Sustainable Shrimp Farming: Estimations of a Survival Function

Anantha K. Duraiappah, Adis Israngkura and
Sombat Sae-Hae

Working Paper No 31

July 2000

International Institute for Environment and Development, London and Institute for Environmental
Studies, Amsterdam

Authors

Anantha K Duraiappah is a senior researcher, and coordinator of the CREED Programme. He may be contacted at**:**

Institute for Environmental Studies
Vrije Universiteit
De Boelelaan 1115
1081 HV Amsterdam
THE NETHRELANDS

Tel: 31 20 444 9555 Fax: 31 20 444 9553; email: anantha@ivm.vu.nl

Adis Israngkura and Sombat Sae-Hae are researchers at Thailand Development Research Institute(TDRI). They may be contacted at:

Email: adis@leela1.tdri.or.th

The programme of Collaborative Research in the Economics of Environment and Development (CREED) was established in 1993 as a joint initiative of the International Institute for Environment and Development (IIED), London, and the Institute for Environmental Studies (IVM), Amsterdam. The Secretariat for CREED is based at IIED in London. A Steering Committee is responsible for overall management and coordination of the CREED Programme.

Environmental Economics Programme, IIED

IIED is an independent, non-profit organisation which seeks to promote sustainable patterns of world development through research, training, policy studies, consensus building and public information. The Environmental Economics Programme is one of seven major programmes of IIED; it conducts economic research and policy analysis for improved management of natural resources and sustainable economic growth in the developing world.

Environmental Economics Programme
IIED, 3 Endsleigh Street
London WC1H 0DD, UK
Tel +44 (0)171 388 2117; Fax +44 (0)171 388 2826
e-mail: Jacqueline.Saunders@iied.org

Institute for Environmental Studies, (IVM)

IVM is a non-profit research institute, based at Vrije Universiteit, Amsterdam. The Institute's primary objective is to carry out multi- and interdisciplinary research on environmental issues, based on cross-fertilisation of monodisciplinary sciences. Environment and the Third World is one of eight major IVM research programmes.

IVM, Vrije Universiteit
De Boelelaan 1115
1081 HV Amsterdam
The Netherlands
Tel: +31 20 444 9555; Fax: +31 20 444 9553
e-mail:secr@ivm.vu.nl

CREED Steering Committee members include:

Prof Johannes Opschoor, Institute for Social Studies, The Netherlands (Chair)
Prof Gopal Kadekodi, Centre for Multidisciplinary Development Research, India
Dr Ronaldo Seroa da Motta, IPEA, Brazil
Dr Mohamud Jama, Institute for Development Studies, Kenya
Dr Anantha Duraiappah, IVM, The Netherlands
Prof Harmen Verbruggen, IVM, The Netherlands
Joshua Bishop, IIED, UK
Maryanne Grieg-Gran, IIED, UK

Abstracts of CREED publications and details of all CREED projects
are now available on the Internet. Visit the CREED Web site at:

http://www.iied.org/creed

Abstract

Survival rates of farmed shrimp depend on a number of factors such as water quality, stocking densities and feed stock. Inappropriate management can induce stress, diseases and ultimately death in shrimp. This article systematically describes these relationships and develops a reduced form equation to determine shrimp survival. The reduced form shrimp survival function is estimated using data from a farm survey carried out in eight provinces in Thailand. A translog functional form provided the best fit. Preliminary results show that feed and stocking (seed) management are significant in explaining shrimp survival. The square terms of feed and stock density have negative signs as expected and are also significant. The interaction term between them is also statistically significant. It is observed that farm density and water management system have correct signs but statistical significance is weak. The results indicate that the Thai shrimp sector is presently operating at sub-optimal levels and there is scope for improvement.

Abrégé

Le taux de survie des crevettes d'élevage dépend d'un certain nombre de facteurs, comme la qualité de l'eau, les densités de stockage et les stocks alimentaires disponibles, qui peuvent, si on ne les gère pas de façon appropriée, être cause, pour les crevettes, de stress et de maladies. Cet article présente une description systématique de ces relations et développe une équation réduite, déterminatrice du taux de survie des crevettes. Pour estimer la fonction réduite de survie des crevettes, on a fait appel à des données tirées d'une enquête menée sur des élevages de huit provinces thaïlandaises. C'est une forme fonctionnelle translogarithmique qui s'est avérée le mieux convenir. Les résultats préliminaires montrent que l'alimentation et la gestion du stockage sont des facteurs significatifs de l'explication de la survie des crevettes. Dans cette équation, les termes au carré de l'alimentation et de la densité du stock, sont négatifs, comme on s'y attendait, et sont eux aussi significatifs. Le terme d'interaction qui les relie est lui aussi statistiquement significatif. On observe que les signes de la densité d'élevage et du système de gestion de l'eau sont corrects, mais que leur signification statistique est faible. Les résultats finaux indiquent que le secteur de la crevette en Thaïlande est actuellement exploité à un niveau sous-optimal et qu'il y a place pour améliorer cette situation.

Resumen

Las tasas de supervivencia de los camarones cultivados dependen de varios factores tales como la calidad del agua, la densidad y la calidad del alimento, los cuales pueden producir enfermedades y stress en los camarones si no se manejan bien. En este artículo se describen de forma sistemática estas relaciones y se desarrolla una ecuación reducida para calcular la supervivencia de los camarones. La función reducida de supervivencia se calcula usando datos provenientes de un examen de cultivos realizado en ocho provincias de Tailandia. El esquema que ofrece el mejor ajuste es la forma funcional translogarítmica. Los resultados preliminares demuestran que el manejo del alimento y de los alevines son importantes para la supervivencia de los camarones. Los términos cuadráticos de alimento y densidad son de signo negativo, como se anticipaba, y además son significativos. El término de interacción entre ellos también es estadísticamente significativo. La densidad en los cultivos y el manejo del agua presentan signos correctos, pero su importancia estadística es limitada. Los resultados indican que el sector de cultivo de camarones en Tailandia presenta un comportamiento sub-óptimo y puede aún mejorar.

Contents

Introduction

The shrimp farming industry is characterised by boom and bust cycles (Csavas 1992; Gross et al., forthcoming). The latter are usually caused by production crashes resulting from disease outbreaks. The economic and socioeconomic consequences of these crashes have dire impacts across all levels of the economy but especially for the local communities directly involved in and dependent on shrimp farming for their livelihoods (Briggs 1994; Dewalt et al 1996). Moreover, shrimp production is a major contributor to coastal zone pollution and degradation (Dierberg 1996; Briggs 1994).

Another common characteristic of the industry is the use of intensive farming methods. Encouraged by the high and quick profits (Masae and Rakkheaw 1992), intensive farming is perceived by many to be the only profitable option (Primavera 1993). It involves high stocking densities and excessive use of artificial feed to supplement growth. While there is growing evidence of a strong correlation between intensive farming and disease occurence (Funge-Smith and Briggs 1995), farmers are willing to risk intensive production.

Effectively farmers have two choices. The first is to employ intensive farming techniques and hope for no disease. In the event that they do occur farmers may opt for an early harvest, but for a lower price due to smaller shrimp size. The second choice is to employ techniques which require lower stocking levels and less risk of disease outbreaks. However, many farmers believe that disease occurrences are beyond their control and that, irrespective of their actions, outbreaks will occur. It is certainly the case that disease outbreaks are to a large extent dictated by the actions of the other farmers. This is because the water they use for the ponds comes from a common system and disease from one farm is easily transmitted through the water channels, with a high probability of wider infection (Liao 1990; Boyd and Musig 1992; Chua 1993). In a sense we have a prisoner’s dilemma, and unless cooperation among farmers is guaranteed, it is optimal for individual farmers to choose a high risk strategy and to take their chances (Briggs and Funge-Smith 1994). With luck a farmer may harvest a full crop; if not there is still a harvest, albeit at a lower price.

Many aquaculturists argue that intensive farming is not the only cause of disease outbreaks. They emphasise that, with good pond management, intensive farming can be made sustainable. It must be stressed that diseases cannot be completely eradicated as there is always the natural random factor. Moreover, as mentioned above, individual farm management can only reduce the disease probability to a certain extent. Yet even this can be mitigated to a certain extent with new water management techniques which reduce the frequency of water exchange with the common system (Lin et al 1991). This, coupled with the use of chemicals to clean the water, has gone a long way to reduce the degree of dependency on other farming strategies.

Although these factors have been highlighted as critical variables governing the probability of disease outbreaks, there have been very few studies analysing the quantitative contribution to this probability. This study is an attempt to fill this gap. In the next section, a description of the various critical factors which play a role in determining disease probability is provided. The third section presents the econometric model developed for this study followed by a brief description of the data. The results from the econometric exercise are provided in the fifth section. The paper ends with some concluding remarks and suggestions for future research in this field.

Critical Factors

Good pond management is a necessary, if not a sufficient condition to minimise disease outbreaks. This includes stocking density, seed quality, feed management, water quality management and sediment management.

Stocking density and seed quality

Stocking density relates to the number of juvenile post larvae (PL) shrimps per unit area. Until recently, the average stocking density was approximately 10-20 PL per sq.m, but, due to a number of factors, this has increased over the last two decades to about 50-100 PL per sq.m. In the past, when seed was caught in the wild, supplies were constrained by the natural environment. However, with improvements made in culturing seed in artificial hatcheries, this constraint no longer applies. Second, with land being a major cost item in many countries, many farmers realised that economies of scale could be achieved with higher stocking densities.

However, higher stocking densities are accompanied by higher mortality rates. First and simply, more shrimps per unit area translates to a ‘crowding’ effect which induces high stress levels in the shrimps. This in turn lowers their resilience to viruses and makes them more susceptible to diseases. Secondly, higher densities produce more waste per unit area of water, which, if not cleaned properly, can become toxic. Again, the deteriorating environment produces stress in the shrimps which increases their vulnerability to diseases. Thirdly, unlike their wild cousins, cultured seed is produced from a limited gene pool. This produces inferior quality juveniles which similarly have a lower tolerance to diseases (Olin and Fast 1992; Briggs 1992; Fegan 1992).

Feed management

The growth in intensive farming practices was accompanied by increasing use of artificial food. It was used as a supplement to natural food to promote faster growth as well as higher body mass in each shrimp. This, together with higher stocking densities, meant that the amount of feed increased exponentially.

But not all the food is converted to body mass. Based on the food conversion ratio, a certain proportion is converted to waste, some of which dissolves in the water while the rest is deposited at the bottom of the pond (Briggs and Funge-Smith 1994; Boyd 1992). The main nutrients in the feed are nitrate and phosphorus which at high levels become toxic for the shrimps. A high loading of these nutrients causes stress in the shrimps and, as in the case of stocking density, increases the susceptibility of the shrimps to diseases (Lightner 1985; Chien 1992). If food levels go beyond a critical point, stress sets in and mortality rates increase.

It is important to recognise that there is an optimum combination between stock density (seed) and feed. Any sub-optimal utilisation between these two inputs will be detrimental to shrimp survival.

Water management

Water is a crucial input in shrimp production. Clean water with the right degree of salinity produces the best crop and reduces the probability of disease outbreaks. Unlike seed and feed management, water quality is, to a certain extent, beyond farmers' control. Until recently, farms used an open system for water management, where dirty water was continuously flushed out from the ponds into the ocean via canals and clean water was pumped in from the ocean. However, as the number of farms increased within the region, the amount of water flushed out with excess nutrients increased and at a certain point went beyond the coastal systems regenerative capacity to cleanse the polluted water (Tookwinas 1995). Moreover, accessing water from a common pool also meant a greater exposure to diseases transmitted from other farms in the area.

Over the last five years, as farm density has increased, many farms have switched to a closed system, where water is accessed only once during the crop cycle. The water is stored in storage ponds where it is treated with chemicals. This water is then used in the grow out ponds. At the end of the crop cycle, the water is moved into another pond where it is again treated with chemicals before it is reused or flushed out into the ocean, depending on the number of times it had been recycled. Initial evidence suggests that farms practicing the closed system have a lower mortality rate than those with open systems.

Sediment management

In intensive farms, where stocking density and feed intensity is high, there is a significant amount of sediment formation at the bottom of the ponds (Boyd 1992). At the end of each crop cycle, the sediment must be scraped and removed. This is now considered to be one of the more important environmental impacts of shrimp farming. The sediment is highly toxic and saline and if improperly disposed can cause serious problems to the shrimp sector and/or other land uses in the vicinity (Briggs and Funge-Smith 1994).

Shrimp Survival Function

Shrimp survival rates ($SURV$)[1] are defined as the volume of shrimp harvested as a percentage of what is expected at the end of the cycle. As mentioned in the previous section, the occurrence of disease is a key determining factor in shrimp survival rate. However, regressing disease occurrence on survival rate does not really provide us with any valuable information for improved farm management. The interesting causality link is between management options and disease. In this section, we describe the model which was developed to capture this link.

We begin by suggesting that survival rate is a function of disease. The survival rate we use here is that which is net of the natural survival rate. In the shrimp sector, the natural survival rate is approximately 45 percent. This takes into account of natural calamities as well as the shrimp's natural mortality rate.

Equation (1) shows that the survival rate ($SURV$) is determined by the occurrence of disease (*disease*) and shrimp stress level (*stress*).

$$SURV = f(disease, stress) \tag{1}$$

Equation (2) shows that the occurrence of shrimp disease (*disease*) depends on the quality of water in the ponds*(pondwater)* and water management ($CLOSE$). We make the distinction between water quality in the pond and water management to capture local water quality, ie, within the pond, and water quality in the common water system. The introduction of water management systems, closed or open, lets us model the degree of pond interaction with the outside system. A closed system indicates limited exposure while an open system denotes high degree of contact via frequent water exchanges.

$$disease = f(pondwater, CLOSE) \tag{2}$$

Equation (3) models the factors influencing pond water quality (*pondwater*). In this study we assume that the combination of feed ($FEED$) and stock density ($SEED$) determine pond water quality. Higher feed intensity based on a fixed food conversion ratio (FCR) translates to higher sediment accumulation and ultimately lower water quality. Similarly, higher stocking densities imply higher waste discharge leading to deteriorating water quality. However, aerators ($AERATOR$) can be used to improve water quality (Hopkins et.al 1994). Another factor which plays a role in determining water quality is the quality of sea water which is taken into the ponds.

$$pondwater = f(FEED, SEED, AERATOR, seawater) \tag{3}$$

The next link in the causality chain is the factors which determine the quality of sea water. In equation (4) below, we have identified two factors which can play an important role in determining the levels of sea water quality. The first is farm density ($FARMDENSE$). The larger the number of farms per unit area, the higher the levels of discharge into the sea.

---

[1] For notational purposes, exogenous variables are denoted by capital letters while endogenous variables are represented by lower case letters.

Another factor is the hydrological properties of the coastal zone. Hydrological property is defined as absorptive capacity or cleansing capability measured in terms of range of high-low tide. In other words, farms located in a province which faces the open ocean have better hydrological properties than a province located within a closed bay.

$$seawater = f(FARMDENSE, HYDRO) \qquad (4)$$

We now turn our attention to the second variable in equation 1, stress. Stress (*stress*) is an important factor determining survival rate. Equation (5) below illustrates that stress level is determined by feed (*FEED*) and stock density (*SEED*) strategies.

$$stress = f(FEED, SEED) \qquad (5)$$

We begin by replacing stress and disease in equation (1) with equation (2) and (5) respectively to arrive at equation (6). Variables disease (*disease*), pond water quality (*pondwater*), quality of seawater (*seawater*) and stress level (*stress*) drop out of the survival function.

$$SURV = f(PONDWATER, CLOSE, FEED, SEED) \qquad (6)$$

We next replace the pondwater in equation (6) with equation (3) and subsequently the variable seawater by equation (4) to get equation (7):

$$SURV = f\,(FEED, SEED, AERATOR, FARMDENSE, HYDRO, CLOSE) \qquad (7)$$

Equation (7) represents the reduced form shrimp survival function to be estimated. An advantage of replacing variables such as disease (*disease*), pond water quality (*pondwater*), quality of seawater (*seawater*) and stress level (*stress*) is that these variables are difficult to quantify and data are difficult to obtain. The variables shown in equation (7) are easier to quantify and these data are generally available from farm surveys. Moreover, equation (7) will provide information and practical solutions to shrimp farm management as variables in equation (7) can, to some extent, be controlled.

In this study, we experimented with two functional forms and two estimating procedures. The functional forms used are the: a) Cobb-Douglas with constant return to scale; and b) translog which includes second order terms and interaction terms. OLS and Tobit procedures were used in each case.

Data

The data used in this study were collected from a survey of 348 shrimp farms in Thailand. The survey was conducted in 1996 covering farms located in three different areas: the Gulf of Thailand, Andaman and Eastern Thailand. Table 1 shows the variables used in this study.

Table 1 Variable description

Variable names	Variable description
1. SURV	Survival rate (percent at each farm (Dependent variable)
2. FEED	Kilograms of shrimp feed per rai at each farm
3. SEED	Stock density measured as the number of see per rai
4. AERATOR	Present value of total aerators used per rai
5. FARMDENSE	Pond area in province per sq. kilometer of coastal land at various province multiply by 100
6. HYDRO	Hydrological flushing capacity measured as a range between high and low tide at various province (meters)
7. CLOSE	Farming systems: 1 = opened system; 0 = closed system

Note: Rai is a land measurement unit in Thailand. 6.25 rai =1 acre.

Empirical Results

Both Cobb-Douglas and semi-translog forms are estimated using ordinary least squares (OLS) and maximum likelihood Tobit procedures. The semi-translog functional form was chosen because it maintains simplicity in the estimation procedure but yet allows for sufficient flexibility for the model to capture second order effect (increasing or decreasing marginal product) and the interaction between feed and seed as well as between farm density and water management system[2]. Tobit procedure is experimented because the dependent variable, survival rate (*SURV*), is measured as percentage and therefore is truncated at the lower end at zero and also at the upper end at 100. Both Cobb-Douglas and translog are estimated without a constant or intercept term because if inputs equal zero then one would expect output (survival) to be zero as well. Equations (8) and (9) are the stochastic representation of equation (7) for the Cobb-Douglas and semi-translog models respectively.

$$\begin{aligned} Ln(SURV) = {} & \beta_1 Ln(FEED) + \beta_2 Ln(SEED) + \beta_3 Ln(AERATOR) + \beta_4 Ln(FARMDENSE) + \\ & \beta_5 Ln(HYDRO) + \beta_6 (CLOSE) + e_i \end{aligned} \qquad (8)$$

$$\begin{aligned} Ln(SURV) = {} & \beta_1 Ln(FEED) + \beta_2 Ln(SEED) + \beta_{11} Ln(FEED)^2 + \beta_{22} Ln(SEED)^2 + \\ & \beta_{12} (Ln(FEED)/Ln(SEED)) + \beta_3 Ln(AERATOR) + \\ & \beta_4 Ln(FARMDENSE) + \beta_{44} Ln(FARMDENSE)^2 + \\ & \beta_{46} (Ln(FARMDENSE)*(CLOSE)) + \beta_5 Ln(HYDRO) + \\ & \beta_6 (CLOSE) + e_i \end{aligned} \qquad (9)$$

---

[2] The variables *FEED* and *SEED* entered the model directly, as squared terms and interaction term as well. The interaction term used in this study is *FEED* divided by *SEED* as it is hypothesised that any combination of *FEED* and *SEED* that is above or below what is considered optimal will be detrimental to survival rate. Similarly, second order term is also used for farm density. The interaction term between farm density and water management system is also included to capture the phenomenon that shrimp farms located in areas with high farm density tends to adopt close system.

Table 2 Parameter estimates of the survival function

Variables	**Cobb-Douglas (CRTS)** **OLS**	 **Tobit**	**Translog** **OLS**	 **Tobit**
FEED	0.4603 (8.264)	0.4652 (8.260)	4.9864 (3.193)	5.1037 (3.248)
SEED	0.0019 (0.050)	-0.1306 (-0.035)	1.6493 (2.262)	1.6557 (2.262)
$FEED^2$	na	na	-0.1151 (-2.225)	-0.1189 (-2.281)
$SEED^2$	Na	Na	-0.1777 (-2.866)	-0.1800 (-2.889)
FEED/SEED	Na	Na	-33.7321 (-2.567)	-34.4200 (-2.607)
FARMDENSE	0.1268 (3.598)	0.1265 (3.552)	-0.3215 (-1.462)	-0.3244 (-1.470)
$FARMDENSE^2$	Na	Na	0.0501 (1.682)	0.0505 (1.688)
*FARM*CLOSE*	Na	Na	-0.0957 (-1.280)	-0.0970 (-1.290)
HYDRO	0.1154 (1.557)	0.1156 (1.545)	Na	Na
CLOSE	0.0826 (0.961)	0.0835 (0.962)	0.4355 (1.537)	0.4404 (11.547)
σ	Na	0.6606 (25.701)	Na	0.6174 (25.584)
Observation	348	348	348	348
R2	0.1103	Na	0.2226	Na
Adj. R2	0.0992	Na	0.2042	Na
F-statistics	10.63	Na	12.13	Na
Log likelihood	Na	-356.4454	Na	-333.4140

Table 2 shows the parameter estimates of equations (8) and (9). The differences in the functional form yielded significant differences in estimated parameters while the different estimation procedures did not result in any major changes. Variable *AERATOR* has been dropped from both models due to unsuitable data format.

The Cobb-Douglas functional form does not perform as well as the translog. Although the Cobb-Douglas coefficients on *FEED* are positive and significant as expected, the coefficients on *SEED* are insignificant and have the wrong sign when estimated with Tobit procedure. Moreover, farm density (*FARMDENSE*) in the Cobb-Douglas estimation has a positive sign and is significant. This result implies that provinces with high farm densities tend to have high survival rates which is contrary to empirical evidence. *HYDRO* have positive signs as expected but t-scores are insignificant.

When the survival function is estimated using a translog functional form most variables have the correct signs and are significant. This is probably due to the flexibility of the translog that allows for second order approximation and interaction. Signs on second order terms also

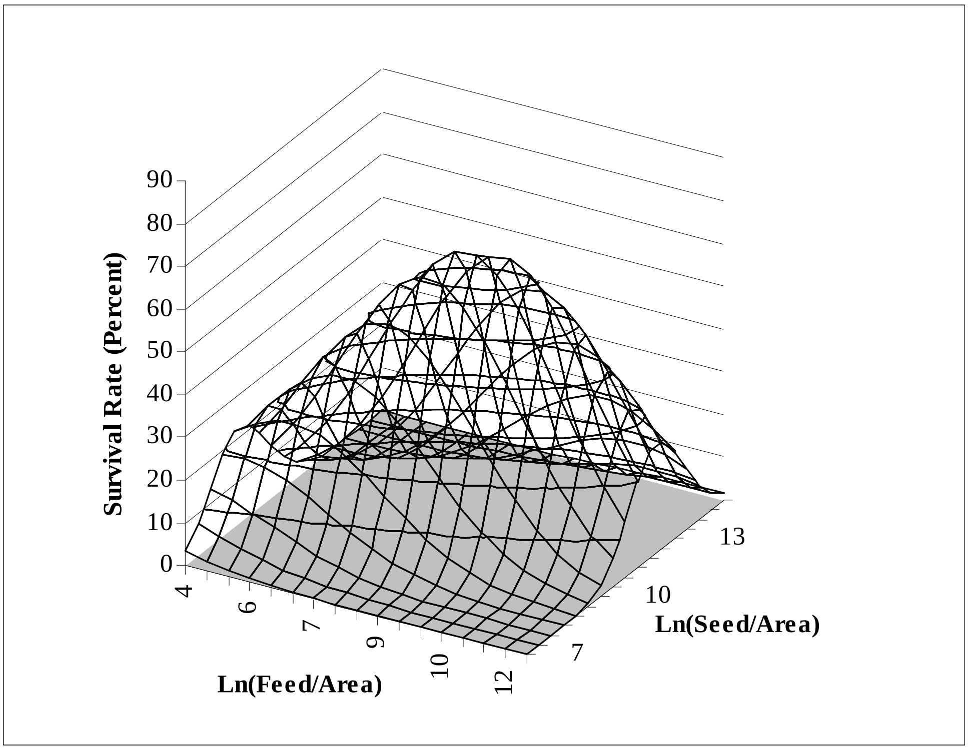
conform to economic theory. As estimates from OLS yield similar results to that of Tobit only results from Tobit will be discussed hereafter.
As the results shown in Table 2 demonstrate, *FEED* and *SEED* have positive and significant signs as expected with second order terms $FEED^2$ and $SEED^2$ having negative signs and also significant. This shows that shrimp survival rates increase with *FEED* and *SEED* but at a decreasing rate – diminishing marginal product. The interaction term *FEED*/*SEED* is also significant indicating that the interaction between them cannot be ignored. It will also be important in determining the optimal combination between *FEED* and *SEED* which will be discussed later.

Farm density (*FARMDENSE*) is negative as expected. This confirms the current situation that provinces with a high degree of farm density tend to experience water pollution and hence disease problem. The second order term of farm density ($FARMDENSE^2$) is positive. This means that the disease problem becomes increasingly more serious as a province becomes crowded with shrimp farms. The coefficient on *CLOSE* is also positive as expected although its t-score is not very strong. This shows that farms which practice closed water management systems tend to experience a higher survival rate.

HYDRO did not perform well in the translog specification and was subsequently dropped.. There are two possible reasons for this. First, there may be insufficient variation in the data points. As all the farms in the same province get assigned the same value for *HYDRO*, there are only eight values of *HYDRO* assigned to all 348 farms. This lack of variation may prevent the model from capturing the hydrological effects of the ocean. Second, the complexity of the impacts of hydrological properties of the ocean on shrimp survival cannot be explained by a single variable. A more sophisticated model is needed to capture how shrimp survival is affected by the hydrological properties of the ocean.

In Figure 1 a three dimensional plot describing shrimp survival rates against feed (*FEED*) and *SEED* is shown. All the other variables are held constant at their means. The graph shows that there exists an optimal feed seed combination which maximises the survival rate.

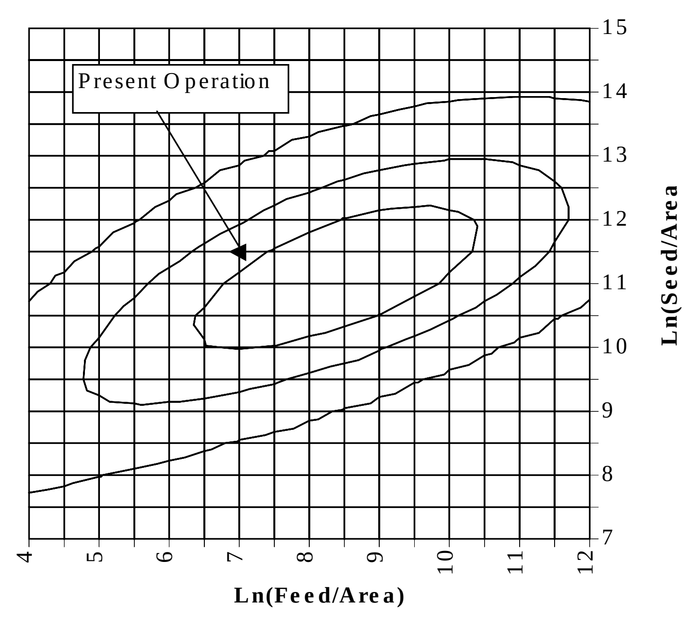
Figure 1 Shrimp survival rate as a function of feed and seed



At a feed intensity of 8.5 kg/rai and a stock density of around 11 PL/rai, the survival rate is maximised at 66.19 per cent. Too much or too little feed or seed will reduce the survival rate. The finding of this study confirms existing empirical evidence which suggests that farms which attempt to increase both feed and stock density experience a lower survival rate.

Figure 2, an *iso-survival rate contour*, is a bird's eye view of Figure 1. The inner circle represents the combination of feed and stock density where the survival rate is above 50 percent. As feed and stock density combinations moves farther away from the center the survival rate falls. Currently, an average Thai farm from the survey is experiencing a survival rate of around 49 percent which is just outside the circle.

Figure 2 Shrimp survival rate as function of feed and seed (Iso-percent contour)



Note: Inner circle = 50-70 percent survival rate
Middle to inner circle = 30-50 percent survival rate
Outer circle to middle circle = 10-30 per cent survival rate.

Figures 3 and 4 show the impact of water management systems on shrimp survival rate. The results from this study confirm that farms which adopt closed water management systems tend to experience higher survival rates (Figure 3) while farms which opt for open systems experience lower survival rates (Figure 4).

Figure 3 Shrimp survival rate as function of feed and seed for closed system

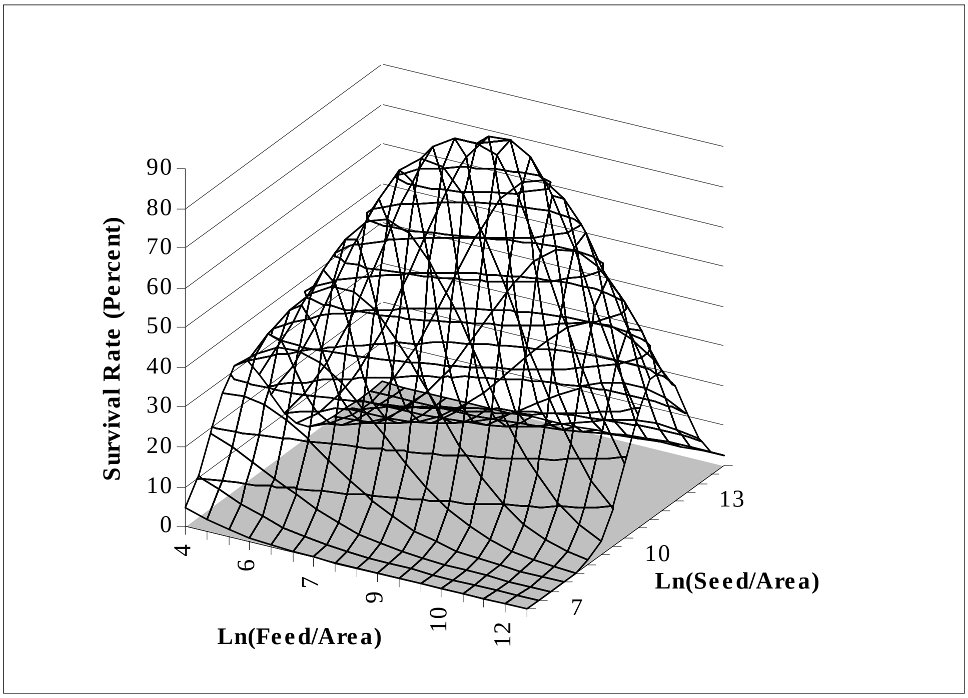
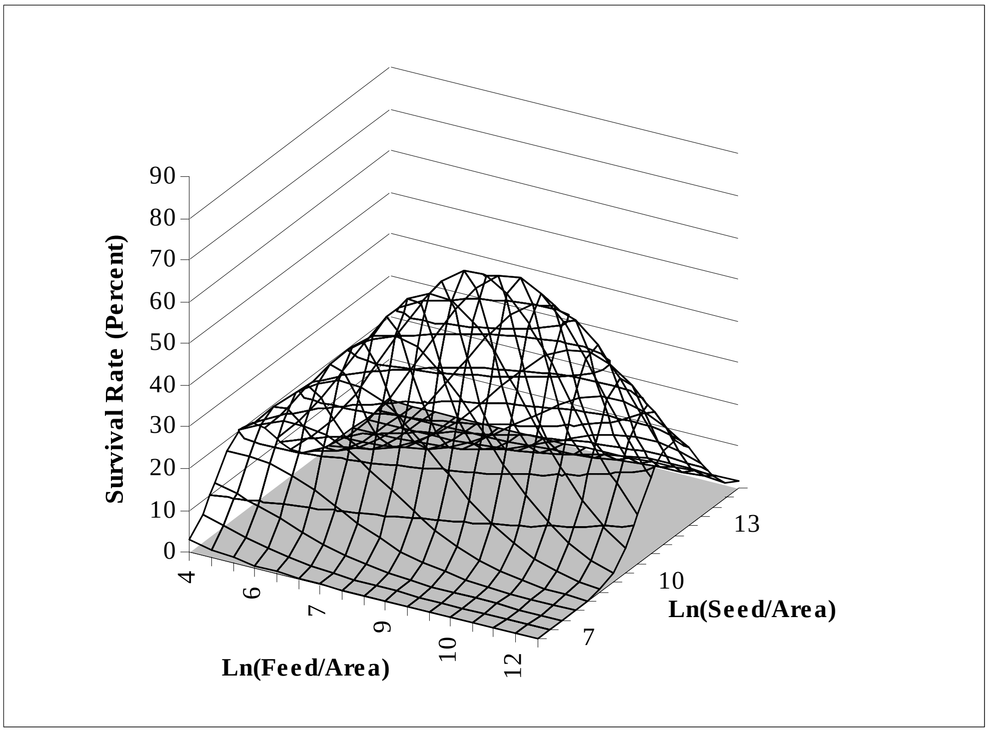


Figure 4 Shrimp survival rate as function of feed and seed for opened system



Conclusion

This study has used the production function approach to capture shrimp survival rates. A reduced form equation determining shrimp survival is developed and the unknown coefficients are estimated using Cobb-Douglas and translog functional form. The results show that the translog specification out performs the Cobb-Douglas. When shrimp survival is estimated with a translog key variables have correct signs and are significant. The flexibility of the translog specification allows the researcher to examine the optimal combination between feed and stock density.

The study findings confirm that farmers who adopt high stock densities and use large amounts of feed will generally experience a deterioration in the survival rate. It also demonstrates that shrimp farms which adopt closed water management systems tend to experience higher survival rates compared with open system farms. The analysis also shows that provinces which are crowded with shrimp farms tend to experience greater disease outbreaks and hence lower survival rate.

Preliminary results suggest that there is scope for improving the management of the Thai shrimp sector. An optimal stocking density of 11 PL/rai and a feeding strategy of 8.5Kg/rai will produce the highest survival rate. This is of course holding all other variables constant at their means. But we need to exercise some caution here in prescribing this as an optimal strategy for the farmers. A more detailed cost-benefit analysis needs to be carried out whereby the economics of shrimp farming need to be incorporated into the decision making framework. This analysis will form the second part of this project study.

References

Boyd, C.E. 1992. ‘Shrimp pond bottom soil and sediment management.’ In *Proceedings of the Special Session on Shrimp Farming*, ed. J. Wyban. World Aquaculture Society, Baton Rouge, USA.

Boyd, C.E and Musig, Y. 1992. ‘Shrimp pond effluents: observations of the nature of the problem on commercial farms.’ In *Proceedings of the Special Session on Shrimp farming*, J. Wyban (ed) World Aquaculture Society, Baton Rouge, USA.

Briggs ,M.R.P. 1992. ‘A stress test for determining vigor of post-larval penaeuse monodon fabricius. *Aquaculture and Fisheries Management* 23: 633-637.

Briggs, M.R.P. 1994. ‘Status, problems and solutions for a sustainable shrimp culture industry.’ In M.R.P. Briggs (ed). *Development of strategies for sustainable shrimp farming. Final report to the Overseas Development Administration.* Research Project R4751. Institute of Aquaculture, University of Stirling, UK.

Briggs, M.R.P. and Funge-Smith, S.J. 1994. ‘Unsustainable shrimp culture. A review of causes and potential solutions from experience in Thailand.’ In M.R.P. Briggs (ed). *Development of strategies for sustainable shrimp farming. Final report to the Overseas Development Administration.* Research Project R4751. Institute of Aquaculture, University of Stirling, UK.

Briggs, M.R.P and Funge-Smith, S.J. 1994. ‘A nutrient budget of some intensive marine shrimp farms in Thailand.’ *Aquaculture and Fisheries Management* 25: 789-811.

Chien, Y.H. 1992. ‘Water quality requirements and management for marine shrimp culture.’ In *Proceedings of the Special Session of Shrimp Farming.* J. Wyban (ed). World Aquaculture Society, Baton Rouge, USA.

Chua, T.E. 1993. ‘Environmental management of coastal aquaculture development.’ In R.S.V. Pullin, H. Rosenthal and J.L. Maclean (eds*). Environment and aquaculture in developing countries.* ICLARM Conference Proceedings 31: 199-212, ICLARM, Philippines.

Csavas, I . 1992. ‘Impacts of aquaculture on the shrimp industry.’ In H. deSaram and T. Singh (eds). *Proceedings of the 3rd Global Conference on the Shrimp Industry, Shrimp ’92*, Hongkong, 14-16 September, 1992, pp6-18.

Dewalt, B.R., Vergne, Ph. and Hardin, M. 1996. ‘Shrimp aquaculture development and the environment: people, mangroves and fisheries on the Gulf of Fonseca, Honduras.’ *World Development* 24(7): 1193-1208.

Dierberg, F.E. and Woraphan Kiattisimkul. 1996. ‘Issues, impacts, and implications of shrimp aquaculture in Thailand.’ *Environmental Management* 20(5):649-666.

Fegan, D.F. 1992. Recent developments and issues in the penaeid shrimp hatchery industry. In Proceedings of the Special Session on Shrimp Farming, (ed J. Wyban) World Aquaculture Society, Baton Rouge, LA. U.S.A.

Funge-Smith, S.J. and Aeron-Thomas, M. 1995. *The economic factors and risks influencing the sustainability of Thai intensive shrimp farms*. Institute of Aquaculture, University of Stirling, UK.

Funge-Smith, S.J. and Briggs, M.R.P. 1994. 'The origins and fate of solids and suspended solids in intensive marine shrimp ponds in Thailand.' In M.R.P. Briggs (ed). *Development of strategies for sustainable shrimp farming, Final report to the Overseas Development Administration.* Research Project R4751. Institute of Aquaculture, University of Stirling, UK.

Funge-Smith, S.J. and Briggs, M.R.P. 1995. *Water quality and nutrient discharge of intensive marine shrimp*. Institute of Aquaculture, University of Stirling, UK.

Gronski, R. and Heffernan, W. 1996. *Development and degradation: commercial shrimp culture and stressful waters in southern Thailand*. Paper presented at the Rural Sociological Society Conference, Des Moines, Iowa, August 1996.

Gross, J., Burch, D. and Rickson, R. Forthcoming. 'Agri-food restructuring and Third World transnationals: Thailand, the CP Group and the global shrimp industry.' *World Development*.

Hopkins, J.S., Sandifer, P.A., Browdy, C.L. and Heffernan III, J.A. 1994. 'Effect of two feed protein levels and feed rate combinations on water quality and production of intensive shrimp ponds operated without water exchange'. *Gulf Research Special Issues*.

Liao, I.C. 1990. 'Aquaculture in Taiwan.' In M.M. Joseph (ed). *Aquaculture in Asia.* Asian Fisheries Society, Indian Branch, Mangalore.

Lightner, D.V. 1985. 'A review of the diseases of cultured penaeid shrimps and prawns with emphasis on recent discoveries and developments.' In Y. Taki, J.H. Primavera and J.A. Llobrera (eds) *Proceedings of the First International Conference on the Culture of Penaeid Prawns/Shrimps* Aquaculture Department, SEAFDEC, Iioilo City, Philippines.

Lightner, D.V., Bell, T.A., Redman, R.M., Mohney, L.M., Natividad, J.M., Rukyani, A. and Poernomo, A. 1990. 'A review of major diseases of economic significance in penaeid prawns/shrimps of the Americans and Indo-Pacific.' Presented at the *Symposium on Diseases in Asian Aquaculture,* 26-29 November 1990. Bali, Indonesia. Asian Fisheries Society.

Lin, C.K., Ruamthaveesub, P. and Wanuchsoontorn, P. 1991. 'Wastewater of intensive shrimp farming and its potential biological treatment.' In *Proceedings of the seminar/workshop on agro-based wastewater treatment and recovery systems.* C. Polprasert, P.Y. Yang and N. Kongsricharoern, and W. Kanjanaprapin (eds). Environmental Engineering Division, Asian Institute of Technology, Bangkok, Thailand.

MacIntosh, D.J. and Phillips, M.J. 1992. 'Environmental issues in shrimp farming.' In H. de Saram and T. Singh (eds). *Shrimp '92, INFOFISH and EUROFISH.* Hong Kong.

Masae, A and Rakkheaw, S. 1992. *Social aspects of artisanal fisheries and shrimp farming in Pak Phanang Bay.* Asian Fisheries Social Science Research Network: Coastal Resources Institute, Prince of Songkhla University, Hat Yai, Thailand.

NACA (Network of Aquaculture Centres in Asia-Pacific). 1994. *The environmental management of coastal aquculture. an assessment of shrimp culture in southern Thailand.* Final Report to the Office of Environmental Policy and Planning, Network of Aquaculture Centers in Asia-Pacific. January 1994.

NACA 1996. *A survey project for the sources of water pollution from coastal fishery.* A research report submitted to the Department of Pollution Control, Ministry of Science, Technology, and Environment, Thailand. (in Thai).

Olin, P.G and Fast, A.W. 1992. ‘Paenaeid pl harvest, transport, acclimation and stocking.’ In A.W. Fast and L.J. Lester (eds). *Marine shrimp culture; principles and practices.* Elsevier, Amsterdam.

Paruelo, J.M. and Tomasel, F. 1997. ‘Prediction of functional characteristics of ecosystems: a comparison of artificial neural networks and regression models.’ *Ecological Modelling* 98: 173-186.
Primavera, J.H. 1993. ‘A critical review of shrimp pond culture in the Philippines.’ Reviews in *Fisheries Science* 1(2): 151-201

Tookwinas, S., Malem, F and Songsangjinda, P. 1995. ‘Quality and quantity of discharged water from intensive marine shrimp farms at Khung Krabaen Bay, Chanthaburi Province, Eastern Thailand.’ In Snidvongs, A et al (eds). *Proceedings of the NRCT-JSPS Joint Seminar on Marine Science,* December 2-3, 1993, Songkhla, Thailand.

Tookvinas, S. 1996. *Environmental impact assessment in intensive marine shrimp farming in Thailand, Bangkok.* Mimeograph. Coastal Aquaculture Division, Department of Fisheries.

PUBLICATIONS AND ORDER FORM

Paper Nos. 1-16 may be obtained free of charge; however orders for large quantities (more than 6) will incur postal charges. Full copies of papers Nos. 17 onwards may be downloaded from the CREED web site free of charge, at http://www.iied.org/creed. Alternatively hard copies may be obtained from IIED; a charge of £5 plus postage, will be levied for northern readers only.

The following papers are available from the CREED Programme. Please check the publications you wish to obtain and return the order form to Jacqueline Saunders, Environmental Economics Programme, International Institute for Environment and Development, 3 Endsleigh Street, London WC1H 0DD, or email your requests to Jacqueline.Saunders@iied.org.

CREED Working Paper Series.

☐ **No 1. Adjustment Policies and the Environment: A Critical Review of the Literature.** Carlos E.F. Young and Joshua Bishop. July 1995.

☐ **No 2. Environmental Regulations as Trade Barriers for Developing Countries: Eco-labelling and the Dutch Cut Flower Industry.** Harmen Verbruggen, Onno Kuik & Martijn Bennis. July 1995.

☐ **No 3. Economic Incentives for Watershed Protection: A Report on an Ongoing Study of Arenal, Costa Rica.** Bruce Aylward, Jaime Echeverría & Edward B. Barbier. September 1995.

☐ **No 4. Economic Policies for Sustainable Water Use in Thailand.** Ritu Kumar and Carlos Young. June 1996.

☐ **No 5. The Informal Sector and Waste Paper Recovery in Bombay**. Pieter van Beukering, Edwin Schoon and Ajit Mani. June 1996.

☐ **No 6. Economic Trends in the Timber Industry of the Brazilian Amazon: Evidence from Paragominas.** Steven Stone. July 1996.

☐ **No 7. Input Substitution in the Indian Paper Industry: A Variable Cost Function Approach**. K.V. Ramaswamy, R.R. Vaidya, M.J. Bennis and J.G.M. Hoogeveen. July 1996.

☐ **No 8. Poverty and Environmental Degradation: A Literature Review and Analysis.** Anantha K. Duraiappah. October 1996.

☐ **No 9. Valuation and Evaluation of Management Alternatives for the Pagbilao Mangrove Forest.** Ron Janssen and Jose E Padilla. October 1996.

☐ **No 10. The Economic and Environmental Impacts of the Waste Paper Trade and Recycling in India: A Material Balance Approach.** Pieter van Beukering and Anantha K. Duraiappah. November 1996.

☐ **No 11. Incentives for Eco-efficiency: Lessons from an Evaluation of Policy Alternatives; A Case Study of the Steel Sector in India.** Ritu Kumar, Nick Robins, A.K. Chaturvedi, R. Srinivasan and J. Gupta. December 1996.

☐ **No 12. Poverty and Environment Linkages in Mountains and Uplands: Reflections on the 'Poverty Trap' Thesis.** Sanjeev Prakash. February 1997.

☐ **No 13. The Economic Importance of Wild Resources in the Hadejia-Nguru Wetlands, Nigeria.** Derek Eaton and Marie-Thérèse Sarch. May 1997.

☐ **No 14. Economic Valuation of Mangrove Ecosystems: Potential and Limitations.** Frank Spaninks and Pieter van Beukering. July 1997.

☐ **No 15. The Use of Environmental Functions to Evaluate Management Strategies for the Pagbilao Mangrove Forest.** Alison J. Gilbert and Ron Janssen. August 1997.

☐ **No 16 Trends and Issues in the Plastics Cycle in China, with Special Emphasis on Trade & Recycling.** Pieter van Beukering, Li Yongjiang, Zhao Yumin & Zhou Xin. December 1997.

☐ **No 17. Economic Valuation of Communal Rangelands in Botswana: A Case Study**. Jaap Arntzen. February 1998.

☐ **No 18. Environmental Product Measures: Barriers for South-North Trade?** Harmen Verbruggen, Onno Kuik, Martijn Bennis, Hans Hoogeveen, Roland Mollerus. March 1998

☐ **No 19. The Shrimp Aquaculture Sector in Thailand: A Review of Economic, Environmental and Trade Issues.** Direk Patmasiriwat, Onno Kuik and Sunil Pednekar. October 1998**.**

☐ **No 20. An Analysis of Private and Social Discount Rates in Costa Rica**. Bruce Aylward and Ina Porras. December 1998.

☐ **No 21. Institutional Arrangements for Watershed Management: A Case Study of Arenal Costa Rica.** Bruce Aylward and Alvaro Fernandez Gonzalez. December 1998.

☐ **No 22. Farmers' Perceptions and Sustainable Land Use in the Atacora, Benin.** A. Adegbidi, K. Burger, E. Gandonou and I. Mulder. February 1999.

☐ **No 23. Sustainable Livestock Management in the Kalahari: an Optimal Livestock Rangeland Model.** Anantha K. Duraiappah and Jeremy S. Perkins. March 1999.

☐ **No 24. Analysing Urban Solid Waste in Developing Countries: A Perspective on Bangalore, India.** Pieter van Beukering, Madhushree Sekher, Reyer Gerlagh and Vijay Kumar. March 1999.

☐ **No 25. Market and Policy Incentives for Livestock Production and Watershed Protection in Arenal, Costa Rica.** Bruce Aylward, Jaime Echeverría, Katherine Allen, Ronald Mejías and Ina T. Porras. March 1999.

☐ **No 26. Integrated Modelling of Solid Waste in India.** Reyer Gerlagh, Pieter van Beukering, Madhu Verma, P.P. Yadav and Preety Pandey. March 1999.

☐ **No 27. The Plastics Sector in China: Issues in Production, Recycling and International Trade**. Anantha K. Duraiappah, Zhou Xin and Pieter van Beukering. March 1999.

☐ **No 28. Farmers' Perceptions of Soil Fertility in Benin** Ingrid Mulder. February 2000.

☐ **No 29. Automobile Pollution Control in Brazil**. Claudio Ferraz and Ronaldo Seroa da Motta. June 2000.

☐ **No 30. Soil Fertility: QUEFTS and Farmers' Perceptions**. Ingrid Mulder. July 2000.

No 31. **Sustainable Shrimp Farming: Estimations of a Survival Function .** Anantha K. Duraiappah, Adis Israngkura and Sombat Sae-Hae. July 2000.

CREED Final Reports

The following reports are available from recently completed CREED projects. A charge is levied for all readers as indicated**.**

☐ **International Trade and Recycling in Developing Countries: The Case of Waste Paper Trade in India**. P. van Beukering and V. Sharma (eds). November 1996. 155 pages. £20

The importance of international trade in the global economy is expanding, not only for primary products but also for recyclable waste. The main objectives of this study were to determine the economic, social and environmental impacts of international trade of waste paper for recycling purposes in India. The report addresses three main sectors: (i) the world market for waste paper, (ii) the local waste paper market and (iii) the Indian paper industry. It also makes recommendations for policy makers at an international, national and local level: international agreements should distinguish between hazardous and non-hazardous waste; national trade barriers to waste imports should be eliminated; and existing local informal recovery sectors should be favoured over formal Western-style recycling systems.

☐ **Mangroves or Fishponds? Valuation and Evaluation of Alternative Uses of a Mangrove Forest in the Philippines.** Ron Janssen & Jose Padilla. September 1997. 258 pages. £25.

One of the major threats to mangroves in the Philippines is the rapidly increasing aquaculture industry. This study includes a review of valuation methodologies and their application to the case study area of the Pagbilao experimental mangrove forest in the Philippines. Valuations of goods and services and environmental functions of the forest are employed to assess alternative management regimes using both cost-benefit analysis as well as a multi-criteria approach. Much depends on the management objectives: conversion to aquaculture is the most economically efficient management option. However, if equity and sustainability objectives are included, commercial forestry is the preferred alternative.

☐ **Incentives for Eco-Efficiency. Market Based Instruments for Pollution Prevention: A Case Study of the Steel Sector**. Ritu Kumar, Nick Robins, A.K. Chaturvedi, R. Srinivasan and J. Gupta. December 1997. 96 pages. £20.

Mounting pressures on industry to reduce pollution, to remain globally competitive and to meet the requirements of international standards, require fundamental changes in government policy and corporate approaches to environmental management. This report presents the results of an international study assessing the potential for market-based instruments for pollution prevention in the steel sector in India. It recommends a set of policy measures to reduce discharge levels in the most cost effective manner, to induce firms to adopt cleaner technologies and to encourage firms to economise on energy and water resources. In this regard, the importance of achieving coherence with existing policies, building trust among key stakeholders and gradually phasing in market-based instruments is emphasised.

☐ **Economic Incentives for Watershed Protection: A Case Study of Lake Arenal, Costa Rica**. Bruce Aylward, Jaime Echeverria, Alvaro Fernandez Gonzalez, Ina Porras, Katherine Allen, Ronald Mejias. February 1998. 323 pages. £30.

Conventional wisdom holds that cutting down tropical forests for livestock production is not only bad business but bad for the environment. In particular, it is thought that conversion of natural forest to pasture leads to a rise in the sedimentation of waterways and resevoirs, increased risk of flooding and loss of dry season water supply. In the case of Lake Arenal, Costa Rica, this conventional view is stood on its head by research showing that ranching, dairy farming and associated downstream hydrological effects represent important positive values to the Costa Rican economy, values that significantly outweigh expected returns from reforestation

☐ **Plastics Recycling in China. An International Life Cycle Approach.** Edited by Pieter van Beukering. April 1999. 148 pages. £20.

Please check the papers you wish to obtain and use this form for delivery, to indicate a change of address, or to be added to the mailing list to receive information about future CREED Working Papers (please tick).

Name ....

Organisation ....

Address ....

....

I enclose a cheque for *£......................made payable to **IIED**/I authorise you to debit my credit card for £.............. My Access/Visa/Mastercard number (please tick as applicable) is:

Expiry date.................................... . Name of cardholder..

Cardholder address...

* For postage within the UK please add 20%, minimum £1 (first class or equivalent)
For postage to Europe please add 25%, minimum £2 (printed matter airmail or equivalent)
For postage to the rest of the world, please add 40% (printed matter airmail or equivalent) or 25% (surface)