A review of economic issues for sustainable shrimp farming in the Mekong Delta, Vietnam*

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Abstract

In recent years, the growth and intensification of shrimp aquaculture in Asia has been explosive. Asia reportedly produces nearly eighty per cent of the world's total farmed shrimp output. With strong demand and high world prices, along with declining wild shrimp stock, shrimp aquaculture in Asia, particularly in coastal regions, is becoming an increasingly important source of income and employment. In Vietnam, shrimp aquaculture is now one of the most important aquaculture practices in terms of area, production, employment and foreign exchange generation. In the coastal regions of the Mekong Delta, where most of the shrimp aquaculture is practised, saline intrusion in the dry season often limits rice production to just one wet season crop per year. The adoption of shrimp culture as a second crop has brought significant income gains for farmers in the region.

The sustainability of shrimp aquaculture, however, is under question. This paper reviews the key sustainable development challenges facing shrimp aquaculture in the Mekong Delta, in the context of a shrimp aquaculture in the whole of Asia. Particular attention is given to the nature of the environmental impacts associated with shrimp farming. In this paper, the application of economics is investigated as a tool for addressing the environmental issues and guiding solutions to the sustainable development challenges facing shrimp aquaculture development.

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Introduction

The rearing of aquatic species is an ancient practice that can be traced back nearly 4000 years (Iwama 1991). The intensification and rapid expansion of aquaculture on the other hand has a history of only a few decades, in which time some serious environmental concerns have emerged. Shrimp is one of the most controversial crops of the rapidly expanding aquaculture industry. The spectacular growth of shrimp aquaculture industry in the 1980's (Figure 1) has meant that farmed shrimp now accounts for 25 per cent of world shrimp supply. Most of the growth of world shrimp aquaculture production has reportedly been in Asia, where eighty percent of the world's cultured shrimp is produced. Thailand is the largest producer (160,000 tonnes) followed by Ecuador, Indonesia, China, India, Bangladesh and Vietnam. In terms of total area under shrimp culture, Indonesia, Vietnam and India were reported as having the largest number of hectares under production (Ahmed 1997). With strong demand and high world prices shrimp aquaculture in Asia, particularly in coastal regions, is becoming an increasingly important source of income and employment. However, the environmental impacts associated with modern shrimp farming have raised some serious concerns about the sustainability of the practice (Barraclough *et al.*. 1997; Phillips *et al.* 1994, Primavera 1991,1996,1998).

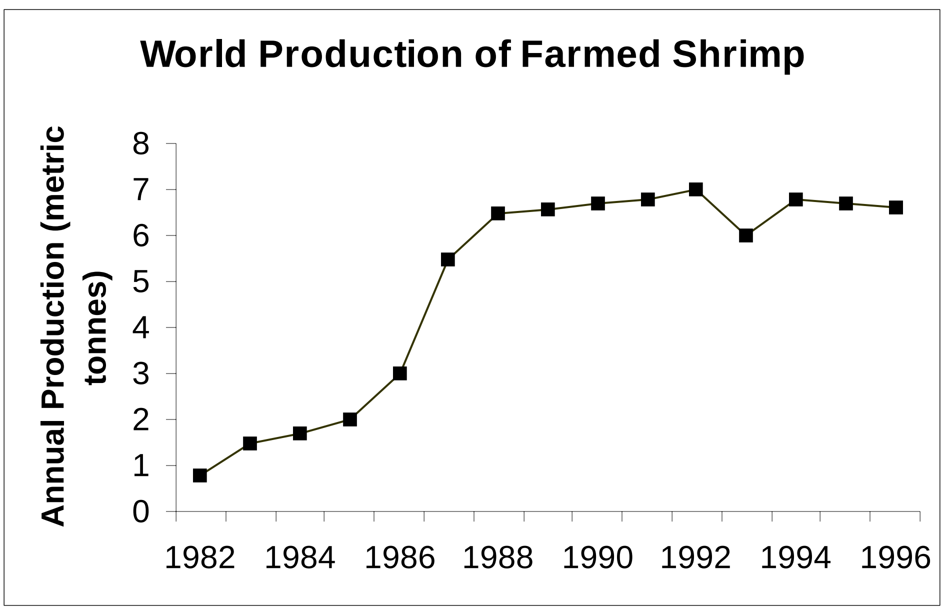

Figure 1: World Production of farmed shrimp (Tonnes)

The key environmental problems associated with shrimp aquaculture include nutrient and sediment loads in water ways, chemical pollution, salinisation of water supplies, infection of native stocks and the destruction of mangroves. The off-farm impacts of environmental pollution have affected local communities relying on water, mangroves and local fisheries and also have impacts on the productivity of neighbouring rice farmers through soil salinisation. The environmental problems associated with shrimp farming can be illustrated by the recent landmark decision taken by the Indian Supreme Court to force the closure of some 100,000 ha of shrimp farms, and to ban the development of shrimp farming in other regions. This decision was based upon the result of a cost benefit analysis that attributed the social costs of shrimp farming to be 4 times the benefit in one location (Primavera 1996). However, such public intervention has been the exception rather than the rule, and aquaculture development in Asia has occurred in the context of a weak regulatory environment (Naylor *et al*. 1998).

In Vietnam, shrimp aquaculture is now one of the most important aquaculture practices in terms of area, production, employment and foreign exchange generation. In the coastal regions of the Mekong Delta, where most of the shrimp aquaculture in Vietnam is practised, saline intrusion in the dry season limits the availability of fresh water for 300,000 hectares of agricultural land, which often limits rice production to just one wet season crop per year (Tran 1994). As a means for improving household income, some farmers have adopted integrated and monoculture shrimp culture practices. The adoption of shrimp culture as a second crop has brought significant income gains for farmers in the region.

However, it is important to note that the promising money returns are received in the context of high risk, both financially and environmentally. The spectacular shrimp production collapses and related environmental impacts experienced by communities in Taiwan, China and Thailand have attracted a strong focus on sustainability issues worldwide, leading to an expanding literature which describes commercially grown shrimp as *extreme* - extremely lucrative, extremely risky and extremely destructive.

The purpose of the paper is to review the economic issues for sustainable shrimp farming in the Mekong Delta. The experiences in other parts of Asia were drawn upon to provide greater insight and understanding of the specific issues in the Delta. The paper is not a complete register of the economic issues outstanding, rather the aim is to look at ways in which different people have looked at the issues and explore some of the ways in which economists can contribute. Questioning and exploring the possibilities for sustainable shrimp farming is the underlying theme of our paper.

The outline of the paper is as follows. We begin by briefly outlining the types of environmental impacts that have been attributed to shrimp farming in Asia, and in the Mekong Delta. We then introduce the concept of sustainability, and discuss some of the areas where economic theory may contribute to the debate about the sustainability of shrimp farming. Finally, we examine the environmental and economic sustainability issues concerning shrimp farming in the Mekong Delta.

Interactions between aquaculture and the environment

Shrimp farming involves the rearing of shrimp juveniles in brackish water ponds. There is a wide range of practices used for farming shrimp, all rely on a supply of brackish water and a supply of shrimp juveniles. In general, most shrimp farming systems involve the exchange of water between the pond and an external waterway.

The interactions between shrimp aquaculture and the environment are affected very significantly by the culture method (Iwama 1991). For example, the most extensive (traditional) form of shrimp culture involves no artificial inputs. Farms are stocked with wild juveniles brought in during tidal water exchange, and feed on natural biota. This system is characterised by very low yields, and harvest is mainly for family consumption and to supply local markets.

There is a wide range of culture practices between the extremes of traditional extensive and very intensive shrimp farming. Some farmers practise what is called "improved extensive" culture, which involves the introduction of small amounts of artificial inputs into the natural pond environment. These inputs may include artificial seedstock (purchased shrimp juveniles), stimulation of natural pond productivity through the application of fertilisers, and the deliberate input of feed. These improved extensive systems, when they do stock, they use very low stocking rates (1-2 post larvae (PL) per m2). Other practices involve stocking at relatively higher rates, and as stocking rates increase there is a greater reliance on other inputs such as artificial feed.

The most intensive forms of shrimp culture are heavily reliant on high levels of inputs. For example, stocking rates are extremely high (density of 25-35 PL per m2), which then requires, aeration to supply enough oxygen to the shrimp, intensive feeding practices, and often the use of antibiotics and other chemotheraputents. While these intensive production systems can produce very high returns (producing 10-15 tonnes per ha), they are also very risky. In most parts of Asia where intensive shrimp farming has been significant, a "boom-bust" cycle has been characteristic of the shrimp farming industries. It has been observed that most shrimp farms perform extremely well for the first few years of production, but then suffer declining yields over successive crops (Funge-Smith *et al*. 1998). In some cases, disease has caused devastating mortalities to across large areas of shrimp farms. For example, in Taiwan, where intensive shrimp farming practises were first developed, mass mortalities in 1988 led to a fall in national production by 75 per cent of 1987 levels (Lin 1989). More recently, Thailand has become the dominant producer of farmed shrimp, but mass mortalities experienced in some regions of Thailand have led to abandonment of shrimp farms. Despite these problems, the industry has continued to expand into other regions.

Overview of the main environmental impacts of shrimp farming

In the following section we outline, generally, the main environmental impacts of shrimp farming. Impacts on the environment include both the direct effects on the environment through the output or consumption of materials and secondly, the indirect effects through impacts on biological community structure (Iwama 1991). The sources of impacts outline below have been summarised to include deforestation of mangroves, effluent, salinisation and sedimentation.

Deforestation

The clearing of mangroves for the development of shrimp farms is a common problem in many areas of Asia where shrimp is farmed. For example, in Thailand, some 100,000 hectares of mangrove forests have been turned into prawn farms. The loss of mangrove forests has implications for coastal protection and ecosystem integrity as well as implications for coastal people in terms of lost supplies of building poles, thatching material and medical products as well as flood protection for houses and fields. Moreover, there is some evidence that mangrove destruction impacts upon fisheries production and loss of potential development of integrated aquaculture and fisheries within and adjacent to the mangrove forests themselves (Phillips *et al.*. 1994).

Effluent

One of the most significant interactions between shrimp aquaculture and the environment occurs via the waterway on which shrimp farms depend for a supply of *intake* water and as a sink for *effluent* water. A wide range of environmental impacts has been observed.

One of the most significant impacts is the high level of nutrient and sediment run-off in the case of very intensive shrimp farms. Dissolved nutrients and organic matter stimulate the growth of micro-organisms, increasing the risk of phytoplankton blooms and altering the community structure of the aquatic ecosystem. Similarly, high sediment loads from shrimp farms can contribute to the degradation of coastal and freshwater marine environments.

The chemicals used in intensive shrimp culture can also contribute to pollution from prawn farms. These chemicals include antibiotics, pesticides and disinfectants. Concerns have been raised about the toxicity of these additives to non-targeted species in the aquatic environment (Primavera 1998).

Salinisation

Large volumes of brackish water are used in shrimp production. There are a number of environmental impacts associated with the use of water. First, in many regions the brackish water required for *P Monodon* (black tiger shrimp) culture is obtained by mixing fresh water with seawater. Large amounts of fresh groundwater have been extracted, which have affected the local hydrology, causing saline water intrusion in neighbouring agricultural areas. Saline contamination of domestic drinking water has also occurred (Primavera 1998). High levels of groundwater extraction have also led to land subsidence in some regions (Phillips *et al.* 1993).

In other areas, the disposal of brackish effluent water into waterways results in salinisation of agricultural land or irrigation water supplies. In areas where shrimp farms are located next to rice farms, direct salinisation through leaching and overflow of salts has been reported (e.g. Tran 1994). The expansion of shrimp culture into rice growing areas of Thailand has led to serious concerns about the impacts on rice productivity (K. W. Lin 1998, *pers. comm*).

Environmental impacts in the Mekong Delta

Most of the shrimp aquaculture in Vietnam is practised in the Mekong Delta, in the south. This region is considered to have a large potential for expansion of brackish water aquaculture systems, because of naturally occurring saline intrusion, which affects around 300,000 hectares in the dry season (Tran *et al.* 1998). Extensive and semi-intensive farming methods are the most common farming systems in the Delta. The traditional extensive systems have been improved through stocking with hatchery produced *P.Monodon* seed stock, usually at low levels (1-2 PostLarvae (PL) per m^2). Results of a recent survey by the authors indicate some farmers are stocking at significantly higher levels of up to 10 PLs per $m^{2.}$

While extensive shrimp monoculture systems dominate in areas near the coast, there has been considerable expansion of shrimp aquaculture into agricultural regions affected by saline intrusion. One form of shrimp aquaculture that has been widely adopted is the practice of integrated rice-shrimp farming. This integrated rice-shrimp farming system is the focus of the discussion. However, various other integrated shrimp systems are also practised in the Mekong Delta, including shrimp-mangrove, shrimp-crab, shrimp-crab-fish, and shrimp-fish (Fisheries Master Plan 1996)

The Rice Shrimp Farming System

The integrated rice-shrimp system involves alternative cropping of wet season rice and dry season shrimp on the same field. To practice this system, the rice field must be redesigned with a trench and dike around the periphery of the field. This reduces the available area for rice production, but provides a refuge for shrimp away from the more extreme environmental conditions of the shallow rice field. A flap-gate and trap system are used to the manage flow of water and to retain shrimp until harvesting. At the start of the shrimp season, saline water is brought in from the canals of the Delta, the trenches are filled and the entire field is flooded as well. At the beginning of the wet season, rainfall as well as fresh water from the river are used to flush the fields of residual salinity, before planting the new rice crop. The rice seedlings are often grown in other areas, while the rice polder (or field) is being flushed of salts.

Some farmers rely on recruitment of native seedstock carried in the influent water, while other farmers stock with *P. Monodon*. Low stocking rates (generally less than 2 PL per m2) are common. Some, but not all, farmers add feed and chemical inputs to the pond. In a more recent survey of shrimp feeding practices by the authors, around 46per cent of shrimp farmers were using supplementary feeding, and for 80 per cent of these the diets contained some manufactured feed pellets.

A number of studies have shown that the integration of shrimp into the rice farming systems of the Mekong Delta has enabled farmers to make significantly higher income than the traditional rice monoculture practice (Nguyen, 1992; Tran1994). However, recent experiences with disease outbreak, as well as a number of other environmental problems that have been emerging recently, makes returns highly variable and presents challenges for the sustainability of the such farming systems.

An examination of the sustainable development issues of the rice shrimp farming system is important because there is considerable interest in developing the system in other brackish water regions of the Mekong Delta and other parts of Asia. The two main environmental issues observed in the extensive/semi-intensive shrimp culture practices of the rice-shrimp system are salinisation and sedimentation.

Salinisation

The inundation of brackish water onto rice fields during the dry season raises concerns about the impact of salinisation of the soil, both on the rice-shrimp fields and in neighbouring rice monoculture fields. Rice-shrimp farmers, who inundate their rice fields with salty water for about 4-5 months of the year, have faced the problems associated with salinisation of the soil ever since the farming system was adopted. While farmers claim that they can remove the salts from the soil by flushing the field with rainwater, the efficacy of the leaching process in removing salts from the soil is unknown. It is possible that rice yields are affected by salinisation of the root zone, even after "flushing". Thus there are two potential causes of yield losses from salinisation. The first is the direct yield loss associated with salinised soil, and the second is the yield risk associated with delaying the plant date, in order to flush the soil.

The potential for reduced land productivity, associated with the flooding of saline water on to rice fields, is a private matter for the rice-shrimp farmer, who can make the trade off between potentially lower rice yields, and income earning potential from shrimp culture in the dry season. However, there is evidence to suggest that neighbouring rice farmers are also affected by the saline water, through overflow and/or leaching of saline water from shrimp ponds (Tran, 1994).

Rice monoculture farmers can be affected when saline water leaches or washes over into their bare fields in the dry season, or when saline water leaches into the field when there is a rice crop growing. In the case of the leaching that occurs during the dry season, farmers claim that they can observe the lateral movement of moisture into their dry fields, and it can only come from the neighbouring shrimp fields which are full of brackish water. Similarly, they may be able to observe the incidence of saline water washing over the bund into their rice fields during the growing season. The other main cost associated with the salinisation problem is that of avertive behaviour. Some rice farmers have attempted to reduce the salinisation problem by raising the height of dikes/bunds along the border of the neighbouring shrimp farm.

Sedimentation

The inundation and exchange of turbid river water in the dry season leads to a build up of sediment in the rice fields, which must be removed to allow for effective water management for the rice crop. The removal of sediment is a labour intensive process that must be completed in a short period of time (between rice harvest and before stocking). Thus the removal of sediment imposes a large annual cash cost upon the farm, as it is usually necessary to employ casual labour to complete this task.

The disposal of the large amounts of sediment removed annually from the shrimp trenches is a serious problem. Some farms dump the sediment back in the river, although in some parts of the Delta this practice is illegal. In the majority of cases, accessibility to main canals and the cost of transport mean that there are no alternatives for removing the sediment from the farm (Tran 1994).

Disposal of sediment within the farm boundary can be achieved in several ways. Some farmers are able to dispose of the sediment by spreading it around the house or vegetable plots, and other farmers pile the sediment onto the dikes of the polder. There is a limit to the amount of sediment that can be disposed in these ways, which inevitably leads to the construction of additional dikes within the rice field, solely for the purposes of sediment disposal. The build up of additional dike area removes the area of land available for rice production with implications for the long-term productivity of the farm.

The extent of the sedimentation problem is most pronounced in Gia Rai district, where shrimp farming has been practised for more than 10 years. In these areas, the build up of dike area is so significant on some farms that now dikes take up more than half the rice-shrimp area. In one village, 20 per cent of the farms surveyed had dike areas of more than 50 per cent of the total rice-shrimp area. The average dike area on farms in this village is 34 per cent, compared to an average of 20 per cent in another province where rice-shrimp farming is relatively new (these are the results of a recent survey by the authors).

Whilst the main impacts of sedimentation are on-site, there are potentially off-site impacts, because of the practice of disposing of sediment in the main waterways. For example, large amounts of sediment disposal in a short space of time could cause accumulation of sediment in the local canals. Contamination of the sediment with higher nutrient loads or with dead shrimp could have downstream impacts on native fish populations (Phillips *et al.* 1993).

We now turn our attention to more specifically exploring the concepts and issues surrounding the sustainability of shrimp farming in the Mekong Delta, and ask - is shrimp farming sustainable?

Is shrimp farming sustainable in the Mekong Delta?

The environmental impacts of shrimp aquaculture in some parts of Asia have led to considerable discussion of the sustainability of the practice (e.g. Primavera 1991, Iwama 1991, Phillips *et al.* 1993, Primavera 1998, Funge-Smith *et al.* 1998). However, most of the debate has focused on ecological and social impacts, with little focus on the economic nature of the problem. It is important to explore incentives under which decisions about environmental degradation are taking place, if policies are to be designed to improve the decision making process. Moreover, the focus on ecological impacts has, in some cases, ignored the other issues that may affect the sustainable development of a region in which shrimp farming is located. These include the economic issues affecting the long-term viability of the industry, as well as the pecuniary benefits of economic growth that may arise from an economic activity.

Before exploring in more detail, the nature of the sustainability issues and possible options for addressing the issues, we look very briefly at the concept of sustainable development.

What is Sustainable Development?

Van den Bergh (1996 p.7) notes that sustainable development was originally proposed as a first step toward exploring solutions for the potential conflict that may arise between multiple goals, or between interest groups supporting those goals. He asserts that sustainable development goes well beyond environmental protection, which it has been sometimes limited.

In very simple terms and on a local scale, sustainable development is about maximising the net benefits of an activity while ensuring that such benefits and costs are shared equitably within and between generations. An important question to ask with regard to sustainable development is - what *is* and *is not* valued and how does this vary between the market and the community. Sustainable development is concerned with the valuation of trade-off 's from the perspective of the community rather than from the limited perspective of a particular sector or agent. Hence, perhaps "[t]he philosophy of sustainable development acknowledges that biophysical and social needs must be met, that we have choices regarding how to meet those needs, and that our choices will affect the choices available in the future" (Chesson *et al.*. 1998).

The economic approach to sustainability is totally anthropocentric and tends to be conceptualised in terms of a continuation of human consumption possibilities over time such that welfare is not declining. Consumption is a concern only in that contributes to well-being (utility). Consumption could feasibly include all things, material and non-material.

Substitution possibilities between the natural environment and human-made capital has been a crucial factor in the conceptualisation of sustainability in economics. In fact the difference between the *limits to growth* (that economic expansion must come to an end - see Meadows 1972) and the concept of sustainable development in *Our Common Future* (where economic growth was seen to be desirable to deal with poverty and inequality- see WCED 1987) turns out to be substitution possibilities (*in* Common 1995)

Analysis of sustainability, which allows full substitution between all forms of capital, is known in the literature as weak sustainability. Strong sustainability on the other hand, assumes that *all* forms of capital are not interchangeable and should be conserved separately. In practice a compromise is generally chosen which is based on the concept of acceptable level of impact (Farmer and Randall 1997).

Uncertainty associated with natural resource depletion has been a major concern in the sustainability literature (the precautionary principle). The main concern relates to irreversible decisions. Quiggin notes that the most obvious example of an irreversible outcome is extinction and it is most appropriate to wait for more information rather than making a decision under uncertainty that drives the stock to extinction, and then discover that it should have been preserved (Quiggin 1997)

Temporal issues (intergenerational equity), in the economics of sustainability, while they are fundamental issues, tend to be given overriding importance, perhaps at the expense of spatial and scale issues, which can be significant for addressing development processes and impacts in terms of community well-being of the current generations (intra-generational equity). The process of "Globalisation" has meant that issues of space and scale are becoming increasingly important. For example sustainable development at the local level may be undermined by processes at the provincial, national or global level. Norgaard describes this issue as "distancing" which he attributes to modernisation, where *"[i]creasing globalisation of markets puts both producers and consumers at greater distances from the environmental impacts of their production and consumption. And farmers responding to variations in international prices are not likely to be planting the mix and sequence of crops which sustain agroecosystems"*. In other words, it is argued that consumers have a vested interest in the production process.

An example of an important *distancing* issue, which has important implications for sustainability issues in shrimp farming, is the involvement of the multi-national, vertically integrated, feed manufacturers. Shrimp production in Thailand has been organised through 10 specialised feed companies. The largest company involved is the Thai multi-national organisation, Charoen Pokphand (CP). CP has also been heavily involved in the expansion of shrimp farming in Indonesia, Vietnam, China and India. CPs involvement ranges from operating wholly owned shrimp farms, joint ventures, feed supply in conjunction with the provision of credit and farm extension advice. The company also operates as a purchaser and manufacturer of shrimp (Goss 1998). The *distance* created by such an institutional arrangement will probably mean that without major intervention there will be no incentives for a company such a CP to operate in way that values the well-being of present as well as future generations.

Sustainable development and Market Failure

In the application of economics to the environment, the problem (speaking very generally) is seen as one of scarce resources that need to be allocated between competing ends. The aim is to use resources in a way that maximises the well-being of society. The environmental economic theory suggests that when markets are operating perfectly the allocation of resources in the economy will be economically efficient. An economically efficient outcome will mean that resources are not wasted and that the net benefits accruing to society from the use of resources will be at an optimum (George and Shorey 1978).

Environmental economics, however, identifies a number of concerns with leaving allocation up to the market alone. The concern is that the necessary conditions for which markets operate perfectly often do not prevail. Market failure is a concern as it leads to a divergence between the private and social costs associated with a particular activity with welfare effects. There is a strong economic argument for intervention in environmental pollution and sustainability problems because of market failure problems.

Many of the sustainable development issues raised above could feasibly be described as market failure concerns. Addressing the causes of market failure in shrimp production is probably not sufficient, on its own, to address the full gamut of concerns with regard to sustainable development. It can, however, hopefully provide a basis from which to understand the nature of some of the decision-making problems that underlie the environmental and more broadly sustainability problems.

The causes and impacts of market failure in shrimp aquaculture in the Mekong Delta are outlined below. The main concerns for the sustainability of shrimp culture in the Delta are sedimentation, salinisation, source and quality of seedstock, intensification, and instability. Often the recommended solutions to the sustainability in the literature are technical farm management "tips". For example, tips regarding stocking densities, feed regime, chemical and antibiotic use, effluent control and treatment, disposal of pond sediment.

The policy recommendations to the Government concern recommendations for legislation regulating certain practices, registration, licensing and certification of commercial farms, improved extension, modernisation of aquaculture infrastructures.
Integrated coastal management and zoning is also advocated. The possibility of banning shrimp farming has also been canvassed to a limited extent.

As a preliminary point, before outlining the issues more specifically, economists in the region have raised the issue of "subsidised" shrimp production, which may be distorting price signals for shrimp farmers. In years when incomes are low farmers are given land-tax exemptions. It has been suggested that this subsidises shrimp production, distorts incentives to avoid risk-taking and therefore has implications for sustainability of shrimp farming in the region.

Below we outline four of the main concerns for the sustainability of shrimp culture in the Delta (sedimentation, salinisation, source and quality of seedstock, intensification, and instability) and have tried to explore some of the incentive structures that may be influencing farm-level decision-making.

The Sedimentation Problem in the Delta

Sedimentation has important implications for the long-term productivity of land. In the districts where shrimp has been farmed for longer, this sedimentation is a very pressing issue. Perceivably, sediment dikes will take up more and more land over time. The question of course with regard to sustainability is - why are decisions at the micro-level not taking into account the long-term impacts?

Two possibilities of why the long-term impact of sedimentation is not fully taken into account are, firstly due to the short-term land-use title and secondly, discount rates could be particularly high due to poor credit markets. The limited borrowing possibilities along with the possibilities of generating a large income from shrimp production may entice farmers into the potentially degrading and risky farming system. This would be especially the case in areas of the Delta that are subject to natural saline intrusion, which limits rice-growing to one wet-season crop per year.

Shrimp are farmed under a relatively short15-year land-use title, under the rationale that it is an annual production system. Even if land-use title is renewed after the 15 years and every 15 years there after, renewal is uncertain which possibly encourages a short-term approach to resource management.

An obvious focus of any policy solution should be on the provision of improved certainty of land-use title. Within the context of the current land-use certificates, reclassification of land tenure to reflect longer-term nature of production decisions would be appropriate. For example, longer-term certificates have been given to farmers with perennial cropping systems, recognising the importance of long-term decision making.

The build-up of sediment is related to the frequency of water exchange. One farm management solution that would reduce the problem of sedimentation is to reduce the frequency of water exchange. Farmers practising *P Monodon* culture are more likely to exchange water less frequently, compared to natural shrimp farmers, who usually exchange on a daily basis in order to maximise the recruitment of natural seedstock. Thus the increased adoption of *P Monodon* farming may help reduce the annual rate of sedimentation. Further technical solutions, such as aeration may also be investigated as means for reducing water exchange. The problem still remains, however, as how to encourage the adoption of improved access to technology. Improved extension and better access to low cost credit markets should promote the adoption of such technologies.

The Salinity Problem in the Delta

The salinisation impact of shrimp farming concerns the impact on rice yields in the rice-shrimp system as well as on the yields of neighbouring rice monoculture farmers.
Where the salinisation impacts on rice yields in the rice-shrimp system the impact is private. Of particular concern in terms of sustainability are any off-site impacts on the yields of neighbouring rice monoculture farmers. The off-site costs are paid not by the shrimp farmers but by the "victim" in terms of either reduced rice yields or through the cost of constructing a dike around the monoculture rice field.

Land zoning is one possibility for dealing with the off-site salinity problem. In Hoa Tu, in the My Xuyen district of the Delta, the local government has already adopted this strategy. The commune based institutional organisation in the district is thought to be an important contributor to the successful implementation of a number of policies and projects. One of the projects includes the differentiation of farmland into a fresh water zone for rice monoculture, a brackish water zone for rice-shrimp farmers and a saline water zone where shrimp monoculture (Anon 1995).

The economists' solution to externality problems - to tax polluters - could be applied. Such taxes could easily be administered through the existing land tax system, where farmers pay tax based on specific land classification. A higher rate could be charged to shrimp farmers reflecting the external costs to neighbouring rice growers, which could be used to fund the construction of protective dikes around the rice areas.

Seedstock in the Delta

A large and increasing number of shrimp farmers in the brackish water regions of the Mekong Delta are stocking their ponds with *P monodon* post larvae, which are mainly imported from Nha Trang in central Vietnam. The quality and quantity of the seedstock supply has been identified as a major constraint for sustainability of shrimp farming in the Delta. As a means for quality control, the provincial government has in place compulsory checks on the quality of the post larvae *P monodon* which travel for hundreds of kilometres for several days before reaching the farmers. This quality control may, at the moment, have little impact as the checks are sporadic due to lack of resources for the program.

There are also techniques that farmers can adopt on-ground before stocking the ponds to improve survival rates of the seed stock. The extension required for farmer education of the techniques is essentially a public good, requiring government provision. There is also some price discrimination carried out by some seed stock suppliers that claim they supply larger and healthier seed, however there has not been sufficient scientific analysis for such claims to be validated. There may also be scope for expanding the shrimp hatchery industry in the Delta, which may overcome the problem of supplying healthy post larvae in the longer term.

Production Instability in the Delta

The farming of shrimp is an extremely risky business, and crop failure from disease is quite common. It is generally believed that most crop losses are caused by secondary pathogens that are able to invade shrimp when they are under environmental stress (Funge-Smith *et al.* 1998). The management of good pond conditions is difficult, and this is a particular problem in the Mekong Delta, where intake water quality is affected by upstream pollution. In particular, high levels of pesticides, and highly acidic water (from the large area of acid sulphate soils upstream of rice shrimp regions) may both contribute to increased production risk for shrimp farming.

The implications of production instability on the household economics of poor farmers, who generally have few assets or savings, can be severe. The farming of *P Monodon*, while potentially one of the more lucrative activities in the region, is also the one with the highest level of cash inputs, and the greatest risk of failure. The social and financial implications of production instability need to be given closer consideration in the sustainability debate.

Scope for Intensification in the Delta?

The type of system, the species, the farm management practices as well as the institutional context are shown to influence the performance of aquaculture development with respect to sustainability goals. Exploring possibilities for further intensification of the shrimp farming systems in the Mekong Delta is important. It is not only for exploring the possibilities for increasing the income capabilities in the region, without compromising the income capabilities in the future, but also because farmers are adopting more intense practices. The dire outcomes that have been, and are still being, experienced in other parts of Asia (the issues are outline very comprehensively and in detail by authors such as Philips *et al.*; Primavera; Quarto *et al.*; Barraclough *et al.*; Ahmed.) as a result of rapid intensification give an increased importance on raising the issues and the questions for the sustainability of farming systems in the Mekong Delta.

Summary

We have outlined some of the key environmental impacts associated with the intensification of shrimp farming in the Mekong Delta. We have reviewed the issues in the Delta in the broader context of shrimp aquaculture in Asia.

The ecological and social implications of shrimp aquaculture have been well canvassed in the literature, however there is scope for further investigation of the economic nature of the problem at the farm level. Economists argue that there is a need to explore the incentives at the micro-level, under which resource-use decisions are made if policies are to be designed to improve the decision making process.

Many of the sustainable development issues raised in the paper can feasibly be described as market failure concerns. Although looking at the causes of market failure in shrimp production is probably not sufficient, on its own, to address the full gamut of concerns with regard to sustainable development. The application of environmental economics can however, hopefully bring an understanding of the nature of some of the decision-making problems that underlie the environmental and more broadly sustainability problems.

The dire outcomes that have been and are still being experienced in other parts of Asia as a result of rapid intensification give an increased importance on raising the issues and the questions for the sustainability of farming systems in the Mekong Delta. The main issues for sustainable development that have been raised in the brackish water region of the Mekong Delta include, sedimentation and salinisation, seed stock availability and quality, production volatility, and further intensification. The purpose of the paper was to raise some of the key issues for sustainable shrimp farming in the Mekong Delta. Raising the issues is part of the process of finding solutions that are sustainable and appropriate.

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