substitution industrialization (Lewis and Kapur, 1990). The first national economic and social development plan prescribed scaling back state enterprise, introduced incentives for investment, established tariff protection for new enterprises, and welcomed foreign capital to promote local ventures (Phongpaichit and Baker, 1998). Under the guise of rational development planning, the implementation of reforms propelled the country into a period of relative prosperity. An assortment of infrastructure developments financed by the World Bank assisted the manufacturing sector in becoming a new source of economic wealth (Hewison, 1988). While Thailand was proceeding with import substitution industrialization, other Asian tigers (i.e., Korea, Taiwan, Hong Kong and Singapore) adopted outward-looking policies of export-oriented industrialization (EOI). In the late 1970s, however, the foundations of import-substitution began to destabilize in Thailand. Ultimately, this marked the end of a period driven by growth in agriculture and agricultural exports that had fed the increasing domestic demand and had contributed to a healthy trade balance.

In the early 1980s, the growth of Thailand's economy slowed due to the weakening of agricultural exports, the withdrawal of US patronage, and the inherent limitations of the import-substitution strategy. Constraints to the domestic market appeared as agricultural expansion reached the limit of the land frontier. Additional economic problems resulting from the declining prices of agricultural commodities in world markets were intensified by an oil crisis. Thailand received structural adjustment loans from the World Bank that were conditional upon introducing a package of "export push" reforms to shift the economy towards outward-oriented industrialization (Chaipat, 1992). The transition to export orientation was advocated by technocrats, bankers, potential exporters, and foreign creditors, but blocked by vested interests in business and bureaucracy. From 1983 to 1985, a recession threatened major turmoil in governmental and commercial finance. The government devalued the baht and committed itself to exporting its way out of the crisis (Phongpaichit and Baker, 1997). Henceforth, national economic and social development planners incorporated the strategy of export-oriented industrialization.

The implementation of EOI marked the beginning of an economic boom that reoriented the economy towards export-oriented manufacturing. Displaced agricultural labour effectuated a surge in manufacturing that was promoted by foreign firms escaping from inflating costs, and domestic firms released from the constraints of the import-substitution regime (Phongpaichit and Baker, 1997). Domestic conglomerates diversified into unique export domains and the new globalized context of business provided great opportunities for diversification by the established groups (Bello et al., 1998). Capitalizing on the prolonged recession in a number of developed countries, Thai conglomerates successfully marketed their technology, skill, and expertise on the international market. The final component behind the boom in export growth was the secondary boom, fueled mostly by domestic capital, in “property, retailing, consumer goods, and financial services in the home market” (Phongpaichit and Baker, 1997).

Several authors describe Thailand’s boom period and the subsequent problems in the economy during the early 1990s (see, for example, Phongpaichit and Baker, 1996; Coxhead and Plangpraphan, 1998; Phongpaichit and Baker, 1998). In May 1997, a crisis materialized. Although various assessments provide insight to the origins of the crisis (see, for example, Bello et al., 1998; Siamwalla and Sobchokchai, 1998), there are differing views on what initiated it. Generally, large capital inflows had led to inflation and the appreciation of domestic currencies, which ultimately led to trade imbalances. Some analysts argue that the weak banking system had funneled foreign funds into unprofitable investments. Others claim capital inflows had been too rapid to be productively absorbed, as evidenced by the high level of speculative investments in real estate. In any event, with the beginning of bank failures in May 1997, foreign banks and investors quickly lost confidence and sold off their financial assets, causing the value of the Thai currency and assets to fall precipitously. Investors were driven to renew their portfolios in other countries in the region, and began to question borrowers’ ability to pay off loans. During the latter part of 1997 the resulting financial exodus from Asia amounted to almost $US 100 billion exiting the region (Griffith-Jones, 1998). Thailand was particularly severely hit. In 1995, while net capital inflows amounted to 13% of the GDP in Thailand, the capital outflows were almost 11% of the GDP (TDRI, 1998). Despite agreement that the financial markets overreacted to the Asian economic conditions, this overreaction had overwhelmingly negative economic and social effects on the region (Sussangkarn et al., 1999).

Recent economic events contrast sharply with the rapid growth period of the mid-1980s, although both were triggered by the depreciation of the baht. While a devalued baht in the mid-1980s boosted the export sector, the 1997 collapse of the financial system and the regional meltdown compromised the export sector’s ability to benefit from a falling baht. However, with a depreciated value for the baht continuing, economic planners have vigorously resumed the promotion of export-oriented strategies, which are expected to revive sunset industries such as agriculture, textiles and footwear. Subsequent economic policies have focused specifically on accelerating the diversification of the agricultural and fisheries sectors. Although export-led growth had underpinned previous development strategies, the economic crisis stimulated a renewed interest in several cash crop activities already promoted in Thailand, most significantly the marine shrimp farming industry.

At present, the revenues from marine shrimp farming play a critically important role in the Thai economy. This is a situation that was largely determined by the government's decision to restructure the fisheries and aquaculture sector in favour of marine shrimp farming. This emphasis on marine shrimp farming has been systematically introduced through initiatives funded and directed by successive National Economic and Social Development Plans. With a view towards understanding the importance of shrimp farming development to Thailand's economy, the next section traces the historical development of Thailand's National Economic and Social Development Plans.

3.2 National Economic and Social Development Planning

Thailand's central government has played a variety of roles over time and across different sectors of the economy in fostering economic development. Since 1961, development planning has been centralized and based on a series of five-year economic and social development plans, which have, invariably, heavily influenced the direction of economic development. Through the aegis of these five-year plans (there have been nine so far), the broad based direction for investment in each sector of the economy is decided. While the plans have moved Thailand towards becoming a newly industrialized country, the early plans paid scant attention to the issue of natural resource depletion or other negative social and environmental impacts. Emphasis on natural resource based development, while stimulating the establishment of agribusiness and other resource-based industries, accelerated natural resource exploitation. The upshot was an unsustainable pace of natural resource based development, that has left the resource base severely degraded and/or depleted (see, for example, Hirsch and Warren, 1998; Kaosa-ard, 1998; Rigg and Nattapoolwat, 2001; Rigg and Ritchie, 2002).

The National Economic and Social Development Board, the government agency responsible for producing the national plans, has acknowledged that the development model advocated over the previous four decades has serious flaws (see, for example, Bardacke, 1995; Sonsomsook, 1999). Recent development plans have introduced much needed reforms. Beginning with the Eighth National Economic and Social Development Plan (1997 to 2001), the government attempted to link the patterns of natural resource use with the welfare of rural communities (Prime Minister's Office, 1996). Government efforts to make the plan more relevant in addressing social, economic and environmental concerns involved enlisting the participation of citizens' groups and non-government organizations in the plan formulation. For the first time, human resource development replaced economic targets as the central theme. The Ninth Plan (2002 to 2006), consistent with the Eighth Plan and the 1997 Constitution, aims to strengthen the capability of Thai society in coping with the changing world through development of human resources, family, community and society (Wongcha-Um, 2000). The ninth plan will also attempt to restructure the economic system in order to increase competitiveness in the globalized economic environment (Prime Minister's Office, 2002).

Although Thailand's national plans have only recently incorporated a social reform agenda, they have consistently diversified and restructured the agricultural sector. Agro-industry has been designated as the linkage between the traditional agricultural society and the expanding industrial base (TDRI, 1995). Thailand's industrialization and enduring comparative advantage has remained with what some analysts have referred to as "resource-based" products – the new primary and/or processed products that fit particular niche markets (Lewis and Kapur, 1990). While rice has remained the single most important agricultural commodity, government agricultural diversification policies have encouraged the cultivation of non-rice export cash crop commodities. In order to make these exports competitive, producers have benefited from research and capital investments to increase crop yields and improve production and marketing systems for high-valued cash crop commodities. Notable successes in industrial-based agriculture have been achieved in the development of post-harvest and processing technologies. For example, an increasing share of the industrial sector is based on the processing of agricultural commodities (for example, sugarcane for refined sugar, cassava for processed livestock feed). While producers and the government have a vested interest in increasing export revenues, natural resource management policies to address adverse environmental effects have until recently been low on the policy agenda.

By the mid-1980s, the Thai government had prioritized coastal aquaculture development in national economic and social development plans (Suraswadi, 1987). Thailand wanted to increase foreign exchange and offered incentives such as subsidies, grants and duty-free or concession imports for the industry, and encouraged joint ventures with foreign companies (Pillay, 1997). More importantly, at a time of declining catches from capture fisheries and the downsizing of the fishing industry owing to the establishment of Exclusive Economic Zones which severely reduced Thailand's access to fishing grounds in the Gulf of Thailand and the Andaman Sea the government identified the marine shrimp aquaculture sector as a profitable growth industry. The favourable conditions for export-oriented aquaculture of high valued species like marine shrimp, attracted investors to support the establishment of large-scale farming enterprises (Goss et al., 2000). Coastal shrimp aquaculture became an integral part of a development strategy that initiated an expansion phase of shrimp aquaculture, which established a production and marketing chain for marine shrimp.

Much of the development emphasis on marine shrimp has come through the aegis of national economic and social development planning. The government of Thailand included a "Shrimp Culture Development Project" in its Fifth National Economic and Social Development Plan (1982 to 1986), which was designed to increase local food subsistence in rural areas. By the Sixth Plan (1987 to 1991), the government had received a loan of $US 33.1 million from the Asian Development Bank to promote aquaculture as a viable export industry. In addition to external loans, government planning and policy initiatives have also provided capital to facilitate aquaculture development (Csavas, 1988). Under the Sixth Plan, the government allocated over $US 84 million to marine shrimp aquaculture and during the Seventh Plan (1992 to 1996) coastal aquaculture development policies emphasized marine shrimp (Bailey and Skladany, 1991). The latter plan initiated the extensive cultivation of brackish water species, developed intensive culture techniques for commercial species, and implemented some limited conservation efforts. The Eighth Plan (1997 to 2001) introduced efforts to advance conservation and restoration of marine resources conservation by implementing the Marine Rehabilitation

Plan. Specific targets of the plan included maintaining mangrove forests at 160,000 ha by the end year of the plan and maintaining seawater and freshwater quality at 1996 levels (Kaosa-ard and Pednekar, 1998). There is no specific reference to aquaculture or fisheries development in the Ninth plan (2002-2006), even though these industries are a major employer and generator of foreign exchange and also a source of controversy (Office of the Prime Minister, 2002).

3.3 Management and Regulation of Natural Resources

The management and regulation of natural resources in Thailand has been investigated using several approaches. Some assessments have approached the issues from sectoral domains; primarily land and water resources (see, for example, Boon-long and Christensen, 1993; Thailand Development Research Institute, 1994; Janekarnkij, 1995; Abernethy, 1998; Stephens and Hess, 1999). Others have examined the institutional impediments to effective natural resource management and regulation (see, for example, TDRI, 1987; Arbhabhirama et al., 1988). Both analyses yield a common set of insights, as the problems that befall one natural resource sector are also applicable to the other sectors (MIDAS, 1995). The general conclusion is that definitive policies on natural resource management, environmental regulations or natural resource conservation in Thailand are seldom implemented until such time as the natural resources are exhausted or severely degraded.

Natural resource management and regulatory guidelines are embodied within national plans. Overall, the management and regulation of natural resources within Thailand suffers from systemic institutional shortcomings and bureaucratic inertia. Problems stem not from the scarcity of laws and regulations but rather from the presence of layers of overlapping mandates and jurisdictions that weaken the effectiveness of the governing institutions (Kaosa-ard and Pednekar, 1996). Shortcomings in Thailand's institutional structure have long been recognized. In 1988, the Thailand Development Research Institute (TDRI) identified the institutional barriers in the Thai government affecting natural resource management and regulation. TDRI concluded, "Thailand's administrative structures and procedures could scarcely be better designed to impede progress in areas, which, like natural resources management, demand an integrated approach" (Arbhabhirama et al., 1988:236). Institutional restructuring, decentralization of environment functions and strengthened compliance and enforcement are critical for the government to enhance its ability to implement policies regarding natural resource management. Institutional reform will necessitate a fundamental shift in natural resource management philosophy from open access exploitation to conservation.

In response to management concerns regarding natural resources, Thailand adopted several legal and institutional frameworks for improving environmental management. The *Enhancement and Conservation of National Environmental Quality Act* (NEQA) was promulgated in 1992. This was followed by the formulation of the *Policy and Perspective Plan* for the NEQA for the period 1997 to 2016. Most recently, the *Environmental Quality Management Plan* was revised for implementation during the period of the Ninth Plan, which included the management of natural resources and environment as one of its key strategies. The strategy focuses on conserving the natural resources and environmental base of the country, restoring ecological balance, and enabling all sectors of society to have a decent and environmentally sustainable standard of living. The expectation is that this will be carried out through more efficient and participatory environmental management within the existing legal and institutional frameworks. Among the targeted areas for assistance are land, freshwater, and coastal/marine resources. Details on the management and regulation of natural resources for marine shrimp farming are discussed in section 3.5.2 below.

3.4 Growth and Diversification of Cash Crop Exports

The Thai government recognizes the strategic importance of the agriculture sector particularly in the context of the economic crises for promoting export-led growth. Export growth and agricultural diversification have long formed the basis of development strategies and has been a critical component to Thailand's economic transformation. Aided by tax breaks, duty privileges and other promotional mechanisms, farmers and agri-exporters developed a variety of methods to drive commercial agriculture into upland areas including contract farming and out grower schemes (Phongpaichit and

Baker, 1997). In many instances, the newly diversified high-value agricultural sector was organized by large food-processing enterprises, many of them multinationals. Bello et al. (1998:148) elucidates the changed view towards agriculture since the mid-1980s.

> Since the mid-1980s, Thailand's planners have come to regard rural development not just as a political stabilization scheme but also as a component of a modified development strategy for Thailand. In contrast to the urban industrialization strategy of the NICs, the new paradigm was christened NAIC, or "newly agro-industrializing country", since it envisioned a central role for export agriculture via the consolidation of the country's comparative advantage in traditional export crops and gaining comparative advantage in new-agro industrial exports.

In diversifying and restructuring the agricultural sector, farmers have been encouraged to grow a diverse mix of crops to reduce risk and cease cultivating crops with a falling price trend and low profitability (FAO, 1992). The primary basis for restructuring has been to stem economic deterioration in traditional rice based systems (Coxhead and Plangpraphan, 1998). However, fertile land and abundant water supply had made Thailand the traditional rice bowl of Asia. Thailand is currently Asia's only net food exporter. Thai rice accounts for over 30% of the volume of world rice exports (FAO, 1998b). While rice remains the single most important agricultural commodity, its relative importance has declined. Large numbers of producers have shifted into the production of non-rice cash crops. Fuelled by the development of urban and global export markets and reliable transport infrastructure, a series of export commodities have been encouraged and discouraged in accordance with fluctuations in world market conditions.

Although the fishery sector has long been an important aspect of Thailand's export-led growth, emphasis on agro-industry has accentuated coastal resource utilization, and helped to bring more investment and technology into fishing, aquaculture and processing. Within the marine resource commodities sector, Thailand has focused on industrial seafood freezing and canning (Phongpaichit and Baker, 1997). Over the past three decades, the marine fisheries industry rapidly developed to the extent that Thailand is currently the world's largest producer and exporter of edible fish and fish products (FAO, 2002). Although export data suggest that shrimp and canned seafood are the principal marine resource commodities, cephalopods, fishmeal and shellfish are also processed and exported in large quantities (Office of the Prime Minister, 1995). In 2001 (the most recent year for which data are available), the total combined export value of fish and fishery products earned $US 4.1 billion, nearly $US 2.4 billion of this total, resulted from farm-raised marine shrimp (FAO, 2004a).

Since the late 1980s, national development strategies have promoted intensive marine shrimp production in land-based ponds. In 1993, Thailand became the world's leading supplier of farm-raised shrimp when a disease epidemic destroyed China's shrimp industry (Feigon, 2000). By 2001 (the most recent year for which data are available), the export value of shrimp exceeded that of most of the major agricultural exports, including rubber and rice (Table 3.1). Despite an increasing number of high-value nontraditional agricultural exports, farmed shrimp are likely to continue to play a major role in the Thai economy. During the post-economic crisis period, shrimp exports gained prominence because the lowered value of the Thai currency had improved Thailand's competitiveness in the world market (Bangkok Post, 1998c). Shrimp exports have continued to expand in terms of volume and value because of the stability of the Thai currency, as well as the improving world economic conditions, particularly in the major trading partner countries: the European Union and Japan and the USA (Royal Thai Consulate General, 2005).

Table 3.1 Thailand's Major Agricultural Exports

Commodity	Year	Quantity (MT)	Value (1000 USD$)
Rubber	2002	2,053,817	1,415,917
Rice	2002	7,337,561	1,631,963
Sugar	2002	4,204,554	684,262
Cassava	2002	15,315,438	678,550
Poultry	2002	552,014	1,005,469
Pineapple	2002	486,566	308,242
Crustaceans (primary, processed)	2001	281,150	2,383,131
Total Fish Catch (primary)	2001	167,195	120,639
Fish and Fishery Products (processed)	2001	1,217,230	4,053,478

Source: (FAO, 2004a)

3.5 Marine Shrimp Aquaculture in Thailand

Marine shrimp aquaculture has a long history in Thailand. Solar salt farmers experiencing a recession initiated extensive shrimp farming in the early 1900s along the inner Gulf of Thailand (Tiensongrusmee, 1970). Early practices were simple and relied upon incidental or natural recruitment of juvenile shrimp that fed on the incidental seawater nutrients (Dierberg and Kiattisimkul, 1996). In tidally flooded low-lying coastal areas, seawater was impounded during high tide into man-made enclosures that ranged in size from 8 to 16 ha. With daily water exchange rates of 5 to 10%, annual production was typically 250 to 900 kg per ha (Tiensongrusmee, 1970). The shrimp species reared included the banana shrimp (*Penaeus merguiensis*), the school shrimp (*Metapenaeus ensis*, *Metapenaeus monoceros*), the Indian white shrimp (*Penaeus indicus*) and a small volume of the black tiger shrimp (*P. monodon*). Shrimp farmers increased productivity by introducing push-pumps made from second-hand diesel bus engines to greatly increase water exchange (Csavas, 1994b). Push-pumps produced higher yields over the "trap and hold" extensive techniques demonstrating the feasibility of increased stocking density. This success also increased the demand for seed beyond natural recruitment rates, and generated a need for hatchery development.

The earliest marine shrimp farms were concentrated in and along the estuaries of the inner Gulf of Thailand, in the provinces of Samut Prakan, Samut Sakhon and Samut Songkhram (Tiensongrusmee, 1970). By the end of the 1960s, the industry remained relatively small: 1,052 shrimp farms covering an area of 7,825 ha and yielding some 3,440 tonnes of shrimp (Csavas, 1994a). However, as interest in shrimp farming increased, farms were established along the coasts of Chanthaburi, Nakhon Si Thammarat and Rayong provinces and later in the southern provinces of Surat Thani and Songkhla. Figure 3.1 indicates the coastal shrimp farming provinces.

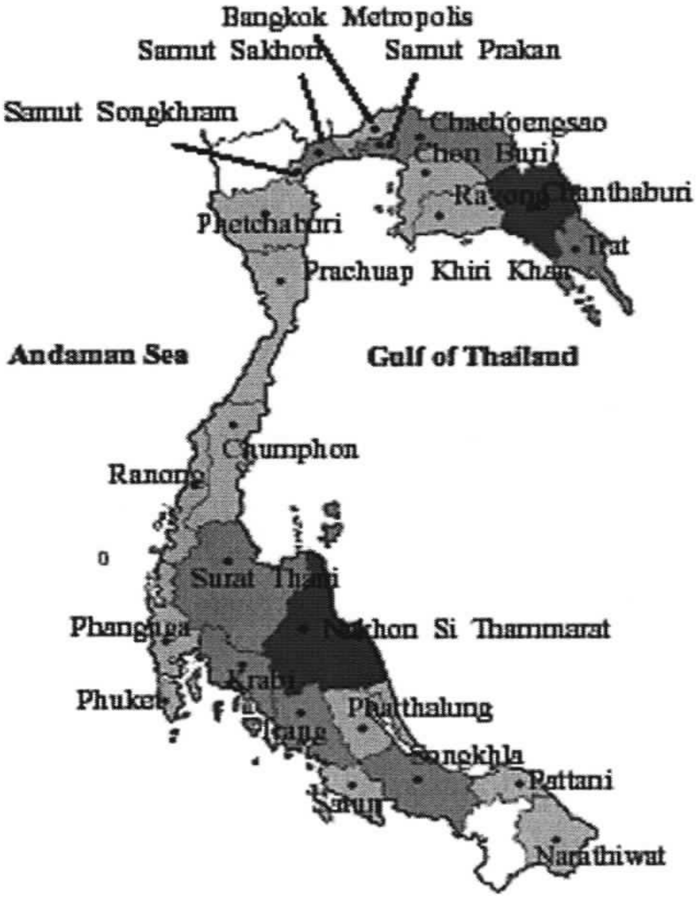
While the area of brackishwater ponds was steadily increasing during the 1970s, national production did not increase significantly until the government offered encouragement and financial assistance to expand marine shrimp aquaculture. In 1972, the Department of Fisheries (DOF) adopted policies promoting coastal aquaculture by encouraging farmers to upgrade farming methods (Goss et al., 2000). In 1973, a breakthrough for the shrimp industry occurred when Thai technicians trained in Japan were successful in hatching and nursing the black tiger and banana shrimp from captured wild spawners at the Phuket Marine Fisheries Station (Flaherty and Karnjanakesorn, 1995). Although not the preferred species domestically, the black tiger was a ready candidate because of its large size, rapid growth rate and growing demand in overseas markets (Briggs, 1994). The first large-scale hatcheries operated by the DOF started to produce black tiger post-larvae in the early 1980s. By the end of the 1980s, almost 2,000 "backyard" hatcheries and nurseries were in operation. The rise of hatcheries greatly facilitated Thailand's transition from a small-scale producer into the world's largest producer of farm-raised shrimp (Kongkeo, 1995). Today, the DOF is no longer a major supplier of shrimp seed as the private sector is well established. Although the development and expansion of seed production capability is heralded as a major breakthrough: seed production continues to depend upon wild captured breeders.

In the early to mid-1980s, information and technology transfer, proliferation of hatcheries, development of formulated feed, and the availability of adequate equipment and processing facilities all came together. The shortage of graduates in aquaculture or fisheries science resulted in most being recruited into companies entering the shrimp business. The majority of small-scale producers entering shrimp culture during this time lacked the technical skills required for intensive shrimp culture. In 1987, the DOF organized workshops and training courses in shrimp culture methods. The crash of the Taiwanese shrimp industry and a rise in world shrimp prices in 1988 initiated the massive development and intensification of shrimp culture operations within a three to five km belt along the entire Upper Gulf of Thailand (Lin, 1989; Sheeks, 1989; Liao, 1992; Chen, 1995). Unlike Taiwan's shrimp industry, which was concentrated in one area, Thailand had ample room for spatial expansion (Patmasiriwat et al., 1998). In a relatively short period, the shrimp industry progressed from the Central region's upper gulf to the Eastern, Southern and Andaman Sea coastal areas.

In the 1990s, continuing improvements in farming methods, seed supply and technology, and ongoing government support enabled Thailand to steadily increase production despite localized production crashes (Miller, 1996). Coinciding with the intensification of culture was a dramatic increase of the number of shrimp farms from

4,939 farms in 1985 to 26,145 farms in 1995 (Department of Fisheries, 1997). While the total area under production expanded from 40,769 ha in 1985 to 74,942 ha in 1995, the average land area cultivated per farm decreased from 7.6 ha in 1985 to 2.7 ha in 1995 indicating the shift to intensive shrimp culture systems. While the above data resulted from an official census of the shrimp industry, the actual number of shrimp farms would increase significantly with the inclusion of unregistered farms. It has been estimated that only 35% of Thai shrimp farms are registered with government agencies (Kaosa-ard and Pednekar, 1998).

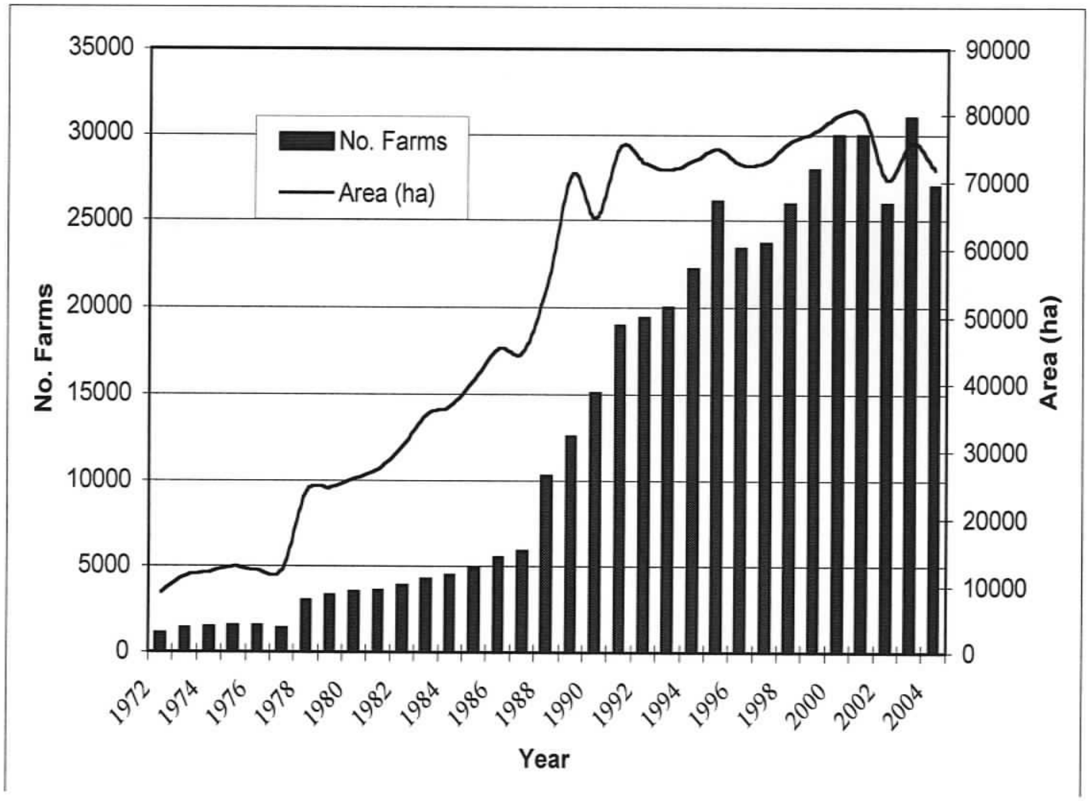
Figure 3.1 Coastal Shrimp Farming Provinces in Thailand



Source: (Department of Fisheries, 1997)

Currently, the industry is comprised of over 27,000 farms, which occupy an area of around 72,000 ha (Figure 3.2) (SHRINFO, 2005a). Almost 80% of all shrimp farms use intensive methods and 7% of the farms use semi-intensive methods. The remainder use extensive methods and produce mainly the banana prawn, *P. merguiensis* (Hall, 2004; SHRINFO, 2005a). Individual intensive farms can achieve production rates of 3,000 kg per ha. In 1999, approximately 98% of Thai shrimp producers were cultivating the black tiger shrimp (Figure 3.3). While the black tiger shrimp has long been the mainstay of Thailand's shrimp exports, in 2000, many producers began changing species to *Penaeus vannamei*, or the Pacific white shrimp to improve revenues. White shrimp are reportedly easier and cheaper to raise than the black tiger shrimp but command lower prices because of their smaller size (Arunmas and Keeratipipatpong, 2003). Production data for the white shrimp are not yet available but it is speculated that white shrimp production totals may soon overtake black tiger shrimp production.

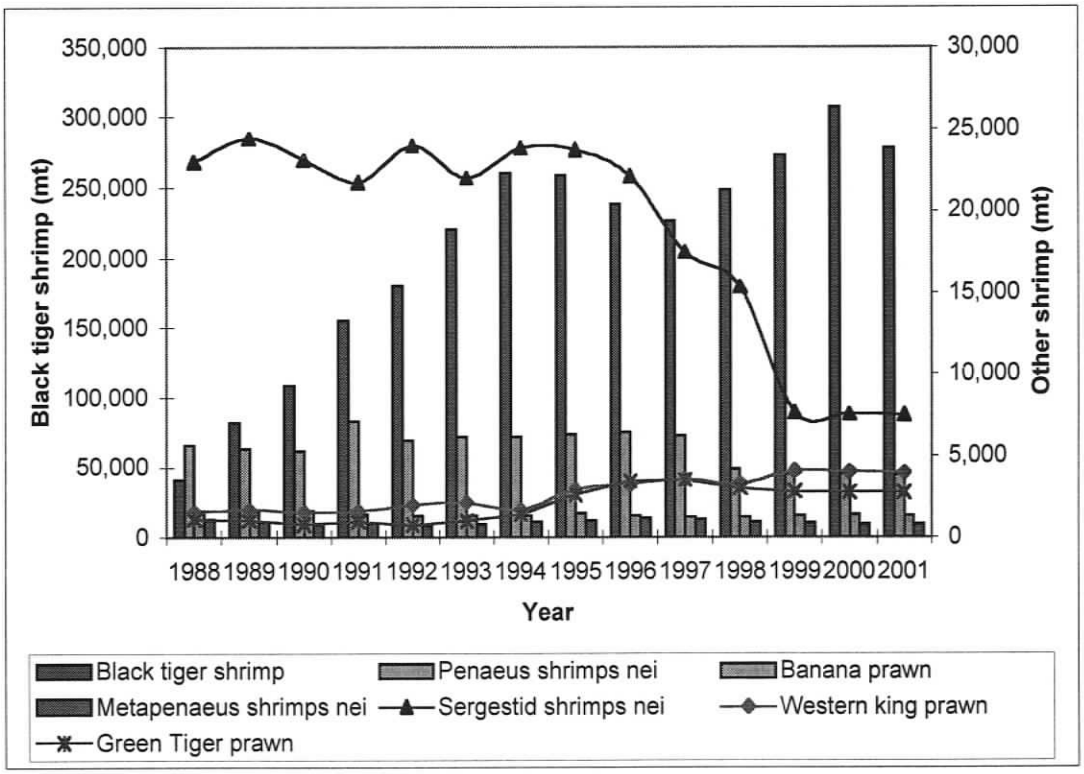
Figure 3.2 Number of Shrimp Farms and Culture Area in Thailand



Source: (FAO, 2004b; SHRINFO, 2005a)

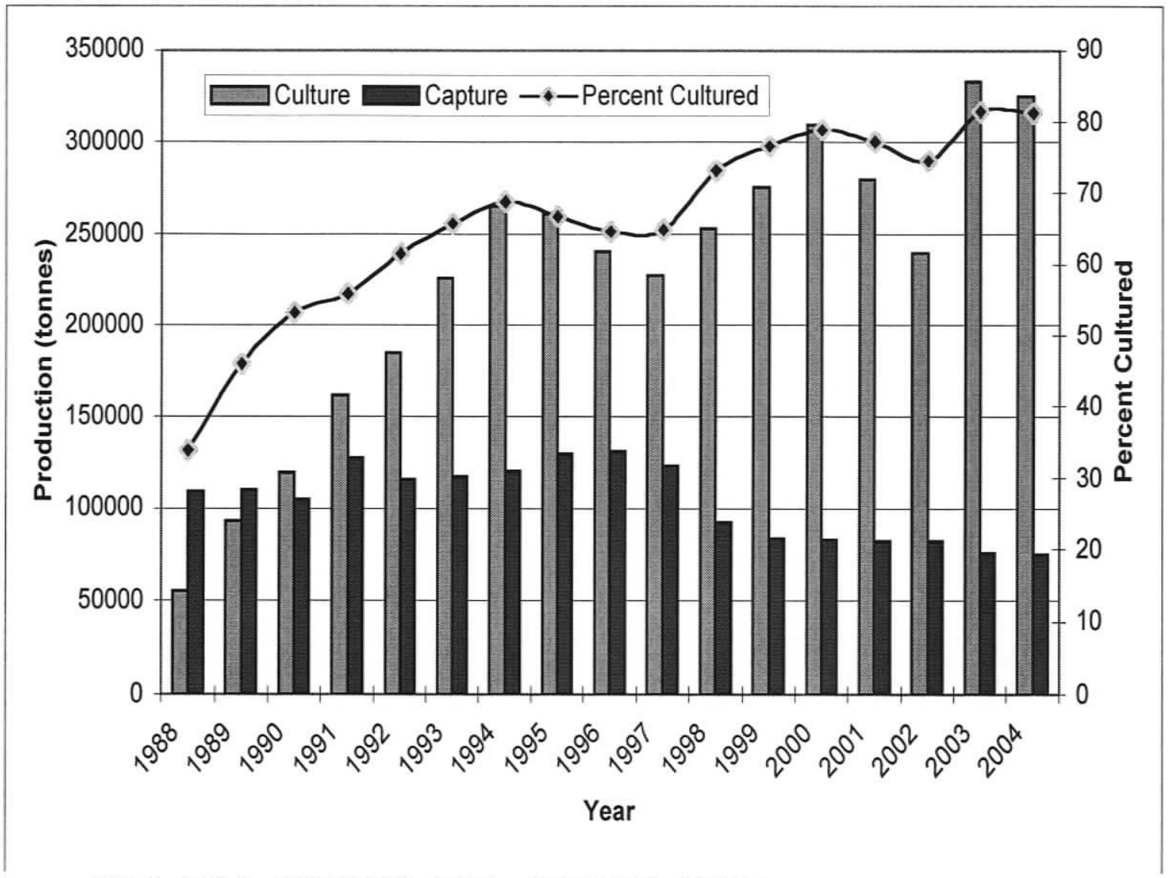
In 2004, Thailand produced 325,000 tonnes live weight of shrimp and accounted for around 22% of the world's cultured production (FAO, 2005b) (Figure 3.4). Farmed shrimp currently represent about 59% of the country's total fishery exports in value terms, or 3.5% of the total exports of goods and services (Department of Export Promotion, 2004). In 2001 (the most recent year for which export data is available), the value of farmed shrimp exports was almost $2.4 billion (FAO, 2005a). Thai shrimp are exported to five principal markets: United States (35.2%), Japan (21.8%), China (10.2%) the European Union (8.3%) and ASEAN (8.3%). The maintenance of export markets for Thai shrimp is an ongoing challenge. For example, Thai shrimp now account for almost half of the U.S.'s shrimp imports. In 2004, shrimp producers in eight US southern states imposed anti-dumping measures against Thailand. Thailand responded by hiring lobbyists in the US to make the case that Thai farmed shrimp are cheaper than US shrimp that are mostly harvested at sea. This case is yet to be resolved.

Figure 3.3 Shrimp Production in Thailand, by Species, for Various Years



Source: (GLOBEFISH, 2003)

Figure 3.4 Shrimp Production in Thailand



Source: (FAO, 2004b; SHRINFO, 2005c; SHRINFO, 2005b)

3.5.1 Policies and Regulations Relating to Shrimp Aquaculture in Thailand

Despite government decentralization, particularly in the management of natural resources, the DOF, as with other ministries of the Thai government, is a hierarchical and centralized organization, which maintains tight control of fisheries policy (ODA, 1996). National aquaculture development policies have major impacts on the distribution of benefits (Williams, 1997). In the 1970s, national policy toward marine shrimp aquaculture emerged when the government promoted marine shrimp aquaculture by introducing financial and technical incentives (Saisithi, 1989). Financial incentives included development loans, tax exemptions for the import of inputs and equipment, and the creation of favourable conditions for private and foreign investment. Financing plans implemented through Thailand's Bank of Agriculture and Cooperatives were developed from the mid-1980s, enabling shrimp farmers to take advantage of soft loans at annual interest, which were considerably lower than those of commercial banks (Weigel, 1992). As the industry progressed, producers received technical support in the way of extension services to address disease problems and increase the quality and quantity of production. The desire to maintain foreign exchange earnings has assumed primacy in national aquaculture development policies.

Shrimp aquaculture development policies have emphasized the need for industry regulation. However, the development and implementation of regulatory frameworks for shrimp aquaculture have proven to be legally and institutionally complex (FAO, 1999a). Few countries have established appropriate legal frameworks specific to marine shrimp aquaculture. Legal frameworks have generally been neglected because aquaculture has been viewed mainly in technical terms and support has been focused on the technical aspects of production (Shehadeh, 1999). In Thailand, the majority of national legislation pertaining to aquaculture is ambiguous, poorly drafted and subsequently modified to the extent that government officials and shrimp farmers find it difficult to understand or apply (MIDAS, 1995). The shrimp industry is not controlled by a single aquaculture law, but is regulated by a complex and unwieldy body of legislation and statutes from different sectors including the land, water, fishery and environmental laws, which have yet to be fully integrated (Tasneeyanond and Rubthong, 1991; Flaherty et al., 1999).

The main legislation regulating shrimp aquaculture in Thailand are the *Fisheries Act* 1947, as amended, and the *Enhancement and Preservation of the National Environmental Quality Act* 1992 (NEQA), along with Ministerial Orders and subsidiary legislation under these enactment's (Miller, 1996). Overall, existing legislation provides for the classification and regulation of public fisheries and controls the trade and importation of aquatic organisms and the handling of poisonous substances that may harm aquatic organisms or public waters. Although the majority of shrimp farms and hatcheries are located on private property and as such do not require a license under the Fisheries Act, these operations are required to comply with a 1991 Ministerial Decree outlined in Table 3.2 (Ministry of Agriculture and Cooperatives, 1991).

Table 3.2 Regulations Pertaining to Hatchery and Shrimp Farming Operations

- Shrimp farms and hatcheries must be registered with the Department of Fisheries
- Shrimp farms greater than 8 ha must be equipped with wastewater treatment or sedimentation pond(s) of not less than 10% of the rearing pond area
- For existing ponds, the retention pond should be completed before registration
- The retention pond must be approved by the DOF before construction
- BOD of effluent water must be below 10 mg/L (ppm) and the Secchi disk transparency greater than 60 cm
- Shrimp farms are prohibited to release saline water into freshwater bodies or discharge of mud, silt or sediment onto public land or into natural water sources

Other related laws that affect shrimp aquaculture include the following:
- Thai Waters Navigation Act (controls activities in coastal and inland waters)
- Irrigation Act (coordinates water allocation)
- Drug Act, Animal Feed Quality and Control Act, and Hazardous Substance Act (regulates drug and chemical use on shrimp farms)

Shrimp farming has proven particularly difficult to regulate because of the industry's rapid expansion and the low level of regulatory compliance by large numbers of small producers. National efforts to restrict the total area of shrimp farming to 80,000 ha have not been ineffective (Plodprasop, 1997). The fact that the Thai constitution strongly delineates on the rights of Thai citizens to conduct or engage in occupations of their choice has hindered the implementation of effective land management practices, and in the case of shrimp farming, may have encouraged coastal mangrove destruction. Although mangrove protection was improved by changes to legislation such as the *Forestry Act* and various cabinet resolutions, the realization amongst farmers that mangroves were not ideal sites for shrimp ponds was probably more significant in reducing aquaculture-related damage.

Government officials are responsible for defining and enforcing regulations regarding land use. Until recently, the policy of local land departments, notably the Royal Forestry Department, however, seemed to be one of laissez-faire, permitting a wide array of private concessions, such as rubber plantations and shrimp farms (Noikorn, 2000). The continued progression of shrimp aquaculture into common property coastal areas, however, has spurred the development of legislation and management efforts to protect mangrove ecosystems from shrimp aquaculture development (MIDAS, 1995). Internal conflict between ministries, namely between the Fisheries and Forestry Departments, has occurred over the use of "degraded" mangrove habitats for shrimp farming. In 2001, the DOF asked the Royal Forestry Department to release as much as 48,000 ha of "degraded" mangrove forest areas from reforestation plans (Samabuddhi, 2001). Ironically, the Director General of the Royal Forestry Department receiving this request was responsible in the early days of shrimp farming development for the establishment of shrimp farming in mangrove areas.

Other legislation is likely to figure more prominently in the future regulation of the shrimp industry. For example, the *NEQA* allows the Ministry of Science, Technology and Environment to require environmental impact assessments (EIA) and establish specific wastewater standards for industrial activities. Also, the *NEQA* empowers provincial governors to set more stringent environmental standards than national regulations and polluters can be fined or forced to pay compensation. However, the *NEQA* has had a limited influence on shrimp farming to date because neither the EIA requirements nor the industrial wastewater standards currently apply to aquaculture.

In Thailand, the DOF assumes the contradictory roles of promoting and regulating shrimp aquaculture development. Regulation refers to the authority to plan, implement and enforce coastal zone activities. The regulation and management of shrimp farming has oftentimes been viewed to be in direct conflict with the role of promoting shrimp farming, especially during periods when shrimp farming is expected to boost Thailand's economy. Industry critics maintain that the contradictory role of the DOF undermines the credibility of this government agency to effectively regulate shrimp farming development.

3.5.2 Low-Salinity Shrimp Farming

In the early 1990's, the application of low-salinity shrimp farming techniques in freshwater areas found widespread appeal in Thailand. Shrimp farmers discovered that black tiger shrimp (a marine species) could be acclimatized to a low-salinity environment (Miller et al., 1999). This innovation in culture techniques opened up vast new areas of Thailand's extensively irrigated central plain to shrimp farming. Around 1994, an explosion of low-salinity culture occurred in the provinces around the Upper Gulf of

Thailand, as the successes of this type of shrimp culture became widely known. Rapid development was encouraged by the belief that marine shrimp farming in freshwater sites was devoid of the diseases that plagued coastal areas. Farmers discovered that the profits from shrimp farming – while the international price for shrimp was high and the farms suffered no disease losses – easily offset the costs associated with trucking saline water from the coast. These factors facilitated the spread of inland shrimp farming into freshwater agricultural areas that never experienced seasonal saline water intrusion. Farms obtained freshwater from the existing irrigation infrastructure, and purchased saline water from tanker truck operators. In a relatively short period of time, farms were established hundreds of kilometers from the coast in provinces such as Prachinburi, Suphanburi, Nakhon Pathom and Nakhon Nayok (Land Development Department, 1998).

In 1998, the expansion of inland shrimp farming into Thailand's irrigated rice growing areas was halted when the Thai government banned inland shrimp farming in all freshwater provinces on the basis of a recommendation from the National Environment Board (Srivalo, 1998b; Srivalo, 1998a). Subsequently, the governors in coastal provinces were instructed to designate land within these areas as freshwater (where shrimp farming would be banned) or brackish water (where shrimp farming could continue). Concurrently, a joint committee with representatives from the Departments of Land Development, Pollution Control Department, and the DOF considered the fate of inland shrimp farming in seasonally brackish areas such as the Bang Pakong River Basin. The Bang Pakong River Basin includes portions of Chachoengsao, Prachinburi, Chonburi, and Nakhon Nayok provinces. This committee submitted a report and recommendations to the government in January 2001. Although various debates over this type of shrimp culture are ongoing, the government decided to uphold their decision.

Despite the continuing ban on marine shrimp farming in freshwater provinces, concerns remain over the government's capacity to enforce the ban, the manner in which brackishwater and freshwater areas have been designated, and the possibility that the ban on inland shrimp farming could be relaxed (Flaherty et al., 2000). These concerns are reinforced by several factors. Shrimp export revenues continue to play an important role in the Thai economy, especially during periods of economic crisis. The government remains a staunch supporter of shrimp farming, and continues to encourage farmers to increase production to offset the global shortfall caused by disease outbreaks in Latin America (Flaherty et al., 2000). While there is some potential for increasing production through intensification of existing coastal farms, this strategy is accompanied by a higher risk of disease outbreaks and crop failure. Expected production increases will likely require additional pond area that will be supplied by a combination of new operators entering the industry or existing farmers expanding operations.

Considering that the future development prospects of marine shrimp farming in coastal areas are increasingly constrained (Dierberg and Kiattisimkul, 1996; Vandergeest et al., 1999a), there is likely to be renewed pressure for the expansion of shrimp farming into freshwater areas (Bangkok Post, 2000b). Evidence of expansion has already been documented in the central region and in other parts of Thailand. In the central region, for example, there has been significant “infilling” of vacant lands with low-salinity shrimp farming. In 2002, this development was observed by RADARSAT imagery taken of several study sites in the central region (Filion, 2003). Further, in Southern Thailand, there has been significant expansion of low-salinity shrimp farming around Songkhla Lake, especially in Pattalung and Songkhla provinces and to a lesser extent in Nakhon Si Thammarat (Tanavud et al., 2001; Vandergeest, 2001).

Despite the likelihood of the continued development of this activity, there is no information in the public domain regarding the key factors behind this innovation. The techniques employed by hatcheries and shrimp farmers have not been fully documented. Additionally, to date there has been very limited attention given to the potential long-term impacts resulting from the development of low-salinity shrimp culture in rice-growing communities. While intensive shrimp farming in freshwater environments represents a major new land and water management challenge, it also raises serious concerns over the disposal of pond effluents and the impact of saltwater intrusion on the surrounding agricultural activities in the central plain. Other concerns relate to the potential for community and self-regulation of shrimp farming, the environmental and social impacts of intensive shrimp culture in agricultural areas, and the human health effects that arise from siting ponds in areas that are proximate to chemical-intensive farming and heavy industries.

Policy and management practices for inland shrimp farming have yet to be developed. Baseline data and other documentation are required on the characteristics of the low-salinity shrimp farming households, and the techniques and practices that have been developed by rice farmers and other agriculturalists in rural areas. Empirical data, collected from inland shrimp farming operations, will potentially serve as starting points for the development of shrimp farming policy. Effective policy will assist in the development of better management practices.

3.6 Summary

Thailand is an industrializing country that has moved away from a traditional agrarian economy towards an export-oriented, service based economy. Thailand's development strategies have enabled this transformation by promoting export growth through agricultural diversification. The result is that Thailand's agri-food sector is now a key component of international trade. On one hand, the revenue from cash crop exports has generated much-needed foreign exchange. On the other hand, there have also been concomitant social, economic and environmental impacts. Thailand's focus on natural resource based development, while stimulating the establishment of agribusiness and other resource-based industries, has accelerated natural resource exploitation.

In the late 1980s, the shrimp culture industry flourished in Thailand's coastal areas as a result of policies promoting export diversification into marine shrimp cultivation. The rapid growth of this industry has been accompanied by increased concerns over the social, economic, and environmental impacts. Intensive shrimp farming has been characterized as a destructive pattern of natural resource exploitation. The government has also been criticized over its ability to effectively regulate this industry. The adoption of intensive low-salinity shrimp culture techniques in freshwater regions opens up vast new areas to shrimp culture development. This innovation also raises concerns over the local and/or regional social, economic, and environmental impacts, increasing the need for detailed information regarding the long-term impacts of intensive shrimp culture in Thailand's prime agricultural areas. The next chapter presents the research design adopted to investigate low-salinity shrimp farming.

CHAPTER 4

RESEARCH DESIGN

This chapter describes the research context and research methodology adopted for the study.

4.1 Research Context

The impact of natural resource-based nontraditional exports in tropical developing economies remains an issue of contentious debate. Much of this debate centers on the rapidly changing character of agriculture and the food industry in the light of recent re-organizations of the global economy. The movement to greater liberalization of trade in the global marketplace is bringing increased pressure for the restructuring of agriculture from traditional, low export value crops to capital intensive, high value crops. Over the past decade a considerable amount of research has focused around the issues of agro-food globalization and agro-food systems to help explain global agro-food restructuring, particularly, as it relates to the linkages between northern (developed world) consumption and southern (developing world) production.

An agro-food system comprises the set of activities and relationships that interact to determine what and how much, by what method and for whom, food is produced, processed, distributed and consumed (Fine, 1998). A primary characteristic of modern agro-food systems is the simultaneous industrialisation and globalisation of the food chain (Friedmann and McMichael, 1989). This has dramatically changed the relationships among, between, and within different agricultural production systems. Because of these changing circumstances, agro-food industries are increasingly in the forefront of important shifts in spatial, social, institutional, and technological organization of world agriculture (Watts, 1994).

In the early 1980s, the social bases and processes of agriculture and agro-food systems first began to shift in significant respects. Prompted by the breakdown of the Bretton Woods international monetary system, and by subsequent stages of liberalization of global movements of financial and industrial capital, the conditions for dismantling of the national food economy and for the globalization of agriculture and food have advanced in tandem (Friedmann and McMichael, 1989). Movement to greater liberalization of trade in the global marketplace brought increased continuing pressure for the restructuring of agriculture from traditional, low export value crops, to capital intensive, high value crops. As globalization spread, a new global process developed in foods: the globalization of foods grown in a variety of southern hemisphere locations (Mexico and Central America, South America, New Zealand, Australia, Southeast Asia, and South Africa) for markets primarily in the northern hemisphere. Much of the literature on globalization, including studies of the global reorganization of agriculture and food, has focused on agricultural commodities and their long-distance movement. Globalization has been a central theme in a number of commodity studies ranging from apples to shrimp, sugar (Mintz, 1985), tomatoes, and frozen meat (Roche, 1999), to name just a few. Many of the classical export commodities (coffee, tea, sugar, tobacco, cocoa and so on) have been displaced by so-called 'high-value foods', such as fruits and vegetables, poultry, dairy products, and seafood products (McMichael, 1994).

Modern industrial shrimp farming provides a classic example of the expansion of nontraditional exports and the restructuring of global agro-food systems. Since the early 1970s, cultured or farm-raised shrimp have been an important commodity in the global food trade market. Shrimp farming offered the potential for substantial economic returns for farmers. The development of intensive farming has also created multimillion-dollar export industries in many producer nations. The Thai shrimp industry typifies the industrialization model for aquaculture that is now being readily adopted by other shrimp producing nations. Revenues from shrimp exports also became an important element in economic recovery strategies. This transformation of aquaculture – from a local source of protein to a high value export system – is part of a development process based on economic growth tied to global markets.

Most agro-food studies to date have been macro-level investigations of how globalisation alters the production, exchange, and consumption of food (see, for example, McMichael, 1994; Friedmann, 1995; Goodman and Watts, 1997; McMichael, 1998). Winter (2003:48) summarizes the focus of these methods and states, "the study of food provision in recent decades has been dominated by approaches that, among other things, emphasize globalizing tendencies and the political economy of the global agro-food system." Winter also states (p. 49) "the key actors in this global agro-food system are seen as multinational food processing and retail capital and political advocates of free trade." Although few would deny the powerful influence of these global processes, considerable conceptual debate within the political economy field has erupted regarding the unevenness of local impacts (Fine, 1994b; Fine, 1994a; Friedmann, 1994; Murdoch, 1994). While local impacts have often been taken to be the direct expression of universal processes (Page, 1997), the study of agro-food systems has increasingly articulated both the local and global scales within the broad arch of world capitalism.

The focus on the global processes has diverted attention from the importance of locality: "The lack of analysis of the changing position of rural areas, and the people living and working within them," Marsden et al. contend, "has become more and more apparent with the recognition that rural change is deeply embedded within restructuring processes more generally" (Marsden et al., 1990:223). They continue (p. 224): "it is essential to develop the means to conduct programmes of empirical work that focus upon explaining the process of change as they are experienced at the local level." The upshot of this scholarly reaction against the perceived universalizing effects of globalization is that the importance of local studies has been reasserted. Moreover, as Rigg and Nattapoolwat (2001:87) suggest, some are interested in globalization not as a process of erasure but as one, which "opens up 'analytical' space for social agency and local diversity".

Previous studies of farm-raised shrimp, consist largely of commodity studies and commodity chain analysis (see, for example, Skladany and Harris, 1995; Uthoff, 1996; Goss et al., 2000). These studies, however, fail to give account of small-scale farmers as active or knowledgeable participants in social change. Also, they do not provide an adequate account of the complete institutional context in which the shrimp farmers are acting (Gronski, 1997). The approach taken by this research changes perspective to the local and addresses the key concerns that have arisen over the changing relationship between rural locales of production and the increasingly globalized markets they serve. This type of information can best be assessed when researchers "step down off their pedestals, and sit down listen and learn" (Chambers, 1983:12). The focus, then, is on definitions of the situation from the standpoint of insiders (Jorgenson, 1989). This research gives voice to local actors, illustrates the local embeddedness of institutions and social practices, and emphasizes the uneven, spatially differentiated impacts of globalization. Ultimately, the farmers are viewed as knowledgeable actors, as opposed to participants acting out a role in a larger structure in which agency is that larger structure. This approach considers that agrifood restructuring is affecting the social, economic, political and environmental conditions among shrimp producers and consumers at all levels of the agri-food chain.

Macro-level processes will continue to shape and create the opportunities for the expansion of shrimp farming. However, the institutional and technical arrangements of shrimp farming are more complex than what is currently acknowledged in globalisation literature. Macro-level studies need to be supplemented by considering the influences created at other scales, notably that of the producers at the farm- and farm-household-level. The macro- and local-level are considered two separate streams, rather than in some hierarchy. The challenge for the researcher is to grasp and untangle the complexities of context and significance of local knowledge and construct a system of analysis whereby theoretical generalizations can be drawn from everyday life.

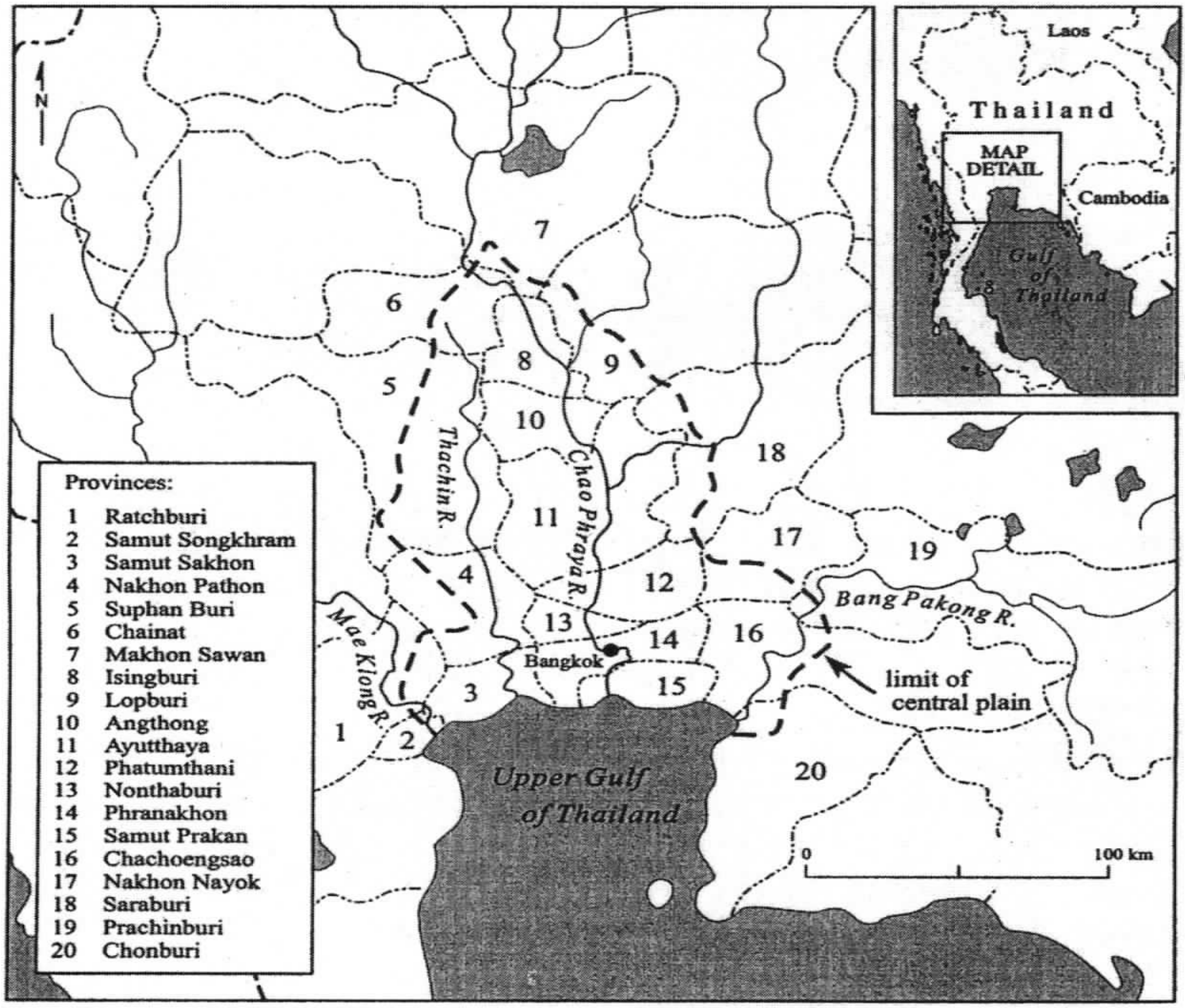
For this study, the perceptions and knowledge that exist in local society about the impacts of shrimp culture on rural communities are considered critical to developing an understanding of the dynamics of the process of globalisation. Emerging analyses of the developmental and environmental assumptions that underpin shrimp aquaculture development suggest the importance of tracing the consequences to the local level (Kelly, 1996). One useful approach in attempting to identify global impacts at the local level is to 'ground' research, that is, to connect global forces to events in specific locations. Such an approach has been well presented in books such as Bonanno et al.'s *From Columbus to ConAgra* (1994); McMichael's *The Global Restructuring of Agro-food Systems* (1994); Burch et al.'s *Globalization and Agri-food Restructuring* (1996); and more recently Kasimis' and Papadopoulos' *Local Responses to Global Integration* (1999) (Bonanno et al., 1994; McMichael, 1994; Burch et al., 1996; Kasimis and Papadopoulos, 1999).

This empirical research, situated in a rural community context, examines inland shrimp aquaculture practices at the producer scale so as to assess the contributions of the different actors at this level. There have been few analyses of new "nontraditional" natural resource-based exports such as farm-raised shrimp products from this perspective. In the case of shrimp farming in Thailand this perspective is particularly significant because Thailand's rise to global dominance in shrimp production has come about through the actions of thousands of small-scale farmers. The importance of garnering the local perspective is supported by a growing concensus that the regional social and environmental impacts of shrimp exports may not mirror the macroeconomic trends. Clarification of the nature and magnitude of regional impacts is important as leaders consider continuing subsidies and financial incentives to support the export-led development strategy. The research perspective of this study will improve our understanding of the local impacts of shrimp production from an emerging form of aquaculture that is now viewed as a driving force behind agrarian change in rural communities.

4.2 Study Area

Thailand's central plain is a lowland that is approximately 175 km wide and 450 km in length and extends southward from the northern ranges and valleys to the Gulf of Thailand (Figure 4.1). Comprised of the alluvial plain of the Chao Phraya River, its tributaries and the surrounding piedmont belt, the plain is well suited for agriculture due to its flat alluvial soils, which are fertile, easily worked, respond well to irrigation and fertilization. Often described as the "Rice Bowl of Asia", the central plain is the richest and most extensive rice-growing area in the country. The plain is located in a tropical Savannah climatic zone (Koppen, 1931). High temperatures throughout the year and a distinct dry season from November to April and a monsoon season from May to November characterize this climatic zone. During the rainy season, precipitation exceeds evapotranspiration resulting in a large water surplus. In the dry season, a substantial water deficit makes cultivation of most crops impossible unless irrigation is provided. The plain is extensively irrigated. The annual temperature throughout the year ranges from a low of 20°C to a high of 35°C, with a mean annual precipitation of 1,156 mm (Royal Irrigation Department, 2000).

Figure 4.1 Thailand's Central Plain



Credit – Ole Heggen, Department of Geography, University of Victoria, Victoria, BC

In addition to water intensive agriculture, the central plain is home to a growing number of low-salinity shrimp aquaculture ponds. Thailand's Land Development Department determined the distribution and culture area of inland shrimp ponds around the Upper Gulf of Thailand using LandSat data (Land Development Department, 1998). Ground survey teams verified the data by differentiating inland shrimp ponds from other types of culture ponds (i.e., fish and freshwater shrimp) and other water bodies. In 1998, the total area of inland shrimp ponds was estimated to be 22,455 ha in 23 provinces (Table 4.1). All of these shrimp ponds were located within the major river basins that drain through the central region to the Gulf of Thailand. The eastern side of the Upper Gulf, or Bang Pakong River Basin, contained the heaviest concentration of shrimp ponds, followed by the Bangkok region and the western side of the Upper Gulf in the Mae Khlong River Basin. The most northerly low-salinity shrimp ponds were located in the provinces of Nakhon Sawan and Uthai Thani. There are no recent assessments of the area of land dedicated to inland shrimp ponds.

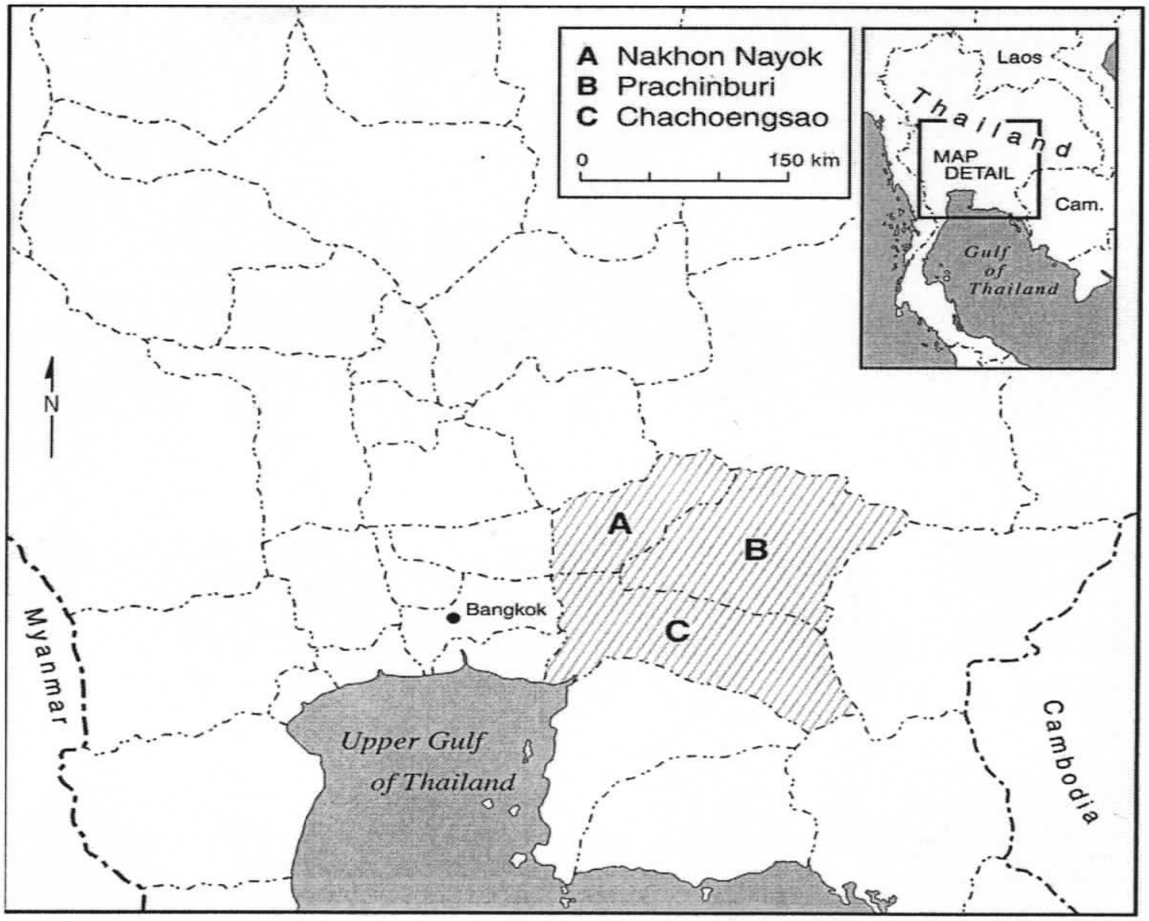
Table 4.1 Estimates of Low-Salinity Shrimp Farming Area in Thailand's Upper Gulf Region

Province/Region	Area (ha)	Province	Area (ha)
Eastern Region	16,335.1	Bangkok Region	3,250.7
Chachoengsao	8,375.4	Samut Sakhon	206.1
Prachinburi	4,577.3	Krung Thep	51.2
Nakhon Nayok	1,751.5	Nonthaburi	22.2
Chonburi	1,630.9	Nakhon Pathom	2,204.0
Lop Buri	48.0	Samut Prakan	518.4
Chai Nat	46.4	Pathum Thani	244.0
Northern Region	54.1	Samut Songkhram	4.8
Nakhon Sawan	44	Central Region	765.8
Uthai Thani	10.1	Ayutthaya	450.6
Western Region	2,049.2	Saraburi	15.5
Suphanburi	1,358.6	Sing Buri	12.5
Ratchaburi	349.8	Ang Thong	192.8
Phetchaburi	321.6	Lop Buri	48.0
Kanchanaburi	19.2	Chai Nat	46.4

Source: (Land Development Department, 1998)

While widespread awareness of low-salinity culture existed in rural communities, all that was known to researchers was that farmers were having success with this type of shrimp culture in the central region of Thailand. Local experts at Burapha University and anecdotal evidence from initial field observations assisted the researcher in determining that low-salinity shrimp farms were fast developing along the irrigation canals and rivers draining to the Gulf of Thailand. The original field research plan was to survey all of the provinces around the Upper Gulf of Thailand. However, the initial investigation of the central region in the spring of 1997 determined that the number and the spatial distribution of shrimp farms greatly exceeded previous assessments (see, for example, Tookwinas, 1997). The field research was then narrowed to a more manageable geographical area (Figure 4.2).

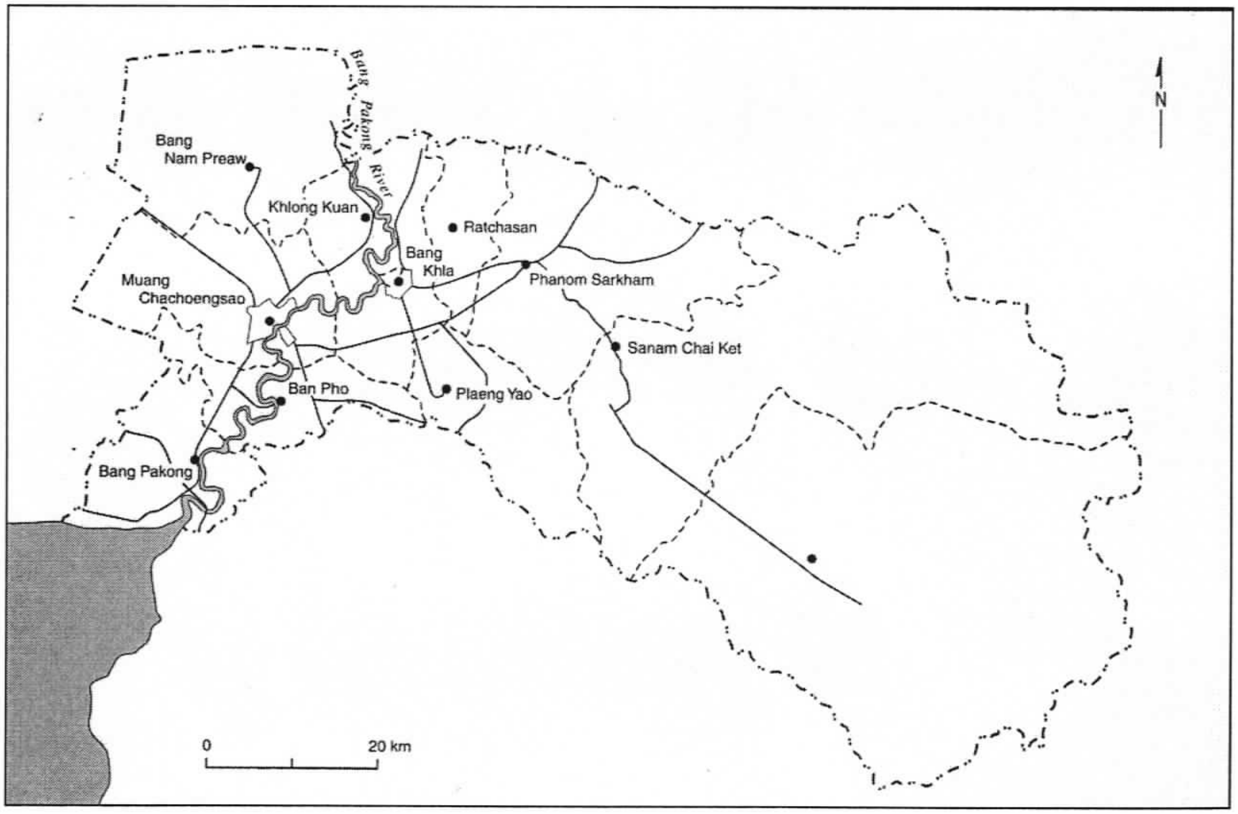
Figure 4.2 Inland Shrimp Farming Survey Area



Credit – Ole Heggen, Department of Geography, University of Victoria, Victoria, BC

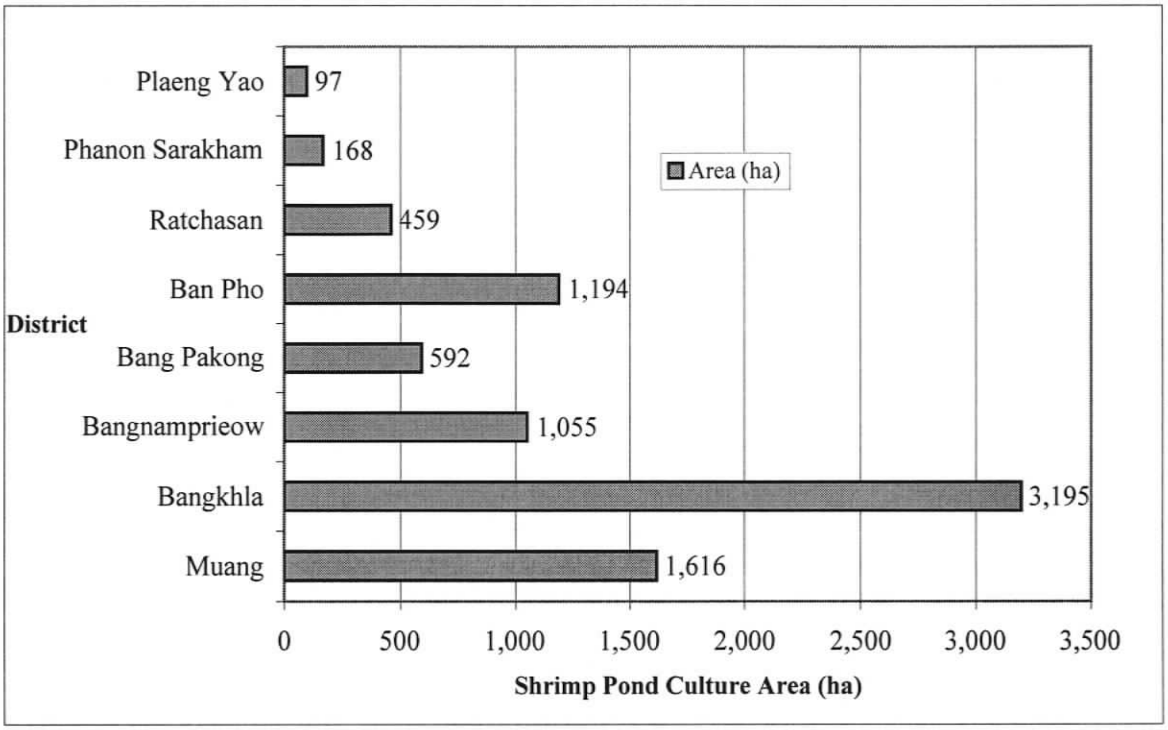
Low-salinity shrimp farms in the eastern region province of Chachoengsao were selected for the detailed field investigation (Figure 4.3). Chachoengsao province had experienced the most widespread development of inland shrimp farms of any province in Thailand. Chachoengsao was reported to contain 8,375 ha of inland shrimp ponds. The district-level estimates of the distribution of low-salinity shrimp ponds in Chachoengsao are depicted in Figure 4.4. This pond area represented almost 40% of the total culture area determined by the inventory completed by the Land Development Department. Chachoengsao is located 82 km from Bangkok. With a total population of 441,065 persons, the province occupies an area of 5,351 km^2 and has some 751 villages in nine districts (Alpha Research Co., 1999). Of the 80,441 households in Chachoengsao, 80% are farming households (Amyot, 1994). The exact number of households engaged in aquaculture has not been determined.

Figure 4.3 Chachoengsao Province, with Districts



Credit – Ole Heggen, Department of Geography, University of Victoria, Victoria, BC

Figure 4.4 Distribution of Low-Salinity Shrimp Ponds in Chachoengsao Province



Source: (Land Development Department, 1998)

4.3 Methodology

The methodology consisted of secondary data review, farm, and key informant surveys utilizing semi-structured interviews, informal interviews and discussions, and statistical description and analysis. The analysis was supplemented with information garnered from farm-level observations, as well as discussions and correspondence with government officials, NGOs, and other scholars in the region. The University of Victoria's Human Subjects Review Committee approved the research work completed in Thailand. The 1997 and 1998 fieldwork was approved under a project funded by the Social Science and Humanities Research Council. In 2004, the field research was approved through a separate application submitted by the researcher.

The research was completed in Thailand during four separate field investigations totaling ten months over an eight-year period (see, Table 4.2). During 1997, 1998 and

2004, 200 semi-structured interviews were completed with shrimp farmers (136), local political leaders (17), and non-shrimp crop farmers (47). Additionally, 25 informal discussions were completed with personnel working in activities associated with shrimp farming (for example, hatcheries and feed suppliers).

Table 4.2 Field Research Survey Summary

Respondent	Survey Period	Number of Surveys
Shrimp Farmer	Spring 1997	50
	Fall 1998	36
	Spring 2004	50
		Sub-Total = 136
Rice Farmer	Fall 1997	26
	Fall 1998	21
		Sub-Total = 47
Key Informant	Fall 1997	7
	Fall 1998	10
		Sub-Total = 17
		Total = 200

4.3.1 Farm Surveys

Farm surveys were the primary data collection method used in the field investigations. This method was particularly appropriate, as farm-level operations like shrimp harvesting or pond water stocking tend to occur infrequently, and randomly in time. The survey method also provides one of the few techniques available for the study of attitudes, values, beliefs, and motives of respondents (Bailey, 1987). Survey analysis offers a high degree of data structuredness and collection efficiency. Structured surveys generate high amounts of data standardization and the data gathered in semi-structured interviews are amenable to statistical analysis (Galtung, 1967).

The rationale for selecting the farm survey research strategy was the lack of baseline data on farm characteristics, and information about the experience and operating practices of low-salinity shrimp farmers. The questionnaire allowed the researcher to learn what the respondents know (facts); what they think, expect, feel, or prefer (beliefs and attitudes), as well as what they have done (behaviors). An attempt was made to formulate questions that would accurately communicate the above noted information between the researcher and the respondent. Data credibility were based on the assumption that the respondents were knowledgeable about shrimp farming and not inclined to distort answers because of personal biases. The shrimp farm survey data were recorded on a researcher-administered questionnaire (see, Appendix 1).

Low-salinity shrimp farms were selected using a systematic sampling procedure. Simple random sampling was precluded because local government authorities did not possess official records of the number and location of shrimp farms, let alone names and addresses of the farming operations. Chachoengsao rural areas contain a mix of farming operations of all types. Kish (1965:172) notes, "If the working universe units are thoroughly mixed or shuffled, systematic sampling would be equivalent to simple random sampling". Given a randomly selected starting point, systematic sampling was a practical approximation of the random sampling procedure.

Systematic sampling is commonly used in agriculture and forestry studies where the population is explicitly ordered in some way and then every kth unit is selected (Moser, 1958). For this research, the requisite assumptions were that low-salinity shrimp and rice farms appeared in random order and there would be sufficient numbers of farms over the course of the field investigation to complete the sampling. Whereas preliminary field investigations validated these assumptions, there was the chance of hitting a cycle: unusual properties associated with similarly numbered units. To avoid hitting a cycle, the sampling frame was divided into provincial village jurisdictions by district (Amphoe). For each field visit, the researcher initiated different random starts within the villages of each Amphoe, and every 10th case thereafter was surveyed. Whenever the researcher encountered a farmer who did not want to be surveyed, or a farm where the operator was not present, the next adjacent farm was selected and so on if necessary.

Low-salinity shrimp farms were easily located once in the field. Most farms were accessible by road and adjacent to fresh water sources – e.g. irrigation canals or the Bang Pakong River because of the need for water exchange. Prior to the field investigations, little or no information existed in the public domain regarding the location and extent of low-salinity shrimp farms, let alone farm and operator characteristics or farm-level management.

During the 1997 and 1998 field seasons, a total of 86 shrimp farms were selected from among eight districts (Amphoe) in Chachoengsao province. Table 4.3 presents the shrimp farming regions sampled during the 1997 and 1998 field seasons. To differentiate the sample by seasons, 50 shrimp farms were surveyed during the dry season (March to May 1997) and 36 shrimp farms were surveyed during the rainy season (September to December 1998). The farms contained 395 shrimp ponds and had a total culture area of 295 hectares. In 1998, the total area under low-salinity shrimp culture in Chachoengsao was estimated at 8,375 hectares (Land Development Department, 1998). Thus, the 1997 to 1998 sample represented approximately 3.5% of the total estimated shrimp culture area in Chachoengsao. Table 4.4 presents the shrimp farming regions sampled during the 2004 field season. The 50 shrimp farm surveys were completed during the transition period from the dry season to the rainy season. The farms contained 235 shrimp ponds and had a total culture area of 106 hectares. The sample area represented a small percentage of the total estimated shrimp culture area.

Table 4.3 Sample Distribution of Shrimp Farm Surveys, 1997-1998

Province	District	No. Ponds	Culture Area (ha)	No. Farms	Share (%)
Chachoengsao	Muang	39	43.4	5	5.8
	Bangkhla	188	146.6	33	38.4
	Bangnamprieow	92	63.9	26	30.2
	Bang Pakong	3	1.3	1	1.2
	Ban Pho	15	3.2	4	4.7
	Ratchasan	9	11.5	4	4.7
	Khlong Kuan	35	20.6	8	9.3
Nakhon Nayok	Ong Karanak	2	0.6	1	1.2
Prachinburi	Ban Sang	12	4	4	4.7
		395	295.1	86	100

Owing to constraints of time and other resources available for the investigation, the field sites were visited only once. In 1997 and 1998, several shrimp farm surveys were conducted in the adjacent provinces of Nakhon Nayok and Prachinburi. Similarly, in 2004, shrimp farm surveys were conducted in the provinces of Prachinburi, Chonburi and Pathum Thani. These data allowed the researcher to contrast and compare these farms with the methods observed in Chachoengsao, so as to verify that the methods of low-salinity shrimp farming were not unique to Chachoengsao.

Table 4.4 Sample Distribution of Shrimp Farm Surveys, 2004

Province	District	No. Ponds	Culture Area (ha)	No. Farms	Share (%)
Chachoengsao	Muang	18	8.7	6	12.0
	Bangkhla	62	29.2	17	34.0
	Bangnamprieow	34	18	6	12.0
	Ban Pho	3	0.6	1	2.0
	Khlong Kuan	7	1.9	3	6.0
Prachinburi	Ban Sang	23	11	5	10.0
Chonburi	Boh Tong	49	20.5	6	12.0
	KA Ko Chan	8	4.8	1	2.0
Pathum Thani	Lam Luk Ka	31	11.4	5	10.0
		235	106.1	50	100

In 1998, the researcher conducted field visits to the eastern Upper Gulf region in the provinces of Ratchaburi, Nakhon Pathom, Phetchaburi, and Suphanburi. The field investigation documented an influx of shrimp farmers from other regions into Chachoengsao province, mostly from Suphanburi province, following the announcement of the government ban on marine shrimp farming in freshwater regions. As the ban was not being enforced in Chachoengsao, outsiders had moved in to lease land for shrimp farming. Although rapid and unchecked expansion of low-salinity shrimp farming had occurred since 1994, the field investigation could not determine the extent of new pond development following the government ban, nor include the area of fallow production ponds. It was observed, however, that even as shrimp ponds were being closed due to disease, new pond construction was underway.

Surveys were also conducted with non-shrimp crop farmers (for example, rice, vegetable, fish, and orchard farmers). Non-shrimp crop farm survey data were recorded on a researcher-administered questionnaire (see, Appendix 2). These respondents were representative of the group from which the majority of new entrants to low-salinity shrimp farming had emerged. If respondents had converted some portion of their land to shrimp farming (i.e. mixed farming operations with both shrimp and rice for example), they were surveyed as shrimp farmers. Forty-seven surveys were completed with non-shrimp crop farming households. Within the sample, 6 farms operated both rice farms and orchards, 30 farms were just rice farms and 10 farms were orchards, and one farm cultivated only vegetables. These farms tended to be located in close proximity to shrimp farms. The sample represented a small fraction of the agricultural farming operations in Chachoengsao province.

4.3.2 Key Informant Interviews

In 1997/1998, semi-structured interviews were conducted with key informants. Survey data were recorded on researcher-administered questionnaires (see, Appendix 3). Data from key informant interviews allowed the researcher to broaden the analysis of low-salinity shrimp farming. The respondents were local political leaders and government officials (for example, Phuyaiban-village leaders, Kamnan-heads of Tambon councils, Nai Amphoe-District Officers). Interview questions focused on the effects of shrimp farming and other economic developments in the region, and the attitudes and feelings of the interviewees concerning these developments.

In 2004, the researcher conducted informal interviews and discussions with several key informants. These included experienced shrimp farmers, hatchery operators, and Thai academics that were knowledgeable about the shrimp farming practices in Chachoengsao. The researcher also completed visits with senior personnel in government agencies that have examined low-salinity shrimp farming. These discussions proved to be extremely beneficial, as they allowed the researcher to gain a broader perspective on low-salinity shrimp culture – i.e., update earlier data collected during in 1997 and 1998 and compare these data with the new information collected in 2004. This comparison was informative given the time that had elapsed since the earlier study. The 1997/1998 field studies were during the time that low-salinity shrimp culture had recently emerged, while in 2004 low-salinity shrimp culture was well established.

Local political leaders play a crucial role in mediating the changing agricultural structure of Thai villages (see, for example, Moerman, 1969; Keyes, 1970). Examination of low-salinity shrimp farming from the standpoint of these insiders was an important means of collecting first hand information, as livelihood activities such as shrimp farming are embedded in a structure of social relations. The data were based on the personal testimony of respondents who were well positioned to comment on the introduction, growth, and operation of low-salinity shrimp farming, as well as its varied impacts on the environment and rural communities.

Key informants and respondents for informal discussions were selected using the strategic informant sampling procedure (Smith, 1975), which assumes knowledge is unequally distributed (Conant et al., 1983). The selection of local political leader informants used two subtype procedures: "snowball sampling" where the researcher assembled a sample of key informants by asking initial informants to identify other potential respondents and expert choice sampling where the researcher solicited "experts" to choose "typical" individuals (Atkinson and Flint, 2001). These experts, however, often "hold differing views on the best way to choose representative specimens, or to decide which are the most representative" (Kish, 1965:179). The selection of the key informant sample was also assisted by the researchers' background experience in conducting shrimp aquaculture research in Thailand. The combination of all of the aforementioned efforts enabled the researcher to locate persons who were believed to be well informed or knowledgeable about the relationship between village-level social systems and low-salinity shrimp farming, or who was involved in activities linked to low-salinity shrimp farming.

Seventeen interviews with local political leaders were completed: 7 from September to October 1997 and 10 from September to December 1998. The major checks on the researcher's data quality in this type of sampling were the repetitiveness and consistency of the informants' observations. When the data formed a coherent whole, sampling ceased. This provided a good measure of the data quality and collection termination. In 2004, the researcher completed ten interviews with the key informants described above.

4.3.3 Informal Discussions

The 1997/1998 and 2004 field surveys were supplemented with informal interviews, discussions, and correspondence with researchers in several Thai universities. The researcher contacted individuals at Kasetsart and Chulalongkorn University in Bangkok, and Burapha University in Chonburi; as well, researchers at fisheries and aquaculture development centers; provincial and district government officials in the Department of Fisheries; officials in other government departments including Forestry and Irrigation; and members of non-governmental organizations (for example, YADFON Association). Discussions with individuals in the technical, financial, marketing and administrative aspects of shrimp farming added an important perspective. Notably, this group of respondents included feed and chemical sales agents; owners of hatcheries and nurseries; shrimp processors; middlemen shrimp purchasers; salt-water brokers; and personnel in large shrimp farming corporations (e.g., Charoen Prokphand). Among the latter respondents, feed and chemical sales agents were considered as the most reliable source of information on the latest trends in low-salinity marine shrimp farming because of their direct business association with the shrimp farmers. They were the group of respondents that had the most frequent contact with low-salinity shrimp farmers and were apprised of the latest developments.

4.4 Questionnaire Design

The development of the questionnaire benefited from the researcher's familiarity with the mechanics of shrimp farming and previous field experience with administering farm surveys in Thailand. Prior to administration, the survey instrument was discussed with other aquaculture experts in the region (i.e., Burapha University and the Network of Aquaculture Centres in Asia Pacific). Feedback from these discussions was incorporated into the questionnaire. Question wording is an important issue in survey research. Following the generally accepted format, the questionnaires were constructed so that they began with general questions, which helped to put the respondent at ease. They then "funneled down" to more specific questions.

Accurate translation of the questions was key to the success of the survey. For consistency, all of the surveys were translated by the same agency. The researcher relied upon several researchers at Burapha University to read the Thai version of the survey in order to determine if there were any problems in understanding the questions being asked.

The questionnaires contained a mix of closed-ended and open-ended questions. Closed-ended questions were used for the answer categories that were discrete, distinct, and relatively few in number. Open-ended questions were reserved for questions that could not be answered in simple categories and required more detail and discussion. For ease of comparison, as many of the questions as possible were designed to call for a "yes" or a "no" response. Additional questions of this nature were incorporated into the questionnaires used during the second and third field seasons. Whenever possible the information garnered from long answers was supplementary to "yes" or "no" questions. This design was similarly applied to the non-shrimp crop farmer and key respondent questionnaires.

The format of the survey remained largely unchanged throughout the field investigation to permit comparison over time. However, additional questions were incorporated during the 1998 field season to garner more detailed information about water use. In 2004, questions were added to examine the nature of the low-salinity shrimp farmers' species switch from the black tiger shrimp to white shrimp. New questions are identified in the survey document with a box around the text of the added question (see, Appendix 1).

In the non-shrimp farm survey several questions were added after the 1997 field season, which allowed for expanded options for occupation (i.e., mango and coconut orchards), and whether the farmer used family or hired labour. Also, the farmers were asked how many rice crops they could cultivate over a one year time period and if they had ever experienced any water shortages. The new questions are identified in the survey document with a box around the text of the added question (see, Appendix 2).

The key informant survey asked several general questions about the development of low-salinity shrimp farming in relation to the community, the environment and whether there had been any community conflicts over shrimp pond development and how these conflicts, if any, had been resolved. They were invited to comment on these aspects of low-salinity shrimp culture and to expand upon their answers. Many of the questions prompted lengthy responses, which the researcher recorded in a field journal. The format of the key informant survey remained unchanged throughout the field investigation, and no new questions were added (see, Appendix 3).

4.5 Field Investigation

The researcher hired a Thai assistant from Burapha University to organize the meeting locations and times with respondents. The assistant conducted the interviews in Thai, using the standardized set of questions and response frameworks. The assistant recorded the responses directly on the questionnaire while the researcher made notes on farm operations. Open-ended responses were later translated into English prior to the post-coding. Although the Thai assistant facilitated most of the discussions, as familiarity with the subject material increased, the researcher undertook to ask some basic questions in Thai. The same field assistant was used for the 1997 to 1998 fieldwork. In 2004, the researcher hired a different field assistant who was an experienced low-salinity shrimp farmer and former student of the Department of Aquatic Sciences at Burapha University in Chonburi. This assistant was a extremely helpful in the success of the 2004 field study because he knew where the farms were.

All questionnaires were administered directly adjacent to the shrimp ponds, rice paddies or at the village leaders household. Most farmers were busy working when first approached and only willing to complete the questionnaire if it was expedient. The initial shrimp farm survey could be completed within 45 minutes to one hour. This was recognized as a problem and rectified prior to commencing the second and third field seasons. During 1998, the shrimp farm survey could be administered in less than 30 minutes including time for discussion of farmer-initiated questions. Surveys of rice farmers, vegetable farmers and orchardists were completed within 20 minutes. The village leader or key informant surveys were usually completed in 10 minutes. Figure 4.5 depicts the typical setting for most of the field interviews.

Figure 4.5 Typical Interview Setting

Photo Credit - Paul Miller, Chachoengsao Province, Thailand, September 1998

Prior to the interviews, the assistant would explain the reason for the survey and explain to the respondents that they were under no obligation to answer all of the questions, and could withdraw from the interview at any time. To ensure confidentiality, no names were recorded. During the interviews, efforts were made to maintain a casual atmosphere, believing the more relaxed the respondents were, the more accurate the information would be. Only one respondent broke off the interview to attend to some shrimp farming work.

The research team would only enter a shrimp farmers' property after the assistant obtained permission to conduct an interview and produced identification from Burapha University. This was also the case for the non-shrimp farm and key informant surveys. As the survey progressed, it became apparent that it was important to inform the respondents that the researchers were not from the Department of Fisheries (DOF) in order to put them at ease. Several shrimp farmers were initially unwilling to answer questions and feared that the authorities, especially the DOF, would use the information to regulate their activities. Distrust of the DOF permeated most of the interviews. Some shrimp farmers preferred to operate anonymously and did not want to see the widespread dissemination of information regarding inland shrimp farming. Since none of the farms in the study area had registered with the government agencies (i.e., DOF), there are no official records of the number of farms at the provincial fisheries offices. According to shrimp farmers, this approach assisted them in avoiding the scrutiny of government fisheries officials and regulatory agencies.

The national ban on low-salinity shrimp farming in freshwater provinces had some repercussions for the field investigation. Low-salinity shrimp farming was a less sensitive issue prior to the ban. Surveys completed in the spring of 1997 were 'pre-ban' and subsequent surveys were 'post-ban'. During the spring of 1997, shrimp farmers were willing to provide detailed information. In the fall of 1997, interviews targeted rice and vegetable farmers in areas adjacent to shrimp farms in order to capture their attitudes towards low-salinity shrimp culture. In the fall of 1998, the third set of interviews targeted shrimp farmers affected by the ban. The ban had a noticeable impact on the willingness of people to participate in the study. Rice farmers previously reluctant to speak against shrimp farming regarded the government's decision to ban inland shrimp farming as a signal that it was okay to speak openly about low-salinity shrimp farming. As for the shrimp farmers, they were anxious to provide information about their operations in order to dispel rumors about the environmental impacts that they had seen reported in the press.

Overall, collecting information from local villagers went well. In a few instances, however, some villagers declined being surveyed. This occurred in areas where the village leaders operated shrimp farms. Larger shrimp farms tended to make more refusals than smaller operations. The reason for this was at the larger farms the first contact was often with hired pond labourers unable or unwilling to speak of the operation whereas the smaller farms were owner-operated.

4.6 Data Preparation

After the information was recorded in the field, a numerical code was assigned to each answer category. Pre-coding of responses to the open-ended questions was impractical. Respondents determined the answer categories since the researcher could not predict the categories in advance, or how many categories would exist for a particular question. This required that the researcher to read all of the respondents' answers to each question. Whenever a new answer was encountered it was recorded, as was the frequency of each answer category. After the answer categories and their frequencies of occurrence were known, post-coding was straightforward. Post-coding offered the advantage of coding multiple answers to a single variable by writing different code number for each combination of answers given.

A codebook was compiled to define the meaning of the numerical codes. Non-responses were coded '99'. Several cases of non-responses were delineated: (1) where the respondent did not answer, didn't know, refused to answer, or the response was not translated (99a); (2) question was not applicable (99b); and (3) the researcher did not ask the question (99c). Code numbers chosen to indicate non-responses were numbers that could not occur as a legitimate response, that is, appear empirically.

For each survey, the interview schedules were examined to identify missing data, and ambiguous answers. Verifying and proofreading of the data file was undertaken to remove incorrect entries. The researcher then conducted contingency cleaning, that is, checked to see that only those cases that should have had data on a particular variable did in fact have such data. Contingency cleaning was undertaken for questions that were not answered by all respondents (i.e. whether or not a respondent was supposed to answer a question was in some cases contingent upon his/her answer to an earlier question). This entailed checking to see that such a question was actually answered only by those respondents whom qualified to answer by means of an earlier response. Open-ended questions eliciting verbatim comments or explanations were accumulated in a separate process to be presented in tabular form or summarized in the narrative as appropriate.

4.7 Summary

This chapter described the research context and research methodology used for the research. The following chapter reports the results of the field survey and discusses them in the context of previous studies on marine shrimp aquaculture.

CHAPTER 5

RESULTS

This chapter presents the insights this study gained into the development and adoption of the low-salinity shrimp farming innovation. It describes the technical operating practices observed in the hatcheries and at inland shrimp farming operations. It also presents a profile of inland shrimp farmers and describes their farm management procedures. This is supplemented by insights from interviews conducted with key informants, rice farmers and other agriculturists in the area.

5.1 Low-Salinity Innovation

Flaherty and Vandergeest (1998) published the first general paper on the development of low-salinity shrimp farming in Thailand. Various aspects of this activity have since been reported (Flaherty et al., 1999; Vandergeest et al., 1999a; Braaten and Flaherty, 2000; Flaherty et al., 2000). These reports, however, provide very general information on the nature and growth of low-salinity culture. They do not provide detailed insights into the low-salinity innovation either in terms of hatchery protocols or farm operations. Nor do they address the farmer characteristics or environmental problems. The following section provides a detailed technical description of the low-salinity shrimp farming innovation based on data collected in field surveys conducted between 1997 and 2004.

5.1.1 Hatchery Procedures

Hatchery procedures are key to the success of the low-salinity innovation. Prior to this field research, no information was available regarding whether or not hatchery operators had modified their techniques to produce post-larvae (PL) for low-salinity shrimp ponds let alone the nature of any modifications. One of the key objectives of the field investigation was to examine hatchery operations and to determine whether any new procedures had been developed to produce PL for low-salinity shrimp farms. Although some new hatcheries have been constructed close to inland growout sites, most of the PL destined for low-salinity farms are produced by coastal hatchery operations owing to the need for large volumes of seawater. The majority of the coastal hatchery operations servicing inland shrimp farms are located in Chonburi, Chachoengsao, Rayong and Phuket provinces.

Standard hatchery procedures for shrimp maturation are well established (see for example, Kungvankij et al., 1986; McVey, 1993). Technological advancements in the shrimp farming industry have been partly based on the development and refinement of hatchery techniques for PL production (Ching-Ming, 1993). Hatcheries have shown the most rapid growth of any ancillary economic activities related to shrimp farming. In Thailand, the hatchery industry infrastructure is dominated by small-scale operations. Thailand is reported to have 1,500 or more of these so called "backyard" hatcheries (Kongkeo, 1997). These "backyard" hatchery operations are a versatile network of small hatcheries containing maturation tanks, spawning tanks and larval rearing tanks (Figure 5.1).

Without exception, all inland shrimp farms depend on hatchery-produced larvae. In the central region provinces of Chonburi and Chachoengsao, an area with a high concentration of coastal hatcheries, many have targeted inland shrimp farms as a niche market. These hatcheries have developed specialized procedures to produce shrimp at the PL stage of development that are acclimatized to a low-salinity environment. Hatcheries are believed to be able to produce so-called "pathogen-free" PL which are reported to have a better growth and survival rates over wild fry (Marte, 2003). This information contradicts other studies which have reported that the use of hatchery-reared PL increases genetic uniformity and disease risk in comparison to the collection of wild larvae where natural selection has already favored the most viable individuals (Kautsky et al., 2000). Regardless, hatcheries are the only reliable source of PL to inland shrimp farms in Thailand. Hatchery-raised PL are all of the same age, are uniform in size and can be consistently produced in large quantities year round as long as broodstock spawners are available. Growers prefer the consistency of hatchery produced PL which results in predictable crops which are uniform in size.

Figure 5.1 Typical Backyard Hatchery in Chachoengsao Province

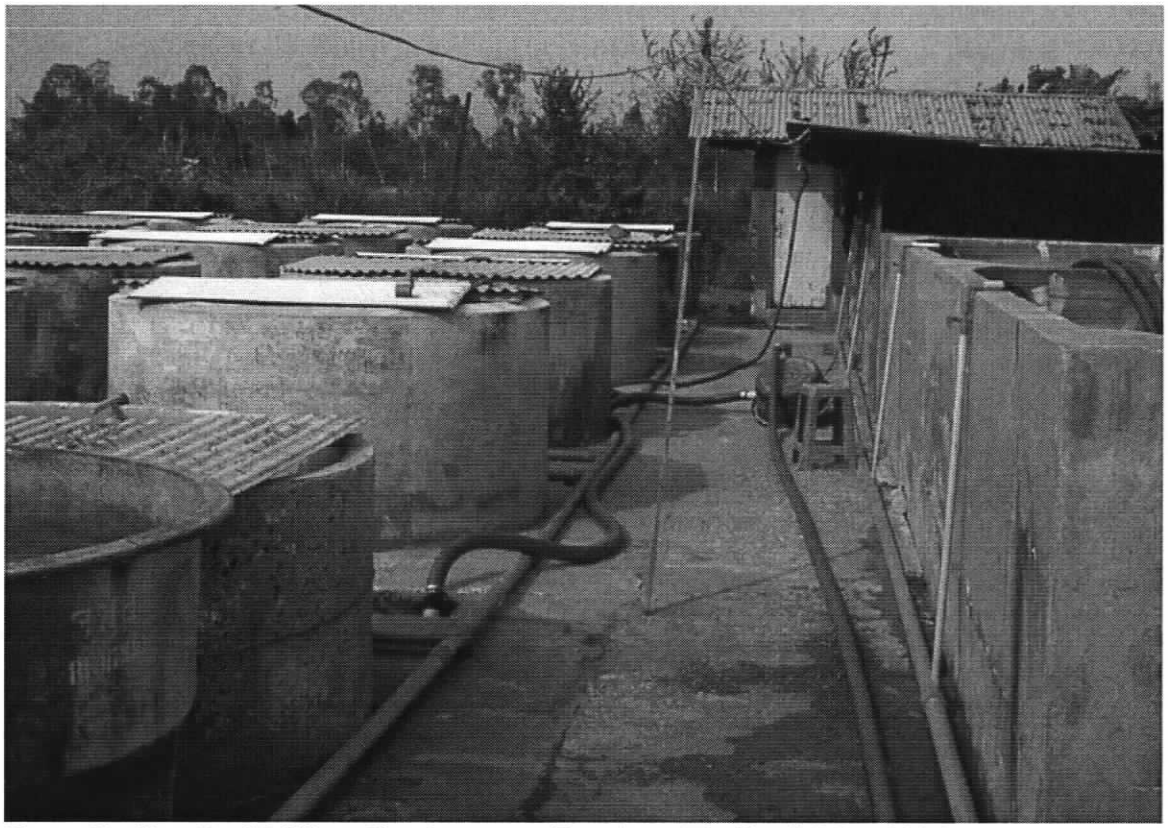


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 2004

The field studies in 1997/1998 and in 2004 found that most hatchery facilities have less than ten tons of tank capacity, and rely upon wild captured broodstock as spawners. Upon arrival in the hatchery, the broodstock are acclimatized in large aerated seawater holding tanks for a period of 4 to 7 days. The broodstock are fed daily with a fresh diet of squid, mussel or cockle meat or pellet feed at a rate of 10% of the total biomass. Water in the holding tank is allowed to flow through continuously or is changed daily at 60 to 70% of total capacity. Once the broodstock have recovered from transport stress, molting is induced by decreasing the water salinity in the holding tank by about 4 to 5 ppt over a period of two days and then increasing back to normal seawater salinity. Adult shrimp mate after the females have molted. Spawning is induced by manipulation of the endocrine system. For this procedure, the females are eyestalk ablated around 2 to 3 days after molting or when their shell is completely hardened. The shrimp mature around two to three weeks after eyestalk ablation, the average interval between the eyestalk ablation and the first spawning being 18 days (Chen, 1979). Spawning activity has been observed in the hatchery between 0200 and 0300 hours at water temperature and salinity ranging from 25 to 30 °C and 28 to 32 ppt, respectively (McVey, 1993).

Female spawners are removed from the tank the morning after spawning and the eggs are collected, counted, and cleaned before being placed back into the tank with clean seawater. Eggs usually hatch within 12 to 18 hours after fertilization at temperature and salinity ranges of 26 to 30 °C and 30 to 33 ppt, respectively (McVey, 1993). Nauplii density is estimated by water sampling one day after hatching. The method for estimating the hatching rate takes into account the total number of nauplii and the egg count. The nauplii are then transferred to the larval rearing tank. At this point, some larger hatcheries prefer to sell nauplii to smaller hatcheries that will then produce the PL for inland shrimp ponds. Regardless, hatchery operators then bring black tiger larvae through various developmental stages including 6 nauplius stages, 3 protozoea stages, and 3 mysis stages and then after 10 to 12 days, they metamorphose into PL (Bose et al., 1991). Figure 5.2 shows some hatchery produced PL.

For coastal shrimp farming operations, the PL are produced and delivered in full strength seawater. The 1997/1998 field studies found that to successfully rear shrimp in low-salinity water, however, the PL must be transferred from high-salinity larval rearing systems to low-salinity growout conditions. Specialized procedures developed for inland shrimp farms are needed to gradually acclimatize the PL to a lower salinity. Once at the PL stage of development, the PL of the black tiger shrimp, are acclimatized and prepared for farm delivery in the hatchery.

The species of shrimp PL produced in the hatcheries at any given time caters to the demands of the shrimp farmers. Up until 2002, without exception, the crustacean species utilized in low-salinity shrimp farming was the black tiger shrimp. The suitability of the black tiger to intensive culture is well-documented (Chen et al., 1989). They have a fast growth rate (Chiang and Liao, 1985; Liao and Murai, 1986), low protein requirements compared to other carnivorous shrimp (Lee, 1971; Deshimaru and Yone, 1978), and possess a high tolerance to stressful culture practices. The key species characteristic for low-salinity shrimp culture is the fact that the black tiger shrimp is euryhaline and can be successfully cultivated in a wide range of salinities and temperatures.

Figure 5.2 Hatchery Post-Larvae

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 2004

The recommended salinity range for black tiger shrimp cultivation is 15 to 30 ppt (Kungvankij, 1984). In coastal shrimp ponds, salinity levels typically range between 10 to 30 ppt, with most operations using full strength seawater (Kongkeo, 1995). In Thailand, black tiger shrimp production has previously been reported in salinities ranging from 0 to 40 ppt (Department of Fisheries, 1995). They are effective osmoregulators and can adapt to changing salinity conditions. Physiological research on the black tiger shrimp partially explains that salinity has no measurable effect on their osmoregulatory process within the range from 5 to 45 ppt (Liao and Murai, 1986). Although the black tiger shrimp's ability to physiologically adapt is not well understood, it appears that rapid salinity change is the cause of high mortality (Tseng, 1987). Low-salinity shrimp farmers have capitalized on this aspect by initiating the growout in low-salinity and only making small incremental salinity adjustments. Farmers widely acknowledged that this is key to the survival of the black tiger shrimp in a low-salinity environment.

The common hatchery features and operator protocols, based on interviews at ten hatcheries in 1997/1998 and five hatcheries in 2004, are as follows. Water temperature and salinity are the most important parameters. Temperature influences PL physiology, mainly metabolism, and salinity affects osmoregulation. Since the black tiger shrimp are able to live in seawater as well as brackishwater the salt concentration in their body fluid is able to change in response to variations in salinity. The ability to make this physiological adaptation is critically important when the fry are transferred from the larval rearing tank to the fry-rearing tank. Operators indicated that high PL mortality would occur during this transfer if the temperature and salinity differences were excessive. The method used to lower the salinity is simple: decrease the water in the fry-rearing tank, and replace it with clean freshwater. The water level is lowered by 5 to 10 cm, and then brought up to the previous level by adding freshwater that is stored onsite. This procedure is repeated daily until the tank salinity matches the pond salinity that the PL will be delivered to. Over a one-week period, hatchery operators can take PL accustomed to 25-ppt water and acclimatize them in 5-ppt steps to water at 5 ppt.

PL are delivered to growout ponds when they are anywhere from 10 to 21 days old and are acclimatized to the future growout pond salinity. Black tiger PL are usually delivered at 15 days old. Hatchery operators maintain communication with farm operators. Each batch of PL is usually custom generated for preestablished clients.

Hatchery operators employ several methods to deliver PL to the shrimp farms. Some use tanks made of plastic, fiberglass or canvas that can be stocked with densities of around 500 to 1,000 PL per liter with aeration. Floating ice wrapped in plastic bags is used to reduce the water temperature. This method can be used to transport PL for up to 10 hours without significant mortality. The most popular delivery method to inland shrimp farms is to place the PL in plastic bags filled with oxygenated water. The plastic bag is first filled with 6 to 8 liters of water at the salinity the PL have been acclimatized to and then packed with around 3,000 to 5,000 PL. Some hatcheries include a small amount of brine shrimp eggs for food, as it is reported to increase survival by at least 10% (McVey, 1993). Density is reduced if the expected transport time is longer. After the bags are sealed, they are placed in Styrofoam boxes or plastic buckets. The water temperature is reduced to about 22 to 25°C by crushed ice mixed with sawdust on the bottom, side and top of the Styrofoam box. Under these conditions, the fry can be kept alive for more than 12 hours during transportation. This delivery method is more than adequate to deliver the PL from the hatcheries to the inland growout ponds. Delivery procedures are designed to minimize the stress on the PL in order to maintain the survival rate in the growout ponds.

In the province of Chachoengsao, many of the hatcheries previously supported the freshwater shrimp industry (i.e., the species *Macrobrachium rosenbergii*). As interest in the black tiger shrimp increased, the DOF facilitated hatchery conversion to marine shrimp. With this extensive hatchery experience and infrastructure in place, the switch to low-salinity culture gave Chachoengsao hatcheries an early advantage in catering to inland shrimp farmers. A typical hatchery produces around 3,000,000 PL per month. In 1998, the farm survey found that fifteen-day-old black tiger PL usually sold for around $CAD 3.20 to $CAD 3.60 (i.e., 80 to 90 Baht) per 1,000 PL. In 2004, farmers paid around $CAD 6.00 per 1,000 PL of the same age. However, PL prices fluctuate. When broodstock sources are in short supply the price of PL increases.

During the first field investigation in 1997, hatcheries focused exclusively on producing an indigenous shrimp species, the black tiger (*Penaeus monodon*). In 2004, it was discovered that many inland shrimp farms had started culturing an exotic (imported) shrimp species, notably the Pacific white shrimp (*Penaeus vannamei*). The reasons given by the farmers for the change in species cultured are discussed in Section 5.2.2. The transition to white shrimp culture has been particularly rapid because the hatchery procedures developed for the black tiger shrimp are easily applied to the white shrimp without a significant increase in cost or increase in mortality rates. In 2004, however, the farm survey found that one thousand 11-day old white shrimp PL cost around $CAD 8.00 (i.e., 200 Baht). They are more expensive than black tiger PL because the broodstock must be imported from sources outside of Thailand.

Hatchery operations depend upon a source of high quality water. In 2001, regional assessments determined that there is low dissolved oxygen and high BOD levels along many portions of the Bang Pakong River (Szuster and Flaherty, 2002). The Bang Pakong River receives large pollution loads from the industrial, domestic and agricultural sectors. These activities have added large quantities of organic wastes to the river and severely diminished the water quality. In addition to saline water quality, many of the hatchery operators indicate that they are limited by the availability and quality of freshwater and have to purchase freshwater used in the PL acclimatization process from other regions in the province. Many hatcheries concentrated along the Bang Pakong River have closed due to declining saline water quality.

Hatchery facilities are engineered to achieve a high degree of water exchange. Unlike earthen ponds where a major part of the wastes and chemicals are trapped, many of the wastes generated in hatchery systems are discharged with effluent waters through the outlet channels, which usually open into nearby drainage systems or rivers. Operators are not concerned with the potential environmental impacts of their waste discharge streams. In the 1997/1998 and 2004 field studies, none of the hatcheries had facilities for monitoring chemical composition of their discharges. There are no published data on the waste loads produced by shrimp hatcheries.

Hatchery procedures for the black tiger shrimp and the white shrimp differ primarily in the source of broodstock (Table 5.1). In Thailand, black tiger broodstock are available locally from either the Andaman Sea or the Gulf of Thailand. The availability of this wild non-domesticated source is often limited. White shrimp broodstock, however, must be imported into Thailand from various countries including the USA (Hawaii, California, Florida), Ecuador and Taiwan. In 2004, the price for one piece was reported to be as high as $CAD 400 (i.e., 10,000 Baht) for broodstock imported from California. Unlike black tiger broodstock, which can only be used to produce viable PL three times, white shrimp broodstock can be pond reared and used many times. Pond rearing closes the life cycle for white shrimp and allows hatchery operators to produce future broodstock within ponds where the environment can be closely monitored. This is a distinct advantage as it permits domestication and genetic selection for favourable traits, eliminating the problems associated with wild broodstock. Thus, for white shrimp Specific Pathogen Free (SPF) and Specific Pathogen Resistant (SPR) lines are already available. However, the SPF animals can sometimes have a high mortality in disease-laden environments. Apart from the initially high purchase price, white shrimp broodstock eventually yield a cheap source of broodstock from ponds. They are also smaller sized broodstock, which means faster generation times.

Table 5.1 Comparison of the Hatchery Procedures for the Black Tiger and the White Shrimp

Hatchery Infrastructure	• Black tiger and white shrimp hatcheries use similar facilities. • No infrastructure change is needed to switch PL production from one species to another.
Broodstock Source	• Black tiger broodstock are captured in the wild. Availability from natural sources (i.e., ocean caught) is often limited. • White shrimp broodstock are mostly imported from the USA. • Pond-reared white shrimp broodstock are available.
Broodstock Price	• White shrimp broodstock are expensive compared to black tiger. • Broodstock can be reused many times. • Pond reared white shrimp broodstock produce less expensive PL for the farmers.
Larval Rearing	• Higher survival rates in hatchery of 50-60% of white shrimp compared to black tiger shrimp (20-30%).
Acclimatization	• Once at the PL stage – similar acclimatization as the black tiger.
PL Delivery	• Same procedures employed for both species.

Healthy broodstock that are not carriers of serious pathogens must be selected to achieve successful hatchery production. In Thailand, permission is needed from the government prior to importing SPF shrimp stocks. Importers are required to apply to the Director General of the Department of Fisheries in Bangkok. Thailand is one of the first shrimp producing countries to have a licensing process for the importation of shrimp broodstock (Department of Fisheries, 2004). Thai companies that import shrimp are also required to have a license. Until about three years ago, Thailand produced only the black tiger shrimp. The majority of broodstock supplies were non-domesticated or wild supplies that were captured locally. The reliance upon these local supplies reduced the need for imported broodstock.

The recent move to importing domesticated white shrimp broodstock is the result of increasing disease in wild black tiger shrimp. In 2004, the Thai government forecast that between 80 to 90 percent of its production would be derived from white shrimp (Pacific Business News, 2004). The shift to white shrimp has substantially increased the need for imported broodstock. To meet the current demand for white shrimp broodstock, government sources have estimated that Thailand will need between 200,000 to 250,000 male/female pairs per year. In early 2003, the Department of Fisheries banned imported white shrimp broodstock to prevent the spread of diseases. In June 2004, however, the government ban on broodstock importation was rescinded, clearing the way for the expansion of white shrimp culture. Government agencies also planned to import breeders to produce post-larvae for farmers (MCOT, 2004). Nine hatcheries were permitted to buy 35,000 pairs per year to meet the farmers' needs, substantially less than what was needed. However, the shortfall in government imported supplies prompted many local companies including Charoen Prokphand Foods to independently import broodstock in order to carry out research and to produce their own PL (Bangkok Post, 2003b).

Thailand and many other governments have allowed the importation of certified disease free white shrimp broodstock from the USA (USMSFP, 2004). The perceived benefits including superior disease resistance and higher growth rates has led to the widespread introduction of white shrimp in Thailand, primarily by commercial farmers. However, the USA is not the only supplier of broodstock. Broodstock that is not guaranteed to be pathogen free is also available. Farmers often buy from these sources because they are less expensive. This practice is believed to have been responsible for the introduction of viral pathogens into Thailand, notably the Taura Syndrome Virus from Latin America (Funge-Smith and Briggs, 2003). For such reasons, there has been caution on the part of many Asian governments (Department of Fisheries, 2004). However, this caution has not been demonstrated by the private sector, which has been bringing stocks of illegal and often disease carrying white shrimp into Asia from many locations, as well as moving infected stocks within Asia. The commercial success of these introductions, despite disease problems, has allowed the development of substantial culture industries for these alien Penaeids within Asia and in Thailand in particular.

In 2004, the field investigation determined that many of the newly established hatcheries are utilizing broodstock where the original sources of the stock and their current health were uncertain. Many of the hatcheries were not able to maintain their stocks as SPF. Invariably they are susceptible to infection from local virus diseases as well as diseases that are typical to the species when cultivated in South America. The 2004 field survey also found that the operators of private sector hatcheries are mostly unaware of the requirements for maintaining clean stocks. Operators are illegally importing, or smuggling in, sub-optimal broodstock, which in at least some cases is disease carrying. While it has proved difficult for researchers to fully document these practices, hatchery operators reported that they have found it easy to circumvent the broodstock importation requirements. In the 2004 field survey, one of the major complaints voiced by farmers was the poor quality of PL. This contrasts markedly with the 1997/1998 study results when the poor quality of PL was not a commonly reported problem. The emergence of problems with the quality of black tiger PL in 2000 coincided with the rise of white shrimp culture. Farmers switched production from the black tiger to the white shrimp as problems with black tiger PL increased. They could only speculate if they would have better success with white shrimp.

White shrimp PL production is increasing rapidly in Thailand. One report indicates that there are currently about 800 hatcheries and nurseries selling white shrimp PL (Bangkok Post, 2003b). Funge-Smith and Briggs (2003) indicate that in 2002 there were only 20 white shrimp maturation facilities and 26 white shrimp hatcheries. The latter report also indicates that there are around 2,000 "other" shrimp hatcheries. In 2004, the field investigation confirmed that it would be extremely difficult to determine the exact number of white shrimp hatchery operations as they switch from one species to another depending on demand. Regardless of the PL supply at any given time, white shrimp farmers, like black tiger shrimp farmers, report that growout success is linked to establishing a high quality supply of PL. In 2004, shrimp farmers were willing to pay a premium for white shrimp PL because they were perceived to be of higher quality than the black tiger PL. While PL quality is an issue with both species, farmers believed that since white shrimp PL were produced from domesticated broodstock their chances of growout success would be higher with this species.

The procedures described in this section, with the exception of the 2004 information on white shrimp, have been summarized in Miller et al. (1999) and Flaherty et al. (2000).

5.1.2 Farm Procedures

The farm procedures unique to low-salinity shrimp farming had not been fully documented prior to the 1997/1998 field investigations. This section presents the results of the examination of the farm procedures developed for stocking the pond with saline water, acclimatization of the post-larvae, and freshwater addition during growout. The application of these techniques, developed and implemented largely through trial and error experimentation by the farmers themselves, facilitated the cultivation of marine shrimp in a low-salinity environment. With the exception of the age of the PL upon stocking in the growout ponds, the 1997/1998 and 2004 field investigations determined that similar farm procedures are applied to both the black tiger shrimp and the white shrimp. This adaptability of procedures to other euryhaline shrimp species is a major reason for the continued progression of low-salinity culture in freshwater areas.

Coastal shrimp farmers in Thailand typically fill their culture ponds with full strength seawater up to the depth that will be used for the duration of the growout. The PL from the hatchery are then released into the entire pond. This practice is not feasible for low-salinity shrimp ponds because of their location. Even with high international prices for shrimp it would be prohibitively expensive to stock inland shrimp ponds with seawater alone. Low-salinity shrimp farmers have developed a method that reduces the amount of saline water required for growout. Inland shrimp farmers prior to placing any water and/or PL into the culture ponds, construct an area that is hereafter referred to as the acclimatization pen, or simply the pen. Farmers build the pen by sectioning off an area from the rest of the growout pond with plastic PVC sheeting. The purpose of the pen is to create an area within which saline water and the PL can be offloaded. Figure 5.3 shows a typical acclimatization pen in a low-salinity shrimp pond. Over the course of the 1998 and 2004 field studies many variations on these structures were observed. Some farmers use relatively small pens that are around 10% of the culture pond area, while others use larger acclimatization pens that represent as much as 50% of the culture pond area. In the latter situation, farmers simply create an earthen bund using the pond soils to divide the pond into two equal parts. Most farmers, however, use smaller acclimatization pens in order to reduce the initial expense of saline water stocking. Once the acclimatization pen is built, and the pond soils are sufficiently dry and pre-treated with lime, the farmer places an order for the delivery of saline water for the acclimatization pen. Shrimp farmers would adjust the initial salinity level after delivery to suit their preferences by mixing bags of sea salt with freshwater.

Figure 5.3 Acclimatization Pen in a Low-Salinity Shrimp Pond

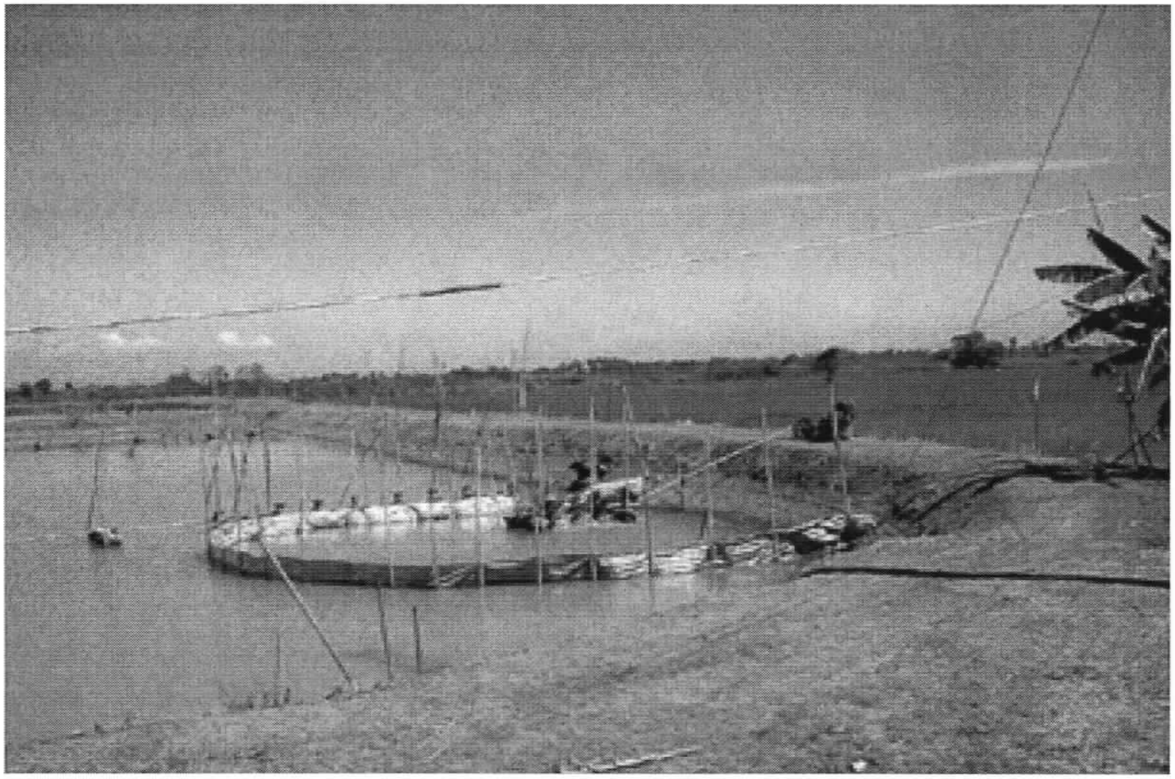


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 1998

Farmers fill the growout ponds with pre-treated clean freshwater to a depth of 30 to 80 cm before stocking saline water into the acclimatization pen. The availability of freshwater is, in some cases, limited by the quality and quantity of water that is available in the irrigation canals. Once the freshwater is in the pond at the desired depth, trucked in hypersaline water is offloaded into the acclimatization pen. For a typical low-salinity growout pond, farmers usually receive several truckloads so as to raise the salinity of the pen water to approximately 10-ppt. Although a salinity of 10-ppt is typical of the majority of inland shrimp ponds surveyed in 1997, some operators use a higher or lower salinity depending upon past experiences and personal preferences. It was also found that farmers with coastal shrimp farming backgrounds preferred to use higher initial salinities, while those with freshwater shrimp experience preferred lower salinities. In 1997, the median salinity level used in the acclimatization pen on the first day of growout is reported in Table 5.2. The key point is that the salinity in the acclimatization pen always matched the final salinity of the hatchery acclimatization process.

Table 5.2 Salinity Level (ppt) Recorded by Shrimp Farmers First Day for PL in the Acclimatization Pen, 1997

Province	District	Minimum	Maximum	Mean[a]	Median[b]	No. of Farms (N=36)
Chachoengsao	Bangnamprieow	9	15	11.5	10	10
	Bangkhla	5	15	10	10	9
	Khlong Keun	10	30	20	20	2
	Ban Pho	15	20	18	18	4
	Muang	6.5	7.5	7	7	2
	Ratchasan	4	10	7.6	8.3	4
Nakhon Nayok	Ong Khanarak	7.5	7.5	7.5	-	1
Prachinburi	Ban Sang	5.5	10	7.9	8	4
	All Districts	4	30	11	10	36

a. The mean value is influenced by a few high and low values.
b. In skewed distributions, the median is the better measure of the central tendency.

Regardless of the shrimp species cultured, farmers use a one-phase production cycle. Bags of PL are placed directly into an acclimatization pen within the growout ponds upon delivery; none use a separate nursery pond. Before the PL are released from the bags into the pen, care is taken to acclimatize the PL to the pond's water temperature by floating the bags in the pond for at least 15 minutes. Farmers also confirm the salinity in the pen and the salinity of the saline water being delivered using salinometers.

Since the water in the pen containing the PL is at a higher salinity than the rest of the growout pond, the shrimp farmers developed a procedure to equalize the salinity between the pond and the pen. Farmers report that it is during the salinity equalization process that the majority of PL mortality occurs. Differences in temperature and salinity are the only parameters that farmers take into account during this process. During the first day that the PL are introduced to the pond, at least two openings are made along the PVC barrier that separates the acclimatization pen from the rest of the pond. The openings are meshed to prevent the PL from leaving the pen while allowing the pen water, normally at 10-ppt, to mix with the 0-ppt water in the growout pond. The most common procedure was as follows: during the first day for 1 hour; on the third day for 2 hours; fifth day for 3 hours; seventh day for 4 hours and on the ninth day for 5 hours. Shrimp farmers adhered to this schedule until a uniform salinity was achieved in the growout pond. Most farms equalized the salinity within ten days. Around the tenth day, the PVC barrier was removed and the PL were allowed access to the rest of the pond for the duration of the growout (Figure 5.4).

Once the pond's salinity is equalized, the farmers gradually add pre-treated clean freshwater to the growout pond. This is done to increase the pond's depth without causing a large or sudden fluctuation in salinity. This is a critical management procedure for ensuring the highest possible PL survival. Low-salinity shrimp farmers applied more stringent limits than is the convention in coastal areas, of never allowing the salinity to fluctuate more than 5 ppt per day. For example, if the farmer started at an initial pond water depth of 50 cm, 5 cm of freshwater was transferred to the pond every 7 days until a final depth of 1.2 to 1.5 m was achieved. A pond water depth of 1.2 m was achieved around the 100th day and 1.5 m was achieved 140 days after removing the barrier. If initially stocked with PL15 (i.e., 15 day old PL), the residence time for the shrimp was 110 and 150 days respectively. The cumulative total of the number of days coincided almost exactly with the time required for the shrimp crop to reach harvest size. However, many farmers are conducting earlier harvests of smaller shrimp so as to pre-empt disease events. Some farms in Chachoengsao harvest their ponds 90 days into growout.

Figure 5.4 Low-Salinity Shrimp Pond Showing Opening in Acclimatization Pen

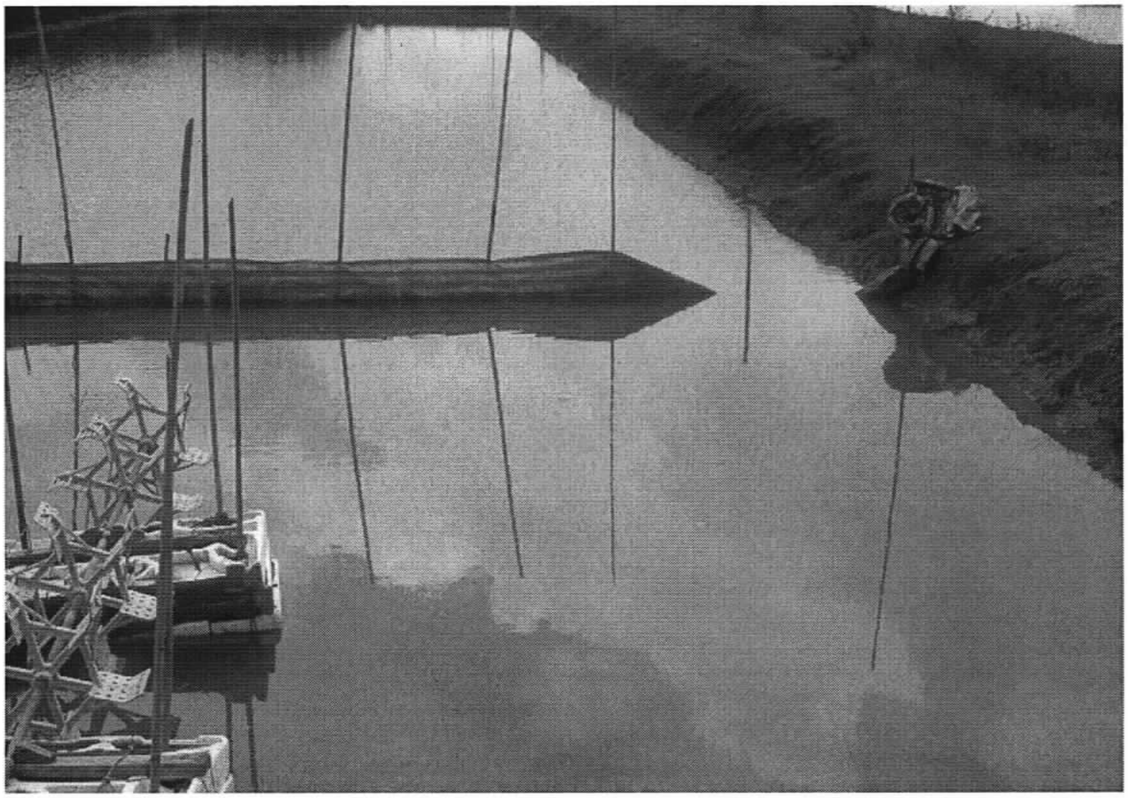


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 1998

In 1997, the field survey documented the salinity levels used throughout the various stages of growout. The median salinity in the acclimatization pen was 10 ppt, and the high maximum value of 30 ppt is attributed to a shrimp farmer in the district of Khlong Keun who had coastal shrimp farming experience. The median pond salinity at the start of growout was around 2 ppt, and within a range between 0 to 9 ppt. After the initial saline water was stocked, freshwater was used to offset water losses. While the initial salinity was dependent upon operator preferences, the final pond salinity was always near 0 ppt at harvest. This practice did not change whether the farmer cultured the black tiger shrimp in the 1997/1998 studies, or the white shrimp in 2004.

5.1.3 Saltwater Infrastructure

Saltwater infrastructure is another key factor contributing to the success of the low-salinity innovation. During the first wave of intensive shrimp farm development in central Thailand's upper gulf region during the 1980s, a second generation of marine shrimp farms was established along the estuaries of the major rivers such as the Chao Phraya, Bang Pakong, Tha Chin, and Mae Khlong (Figure 4.3). During the dry season, reduced water flows in these major rivers allowed the intrusion of saline water from the Gulf of Thailand. It was the availability of brackishwater within the drainage and irrigation canals that supported the establishment of marine shrimp farming operations at greater distances upstream (Flaherty and Vandergeest, 1998). Operating at the interface between freshwater and seawater, these 'brackishwater' shrimp farms enjoyed considerable success. However, brackishwater was not available in upstream areas during the rainy season when elevated stream flows counteracted tidal influences. Most of these estuaries were eventually fitted with irrigation control structures to limit dry season saline intrusion, which might be damaging to rice and other agricultural crops. These structures effectively restricted the seasonal saline water supplies to upstream shrimp farms. Marine shrimp farmers in areas cut off from saline water sources circumvented these restrictions by transporting brine from the coast to upstream areas using tanker trucks. Brine was purchased within the region from the numerous salt farms in Samut Sakhon and Samut Songkhram provinces, at a very low cost.

The capacity to deliver saline water is another important factor to the success of marine shrimp farming in freshwater areas (Figure 5.5). Although many rural inhabitants knew of the existence of, and had even perfected the techniques of low-salinity shrimp farming for some time, this type of shrimp farming did not expand until cost effective methods for saline water delivery were established. Salt-water delivery developed independently in several areas, making it difficult to determine the exact origin of the practice. In 1998, many of the central region salt farm operators surveyed claimed that they had been making a lucrative secondary income selling brine to shrimp farmers for about ten years. This suggests that low-salinity marine shrimp farming started around 1988. This coincides with high farm gate prices for black tiger shrimp, which was driving the rapid expansion of intensive shrimp farming along Thailand's coastline. The first low-salinity shrimp farmers transported salt water themselves for a time before they turned to salt water brokers using leased trucks to deliver saline water. This fits with the information provided by shrimp farmers interviewed in Chachoengsao in 1997 and 1998, who indicated that they had been farming shrimp for about 10 years. In Chachoengsao, some of the early entrants to low-salinity shrimp farming had attended Department of Fisheries seminars at Kasetsart University in Bangkok in 1987 that promoted coastal shrimp farming techniques. The information presented at these seminars was subsequently applied in various coastal and non-coastal regions.

Figure 5.5 Salt-water Tanker Trucks Delivering Saline Water to Shrimp Farm

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 1997

The emergence of saltwater brokers played a crucial role in the development of inland shrimp farming. As inland shrimp farming expanded, the role of saltwater brokers increased in importance. While there is little documentation available that indicates when the practice of transporting saline water commenced, Banpasirichote (1993) reported that it was a shrimp farmer with a large farm in Chachoengsao who was a supplier middleman in shrimp culture, who initiated saltwater transportation by tanker truck. Because of the high volume of seawater that is required by shrimp hatcheries, many operators purchased tanker trucks. Many of these are used to deliver saline water to inland shrimp farms. Saltwater brokers prefer salt farms because pumping equipment to fill the trucks is available on site.

Most inland shrimp farmers purchase saline water or brine through brokers. The brokers obtain saline water from solar salt farms in the central region provinces of Samut Songkhram and Samut Sakhon (Figure 5.6). These salt farms are artisanal operations consisting of evaporation ponds with minimal biological activity because of the short water retention times and high water temperatures. There is a great variance in the salinity of brine water obtained from salt farms at different stages of the salt making process or at different times of the year. During the dry season salt farms sell very high brine concentrations (up to 300-ppt). The salinity may be as low as 100 ppt during the rainy season. However, during the rainy season they are sometimes restricted to selling estuarine water that can be as low as 30-ppt.

The demand for increasing volumes of saline water created by the rapid growth of inland shrimp farming encouraged the development of alternative supply sources. In the central region along the Bang Pakong River and other drainage's connected to salt water, ‘water-concentrating’ operations or ‘saline water farms’ have been established along the estuary banks with minimal capital investment. Using simple procedures, water at the prevailing salinity concentration is diverted from the estuary into man made impoundments. The water can be pumped but typically, tidal action fills any number of shallow rectangular ponds constructed on the edge. Water is subsequently impounded in these ponds and evaporation increases the salinity. Other than evaporation, the water is not treated. Typically, the water entering is brackish with a concentration between 26- and 30-ppt and is concentrated up to approximately 40-ppt; high enough for inland shrimp ponds but much lower than the 300-ppt possible in salt farms. Increased precipitation during the rainy season hampers water-concentrating operations. Tanker trucks pump the water directly from the ponds and deliver it to the shrimp farms. Since these operations have developed solely for inland shrimp farms, some offer delivery.

Figure 5.6 A Typical Salt Farm in Samut Sakhon Province, Thailand

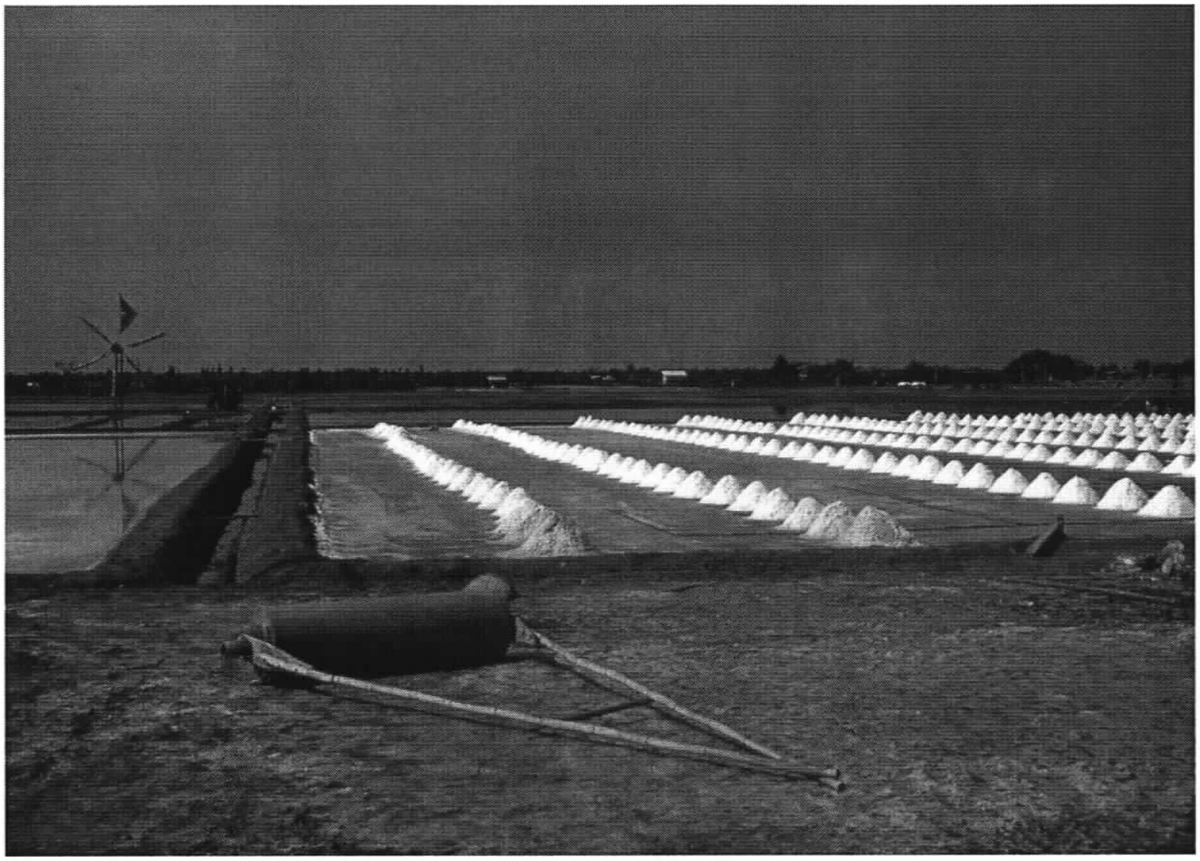


Photo Credit – Paul Miller, Samut Sakhon Province, Thailand, May 1997

Saline water delivery fees are based on the distance the water is to be hauled and the brine concentration. A high concentration of brine and a long distance to the shrimp farm is the most expensive scenario. Tanker truck capacities ranged from 8 to 15 tonnes. The mark up on a typical 15 tonne tanker load of 40-ppt water is substantial. In 1998, the various prices paid for saline water was investigated. Saltwater brokers may pay the salt farmer as little as $CAD 4 for one load, and then charge the shrimp farmer between $CAD 40 to $CAD 120 depending on distance.

The number of tanker truckloads and the salinity levels of water delivered to the shrimp farms are reported in Table's 5.3 and 5.4. The values reported in 1997/1998 were for the cultivation of the black tiger shrimp. The 2004 values included farms cultivating the black tiger shrimp and the white shrimp. The salinity varied between 30-ppt (i.e., estuarine source) and 200-ppt (i.e., salt farm brine). The median salinity of the water delivered to the inland shrimp farms was 50 ppt in 1997/1998 and 100 ppt in 2004. The reason for the increase to 100-ppt in 2004 can likely be attributed to the emergence of local producers and distributors of saline water. This development is discussed below.

A MWU test was used to evaluate the increase in the mean number of tanker truckloads as well as the salinity of the water delivered to the shrimp farms. The level of significance was 0.05. The increase in the number of tanker truckloads delivered was not significant (*p*=0.9518). However, the increase in the salinity of the water delivered to the farms was significant (*p*=0.0117) (Table 5.4). The potential environmental impacts of these increases could exacerbate the salinization impacts of low-salinity shrimp culture. Salinization impacts are discussed in Chapter 6, section 6.3.1.

Table 5.3 Saline Water Delivery to Low-Salinity Shrimp Farms, 1997/1998 and 2004

1997-1998 — Black Tiger Shrimp	Mean	Median	Maximum	Minimum	N=86
Tanker truckloads previous crop	2.6	2	6	1	22
Salinity - water delivered (ppt)	59	50	100	30	26
2004 — Black Tiger Shrimp and White Shrimp	Mean	Median	Maximum	Minimum	N=50
Tanker truckloads previous crop	3.6	2	25	1	39
Salinity - water delivered (ppt)	80	100	200	30	44

Table 5.4 Results of the Mann-Whitney U Analysis of Saline Water Delivery to Low Salinity Shrimp Farm in the 1997/1998 and 2004 Field Studies

	1997/1998 Mean (SEM)[a]	2004 Mean (SEM)	Two-tailed P value
Tanker truckloads previous crop	2.6 (0.40)	3.6 (0.78)	0.9518
Salinity – water delivered (ppt)	59 (5.13)	80 (4.90)	0.0117

a. SEM is the standard error of the mean - standard deviation of the sampling distribution of the mean.

Saltwater delivery brokers are receiving new competition from other low cost suppliers. In 2004, many of the local feed and input suppliers had constructed small holding tanks at their shops, consisting of a strong plastic tarpaulin placed inside a steel frame to form a tank (Figure 5.7). Within this structure, bags of sea salt are mixed with freshwater in order to produce brine at a concentration of around 100-ppt. These suppliers are very close to the shrimp farms. Small pick up trucks with plastic tanks can deliver up to 1000 litres of 100-ppt brine to the shrimp farmers in one trip (Figure 5.8). It is common now for farmers to order lower quantities of saline water from brokers, and to place an order locally for 100-ppt water as a top up in order to save costs. In 2004, the typical cost for 1000 litres of 100-ppt brine was $CAD 8. While these local saline water source options have not replaced the tanker trucks, they offer a convenient and low cost alternative to shrimp farmers. Farmers can initially stock the minimum amount of brine in the acclimatization pens to save money with the option of ordering more brine as needed at short notice.

In Chachoengsao, farm location determines the level of dependency on saline water to initiate growout. Some farms stocked saline water during the dry season for future use during the rainy season. Impounding saline water was common at farms with more than one growout pond and represented a significant cost saving. Shrimp farms not connected to estuarine sources or road infrastructure utilized indirect methods to stock saline water. Saline water would be off loaded to a nearby pond or reservoir and pumped to the shrimp pond incrementally through a series of natural or man made ditches, ponds, reservoirs, or irrigation canals. In 1998, the field survey found that, for a fee, some shrimp farming operations had appropriated the use of the smaller concrete freshwater irrigation canals to relay brackishwater to shrimp ponds. Brackishwater was pumped into these canals from pumping stations situated on the edge of the Bang Pakong River. In one location, protests by rice farmers over the use of irrigation canals for saline water transfer convinced the local Kamnan to stop this practice. No reports of this type of action were recorded in the 2004 field study.

Flaherty and Vandergeest (1998) speculated that the limits to the expansion of inland shrimp farming could be tied to the distance that a tanker truck could economically haul saline water to the shrimp farms. The distance of the shrimp ponds from the saline water broker and the delivery cost is a major factor limiting the spatial distribution of inland shrimp ponds. This is still true. This research found, however, that competitiveness amongst the saltwater brokers, combined with the sustained growth of inland shrimp farming has kept brine delivery fees in check despite increased delivery distances. Evidence of the adoption of inland shrimp farming in regions further a field suggests that the upper limit has yet to be reached. This may be related to the fact that initial brine prices were high enough to allow for price-cutting amongst brokers. It is also related the development of competitive lower cost alternatives in close proximity to the shrimp ponds forcing brokers to decrease their prices and lower their profit margin.

Figure 5.7 Local Distribution System Setup for Saline Water Delivery to Low-Salinity Shrimp Farms

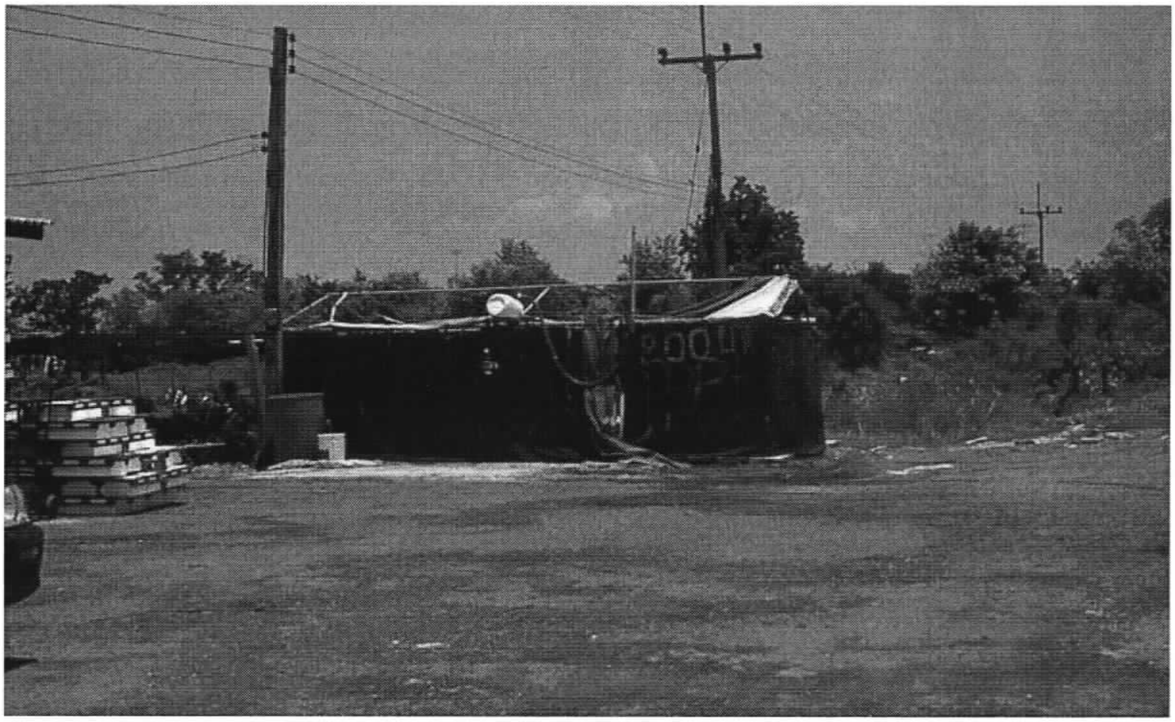


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

Saline water transfer within the region raises several important issues for the industry. Of particular concern is the potential for the wider distribution of pollutants and shrimp diseases. Water brokers assume no responsibility for water quality other than guaranteeing the salinity. The primary sources of saline water for the shrimp farms are located in coastal areas where the water is often polluted with industrial and agricultural contaminants including pesticides and heavy metals (Miller, 1996). If the brokering of salt water becomes even more competitive, brokers might be forced to guarantee water quality. If this does not happen, shrimp farmers are likely to become more careful in selecting their sources of saline water. In the 1997/1998 field studies several shrimp farmers reported that they already preferred saltwater from salt farms over the estuarine salt water concentrating operations. Farmers believe that saline water from the salt farms contains fewer disease pathogens. However, there are no studies that document the appropriateness of different concentrations of brine water for use in shrimp farms, including the beneficial levels of the major ions and the most appropriate level of salinity to prevent disease.

Figure 5.8 Small Pickup Truck with Tank Used for Local Saline Water Delivery to Low-Salinity Shrimp Farms

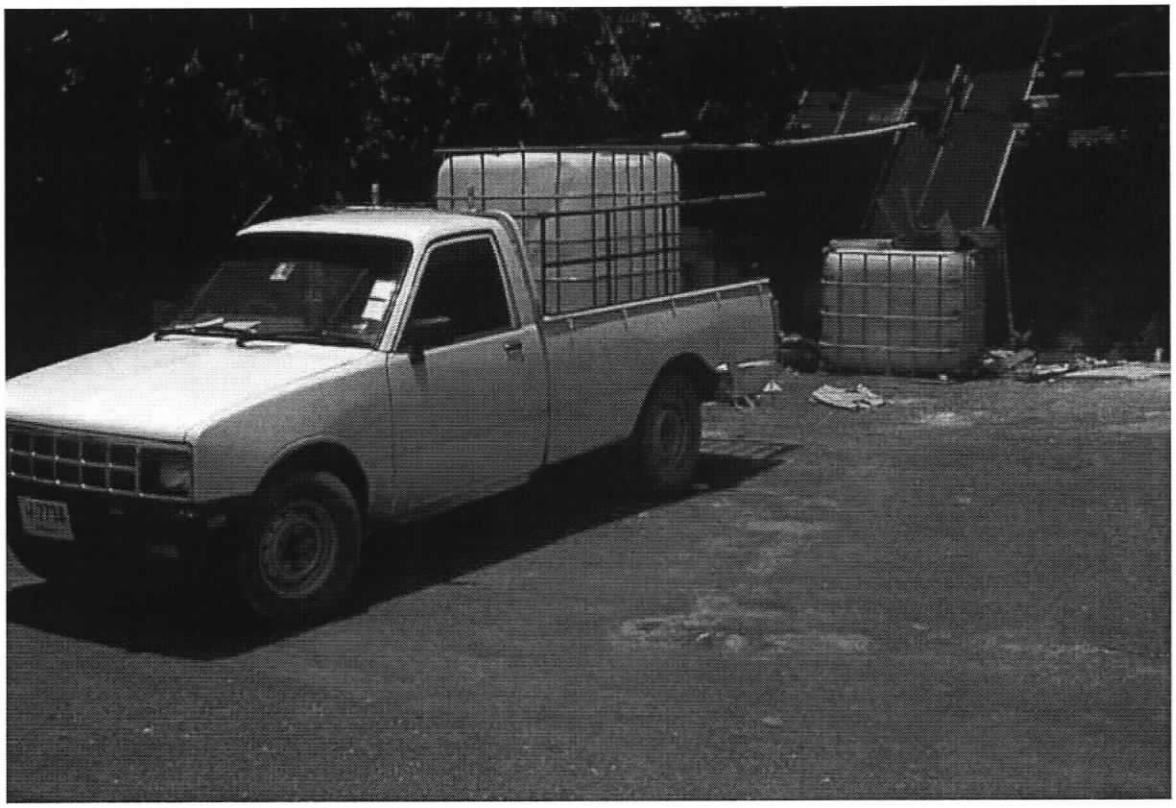


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

5.1.4 Diffusion of Low-Salinity Techniques

Another key factor behind the low-salinity innovation was the process by which information about this type of shrimp culture was dispersed. The headman of Bangsorn reportedly first introduced low-salinity techniques to Khlong Ban Pho in Chachoengsao province from the Mahachai region of Samut Songkhram province (Banpasirichote, 1993). Prospective shrimp farmers in inland areas had experimented prior to adopting intensive culture techniques. This experimentation was supplemented by informal discussions amongst farmers and with the agents of locally based feed and chemical shops. Initial adoption rates were tempered by the perception that shrimp farming was a high-risk venture. Once the feasibility of this type of shrimp farming was established, however, residents of other villages quickly copied the techniques. Due to the absence of formal information networks other than word of mouth among rural inhabitants, inland shrimp farming gradually spread without widespread attention from the government and other agencies.

Feed and chemical agents played a central role in disseminating information about the low-salinity innovation. As sales to coastal shrimp farming declined following widespread disease epidemics, these agents sought ways to expand their business. As they became aware of low-salinity shrimp farming, and of the potential for increased sales to low-salinity operations, agents provided free seminars to explain and promote low-salinity shrimp farming. In 1997, interviews conducted with these agents confirmed that feed and chemical sales to inland shrimp farmers increased rapidly as the technical feasibility and economic viability of marine shrimp culture under low-salinity conditions was established. The initial clients were landowners who could afford the capital outlay for pond construction and other infrastructure. Frequently these landowners were the village leaders. These well-capitalized individuals were the catalysts for the widespread adoption by rural rice farmers in freshwater areas. In 2004, the field investigation found that information seminars hosted by feed and chemical agents remains a popular strategy to disseminate information about low-salinity shrimp culture and increase their sales revenues.

5.2 Shrimp Farm Survey Results

Another aspect of the 1997/1998 and 2004 field studies was to investigate whether the operating practices and techniques used by shrimp farmers varied within or between the farming areas. It was found that the operating practices and techniques were quite dynamic, governed by the changing condition of the shrimp, pond water quality, and by the acquisition of new knowledge. This lack of consistency makes it difficult to describe the exact operating practices involved in low-salinity shrimp farming. However, the general characteristics of low-salinity shrimp farms in Chachoengsao are not much different from those of other shrimp farms in Thailand. Marine shrimp farmers in freshwater areas employed similar methods and management techniques to those practiced along the coast (Miller et al., 1999). Standard operating practices included high stocking densities, aerated ponds, and the application of formulated feeds and chemotherapeutants. Although the data confirmed that a degree of consistency existed in regard to certain aspects of low-salinity culture, the field investigations in 1997/1998 and 2004 documented that, in some instances, the overall land and water management practices varied dramatically between individual operations. Most of these differences arose from economic considerations, management factors, and the background and experience of individual shrimp farmers.

5.2.1 Types of Low-Salinity Shrimp Farms

In the absence of detailed farm-level information, low-salinity shrimp farming has been treated as a homogeneous activity. The results of the 1997/1998 and 2004 field investigations, however, make it possible to define several different types of low-salinity shrimp farms based on the source of saline water and farm location. Low-salinity or inland shrimp farming operations included farms sited in freshwater areas that relied solely upon the delivery of saline water, and farms located in brackishwater or seasonally saline estuarine areas that imported saline water during the rainy season. In some locations, farmers capitalized on the ambient soil characteristics, which supported marine shrimp culture by adding freshwater to ponds excavated in saline soils. In all cases, bags of sea salt were used to make minor salinity adjustments as required. Although there were many variations on techniques employed at individual shrimp farms, for the purposes of this research low-salinity shrimp farms are categorized as follows:

- Farms in freshwater areas: culture with brine or saline water obtained from coastal areas or saltpans.
- Farms located in seasonally saline estuarine areas: draw brackishwater from estuary when available and supplement with brine or saline water transported from coastal areas or saltpans during the rainy season.
- Farms that use salt from the soil: stock only freshwater in ponds and rely upon naturally occurring salts in the soil make the water suitable for marine shrimp.

Although the field survey visited farms in all of the above categories, the most common type of low-salinity culture operation encountered in this research were farms located in freshwater areas.

5.2.2 Shrimp Species Cultivated

In the 1997/1998 field studies, there was only one combination – intensive monoculture with the black tiger shrimp (Figure 5.9). However, poor performance, slow growth rates and disease susceptibility have prompted many producers to switch to white shrimp cultivation. The first reported introduction of white shrimp in Thailand occurred in 1998 (Funge-Smith and Briggs, 2003). In 2004, low-salinity shrimp farmers reported that they began culturing the white shrimp in 2002. White shrimp are a marine species that are tolerant to a wide range of salinities (0.5 to 45 ppt) and are reportedly more amenable to inland culture sites than the black tiger shrimp (Funge-Smith and Briggs, 2003). Some inland farmers also reported culturing the freshwater shrimp species *Macrobrachium rosenbergii* for domestic markets, but the production volume of this species is insignificant compared to either the black tiger or white shrimp. This study focused on the black tiger and the white shrimp. These species were cultivated in farms that were limited to family or household operations that used intensive methods with formulated feeds.

Figure 5.9 Black Tiger Shrimp at Harvest Size

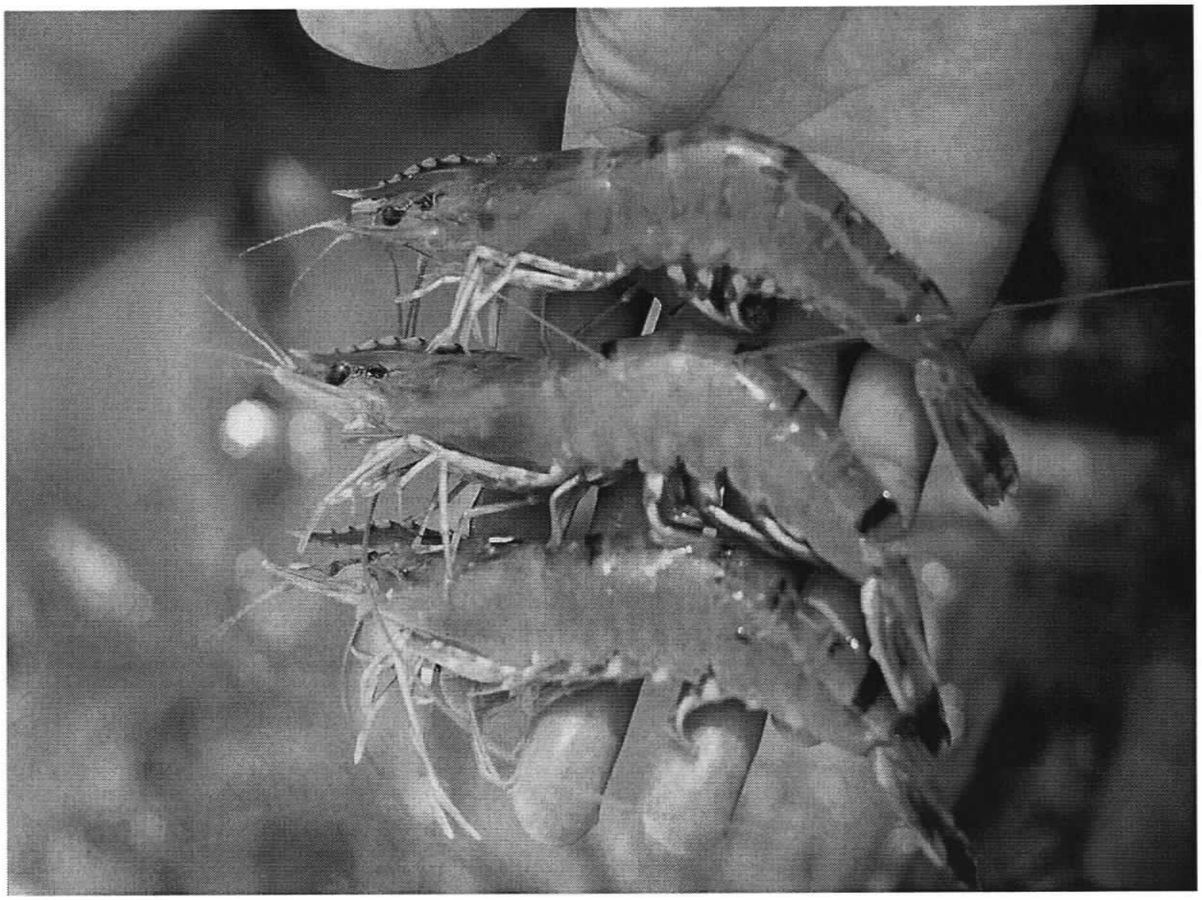


Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 2004

The combinations of shrimp species cultured at low-salinity shrimp farms are outlined below. These combinations are not a definitive set. As shrimp farming evolves, farmers may try to increase the number of combinations. In 2004, however, the most common combination was still intensive monoculture but operators either cultured the indigenous black tiger shrimp and/or the exotic white shrimp.

- <u>Intensive Monoculture – Indigenous Species</u>: cultivate black tiger shrimp in low-salinity. Rely on local hatcheries for acclimatized PL produced from wild caught broodstock that are sourced in country.
- <u>Intensive Monoculture – Exotic Species</u>: cultivate the white shrimp. Rely on local hatcheries for acclimatized PL from imported broodstock.

- Intensive Shrimp Polyculture – Indigenous and Exotic Species (same pond): cultivate the black tiger and the white shrimp in the same pond. Conduct joint harvests. PL from local hatcheries for both species. Harvest requires more labour to sort the species.

- Intensive Shrimp Polyculture – Indigenous and Exotic Species (different ponds): cultivate the black tiger and the white shrimp in different ponds at the same farm. PL from local hatcheries for both species. Flexible operation and can harvest one pond independently from another.

In 2004, the field study found that many low-salinity shrimp farmers (74% of the sample) now switch the species that they culture from crop to crop (Table 5.5). Some farmers reported that they cultivate the black tiger shrimp and the white shrimp at the same time, in either the same or separate ponds. Separate ponds are preferable as it allows the farmers to separate the crop cycles by species. Farmers also claimed that the potential for transference of disease between the black tiger shrimp and the white shrimp was another reason that they preferred to culture them in separate ponds. There are few farms, including new entrants, which cultivate the white shrimp exclusively. In the 1997/1998 field studies, no farmers reported that they cultured the white shrimp.

Table 5.5 Shrimp Species Cultivated, 2004

	No	Percent (%)	Yes	Percent (%)
Do you culture the white shrimp? (N=50)	9	18.0	41	82.0
Do you culture the black tiger shrimp? (N=50)	2	4.0	48	96.0
Do you switch shrimp species between crops? (N=50)	13	26.0	37	74.0

Shrimp farmers gave many reasons for switching the species they cultivate (Table 5.6). The primary reason is that farmers want to culture the species that is easiest to grow and will yield the best price at harvest. Farmers who switch species between crops, however, indicated that the key determinant is the market price for the species at the commencement of growout. As problems occur with one species during growout they look for a solution by switching to another species in subsequent crops.

Shrimp farmers reported problems with this strategy. They are dismayed by the oftentimes-dramatic shift in the farm gate price of shrimp between the time when they commence the growout and when the shrimp are harvested. This is a problem with the black tiger shrimp as well. At harvest, the farmgate price of the shrimp species in the growout pond often has dropped to the point where profits are minimal. Essentially the farmers feel that they are gambling from crop to crop. In 2004, the results of the field survey indicated that while a great number of farmers have tried white shrimp culture, most have also continued cultivating the black tiger shrimp.

Table 5.6 Principal Reasons for Switching to White Shrimp Culture, 2004

	Number of Farms	Percent (%)
Easier to culture white shrimp	23	46
Following the community trend in shrimp culture	3	6.0
Problems with black tiger shrimp culture (Slower growth rate than the white shrimp, poor quality PL, low price, and difficult to feed)	15	30.0
Do not cultivate white shrimp	9	18.0
	50 [a]	100

a. In 2004, 9 of the 50 farmers surveyed reported that they did not grow white shrimp.

In 2004, shrimp farmers reported that many of the expected benefits of white shrimp culture have not yet materialized or have been diminished by the emergence of growout problems (Table 5.7). Many of the reasons used to support the switch to white shrimp culture are similar to problems reported with black tiger shrimp culture. The problems are common to both species but are more related to the nature of intensive shrimp culture. It was difficult to classify the farmer responses as many of the respondents reported multiple problems. Many of the problems are interrelated making it difficult to categorize their responses into discrete categories.

Table 5.7 Principal Problems with White Shrimp Culture, 2004

	Number of Farms	Percent (%)
Price of shrimp (low farmgate price for white shrimp at harvest)	3	6.0
Slow growth; slow to develop hard shell, high feed conversion ratio	9	18.0
Environment (poor soil quality, not enough water, pond predators, low dissolved oxygen, low alkalinity)	5	10.0
Post-larvae (low grade, poor quality, disease – shrimp die after one or several months)	21	42.0
No problems (N=3) or do not cultivate white shrimp (N=9)	12	24.0
	50[a]	100

a. In 2004, 12 of the 50 farmers surveyed reported no problems with white shrimp culture, or that they did not grow Pacific white shrimp.

5.2.3 Production Characteristics

The observed production characteristics of low-salinity shrimp farms offer a means of comparison to other shrimp farms. Statistical analysis was used to compare the production characteristic data of low-salinity shrimp farms in Chachoengsao surveyed in the 1997/1998 and 2004 field studies. The Mann-Whitney U Test (MWU) was used to analyze the data collected for the number of shrimp ponds, total farm growout area, individual pond area, number of years of shrimp production, number of crops produced (since commencing farming), and the number of crops cultivated per year. In all cases, the level of significance was 0.05. The MWU test was used in place of the simple t- test because the data did not originate from a normally distributed population. The results of the analysis are summarized in Table 5.8.

Table 5.8 Results of the Mann-Whitney U Analysis of the Production Characteristics in the 1997/1998 and 2004 Field Studies

	1997/1998 Mean (SEM)	2004 Mean (SEM)	P value
Number of shrimp ponds	4.6 (0.60)	4.7 (0.45)	0.1077
Total farm growout area (ha)	21.4 (3.53)	13.3 (1.69)	0.8923
Individual pond area (ha)	3.8 (0.31)	2.6 (0.17)	0.0165
No. of years of shrimp production	3.4 (0.23)	6.7 (0.43)	< 0.0001
Number of crops produced	6.7 (0.61)	14.5 (1.19)	< 0.0001
Number of crops per year	2.0 (0.04)	2.4 (0.07)	0.0004

In 1997/1998, farms operated an average number of approximately 5 shrimp ponds. The minimum number of ponds was 1 and the maximum was 39. In 2004, farms operated an average number of approximately 5 ponds. The minimum number of ponds was 1 and the maximum was 15. No significant difference was found in the mean number of shrimp ponds between the 1997/1998 and the 2004 field studies (p=0.1077). Therefore, it can be inferred that the two samples were not significantly different.

In 1997/1998, the mean total farm growout area was approximately 21 ha. There were few large farms, and no evidence of large-scale corporate shrimp farming development. The minimum total farm growout area was 0.08 ha (enough for a single pond) and the largest farm had 30 ha of growout area. In 2004, the mean total farm growout area was approximately 13 ha. The smallest total farm growout area was 1.5 ha and the largest farm had 50 ha of growout area. No significant difference was found between the total farm growout area between the 1997/1998 and 2004 field studies (p=0.8923). Therefore, it can be inferred that the two samples were not significantly different.

The individual pond area (ha) at each farm was calculated by dividing the total culture pond area (ha) by the number of ponds representing this area. In 1997/1998, the mean individual pond area was approximately 4 ha. The smallest total culture pond was 0.08 ha (single pond) and the largest was 17.5 ha. In 2004, the mean individual pond area was approximately ha. The smallest pond was 1.5 ha and the largest pond was 6.5 ha. The difference between the samples was significant (p=0.0165). In 2004, the results indicate that farmers used smaller sized ponds to grow shrimp.

In 1997/1998, the mean number of years that the farmer's had been culturing shrimp was around 3. The minimum number of years was 0.25 (3 months) and the maximum was 10. In 2004, the mean number of years that the farmer had been culturing shrimp was approximately 7. The minimum number of years was 1.5 and the maximum was 15. There was a significant difference between the 1997/1998 and 2004 field studies (p<0.0001). Therefore, it can be inferred that the observed differences were not due to chance. In 2004, the farms surveyed had been growing shrimp for a longer period of time, and this finding was an indication of more experienced shrimp farmers.

In 1997/1998, the mean number of crops harvested since commencing operations was around 7. The minimum number of crops produced was 0 (first crop was in the pond) and the maximum was 19. In 2004, the mean number of crops produced since commencing operations was approximately 14. The minimum number of crops produced was 1 and the maximum was 40. There was a significant difference between the 1997/1998 and 2004 field studies ($p<0.0001$). Therefore, it can be inferred that the observed differences were not due to chance. In 2004, the farms surveyed had been operating for a longer period of time and had produced more crops.

In 1997/1998, the mean number of crops produced per year was 2. The minimum number of crops produced was 1 and the maximum was 3. In 2004, the mean number of crops produced per year was about 2. The minimum number of crops produced was 2 and the maximum was 3. There was a significant difference between the 1997/1998 and 2004 field studies ($p=0.0004$). Therefore, it can be inferred that the observed differences were not due to chance.

5.2.4 Post-Larvae Quality and Pond Stocking Density

In the 1997/1998 and 2004 field studies, shrimp farmers reported that PL quality had a major impact on production and profitability. Farmers regarded PL survival rates as critical to their farm's economic viability. PL quality was determined by visual assessment upon delivery. High-quality PL possess transparent bodies with grayish or dark streaks along the body, a noticeably open tail, are strong and uniform in size (Ponza, 1999). Most low-salinity shrimp farmers had preferred PL suppliers and sourced them from the local hatcheries within the same province (Table 5.9). In 1997/1998, hatcheries supplying inland shrimp farms produced only black tiger PL. In 2004, however, the field investigation found that many of these same hatcheries had switched to producing both black tiger and white shrimp PL.

Once farmers establish a reliable source of PL, they tend to continue using the same supplier regardless of the species cultured. Information collected in other provinces in 1998 highlights some of the differences in farmer preferences. For example, several shrimp farmers in Nakhon Pathom province reported that they would not use locally available PL and preferred to purchase PL from Surat Thani province. According to these farmers, hatcheries in Surat Thani used broodstock only once, whereas hatcheries in Chonburi and Chachoengsao provinces used broodstock three times or more. Farmer preferences were based on local knowledge and experience and agreed with scientific evidence showing that repeated use of broodstock leads to a loss of culture performance (Lee and Wickens, 1992b).

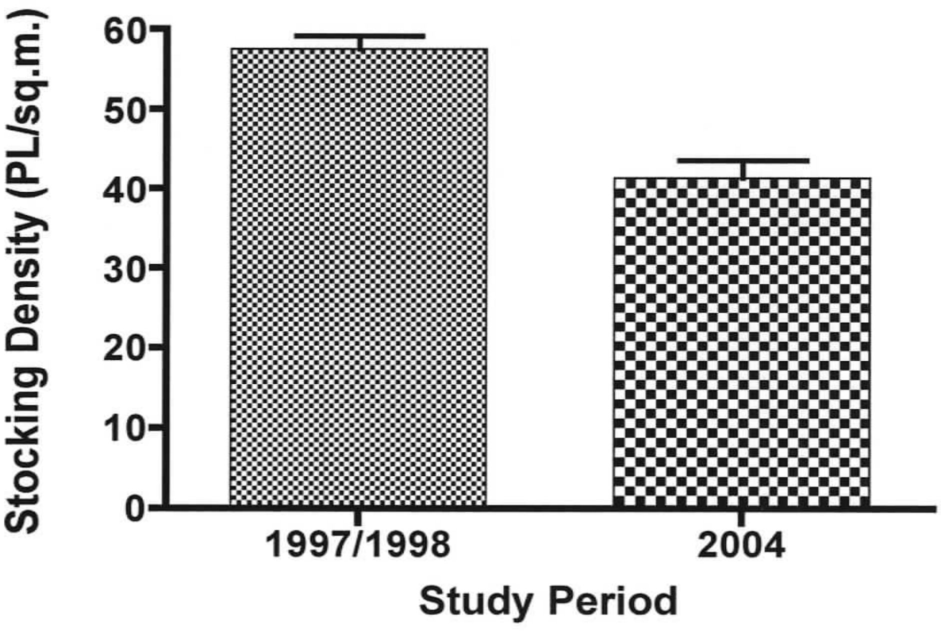
Table 5.9 Post-Larvae Sources, 1997/1998 and 2004

	1997/1998 (N=86)		2004 (N=50)	
Hatchery Location	No. of Farms	Percent (%)	No. of Farms	Percent (%)
Chonburi	6	7.0	6	12.0
Chachoengsao	76	88.4	43	86.0
Rayong	1	1.1	-	-
Phuket	-	-	1	2.0
Did not know	3	3.5	-	-
	86	100	50	100

In 1997/1998, only a small number of shrimp farmers reported problems with PL quality. In 2004, however, the majority of farmers reported that PL quality was poor and was causing major problems in the growout phase. Farmers believed that poor quality PL resulted from the broodstock selection and handling procedures used in the hatcheries. In 2004, the hatchery managers claimed that there was a shortage of high quality black tiger broodstock, leading them to use their broodstock supplies repeatedly. This practice would likely result in a reduction in the PL viability. Ideally, the eyestalk ablation procedure used on the black tiger shrimp broodstock would only be completed once. However, this procedure can be completed up to three times before the broodstock dies. There is a strong incentive for hatchery managers to use broodstock repeatedly so as to increase profits, especially if there is a shortage. For white shrimp broodstock as well, the repeated use of low quality stock also leads to poor quality PL. However, since hatchery operators must purchase the broodstock, often at great expense, they are inclined to use them repeatedly. It is for this reason that farmers preferred to purchase PL from hatcheries that used good broodstock management practices.

In 1997/1998, the mean stocking density was approximately 58 PL/m^2. One farm reported an extremely high stocking density of 125 PL/m^2 for no justifiable reason, while another reported a low stocking density of only 19 PL/m^2. The latter farm was located in Ban Pho district and had had problems stocking at higher densities during the previous crop. In 2004, the mean stocking density was approximately 41 PL/m^2. One farm stocked at a very low stocking density of 8 PL/m^2. This farm had experienced problems with the previous crop, which had been stocked at a much higher density. A MWU test was used to analyze the stocking densities reported in the 1997/1998 and 2004 field studies. The results indicated strong evidence of a significant finding (*p*<0.0001). Therefore, can be inferred that the observed differences in stocking density were not due to chance (Figure 5.10).

Figure 5.10 Box Plot Comparison of the Mean Stocking Densities Between the 1997/1998 and 2004 Field Studies (p<0.0001)



Ideally, the aim of stocking is to place an appropriate number of high-quality PL into the pond to guarantee maximum sustainable production. In reality, farmers routinely stock the growout ponds at excessively high levels. Shrimp farmers indicate that high stocking levels are essential to obtaining an adequate return on their investment. Farmers also reported that lower stocking density reduced management stress. At lower stocking densities they could raise larger sized shrimp in a reduced amount of time. Farmers also reported using lower stocking densities as a result of negative experiences, namely disease, with stocking at higher densities. Although densities have decreased, most still used stocking densities that were well above those recommended for intensive culture, which is 30 PL/m^2.

Although farmers often use higher stocking densities so as to generate immediate returns from their shrimp ponds, they occasionally try different stocking densities. In 1997, for example, 12 of the 50 shrimp farmers reported experimenting with different stocking densities to compare performance. Most farmers acknowledged that increasing the stocking density increased pond management problems, and lower stocking densities improved performance. Shrimp farmers who lowered stocking densities reported that their feed costs were reduced, the shrimp grew faster, and the growout period was shorter. Nevertheless, the majority of inexperienced farmers often assume, incorrectly, that stocking more shrimp yields higher profits. Many farmers reported that they increase stocking densities in subsequent crops after experiencing problems as a means to recoup losses. In most cases, if the price of shrimp is high, shrimp farmers tend to increase stocking densities.

In Thailand, shrimp farmer preferences for high stocking densities have long been a problem, particularly amongst low-salinity shrimp farmers in Chachoengsao province. In the early 1990s, the rapid decline of inland shrimp farming in Ban Pho district was attributed to farmer preferences for excessively high stocking densities (Banpasirichote, 1993). This was examined further in the 1997 field study. In Ban Pho district, farmers had not been successful in their efforts to stock at higher densities since experiencing major disease losses in 1994. It was beyond the scope of this research to determine the multitude of factors behind this decline. On the other hand, shrimp farmers in Amphoe Bangnamprieow, a relatively new area for low-salinity shrimp culture, which had yet to experience major disease losses, tended to utilize higher stocking densities.

5.2.5 Pond Productivity and Survival Rates

The annual production from intensive coastal shrimp ponds can range from 5 to 15 tonnes per ha (Fast, 1992b). In 1997, inland shrimp farms achieved a mean production of around 3.3 tonnes per ha per crop. If the farmer produced the typical two crops per year this would equate to an annual production of around 6.6 tonnes. The maximum single crop production was 8 tonnes per ha. Farms reporting zero production were newly established with the first crop in the ponds. The pond productivity levels recorded in the 1997 studies are comparable to the production rates reported in other studies of inland shrimp ponds. Tookwinas (1997), for example, reported the annual production for two crops in a freshwater area of 11.7 tonnes per ha, 6.4 tonnes per ha for the first crop and 5.3 tonnes per ha for the second crop.

In 2004, inland shrimp farms achieved a mean production of around 3.4 tonnes per ha per crop. If the farmer produced the typical two crops per year this would equate to an annual production of at least 6.8 tonnes. This is comparable to that reported in 1997. The highest productivity (9 tonnes per ha in Lam Luk Ka district in Pathum Thani province and in Bangnamprieow district in Chachoengsao province) is attributable to several factors. These farms were well managed by veteran shrimp farmers and the sites had favourable growout conditions that included good water and soil quality. A MWU test was used to analyze the production data from the 1997 and 2004 field studies. The results indicated that there was no significant difference in pond productivity between the 1997 and the 2004 field studies (p=0.9919).

While farm productivity is one measure of performance in shrimp culture, another is the growout survival rate. The typical growout survival rates in coastal shrimp farming areas are 80 to 90% if there are no major disease events (Fast, 1992a). The 1997/1998 field studies did not collect information that would allow the researcher to report the growout survival rates of low-salinity shrimp ponds. However, the results of other studies of inland shrimp ponds around the same time reported an average growout survival rate of 72% for the first crop and 75% for the second crop (Tookwinas, 1997). In 2004, several inland farms reported growout survival rates ranging from 65 to 73% for the black tiger shrimp, and 75% for the Pacific white shrimp. Therefore, the growout survival rates of inland shrimp farming areas are comparable to those of coastal shrimp farming areas.

5.2.6 Pond Cleaning and Renovation

Pond cleaning and renovation includes activities undertaken to prepare the pond before it is used for the first time or prior to each subsequent crop. It is done to provide the shrimp with a clean pond bottom and stable water quality. In low-salinity operations, the most important condition necessary for PL input includes establishing a suitable pond environment for reduced salinity culture. Farms with more than one pond usually rotate production pond use. They seldom have all of their ponds producing shrimp at the same time. The intensity of the culture system determines the amount of organic material that accumulates in the pond during the growout. In intensive operations, sediment must be removed or broken down to sustain production and to prevent the over-accumulation of organic material. If the sediment is not removed, pond productivity deteriorates with each successive cycle. In 1998, farmers reported that the more crops harvested from a pond, the greater the incidence of poor growth, uneven sizes, soft shelling and blue discoloration in the shrimp. The standard practice is for inland shrimp farmers to remove accumulated wastes in the growout and settling ponds at the end of each production cycle, and less frequently from the reservoirs and drainage canals (Figure 5.11).

Shrimp farmers employ several methods to clean the pond bottom. Most use the dry method. For this, they allow the pond to dry out for a set period after the harvest and then physically removed the waste. Ideally, the waste should not be placed on the pond walls or near the supply canal where the waste could re-contaminate the pond. In practice, however, the sediment is almost always stored on the banks of the ponds. The cost of removal prevents removal off site. However, farmers report that the large volume of accumulated sediment eventually creates a storage problem. Several of the smaller farming operations reported that the amount of accumulated sediment generated in three years of culture forced them to consider moving operations to a new farming site. Only a small number of farms transfer sediment off site, or to an area of the farm where the sediment leachate would not interfere with the pond water or contaminate the surface water systems. Although the abovementioned practices were found to be similar in the 1997/1998 and 2004 field investigations, problems with the storage of accumulated sediment had become more acute in 2004. The longer the shrimp farm had been in operation the more problems the farm had in dealing with sediment.

Figure 5.11 Sediment Removal from a Low-Salinity Shrimp Pond

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

Farmers generally put ponds back into production as soon as possible after harvest. The number of days between crops is referred to as the fallow period. The fallow period must be sufficiently long in duration so as to allow for the pond to be prepared for the next crop. Shrimp farmers have often been accused of using short fallow periods in order to increase the number of crops produced in one year. In 1997, the mean fallow period was around 55 days. The minimum fallow period was 7 days, which is exceptionally low. The maximum was 360 days, which was due to unique local conditions created by the farm's location on the banks of a canal that inundated the culture ponds for several months of the year. In 2004, the mean fallow period was about 31 days. The minimum fallow period was 10 days and the maximum was 60 days. A MWU test was used to analyze the data from the fallow periods observed in the 1997/1998 and the 2004 field studies. No significant difference was found in the fallow period between the 1997/1998 and the 2004 study periods (p=0.2435). However, this finding does indicate that farmers in 2004 put their shrimp ponds back into production in a shorter period of time than what was documented in the 1997/1998 field studies.

5.2.7 Soil and Pond Water Conditioning

Low-salinity shrimp farmers use an array of soil and pond water conditioning agents. These agents are added to the ponds by hand broadcasting in measured quantities during all phases of production commencing during pond renovation before PL stocking and continuing during growout. The soil and water-conditioning agents used by low-salinity shrimp farmers in 1998 are reported in Table 5.10. All farmers acknowledged that soil and pond water conditioning additives should only be used as required. However, the application rates for most farms routinely exceeded the recommended amounts. Often the use of soil and pond water conditioning agents is not based on an identified need, but rather is related to the shrimp farmers' adherence to the chemical treatment systems proffered by feed and sales agents.

Table 5.10 Soil and Pond Water Conditioning Agents Used by Low-Salinity Shrimp Farmers in Chachoengsao Province, 1998

Compound	Purpose
Liming materials: • Calcium Oxide or quick lime • Calcium Hydroxide or slaked lime • Calcium Carbonate [$CaCO_3$] or agricultural lime • Dolomite [$MgCO_3$]	Neutralization of acidity and sterilization of pond bottoms. Most common is agricultural lime.
Zeolite	Ammonia removal
Potassium Permanganate [$KmnO_4$]	Oxidizer and detoxifier

Lime is the most common conditioning agent used by low-salinity shrimp farmers. Once the ponds are cleaned, and still empty, lime is applied to neutralize pond bottom acidity, increase total alkalinity of the pond water above 20 ppm, and to increase total hardness in the soil and water of growout ponds (Figure 5.12). Lime is also routinely applied to the pond water during the growout. The most common forms are agricultural lime, hydrated or slaked lime [$Ca(OH)_2$] and burnt lime or quick lime (CaO). Lacking the means to determine exact lime requirements, farmers usually apply between 200 to 300 kilograms per hectare. The pond is then sun dried for at least three weeks until the soil surface cracks. Lime is relatively inexpensive. In 1998, a 10-kg bag, for example, cost around $CAD 0.80.

Figure 5.12 Empty Low-Salinity Shrimp Pond with Lime Application

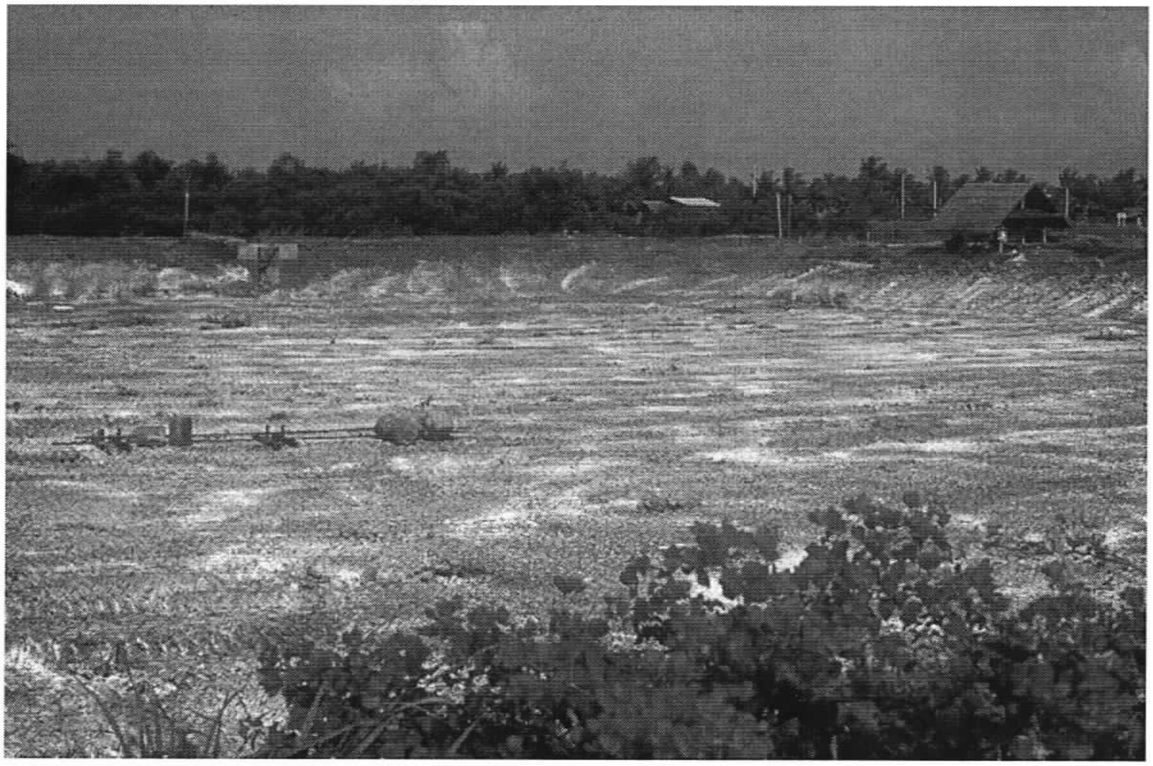


Photo Credit – Paul Miller, Samut Sakhon Province, Thailand, January 1996

The 1997/1998 and 2004 field studies found that another commonly used pond conditioning agent was zeolite. Farmers used zeolite at the 2 to 3 month mark of the growout to remove ammonia, improve the colour of the water, and to increase the pH of the pond water. Farmers applied zeolite by hand broadcasting from the pond edges. Typically, a 25-kg bag cost around $CAD 2.80 in 1998. Farmers usually added around 300 kilograms per hectare every 10 days throughout the culture period. This application rate amounts to 3,600 kilograms per hectare over the standard growout period of 120 days, and would cost a shrimp farmer just over $CAD 400. Even though these agents are relatively inexpensive, the proven efficacy of some is speculative, especially for zeolite (Boyd, 1995).

After treating the empty pond surfaces with lime, shrimp farmers add treated freshwater. Shrimp farmers use chemotherapeutants, disinfecting agents, and biocides including herbicides and piscicides for freshwater preparation. Biocides kill any potential vectors of viral disease and unwanted shrimp, swimming crabs, and zooplankton. Typically, the biocide calcium hypochlorite is applied at about 250 to 300 kg/ha. Increasingly, shrimp farmers use more specific organophosphate pesticides due to the effect of chlorine on the phytoplankton. Chlorine can impede the establishment of a healthy plankton bloom in the shrimp ponds. Nevertheless, most farmers rely upon the cheaper chlorine-based disinfectants. After chlorinating, farmers add more lime and aerate the ponds to disperse residual chlorine and stimulate a phytoplankton bloom. Sometimes fertilizer is added to promote a plankton bloom. The water is usually ready for culture 10 days after applying calcium hypochlorite. In 1998, the farmers indicated that the pond was ready for use when the transparency of the water was usually about 50 to 80 cm.

Formalin is another common pond water disinfectant used by shrimp farmers as a fungicide and parasiticide. If used, shrimp farmers usually added around 125 liters per hectare of formalin at about 40% concentration to the reservoirs. The reservoir water was then vigorously aerated for at least one week prior to transfer and use in the growout ponds. If the farmer has no reservoir, the procedure is completed directly in the growout ponds. Reservoirs and culture ponds are normally situated in close proximity so that a simple lift pump could transfer the water to the ponds. During water transfer a fine mesh filter at the outlet of the pump was used to prevent the transfer of debris, predatory fish, and excess plankton.

In the 1997/1998 and 2004 field studies, shrimp farmers claimed that seasonal water quality differences affected their decisions regarding water preparation for shrimp culture. During the dry season period from January to June, for example, shrimp farmers reported that there is usually a water deficit and that water quality is poor. During this time, some farmers are not able to cultivate shrimp. However, during the rainy season from September to December, farmers reported that they could stock their reservoirs and growout ponds from precipitation. In some locations, there are problems with flooding by excess surface water. When floods are anticipated, some farmers do not culture shrimp. Others, with crops in the pond, erect PVC plastic fences along the pond edges as a barrier to prevent the shrimp from escaping.

5.2.8 Growout and Harvest

Previous studies have reported that the duration for a typical growout in intensive shrimp culture systems is between 100 to 120 days post stocking (Funge-Smith and Briggs, 1998). After 120 days of growout, there is an increased probability that stressful conditions, slow growth, and disease outbreaks will occur. In the 1997/1998 and 2004 field studies, the duration of a typical growout in low-salinity culture was found to be similar to established limits. In 1997/1998, the mean growout for low-salinity shrimp culture systems was about 118 days, while the maximum was 150 days and the minimum was 80 days. In 2004, the mean growout was about 112 days, while the maximum was 140 days and the minimum was 90 days. A MWU test confirmed that there was a significant statistical difference in the duration of the growout periods in the 19971/998 and the 2004 field studies (p=0.0099).

The harvest strategy of most farmers, if there are no disease events, is to quickly extract the shrimp from the growout ponds in good condition when they reach market size, and, if possible, when prices are high. Farmers closely monitor the size of their shrimp and check market prices daily. Commonly, the harvest occurs when the shrimp stop feeding or when the farmers observe that they are no longer growing. Harvesting is labour intensive. It may be completed as a single operation or spread over several days. It is usually timed to coincide with the middle inter-moult stage so as to reduce shell damage and water loss. Low-salinity shrimp farmers have also stated that they have been conducting earlier harvests of smaller sized shrimp to improve the cash flow, save feed costs, and reduce the risk of a complete loss due to disease. The practice of conducting earlier harvests was first documented but not common during the 1997/1998 field studies. In 2004, this practice was found to be an established harvest strategy. Shrimp farmers reported that shrimp health decreased and associated development risks increased because of the shrimp's exposure to decreasing salinity levels. Growout continued until the first signs of disease appeared when the crop was immediately harvested and could still be marketed, but at lower quality and for a much lower price.

The harvest is carried out by attaching a net to the pond outlet and opening the pond to this net. To expedite the harvest, the pond water level is reduced several hours prior to the harvest. The opening is periodically closed and the net is emptied. Shrimp are continuously transferred from the tail end of the net and are placed on ice in large plastic containers. Each container holds around 25 kg of shrimp. The shrimp are then transported to a sorting area in the shade where they are also washed and weighed. Harvesting teams normally comprised only of women separate the shrimp according to size (Figure 5.13). Smaller single pond operations drain the pond water using a lift pump with a mesh to prevent shrimp from being removed while the farmer uses a cast net to remove the shrimp. When the pond is fully drained, both methods require the remaining shrimp to be manually gathered from the pond substrate. These shrimp are usually dirty and must be carefully washed before they can be sorted.

Marketing shrimp at a profitable margin is affected by many factors, most beyond the control of individual shrimp farmers. Consumer preferences for shrimp size and product forms determine what sells. Small farms do not have sufficient volume to sell directly to the markets or processing plants. Most sell their crop pond side to middlemen on harvest day. Usually, shrimp farmers receive a good price for their shrimp crop because there is competition amongst the middlemen for the purchase. The middlemen use a freezer truck to transport the harvest to the major shrimp markets or directly to the processing plants in the Maha Chai area of Samut Sakhon province. This process repeats itself on a daily basis throughout Chachoengsao, as the middlemen fill shrimp quotas by purchasing various lots of shrimp. Since the bulk of Thailand's farm-raised shrimp production is exported, the processing activities include cleaning, grading, preparing, packaging, and freezing in compliance with importing country health and sanitation requirements. Final product forms include whole or headless shrimp that are individually quick frozen or frozen with water into 2-kg blocks. Cooked shrimp and a broad range of value-added processed forms are also produced. A very small amount of cultured shrimp is sold live in the Japanese market.

Figure 5.13 Harvesting Team Sorting the Shrimp

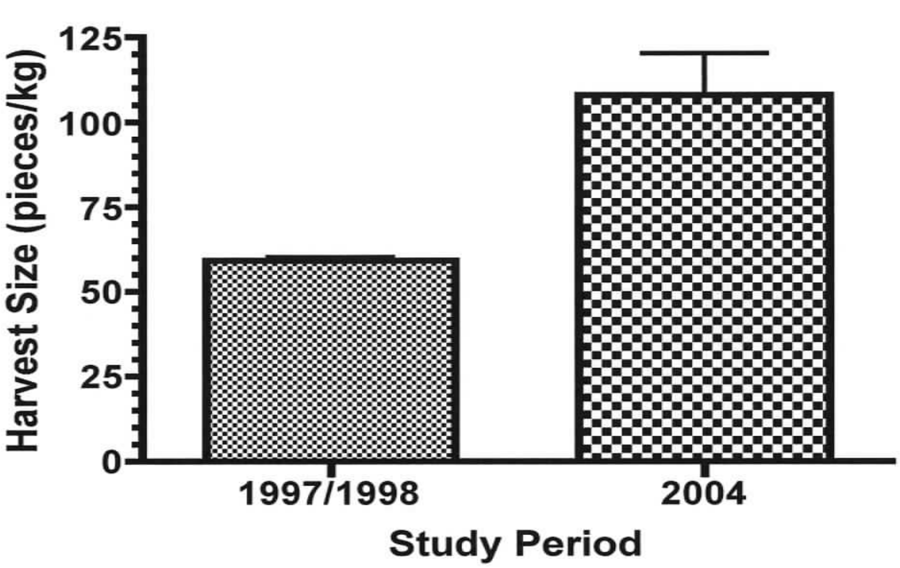
Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

Shrimp cultivated in a low-salinity environment are reported by some middlemen purchasers to taste and look different from shrimp grown in marine waters. Dissolved organic matter may be responsible for imparting an unpleasant odor and taste to the shrimp flesh (Laubier, 1990). Inland shrimp feed on some amount of freshwater blue-green algae that may impart a "muddy smell" or poor taste to the shrimp. However, the 1997/1998 and 2004 field surveys recorded no instances where the quality of shrimp produced in low-salinity resulted in market differentiation of the product at the farm level. Daily shrimp prices are based on a set amount of money per kilogram. Higher prices are set for larger sized shrimp. There are no price differences for shrimp produced in low-salinity between shrimp produced in coastal shrimp farms. Although some middlemen try to use these product perceptions in order to buy low-salinity shrimp at a lower price, coastal and inland shrimp are processed in the same stream regardless of pond origin (Miller, 1999). Processors sell shrimp on a size/weight basis and shrimp from coastal and inland sources are mixed if of the same size. This makes it difficult to calculate the contributions of inland shrimp farms to national production figures. Information from several processors indicates that an increasing amount of their daily shrimp inventory processed is derived from inland shrimp farms.

In 1997/1998, the mean size of the harvested shrimp was about 59 pieces/kg, which equates to an individual weight of around 17 grams. The harvest range of 35 to 90 pieces/kg corresponded to individual shrimp weights of around 29 to 11 grams respectively. In 2004, the mean size of the harvested shrimp was about 108 pieces/kg. In Bang Pakong district, one farmer reported an individual shrimp harvest size of 650 pieces/kg, which was exceptionally high. However, the farmer had calculated that he could make a profit with this small size of shrimp so he decided to harvest. Farmers harvested the shrimp as soon as they could find a market for them and at a price that allowed them to make a profit. Overall, the mean size of shrimp at harvest in the 1997/1998 and 2004 field studies was quite small compared to earlier conventional harvests of 30 pieces/kg in coastal shrimp farms.

A MWU test was used to analyze the data for the harvested shrimp size in the 1997/1998 and 2004 field studies. A significant difference was found between the 1997/1998 and the 2004 field studies ($p<0.0001$) (Figure 5.14). In 2004, the size of the shrimp at harvest was much smaller than the size of the shrimp at harvest in the 1997/1998 field studies. This trend towards harvesting smaller sized shrimp is a reflection of farmers harvesting earlier to reduce risk and to save feed costs, and responding to changing consumer preferences for smaller sized shrimp. In 2004, farmers reported that there is now a market for smaller sized shrimp, a trend that benefits farmers who prefer to harvest earlier.

Figure 5.14 Box Plot Comparison of the Mean Harvest Size of Shrimp (pieces/kg) in the 1997/1998 and 2004 Field Studies ($p<0.0001$)



5.3 Farm Management and Growout Problems

In the 1997/1998 and 2004 field studies, shrimp farmers reported that success in low-salinity culture was contingent upon adherence to predetermined management practices (often directly duplicating neighboring farm procedures), the acquisition of intuitive faculties, improved observation skills and an understanding of the local conditions. Farmers emphasized that information from scientific papers and books frequently did not correspond with preferred practice. At the farms, there was little evidence of established formulae or rules. Farmers often expressed pride in developing solutions to culture problems independently and without external assistance. Generally, once the desired environmental conditions in the ponds were established, the farmer worked to maintain the ponds in a stable state. Abrupt changes in established growout procedures were avoided unless there was a specific need that required immediate intervention like rapidly declining water quality, excessive phytoplankton bloom, low dissolved oxygen or the onset of disease.

As much as farmers endeavor to maintain a stable pond environment, this condition is usually not possible in intensive culture. Managing the pond environment is difficult and requires procedures that are flexible, especially during the latter stages of growout. Farmers indicated that only management practices that were adaptable to changing conditions worked. Their decisions regarding water exchange, feeding, aeration and water circulation were usually based on direct observation. Subsequent management decisions were influenced by a number of internal and external conditions including the shrimp size, biomass, shrimp behavior, time of day, atmospheric and climatic conditions, water colour, appearance, thickness and viscosity of the pond water, and other parameters. The shrimp crop represented a significant capital investment, and at a typical inland shrimp farm the ponds were monitored closely throughout the day and until late in the evening, sometimes overnight, seven days a week.

5.3.1 Freshwater Management

Low-salinity shrimp farmers employed various methods to acquire, move and otherwise manage freshwater. In 1998, shrimp farmers indicated that when freshwater is transferred into the ponds the water chemistry changed, and that this process had the potential to adversely affect the shrimp. The common view was that water exchange often created more problems than it solved. For this reason, shrimp farms generally operated as water conserving operations in order to minimize freshwater requirements. Water exchanges, if necessary, were always gradual and undertaken with caution. In the 1997/1998 and 2004 field studies, farmers reported that they acquired freshwater from two main sources: canals directly connected to a river or from the main and tertiary irrigation canals (Table 5.11).

The 1997/1998 field studies found that 15 of the 86 shrimp farms surveyed had constructed private access to irrigation canals to withdraw freshwater directly to their ponds and/or reservoirs. Shrimp farmers were not aware how these alterations affected the overall performance of the irrigation systems. However, rice farmers and other agriculturists reported that shrimp pond development had noticeably reduced the quantity and quality of freshwater supplies. It was also found that shrimp farmers had in some locations appropriated the irrigation water source exclusively for their shrimp ponds. Further, shrimp farmers in some areas reported that they were waiting for water to be let into the irrigation canal and that the irrigation canals are not always able to meet their water requirements. Water allocation from the irrigation systems, determined by the local designates of the Royal Irrigation Department, does not account for the withdrawals by inland shrimp farming.

Table 5.11 Principal Sources of Freshwater

	1997/1998		2004	
	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Canal connected to river	34	39.5	3	6.0
Irrigation canal – direct	37	43.0	46	92.0
Irrigation canal – constructed private access	15	17.5	1	2.0
	86	100	50	100

In the 1997/1998 and 2004 field studies inland shrimp farmers reported several water quantity problems. Shrimp farmers are tied to freshwater irrigation systems. The distribution schedule is always designed to fit the needs of rice farming. The timing of water releases to the canals may not fit the needs of shrimp farmers. Regardless, freshwater is readily available in the rainy season and in most locations during the dry season. Shrimp farms face similar problems as rice farmers in the dry season. In some locations, water is not always available and operations are forced to stop until freshwater arrives in the irrigation canals. In other situations, there is too much water (i.e., rainy season flooding).

Freshwater quality influences water exchange rates. Inland shrimp farmers prefer to reduce their water intake from external sources as much as possible, and typically add less water during the latter stages of growout. If the water quality is good, farmers do not exchange water. Farmers report that water quality in the supply canals or reservoirs is often of lower quality than the water in their ponds. Some inland shrimp farmers try to operate the ponds as low water exchange systems believing that water exchange triggers disease outbreaks. Evidence suggests that the viral disease yellow head is transmissible in water and that white spot disease is introduced by crustacean intermediates during water exchange (Funge-Smith and Briggs, 1998). Inland shrimp farmers also use low water exchange systems as means of protecting the shrimp from external sources of water pollution and conserve the pond salinity levels. With saline water trucked in at the beginning of the culture period, freshwater is only added during growout to increase the pond water depth and to offset water losses due to evaporation and seepage. Depending upon the pond location, seepage losses can be significant.

The annual water requirements of aquaculture ponds depend on soil conditions, environmental factors, species cultured, and the culture and harvest methods. In order to determine the overall freshwater requirements during the growout, shrimp farmers were asked during the 1998 field season how often they added freshwater to the shrimp ponds. To answer this question, most farmers indicated what depth of freshwater they added over a set period of time, most weekly. The format of farmer responses includes the prevailing seepage rates of the pond soils and evaporation losses. In 1998, inland farmers used 15,000 m^3 of freshwater per ha over the standard growout of 120 days. The value would be doubled over the year as most farmers cultivate at least two crops of shrimp, one during the dry season and one during the wet season. Over the 36 shrimp farms sampled in 1998, the lowest reported value was 4,500 m^3 per ha and the highest reported value was 51,000 m^3 per ha. The latter value is attributed to high seepage rates and an individual farmer preference for higher water exchange. For the low water use value, the shrimp farmer managed without the need to exchange water as often. While this study did not investigate water addition rates over a long period, the consistency of responses is sufficient to develop a reasonable estimate of freshwater use. The rates determined in this study are consistent with previous detailed examinations of water use in inland shrimp farming sites (see, for example, the results reported by Ponza, 1999; Braaten and Flaherty, 2000).

All of the low-salinity shrimp farmers acknowledged that the use of reservoirs is a good management practice. The use of reservoirs is strongly encouraged in the Thai *Code of Conduct for Marine Shrimp Farming*. Statistical analysis was used to compare the survey data regarding several aspects of freshwater management in the 1997/1998 and 2004 field studies (Table 5.12). In 1997/1998, 78 out of 86 respondents (91%) indicated that they used a reservoir for the storage and treatment of freshwater. In 2004, 39 out of

50 respondents (78%) reported using a reservoir. A Chi-Squared test of independence was performed to examine the relationship between reservoir use in 1997/1998 and in 2004. The relation between these variables was not significant (p=0.0714).

Table 5.12 Results of Chi-Square Analysis of Freshwater Management Practices for the 1997/1998 and the 2004 Field Studies

	1997/1998 (N=86)				2004 (N=50)			
	Yes	Percent (%)	No	Percent (%)	Yes	Percent (%)	No	Percent (%)
Use reservoir [a]	78	90.7	8	9.3	39	78.0	11	22.0
Willingness to pay for freshwater? [b]	24[c]	66.7	12	33.3	2	4.0	48	96.0

a. Chi-Square = 3.251, p=0.0714

b. Chi-Square = 37.447, p<0.0001

c. The question regarding willingness to pay for freshwater was added in 1998, so for this question the sample number was 36 farms in 1997/1998. In 2004, sample was 50 farms.

In 1998, 24 of the 36 respondents (67%) indicated that they would be willing to pay for freshwater. They were willing to pay for their fair share and specified that other activities should also be required to pay for freshwater. In 2004, however, the willingness to pay for freshwater had markedly declined. Only 2 out of 50 farms (4%) of the farmers reported that they were willing to pay for freshwater. A Chi-Squared test of independence was performed to examine the relation between the 1998 and 2004 field studies in regard to willingness to pay. There was strong evidence of a significant finding (p<0.0001). In other words, farmers surveyed in 2004 were not willing to pay for freshwater.

5.3.2 Water Quality Management

The survival and continued growth of a shrimp crop is dependent on the maintenance of the physico-chemical characteristics of the pond water within preestablished parameters. As the growout progresses, pond water quality deteriorates and parameters such as nitrite, ammonia, pH, silicon, phosphate, BOD and turbidity increase to higher levels than external sources. Farmers reported that water quality changes as soon as water is added to the pond and the shrimp larvae are released into the ponds and start feeding. The rate of change depends upon stocking density, water source quality, feeding rate, water exchange, local soil conditions and overall farm management. Shrimp farmers report a number of water related management problems including lack of water (i.e., seasonal or supply canal constraints), flooding, and exposure to pathogens and environmental pollutants (i.e., rice farming pesticides).

Water quality is a serious concern for all inland shrimp farms, regardless of size. In the 1997/1998 field studies, 56 of the 86 farms (65%) surveyed reported water quality problems. In 2004, 35 out of 50 farms (70%) surveyed reported water quality problems. A Chi-Squared test of independence was performed to examine the relation between the 1997/1998 and 2004 field studies. There was little evidence of a significant finding (p=0.7621).

Table 5.13 presents the water quality problems reported in the 50 farms surveyed in 1997. Most of the problems occurred during the rainy season and the most frequently reported problem was plankton blooms. The usual response to a plankton bloom was to apply calcium hypochlorite at a rate of 3 to 6 kg/ha, net the plankton out of the pond by hand, and filter the water released from the pond. The plankton species most affecting inland shrimp farming was *Zoothamnium*, and the farmers indicated that one solution was to raise pond salinity. Respondents with coastal shrimp farming experience indicated that the problems with plankton are more severe in low-salinity operations. A small number of farmers stocked fish in their inactive ponds and reservoirs to assist in water treatment. A relatively large number of shrimp farmers (32%) reported that they did not know the source of their water quality problems. In situations where the farmers could not diagnose the problem, they were uncertain as to what management practices should be used.

Table 5.13 Water Quality Problems in Low-Salinity Shrimp Farms, 1997

Problem	Number of Farms (N=50)	Percent (%)
Plankton density (too high [bloom, toxic] / too low [crash])	14	28.0
Wastewater (shrimp farms, industry, agriculture, disease)	11	22.0
Water quality (high ammonia, high pH)	5	10.0
Disease (contamination, slow growth)	4	8.0
Did not answer or don't know	16	32.0
	50	100

Most shrimp farms self-pollute their water supply canals with shrimp farm effluent. The water supply to the shrimp farm is also polluted with wastewater from other shrimp farms, and with domestic, industrial and agricultural wastewater draining through the central region and surrounding watershed areas (Miller, 1996). Farmers report that the increased development of industry and other agricultural activities around their farms has increased the severity of the water quality problems. The effluent discharged from swine slaughterhouses and alcohol beverage factories affects many of the water sources around Chachoengsao shrimp farms (Szuster and Flaherty, 2002). This water pollution combined with the intensification of culture methods potentially leads to deterioration in pond water and soil quality, resulting in stress in the shrimp, disease outbreaks and high mortalities.

Shrimp farmers reported that water pollution is a major problem. There has been relatively little success in reducing let alone in eliminating anthropogenic sources of pollution as they are by and large from 'non-point sources'. The identification of responsibility is difficult given the large number of possible offenders. Moreover, the receiving waters are still regarded by shrimp farmers as limitless absorbers of wastes from various activities. Although little is known about the quality of the hyper-saline water delivered to the shrimp ponds, the majority of "water concentrating" operations and saltpans are located in heavily polluted areas. The water delivered to the shrimp farmers could contain a large number of potentially harmful substances.

Shrimp farmers claimed that rice farmers use a significant quantity of herbicides and pesticides, most having been rice farmers themselves. Although lacking quantitative information, farmers are aware that insecticide and herbicide residues from nearby agricultural operations could adversely affect shrimp health. Most shrimp farmers do not have the capability to measure the levels of pollutants in the water supply. However, over time shrimp farmers have adopted simple methods to gauge the severity of pollutants. They routinely observe the viability of fish in the canals prior to the intake of water. Water is seldom drawn directly into an active growout pond, but is stored onsite and treated prior to use. Several shrimp farmers opined that the pollutants from rice farming are so excessive that rice farming should cease so that shrimp farming can continue.

Although unrealistic, the sentiment of shrimp farmers is one indication of the increasing tensions between rice farming and shrimp farming.

Rice farming pesticides are a major concern to low-salinity shrimp farmers for several reasons. Shrimp are closely related biologically to insects and are vulnerable to insecticides throughout their life cycle. Miller (1996) found that the levels of organic contaminants detected in the intensive and extensive shrimp ponds showed similar or higher levels to those detected in the water supply canals. Organic contaminants were ubiquitous and culture ponds for shrimp were not impervious to the effects of agriculturally derived contaminants. In Samut Sakhon province, higher heptachlor values were recorded in an intensive shrimp pond adjacent to agricultural activities (Miller, 1996). Higher DDT values in the extensive shrimp pond were attributed to the high values detected in the canal directly supplying the pond. Miller (1996) notes that all types of shrimp culture systems, from extensive to intensive, receive contaminants via the water supplies, and suggests that contaminated water sources in the Upper Gulf region are a factor behind the trend of relocating inland or out of the region.

The 1998 and 2004 field studies investigated the level of concern among shrimp farmers over pesticide residues (Table 5.14). In 1998, 65 of the 86 farms (76%) reported concerns about the risks of shrimp crop exposure to pesticides used by rice farmers. Only 5 farms out of 86 reported that they had tested for pesticide residues. In 2004, 30 out of the 50 shrimp farmers (60%) reported that they were concerned about pesticide residues. Only 11 farms out of 50 reported that they had tested for pesticide residues. In 1998 and 2004, although concern over pesticide residues was high, none of the shrimp farms possessed the skills or expensive testing equipment needed to determine residue levels. A Chi-Squared test was used to compare the data regarding pesticides collected in the 1998 and 2004 field studies. The findings were significant in regard to concerns about pesticides (p=0.0517), and in regard to whether the farmers had tested for pesticides (p=0.0136).

Table 5.14 Results of Chi-Square Analysis of Water Quality Management for the 1997/1998 and the 2004 Field Studies

	1997/1998 (N=86)		2004 (N=50)		Chi-Square	P value
	Yes	No	Yes	No		
Concerned about pesticides?	65	31	30	20	3.785	0.0517
Test for pesticide residues?	5	81	11	39	6.091	0.0136

5.3.3 Aeration

Low-salinity shrimp farms used aeration in the acclimatization pens, growout ponds and in the reservoirs during water conditioning procedures. In the growout ponds, accumulated feed was a major problem and aeration was used to increase dissolved oxygen in the water column and expedite the biological breakdown of metabolic and accumulated feed waste (Figure 5.15). Generally, the number of aerators used increased as the stocking density increased. Aerator use is matched to the growth and respiratory requirements of the shrimp. Shrimp farmers used roughly six aerators per ha of culture area (i.e., one aerator per rai). To stabilize water conditions, aerators were used in the growout ponds two days before stocking. Aeration was reported to be critical during the first day that the PL were introduced to the acclimatization pen. During this period, the aerators were run at slow speeds to ensure optimum dissolved oxygen levels and to maintain uniform salinity in the pen. Most shrimp farmers indicated that after a full day of aeration in the acclimatization pen, aeration was generally not used again until the 2-month mark in the growout. This corresponds with reduced dissolved oxygen levels that result from the high feeding rates. After the 2-month mark, aerators were usually run continuously at full speed.

Low-salinity shrimp farmers did not restrict the use of aerators due to costs. Aerators were often operated at night and on rainy or cloudy days. Aeration prevented salinity stratification during freshwater addition. Aeration was also used when the crop succumbed to disease, water quality decreased or to increase dissolved oxygen levels during a plankton bloom. Aerators were positioned to create a pond water circulation pattern that moved the majority of accumulated sediment to areas where it could be siphoned out of the pond. Generally, farmers preferred to move the sediments to the pond center where the shrimp tended not to congregate. Outside of the culture ponds, strong aeration was used in the reservoirs during the water treatment period preceding the pond water stocking.

Figure 5.15 Large Low-Salinity Shrimp Pond with Aerators

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

The type of aerators most commonly used were the conventional 6 to 8 paddle wheel type that were gear driven from small stationary diesel tractor engines on the pond edges. The stationary engines were modified from rice farming tractors. In Chachoengsao province, some farms used simple non-mechanical blower-type aerators configured to deliver low-pressure air to the pond bottom through a network of pipes and tubes. Although not used in most inland pond systems, this type of aeration was commonly used in hatcheries and at shrimp farms with deep ponds to reduce temperature stratification. The limited application in shrimp farms related to the high initial costs and the need to remove parts of the system prior to harvest.

5.3.4 Feed Management

Feed management is an important aspect of successful shrimp production. Shrimp feed is one of the main inputs to the system accounting for 45 to 50% of the operating cost in intensive systems. Inland shrimp farmers use the same high quality commercial feeds utilized in coastal shrimp farming. There are many varieties of commercially formulated feeds on the market. In Thailand, Charoen Prokphand is the major feed manufacturer and distributor to local suppliers. Local suppliers provide all of the feed for larval to growout stages. Feed and chemical salespersons have experienced a renaissance in catering to the inland shrimp farming. Distributors of feed and chemical products easily adjusted to, and contributed to the growth of, inland shrimp farming. Financing schemes and access to credit for feed purchase are in place at the local level. Suppliers also provided marketing information on the feed and markets trends, and acted as consultants on chemical application and disease control.

The basic principle in feeding is that the shrimp should be fed exactly to satiation. If they are fully fed, the shrimp are not stressed and they will be less susceptible to opportunistic pathogens. This requires the farmer to have the skills to estimate how much feed is needed. Farmers reported that proper feed management minimizes pond bottom deterioration and maintains productive pond water quality. When yields fell short of expected, it was common for shrimp farmers to blame water quality, feed, PL, and diseases. In many cases, however, the reason for production problems was poor feed management. The 1997/1998 and the 2004 surveys found that both over- and underfeeding resulted in water pollution, higher incidence of disease, higher feed conversion ratios, reduced survival, and poor product quality. Ideally, feeding regimes should vary according to pond environmental factors and the condition of the shrimp crop.

Feed management affects overall production and is linked to the feed conversion ratio (FCR). The FCR is calculated from the number of kilograms of feed that are used to produce one kilogram of whole shrimp. Farms reporting a low FCR normally have good management practices in place, with no overfeeding and very low, if any, mortalities.

Shrimp grow fast in low-salinity systems and some analysts report that the feed conversion ratio can be as low as 1.3 to 1.4 (Funge-Smith and Briggs, 1998). In 2004, several of the shrimp farming operations reported feed conversion ratios ranging from 1.31 to 1.47. Most farmers do not know the exact feed conversion ratio for their crops. They know that overfeeding or underfeeding will increase the FCR, and simply focus on closely monitoring feed consumption on a day-to-day basis. Most farmers based their feed inputs on a schedule received from the feed agent.

In Thailand, all shrimp farmers broadcast feeds from the pond bank or from small boats. Then they lower feeding trays — small (about 1/2 square meter), circular or rectangular, mesh-bottomed baskets containing feed — into the pond to monitor consumption and estimate the standing crop in the ponds. Regular monitoring and estimation of shrimp biomass was not usually carried out as long as the shrimp appeared to be healthy. This contrasts with the feeding practices commonly used in some countries such as Brazil, Guatemala, and Mexico where feeding trays are placed throughout the pond to feed the shrimp crop. Although labour, construction, and equipment costs are higher with this technique, feed conversion ratios are much lower as more of the feed is consumed. Feeding trays offer the following advantages: less pollution and cleaner pond bottoms, reduced stress, fewer disease problems and faster growth, reduced pumping and aeration costs, controlled administration of medicated feeds and many others. Thai shrimp farmers do not use the latter types of feeding trays because of the added costs for labour, construction and equipment. Further study on how to introduce these systems into Thailand is required.

5.3.5 Waste and Effluent Management

The wastes and effluents from inland shrimp ponds are mainly composed of uneaten food, fecal and urinary wastes, principally consisting of organic solids and dissolved organic and inorganic nutrients, such as nitrogen and phosphorus. Studies of the nutrient and solids budgets of Thai intensive shrimp ponds report that the solids discharge of effluent organic matter was 4.8 tonnes per ha and total solids of approximately 12.6 tonnes per ha (Funge-Smith and Briggs, 1998). Excessive nutrients and organic matter result from overfeeding, and eventual pond discharges to inland waters in large volumes create a situation in which the loads exiting the shrimp farms may exceed the capacity of the receiving waters. Organic wastes, as pollutants are much like nutrients in that once they enter aquatic waters, little can be done to lessen their effects (Funge-Smith and Briggs, 1998).

The nature of accumulated pond sediment is dependent upon the culture intensity, pond salinity levels, pond soil organic content, and water exchange practices. In the 1997/1998 and 2004 field studies, the farmers indicated that inadequate cleaning between crops leaves organically enriched sediment on the pond bottom. Due to its non-compacted nature, the sediment is easily suspended by the action of aerators during the next production cycle if it is not removed. Organic matter released from the sediment tends to stimulate very heavy plankton blooms in the first month of production. For this reason, old ponds in Thailand are rarely fertilized to stimulate a phytoplankton bloom.

In 1997/1998, 55 out of 86 farms (64%) indicated that they used an effluent treatment pond. In 2004, 27 out of the 50 farms (54%) indicated that they used an effluent treatment pond. Statistical analysis was used to compare the waste and effluent management practices of low-salinity shrimp farms surveyed in the 1997/1998 and 2004 field studies. The results are summarized in Table 5.15. The findings suggest that there little evidence of a significant finding in regard to use of an effluent treatment ponds (*p*=0.2653) and in the removal of sediment between crops (*p*=0.1223). However, the was analysis found a significant finding in regard to the treatment of effluent prior to discharge from the shrimp farm (*p*=0.0584).

Table 5.15 Results of Chi-Square Analysis of Waste and Effluent Management for the 1997/1998 and the 2004 Field Studies

	1997/1998 (N=86)		2004 (N=50)		Chi-Square	P value
	Yes	No	Yes	No		
Do you use an effluent treatment pond?	55	31	27	23	1.289	0.2653
Do you treat effluent before discharge?	53	33	22	28	3.841	0.0584
Do you remove sediment between crops?	33	53	40	10	2.387	0.1223

Table 5.16 reports the number of inland shrimp farms that removed accumulated sediment in the 1998 and the 2004 field studies. There was a slight decrease in the number of farms that reported removing accumulated sediment from the shrimp ponds after harvest between the initial and final field studies. In 2004, it had become more common for farmers to only remove sediment after several crops – as opposed to after every crop. Between crops where they do not remove sediment they tilled the soil and let oxidation do its work. In 2004, farmers reported that this management practice saved a significant amount of time and labour and allowed for a quicker transition to the next crop. Farmers treated the tilled sediment that was left in the pond with large quantities of lime.

Table 5.16 Sediment Removal from Low-Salinity Shrimp Ponds

	1998		2004	
Response	No. of Farms	Percent (%)	No. of Farms	Percent (%)
Yes	30	83.3	40	80.0
No	5	13.9	10	20.0
Did not answer	1	2.8	0	0
	36[a]	100	50	100

a. The question pertaining to the removal of sediment after every crop was not asked during the 1997 field study.

5.3.6 Use of Chemicals and Chemotherapeutants

In 1998, low-salinity shrimp farmers reported using over 40 chemical and biological preparations during growout. Some of the chemical products used by farmers and their primary uses are listed in Table 5.17. Many others were available in the market at the time of the study. A few are considered standard inputs, but many are new to Thai aquaculture, mostly imported commercial aquaculture products or compounds used in the sewage treatment industry. Shrimp farmers and hatchery operators often change the number, amount and frequency of the chemical applications during growout.

The use of chemicals in shrimp production raises the issue of proper use. Incorrectly administered chemical treatments can potentially kill the crop, which would increase the chances of farm failure for smaller operations. For pest control chemicals, such as potassium permanganate, the effect of misuse can be drastic; most farmers had learned to use this substance properly. For most chemicals, however, the results of misuse are largely unseen. Some farmers reported having witnessed toxicity problems to their shrimp crops from chemicals administered in neighboring shrimp ponds. Hatchery operations also use a large number of chemicals, especially antibiotics. Antibiotics are widely and extensively used in crustacean hatchery management of bacterial disease. Commercial shrimp feeds have antibiotics included, and represent the major input of antibiotics to shrimp pond systems.

Table 5.17 Chemicals and Chemotherapeutants Used at Low-Salinity Shrimp Farms, 1998

Chemical Group	Use
Oxytetracycline Chloramphenicol Benzalkonium chloride Iodine Potassium permanganate Formalin Malachite green	Therapeutants and disinfectants (Antibiotics and antibacterials)
Bacteria + enzyme preparations "EM" – Effective Microbial	Organic matter decomposers (Probiotics)
Copper compounds	Pesticides and algicides
Inorganic fertilizers Organic fertilizers	Plankton growth promoters
Vitamins and minerals	Feed additives

The field survey documented whether the shrimp farmer used chemicals in shrimp culture. In 1997/1998, 67 out of 85 shrimp farms (79%) of the shrimp farmers reported that they used chemicals. In 2004, 13 out of 50 shrimp farms (26%) of the shrimp farmers reported that they used chemicals.

5.3.7 Disease

Losses due to disease are a persistent problem in shrimp aquaculture. Farmers acknowledged that disease couldn't be completely prevented, but also believed that the incidence of disease could be greatly reduced. Most disease control programs emphasize pathogens like microbiological diagnosis, vaccine development and chemotherapeutant treatment. However, poor water quality and inadequate nutrition are often the basic determinants of disease outbreaks (Sindermann and Lightner, 1988). Experience has shown that management of the pond environment is the most important factor for disease prevention in shrimp farming (Flegel, 1996). Intensive shrimp farms produce large quantities of waste and experience serious disease and mass mortality triggered by water-borne disease (Thongrak et al., 1997).

The 1997/1998 and 2004 surveys found that there is contradictory information regarding disease problems in low-salinity shrimp farming. Several authors have reported that disease in low-salinity shrimp farming is not as prevalent as coastal shrimp farming (Kongkeo, 1997; Plodprasop, 1997). Other studies, however, have shown that shrimp culture in low-salinity causes physiological stress in shrimp and lowers their tolerance to pollutants, indicating that toxicants in combination with environmental factors may act synergistically (Tedengren et al., 1988). In the 1997/1998 and 2004 field studies there were mixed feelings amongst the farmers on disease in low-salinity shrimp culture. A small number of respondents indicated that viruses kill the shrimp faster in higher salinity than in lower salinity. Most, however, felt that diseases are equally present in both coastal and inland operations.

Farmers generally do not like to speak candidly about production problems. Mortality and shrimp crop loss information is, therefore, scarce. To overcome this problem the survey questions focused on asking if the farmer had ever experienced problems with disease. Attention then shifted to the outcome of this event. Disease problems accounted for more production losses than any other problem reported by the farmers. In 1997/1998, 57 of 86 shrimp farms (66%) had experienced serious disease problems. In 2004, the field survey found that 36 of the 50 shrimp farms (72%) had experienced serious disease problems.

The 1997/1998 and 2004 field surveys also investigated the outcome of reported disease events (Table 5.18). In 1997/1998, more than 42% of the respondents had experienced total loss of the shrimp crop, and around 53% of these farmers received some money by harvesting early and receiving a lower price and lower production. In

2004, more than 35% respondents had experienced a total loss, while the remainder reported either lower or reduced production and lower price for their crop. In both the 1997/1998 and 2004 field studies, the respondents indicated that their first response to solving disease problems was through increased chemical and chemotherapeutant inputs.

Table 5.18 Results of Disease Events in Low-Salinity Shrimp Farms

	1997/1998		2004	
Result	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Total loss	24	42.1	13	35.1
Lower or reduced production	9	15.8	22	59.5
Lower or reduced price	2	3.5	-	-
Reduced price and reduced production	15	26.3	2	8.4
Harvest early	2	3.5	-	-
Recovered	2	3.5	-	-
Did not answer	3	5.3	-	-
	57	100	37	100

During the 1997/1998 field studies, biosecurity was a relatively unknown concept. In 2004, however, the field investigation found that farm-level biosecurity has become a very important issue for shrimp farmers. Unfortunately, while farmer awareness had increased substantially, only rudimentary procedures have materialized at the farm level. Shrimp farmers know that the mechanisms for horizontal disease transmission from pond-to-pond or farm-to-farm are birds and other animals, including humans. For this reason, it is common for farmers to try to shoot all of the birds that fly near the ponds. Some also install finely meshed nets around the periphery of the farm to deter the birds from landing in or near the ponds. Some shrimp farmers are hesitant to allow visitors to their farms for fear of introducing disease from another farm.

The high incidence of disease problems documented in the field studies, suggests that one of the contributing factors is poor biosecurity. This research found that some low-salinity shrimp farmers now routinely treat diseased pond water with heavy doses of chlorine prior to discharge to surrounding waterways. Despite these basic steps, the majority of shrimp farmers have not been able to minimize or eliminate exposure to disease vectors.

5.4 Profile of Low-Salinity Shrimp Farms and Farmers

The majority of low-salinity shrimp farms are family operations in which the entire household is committed to working on the farm. Most of the survey respondents were male. In 1997/1998, 85% of the shrimp operations were owner-operated in (Table 5.19). The median age of the shrimp farmers was 42 years in both the 1997/1998 and 2004 field investigations. Most respondents had also lived in the same district for a long time. In 1997/1998, the median length of time was 40 years. In 2004, the median length of time was 12 years. The reason for the latter is that many of these respondents had reported moving districts within Chachoengsao to commence shrimp farming. While they were long time residents of Chachoengsao province, they were new residents to the district where they operated their shrimp farm.

Most respondents had little or no prior experience in aquaculture. In 1997/1998, 57% of respondents had previously worked only as rice farmers and 21% had worked as orchardists. In 2004, only 28% of respondents had worked previously as rice farmers and 42% had worked as orchardists (Table 5.20). Orchard activity refers to the primary cultivation of mango, coconut and areca palm, and the maintenance of gardens for various crops and vegetables. Although the family would keep a small amount of the orchard products for themselves, most of these products were sold to the market for cash. Some respondents who had indicated rice farming as a previous primary occupation also maintained orchards.

Table 5.19 Age of Respondents and Length of Residence in This District (years)

Year	Question	Minimum	Maximum	Mean	Median	No. of Farms
1997/1998	Age	19	71	42	42	86
	How long lived in this district?	0.42	71	36	40	86
2004	Age	25	73	44	42	50
	How long lived in this district?	1	70	18	12	50

Many of the respondents with no previous aquaculture experience had developed skill in water management. However, they had less knowledge than former aquaculturists of how biological, chemical, and physical phenomena in the aquatic medium affected the metabolic processes of the shrimp. Farmers with previous experience in fish or shrimp aquaculture reported fewer difficulties in growout. Although few respondents indicated primary backgrounds in livestock, fish or shrimp culture, many had experience in fish or freshwater shrimp cultivation even though this was not indicated as their main previous occupation. As in many other parts of Thailand, Chachoengsao is undergoing a transition whereby people no longer depend upon rice farming as their sole source of income. Many respondents were engaged in more than one occupation.

Table 5.20 Main Occupation Prior to Low-Salinity Shrimp Farming

	1997/1998		2004	
Main Occupation	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Rice farming	49	57.0	14	28.0
Orchard or Garden (mango, coconut, sugar cane areca palm, rubber, and vegetables)	18	21.0	21	42.0
Livestock (pigs, chickens), fish culture, shrimp culture (coastal)	3	3.5	3	6.0
Other (trading, salesman, private company, government officer, general labour, factory worker)	13	15.0	12	24.0
Did not answer	3	3.5	-	-
	86	100	50	100

How respondents first learned about low-salinity shrimp farming is important, as information sources used by the farmer's plays a role in determining how the shrimp farms are managed. In 1997/1998, most of the respondents indicated that they had initially learned about shrimp farming by himself or herself or from a neighbor or relative with a shrimp farm. In 2004, the findings were similar (Table 5.21). Personal "learning experiences" usually involved attending training and information sessions provided by feed and chemical agents. The most readily used source to new farmers was direct observation and discussion with shrimp farmers, neighbors and relatives, and the commercial agents of feed and chemicals. Since most shrimp farmers have extensive informal education and low levels of formal education, most learned aquaculture techniques from the local experienced farmers.

Table 5.21 How Did You First Learn About Low-Salinity Shrimp Farming?

	1997/1998		2004	
	Number of Farmers	Percent (%)	Number of Farmers	Percent (%)
Personal experience	22	25.6	16	32.0
Neighbor, friend, or relative with farm	56	65.1	33	66.0
Seminar from company feed merchant	5	5.8	1	2.0
Did not answer	3	3.5	-	-
	86	100	50	100

Low-salinity shrimp farmers utilized several training and information sources (Table 5.22). The majority of farmers contacted indicated that seminars and information sessions were their primary methods of training. Seminars were regularly scheduled events and were provided by industry agents free of charge. If the seminar participant decided to undertake shrimp farming, the agent would sell them the supplies and equipment that were needed.

Table 5.22 Shrimp Farming Training and Information Sources

	1997/1998		2004	
Training Source	Number of Farmers	Percent (%)	Number of Farmers	Percent (%)
Seminars from industry agents	46	53.5	26	52.0
Government Extension	-	-	4	8.0
Combination (industry agent, government extension, education)	8	5.8	5	10.0
Did not answer	1	1.2	-	
Did not receive aquaculture training	31	36	15	30.0
	86	100	50	100

Thailand has one of the strongest institutional support systems for aquaculture in Asia. The government has a well-organized research and extension system with facilities in nearly every coastal province. Despite a professional, relatively well-organized extension and research system, however, the 1997/1998 and 2004 field surveys found that low-salinity shrimp farmers had little contact with government officials from the fisheries stations. Of the 86 shrimp farmers interviewed in 1997 and 1998, only 8 reported contact with the DOF. In 2004, none of the respondents reported contact with the DOF. Assistance consisted of occasional farm visits by biologists to check pond water quality, with the frequency ranging from once per crop to once per year. Most shrimp farmers expressed mixed feelings about this lack of contact. One of the fears associated with contact with government agencies is increased regulation. On the other hand, some felt that they have not received assistance when required in order to solve disease or other growout problems. Others felt that they could benefit from increased contact with extension programs aimed at addressing shrimp farming problems. Shrimp farmers indicated that they are often the focus of negative criticism over their actions, and add that there are other activities in rural areas that deserve closer scrutiny (e.g., swine slaughterhouses and alcoholic beverage plants).

Despite some farmers indicating that they would likely benefit from extension programmes, most are reticent to speak to local government authorities, preferring anonymity. They adhere to a tradition of being reluctant to bother persons of higher status. Direct contact between the villagers and government representatives is also limited by the government agencies themselves. Many officials are hesitant to get involved with inland shrimp farming owing to the controversy over its operation in rice growing areas. For this reason, they have tended to turn a blind eye to its development.

The farmers reported many reasons for adopting low-salinity shrimp farming (Table 5.23). The main reasons were suitable location and high-income potential. A less frequently reported, but important reason, is failure in rice farming or other agriculture. There was not a significant change in the reasons for adopting low-salinity shrimp culture between the 1997/1998 and the 2004 field studies.

In 1997, 31 of the 50 shrimp farmers surveyed indicated that low-salinity shrimp farming had several advantages over coastal shrimp farming (Table 5.24). These included fewer disease problems in low-salinity than in high salinity, and water quality and plankton control is easier to manage. It was interesting that over 20% of the farmers felt that there were no advantages with low-salinity culture. In 2004, shrimp farmers provided similar reasons for adopting low-salinity culture. However, they all reported that they were experiencing growout problems, which seemed to outweigh the perceived advantages.

Table 5.23 Main Reasons for Adopting Low-Salinity Shrimp Farming

	1997/1998		2004	
Reason	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Suitable area; freshwater available all year	46	53.5	-	-
High income potential	28	32.5	28	56.0
Failure in rice farming or other agriculture (orchard); failure in fish farming	6	7.0	6	12.0
Other (no seawater source, good growth, less disease problems than high salinity culture, experiment by him/herself, no jobs, following community trend)	5	5.8	15	30.0
Did not answer	1	1.2	1	2.0
	86	100	50	100

Table 5.24 Perceived Advantages of Low-Salinity Shrimp Farming, 1997

	Number of Farms	Percent (%)
Less disease problems	5	10.0
Shrimp grow faster, good growth	7	14.0
No impact on the environment	3	6.0
Dependent upon the natural water conditions	1	2.0
Combination (culture easier than high salinity, water quality and plankton control easier, chemicals more effective, culture more than one crop per year)	15	30.0
No advantages	12	24.0
Did not answer	7	14.0
	50	100

5.4.1 Land Utilization and Farm Location

Low-salinity shrimp farmers demonstrated a detailed knowledge of the local land and water conditions, and some level of awareness to the potential environmental impacts of their activities. However, they have a low level of concern regarding the impacts of shrimp farming on the environment. Most concerns are focused at the farm level and are related to self-pollution. In regard to future plans for production area, 38 of 50 farmers (76%) surveyed in 1997 had no plans to increase production area. The reason is that most had already dedicated the majority of their land area to shrimp farming. All farms were operating intensively and production area was seldom sacrificed for treatment systems. This was most apparent in leased operations, but is also evident in comparing the large and small operations.

In most villages of Chachoengsao, the majority of rice farmers and mango orchardists have already converted a portion of their paddy or orchards to shrimp farms. Some of the rice farmers are considering switching to shrimp from paddy production. Most of the rice farmers indicate that paddy production declines when shrimp farming commences adjacent to their rice plots. A minority of the older rice farmers, however, has decided to continue rice farming despite the pressure to convert to shrimp. However, the consensus among most rice farmers is that they would eventually be shrimp farmers.

Chachoengsao is extensively irrigated for water intensive agriculture. Farm location was determined on access to the freshwater supply. Since saline water is delivered, freshwater availability is a limiting factor in the success of inland shrimp farming. The intensive practices used by inland shrimp farming necessitate an "intensification of water flow". The high cost of water transportation can be covered only by returns from the production of high value species such as shrimp, but not for the production of popular, low price, species such as common carp or tilapia.

5.4.2 Land Holding and Land Tenure

Most low-salinity shrimp farms are established on owner-occupier land holdings (Table 5.25). In 1997/1998, 56 out of 86 farms (65%) surveyed reported that they owned their land. Also, 26 out of 86 farms (30%) reported that they leased land for shrimp farming. In 2004, 37 out of 50 farms (74%) surveyed reported that they owned their land. Also, 13 of 50 shrimp farming households (26%) leased the land that they were using for shrimp farming. A Chi Squared test of independence was performed to compare land ownership between the 1997/1998 and 2004 field studies. The results indicate that the two samples are not significantly different (p=0.3174).

Chachoengsao has one of the highest rates of land tenancy in the central region at 28% (Amyot, 1994). The 1997/1998 and 2004 field studies found comparable rates of land tenancy for low-salinity shrimp farming. Although many farmers own land for rice farming, they prefer to lease the land for shrimp farming. Sometimes the leased land is in the same village and sometimes the land is in other locations. The respondents leasing land were either outside investors from Bangkok or younger farmers trying to make a living. These data reflect on the relative standing of younger shrimp farmers in the social structure. Most young Thai farmers face rising land prices associated with the growth of the greater Bangkok economy, which prevent small farmers from buying land. Shrimp farmers who lease land have little incentive to invest in infrastructure, while owners are more inclined to do so.

Table 5.25 Low-Salinity Shrimp Farm Land Ownership in Chachoengsao Province

	1997/1998		2004	
Lease or own	No. of Farms	Percent (%)	No. of Farms	Percent (%)
Owned	56	65.1	37	74.0
Leased	26	30.2	13	26.0
Combination (leased/owned)	3	3.5	-	-
Did not answer	1	1.2	-	-
	86	100	50	100
Chi-Square (2, N=135)=2.295, p=0.3174				

Thailand has a complex land tenure system. The highest form of land title is the *Chanode Thedin*, which represents an unrestricted land title deed and is similar to the fee-simple ownership system in North America. The types of land documents held by shrimp farm operators in Chacheongsao province are reported in Table 5.26. The most widely held land document in the study area was the land title deed. The high rate of private land ownership in Chachoengsao reflects the longstanding settlement and occupancy of the region for wet rice production. A Chi-Squared test of independence was performed to evaluate the land documents held by the farmers in the 1997/1998 and the 2004 field studies. Therefore, there was evidence of a significant finding (*p*=0.0385).

Landowners in Chachoengsao have owned land for many years (Table 5.27). In some cases, respondents indicated the land had been inherited from their parents, which was recorded, rather than in years. In 1997/1998, 18% of the respondents had owned their land for more than 30 years. In 2004, 44% of the respondents had owned land for 10 years or less. In 2004, all of the respondents owned land, and 13 out of 50 farmers also leased land for shrimp farming. A Chi-Squared test of independence was performed to evaluate the number of years of land ownership in the 1997/1998 and the 2004 field studies. The results indicate that the two samples were not significantly different (*p*=0.3174).

Table 5.26 Land Documents Held by Low-Salinity Shrimp Farmers in Chachoengsao Province

	1997/1998		2004	
Document	No. of Farms	Percent (%)	No. of Farms	Percent (%)
NS-4 (Chanod)	56	94.9	32	86.5
NS-3 (Nor-Sor-Sarm)	2	3.4	-	-
STK (Sor-Tor-Kor)	1	1.7	5	13.5
	59	100	37	100
Chi-Square (2, N=96)=6.512, *p*=0.0385				

Table 5.27 Number of Years of Land Ownership in Chachoengsao Province

	1997/1998		2004	
Time Period	No. of Farms	Percent (%)	No. of Farms	Percent (%)
0-10 years	14	16.3	22	44.0
11-20 years	13	15.1	11	22.0
21-30 years	5	5.8	11	22.0
More than 30 years	16	18.6	6	12.0
Inherited from parents	10	11.6	-	-
Did not answer	3	1.2	-	-
Not applicable	25	29.1	-	-
	86	100	50	100
Chi-Square (2, N=135)=2.295, *p*=0.3174				

5.4.3 Education and Experience

Most of the shrimp farmers had achieved Level 4 primary education (Table 5.28). A Chi-Squared test of independence was performed to evaluate the education levels of the farmers in the 1997/1998 and the 2004 field studies. The results indicate that the two samples are significantly different (p=0.0009). The farmers with higher levels of education were mostly younger outsiders who had started shrimp farming as a money making venture. The farmers with lower levels of education tended to be older locals, mostly former rice farmers. Many of the older rice farmer respondents do not want their children to grow rice for a living. They use any surplus income from shrimp farming towards the education costs of their children. In 2004, a higher number of respondents had diplomas or university degrees. These respondents were younger entrepreneurs who had studied aquatic sciences or animal husbandry, and were applying their education to shrimp farming. Most of these respondents had not worked as rice farmers except as children on their family farms.

Table 5.28 Education Levels of Low-Salinity Shrimp Farmers in Chachoengsao Province

	1997/1998		2004	
Education level	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Level 3	5	5.8	3	6.0
Level 4	49	57.0	15	30.0
Level 5	2	2.3	4	8.0
Level 6	14	16.3	10	20.0
> Level 6[a]	7	8.1	17	34.0
Did not attend school	9	10.5	1	2
	86	100	50	100

Chi-Square (4, N=126)=18.77, p=0.0009

a. This group consists of Level 7, Level 8, and those who obtained a university degree or diploma.

5.4.4 Financing: Debt and Sources of Loans

In the early 1990s, major bank support for new shrimp farming ventures contracted as most of the coastal marine shrimp farms failed after experiencing major disease losses. The 1997/1998 and 2004 studies found, however, that there are few impediments to procuring capital for low-salinity shrimp farm development. Shrimp farmers draw capital from a variety of sources (Table 5.29). As a significant cash outlay is needed to initiate a shrimp crop, most respondents borrowed money from a combination of private capital and local banks. Private capital was often procured by taking loans on the first crop from the local feed and chemical agents. In many instances, the feed required for the first crop is advanced with an agreement for repayment upon successful harvest. The economic position of the shrimp farmer is dependent upon a successful first crop.

Table 5.29 Sources of Finance Capital for Low-Salinity Shrimp Farming, 1997/1998 and 2004

	1997/1998		2004	
Source	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Foreign bank	6	7.0	-	-
Local bank	24	28.0	-	-
Private/own capital	23	26.7	39	78.0
Private/own capital + local bank	17	19.8	7	14.0
Local bank + loan from neighbor, relative	1	1.2	2	4.0
Private/own capital + shrimp feed agent	11	12.8	2	4.0
Does not know or did not answer	4	4.7	-	-
	86	100	50	100

In 2004, many of the shrimp farmers reported financial problems. The price of shrimp, whether black tiger or white, was extremely low, while the price of feed was extremely high. The quality of PL is poor – so growout survival is lower and the chance of disease is much higher. One farmer reported that she had lost money on the last crop and she remained in debt to the feed company. The farmer joked that she "*did not even have enough money to buy underwear after the last harvest.*" She had obtained the feed, and postlarvae, on credit from the feed company. The same company organized the harvest and the money from the harvest – because of the low farm gate price – was not enough to cover the debt. Although this farm was idle, she was planning on stocking shrimp again during the upcoming rainy season.

5.4.5 Farm Income

Table 5.30 and Table 5.31 present the data on harvest volumes and prices. In 1997/1998, shrimp farmers produced a median harvest volume of 3,000 kilograms during the most recent harvest. This would occur at least twice a year, although yields vary greatly between operations. Many farmers declined answering questions regarding harvest volume (16 of 86 farms in 1997/1998). Similarly, 17 of 86 farms in 1997/1998 would not report their most recent harvest price. In these cases, the respondent was either a family member who claimed that they did not have the information or that they did not remember the most recent harvest price.

Total farm revenue was estimated from farmer reports of the volume of the harvest (Table 5.30) multiplied by the price received for the most recent harvest (Table 5.31). In 1997/1998, for the 65 shrimp farms that provided information, the median gross revenue was $CAD 19,200. The median gross values ranged from $CAD 538 to $CAD 296,000 (Table 5.32). It is misleading to consider the minimum and maximum total revenue figures, however, because of the calculation method used (i.e., multiplying the maximum price paid per kilogram amongst the entire sample with the maximum harvest volume). The result for the maximum revenue is indicative of the potential amount of money that can be generated if the farmer has a large harvest and receives a good price. In reality, this seldom happens. Therefore, the median value of $CAD 19,200 is most representative of the gross revenue for one crop. This value would also be received two or possibly three times in a given year, as most farmers cultivate more than one crop of shrimp annually.

Table 5.30 Most Recent Harvest Volume (kilograms), by District, 1997/1998

District	Minimum	Maximum	Median	Number of Farms	99a[a]	Total
Bangnamprieow	112	10,000	2,300	20	6	26
Bangkhla	440	20,000	3,450	30	3	33
Khlong Keun	2,600	5,000	4,000	5	3	8
Ban Pho	500	10,000	2,000	7	1	8
Muang	4,300	4,300	4,300	1	1	2
Ban Sang	1,500	8,000	3,400	3	1	4
All Farms	112	20,000	3,000	66	15	81

a. Farmers that did not answer this question.

Table 5.33 reports the responses to the question of whether the previous crop harvest volume was typical of what the farmer had produced in the past? Apart from farms cultivating their first crop, the reasons why the harvest volume was not typical included low growout survival rate, disease problems, small size, slow growth, and poor water quality. In 1997/1998, 34 out of 86 farms (40%) indicated that the harvest volume was typical. In 2004, only 9 out of 50 farms (18%) of farmers reported that the previous harvest volume was typical. There had been a marked decline over the study period in the number of farmers reporting that the previous harvest volume was typical. On the other hand, the number of farms reporting declines in harvest volumes had increased from 44% to 80% between the 1997/1998 and 2004 investigations.

Table 5.31 Most Recent Harvest Price (Baht/kilogram), by District, 1997/1998

District	Minimum	Maximum	Median	Number of Farms	99a[a]	Total
Bangnamprieow	120	270	160.5	20	6	26
Bangkhla	123	220	160	29	4	33
Khlong Keun	127	160	151	5	3	8
Ban Pho	60	370	140	7	1	8
Muang	248	248	248	1	1	2
Ban Sang	180	210	202	3	1	4
All Farms	60	370	160	65	16	81

a. Farmers that did not answer this question.

Table 5.32 Gross Revenue ($CAD) Most Recent Harvest, 1997/1998

District	Minimum	Maximum	Median	Number of Farms	99a[a]	Total
Bangnamprieow	537.6	108,000	14,766	20	6	26
Bangkhla	2,164.8	176,000	22,080	29	4	33
Khlong Keun	13,208	32,000	24,160	5	3	8
Ban Pho	1,440	148,000	11,200	7	1	8
Muang	42,656	42,656	42,656	1	1	2
Ban Sang	10,800	67,200	27,472	3	1	4
All Farms	537.6	296,000	19,200	65	16	81

a. Farmers that did not answer this question.

In 1997/1998, 59 of the 86 shrimp farmers indicated that the price received for the last crop was not typical of what they had received in the past. In 1997, farmers indicated that the price was lower because of the low quality and small size of the shrimp, disease problems, reduced market demand, and lower production. In 1997, only a few farmers reported receiving higher prices than the previous crop. In 2004, only 2 out of 50 farms reported higher prices. Over the study period, the trend was towards reduced harvest volumes and declining shrimp prices.

Table 5.33 Response to the Question Was the Previous Harvest Volume Typical?

	1997/1998 (N=86)		2004 (N=50)	
Response	Number of Farms	Percent (%)	Number of Farms	Percent (%)
Yes	34	39.5	9	18.0
No	38	44.2	40	80.0
First crop	8	9.3	-	-
Previous crop failed	1	1.2	-	-
Did not answer	5	5.8	1	2.0
	86	100	50	100

On top of the salary for the hired workers, some farmers paid harvest commissions as incentives to improve their performance. In 1997/1998, 35 out of 86 farms (40%) indicated that they paid harvest commissions (Table 5.34). This would also be 35 out of the 52 farms (over 67%) for which this question applied. In 2004, most hired workers also received a share of the crops sale value. The number of respondents would be 34% of the entire sample of 50 farms, or 17 out of 18 farms (94%) in which this question applied.

Table 5.34 Harvest Commission Paid by Owners to Low-Salinity Pond Workers

	1997/1998 (N=86)		2004 (N=50)	
Response	No. of Farms	Percent (%)	No. of Farms	Percent (%)
Yes	35	40.7	17	34.0
No	5	5.8	1	2.0
Did not answer	7	8.1	-	-
Does not apply	39	45.4	32	64.0
	86	100	50	100

In 1997, only 24 of the 50 shrimp farms paid commissions to their pond workers (Table 5.35). The structure of the commission was usually a small percentage of the total volume harvested. A higher volume harvested would equate to a higher commission for the hired worker. Over 74% of respondents paid at least 1 baht per kilogram of shrimp harvested. For a typical harvest volume of 3,000 kilograms (i.e., 3 MT) paying the minimum reported commission would amount to around $CAD 120 per worker.

Table 5.35 Amount of Harvest Commission Paid, 1997

Harvest Commission	No. of Farms	Percent (%)
1-2 Baht/kg of shrimp	18	74.8
5 Baht/kg of shrimp	1	4.2
25,000 Baht/crop	1	4.2
Bonus of double the monthly wage if good production	1	4.2
Sometimes and the amount varies	1	4.2
2 Baht/kg (salary worker), 5 Baht/kg (non-salary worker)	1	4.2
Seldom	1	4.2
	24	100

During the key informant surveys, the Phuyaiban in several villages indicated that some shrimp farmers pay monetary compensation to rice farmers when discharging to a common water source. The reason for payment was that the effluent from the shrimp ponds could impact on the rice farmers' crop. The amount paid was quite low. None of the shrimp farmers interviewed in either the 1997/1998 or 2004 study reported paying compensation to local people when discharging effluent.

5.4.6 Labour

There are many different tasks in shrimp farming. In most instances, the family supplied the labor for day-to-day operations and during harvest, in which case, labour is a non-cash cost. Larger shrimp farms generally employ non-family workers to carry out the daily tasks of feeding and water management.

Although there were some absentee owners among the inland shrimp farmers, most were owner-operators. The majority of farms have only a few ponds and these operations usually rely solely upon household labour. If needed, the labour for harvesting is often provided through a shrimp-purchasing agent, or mobilized as exchange labour. In some of the larger operations, undocumented foreign workers, usually from neighboring Myanmar, provided some of the farm labour. The respondents at the larger farms were generally reticent to divulge the number of foreigners, if any, working on the farm. They simply confirmed that their labourers were not from the local district. Often workers are from Isan. Respondents indicated that workers from Isan work harder than locals and are stronger and more capable of sustained hard work that is often required in shrimp farming.

One consequence of shrimp farming is that is has reintroduced the rice farming tradition of labour sharing. People lend a hand when the shrimp are ready for harvest. The villagers have compared the social atmosphere of rice farming with shrimp farming, and say that they group together and talk about shrimp and to help each other out from time to time. In several villages the respondents indicated that they do not hire labour, but are assisted by their neighbors (who also have shrimp farms) during periods requiring increased manual labour, notably the harvest. Those lending a hand would receive reciprocal assistance during their harvests.

5.5 Key Informant Survey Results

Key informant interviews with local political leaders were conducted during the 1997/1998 field investigations. In addition to their political duties, most of the key informants were rice farmers by occupation (Table 5.36). Additional key informant surveys were completed in 2004.

Table 5.36 Main Occupations of Key Informants, 1997/1998

	Number of Respondents	Percent (%)
Rice farmer	5	50.0
Orchard (mango)	1	10.0
Livestock (cows)	1	10.0
Shrimp and fish	2	20.0
Rice and shrimp	1	10.0
	10	100

Table 5.37 summarizes the discussions with key informants on the development of low-salinity shrimp farming. In 1997/1998, over 94% of key informants believed that shrimp farming was good for the community. However, over 40% of these respondents acknowledged that this type of shrimp farming development represented a threat to the environment. They report that many of the potential community impacts have yet to be realized. Concerns are increasing, however, over the amount of land being converted to shrimp farming. Most indicated that if shrimp farming fails, there is little possibility of returning to previous occupations. In some villages over 80% of the households are engaged in shrimp farming. The previous occupation of most had been mango orchards. When asked what would happen if shrimp farming failed, the only option for land use would be fish farming. However, the respondents indicated that fish farming would not yield the same economic returns.

Table 5.37 Key Informants and Low-Salinity Shrimp Farming, 1997/1998

	Yes (%)		No (%)		Number of Respondents
Is shrimp farming good for the community?	16	94.1	1	5.9	17
Is shrimp farming a threat to the environment?	7	41.2	10	58.8	17
Are there disputes between shrimp and rice farming?	5	29.4	12	70.6	17

The village leaders indicated that low-salinity shrimp farming has not yet created any major conflicts between shrimp farmers and rice farmers. Most respondents indicated that the expansion has been so rapid and extensive, that the full extent of the environmental impacts may not be known for some time. This is also an underlying reason why opposition to this type of development within rural areas has been minimal. Most of those not participating in shrimp farming are older farmers who are not as likely voice concerns.

In 2004, the field study determined that inland shrimp farming is continuing to develop rapidly in Chachoengsao's rural areas. Overall, the village leaders and other key informants continued to support the development of low-salinity shrimp farming. However, they reported that they are not really in a position to influence the nature of this development. They continued to rely mostly upon informal discussions in their jurisdictions to minimize or reduce conflicts between rice farmers and shrimp farmers. This practice was not effective during the 1997/1998 field studies of the region. They do not have the legal authority to force shrimp farmers to adopt better management practices. They had examined the possibilities for alternative occupations for their constituents should shrimp farming fail. Many believed that this would eventually happen. They also acknowledged that, to date, there is no replacement activity that would earn the type of money that shrimp farming offers.

5.6 Summary

Central Thailand's irrigated lowland is experiencing an extensive conversion of low-yield rice production systems to high-yield shrimp production systems. This chapter has described the factors behind the low-salinity innovation, as well as the hatchery techniques and saltwater infrastructure that have developed in support of low-salinity shrimp farming. It has also presented the growout procedures that are used by shrimp farmers in freshwater areas, the farm characteristics, and a profile of low-salinity shrimp farmers.

The following chapter discusses the field investigation results, and focuses on the environmental management of low-salinity shrimp farming. It examines the underlying factors that have contributed to the emergence and continuing widespread adoption of inland shrimp farming in the central region of Thailand. The following chapter also discusses some of the community and social impacts of low-salinity shrimp farming, and presents a number of recommendations for improving the management of the shrimp farming sector.

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

The field studies conducted in 1997 and 1998 were completed when low-salinity shrimp farming was a relatively new development. The final study conducted in 2004 occurred when low-salinity shrimp farming was a fully established form of shrimp culture. This chapter discusses the results of the 1997/1998 and the 2004 field studies. It first examines the environmental management and other policy responses to the social, environmental, and economic issues that result from the rapid development of low-salinity shrimp farming in Thailand's central region. These issues are examined at several levels: farm level and its immediate surroundings, regional level, and at the national level. The farm-level management and technical operating practices in the context of the initial and final field studies are then discussed. The final section presents the study's recommendations in two categories: those offered to the policymakers in the national government and those offered to the hatchery managers and the farmers in the shrimp producing areas.

The results of the 1997/1998 and 2004 field studies indicated that the scope for improvement in the environmental management of low-salinity shrimp farming is large. Management concerns are escalating because this type of marine shrimp farming is continuing to spread into the freshwater areas of Thailand's central plain and has the potential to affect both local and regional soil and water resources. There are two related issues in regard to the addressing management concerns. The first is that the government has not yet developed environmental management standards for low-salinity shrimp farming, or attempted to enforce earlier standards with existing regulations and laws. The second issue is that low-salinity shrimp farmers are unlikely to implement management improvements on their own without stronger government intervention. New farms continue to be established haphazardly because there are no established criteria for determining appropriate areas for inland shrimp farming. Inaction regarding environmental management calls into question the government's willingness and capacity to regulate these operations at all levels, regionally and nationally. Also, the lack of mandated environmental management standards for low-salinity shrimp culture should not preclude farmers from investing in these improvements.

6.1 National Shrimp Farming Policy and Regulation in Thailand

Since the early 1990s, Thailand has made some effort to develop and implement policies and regulations pertaining to marine shrimp farming in coastal areas. Initially, these measures were reactionary and intended to contain the rapid expansion of marine shrimp farming which was at the time a relatively new industry. Regulations focused on reducing environmental impacts, increasing industry productivity, and containing the spread of disease. These regulations, however, have seldom been enforced. In a statement posted for the *Shrimp Tribunal Online* regarding the regulation of shrimp farming the Director General of Thailand's Department of Fisheries Dr. Plodprasop Suraswadi provided some insight into this situation.

> The Thai are good about making laws but not so good about enforcing them, unless to enforce a law in a particular situation coincides with benefits to the enforcers. The benefits are usually to make money or to please a superior. The Thai are happy to make laws that satisfy international ideologies, and then simply not to enforce the laws (Plodprasop, 1997:12).

The development of low-salinity shrimp farming has shifted the location of the predominant shrimp production, and thus policy and regulatory concerns, from the coast to inland areas. In 2002, it was reported that 70% of the shrimp produced in Thailand, or about 300,000 MT a year, was produced from farms using low-salinity culture (Limsuwan et al., 2002). The establishment of large numbers of new inland shrimp farms is beyond the capacity of the government to control. The monitoring of present shrimp farm development has not kept pace and enforcement of existing regulations has simply not occurred. The Department of Fisheries and the Royal Forestry Department lack the staff needed to capably monitor issues falling under their responsibility (Huitric et al., 2002). As was the case during the early development of coastal shrimp farming, the existence of regulations also proved no guarantee that farming practices would change at the farm-level. While a number of inland shrimp farms are constructing sedimentation and treatment ponds, for example, farmers surveyed in the 1997/1998 and 2004 field studies reported that these investments were prompted solely by self-preservation efforts against disease and not for regulatory compliance. Arguably, legislation is only as good as its enforcement, and where legislation is not enforced, its capacity to secure improvements in practice is greatly undermined.

Shrimp farming policies and regulations have not influenced the practices of the majority of inland shrimp farmers. The 1997/1998 and 2004 field investigations found that inland shrimp farmers are aware of the existing regulations, but choose to ignore them knowing that the regulatory environment is weak and easy to circumvent. From the shrimp farmers' perspective, even if fines or sanctions were imposed, they would only amount to a small percentage of the money earned from a successful crop. More importantly, none of the farmers interviewed had ever been fined for non-compliance.

Shrimp farming has also been treated as a homogenous activity by government agencies. Regulations developed for coastal shrimp farming, however, are not always relevant to inland shrimp farming due to the uniqueness of this activity. Although the 1991 decree stipulates that all marine shrimp farms must register, none of the inland farms surveyed were registered. The decree also stipulates that shrimp farms over 8 ha in total area must have wastewater treatment or sedimentation ponds equal to 10% of the farm area. Most inland farms are smaller than 8 ha and are exempt from this regulation. Thailand's shrimp farming regulations also prohibit the draining of salt water into public freshwater systems or farming areas. The regulation is ambiguous, however, because there are no associated measurable values to "saltwater", and the regulation applies only to surface waters. There is no mention of pond seepage to groundwater systems, which for inland shrimp farming is critically important considering the predominant pathway of salts. There is no policy on the storage of salt entrained sediment, which is another significant aspect of the "salt" issue arising from low-salinity shrimp farming. As for the biological oxygen demand (BOD) of shrimp farm discharge, most shrimp farms, including inland operations, do not routinely measure BOD. Most farmers do not check effluent quality, and subsequently discharge pond water directly into the canals without treatment.

The structure of the Thai shrimp industry with a high incidence of private land ownership makes it extremely difficult to regulate low-salinity shrimp farming. Private property rights are recognized and protected as one of the constitutional rights of the Thai people. It is politically difficult for the government to enact regulations to direct or influence the actions of farmers on private land. However, without stronger government intervention, shrimp farmers are not likely to voluntarily adopt management practices that will help mitigate environmental impacts. The government has not effectively communicated to farmers the long-term benefits of compliance with existing shrimp farming policies and regulations. Inland shrimp farmers equate any type of regulatory compliance with added costs of production. Although clearly in their best long-term interests, there are no compelling reasons for farmers to comply with regulatory policies since there is no capacity to enforce regulations or collect fines from farming operations that do not comply. The government has not yet developed policies, and/or regulations specific to low-salinity shrimp culture. The only effort is to control where farming is permitted and to limit the expansion of inland shrimp farming.

6.1.1 Inland Shrimp Farming Ban

Thailand's National Environment Board (NEB) passed a resolution to ban marine shrimp farming in freshwater zones in July 1998 (The Nation, 1998b). The move was prompted by concerns over the rapid spread of marine shrimp farming from the coastal provinces to prime agricultural land and fears of salinity problems and environmental degradation in Thailand's "rice bowl". This action was opposed by the Department of Fisheries and led to a heated debate on the means of potential enforcement of the resolution (Inchukul, 1998a). Proposals to lift the ban have been viewed as an attempt by the industry proponents to continue with business as usual (Bangkok Post, 2000). In response to pressure from local communities and environmentalists, the NEB decided to maintain the ban on marine shrimp farming in freshwater zones in inland areas. In 2001, requests for expansion of the land used for marine shrimp farming in the central region were not approved by the NEB as inland shrimp farming did not comply with Article 9 of the Environmental Act B.E. 2535 (ONEP, 2001).

The ban on marine shrimp farming remains in effect. However, the ban does not apply to all inland provinces; shrimp farms in 25 provinces that already had inland marine shrimp farming including Chachoengsao, Nakhon Nayok and Prachinburi have been exempted (Inchukul, 1998d). In Chachoengsao, there has been an immigration of shrimp farmers from other provinces where the ban is being enforced. Newly arrived farmers typically lease the land used for shrimp farming creating tensions between "non-locals" and "local" shrimp farmers and agriculturalists. Local farmers were quick to argue that the "bad" practices being reported in the popular press resulted from the irresponsible methods employed by outsiders. The 1997/1998 field surveys found that many of the shrimp farmers had moved to Chachoengsao province from Suphanburi province where the ban had been strongly enforced. The government's decision to enforce the ban in Suphanburi resulted from the pressures from the strong rice lobby group backed by an influential local politician who opposed shrimp farming.

The regulatory aspects of inland shrimp farming are fueling institutional conflicts and jurisdictional debates within several government ministries. The responsibility for implementing the July 1998 cabinet resolution, for example, created tension between the Department of Fisheries (DOF is in the Ministry of Agriculture and Cooperatives), and the Ministry of Science Technology and Environment (MOSTE). The DOF refused to enforce the ban, arguing that it would be inappropriate to do so because it promotes shrimp farming. The DOF argued that enforcement should be MOSTE's responsibility since it is in its jurisdiction (ONEP, 2001). In response, the Office of Environmental Policy and Planning within MOSTE indicated that fishery officials were legally bound to enforce the ban, as the ban was a government policy and the DOF should be the line authority for implementing the ban (Inchukul, 1998a). Amidst all of this confusion, the Interior Ministry, under direction from the NEB, was assigned to enforce the ban and pursue legal action against violators. The NEB recommended the zoning of areas for shrimp farming with farms to be prohibited in freshwater areas, irrigation areas, and groundwater recharge areas. The Interior Ministry has since delegated the responsibility for implementing the ban to the provincial governors. The timeline for implementation was not stipulated thus providing the opportunity for inaction.

Nationally, jurisdictional problems over the regulation of inland shrimp farming remain unresolved. The 1997/1998 and 2004 field investigations determined that inland shrimp farmers are far removed from these national level discussions. At the farm-level, the majority of shrimp farmers are disinclined to "engage" regulatory issues. Farmers reported that they were not willing to invest in more expensive management practices. Since there is no support for farmers when their crops fail, they felt they should not be responsible for improving the system at their expense. After all, they have developed inland shrimp farming techniques without government support and are fiercely proud of their independence. Shrimp farmers were acutely aware of the criticisms of inland shrimp farming, but felt that the environmentalists were unfairly targeting them. They point to other industries like swine slaughterhouses and alcohol factories that are equally, if not more, responsible for environmental damage. Most felt that in time they would be more stringently regulated. For the time being, however, they prefer to operate anonymously until forced to do otherwise.

Industry analysts assert that what is needed are self-regulating mechanisms in which the farmers have a personal interest to pursue activities which will help the shrimp sector become more sustainable (Bangkok Post, 1998a). One possible course of action is the introduction of more environmentally friendly aquaculture (i.e., lower intensity, polyculture) within the broader framework of community-based, integrated area management. The recent development of voluntary codes of conduct for marine shrimp farmers could potentially address some of the management and regulatory problems in the shrimp farming industry (Tookwinas et al., 2000; Boyd et al., 2002).

6.1.2 Thai Code of Conduct for Marine Shrimp Farming

To assist national governments in their efforts to develop effective regulations, the FAO has developed broad environmental management strategies that are directly relevant to marine shrimp farming. These strategies are outlined in the *FAO Code of Conduct for*

Responsible Fisheries and related *Technical Guidelines* (FAO, 1995; FAO, 1997a). In addition to the dissemination of technical guidelines to support implementation, and discussion in regional fisheries organizations, several initiatives applicable to shrimp aquaculture have also been facilitated by the FAO, in cooperation with partners including the *Technical Consultation on Policies for Sustainable Shrimp Culture* (1997) and *The Bangkok Declaration and Strategy for Aquaculture Development* (2000) to name just a few. These documents and related initiatives provide comprehensive information on improving the environmental management of the shrimp sector.

In Thailand, a comprehensive set of environmental management policies for the shrimp industry does not exist. However, the government and industry have developed an environmental management program based on a voluntary *Code of Conduct* and have implemented several initiatives to improve the quality of marine shrimp farming (Tookwinas et al., 2000). The *Code of Conduct* is a set of guiding principles consisting of broad statements about how management and other operational activities should be conducted. Thailand's *Code of Conduct for Marine Shrimp Farming* (hereafter, the *Code*) is a package of regulatory measures designed to improve the environmental management of shrimp farming. The Thai code, like other codes of conduct, is a uniform set of rules that policy-makers hope all farmers will adopt.

Thailand's Department of Fisheries, with primary responsibility for the shrimp aquaculture industry, is the lead agency implementing the *Code*. Separate guidelines have been established for marine shrimp hatcheries and nurseries, and for marine shrimp farms. Each of the guidelines consist of various items which are verified and includes site selection, farm management, stocking density, feed management, shrimp health, chemotherapeutic agents and chemicals, effluent and sediment, harvest and transportation, social responsibilities, farm grouping and data collection. The government anticipates that the capacity for farm-level environmental management of the shrimp aquaculture sector will improve through these initiatives. However, considerable uncertainty exists over the likelihood that any of these initiatives will yield positive results in the short term. Some analysts argue that it is a matter of "too little too late" to effect any meaningful changes to an industry that is otherwise not sustainable (Miller, 2003).

Successful implementation of the *Code* will involve coordination amongst Thai government agencies and between the shrimp farmers themselves. The need for shrimp industry regulators to integrate the shrimp farming code with other agricultural policies is highlighted by the conflict between rice farmers and shrimp farmers over freshwater resources. The *Code* does not have a mechanism to prevent shrimp farmers from "free riding" on the irrigation infrastructure developed for rice agriculture. Shrimp farmers have open access to the freshwater supply. There are no charges for its use and farmers are not required to pay any maintenance funds towards the upkeep of the irrigation infrastructure. Thus, shrimp farmers have little or no incentive to improve their water use practices. As funds are lacking for the upkeep of irrigation infrastructure, even less is available to farmers for the implementation of better water management practices. Weak financial support for shrimp farm management is one of the immediate actions that are recognized for the industry. Specifically, farmers require the government's assistance in developing cost effective methods for sediment treatment and disposal, wastewater treatment and in disease diagnostics.

The implementation of the *Code* does have the potential for securing longer-term improvements in the management practices at inland shrimp farms. For example, the *Code* attempts to shift the shrimp industry from managing farm waste through "end of pipe" regulation towards more ecologically sustainable production. The *Code* recommends farm management practices that would minimize the contaminant levels in discharge waters and ultimately improve farm profitability. Although there are regulations governing the disposal of pond effluents, most inland farmers do not adhere to them. The key issue for government is to convince the farmers that it is in their best interest to cooperate, and to educate the farmers of the long-term benefits of adopting better farm-level management practices.

It has been suggested that farmers, without significant cost, and with potential short and longer-term financial benefits, can adopt most of the management practices promoted in the *Cod*e. However, care needs to be taken in adapting the generic principles of the *Code* to fit the local farming situation. Selected articles of the *Code*, particularly those requiring effluent treatment ponds, may be more problematic and costly to implement for small-scale farmers with only one or two ponds. Here, cooperation between the farmers is necessary to implement effective water treatment measures, by sharing treatment ponds and/or reservoirs. This may also require modifications to the existing pond systems. The best chance for success will be achieved if government agencies are willing to invest in extension work to convince farmers to adopt the *Code*. However, the Thai *Code*, like other codes that have been introduced elsewhere, does not have any legal authority. Adoption is voluntary. The code is not specific to any type of marine shrimp farming and does not have a mechanism to regulate the number of farms that are established within specified geographical boundaries (i.e., watersheds, agriculture regions). Farmers in this study generally perceived the code as something the government created but with which the shrimp farmers have had little or no involvement.

6.2 Farm-Level Management and Technical Operating Practices

Without an accurate assessment of the farm-level management and technical operating practices of the shrimp farmers it is difficult to determine the courses of action that are needed to improve the sustainability of low-salinity shrimp farming. Improving the overall performance of the Thai shrimp sector ultimately hinges on the adoption of appropriate and effective management and operating practices at the farm-level. Ideally, these measures would include proper planning and design, in particular, through site selection allowing for sufficient water exchange, and; improved farm operation and maintenance, including selection of species, suitable stocking rates, appropriate feeding regimes and the careful use of chemicals and chemotherapeutants.

The 1997/1998 and 2004 field studies found that there is plenty of scope to improve the farm-level management and operating practices of inland shrimp farming. Even the best practices employed at inland shrimp farms fall short of what is needed and what appears to be possible. The source and quality of information available to shrimp farmers influences how the farms are managed. While most of the respondents have some experience with agriculture, and to a lesser extent, with fish or freshwater shrimp culture, most acquire the necessary shrimp farming management techniques on their own without formal training. Critical management information is often obtained from informal discussions with other shrimp farmers and by attending seminars hosted by local industry agents, typically feed and chemical sales representatives. Seminar attendees are often recruited to farm shrimp and to become feed customers. Shrimp farmers regularly receive suggestions from industry agents on how to improve production. In order to implement these suggestions, however, the shrimp farmers must purchase the products being promoted.

The 1997/1998 and 2004 field studies found that farm-level management and technical operating practices depended on the farmers' abilities to acquire funds, land, technical information, and their knowledge of environmental factors. The government does not have a well-developed system in place to effectively disseminate information on farm-level management and technical operating practices despite an extensive literature on shrimp farm management. In 1998, 87% of the low-salinity shrimp farms surveyed had no contact with government agencies. Similarly, in 2004, none of the farms surveyed had reported any contact with government agencies. Farmers feel that the farm-level management information from government agencies is not readily available and is usually not responsive to local priorities. They are also extremely reluctant to change their management practices, partly due to lack of know-how and experience in shrimp farming, and partly due to a lack of capital. To overcome these constraints, institutional reforms are necessary at the farm, provincial and national government levels. The most expedient method to bring about meaningful improvements in farm-level management is to deliver increased technical support through government extension and education.

The 1997/1998 and 2004 field studies determined that low-salinity shrimp culture requires unique operating practices to effectively manage water releases and sediment disposal. Technical solutions to these problems are not well established and the lack of contact with government agencies leaves the farmers to deal with solving these growout problems by themselves. With the onset of production losses, farmers have focused on improvements in pond management to reduce disease. This research found, however, that the majority of farmers are skeptical about the sustainability of shrimp farming. These rather pessimistic views may be related to the fact that farmers reported experiencing a host of increasingly complex management problems for which there seemed to be few practical solutions.

In 2004, the study documented instances of farmers voluntarily adopting better management practices. Some of these progressive farmers had been the targets of the government's limited efforts to implement the best management practices (BMPs) proposed in the *Code*. The 2004 field study revealed, however, that the adoption of BMPs does not occur spontaneously. Farmers are often reluctant to change management practices, and they do not respond well to coercion. The fear of failing to comply with regulations or threats of market losses because of consumer rejection of products produced by practices harmful to the environment have not resulted in the widespread adoption of BMPs. The most beneficial approach to encouraging BMPs is to educate farmers about the environmental benefits of BMPs, and more importantly, the greater profits that could accrue to farmers. While this shift in approach would result in higher production costs for the farmers in the short term, the farmer would achieve smaller profits per crop over a much longer period of time (i.e., resulting in more years of shrimp production).

6.2.1 Land Management

Farm density is a critical issue for low-salinity shrimp farming. In Thailand, there are no mechanisms in place to limit farm density within specified geographic areas based on resource availability. The only government policy that attempts to address the issue of farm density is the effort to limit national production area to 80,000 ha. This policy, however, does not establish limits on the number of farms within geographical regions. Farm crowding occurs as pond development proceeds without direction from a comprehensive plan, which takes into account the relationship between the total areas of shrimp ponds at a particular site and the carrying capacity of the supplying and receiving water bodies at that site. Local and/or regional land management problems caused by increased nutrient, organic and microbial loads can arise in enclosed waters or where there is a very high density of ponds. These changes have had a negative influence on the sustainability of inland shrimp farms, because such crowding has inevitably resulted in disease outbreaks. Such is the case in Ban Pho district, for example, one of the early centers for inland shrimp pond development. Farmers in this district have been unable to achieve the earlier shrimp production levels after suffering devastating disease losses.

The potential land management issues resulting from the development of low-salinity shrimp farming were initially overlooked. The first inland shrimp ponds had the advantage of being more dispersed than the tightly concentrated culture operations along the coast. According to some, this helped reduce the risk of water contamination by adjacent operations and the transmission of disease between the ponds. However, as the density of inland shrimp culture ponds has increased, farmers have encountered the same problems with freshwater quality deterioration as in coastal areas. Stronger government intervention is required to encourage cooperation among shrimp farmers. The entrepreneurial and adaptive nature of shrimp farmers suggests that improved land management practices are only likely to be adopted if given the right set of incentives, educational opportunities, and government policies. At present, the individual actions of the shrimp farmers are resulting in collective disbenefits.

Collective or regional land management solutions are difficult to implement because of the atomistic structure of the industry. The required initiatives to improve land management are diverse and could potentially include the use of environmental impact assessment at the sector or farm-level, and/or a combination of tools and incentives to promote better siting or more sustainable farming practices. This could include assessments of environmental capacity and its relation to the quantity or location of aquaculture production.

A fundamental tool of land use management is the identification and protection of key ecosystems, which need to be conserved to ensure resource sustainability. The aim of zoning is to establish clearly demarcated geographic zones with specific permissible and nonpermissible uses, which could include identification of zones for aquaculture and for habitat conservation. A municipality, or regulatory or planning agency, that have the authority to make and enforce decisions, can adopt zoning schemes.

In Thailand, there are currently no effective zoning or permitting practices for the siting of marine shrimp farms. Further study is needed on developing a zoning system for low-salinity shrimp culture. The proximity of intensive shrimp farming and intensive rice farming – and the increasing conflicts between these two activities – offers an ideal situation for the application of a zoning system. This system would help shrimp farmers in choosing the best farming area and confine the farms within this area so that any saltwater residue and effluent discharge from the shrimp farms cannot adversely impact neighboring farms. While the process of zoning may not be easy, in the long run it can make enforcement easier and can help reduce conflicts between aquaculture operations and other resource users. Elements of zoning would include: a specific list of allowable and non-allowable uses; precise designations of the water, and land areas covered by the zone; a regulatory procedure for issuing and enforcing permits; sanctions for violating the terms of the permit, as well as of the zone; and policies and procedures for giving variances for activities in the zone or to nonconforming uses. In the long term, zoning is integral to developing sustainable operating principles for sectoral management. In developing such a system, the government should ensure that zoning and access to resources is transparent and that all interested parties are consulted in the process. The government should also ensure that resource use and rights are clearly defined and compatible for all resource users.

6.2.2 Growout Practices

Statistical analysis of the data collected during the initial and final field studies determined that several of the growout practices had changed. The analysis indicated significant findings between the initial and the final field studies for the following growout practices: number of years of shrimp production, number of shrimp crops produced, growout period, crops per year, and the stocking density.

In 2004, the farmers had been growing shrimp for a longer period of time and had produced more crops. These findings were not surprising given that low-salinity farmers had continued to grow shrimp and new entrants had continued to enter into farming. The duration of a typical growout had decreased. The related finding that farmers cultivated more crops over a one-year period supported this result. The smaller sized shrimp at harvest evidences the shorter duration for growout. The practice of shortening growout and cultivating more crops annually is a clear indication risk reduction (i.e., less time in the pond equals less chance for disease) and cost savings to the farmers in terms of feed inputs. These results substantiated the finding that it has become standard practice for farmers to conduct harvests more frequently and with smaller sized shrimp. Farmers had adopted growout practices, which by coincidence catered to the preferences of shrimp consumers for smaller sized shrimp. If farmers cultivated more crops in one-year they could potentially earn more income from shrimp farming if they did not suffer any disease events.

The total farm growout area and individual pond area had decreased, but the number of shrimp ponds in a typical low-salinity shrimp farm had remained the same. The mean fallow period had decreased from 55 days in 1997/1998 to 31 days in 2004. Although this finding was expected, as farmers had increased the number of crops produced in one year, this would not be a recommended practice.

6.2.3 Water Management

In the 1997/1998 and the 2004 field studies, exchanging water was the most frequently used water quality management strategy. All of the farmers used low water exchange systems as a means of protecting themselves from external sources of pollution, shrimp pathogens, as well as to maintain pond salinity levels. Once water is onsite, it was routinely treated with chemicals to disinfect and to kill predators and disease-causing organisms, and then stored until it was clear of sediment. Once the water was transferred to the growout ponds the farmers had various protocols in place to monitor water quality. All of the farms surveyed were equipped to monitor the basic water quality parameters. Temperature and dissolved oxygen (DO) were measured every day, usually early in the morning around 6 a.m. when DO was at its minimum level. The health of the shrimp are at increased risk in ponds where the DO level is below the threshold suitable for shrimp culture. In case of dangerously low DO levels; all farmers reported that they increased the rate of water exchange. Shrimp farmers rely upon personal experience when it comes to making water management decisions. They visually monitor the evaporation and seepage losses and, if needed, add freshwater in small increments. Although each crop is different – and seasonally dependent – a standard rate has emerged. Most increase the pond water depth at a rate of around 5 to 7 cm of water every week. As the growout progresses, the rate of addition is refined somewhat to coincide with the pond being at full capacity around harvest. Figure 6.1 depicts a typical water transfer from an irrigation canal to a shrimp farm water intake structure.

Figure 6.1 Freshwater Transfer from Small Irrigation Canal to Intake Structure for Low-Salinity Shrimp Farm

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 1998

Depending on the availability of land at individual farms, freshwater supplies are either stored within a reservoir or directly transferred from nearby water sources such as irrigation canals. The use of reservoirs and careful water management are critical to successful inland shrimp farming. However, reservoirs can only be constructed on farms with adequate land holdings, and the farmer must also be willing to sacrifice production area. Reservoirs act as buffers between water sources that contain disease pathogens or surface water pollutants, and can serve as receptacles for nutrient enriched harvest effluent. Reservoirs encircling the production ponds can also reduce saline water intrusion to adjacent rice paddies. The most common and simplest reservoir system is a water ditch barrier between shrimp ponds and surrounding rice paddies. There is no mandatory requirement for inland shrimp farms to construct reservoirs or perimeter ditches, and some operators forgo their benefits for increased production area. In 2004, fewer shrimp farmers reported using reservoirs. The analysis of the survey data from the 1997/1998 and 2004 field studies determined that there was some evidence of a significant finding. The reduction is use of reservoirs is not a recommended management practice and could only be explained by farmers wanting to maximize their production area.

Shrimp farmers have never been asked to pay for freshwater. In 1997, 69% of the farmers indicated that they would be willing to pay for freshwater on the condition that other users should also pay. In 2004, only 4% of the farmers were willing to pay for freshwater. Similar results were found for concerns over the level of pesticide residues in the freshwater supplies, and the farmer's inability to test for them. Concerns were high and the ability to test for them was not possible in any farms save a few.

6.2.3 Wastewater Management

In 1997/1998, 64% of the shrimp farmers interviewed had effluent treatment ponds as compared to 54% of the shrimp farmers in 2004. The use of effluent treatment ponds developed out of necessity rather than farmers complying with regulatory requirements. Ponds are used to reduce the suspended sediment and nutrient organic loads prior to discharge to the external environment. These ponds are also used to receive water from external sources for treatment prior to use in the growout ponds. Inland shrimp farmers have reported benefits associated with the use of settlement canals and ponds to treat effluent. In 2004, shrimp farmers reported that using the water from effluent treatment ponds reduces by 10 to 20 days the time it takes to condition water for the next crop. This advantage, however, would not be available to small farms that do not have the area set aside for an effluent treatment pond.

The most effective way of managing the negative effects of wastewater from shrimp farming to aquatic waterways is to minimize discharges. Most of the nutrients discharged from shrimp ponds originate from feed inputs (Briggs and Funge-Smith, 1994a; Jackson et al., 2003). Therefore, improving the water stability of feeds and reducing feed wastage has the potential to substantially reduce nutrient discharge loads (Burford and Williams, 2001). There is considerable scope for reducing the suspended solid and ammonium discharge loads by lining the banks or entire ponds to reduce or eliminate erosion. Removing deposited sludge from ponds soon after it accumulates also reduces the sediment load to the receiving environment as well as remineralization of nutrients (Hopkins et al., 1994). Passive sedimentation ponds can substantially reduce the total suspended solids. The performance of treatment systems for farm discharge water may be improved by incorporating active nutrient removal strategies such as culture of bivalves, macroalgae, fish and nitrifying bacteria (Páez-Osuna, 2001). Shrimp farmers have achieved some reduction in discharges by recirculating water within the farms. Ideally, this type of management practice would be coupled with treatment systems.

Onsite wastewater treatment is one management option available to farmers. Some inland shrimp farmers incorporate biological treatment systems into their shrimp growout systems (Figure 6.2). Plants and/or fish are introduced to the ponds in an effort to reduce nutrient loadings and particulate matter. The method involved stocking fish in the effluent ponds, reservoirs, or inactive shrimp ponds. In 1997/1998, only 17 of the 86 farms surveyed (20%) indicated that they practice some type of fish culture. In 2004, 66% of the shrimp farmers interviewed reported that they culture fish in their reservoirs. This system is either a form of effluent treatment prior to discharge or is part of a farm recirculation system in which the plants/fish improve the water quality for reuse within the shrimp farm. However, there are limitations to this management practice. Biological treatment systems can only be used to treat operational farm effluent, not the wastewater during harvest. The wastewater from harvest must either be directed to a settling pond, or to the external environment.

Polyculture, or raising more than one species of fish and shrimp in the same growout pond, is another type of biological treatment system that could be used to treat wastewater. However, polyculture was only observed at a limited number of farms. If stocking fish directly into the shrimp ponds, the fish stocking density ranged from 3,000 to 6,000 fingerlings per ha. The shrimp had been in the growout pond for about 90 days or were individually around 10-g in size. The main consideration is the shrimp need to be large enough to escape being consumed by the fish. Several modifications to this direct polyculture method were observed. Shrimp farmers erect a bamboo fence in the pond center to separate the fish from direct contact with the shrimp. The location of the fence coincided with the area where uneaten feed accumulated. Fish, normally Tilapia, were placed into this area. The fish consumed the feed that would normally end up in the waste stream. The result was cleaner pond water as well as extra income from selling the fish.

Figure 6.2 Biological Treatment Pond Adjacent to Low-Salinity Growout Pond

Photo Credit – Paul Miller, Chacheongsao Province, Thailand, May 1998

Low-salinity shrimp culture in freshwater regions generates unique management considerations in dealing with wastewater. In coastal shrimp farming, wastewater would normally be discharged to coastal waters with a larger assimilative capacity. In inland areas, this management practice is not possible. The 1997/1998 and 2004 field studies found that some inland shrimp farms utilize the nutrient rich 'wastewater' generated from shrimp production for irrigation. The discharge from the shrimp ponds during harvest is diverted into adjacent orchards and/or rice paddies. Irrigating with aquaculture effluents can potentially reduce some of the pressure placed on freshwater resources and help to reduce the reliance on chemical fertilizers. However, shrimp farmers acknowledged that they did not have much appreciation of the long-term impacts associated with discharging salt laden suspended sediment into adjacent agricultural operations. While using effluent generated on the shrimp farm to irrigate field crops eliminates effluent disposal problems and/or treatment concerns, the concentrated load of dissolved solids makes this water a two-edged sword. With the dissolved solids, come concerns of soil salinization. Anecdotal evidence from some of the respondents indicated that fields irrigated with shrimp pond effluent are more productive than those irrigated directly from the canals. This apparent increase in productivity has yet to be quantified. More study is needed before this could become a recommended practice.

6.2.4 Sediment Management

Low-salinity shrimp farms generate large volumes of sediment. The 1997/1998 and 2004 field studies found that there is considerable scope for improving sediment management. Sediment that accumulates in canals, ponds and settling basins on shrimp farms is mostly mineral soil enriched with organic material. The direct disposal of sediment into estuaries, irrigation canals, or freshwater streams causes pollution. Shrimp pond sediment contains a burden of water-soluble salt from contact with saline water. If saline sludge is disposed of outside water-holding structures in freshwater areas or on agricultural land, salinization may result. Downward seepage can also result in salinization of freshwater aquifers. Sediment accumulation in canals also reduces the volume and efficiency of water conveyance. Under some circumstances, the discharge volume of re-suspended solids can prevent the use of the receiving water bodies as water sources even for shrimp farming. In ponds, sediment reduces water depth and has adverse effects on bottom soil condition and water quality. Currently, none of the regulations regarding pond sediment disposal are enforced. Poor enforcement of effluent regulations, for example, allows some farms to continue the illegal practice of using high-pressure water to remove accumulated sediment from the ponds (Figure 6.3).

Figure 6.3 Using High-Pressure Hoses to Remove Accumulated Sediment from the Shrimp Ponds After Harvest

Photo Credit – Paul Miller, Samut Sakhon Province, Thailand, January 1996

In most operations, accumulated sediment is usually physically removed from the culture ponds between successive crops (Figure 6.4). In 1998, 30 of 36 shrimp farmers (83%) surveyed reported that they removed accumulated pond sediment after every crop. In 2004, 40 out of 50 shrimp farms (80%) reported that they removed accumulated pond sediment after every crop.

Figure 6.4 Bulldozer Removing Dried Accumulated Sediment from a Low-Salinity Shrimp Pond in Chachoengsao Province

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

The ongoing need for the removal of large volumes of pond sediment between crops created management constraints for low-salinity shrimp farmers. Space constraints imposed by the small farm sizes prevent most farmers from using all but the most rudimentary disposal techniques. Farmers have no place to relocate the pond sediment so it is usually placed on the banks of the shrimp pond. Over time, the volume of sediment creates storage constraints. Some shrimp farmers indicate that the volume of sediment accumulations reduces farm site viability to a period of around three years, after which time they must move to a new location. In some farms, sediment is stored in reservoirs. However, the storage capacity of reservoirs is limited and their construction is an added expense. A viable and cost effective means of sediment disposal is urgently needed and would alleviate the necessity to shift farming locations and help to stabilize current farming operations.

6.2.5 Management of Chemicals and Chemotherapeutants

The 1997/1998 and 2004 field studies determined that there is considerable scope for improving the farm-level management of chemicals and chemotherapeutants. The key management issue is that many of the farmers participating in these studies did not have sufficient information on the benefits and risks of chemical use. Improved husbandry, better water quality, higher quality feed, and improved PL quality reduce the likelihood of disease and, therefore, the need for and use of chemicals. Farmers must acknowledge that the use chemicals and chemotherapeutants should not be the first option when combating disease but used only as a last resort. If chemicals are needed, there are many reports regarding the safe use of chemicals, and if followed, the problems and impacts would be greatly reduced. However, farmers have been slow in adopting these guidelines and the government has not implemented an effective program to prevent the misuse of chemicals.

The main concern over chemical use is that the chemicals used to treat shrimp diseases can result in residues in shrimp tissue that are a potential health hazard to humans. Concerns over the contamination of shrimp products with chloramphenicol and nitrofuran antibiotics, which are banned for use in food production in all countries, have become an issue in international markets (Bangkok Post, 2003a; The Nation, 2003). The latter have to a large extent prompted farmers to more carefully consider chemical use during growout in order to remain competitive and prevent their shrimp from being rejected by the market. Farmers are fully aware that failure to comply with regulations banning the use of certain chemicals can have serious economic consequences to all involved in the import chain.

In 2004, farmers were much more aware of the issues surrounding chemical use than during the previous field studies in 1997/1998. However, this result is misleading for several reasons. Farmers do not consider the pond soil and water treatments containing agents like chlorine as "chemicals". Their responses refer to chemicals used in the growout pond. They also do not consider that they are still using medicated feeds that contain antibiotics. Many farmers simply choose not to disclose information regarding chemical use because it is viewed as a bad management practice. Also, farmers are aware of the sensitivity of consumers to producers who use chemicals, much more so than in 1998. This is because many of Thailand's shrimp shipments have been rejected on the basis of antibiotic residues found in exported shrimp (Holström et al., 2003).

At present, there are few established methods for producers to safely remove the residues of chemotherapeutants, pesticides, and other chemicals. This is partly because few regulatory bodies have placed limits on the concentrations of such chemicals in effluent. Although no such guidelines exist for Thailand, inland shrimp farmers can use their inactive ponds for sedimentation prior to final water discharge to reduce the amount of chemicals entering the receiving waters. This practice increases the residence time of effluent waters and permits the settlement of organic materials and associated chemicals. The increased farm residence time for water also increases the likelihood of degradation and dilution of soluble chemicals before effluent discharge. A number of management strategies, with low capital investment, might further enhance the utility of settlement ponds. For example, sediment ploughing following pond drainage would increase aerobic degradation of sediment-associated antibacterials. The introduction of filter feeders, macrophytes, and/or other aquatic organisms into effluent ponds could also provide a means to bioconcentrate and/or metabolize the residual chemotherapeutants. Subsequent harvesting and incineration of these natural 'treatment' agents could substantially reduce the amount of chemicals entering receiving waters.

Until recently, the focus of farm management in regard to chemical use has been directed at limiting residues in shrimp products. However, the improper use of chemicals can harm aquatic organisms that live in the water into which shrimp farms discharge. Assessment of the risks posed by aquacultural chemicals is constrained by the absence of data on the environmental fate and effects of many of these compounds. The environmental issues associated with chemical residues in wastewater have been largely ignored. Information is available for some pesticides (e.g., organophosphates) because, in terrestrial applications, the aquatic fate and effects of these compounds have long been a concern. However, in many instances aquacultural chemicals were not developed specifically for aquacultural use. Thus, the data needed to assess risks in the aquatic environment are not available.

Another important related management issue in regard to chemicals in the aquatic environment results from the fact that the majority of low-salinity shrimp farms are built on land previously used for agricultural or other purposes. Pesticides and other chemicals applied during these previous uses can remain in the land's soil and water in small amounts and be taken up by shrimp in the production ponds. Heavy metals and other by-products of previous land use can similarly affect farmed shrimp. Such compounds pose a potential health risk to some elements of the human population. The 1997/1998 field studies found that in some of the farms the shrimp that failed testing standards required for international markets were not always discarded. Often the shrimp farmer attempted to recover losses by selling these shrimp to local markets at a lower price. The local consumers faced the uncertain risks associated with chemically contaminated shrimp. The1997/1998 field investigations also found that some farmers harvested diseased shrimp, and when unable to sell them internationally for a good price, sold to local markets. Local consumers were again placed at risk.

6.2.6 Shrimp Health Management and Biosecurity

The majority of inland shrimp farmers reported experiencing serious problems in shrimp health management. In the 1997/1998 and 2004 field investigations, they cited many reasons for production crashes, with disease outbreaks being the major cause. This refutes the claim that inland shrimp farming areas are devoid of the disease pathogens that plagued coastal areas. Shrimp pathogens have spread in inland regions much the same as they dispersed in coastal areas. The routes by which viruses have entered the farm environment were through incoming water, potential virus carriers, and shrimp PL. The primary factor that is linked to the onset of disease outbreaks is high farm density in the farming regions and poor water quality caused by farm management strategies.

The management actions taken by the farmers, government, and international agencies have had only limited success in dealing with shrimp disease. Defining adequate shrimp health management practices is a complicated task since it is hard to set specific limits for a healthy pond environment. As a general rule, avoiding stressful conditions minimizes the chance of infections by opportunistic pathogens. The 1997/1998 and 2004 field studies found that shrimp farmers were acutely aware of disease vectors, yet had not taken even the most rudimentary measures to limit the spread of disease despite experiencing major losses. It was common practice for farmers to just reset their production ponds after such a loss and try another crop. Ignoring their own management strategies, farmers claimed that the major reason for the lack of action is that they felt incapable of improving the quality of incoming water or improving the quality of post-larvae – two of the most reported causes of shrimp health management problems.

Good shrimp health management should focus on the prevention of disease rather than disease treatment with chemical compounds. The best ways of controlling diseases in shrimp farming are to avoid stocking diseased PL, lower the stocking density, reduce water exchange for less exposure to disease organisms in intake water, reduce chemical inputs, and maintain good pond soil and water conditions to avoid environmental stress to shrimp. Inland shrimp farmers have been slow to incorporate information regarding shrimp health management. The 1997/1998 field studies found that most farmers stock their shrimp ponds at extremely high densities. Moreover, many of the standard methods for improving shrimp health management are not in place. These methods include the use of screens at the entrance and exits to ponds, better water quality monitoring, stricter control of feeding rates, and improved health surveillance. Improved health management would also include reducing the number of cycles per year, and increasing drying time between crops, and disinfecting soils.

An important finding of this study was that despite major advances in shrimp disease research, shrimp farmers have received little government support in the area of disease diagnostics. The 1997/1998 and 2004 field investigations determined that inland shrimp farmers have very limited capability in diagnosing disease. In many instances, shrimp farmers never know the true nature of disease events and simply apply chemical treatments in the absence of any diagnosis. While some of the disease risk factors are within the control of the farmer, others like biosecurity measures are more difficult to control and require cooperation between the farmers, and between the farmers and the government.

A biosecure shrimp culture system would include the identification of pathogen entry routes, quarantine and screening of hosts introduced in the system, disinfection at defined critical control points, restricted access and identification of risk factors that favour pathogen establishment and spread. A biosecure system could be based on specific pathogen-free stocks, including enclosed, reduced water-exchange/increased water-reuse culture systems, biosecure management practices, and co-operative industry-wide disease control strategies. Implementing scientific health management strategies, incorporating principles of biosecurity at the pond, farm, national and regional levels is increasingly becoming crucial for ensuring successful and sustainable shrimp aquaculture.

In 1998, the importance of biosecurity was not widely acknowledged amongst inland shrimp farmers and the shrimp farming community in general. In the 2004 study, 40 out of the 50 farms reported that they had implemented biosecurity procedures. However, the measures taken in 30 out of the 40 farms was limited to expelling birds by shooting them, making loud noises to scare them off, or erecting finely meshed nets to cover the ponds. Birds are considered as one of the main sources of shrimp pathogens as they prey upon diseased shrimp in one farm and then carry the pathogens to other farms. These measures are rudimentary in comparison to practices now considered vital to ensuring farm level biosecurity. In 2004, the field study found lapses in farm level biosecurity at every stage of the culture operations. These included: improper pond preparation, lack of water treatment, stocking of unscreened PL, sharing of farm equipment and labour between ponds, unrestricted access, and absence of disinfection programmes. Other biosecurity lapses were noted with the handling of disease outbreaks (e.g. improper disposal of dead shrimp, release of contaminated pond effluents, lack of post outbreak considerations).

The absence of adequate farm level biosecurity could potentially have major negative consequences to ponds and farms in the vicinity. Therefore, awareness and capacity building of farmers on farm-level biosecurity concepts should be given top priority by government agencies. Methods to apply the principles of biosecurity to inland culture systems which are small-scale, open farming systems with regular water exchange and with little, if any, control over pathogens or carriers entering the pond requires further study. However, implementing strict biosecurity measures at the farm level can be very expensive and may not be feasible in open farming systems. Biosecurity measures will be adopted at the farm level only if they are shown to effectively prevent the occurrence of the disease and at a cost the farmer can afford. System specific and cost-effective, better management practices (BMPs) incorporating principles of biosecurity should be developed, demonstrated, and validated. There is considerable information on better management practices for shrimp disease management to assist in these efforts. The Thai government's initiatives to control aquatic animal diseases should explore effective extension approaches to promote widespread adoption of BMPs, which include concepts of farm level biosecurity.

6.3 Shrimp Farm Management and Environmental Impacts

The environmental impacts associated with inland shrimp farming have yet to be thoroughly investigated. Most of the existing information has been drawn from desk study comparisons to coastal shrimp farming with little or no field investigation. Although this study did not undertake a detailed farm-level assessment of the environmental impacts of inland shrimp farms, it did investigate the concerns of those intimately connected with inland shrimp farming – the shrimp farmers, rice farmers and the village leaders. These responses provide important insights into the nature of the environmental problems created by and being faced by the industry, as well as the ways in which the industry can be made more sustainable.

6.3.1 Salinization of Land and Water Resources

One of the most publicly criticized aspects of inland shrimp farming is the potential for salinization of land and water resources in Thailand's lowland agricultural heartland. Salt is exported to the environment through the combined fluxes of effluent, seepage and leaching from the accumulated pond sediment. The institutional thinking regarding methods to curb inland expansion of shrimp farming warrants mention. In 1997, the Director-General for the Department of Fisheries stated:

> As far as the increasing trade in seawater to inland water we are not happy at all. We tried to stop them but it is taking time because they are poor. Once the poor people are making money, it is not easy to tell them to stop. But we are not happy at all… We don't know what to do with them. There is no law… But at least we tried... We try very much to control this. Not because we are convincing them to use these to compensate for the abandonment of shrimp farms near the sea (Plodprasop, 1997:14).

Salinization is not an issue of concern to shrimp farmers, as it has no impact on the operation of their farms. The field research, however, examined the issue from the perspective of rice farms who were situated adjacent to shrimp farms. It was found that small-scale rice growing households have very limited means of protecting themselves from the saline impacts of inland shrimp farming. Shrimp pond discharge raises canal salinity to levels that impact on yields of irrigated rice and orchard crops, the main agricultural land uses in the region. In Chachoengsao, fruit and vegetable growers report that inland shrimp culture has negatively impacted their crops. Several rice farmers reported productivity declines as high as 30% since the start of inland shrimp farming adjacent to their rice paddies. Although their estimates may be exaggerated, there is nonetheless sufficient basis to warrant more detailed investigation and/or mitigation efforts.

Some shrimp farmers have adopted measures to reduce or mitigate potential salinization impacts. They build buffer ditches around their ponds to minimize saline seepage. Shrimp farmers initiated this practice when adjacent agriculturists noticed declines in rice production. Mango orchards adjacent to inland shrimp ponds have also been impacted by salinization from inland shrimp ponds (Figure 6.5). In Bangkhla, Hua Sai, Moo 2 district of Chachoengsao province, mango farmers reported that the number of fruit as well as their size had declined. While improved drainage around the shrimp farms may help to limit the local impacts of salinization, they do not address concerns over regional impacts as the buffer ditches around the farms usually drain to the irrigation canals. There are, however, few data available on the salinization impacts of low-salinity shrimp culture, and no data on the salinization impacts to groundwater and aquifer sources.

The salinization impact from the storage of accumulated pond sediment represents a potentially major local and/or regional environmental concern. The 1997/1998 and 2004 field studies confirmed that shrimp farmers have problems finding places to dispose of this sediment. This sediment contains a high salt burden, and is usually piled adjacent to the shrimp pond onsite. Leachate from these piles will undoubtedly lead to salinization of the local area around the piles, and could eventually reach the adjacent irrigation canals. At the very least, salt laden sediment should be covered to prevent the leaching of salts from the pile during the rainy season. However, there are no guidelines for dealing with accumulated sediment.

Figure 6.5 Degraded Mango Orchard Adjacent to a Low-Salinity Shrimp Pond

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 2004

Some industry proponents argue that the most significant way for inland shrimp farms to mitigate the salt impacts in freshwater environments is to adopt zero-discharge farming techniques. This research found that the adoption rate of this type of system by inland shrimp farmers is very low, despite claims of widespread adoption by Thai shrimp farmers. However, even in zero-discharge ponds, almost half (45%) of the initial pond salt content is exported through seepage (Braaten and Flaherty, 2001). The use of pond liners would prevent saline seepage. However, inland shrimp farmers do not use them. Liners are costly and farmers report that they are disinclined to spend money on something that does not add to their profit margin and is not required by regulation. Also, the 1998 field study found that farmers leasing land for shrimp farming make the minimum investment needed to undertake culture. Liners, however, are not without their own problems. While their use would prevent salt from escaping the ponds, this would have the effect of increasing the salinity levels within the ponds. This presents a disposal problem when the time comes to empty the pond at harvest.

6.3.2 Water Use Conflicts

One factor that has been critical to the spread of inland shrimp farming into rice growing regions was that the required water infrastructure was already in place. The 1997/1998 and 2004 field studies confirmed that most of the low-salinity shrimp farms were situated within controlled irrigation areas, and that farmers drew their freshwater supplies from the irrigation canals. Water use conflicts associated with shrimp farming typically involve excessive consumption or competition between rice and shrimp farmers for limited supplies, and the pollution of available supplies (Miller et al., 1999).

Low-salinity shrimp culture requires substantial quantities of freshwater to fill the ponds and maintain environmental conditions during the grow-out period. In 1998, inland farmers used approximately 15,000 m^3 of freshwater per ha per crop. The value would be doubled over the year as most farmers cultivate at least two crops of shrimp, one during the dry season and one during the wet season. These findings are similar to another study which found that a typical inland shrimp farm consumes approximately 9000 m^3 of water per hectare per crop (Braaten and Flaherty, 2000). These figures are similar to the amount of water required to raise crops such as wet rice, banana or sugarcane. This suggests that inland shrimp farming should not have a significant effect on consumptive water use within irrigated agricultural areas. In non-irrigated areas, however, inland shrimp farming may still have the potential aggravate existing water use conflicts. The dry season is the optimum period for raising shrimp, and this preference may increase fresh water demand during a period of limited supply. Dry season demand for freshwater may even increase in areas that have saltwater naturally available as a result of intrusion, because shrimp farmers generally avoid this water source due to concerns over quality and virus transference.

Government policies pertaining to freshwater use for agriculture in rural areas are contradictory. On one hand rice farmers are discouraged from cultivating a second rice crop during the dry season so as to conserve water, while at the same time the year round cultivation of shrimp is promoted. Local regulators of the irrigation infrastructure have not been able to accurately account for the water withdrawal rates by inland shrimp farms. Because freshwater supply remains constant – while demands increase – conflicts among shrimp farmers and rice farmers are occurring. The outcome of these conflicts tends to favour farms owned by local elites or the farms located at the beginning of the canal which receive water first. The incidence of water use conflicts increased from the initial field study in 1997 and the final study in 2004. However, both field investigations documented cases where shrimp farms near the end of an irrigation canal lacked sufficient freshwater to maintain their operations. While seasonal constraints were mostly to blame, the increase in the number of farms may be a factor. In 2004, farms that were furthest along the canal from the source reported more problems with water quality and shrimp disease.

Even if the switch from rice farming to shrimp farming does not add to overall freshwater demand, most of the freshwater drawn by inland farmers is discharged as pond effluent into the irrigation canals (see, Figure 6.6 and Figure 6.7). This practice is commonplace and has resulted in tension among shrimp farmers. Pond effluent is laden with sediment – and the sediment loading has caused the smaller canals to fill up or become blocked (Figure 6.8). Dredging is required to clear the canals from time to time. The potential for conflict revolves around determining who will pay for dredging of the supply canals.

Figure 6.6 Water Discharge into a Small Ditch from Shrimp Pond to Improve Pond Water Quality

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

In 2004, many farms used less water-intensive methods compared to the farms surveyed in 1997/1998; they still produced significant effluent flows during harvest and disease events. When disease strikes, the most common management reaction is to discharge pond effluent into the adjacent canals or freshwater streams. Other high volume effluent events occur when there is poor water quality in the growout ponds and the farmer discharges some of the pond water and replaces it with new water. Farmers report the localized impacts are reduced water quality – water in the smaller canals is not fit for use in the shrimp farm. The management practices of each individual farmer determine the potential impact of pond effluent. If more shrimp farms adopt onsite treatment of pond effluent through wastewater treatment ponds, the impact of pond effluent could be reduced significantly.

Figure 6.7 Shrimp Pond Effluent Discharge into Small Irrigation Canal

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, May 1997

As low-salinity shrimp farming continues to expand into freshwater regions, the water use conflicts between shrimp farming and rice farming have intensified. The 1997/1998 and 2004 field studies documented numerous instances where shrimp farms could not use the water available in the irrigation canals and freshwater streams because of poor water quality. On one hand, shrimp farmers claimed that the pesticides and herbicides used in rice farming were causing most of their freshwater quality problems. On the other hand, rice farmers contacted in the 1997/1998 field studies reported that untreated shrimp pond effluent released to the irrigation canals was the major cause of their water quality problems. Shrimp farmers reported that even if they adhered to responsible chemical use in their own shrimp culture operations, their crops faced exposure risks to potentially harmful, sometimes lethal, pesticide residues introduced into the freshwater systems by rice farmers. To minimize conflicts between intensive rice farming and intensive shrimp farming, further study is needed on examining the feasibility of the mutual coexistence of these activities. The zoning of sites for intensive shrimp farming and intensive rice farming is one specific course of action that urgently requires further study.

Figure 6.8 Small Irrigation Canal Occluded by Shrimp Farm Sediment

Photo Credit – Paul Miller, Chachoengsao Province, Thailand, April 2004

6.3.3 Pollution

The majority of the nutrients added to shrimp ponds in the form of fertilizer or feed are not incorporated into the shrimp, but end up being deposited in pond sediments or discharged as effluent (Funge-Smith and Briggs, 1998). While water quality problems are common in all shrimp farming areas, these can be especially problematic in inland regions where irrigation canals possess a relatively low assimilative capacity. Pollution problems stem from the multiple users of the irrigation canal water and the return of wastewater to the canals. Most inland shrimp farms ponds completely drain the growout ponds at harvest, and release large quantities of untreated effluent directly into adjacent water bodies. Only a relatively small number of operations treat and recycle effluent within reservoirs. The decomposition of organic waste in surface waters reduces dissolved oxygen levels, can suffocate or smother aquatic fauna, and produces toxic chemicals such as ammonia and hydrogen sulfide (Primavera, 1998). This is an externality that downstream water users have little control over, and they usually must accept the consequences without any recourse.

Inland shrimp farms operate somewhat differently than coastal farms, as very little effluent is released during the first 60 days of the grow-out cycle (Braaten and Flaherty, 2000). Feed requirements are relatively modest at this point, and additions of freshwater are usually sufficient to maintain water quality in the pond. During the latter half of the culture cycle, however, water exchange is used to maintain the growing environment and effluent is discharged. A significant amount of nutrient enriched effluent is also released during harvest when the ponds are completely drained. Very little information is available on the composition and impact of inland shrimp farm effluent, but it has been estimated that culture period and harvest effluent contain BOD concentrations of between 10 and 25 milligrams per litre (Pollution Control Department, 1996).

Although the effect of shrimp farm effluent on receiving waters is of concern, a much more serious issue exists with regard to the disposal of semi-liquid sludge that remains in the grow-out ponds after harvest. This material consists of uneaten feed, faeces, and sediments eroded from the pond enclosure and is highly polluting with BOD concentrations of 1500 milligrams per litre or higher (Funge-Smith and Briggs, 1998). Pumping pond sludge directly into adjacent water bodies is illegal, and this material is usually maintained on site where is it is kept in holding ponds or packed onto pond banks. The illegal dumping of pond sludge into freshwater bodies is not uncommon, however, due to a lack of farmer awareness and regulatory enforcement (Pollution Control Department, 1996).

Other important water pollutants originating in the shrimp ponds are the chemicals and chemotherapeutant products added to the ponds by the farmers. These chemicals can leave the ponds through effluent, seepage through pond bottoms, and through the removal and disposal of bottom sludge. One of the most common and worrisome pond additives is antibiotics. Most commercial shrimp feeds are enriched with common antibiotics such as oxytetracycline. Studies of fish farms have shown that the majority of antibiotics added in feed are not assimilated by fish but go into environment (GESAMP, 1997). Once in the environment antibiotics can have a wide range of effects. In surface water, they may lead to antibiotic resistant pathogens or accumulate in the tissues of wild fish. If they accumulate in sediments, antibiotics may prevent natural bacterial decomposition and consequently alter the natural benthic environment (Chua et al., 1989).

6.4 Community and Social Impacts

Most of the new entrants to shrimp farming have previously grown rice. Despite the inherent risks in shrimp culture, most farmers do not want to continue growing rice, because paddy prices keep declining. The low returns from rice farming have helped create an economic environment in which there is no shortage of sites available for purchase or short-term lease for shrimp farming. The conversion of rice farms to shrimp farms is having both positive and negative social impacts. The difference in economic benefits between shrimp farming and paddy field rice farming is large. In 1998, it was estimated that the return from just one harvest from a traditionally managed shrimp pond made a gross income six times that of rice in one year of production (with two growing cycles).

The 1997/1998 and 2004 field studies found that one of the largest positive community and social impacts of the industry is farm-level employment. Other positive employment impacts result from the linked activities, such as trucking, banking, shipment, and packaging services. Shrimp farming also provides the opportunity for a large number of women to be employed in shrimp processing enterprises, and to improve their role and position in the family. It has also contributed to human capital development by creating many new entrepreneurs (Polioudakis, 2000).

The 1997/1998 and 2004 field studies also found that there is an extremely strong demonstration effect associated with shrimp pond development. The success of the early adopters, often the community leaders, demonstrated to those on the margins, mostly rice farmers, that shrimp farming was a lucrative, albeit risky, activity. Unfortunately, there has been a tendency on the part of shrimp farmers and those promoting the industry to hide the negative aspects and over emphasize the positive aspects. While some farmers are successful, many others are less fortunate. This research provides further support for the findings of other analysts (Tasneeyanond and Rubthong, 1991), which is that many small-scale shrimp farmers do not have adequate knowledge of intensive shrimp culture practices to manage their farms sustainably. The majority of small-scale farmers have limited education, usually less than 4th-year primary education, and no previous training in shrimp farming.

Many of the positive community and social impacts of inland shrimp farming are diminished by the fact that farmers do not have alternative sources of income in place if shrimp farming fails. Most inland shrimp farmers had committed most of their savings into establishing their shrimp farm. They had also borrowed money for startup and were economically dependent upon success. The farmers claimed that they could sustain one crop loss and survive, however, most were ill prepared for the consequences if the losses were much more.

The response of rice farmers and orchardists to inland shrimp farming has been popularized by press reports condemning shrimp culture for the destruction of Thailand's "rice bowl" (Bangkok Post, 1998b; Bangkok Post, 1998a; Techawongtham, 1998; The Nation, 1998a). Rice farmers and fruit growers in Bangkok organized protests when information on the extent of inland shrimp culture became known. However, very little has been reported since the government's decision to uphold the ban (Ridmontri, 1998b; Ridmontri, 1998a). The 1998 field surveys found that some inland shrimp farmers maintain rice plots while farming shrimp on a separate parcel of land, or have dedicated some portion of their rice paddy to shrimp production. With success in shrimp, however, the rice farmer gradually builds more and more ponds until most of the rice paddy is converted to shrimp ponds.

The 1997/1998 field studies documented several cases in rural areas where local agriculturalists have resisted the temptation to convert their land to shrimp ponds. However, most believe that shrimp farms are surrounding their lands and that they are powerless to stop this type of development. While rice farmers have been the focus of media attention, orchardists represent a large number, but virtually unheard aspect of the debate over inland shrimp pond development. Many of the orchardists interviewed for this research expressed frustration over shrimp pond development. In several villages visited during the 1997/1998 field studies, more than 80% of the village area has been converted from productive mango orchards to shrimp ponds. These respondents indicated that they couldn't revert to mango orchard farming once the shrimp ponds fail. Concerns in the farming community over shrimp pond development are escalating and most realize that the government will do very little to curtail future low-salinity shrimp pond conversion.

Local people have had a difficult time voicing opposition to the expansion of shrimp farming, as the police, the army and the justice system generally stand in support of those with money and political connections. Shrimp investors feel free to do what they like, and sometimes go far beyond what is acceptable. In January 2001, for example, Mr. Jurin Rachapol, a conservationist and advocate of community forestry in Phuket province was assassinated. His family and friends believe that Jurin's activism against shrimp farming was the reason he was killed. The *Bangkok Post* characterized the conflict as one of "conservation" and "wise use and management" against, "over-exploitation of natural resources" and "greed" of shrimp farmers (Bangkok Post, 2001; Chueniran, 2001).

There is little documentation of the struggle between rice farming and shrimp farming. Oyvind (1999) reports some of the testimony provided by Suphanburi rice farmers. Sawai Pribwai, 68 years old, is known in Suphanburi as a skilled rice cropper with good harvests. A few years ago, he was one of only a few farmers who managed to save their crops from disease, which destroyed most of the crops in the district. He used a local variety of rice that was resistant to the disease. Now, his rice fields lie fallow. "I have no chance at all against salt," he admits. "We have never had any problems with salt here before, Suphanburi is too far from the ocean," he explains to the Bangkok newspaper *The Nation*. The old farmer does not care to voice his criticism publicly, so he used a fake name. "I don't want to be killed by a bullet. These people mean business," he says.

6.5 Recommendations for Improved Management of the Shrimp Sector

This research provides several insights into ways of improving the management of marine shrimp farming in Thailand. While the following recommendations have arisen from an indepth study of low-salinity shrimp culture operations, many also apply to the marine shrimp culture sector. The recommendations are presented in two sections. The first set pertains to the national government, and the second set pertains to the shrimp farmers and hatchery managers. The national level recommendations address some of the larger industry wide management and policy issues that are undermining sustainability. The shrimp farmer and hatchery manager recommendations specify what could be implemented at the farm-level to make shrimp farming more sustainable. Ultimately, action on both levels is needed to improve the sustainability of shrimp farming. The recommendations in each of the following components are presented in order of priority.

6.5.1 Recommendations for the National Government

This section outlines recommendations for the national government in three components: (a) regulatory, (b) education, and (c) policy.

Regulation, Enforcement and Jurisdictional Conflicts in the Shrimp Farming Sector

- Establish a separate legal and administrative government department to deal specifically with the unique management problems of the shrimp farming industry.
- Implement a mandatory requirement for shrimp farming proponents to complete independent environmental impact assessments prior to any new shrimp farm development.

- Enforce existing regulations and implement industrial wastewater standards for marine shrimp aquaculture within the *National Environmental Quality Act*.
- Implement specific regulations for low-salinity shrimp farming and maintain the ban on the siting of marine shrimp farms in freshwater regions.
- Support the use of economic incentives/disincentives to induce behavioral changes towards the environment and to generate revenues to finance environmental policy programmes. These may take the form of taxes, penalties and credits for effluent disposal, payments for groundwater abstraction, and chemical use.
- Withdraw subsidies and tax breaks, or at least require, environmental planning and performance as preconditions to the approval of loans, credits, and subsidies, and access to resources used in shrimp culture.
- Reduce pressure on wild-caught PL, broodstock, and spawners by supporting research and development on broodstock domestication. The use of domesticated broodstock would greatly reduce the need for shrimp transfer between regions and countries.
- Enforce stricter guidelines for disease inspection and quarantine to reduce the risk of spreading disease through the transfer of non-native species.
- Improve the control and regulation of the transfer of shrimp PL, broodstock and spawners to reduce the spread of disease between regions, countries and continents.

Education and Extension Services

Laws and regulations will not on their own ensure sustainable shrimp culture. Therefore, the government should, along with legislation, implement education and extension programs in rural areas in order to promote more sustainable shrimp culture practices.

- Provide increased technical and financial assistance to improve culture practices and operating procedures for better productivity and sustainability.
- Provide extension services for rapid disease diagnostics.
- Provide financial support to local grower organizations in order to implement extension training for better land and water management practices.

Policy, Sectoral Planning, and Natural Resource Management

The groups most vulnerable to the negative effects of shrimp culture generally do not participate in the formulation and implementation of public policies pertaining to shrimp farming. The resulting view of shrimp farmers in Thailand of the state's role in aquaculture development is very negative. To redress this perception, local stakeholders need to be involved in policy formation and implementation, and in the planning of protocols and codes of conduct. Shrimp farmers must be directly involved in government initiatives to improve farm-level management and operating practices.

- Include local stakeholders in policy formulation and implementation in order to build up the capacity of the small-scale shrimp farmers.
- Transfer land and water management responsibilities to local institutions. Shift the planning approach from a centralized "command-and-control" structure towards a decentralized structure that uses local institutions for shrimp sector management.
- Encourage the farming of low trophic level fish with herbivorous diets. Instead of favoring the rapid expansion of high-valued carnivorous species like shrimp, the focus should be on species like carp, tilapia, catfish, milkfish and molluscs.
- Support co-management and community-based management approaches. Under community-based management, regional aquaculture development plans would have a much higher positive impact on jobs and the environment, and face reduced community opposition.
- Develop, implement, and enforce a sectoral planning strategy for the shrimp industry that addresses the issue of farm densities within specified geographical boundaries (e.g., watersheds and irrigation areas).
- Involve local communities in creating separate zones and enforcing practice rules for freshwater and brackishwater aquaculture.

- Support land use planning and zoning, together with environmental impact assessment procedures, to minimize conflicts between resource users, reduce negative environmental impacts, and enhance sustainable development.
- Determine the infrastructure requirements of shrimp culture by completing an accurate inventory of the land and water resources dedicated to shrimp production.
- Support studies on the development of more efficient feeding techniques and the formulation of feeds that contain less fishmeal.
- Increase the monitoring and control of chemical use in shrimp farming.
- Require chemical agencies to accurately label chemical products. Chemicals and chemotherapeutants sold to inland shrimp farmers should list ingredients and composition, and disclose the possible residue and human health effects, administration dose or expiry information.
- Require that the disposal of offal, sludge, dead or diseased shrimp, excess chemotherapeutants and other hazardous chemical inputs does not constitute a hazard to human health and the environment.
- Support the development of protocols for managing accumulated saline pond sludge to mitigate the environmental effects.
- Support the development of guidelines for treatment, and cost effective methods for sediment disposal.

6.5.2 Recommendations for Shrimp Farmers and Hatchery Managers

The management and operating practices of shrimp farmers ultimately determine the sustainability of shrimp culture. In order to ensure long-term sustainability of their ponds, farmers need to adopt the following practices:

Shrimp Farm Construction and Growout Practices

- Conduct adequate site selection and planning prior to farm construction.
- Cooperate with other shrimp farmers during construction to reduce infrastructure duplication.
- Create buffer zones around the ponds during construction to reduce salinization.

- Reduce stocking density.
- Voluntarily comply with existing regulations.
- Improve pond management, and limit use of chemicals and chemotherapeutants.
- Incorporate integrated aquaculture techniques to re-circulate resources and wastes within the farm. Nutrient recycling through polyculture could be more practical and efficient than controlling or treating the effluents associated with intensive monoculture practices.
- Adopt recirculating or so-called "closed" systems to reduce or eliminate excessive water use, effluent discharge, and soil salinization, while increasing productivity and limiting dependence on large land areas.
- Improved pond design; construction of waste-water oxidation-sedimentation ponds, reduction of water exchange rates; reduction of nitrogen and phosphorous inputs from feed; removal of pond sludge; a combination of semi-closed farming systems with settling ponds and biological treatment ponds using polyculture systems.
- Keep better pond management records.
- Water quality (such as temperature, pH, salinity, oxygen, ammonium and nitrate concentrations, turbidity, flow rates etc) should be monitored and recorded regularly.

Wastewater and Sediment Management

- Maintain effluent standards and develop wastewater management plans.
- Farms shall contain sediment from ponds, canals, and settling basins in order to reduce salinization or other ecological impacts to surrounding land and water.
- Reserve at least 10% of the total farm area for sedimentation ponds or wastewater treatment ponds in the farm layout.
- Construct water storage reservoirs with necessary treatment facilities and introduction of water recycling systems in farms.
- Utilize biological treatment systems in the design of settling ponds.
- Limit soil and water salinization through the use of pond liners to minimize seepage.
- Minimize and/or prevent sludge disposal by leaving pond fallow to enhance the decomposition of organic matter by bacteria.

- Pond bottoms should be dried and tilled to allow oxidation and mineralization of sediments between crops. They should not be wet flushed.
- Dispose of pond sediment or sludge on high ground or where it does not result in polluted runoff.
- Never dispose of sludge or pond sediment in drainage canals or in fresh water.
- Saline water should not be discharged from inland farms, and a ditch to intercept seepage should surround farms.
- Construct vegetative barriers of salt-sensitive vegetation around farms to help detect or limit the movement of salt into adjacent areas.

Shrimp Health Management and Biosecurity

- Farms should develop shrimp health management plans that indicate procedures to avoid the introduction of disease, protocols to maintain water and soil quality in ponds, and shrimp health monitoring and disease diagnosis techniques.
- Shrimp health management plans should explain the steps to be taken when a diagnosed disease will be treated with approved chemicals.
- Cultivate only indigenous/native shrimp species to minimize the spread of disease and reduce the risk of introducing an alien species.
- Where non-native species have already been introduced – as in the case of white shrimp – the risk of escape must be recognized and minimized.
- Purchase or hire laboratory equipment and develop better testing protocols for disease diagnostics.

6.6 Summary

The widespread and continuing development of low-salinity shrimp culture in Thailand's central plains underscores the importance of environmental management. The responsibility for improving the environmental management of the Thai shrimp sector lies at many levels. National government policies and regulations have not been able to redirect the shrimp farming industry on to a sustainable path. This research has determined that the problems and opportunities associated with inland marine shrimp aquaculture development can only be realized through: improvements in siting, farm design, technology, and management at the farm-level (requiring a set of incentives and constraints to promote these changes); better location and spatial distribution of the sector as a whole (implying some form of zoning); better water supply for the sector as a whole; better health management, including disease and stock control at individual farm and sector levels; improved communication and information exchange; improved access to markets and trade opportunities; and more equitable distribution of the benefits derived from aquaculture development. This implies strategic intervention by government and producer associations or industry organizations to allocate and use resources more equitably and efficiently in both time and space – in other words, more effective and integrated planning and management of the sector. The following chapter presents the conclusions of this study.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The movement to greater liberalization of trade in the global marketplace is bringing increased pressure for the restructuring of agriculture from traditional, low export value crops such as rice, to capital intensive, 'nontraditional' high value crops such as fruit, vegetables, poultry, and seafood products. The dramatic expansion of marine shrimp farming is a classic example of the restructuring of global agro-food systems in the aquaculture sector. Since the early 1970s, marine shrimp have been an important export commodity in the global food trade market. The shrimp sector is a major source of export earnings for a number of countries in Asia and Latin America. However, the rapid development of marine shrimp farming has also emerged as one of the most important environmental challenges facing tropical developing nations.

One of the objectives of this study was to document the integration of shrimp farming into Thailand's national development strategy. Beginning in the late 1980s, the Thai government's agricultural restructuring policies actively promoted intensive marine shrimp production in land-based ponds. Marine shrimp have since become one of Thailand's most important agricultural exports. First generation shrimp farms, located mostly in coastal areas, however, have given way to a second generation of shrimp farms located in freshwater and brackishwater areas. Primarily through technical innovation, farmers discovered that black tiger shrimp (a marine species) could be acclimatized to a low-salinity environment. Since the mid 1990s, the most significant industry expansion has occurred in the irrigated floodplain and delta of Thailand's central plain. Low-salinity shrimp culture now accounts for a large and rising proportion of total Thai production, and is thus a significant component of world production.

Investigating the nature of the low-salinity shrimp culture innovation, including the operating practices and techniques of low-salinity shrimp culture systems was one of the primary objectives of this study. This study found that most of the culture practices commonly utilized in low-salinity culture were similar in function to practices utilized in coastal shrimp farming – i.e., site selection, farm construction, pond soil preparation, water storage and sterilization, feed and chemical management, liquid and solid waste disposal, and harvesting. However, the farmers had modified culture practices in several key areas of the shrimp production process. The 1997/1998 studies determined that the key innovations occurred in hatchery techniques, development of saltwater infrastructure, modifications to growout pond construction, and the development of management practices to support the growout phase of low-salinity culture. In 2004, the field study also found that while some procedures had remained the same, more innovations had occurred in saltwater delivery and in the adoption of an exotic species of shrimp. Feed and chemical agents generated local brine sources by constructing holding tanks at their shops giving farmers the ability to purchase smaller quantities of high concentration brine cheaply on short notice. Prior to this study, the switch to white shrimp by low-salinity farmers was unreported.

One of the important aspects of this study was that during the course of the field studies low-salinity shrimp farming transitioned from a fledging 'frontier' activity to a fully established form of shrimp culture. The data collected during the initial field studies in 1997/1998 and the final field studies in 2004 allowed the researcher to identify several important changes in farm-level management practices. Farmers had increased the number of shrimp crops produced in one year, but had decreased the pond stocking densities. They also reported using fewer chemicals during the growout phase and were less willing to pay for freshwater. In 2004, the shrimp farmers had also achieved higher levels of education compared to farmers surveyed in the 1997/1998 field studies, which could potentially translate into improved management techniques. The combined effects of these improvements in farm-level management, however, had not noticeably increased the performance of low-salinity shrimp farming as a whole. All of the farmers reported experiencing major production problems in all phases of growout. A related finding, which appeared to be contradictory, was that new farmers continued to enter into shrimp culture despite these problems and tolerated high risks to commence shrimp culture. Once committed, most of the farmers also had no contingency plans for other economic activities if they could not farm shrimp. While they have established their farms without government interference, they have also been insulated from technological advances and information sources that could help to improve farm-level management, and ultimately the sustainability of their operations. This insular tendency was one reason that this type of shrimp farming initially escaped widespread attention. Also, most farmers were reticent to provide information regarding the nature of their activities to outsiders for fear of the government exerting more control over their activities. They were fiercely independent and preferred to develop solutions on their own. However, farmers also resented the fact that they received no support from the government when their crops suffered disease events. The combination of these characteristics, however, was advantageous to producers as the impacts of low-salinity shrimp farming escaped public scrutiny.

This study also set out to identify the ways in which low-salinity shrimp farming is impacting on rural environments and communities. It was found that most farmers were not rich from shrimp farming, but they did make more money raising shrimp than in their previous occupations as rice farmers if they suffered no disease losses. Low-salinity culture has a powerful demonstration effect in rural areas prompting new entrants to take enormous financial risks. Farmers routinely borrowed substantial amounts of money and possessed limited technical knowledge of intensive shrimp culture techniques. Many of their investments had subsequently failed because of disease leaving them indebted to local moneylenders. Despite the emergence of environmental problems in all of the shrimp farming areas, overt community opposition to low-salinity culture was muted because many of the influential people in Chachoengsao's rural areas were also shrimp farmers. However, localized tension over low-salinity culture did occur between some of the shrimp farmers, rice farmers, and village leaders. The local farmers, for example, claimed that outsiders who leased land for shrimp culture did not care about the impacts to the local environment and had adopted culture practices that were more damaging to the environment.

Prior to this study, the prevailing view was that low-salinity shrimp culture was quite localized and of negligible consequence in terms of its environmental impact. The results of this research, however, found that the environmental impacts of low-salinity culture are not always localized, or of negligible consequences in terms of environmental impacts. These findings highlight the need for further research in several areas. Of the environmental impacts, land and water salinization is the most critical issue due to the potential for low-salinity culture to cause long-term damage to agricultural areas. Given the large amount of rice growing areas potentially at risk from salinization, additional studies are required to better understand this phenomenon and to protect the livelihoods of rural agriculturalists. The long-term effects of salt accumulation and distribution in the soil and water systems are not known. The results of these studies may influence policy directions for managing low-salinity culture. One of the most prescient policy needs for low-salinity shrimp culture is for government agencies to develop a set of zoning regulations for marine shrimp farming in freshwater or agricultural areas.

One of the major findings that resulted from examining operating practices was that improvements in farm-level management had the potential to substantially reduce the environmental impacts of low-salinity shrimp farms. The need is urgent as the entire shrimp farming sector is experiencing major problems in all phases of growout. The 1997/1998 and the 2004 field studies found that the primary management problems resulted from poor site selection and farm location, and the farmers' choice of technical operating practices in regard of land and water use. The field studies also found that most, if not all, of these management problems were preventable or they could be substantially reduced through better management practices. Farmers simply did not take responsibility for their actions claiming that they did not have the financial resources to alter practices. The absence of government intervention has also allowed for short-term financial perspectives to dominate management decision-making at the farm-level. Most farmers plainly lacked the skills to successfully manage their farms over the long-term.

The primary task for government agencies must be to establish, maintain and develop an appropriate and transparent legal and administrative framework, which facilitates the development of environmentally responsible shrimp production, including environmental laws with provisions for independent environmental impact assessment.

However, the other important tasking of government agencies – and this is where further study is needed – is how to include farmers in developing solutions. While stronger government intervention is needed, farmers also need to be invited to collaborate with the national and local governments in developing management policies, regulations, and operating procedures.

This study found that one of the more promising areas for regulating the activities of individual shrimp farmers is through community regulation facilitated by NGOs and local governments. Despite their often individualistic and short-term focus, farmers have powerful incentives to engage in collective self-regulation, given their dependence on common property water resources and mutual vulnerability to the questionable practices of other operators. Government agencies could use their limited resources more effectively by incorporating the input from the local communities in the planning and implementation of policies rather than trying to impose and enforce regulations that are rendered ineffective because they are routinely ignored. A consultation process, with multi-stakeholder participation, is critical in better understanding the related issues that taken alone do not point to feasible and practical policy solutions. Planning should be holistic, not sectoral; people should be at the centre, with rural development and the role for shrimp culture determined by an understanding of people's livelihoods.

One of the objectives of this study was to develop a set of recommendations for the government to make policy improvements, and for the hatchery managers and farmers to implement better farm-level management and operating practices. While this has been done, the rapid and complete implementation of these recommendations is unlikely. Thai shrimp farmers have been able to ignore or circumvent recommended actions. A new approach to implementing better practices would be to introduce incremental changes in order to demonstrate the economic benefits of these actions to farmers. It is unrealistic, however, to expect that change in the shrimp industry will result without stronger regulatory measures. However, in Thailand, and in other shrimp producing countries, a complete transformation of the shrimp industry will be difficult during the current time of fast growth in the industry because political, market, labor, and consumer forces are all pushing the industry to the limits of intensification and expanded production. Moreover, Thai shrimp farmers have substantial investments in infrastructure that they would not willingly abandon.

Another objective of this study was to investigate the factors contributing to the rapid adoption of low-salinity shrimp culture in freshwater environments. Low-salinity shrimp culture first evolved when coastal shrimp farms experienced major production losses from disease. The field studies determined that several factors have combined to support the rapid expansion of low-salinity culture allowing Thailand to maintain record high levels of shrimp production. Firstly, the government has been slow to regulate low-salinity culture, which resulted in the unlimited expansion of shrimp farming area and the unrestricted entry of new farmers. These conditions for rapid expansion were fueled by the potentially high profits in shrimp culture and the fact that low-salinity shrimp culture was a relatively easy technology for rural rice farmers to adopt. While the availability of suitable sites for coastal shrimp farming is severely constrained, the availability of vast irrigated areas in Thailand's freshwater regions is continuing to drive the expansion of low-salinity shrimp culture. As the technical feasibility and economic viability of low-salinity shrimp culture is now well-established, low-salinity culture may soon extend beyond the Thai context to other lowland irrigated rice producing river deltas. The conditions that have facilitated the adoption of low-salinity shrimp culture in Thailand are present in other countries in the region (e.g. Vietnam, Indonesia, Bangladesh and Sri Lanka). Large areas in these countries are open to exploitation and development by low-salinity shrimp culture. Therefore, the findings of this study offer critically important insights to the management of low-salinity shrimp culture.

The long-term sustainability of the shrimp farming industry hinges on assisting the farmers in adopting cost-effective management practices that minimize or reduce the environmental impacts of their operating practices. In Thailand, producer associations, with support from government training and extension programs, are ideally suited to assisting in the voluntary adoption of best management practices (BMPs) suggested in the *Thai Code of Conduct for Marine Shrimp Farming*. The lack of government resources, however, as well as prevailing cultural attitudes towards regulation are reasons that BMPs are not likely to be voluntarily taken up on a large scale. However, important improvements in farm-level management have been achieved by restricting the international trade of shrimp products because of food safety issues. Shrimp importing nations now routinely screen shrimp for chemical substances, notably antibiotic residues. Import restrictions on Thai shrimp products found to contain antibiotics, for example, have quickly forced farmers to improve chemical use during growout. Low-salinity shrimp farmers appeared to have acted on these concerns and reported using fewer chemicals during growout. Public awareness campaigns by international NGOs to reduce consumer demand for farmed shrimp could further increase the willingness of officials to enforce laws against violators because failure can result in increased possibility of consumer sanctions.

One of the more confounding aspects of this study was despite an overwhelming amount of information on how to achieve sustainable shrimp culture this information has yet to be of much benefit to shrimp farming operations in Thailand. It seems obvious that farmers would better serve their own interests if they would self organize and assume more responsibility for their actions. Ultimately, the long-term prospects for sustainable shrimp culture hinge on addressing systemic problems by those participating and promoting shrimp farming. This study has determined that the current pathways are unlikely to lead to a sustainable shrimp industry. In the short term, improvements in farm-level management can reduce the environmental impacts, and structural changes to improve access to knowledge, credit, and other resources for the poor could help garner more of the potential social development benefits. In the longer term, however, a complete transformation in the way shrimp are cultured, fed, processed, distributed, and consumed is needed. This would change the way profits and costs are shared, and have to be guided by new institutions and environmentally aware consumption demands that provide a better mix of incentives for good environmental practices by industry. There is an obvious contradiction between efforts to adopt more sustainable practices on one hand and the increasing global demand for fisheries products on the other hand. The gains made in environmental management improvements are likely to be annihilated by even greater consumption. The solution to this likely scenario is to reduce consumption of shrimp products that are natural resource intensive in favour of products produced using more sustainable practices. This implies de-intensifying production in some locations, whereas in many other locations, the solution will be finding alternatives to growing and eating shrimp.

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APPENDIX 1

SHIRMP FARM SURVEY

This survey was utilized during field research in Thailand during 1997, 1998 and 2004. A box around the text indicates an additional question that was incorporated into the 1998 or 2004 field season. **Boxed text is that is highlighted in black indicates a question that was added in 1998, and boxed text that is highlighted in blue denotes a question that was added in 2004.** **Any of the boxed text that is highlighted in red indicates a question that was only asked during the 1997 field season.**

Survey Number:________________ **Date**: (day/month/year):________________

A. IDENTIFICATION

A1. Location of the survey

Province ____________________
District ____________________
Village ____________________
House Number ____________________

A2. What is the farm status at the present time?

Active (shrimp in the ponds) _____________
Active (ponds empty/between crops) _____________
New farm (under construction) _____________
Idle _____________
Abandoned _____________

A3. Respondent is the:

Owner _____________
Owner/operator _____________
Lessee/tenant _____________
Share/contract farmer _____________
Farm manager _____________

Technician ____________
Other ____________

A4. Owner of the shrimp farm is a local or a non-local?
CIRCLE ONE: Local Non-local

If local, how long have you lived in this district? ____________Years

If non-local, from where did you move?

____

A5. Land ownership
Public Land ____________
Leased ____________
Cost per year of lease ____________Baht
Length of lease ____________Years
Owned ____________

A6. If owned, what is the type of land document?
NS-4 (Cha-nord or land title deed) ______
NS-3 (Nor-Sor-Sarm) ______
NS-3K (Nor-Sor Sarm-Kor) ______
NS-2 (Bai-Chong) ______
SK-1 (Sor-Kor-Neung) ______
STK (Sor-Tor-Kor) ______

A7. How long have you owned the land? _____Years

B. SITE DESCRIPTION

B1. Physical parameters of the shrimp farm
Number of culture ponds ______ponds
Total culture pond area ______rai
Culture period per crop ______days
Number of crops per year ______crops
Distance to the seashore ______km
Usual fallow period ______days

B2. How many <u>years</u> have shrimp been raised at this site? ______Years

If more than five years: what do you think is the main reason for your success?

How many shrimp <u>crops</u> have been produced at this site?

B3. What was the land use here <u>before</u> shrimp farming?
Inter tidal Zone

Mangrove ______
Wetland ______
Saltpan ______
Other (aquaculture) ______
Other ______

Supra-tidal Area
Rice farming ______
Coconut ______
Upland crops ______
Other (aquaculture) ______
Other ______

B4. What is the major land use in the area around your shrimp farm?
Shrimp farming ____________
Rice farming ____________
Fruit orchard ____________
Factory ____________
Not sure ____________

B5. Do you culture the black tiger shrimp?
CIRCLE ONE: YES NO

What problems have you had in culturing the black tiger shrimp?

What success have you had in culturing the black tiger shrimp?

Do you culture the white shrimp now?
CIRCLE ONE: YES NO

If no, why do you not culture the white shrimp?

If yes, when did you start culturing the white shrimp?
____________ MONTH and _______________ YEAR

Why did you switch to culturing the white shrimp?

What problems have you had with culturing the white shrimp?

What successes have you had with culturing the white shrimp?

Do you switch shrimp species between crops? (I.e., black tiger now and then white shrimp next crop)

CIRCLE ONE: YES NO
Explain: ____

B6. What stocking density do you use?
____________Pieces/sq. metre OR ____________pieces/ rai

Stocking density for the black tiger shrimp?
____________Pieces/sq. metre OR ____________pieces/ rai

Stocking density for the white shrimp?
____________Pieces/sq. metre OR ____________pieces/ rai

B7. Can you estimate the feeding rate per day?
First month: ______kg/time/day
Second month: ______kg/time/day
Third month: ______kg/time/day

B8. Do you practice polyculture?
CIRCLE ONE: YES NO

If YES, what species to you cultivate?

____

If YES, is the polyculture in the reservoir or in the shrimp ponds? (Check which applies)
Reservoir ____________ Shrimp ponds ____________

C. BRACKISH WATER SUPPLY AND MANAGEMENT

C1. What is the <u>main</u> source of your saline/brackish water?
1. Trucked in from sea/estuary ____________
2. Trucked in from saltpan ____________
3. Estuary ____________
4. Pipeline from sea ____________
5. Canal from sea ____________
6. Mix water with bags of salt onsite ____________
7. Other ____________

C2. If trucked in, where does the water come from? (Give location of source)

____

C3. Provide details of the various salinity levels

First day, fry in the acclimation pen	__________________ppt
Culture pond (start of growout)	__________________ppt
Culture pond (second month)	__________________ppt
Culture pond (third month)	__________________ppt
At harvest	__________________ppt

In your reservoir ___________________ppt

C4. Is the source of your salt water different in the wet season than in the dry season? CIRCLE: YES NO
If yes, explain ____

D. FRESH WATER SUPPLY AND MANAGEMENT

D1. Do you use fresh water at this site?
CIRCLE ONE: YES NO

D2. If YES, what is your source of fresh water? (Check all that apply)

1. Canal connected to a river ______
2. Irrigation canal ______
3. Ground water from a well ______
4. Reservoir ______
5. River ______
6. Stream ______
7. Other source ______

If other, please explain: ________________________________

D3. Do you have access to a good supply of fresh water?
CIRCLE ONE: YES NO
If NO, briefly explain ____

D4. Have you constructed your own access to the irrigation canals to provide fresh water to your ponds?
CIRCLE ONE: YES NO

D5. Do you use a water storage reservoir?
CIRCLE ONE: YES NO

If YES, can you estimate the total area of storage reservoirs on your farm (in rai)?

0-2.5 _____________
2.5-5 _____________
5-7.5 _____________
7.5-10 _____________
More that 10 rai _____________

IF YES, how deep are your storage reservoirs?
___________________Metres

D6. Is your source fresh water affected by the season?
CIRCLE ONE: YES NO
If yes, explain _________________________________

If NO, explain why not ____________________

D7. How often do you require add fresh water to the culture ponds?

Once per day ________
Several times per day ________
Depends on the season ________

D8. Could you estimate the quantity of fresh water you require on a daily basis?

CIRCLE ONE: YES NO

D9. If YES, how much fresh water do you use?

____

D10. Has your shrimp farm ever experienced a fresh water shortage?

CIRCLE ONE: YES NO

If YES, check which applies:

Frequently ____________
Sometimes/Occasionally ____________
During the dry season ____________

D11. Do you think that shrimp farming reduces the availability of fresh water in this area?

CIRCLE ONE: YES NO

D12. What would you do if there were a shortage of fresh water for an extended period of time?

Explain ____________________________

D13. Who controls the fresh water supply to your farm?

Explain ____________________________

D14. What is your access to a fresh water supply?

Explain ____________________________

D15. Is there enough fresh freshwater for everyone?

CIRCLE ONE: **YES** **NO**

If NOT, please explain ____________________________

D16. Do other shrimp farms share the same fresh water supply as you?

CIRCLE ONE: YES NO

D17. Would you be willing to pay for fresh water?

CIRCLE ONE: YES NO

D18. Do you discuss fresh water allocation amongst other water users in your area?

CIRCLE ONE: YES NO

D19. Do you culture fish or any other species in your reservoir?
CIRCLE ONE: YES NO

D20. Do you have an effluent treatment pond?
CIRCLE: YES NO
If YES, how many rai? ______Rai

E. WATER TREATMENT AND WASTE DISCHARGE

E1. Do you treat your intake water?
CIRCLE: YES NO

If yes, explain how you treat intake water?

If no, explain why you do not treat intake water?

E2. Do your treat the pond effluent?
CIRCLE: YES NO

If yes, explain how you treat pond effluent?

If no, explain why you do not treat pond effluent?

E3. Where do you discharge your pond effluent?

____

E4. Do you remove accumulated pond sediments from the pond after harvest?
CIRCLE: YES NO
If YES, what do you do with the sediments?
____

Do you have a problem with storing accumulated sediment?

If yes, how do you solve this problem?

If no, why do you not have a problem?

E5. Has this farm had any serious disease problems?
CIRCLE: YES NO

If YES, what was the type of disease, last occurrence and end result?
Type ____________________
Last occurrence (month/year) ____________________

Which Species? ________________

Result

Total loss	________________
Reduced harvest	________________
Market rejection	________________
Reduced price	________________

What biosecurity measures or precautions do you take at this farm?

E6. What will you do if this shrimp crop fails?

Don't know/Not sure	____________
Try again	____________
Seek help, try again	____________
Seek help, try something else	____________

E7. Do you use chemicals during grow-out?

CIRCLE: YES NO

What natural products, if any, do you use in your shrimp ponds?

E8. Where is the nursery/hatchery that supplies your post-larvae?
(Give location) ________________________________

E9. Do feed company representatives analyze your pond water?

CIRCLE: YES NO

E10. Are you able to grow shrimp year around?

CIRCLE: YES NO

E11. Do you have problems with water quality?

CIRCLE: YES NO

E12. Are you concerned about pesticide residues in your ponds?

CIRCLE: YES NO

E13. Has anyone tested the pond water for pesticides?

CIRCLE: YES NO

F. ECONOMIC

F1. Farm Operation

Company	______		
Private	______	Number of households	______
Partnership	______	Number of investors	______

F2. Source of Finance
Foreign collaboration/bank ____________
Local bank ____________
Private/own capital ____________
Other ____________

F3. Family farm labour (number of people)
Men ______
Women ______

Family Labour (person days/month)
Men ____
Women ____

Family Labour (person days/month)
Men ____
Women ____

F4. Are all the hired laborers local?
CIRCLE: YES NO

F5. Do workers receive a share of the crop's sale value?
CIRCLE: YES NO

If YES, what percentage? _____Percent

F6. Most recent harvest (or expected harvest from first crop):
Date ____________(day/month/year)
Volume ____________(MT)
Number of ponds harvested ____________
Total area harvested ____________rai
Number of pieces/kg ____________
Price/kg ____________Baht
Total sales revenue ____________ Baht

F7. Was this <u>volume</u> typical of what you have produced in the past?
CIRCLE: YES NO FIRST CROP

F8. Was this <u>price</u> similar to what you have received in the past?
CIRCLE: YES NO FIRST CROP

How do you respond to changes in the market price for shrimp?

If you have stopped shrimp culture, when will you start the next crop?

F9. Do you pay compensation to local people when you discharge effluent?
CIRCLE: YES NO

G. ADOPTION OF LOW-SALINITY

G1. Why did you start shrimp farming??

____

G2. How did you learn about low-salinity culture?

____

G3. Do you receive any assistance from the Department of Fisheries?
CIRCLE: YES NO

G4. Do you purchase salt water to stock the ponds?
CIRCLE: YES NO

If YES, what is the cost in Baht per tanker load?
____________Baht Per truckload of sea water @ ______________ppt
OR
____________Baht Per truckload saltpan water @______________ppt

G5. How many tanker loads of salt water did you use for your last crop of shrimp?
____________Truckloads for __________________(rai)

G6. Does the salinity level used for culture vary with the season?
CIRCLE: YES NO

G7. Does the discharge of salt water from your site have any harmful effects on surrounding land uses, or freshwater supplies?
CIRCLE: YES NO

G8. Are there any regulations that prohibit the discharge of salt into freshwater areas?
CIRCLE: YES NO

G9. What is the major source of water pollution in this area?

____

H. SOCIAL

H1. Respondent information

Age	____________
Marital Status	____________
Education	____________

H2. Do you have any formal training in aquaculture?
CIRCLE: YES NO

H3. If yes, who provided the training to you?

Seminar from industry agents	______
Government extension	______
Degree program	______
Other	______

If OTHER, please provide details
____

H4. Give the main occupations today in this household.
____

H5. What were the main occupations of this household prior to shrimp farming?
____

How much land does members of this household:

a. Own:__________ Rai
b. Rent or jumnong (pawn): _______ Rai at ___ Baht
(More than one parcel: continue on back)

This land is used for:
c. Rent or jumnong out: ____ Rai at ___ Baht
This land is used for:

H6. Has this household bought land since you started shrimp farming?
CIRCLE: YES NO

If yes, please provide details:

Parcel #	bought or sold?	How long ago?	# Rai	Total Price? (baht)	document? (specify)
1					
2					
3					

(if more, continue on back)

H7. Has this household sold land since you started shrimp farming?
CIRCLE: YES NO

Parcel	*Sold to local* or non-local?	*If non-local,* from where?	*Current use* of this land	*Past use of* this land?

1 ____
2 ____
3 ____
(if more, continue on back)

H8. In the past year has anyone in this household worked as hired labour on a shrimp farm?
CIRCLE: YES NO

If yes,

Name	**Tasks**	**Days per Year**	**Wage**

H9. In the past year, has anyone in this household worked as hired labour in a shrimp processing facility or hatchery?
CIRCLE: YES NO

If yes,

Name	**Tasks**	**Days per Year**	**Wage**

I. SHRIMP FARMING AND THE GENERAL ENVIRONMENT

1. Does this household grow agricultural crops for sale?
CIRCLE: YES NO
If yes, what do you grow?

____

Has any of this household's agricultural land been affected by shrimp farming?
CIRCLE: YES NO
If YES, describe the effects.

2. Has the water supplies of this household been affected?
CIRCLE: YES NO

If YES, complete the following:
a). Surface water (khlongs, streams etc):
CIRCLE: YES NO

If YES, how affected?

____

What has the household done to replace this water?

b) Well water

CIRCLE: **YES** **NO**

If YES, how affected?

____

I1. Have you experienced any conflicts with other groups or individuals relating to the operation of this farm?

CIRCLE: YES NO

If YES, please describe the conflicts

I2. For each conflict, has it been resolved or substantially improved?

CIRCLE: YES NO

APPENDIX 2

AGRICULTURE FARM SURVEY

This survey was utilized during field research in Thailand during 1997 and 1998. A box around the text indicates an additional question that was incorporated into the 1998 field season. Boxed text is black in colour indicates a question that was added in 1998, and boxed text that is red in colour indicates a question that was only asked during the 1997 field season.

Survey Number: ___________________ Date: (day/month/year): ____________

A. IDENTIFICATION

A1. Location of the survey

Province ________________________
District ________________________
Village ________________________
House Number ________________________

B. OPERATION CHARACTERISTICS

B1. Please check which crops are cultivated and provide culture area (rai)

Rice ____________ rai
Fruit ____________ rai

Coconut ____________ rai

Mango ____________ rai

Vegetables ____________ rai
Other ____________ rai

If other, please specify

____

If rice, what is the farm gate price (Baht/MT)? ___________________________________

If rice, what was the production from the last crop?

_________________ (kg) from _________________(rai)

OR
_________________(MT) from _________________(rai)

B2. How many crops of rice per year do you cultivate?

CHECK ONE: Na Pi (one) _____________ OR Na Plung (two)__________

C. OPERATOR CHARACTERISTICS

C1. Size of family? ____________________ persons

C2. Age of respondent? ______________________ years

C3. How long have you lived in this district? ___________ years

C3-b. How many years have you cultivated rice or farmed in this district? _______ years

C4. Land ownership (check which apply)

_________ Owned ___________(rai)

_________ Leased ___________ (rai)

If leased

Cost/year___________________(Baht)

Length of lease_______________(years)

C4-b Have you experienced a fresh water shortage in the past?

YES ____________ NO ____________

C5. If owned, what is the type of land document? (the wording in the Thai translated survey is above the text associated with the typed Number 5)

NS-4 (Cha-nord or land title deed)	_______________
NS-3 (Nor-Sor-Sarm)	_______________
NS-3K (Nor-Sor Sarm-Kor)	_______________
NS-2 (Bai-Chong)	_______________
SK-1 (Sor-Kor-Neung)	_______________
STK (Sor-Tor-Kor)	_______________

C6. How long have you owned the land?

______________ years or inherited from parents

C7. What is the total area that is either leased or owned by this farm?

Owned ________________ (rai)

Leased _________________ (rai)

C8. Labour at this farm? (98) __________Family or _________Hired

D. SHRIMP FARMING

D1. Do you culture shrimp in addition to the agricultural crops produced on this farm?

Circle One: YES NO

If yes, what is the shrimp culture area?

_______________________(rai)

If no, why do you not currently grow shrimp? (Check those which apply)

______________ lack capital
_______________ too risky
_______________ don't know how
_______________ other

IF OTHER, please describe.

____

D2. Do you have plans to switch to other crops in the future?

Circle One: YES NO

If yes, describe your plan? ____

If yes, when? ____

E. ENVIRONMENT

E1. Does shrimp farming on adjacent farms affect the rice farming at this site?

Circle One: YES NO

If YES, describe how? ____

E2. Are you paid compensation when shrimp farms discharge effluent?

CIRCLE: YES NO

If YES, how much does the shrimp farmer pay you? ____________________ Baht

E3. What is the main source of water pollution in this area?

____

E4. Do the rice farms affect to shrimp farms (are you concerned about shrimp farms)?

Circle One: YES NO

If YES, how? ____

If NO, why not? ____

E5. Have you ever have any water shortages?

Circle One: YES NO

If YES, explain why? ____

E6. Do you treat your rice with pesticides? (Not translated for 1997 or 1998 version)

Circle One: YES NO

APPENDIX 3

KEY RESPONDENT SURVEY

This survey was utilized during field research in Thailand during 1997 and 1998. A box around the text indicates an additional question that was incorporated into the 1998 field season. Boxed text is black in colour indicates a question that was added in 1998, and boxed text that is red in colour indicates a question that was only asked during the 1997 field season.

Survey Number:________________ **Date**: (day/month/year):______________________

1. Location of the survey

Province ______________________________
District ______________________________
Village ______________________________
House Number ______________________________

2. What is your position within the community?

Phuyaiban ____________
Kamnan ____________
Nai Amphoe ____________
Other ____________

3. In addition to above, what is your main occupation?

____

4. Do you think that shrimp farming is good for the people in this community?

Circle One: YES NO

If YES, why ____________________________________

If NO, why NOT ______________________________

5. Does shrimp farming pose any threat to the environment?

Circle One: YES NO

If YES, describe ______________________________

If NO, describe why NOT ______________________________

6. The people in your community have expressed what concerns?

____

7. Are there any disputes between rice farmers and shrimp farmers?

Circle One: YES NO

If YES, describe ____

8. How have any of the above conflicts been resolved?

____