Effective Management for Biodiversity Conservation in Sri Lankan Coastal Wetlands

Fieldwork Report 2.3a:

A MEASUREMENT OF THE ECOLOGICAL FOOTPRINT OF SHRIMP FARMING IN THE CHILAW LAGOON AREA

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Preface

This report presents findings from the DEFRA Darwin Initiative funded research project 'Effective Management for Biodiversity Conservation in Sri Lankan Coastal Wetlands'. The project was a collaborative study by the Centre for the Economics and Management of Aquatic Resources (CEMARE) University of Portsmouth, UK, the Department of Town and Country Planning, University of Moratuwa, Sri Lanka and the Department of Forestry and Environmental Sciences, University of Sri Jayewardenapura, Sri Lanka.

This report presents the findings of fieldwork carried out by Ms. Nikola Cattermoul and Mr. Aruna Devendra measuring the Ecological Footprint of Shrimp Farms in the Chilaw Lagoon area. The opinions expressed and conclusions drawn are solely the responsibility of the authors.

The research came as a response to the growing number of shrimp farms in Sri Lanka's west coast, which are believed to have adverse effects on the local lagoon ecosystems.

This fieldwork and data collection was carried out in January and February 2002. Chilaw Lagoon was selected as there is a high density of shrimp farms in the area, and many of the associated problems manifest themselves here.

Acknowledgements

Many thanks to the Chilaw Divisional Secretary's office for their assistance and for sharing their information and knowledge with this research team. We are also grateful to Mr. N. Orlina of CP Aquaculture (India) PVT Ltd for his assistance with shrimp farm data. Thank you also to Mr. Christy of the Consortium for Aquaculture Development, Chilaw, for providing the researchers with his time and information.

1. Introduction

A rising demand for luxury seafood in developed countries and falling returns from capture fisheries has stimulated a rapid expansion of shrimp farming in many tropical developing countries over the past 25 years. In Sri Lanka the race to enter this potentially lucrative market and capture its benefits has lead to a significant level of poorly planed and badly managed shrimp farms, giving rise to environmental, social and economic costs.

The development of shrimp farming has been centred on the north-western coastal area of Sri Lanka. This is because there are a number of coastal lagoons, which are ideal for the establishment of shrimp farms. In addition to this, the locations are close to the international airport, north of Colombo, and are therefore close to international markets, which many of the shrimp products are destined for.

This brief report sets out the results and findings of a restricted survey in the Chilaw Lake environs, which endeavours to take a measurement of the Ecological Footprint. This is a measurement developed by researchers at the Institute for Systems Ecology, Stockholm University, Sweden, from a concept originally proposed by Wackernagel and Rees.

The Ecological Footprint of aquaculture has been thoroughly examined in the initial project report, “Ecological Footprints and Aquaculture: Implications for Wetland Management”, and will not be covered in this report.

2. Background to Shrimp Farming in Sri Lanka

2.1 An overview of the development of Shrimp Farming in Sri Lanka

The global boom in shrimp farming began in the 1980s and was lead by countries such as Thailand, Ecuador, Indonesia and China. However, in Sri Lanka where there has not been a tradition of aquaculture, shrimp farming was slower to take hold. Despite this, the first farms were established in the early 1980's by a small number of entrepreneurs and multi-national companies encouraged by the Sri Lankan Government's (SLG) attractive package of benefit's and taxation incentives (Siriwardena, unpublished).

Shrimp mariculture is one of the fastest growing industries in Sri Lanka. The annual exports reached 6,900 tonnes in 1998, with an export value of US$53,820,000 (table 1). The main species cultured is *Penaeous monodon* the black tiger shrimp, which is a naturally occurring species in Sri Lankan coastal waters.

Table 1: Mariculture of P. monodon in Sri Lanka

	Production of *P. monodon*	
Year	**Quantity (tonnes)**	**Value (1000 US$)**
1984	10	50
1985	250	1,250
1986	400	2,000
1987	500	2,500
1988	669	4,349
1989	700	5,250
1990	1,000	7,800
1991	1,500	10,800
1992	2,000	14,000
1993	2,500	17,500
1994	3,100	21,700
1995	3,329	23,303
1996	3,555	41,594
1997	5,000	40,000
1998	6,900	53,820

(Source: FAOSTAT)

Initially, the industry grew steadily, and in a controlled manner. However, in 1994 a change in government witnessed the rapid and uncontrolled expansion of shrimp farms, in particular in the Puttalam area. Some of these farms were legal, but a large number appear to have been constructed illegally, on government owned land.

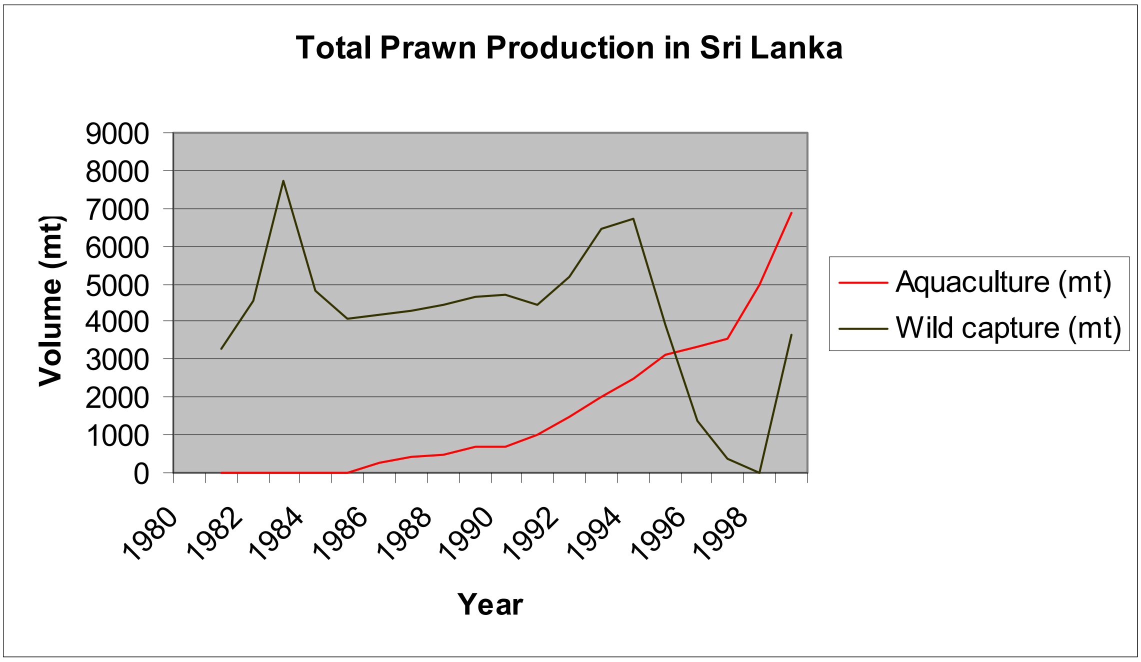
One of the main reasons for an expansion in farming in the Puttalam District is that it is easily accessible by road, it is not in the conflict zone[1], there are a number of coastal lagoons and the land is generally not agricultural. This differs to further south along the coast where land is less accessible due to a variety of housing and industrial developments. This rapid expansion in farming has meant that Penaeus monodon has become one of the fastest growing export-led industries in Sri Lanka (Corea et al., 1998). Shrimps now account for a significant portion of export revenue, in the agricultural and fisheries sector only second to tea in 1998. (See annex 1.)

As illustrated by figure one, it can be seen that in 1994 farmed shrimp production increased notably, and the figures for wild caught shrimp begin their rapid annual decline. No studies have so far been identified that have examined this issue, and because of this it is not known if either the expansion of shrimp farms in the coastal areas have contributed to the decline in wild shrimp catch, or whether this has simply lead to a shift in the overall fishing industry effort.

Generally the data show a massive decline in wild caught shrimps between 1995 and 1998. It is not known what the reason for this is. However, the data does show as aquaculture output increases, wild caught output decreases. This could be a result of a number of factors. The seed shrimp for farming originate from wild caught adults that are bred from in the hatcheries. The juvenile shrimps are raised in the shrimp ponds. This differs to where they normally spend their lifecycle, in the coastal waters and lagoons, where fishermen catch them. By removing them from the ecosystem, the fishery population is reduced, so catches are reduced accordingly. An alternative reason for the decline in wild caught shrimps is pollution of the lagoons by shrimp farming increases the stress on the wild populations and contributes to large-scale mortality.

[1] The north and east of Sri Lanka has been the geographical area of the Tamil Tiger and Sri Lankan Government conflict since the 1980's

Figure 1: Total Sri Lankan shrimp production 1980 to 1998.



(Source: modified from the Sri Lanka Fisheries Yearbook (1999, 1998 & 1997) and FAOSTAT)

The figures for cultured shrimp production in the whole of Sri Lanka show that the land area under production declined in 1998, when compared to 1996, but the intensity of production, measured in mt/ha increased during that time (table 2).

Table 2: Cultured shrimp production in Sri Lanka 1994 to 1998

Year	Area (ha)	Shrimp production (mt)	Average production (mt/ha)
1994	2,700	3,100	1.1
1995	3,450	3,600	1.0
1996	3,782	3,555	0.9
1997	N/A	5,000	N/A
1998	3,750	6,900	1.84

(Source: modified from the Sri Lanka Fisheries Yearbooks 1997, 1998 & 1999)

2.2 The Study Site

The Chilaw Lagoon System and the Deduru Oya mouth are in the north west of Sri Lanka. The 5km long entrance channel to the lagoon and the lagoon itself, which is also known as the Chilaw Lake, have been an important anchorage and servicing point for a significant size fleet of small and medium sized fishing boats.

At present the formation of a sand bar opposite the lagoon inlet restricts the access of larger boats for part of the year. The southern entrance to the lagoon through the inlet at Thoduwawa is completely closed for a part of the year despite construction carried out in the early 1960s to prevent sand bar formation across the inlet. The river mouth is highly changeable with seasonal formation and movement of sandbars. The Deduru Oya is a sinuous river whose catchment straddles the dry zone and the northernmost edge of the wet zone. The main (direct) river mouth which is closed by a sandbar during the months immediately following the South West Monsoon would open automatically with or without some preparatory excavation of the sand bar when the river stages rise at the beginning of the North East Monsoon. The coastline south of the river mouth is fixed along a long sandstone ledge, which runs north to south. The southern opening in the sand bar barely allows the passage of shallow draft vessels during a part of the year into the entrance channel of the Lagoon, which serves as a very important harbour for fisheries. The development of aquaculture in the area has increased the effluent loading on the Chilaw Lagoon, which cannot be fully flushed away when the river mouth is obstructed.

2.3 Shrimp Farming Practices and Inputs in Chilaw

The majority of shrimp farms in the Sri Lankan coastal area are semi-intensive in their production methods.[2] That is, ponds are constructed of mud banks, shrimps are fed formulated feeds and some aeration takes place. In addition to this shrimp farmers also rely on the surrounding lagoon, or canal water, to wash wastewater through the ponds out into the lagoon or canal and to provide clean pond water. This is in contrast to intensive systems, which are characterised by concrete ponds and closed production systems, and extensive systems, which cover vast areas and are more harmonised with the local environment in which they occur.

The types of shrimp farming found on the west coast of Sri Lanka have been categorised into three levels of operation (de Silva & Jayasinghe, 1993). The first, consists of farmers who operate ‘small-scale’ farms no larger that one-hectare in area.

These farms were reported by de Silva and Jayasinghe in 1993 to have no method of aeration, however, observational evidence suggests that this is possibly no longer the case. A number of small ponds have aeration methods, such as a paddle-machine, and produce 2 harvest cycles per year.

The second group are farms that primarily depend on local technology with large investments. Mechanical aeration is generally used in medium and large-scale sized operations. This aeration of the pond water helps to keep oxygen levels at a constant in the ponds, a necessity for the survival of the shrimps.

The third category is farms involved in 'large-scale' operation with more intensive inputs, such as formulated[3] feed, higher stocking densities and are often part funded by joint ventures with foreign personnel and companies. There is observational evidence to suggest that there has been rapid growth of this third category of shrimp farming (Siriwardena, unpublished.).

Post-larvae are generally obtained from wild caught adults sold to the hatcheries by local fishermen. These are then induced to spawn in the hatcheries. The larvae are grown on in tanks until they are 18 days old, when they are ready to go to the ponds and are sold.

Shrimp feed is imported and subsidised by locally caught shellfish, including a lagoon mussel. In addition to this some farmers use feeding trays to monitor the feed intake of the larvae. However, the majority scatter feed by hand over the entirety of the pond.

At least half of the pond water is changed once a week in the Chilaw area, where it is pumped out into the lagoon and canal systems. New water is then pumped into the pond from the same source as the old water was discharged into (Zetterstrőm, 1998).

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[2] A small number of intensive, closed-system farms are in operation, but in general these are the exception and not the rule.

Table 3: Sources of inputs for shrimp farming in Chilaw, Sri Lanka.

Input	**Source**
Aeration	Mechanical (petrol/diesel motor)
Feed	Imported fish meal, subsidised with locally caught shellfish
Water	Chilaw Lagoon/ Dutch Canal
Post larvae	Hatcheries (wild caught gravid females, wild caught males and females)
Land	Mangrove/wetland, rice paddy or coconut plantations

(Source: EMBioC fieldwork 2001)

2.4 Pond siting

The majority of shrimp farms in the Puttalam District are situated on coastal and lagoon fringes and have been constructed on a number of sites whose land use has changed as a result of pond construction. The land use prior to pond construction varies between mangrove habitat, coconut land and rice paddy fields. In the case of private paddy and coconut land, the use has changed as a result of land sales, leasing or a change in policy by the landowner. However in the case of mangrove areas, the public property nature of the land has seen the illegal mass clearance of mangroves by private individuals, often with the consent of local politicians. Normally, if public land is to be used in this manner it must first be released by the Divisional Secretary, before an application to construct a shrimp pond can be made.[4] This is not completed in the case of the majority of these farms. The results of this type of action have been reported in the EMBioC field report "The impacts of shrimp farming on communities in the Chilaw area".

The close proximity to a water source is paramount to choosing a site for the construction of a pond; this is because fresh lagoon water is required in the farming methods being employed in most farms. Less capital inputs are required in the form of water pumps and pipes for irrigation. In the Chilaw area the lagoon and Dutch Canal[5] are crowded with shrimp farms as a result of this.

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[4] See annex 2 for the legal prawn farm approval process
[5] Dutch Canal was originally constructed by the Dutch colonial rulers in order to provide a transport link between the lagoons on the west coast and Colombo

2.5 Establishing a shrimp farm

Ponds in the Chilaw environs are generally less than one hectare in area; this is more likely due to the limited area of land available in the narrow coastal and lagoon belts. If a potential farmer wishes to establish a shrimp farm less than 4 hectares in area, he can do so without requiring the permission of any government agency. All that is required is that he owns, or leases, the land he wishes to develop. For a farm greater than 4 hectares in area, in order to prevent adverse impacts on the environment and deterioration of environmental quality, the applicant must obtain a management license, which costs 2,500 SLR (£20) per acre per year. This comes under the National Environmental Act, No. 47 of 1980. Section 232 was amended by Act No. 56 of 1988 which incorporated the land-use limit (Siriwardena, unpublished). According to these regulations all shrimp farms exceeding 4 ha, but less that 20 ha should submit an Initial Environmental Examination report and those exceeding 20 hectares submit an Environmental Impact Assessment (EIA) to an approving body.

As a result of this legislation there has been an enormous growth in farms that are less than 4 hectares to avoid the constraints of the lengthy approval process. The resulting overcrowding of the coastal and lagoon areas has bought about increased lagoon and canal water pollution, the source for clean water and the waste-disposal method for used shrimp farm water. This has resulted in self-pollution of water resources and increased disease prevalence due to the sharing of contaminated water (Corea *et al*, 1998).

In order to develop the industry in a more sustainable manner a number of organisations including NARA, the Consortium for Aquaculture Development, NAQDA, Ministry of Fisheries, have begun to reinforce recommendations made for shrimp farming development in the past.

These include:

- Enforce existing legislation on shrimp farming including 20% of the pond area to be utilised as sedimentation and treatment tanks.

- Legalise all existing shrimp farms, which meet the environmental regulations. Illegal farms that do not meet environmental regulations should be closed.
- Review, gazette and enforce the proposed aquaculture effluent standards in view of the poor water quality parameters observed in Dutch Canal.
- Continue experiments in which seaweeds, seagrasses and molluscs are used to treat effluents, so the efficiency of such biological clean-up systems can be improved.

(Source: Siriwardena, unpublished)

3. Methodology

The methodology and theoretical background were covered in the original literature review, dated October 2000.

The results presented here are a product of primary and secondary data collection. Data was collected from NGO's, from interviews and from private companies. This data was then compared to the results that had been generated by Larsson *et al* in a study on the ecological footprint of shrimp farming in Columbia (1994).

The following is a brief overview of the findings of the study undertaken in Columbia:

- **Marine upwelling ecosystem:** calculated that the mean marine fish yield is 6.71 tonnes C/km^2, estimated that 2.44 t of fish with carbon content was used per year in the study area. The marine area was calculated at 14.5ha/ha of shrimp farm.

Data for the marine upwelling calculation will be based on data collected on feed quantities from the Chilaw site and the data from the original footprint study of shrimp farming in Colombia. The same calculation will be used to obtain Chilaw results.

Little is made of the contribution of shrimp farming waste to the lagoon and coastal ecosystems in the work completed by Larsson *et al*, which it may be necessary to take into consideration (see section 4.5 for details). The flushing of lagoon water into the coastal ecosystems may well increase the productivity of the coastal fisheries (Roth *et al*, 2000). However, this is beyond the scope of this research and will not be addressed here.

- **Agricultural ecosystem:** calculated that the mean yield is 3.5 tonnes/ha (dry weight), estimated that 1.5 t was used per year in the study area. The agricultural area was calculated at 0.5 ha/ha of shrimp farm.

This will be taken as the amount of crop based feed used per hectare, per year in Chilaw farming practices.

- **Postlarval mangrove nursery:** calculated that the mean postlarval density in mangroves is 0.3 – 1 individual/m^2, assuming a pre-stocking mortality of 50% and the proportion of post-larvae derived from wild fry (as opposed to hatchery-raised) assumed to be between 10 and 50%. The postlarval area was estimated to be anywhere between 9.6 and 160 ha/ha of shrimp farm.

Postlarval calculations are not required for the study in Chilaw as all fry are raised in hatcheries from wild caught adults. However, adult wild-caught shrimp do rely on the mangroves for nursery grounds when they are juvenile. Larsson *et al* suggest using a figure of 10 times the area of the shrimp and as a footprint indicator for post-larval mangroves.

- **Mangrove support area:** calculated that the mean area required to yield sufficient leaf litter to provide 30% of shrimp feed estimated on the basis of productivity measures with an average mangrove litterfall of 5 t/ha and a 10% trophic efficiency in converting mangrove carbon into detrital organic matter available to the shrimp. The mangrove support area in Colombia was estimated to be 4.2 ha/ha of shrimp farm.

Instead, perhaps as Larsson *et al* have done in measuring the amount of mangroves needed to support the farms in the form of shrimp feed, it would be more useful in the case of Chilaw to measure the amount of mangroves needed to remove the high levels of nutrients in the form of waste products flushed form the ponds on a weekly basis. Again, this is beyond the scope of this study and will not be undertaken here.

- **Lagoon support area:** calculated as the area of the pumped yearly volume (10% daily, ponds 1.2 m deep, 300 days per year) assuming the source lagoon is on average 5 metres deep. The lagoon support area in Colombia was estimated to be 7.2ha/ha of shrimp farm.

The same method will be used for calculating the lagoon support area required for Chilaw.

- **CO_2 sequestering area:** calculated as area required to absorb CO_2 from direct energy use (fuel) 6085 litres/ha; the total CO_2 released by the study area aquaculture activities was estimated to be between 14.9 and 45.1 tonnes of CO_2/ha. In order to estimate the surface area needed for carbon sequestration a carbon assimilation capacity of 5 t/ha or 18.3 CO_2/ha was assumed. The CO_2 sequestering area was estimated to be between 0.8 and 2.5 ha/ha of shrimp farm.

4. Fieldwork findings

4.1 Growth of Shrimp Farming in Chilaw

Initial results show the total number of farms in the Chilaw area has grown to 183 since 1993, when the CEA/Euroconsult survey estimated there to be approximately 18 farms in operation. This is a ten-fold increase on the numbers estimated in 1994. The area under cultivation in 1994 was approximately 52 hectares. In the 2001 survey it was estimated to be 247.8 hectares, nearly a 5-fold increase in a seven-year time-span. This reflects the rapid growth that has been reported through discussions with various individuals and organisations.[6]

Table 4: Shrimp farm statistics of the Chilaw Division (2001)

GN division	Number of farms	Land area (acres)	Ponds area (acres)	Number of ponds	Number of stock tanks	Number of sedimentation tanks	Number of workers
Inigodawella	8	49.50	19.25	22	0	0	32
Marawella	7	7.20	4.20	10	0	0	11
Ambakandawilla	32	231.76	172.50	77	2	2	143
Mykkulum	10	56.75	58.25	48	4	0	49
Kakpalliya	12	38.99	33.29	33	1	0	27
Daduruoya	6	25.44	15.75	20	2	1	21
Weralabada	4	60.20	41.68	41	1	0	51
Wattakaliya	16	107.06	32.00	42	2	0	45
Welihena	84	262.08	232.49	179	6	1	239
Olidaluwela	4	16.09	10.09	9	0	0	19
Total	**183**	**855.07**	**619.50**	**481**	**18**	**4**	**637**
Total (hectares)		**342.03**	**247.80**				

(Source: DS Chilaw 2001)

Very few of the farms have sedimentation tanks, whose adoption and use are presently being promoted by both the Consortium for the Development of Aquaculture (Chilaw) and by NARA (National Aquatic Resources Agency). Low-water exchange pond management, such as closed and semi-closed re-circulation systems, will reduce the dependence on lagoon water and eventually help improve the quality of the lagoon water, vital to the health of the ecosystem on which shrimp farming in Sri Lanka depends for its seed stock.

The Gramasevekara's of Ambakandawilla and Welihena have the most number of shrimp farms in their vicinity. This is due to the high area of land that was originally government owned mangrove and wetland in the environs. The shrimp farming fever that swept this coastal area in 1994 saw this apparently unused land converted to shrimp ponds under the *de facto* authority of local politicians. Ponds were constructed under the cover of darkness, without the knowledge or approval of many of the villagers, in order to avoid conflict over the change in land use. As this practice continued a number of the more wealthy villagers witnessed the benefits in shrimp farming and began to invest in farms themselves.

[6] Includes Consortium for Aquaculture Development; Small Fishers Federation, Pambala; Chilaw Divisional Secretary and NARA.

4.2 Farming Inputs and Outputs

Based on calculations on the data provided by CP Aquaculture (India) PVT Ltd. The following data, scaled-up for the whole of Chilaw shrimp farming industry estimates harvest and feed for Chilaw if all ponds are in use.

Inputs and Outputs	
Pond area (hectares)	247.8
Harvest (tonnes per cycle)	920.3
Feed (tonnes per cycle)	1258.3
Yield (tonnes per cycle per hectare)	3.72

(Source: EMBioC Fieldwork 2002)

4.3 Employment

Employment on shrimp farms is fairly limited in scope; this is because the only labour intensive stages of shrimp farming are during the construction of the ponds, and again during the harvest. On average each farm employs 3.5 people. These employment figures are not significant, however, when compared to the numbers employed in coastal lagoon and sea fishing (3,665) (Chilaw DS, 1998).

In discussions with the local communities it was found that the general feeling is that those employed on the farms are termed 'outsiders'. That is, they are not from the local villages, but may originate from nearby Chilaw town, Negombo or Colombo. However, this is changing, in further discussions with villagers during the household surveys undertaken (Fieldwork Report 2.3b) villagers were not only being employed on existing shrimp farms, but many were either engaged in shrimp farming, or had owned a farm in the past. Significantly, those no longer farming had given up due to the loss of successive harvests due to disease amongst the stock. The majority of these householders had returned to their original trade of either lagoon or sea fishing.

4.4 Farm costs and revenues

A cost and revenue survey of shrimp farms in the Chilaw area undertaken by a private company (CP Aquaculture (India) PVT Ltd.) provided the majority of the data in table 5.

Table 5: The average total cost and revenue of shrimp farming per cycle in Chilaw Lake[7].

Farm pond size	**Less than 0.4 hectare**	**0.4 – 0.499 hectare**	**0.5 – 0.599 hectare**	**0.6 – 0.699 hectare**	**1.0 hectare**
Average Pond area (hectares)	0.327	0.418	0.509	0.620	1.007
Initial stock PPL	69,933	75,800	90,778	100,000	180,875
Harvest (kg)	1,365	1,547	1,626	2,614	3,844
Total feed (kg)	1,931	2,127	2,144	3,085	4,992
Selling price (US$/kg)	5.03	6.32	5.52	6.8	5.92
Total number of cycle days	117	117	122	99	114
Seed cost (US$)	430	299	418	400	832
Feed cost (US$/kg)	1.65	1.67	1.65	1.7	1.67
Total feed cost (US$)	3,145	3,582	3,516	5,244	8,325
Labour cost (US$)	470	470	486	396	979
Estimated cost of aeration (US$)	89	89	92	75	185
Estimated quantity of fuel used for aeration (litres)	178	178	185	150	371
Estimated cost of water exchange (US$)	293	373	455	554	900
Estimated quantity of fuel used for water exchange (litres)	585	747	910	1,109	1,801
Water source	Lagoon	Lagoon	Lagoon	Lagoon	Lagoon
Total revenue (US$)	7,086	10,046	8,754	17,775	23,468
Total cost (US$)	4,426	4,813	4,967	6,670	11,221
Total profit (US$)	2,659	5,232	3,787	11,105	12,246

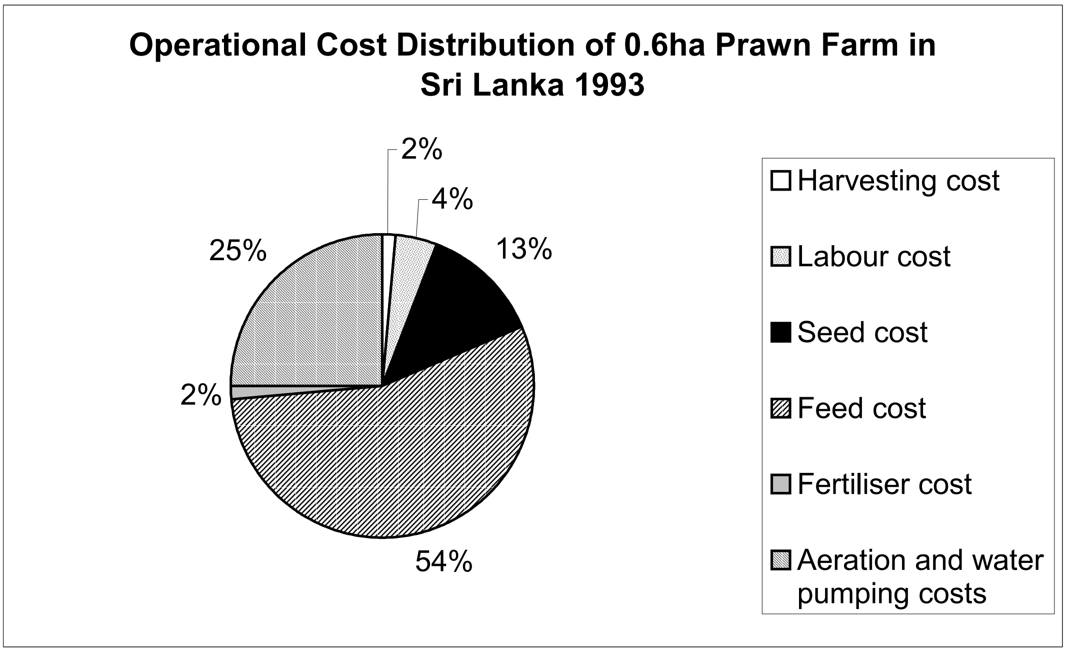
(Source: modified from survey data provided by CP Aquaculture (India) PVT Ltd., 2001)

The annual shrimp farm productivity based on the data in table 5 is 3,714 kg ha $^{-1}$. This is relatively high when compared to the annual productivity of the farm studied in Colombia by Gautier *et al* (2,000 kg ha $^{-1}$) (2001).

Production costs at Chilaw average at US$3.24 per kg and as is evident from table 5 the total profits made are significant. In fact, profits are considerably more than can be made from fishing during the same amount of time. The incomes from sea fishing are reportedly more likely to be between Rs. 100-2000 (US$1.4 – 28) per day, per boat. The largest catch one boat achieved during fieldwork by Stirrat (1988) in a single day was Rs. 20,000 (US$ 285, the equivalent of four to five months wages for a shrimp farm labourer). Hence, the incentive for those fishermen who can afford it to invest in shrimp farming is immense, as the profits are far greater than can consistently be made from fishing.

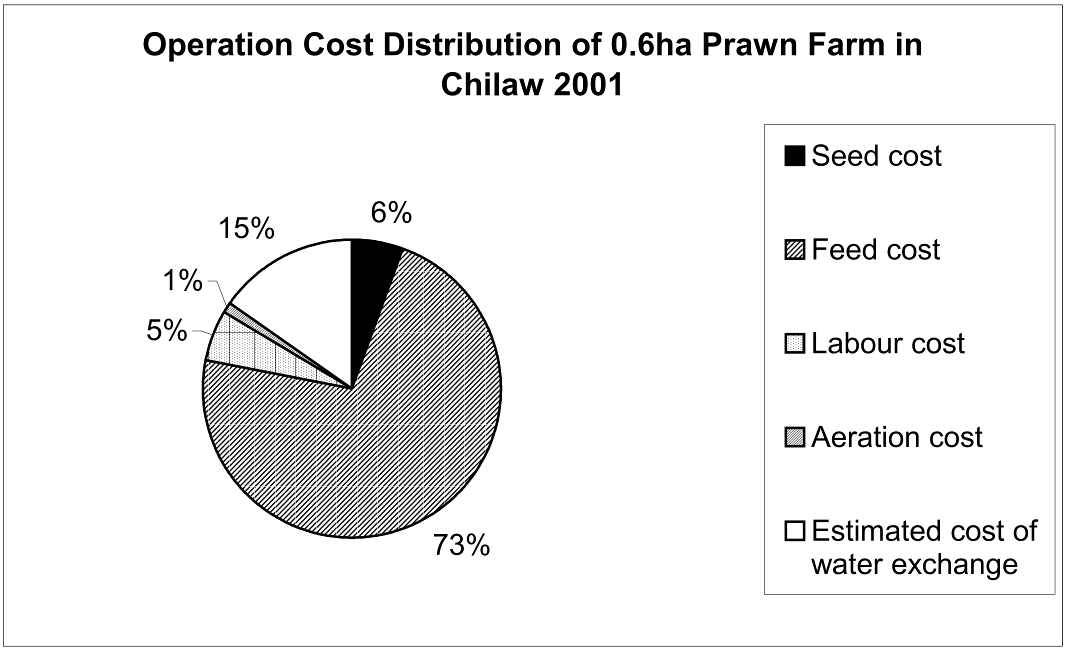
Figure 2 shows the operational cost distribution of shrimp farming. The cost of feed as an input to farming is very high, accounting for 71%, an increase on the costs calculated by de Silva and Jayasinghe during their study in 1993 (55%). The proportional cost of seed inputs has halved (13% and 6%), whereas the percentage cost of aeration and water exchange has also decreased (25% and 16%).

Figure 2: Operational cost distribution of shrimp farming in 1993 and 2001



(Source: De Silva and Jayasinghe, 1993)

[7] Generally 2 cycles per year is average production for farms in the Chilaw area



(Source: modified from survey data provided by CP Aquaculture (India) PVT Ltd., 2001)

4.5 The Ecological Footprint

4.5.1 Direct Transfer of a Different Site Measurement

If the very basic Larsson *et al* measure that was calculated for the footprint of shrimp farms in Colombia is applied to the farms in the Chilaw area, i.e. the total footprint of shrimp farms is somewhere between 35 and 190 times as large as the actual surface area of the ponds, then in 2001, the total pond surface area of Chilaw's shrimp farms (both used and unused) was 247.8 hectares. This would equate to a measurement of the farms requiring a total ecosystem support area of between 8,645 ha and 47,120 ha (86.45 km^2 and 471.20 km^2).

4.5.2 Chilaw's Farming Footprint

Post-Larval Mangrove and Mangrove support systems:

The situation differs in Sri Lanka to that in Colombia. The post-larvae in Colombia depend on the mangrove ecosystem for nursery grounds, whereas the farms in Sri Lanka obtain their post-larvae form hatcheries and not from wild caught sources. However, Larsson *et al* calculate that an area of 10 times the area of the pond is required if less than 10% of the seed is wild caught. This makes a major difference to the possible outcome of a 'footprint' measurement and for the purposes of this study; the latter mangrove post-larvae support system will be used. Mangrove detrital matter is not directly incorporated into the farming systems found in Chilaw, and as a result the measurement will not be taken. However, consideration should be taken of the waste assimilation capacity of the mangroves in reducing the footprint. The Larsson study does not consider the 'cleaning' function that the mangroves and fish within the lagoon may perform on the effluent water and the possible reduction of the 'footprint' as a result of this.

Marine upwelling and agricultural support areas:

Marine upwelling and agricultural support areas can be based on the known contents of shrimp feeds used in Chilaw and quantity fed per cycle. The feed types were confirmed through observations in the field at Chilaw, with findings in the report by Zetterstrőm (1998). Table 6 shows a breakdown of this information.

Table 6: the contents of shrimp feeds fed in Chilaw farms.

	Golden Brand	**CP Aquaculture**	**Grobest Inodmakmur**
Protein	39% min	42 % min	40% min
Fat	2.8 % min	5 % min	4.5 % min
Ash	17 % max	-	-
Hydrochloride insoluble	2 % max	-	-
Crude fibre	3 % max	3 % max	3 % max
Moisture	13 % max	11 % max	12 % max
Ingredients	-	Fish meal, shrimp head meal, squid meal, soybean, cod liver oil, broken rice, wheat flour, cholesterol, phospholipid, vitamins and minerals.	Fish meal, wheat flour, shrimp meal
Country of origin	Taiwan	India	Indonesia

(Source: Zetterstrőm, 1998 and CP Aquaculture (India) PVT Ltd.)

Lagoon support area:

The heavy dependence of the farming systems in Chilaw on the Lagoonal water inputs mean this measurement is very important to the footprint of farming. Ponds are 1 metre deep on average, and half of the pond water is changed per week for 2 cycles per year. The pond surface area is 2,478,000 m^2, half of which is removed weekly, which is 1,239,000 m^3, as the ponds are generally in use for 33.66 weeks of the year, this means that 41,704,740 m^3 used in water exchange with lagoon per year.

CO_2 sequestering area:

This is based on direct fuel consumption at the farm site.

Natural resource and energy inputs for shrimp culture at Chilaw are shown in table 7. Details of the calculations are shown in the notes to table 7. Shrimp culture was found to have a total Gross Primary Productivity of 3,231 GJ/ha. This is lower than that estimated by Larsson as neither the post-larval mangrove, or mangrove support system was not calculated, as these are not directly used in shrimp farming.

Table 7: minimum resource and energy inputs from natural ecosystems for Shrimp Culture at Chilaw

Input	**Shrimp Culture at Chilaw**
Marine ecosystems:	
Fish to pellets	2.03 t/ha
Imported food energy	68.55
Marine NPP energy required	2299 GJ/ha
Agricultural ecosystems:	
Crops in Pellets	2.44 t/ha
Imported food energy	32.65
Agricultural NPP energy required	145 GJ/ha
Total food energy	159.2 GJ/ha
Total NPP energy required	2444 GJ/ha
Total GPP energy required	3231 GJ/ha

Notes to table 7
NPP = net primary productivity
GPP = gross primary productivity

Marine ecosystem per year (i.e. for 2 farming cycles)
Fish to pellets: 40 % protein 1258.2 tonnes of feed per year (40 % of weight of feed is 503.28 tonnes) is 2.03 tonnes/ha.
Imported food energy: energy content of fish used in fish meal 6.14 GJ/t wet weight, wet weight = 5.5xdry weight. 6.14 x 5.5 x 2.03
Marine NPP energy required: fish yield of Southeast Pacific upwelling system 6.71 gCm^{-2}, primary productivity of SP 225 gCm^{-2}. (225 x 68.55)/6.71

Agricultural ecosystem per year

Crops in pellets: 12 % is water, assume 48 % agricultural produce 1258.2 tonnes of feed per year (48 % of weight of feed is 603.94 tonnes) is 2.44 tonnes/ha
Imported food energy: agricultural products 1.78 t/ha wet weight, food energy 13.38 J/t, 2.44 x 13.38
Agricultural NPP energy required: total energy content of cereal and soybean plant equal to 4.44 times the energy content of edible products. 32.65 x 4.44

Total food energy
Shrimp yield (3.72 t/ha) x (0.26 dry weight) x (energy content 25.953GJ/t) / (shrimp growth efficiency 0.15766 J/J)
Total NPP energy required
Marine NPP + Agricultural NPP. 2299 +145

Total GPP energy required
GPP = Agricultural GPP + Marine GPP; Agricultural GPP = 1.67 x NPP, marine GPP = 1.3 x NPP. 242 + 3989

The results in table 8 show the total industrial energy required per hectare of shrimp farm per year. These calculations show that for every hectare, 265 GJ of industrially produced energy are needed to produce 46 GJ of shrimp energy. That's a ratio of 5.8:1, which is considerably less that that calculated by Larsson *et al* (295:1). This probably reflects the less industrially intensive nature of farming in Chilaw as compared to that in Columbia. However, this does not necessarily imply that the current farming methods in Chilaw are sustainable, as they clearly are not.

Table 8: Industrial energy inputs for shrimp farming in Chilaw

Input	**Shrimp Culture at Chilaw (GJ/ha)**
Investments	9.31
Labour	10.50
Pellets	14.24
Postlarvae	10.64
Fuel	216.00
Misc	4.37
Total	265.06

Notes on table 8:
Investments:
US$ = average 640,000 SLR (US$ 6,655) useable for 10 years. US$665
Labour/ha/year:
72,000 SLR for 2 cycles (US$750) per ha/yr.
Pellet industrial energy input:
25-70 GJ/t (US$1017)
Postlarvae cost:
73,163 SLR for 2 cycles (US$760) per ha/yr.
Fuel cost:
880 gallons/ha, energy content = 137 MJ/gallon

Miscellaneous:
30,000 SLR for 2 cycles (US$312) per ha/yr.
0.014GJ/US$ (in Sri Lanka) by total energy use/GNP (221,525,000 GJ/15.7 US$ billion)
Shrimp energy content = 6.14 GJ/t
Shrimps produced = 7.44 t/ha/yr
Shrimp energy produced per hectare per year = 45.68 GJ

The ecosystem support areas required by farms in Chilaw is considerably smaller than the range measured for farms in Columbia, whose footprint was measured at somewhere between 36 and 186 ha/ha cultivated area. In Chilaw the footprint is 27.86 ha/ha of cultivated area (see table 9). By this method, a total ecosystem support area of 6,904 hectares (69.04 km^2) is required by shrimp farms operating in the Chilaw lagoon environs. The total mangrove post-larval support area required is 2,478 hectares. An area somewhat larger than the 100 hectares of mangroves estimated to cover the fringes of Chilaw lagoon in 1994 (CEA/Euroconsult, 1994), and which appears to be considerably less in 2001.

Table 9:External ecosystem life support areas for shrimp farms in Chilaw

Ecosystem support area	**Support area required ha/ha shrimp farm**
Marine upwelling area	12.1
Agricultural support area	0.81
Post-larval mangrove support nursery	10
Mangrove support area	-
Lagoon support area	4.5
CO_2 sequestering area	0.45
Total footprint per hectare of farm	27.86

Notes for table 9:

Mangrove Support Area:

Not measured for the support of farming, as farms feed pellets only and do not depend on mangrove detritus. Mean NPP of mangroves in Chilaw 701.05 g m^{-2}

Lagoon support area:

Ponds are 1 metre deep on average, and half of the pond water is changed per week for 2 cycles per year. 2,478,000 m^2 (pond area) x 0.5 m (depth of water removed) = 1,239,000 m^3 x 33.66 weeks (no. of weeks ponds in use per yr.) = 41,704,740 m^3 used in water exchange with lagoon per year. Chilaw lagoon contains approximately 2,000m x 4,000m x 1.2m = 9,600,000 m^3 at any one time (data from Sri Lankan Fisheries Yearbook 1999).

CO_2 sequestering area:
Fuel: cost of aeration = 21,853 SLR; cost of pumping = 89,484 SLR; total cost = 111,337 SLR;
cost of fuel/litre = 0.27 SLR; litres used = 824,718; litres/ha/yr = 3,328; release 8.15 t CO_2/ha/yr, in order to estimate the surface area needed for carbon sequestration, a carbon assimilation capacity of 18.3 t CO_2/ha. Not including CO_2 produced in shrimp feed manufacturing, industrial fishing etc.

The area required for lagoon water support is calculated to be 4.5 times the surface area of the farms. This means a lagoon water surface area of 1,115 hectares is required per year to support farming in Chilaw. This, perhaps, can help explain the problems the industry in Chilaw, Mundal and Puttalam has suffered from poor quality lagoon water as a result of self-pollution.

4.6 Mangroves as Biofilters

To suggest a management plan for the implementation of mangroves as biofilters in Chilaw lagoon is beyond the scope of this research. However, it is an interesting option, which may assist in a more sustainable development of shrimp aquaculture, and one that is considered briefly here.

The potential benefit of integrating mangrove and shrimp farms to protect ponds against erosion, to enhance the productivity of supply water and to treat pond effluents has been investigated extensively in the past (Gautier *et al*, 2001). Effluents from shrimp ponds have in the past been treated by the use of sedimentation ponds, mollusc culture and seaweed and microalgae culture. However, there are drawbacks to these methods, including the need for increased space on a farm for sedimentation ponds, something, which in an overcrowded coastal zone is not always feasible (*ibid.*).

An alternative is the use of wetlands as a biofilter for the effective removal of solids and the transformation of excess nutrients. Experimental constructed wetlands, using planted vegetation, have been tested successfully for treating effluents from fresh water catfish ponds in the USA, and for treating salt-water shrimp ponds in Thailand (*ibid.*). The processes involved in suspended solids and nutrient removal in wetlands include sedimentation, decomposition of organic matter, uptake of nutrients by plants and bacteria, nitrification-denitrification and absorption of ions by soil. Mangroves forests have also been reported as sinks of phosphorous and nitrogen and several authors have reported their effectiveness in removing nutrients from effluent water (Gautier *et al*, 2001).

The approach of combining shrimp farms and mangroves to act as biofilters, is supported by many environmentalists, as a positive move in the sustainable management of shrimp farms. In theoretical studies (Rivera-Monroy *et al*, 1999), calculations have estimated that 0.04-0.12 ha of mangrove could remove the dissolved inorganic nitrogen from effluents produced by a 1 ha, semi-intensive shrimp pond (Gautier *et al*, 2001).

In a site based study of a Colombian shrimp farm using a mangrove area as a biofilter, Gautier *et al.* found that the mangrove was indeed an efficient way of removing suspended particles from the effluent. However, they also went on to highlight the fact that differing mangrove ecosystems would have differing capacities to perform as a biofilter. In addition the effect of permanent flooding was not known on the mangrove ecosystem, and could cause long-term problems and threats to biodiversity. In addition to this, Gautier *et al* found that, in general, sedimentation ponds were as efficient as mangroves as reducing sedimentation.

Nevertheless, the benefits of mangroves as biofilters for shrimp farm effluents may be significant in areas such as Chilaw, where space is limited for the siting of sedimentation ponds, and the regeneration of mangroves may be beneficial to more interest groups than simply shrimp farmers. Here, the replanting of mangroves, if managed effectively could benefit local communities for livestock fodder, firewood and traditional uses and fisher groups, as the presence of mangroves have been shown to increase shrimp fishery productivity in Chilaw lagoon (Jayasundera *et al.* 1999).

5. Tentative conclusions

Shrimp farming in Chilaw has many environmental problems including self-pollution of the lagoon water, which contributes towards the spread of shrimp diseases. This reduces the productivity, and success of farming ventures in the lagoon, increasing vulnerability to the shocks and stresses experienced by less wealthy farmers has negative impacts on household income and increases hardship.

The clearance of mangroves also has an affect on the capacity of the lagoon to sustain the present levels of production in Chilaw. The cleaning capacity of mangroves will continue to be important to the productivity while the farms are dependent on lagoon water working in open-culture systems. NARA, the government agency concerned with research into shrimp culture has recommended an increase in the use of closed culture systems. Essentially, there are too many farms in the vicinity of the lagoon given the current farming methods, should the farms change their methods in favour of closed-farming systems, then this situation would alter.

The ecological footprint of shrimp farming in Chilaw is not as large as that observed in the farming methods of Colombia. However, it is sufficient in size to be a cause for concern when the footprint is scaled up to consider all farms in Sri Lanka. The area under cultivation in 2001 was estimated to be 2,760 ha (Siriwardena, unpublished). The minimum footprint measure is then a total ecosystem support area of 76,894 ha, and a required mangrove support area of 27,600 ha. Sri Lanka's mangroves are approximately 12,500 ha in extent. By this measure the mangrove area in Sri Lanka is insufficient to support the current area of shrimp farms.

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Annex 1: Value of Major Natural Resource Exports of Sri Lanka

	Value of exports (1000 US$)					
Year	*Tiger shrimp*	*Coconut*	*Coir*	*Rubber*	*Tea*	*Marine fish*
1984	50	1,109	16,375	129,695	615,129	n/a
1985	1,250	1,334	16,949	95,042	440,905	39
1986	2,000	1,952	16,793	94,393	331,451	60
1987	2,500	2,381	15,906	99,596	360,666	76
1988	4,349	2,183	15,715	115,005	380,342	239
1989	5,250	2,530	20,590	88,182	379,697	78
1990	7,800	3,125	17,455	531	493,902	99
1991	10,800	3,658	13,794	258	426,085	15
1992	14,000	4,969	16,187	2,496	339,175	210
1993	17,500	3,604	9,822	1,137	260,996	908
1994	21,700	2,125	9,791	1,139	207,450	463
1995	23,303	3,470	19,947	1,438	369,009	5,357
1996	41,594	4,043	18,875	643	544,957	6,365
1997	40,000	4,684	25,191	236	716,630	8,699
1998	53,820	4,426	27,660	30	747,806	n/a

(Source: data compiled from FAOSTAT 2002)

Annex 2: Shrimp Farm Legal Process

Extract from: Foell *et al.* (2000)

PROJECT APPROVING PROCEDURE FOR SHRIMP FARMS IN NWP

(Provincial Environmental Statue No 12, 1990. Source: Rohitha 1997)

1. If land for a proposed shrimp farm is not privately owned, it has to be released by the DS (leases are issued by the PLC), before an application can be made.
2. Applications for the approval of shrimp aquaculture projects have to be made to the PEA, who makes a decision on whether an IEE or an EIA is needed.
3. The application as well as the EIA report is then evaluated by a scooping committee that includes representatives of PEA, PMOF, FD, NARA, DWLC, CCD, DI, DS, ISB, and MFARD. The LRDB, CCB, or the Water Resource Board are involved if deemed necessary.
4. After the evaluation, a conditional approval will be granted. An environmental protection license is issued once the farm is developed.

Overall, there are thirteen central Government institutions officially involved in the management of the shrimp industry. New developments have in principle to be approved by all of them. Organisations range from the Ministry of Fisheries and Aquatic Resources (MFARD) and its newly established National Aquaculture Development Authority (NAQDA) to the Coconut Cultivation Board (CCB) and the CCD. On the provincial level, another five institutions are involved, including the Provincial Ministry of Fisheries (PMOF) which now also runs a Aquaculture Service Centre (ASC), and the Provincial Environmental Authority (PEA) (Rohitha 1997). The PMOF and NAQDA are responsible for the management of existing developments, for the enforcement of regulations, as well as for extension services. But responsibilities of these two organisations overlap, a situation that results in some confusion. Furthermore, the PMOF’s responsibilities have recently been widened to include the agriculture portfolio for NWP, thus increasing the Ministry’s workload and potentially weakening it.

Responsibility for state land, on which many of the illegal farms are located, lies with the Divisional Secretariats (DS). Furthermore, the DS are vested with the power to enforce many of the regulations that officially fall under one or more of the Government Institutions such as the Forest Department (FD) or the CCD. The FD is the responsible agent for mangrove areas. The CCD is responsible only for a strip reaching 300m inland from the sea. Whilst all hatcheries fall under its authority, few shrimp farms are located within this zone.

Development was reportedly well planned in the past. A zoning plan identifying suitable areas for shrimp aquaculture was drawn up with the help of the FAO in the 1980s. The Asian Development Bank (ADB) funded a Government-run model farm that served to disseminate technical knowledge for private development. However, the zoning plan collapsed after the change of Government in 1994. The FAO also funded a disease prevention project over the past two years. A number of workshops were organised in Puttalam District and a screening machine to test PLS was set up in Colombo (a considerable distance away from most hatcheries). The project also attempted to aid regulation of illegal farms, but few people followed the call for registration.

Being located within the coastal zone area, shrimp farms fall under the jurisdiction of the Coast Conservation Department (CCD), which itself is answerable to the Central Environmental Authority (CEA). These agencies have developed a legal framework for the development of shrimp aquaculture in the Sri Lankan coastal zone.

If a potential farmer wishes to establish a shrimp farm less than 4 hectares in area, he can do so without requiring the permission of any government agency. All that is required is that he owns, or leases, the land he wishes to develop. For a farm greater than 4 hectares in area, in order to prevent adverse impacts on the environment and deterioration of environmental quality, the applicant must obtain a management license, which costs 2,500 SLR (£20) per acre per year. This comes under the National Environmental Act, No. 47 of 1980, Section 232 was amended by Act No. 56 of 1988 which incorporated the land limit (Siriwardena, unpublished). According to these regulations all shrimp farms exceeding 4 ha, but less that 20 ha should submit an Initial Environmental Examination report and those exceeding 20 hectares submit an Environmental Impact Assessment (EIA) to an approving body (depending on the province in which the farm is to be constructed).

The application for the development of a farm in the Chilaw environs must go before the north-west province, which then passes it on to a scoping committee which is called to meet once a month to discuss current applications. This committee consists of the following individuals and organisations:

- Land Commissioner
- Provincial Land Commissioner
- Deputy Land Commissioner
- Chairman CLA
- Chairman NARA
- Chairman Urban Development Agency
- Chairman Sri Lankan Land Reclamation and Development Corporation
- Director General NARESA
- Director CCD
- Director Aquatic and Coastal Resources
- Secretary for the Ministry of Fisheries
- Divisional Secretary Puttalam
- Divisional Secretary Mundel
- Divisional Director of Irrigation, Puttalam
- DFEO Puttalam
- Environmental Authority NW Province

NARA inspects the land, as does the Irrigation Department. The CCD examines the application and reports on the contents.

According to the CCD guidelines, the farm must be sited at least 100 metres from the waters edge (both sea and lagoon), and there must be a thirty-metre buffer zone between itself and other farms. This buffer zone is also used to provide access to the lagoon for the local fishermen. Once clearance is given by these agencies, the committee reconvenes and a decision is made. The entire application process can take up to 2 years.

Annex 3: capital costs of shrimp farming in Chilaw area

Item	**Cost (rupees)**	**Comments**
Fixed costs:		
Building of pond	100,000	Manually dug. Concrete in- and outlets
Lights and wiring	35,000	-
3 paddle wheels	100,000	Secondhand
Generator	200,000	-
Water pumps	55,000	-
Total:	**490,000**	**US$ 7,000**
Variable costs:		
Pond preparation	10,000	Includes pond cleaning and preparation of the soil
PLS	55,000 – 100,000	Depends on market price and stocking density
Feeds	150,000 – 300,000	Depends on survival rate, stocking density, market price of feed, and duration of different stages of cultivation
Fuel	140,000	35,000/month, no electricity from the grid
Labour	36,000	2 labourers at 4,000/month each, plus additional labour for harvest
Consultant	5,000	
Total	**396,000 – 591,000**	**US$ 5,650 – 8,440**

(Source: Foell *et al*. 2001)