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F WATER QUALITY OF SEA GRASS HABITATS ON COMMERCIALLY IMPORTANT SHRIMP LARVAE IN THE NEGOMBO LAGOON

By

B. R. C. Mendis

M. Sc **2009**

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ATER QUALITY OF SEA GRASS HABITATS ON COMMERCIALLY IMPORTANT SHRIMP LARVAE IN THE NEGOMBO LAGOON

BY

B. R. Chandani Mendis B.Sc (Hons)

This Dissertation is submitted in partial fulfillment of the requirement of the Degree of Master of Science in Forestry and Environmental Management

Department of Forestry and Environmental Sciences,

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Nugegoda,

Sri Lanka.

November, 2009

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DECLARATION

The work described in this thesis was carried out by me at University of Sri Jayewardenepura, Sri Lanka under the supervision of Dr. Prashanthi Gunawardena and a report of this has not been submitted to any university for another degree.

01-12-2009 B.R.C. MENDIS

Signature

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RVISOR'S CERTIFICATION

This is to certify that this report is based on the study carried out by the candidate herself and is now approved for submission.

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ANNEXURE

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ST OF ABBREVIATIONS

ANOVA	Analysis of Variants
APHA	American Public Health Association
CN	Cast Net
C	Centigrade degree
cm	Centimeter
E	East
GF/F	Glass Fiber/Filter
GPS	Global Position System
ha	hectare
HCl	Hydro Chloric Acid
µm	Micrometers
mg/l	Milligrams per liter
ppt	Parts per thousand
Sq m	Square meter

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ACKNOWLEDGMENT

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ABSTRACT

The present study was to evaluate the effect of water quality of sea grass habitats on commercially important shrimp larvae in the Negombo Lagoon. The objectives of the study were to investigate salinity and nutrients levels and examine the relationship between the shrimp larvae and environmental factors in sea grass ecosystem. Sea grass habitats are providing habitats and also act as nursery ground for economically and ecologically important shrimp species.

The sea grass habitats located in the Negombo lagoon mainly Kadolkele, Negombo Pitipana, Aluthkuruwa, Thalahena, Sethapaduwa, Liyanagemulla, Katunayake and Kurana were selected for this study. The shrimp population depends on both physical and chemical parameters of the seagrass habitats. Samplings were collected on salinity, ammoniacal - nitrogen, nitrate - nitrogen, nitrite - nitrogen and phosphate - phosphorous and number of shrimp larvae, for a period of one year during the period from July 2007 to July 2008.

Kodolkele, Thalahena and Kurana had the highest abundance of sea grass communities. It was found that the abundance of shrimp larvae catch in sea grass habitats areas is higher than in without sea grass habitats areas. The abundance of shrimp larvae in Negombo Lagoon was negatively correlated with nitrite-nitrogen content in the water and is positively correlated with nitrate-nitrogen content in the habitats.

The seasonality in the shrimp larval catch and water quality parameters were observed with a peak periods from May/June to October/November, which apparently coincided with the south west monsoon and the onset of north east monsoon of the island respectively.

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CHAPTER - 1

INTRODUCTION

1.1 Negombo Lagoon

Negombo lagoon is one of the most productive semi enclosed shallow brackish water estuary in Sri Lanka (Pillai, 1965). It is situated in the Gampaha district on the western coast about 20 km north of Colombo at $7^{0}\ 7^{\hat{o}}$ N and $79^{0}\ 50^{\hat{o}}$E. It is 12 km in length and 3.75 km at its widest point. The greatest recorded water depth is 2.6 m but 12% of the lagoon has a water depth of less than 0.5 m (Jayakody, 2001). Lagoon is essentially a semi enclosed open water body between the sea and a river delta. It is a mixing ground not only for sea water coming in through the tidal inlet and fresh water entering through the river delta, but also for dissolved inorganic and organic constituents and particulate matter, sediment and biomass. Therefore its physical nature, chemical composition and biological diversity are always determined by the diurnal and seasonal changes and the catchments induced freshwater inflow (Silva, 1996).

The lagoon covers an area of approximately 3,164 ha (Anon, 1994) and opens to the sea at its northern end and to the southern, it is connected to the Muthurajawela marsh which covers an area of approximately 3,100 ha. The lagoon and marsh together constitute a conjoined, tidally influenced coastal wetland. The main fresh water input comes from rivers

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al but the lagoon is characterized by a brackish water flora sea grass and some mangrove forests in the northern, eastern and western part (Map 1). These zones are very important ecologically as well as economically. Their productivity is high and they act as a silt trap and provide spawning, nursery, feeding grounds and sheltering for a variety of economically important shrimp species during the juvenile phase of their life cycle.

1.2 Distribution of sea grass ecosystem

The sea grass habitats located in the Negombo lagoon boundary ecosystem namely, Kadolkele and Negombo Pitipana on the northern shore, Aluthkuruwa, Thalahena and Sethapaduwa on the western shore and Liyanagemulla, Katunayake and Kurana on the eastern shore were selected for the study site (Figure 1).

Sea grass beds cover 22% of the lagoon area and are highly productive, providing habitats for a variety of brackish water organisms including many economically important species of shrimp resources (Jayasuriya, 1990). These sea grass habitats are very sensitive to salinity and nutrients of water. These grasses are highly productive and provide habitat for a variety of aquatic organisms including many commercially important shrimp larvae.

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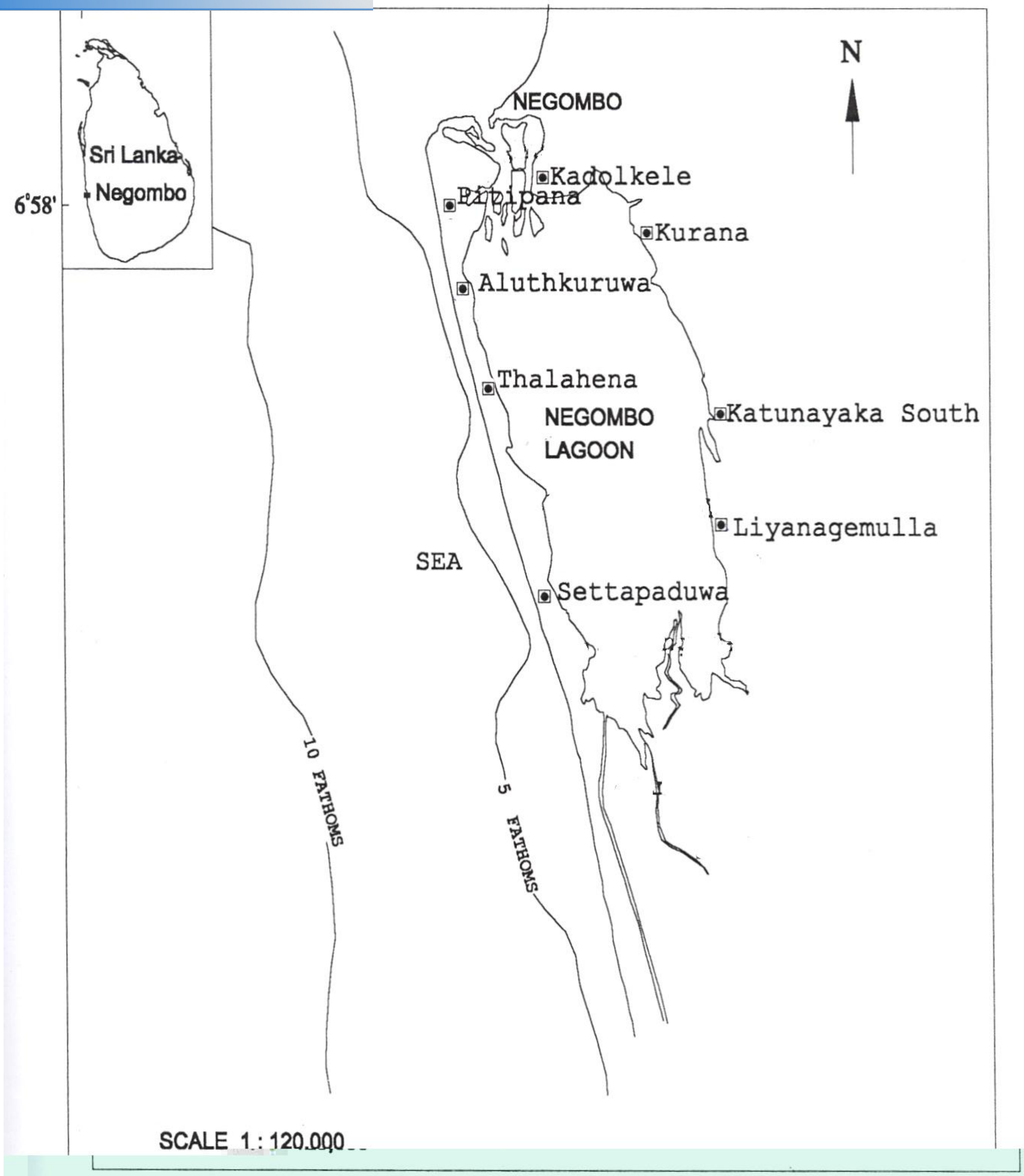

Map 1 Location Map of the Negombo Lagoon

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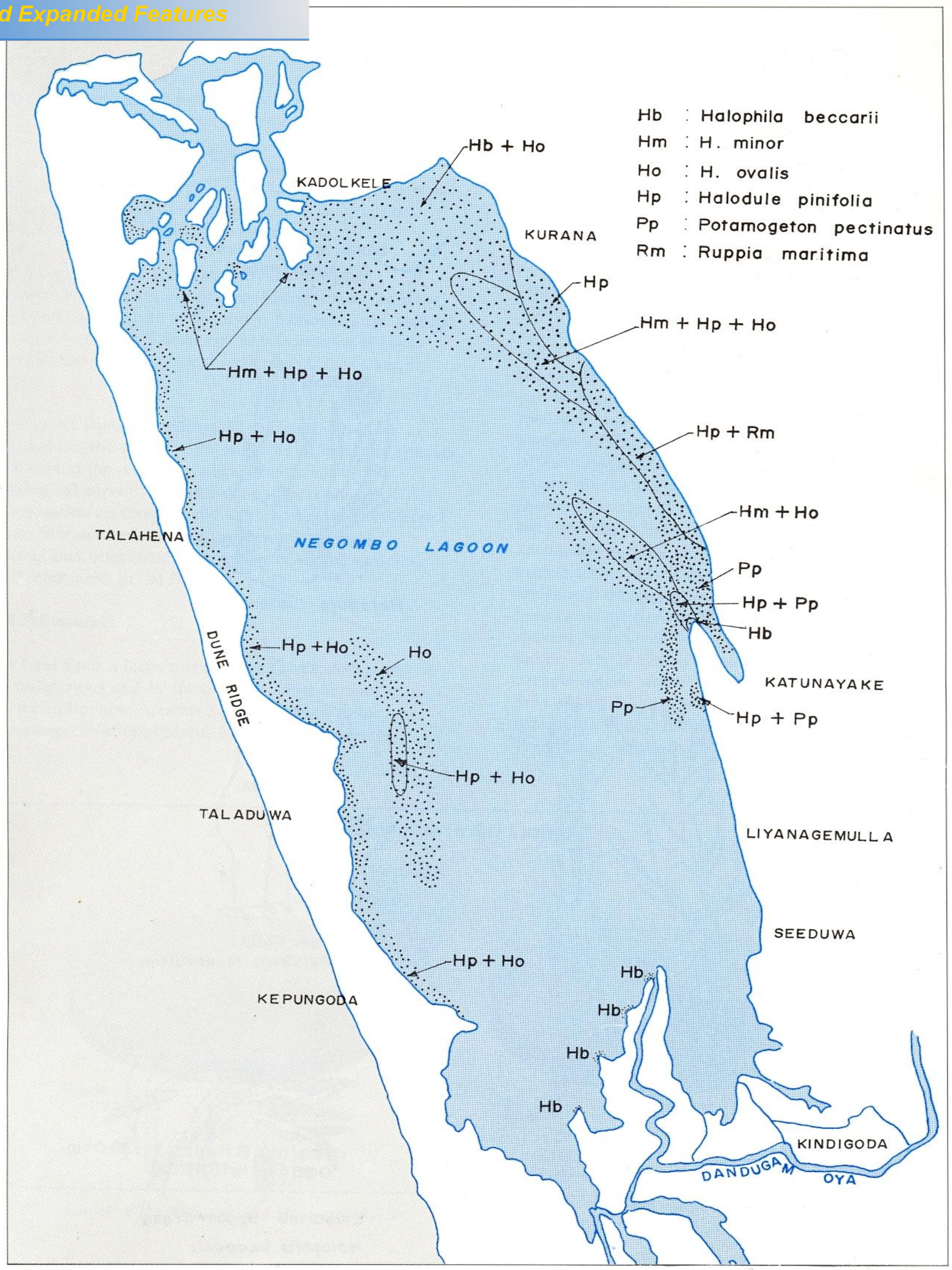

Figure 1 Sea grass composition and distribution in Negombo Lagoon

(Source: Jayasuriya, 1990)

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nd six sea grass species have been recorded in the Negombo Lagoon. Their distribution ranges are given in Figure 1. The recorded species in the Negombo Lagoon were *Halodule pinifolia, Halophila minor*, *Potamogeton pectinatus* and *Rappia maritima* and they appear to undergo major seasonal changes and they can adapt to low salinity levels and in fact reach their maximum height during the rainy season when the salinity of the lagoon water is lowest. Consequently, they occur near places where fresh water from rivers enters the lagoon. It is a common belief among fisher folk that shrimps will breed only in the dense mats formed by these sea grasses. This could mean that a general decline of salinity levels in the lagoon is taking place, probably as a result of small scale reclamation activities at the lagoon outlet gradually inhibiting the entrance of sea water into the lagoon. If these trends of increased siltation and decline in salinity continue, the ultimate effects on fish and shrimp productivity in the lagoon would be clearly disastrous.

1.3 Importance of sea grasses

The sea grass communities are the most conspicuous and widespread biotypes in the shallow brackish water environment. They form extensive animal spawning grounds and nursery habitats. Additionally sea grass blades can be lucrative substrates for plants and epiphytes as well as being a direct food resource for grazing animals such as some fishes (Odum, 1974). Their elaborate rhizome and root systems trap and stabilize the sediments. Sea grasses are the only truly marine angiosperms and can be used for monitoring purposes because they are sensitive to human disturbance.

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ıce and ecological condition are highly variable and sensitive and causes of deviation from proposed reference conditions are multiple may frequently be obscure and are rarely quantifiable. Shallow water body habitats are among the most productive ecosystem on earth and in many locations they are subjected to a variety of anthropogenic activities such as pollution and eutrophication. Such ecosystems face the additional stressor of climatic changes and the combined effect of all these stressors are difficult to predict. Climate change impact on coastal habitats through accelerated sea level rise, include direct warming and increased frequencies of extreme weather events such as flood and storm.

Sea grasses consist of specific species of rooted marine angiosperms which are widely distributed around the world, and are often a biotype which is heavily disturbed by natural and human induced causes. Their favored habitats are mainly lagoons and in addition, their roots enable them to export the generally higher nutrient levels found within the sediments, nutrients which are often unavailable to other primary producers in the ecosystem. Sea grass meadows of shallow estuarine ecosystem represent one of the largest contributors of fixed carbon, a source of secondary production via, for example the associated, herbivores (West and Larkum, 1983).

Sea grasses also create congenial conditions for a number of dependent organisms. Through their high productivity, sea grasses build up large carbon reserves which are utilized in the tropics by herbivores such as birds and brackish water organisms. Typically Sea grass beds are among the most productive submerged biotopes on earth, yet the waters

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low levels of dissolved nutrients, some sea grass meadows are therefore possibly nutrient limited (Duarte,1990).

Estuaries are very dynamic environments, where salinity affects habitat complexity and species distribution of shrimps have a complex life cycle that includes an estuarine phase, when post larvae enter the mouths of estuaries, disperse into the inner reaches, settle and become juveniles, grow for several months and subsequently migrate into the sea as sub adults.

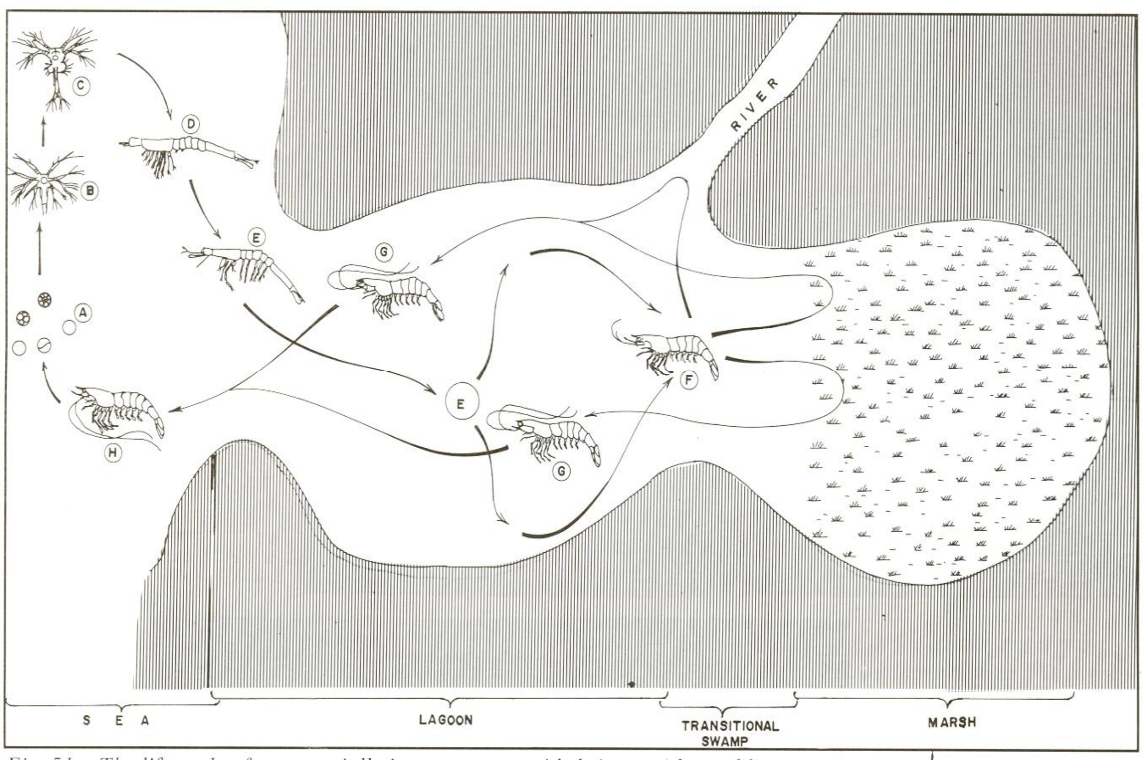

Figure 2 The life cycle of commercially important shrimps with an Obligatory estuarine stage

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earch

The study was limited only to lagoon boundary area of the north western and eastern shore of the Negombo lagoon. So other fish species are also dependent on the sea grasses, but here the focus is on the shrimp because it is critically dependent on salinity and nutrients levels in water.

The main objective of this research is to

(i). Investigate salinity and nutrients levels in sea grass ecosystem.

(ii). Examine the relationship between the shrimp larvae and environmental factors.

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CHAPTER - 2

LITERATURE REVIEW

This chapter reviews some theories of environmental factors affected on shrimp larvae in sea grass ecosystem.

2.1 Significance of valuing sea grasses

Sea grasses are a special category of shallow coastal lagoon ecosystem which shelter estuaries. This peculiar ecosystem which is rich in biodiversity provides direct and indirect benefits to the mankind and ecological services to environment. Many sea grass resources are harvested for subsistence purposes. Mangrove communities near the lagoon are heavily dependent on sediment trap for their soil. River bank and shoreline stabilization, flood control ground water recharge and pollution control etc, are a few major ecological services provided by sea grass ecosystems. It also acts as breeding and spawning ground for the commercially important shrimp. Conversion of such ecosystem to alternate development activities deprive all the beneficial uses of sea grass ecosystem thus would adversely affect the well being of mangrove dependent communities, countryợs economy and social welfare. Sea grass habitat offer food, shelter and essential nursery areas to commercial and recreational fishery species and to the countless invertebrates that are produced within or migrate to ecosystem. The complexity of sea grass habit is increased when several species

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ir leaves concealing juvenile fish, smaller finfish and benthic invertebrates such as crustaceans, bivalves, echinoderm and other groups. Juvenile stages of many fish species spend their early days in the relative safety and protection of sea grasses. Additionally sea grasses provide both habitat and protection to the faunal organisms living within the substrate as sea grass rhizomes intermingle to form dense networks of underground runners that deter predators from digging in faunal prey from the substratum. Sea grass meadows also help dampen the effect of strong currents providing protection to fish and invertebrates, while also preventing the scouring of bottom areas. They support commercial and recreational fishers that provide a wealth of benefits to the natural economy.

2.2 Sea grass habitat distribution in Negombo Lagoon

Sea grass to be widely distributed throughout the lagoon and it confirmed that the majority of six species and four genera of sea grass beds comprised of the *Halodule pinifolia, Halophila minor, Potamogeton pectinus and Rappia maritima* are the most common. The distribution pattern of these six species is influenced by the nature of the habitat and physico - chemical parameters of the lagoon. *Halodule pinifolia* narrow leaf variety seems to have a high range of salinity tolerance as it is found in the northern, western and eastern parts of the lagoon. This species appears to be the most common sea grass in the areas. The *Halodule* species is mostly confined to these areas by its rhizome mat with an extensive network of horizontal axis.

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measurement in sea grasses

Impact of sea grasses over the last 20 years, lead to the losses of sea grasses along the lagoon, with some areas losing up to 95% of their coverage. Other areas however have remained stable and productive. Reduced light transmittance through the water body has been one of the major factors implicated in loss of sea grass coverage. Sea grass loss due to light attenuation usually starts at the outer edge of the beds, where the light reaching the plants is only marginal and progresses towards the shallower regions as conditions deteriorate. Several factors are important in reducing light penetrating to a given depth of the water body.

Phytoplankton and algal blooms are often caused by increased nutrient loads from sewage discharges and from agricultural and residential fertilizers, which run off into the lagoon. Increased nutrients levels also cause an increase in the density of epiphytes, suspended particles are introduced in to the water body via run off from commercial agricultural and residential areas and also from activities within the estuary such as dredging and sediment resuspension caused by boat engine. Dissolved organic material has many sources including residential and commercial pesticides and fertilizers, marsh vegetation and others. The Negombo town area of sampling site is highly polluted due to sewage discharged from the households further, the circulation of water at this part of the lagoon was also observed to be very poor, Sea grass habitats are reported to be rare in heavily polluted waters (Pearson and Rosenberg, 1978).

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ction values observed in this study all fall in the lower range when compared to those of other similar studies (Jayasuriya, 1991). This can also be explained by salinity and nutrient although this explanation needs further study. Several factors indicate that Negombo Lagoon is tending towards a eutrophic state (Jayasuriya, 1991); Ammoniacal nitrogen occurs in high concentrations, the sea grasses are covered with thick layers of algae and blue algae and the water is very turbid with large concentrations of phytoplankton and suspended particles. Clearly simple measurements of nutrient concentrations may not necessarily reflect the wider nutrient status of an ecosystem and may if the water is very mobile. In the Negombo Lagoon however the residence time has been reported to be between 28 days thus the nutrient values reflect the nutrient dynamics or balance in the ecosystem rather well. It has also been argued that water nutrient content is a bad indicator of eutrophication due to the communityôs rapid processing of soluble nutrients.

One approach to analyzing community nutrient cycle is examining the nutrient content of the included organisms. Nitrogen: Phosphate ratios and then from the production numbers are useful to derive the required intake of Phosphate and Nitrogen of the system. (Johnson and Preston, 1993). The bulk of the nitrogen supplied to the sea grasses is thus likely to come from the sediments whilst an amount of the noon benthic derived nitrogen may come from internal recycling of nutrients within sea grasses from older to younger parts of the plant. The high nutrients data observed at site Sethappaduwa and Negombo Pitipana may be due to a range of factors including microbial processes such as denitrification, but may also be due to enhanced uptake by epiphytic organisms (Jayasuriya, 1991).

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ed is seasonality of the variations of climatic changes. Sea grasses can exhibit large variations in production of the shrimp larvae in life cycle (Jayasuriya, 1991). Seasonal variations can be attributed to the factors such as temperature, salinity and nutrient availability. The range of salinity and nutrients were acceptable for the survival and growth of shrimp larvae (Simpson *et al*, 1983).

2.4 Migration of shrimps in reproductive period

The shrimp species that are of great significance for fisher folk of Negombo lagoon are the crustaceans. Many of these species have an obligatory brackish water stage. The adults breed at sea and their larval floating stages are passively carried into the Negombo Lagoon by the tide. The emigration of shrimps from the Negombo lagoon is apparently greatly influenced by the osmotic stress due to low saline waters in the lagoon during the periods of high precipitation. Salinity and precipitation are the major factors influencing the shrimp catch from the different gear types operating in the lagoon. Within the lagoon these floating stages settle among the sea grasses, which constitute their critical nursery habitat as they grow.

The maintenance of lagoon stocks of this organism depends critically on the connection between the sea and the fresh water discharge which dilutes sea water adequately. The continued existence of abundant populations of shrimps in the sea grass ecosystem also depends upon nursery and feeding relationships. Some of the earliest stages of shrimps feed

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oplankton). As they grow, they begin feeding on plants such as sea grasses, decaying plant material and organisms growing upon other plants.

The Sea grass and Mangroves appear to be important sources of the organic detritus in Negombo Lagoon. The sea grass environment contains a higher proportion of finer sediments, salts and higher organic content (Peterson *et al*, 1984).

2.5 Review of factors influencing distribution of shrimp larvae

Many factors are reported to affect the distribution of shrimps in estuaries. These include salinity and nutrient content and extent of sea grass cover (Tookwinas *et al*, 1985). The salinity of coastal and estuarine waters fluctuates highly during the year. The salinity and nutrients gradients in estuaries depend in the relative balance of the following factors (Tookwinas *et al*, 1985).

(i). Run-off from the land

(ii). Rainfall

(iii). Evaporation from the estuary itself

(iv). Tidal influence and distance from the coast line

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The salinity variation is found to be greater near the surface than at the bottom. This is due to specific gravity of sea water being greater than that of fresh water (Tookwinas *et al*, 1985). For aquatic organisms osmotic regulation is essential to keep water content and nutrient concentration of the body at the desired level. When the salinity of water decreases, aquatic organisms take up more dissolved oxygen for the respiration process. Then, the rate of metabolism is increased (Tookwinas *et al*, 1985). Further, the salinity pattern in the lagoons has been found to influence the survival and growth rate of aquatic organisms. The effects of reduction of salinity on the survival rate of sea grasses have been studied by (Tookwinas *et al*, 1985a). When salinity was decreased to 6 - 8 ppt, heavy mortality of this species was recorded. The mean survival time was observed to be 68.2, 82.5 and 89.0 hours at salinity levels of 2.0 ppt and 5.4 ppt respectively (Tookwinas *et al*, 1985). Different life history stages of shrimp have different tolerance limits and optimal for salinity. Ranges of tolerance for environmental factors of early embryos and larvae are usually narrower than those of the adults (Davis and Calabrese, 1964, and Kennedy *et al*, 1974).

It has been recorded that the shrimps can tolerate a salinity ranging from 20 ppt to 38 ppt (Castagna and Chanley 1977). Once natural geographical distribution is known for a candidate species, that species salinity and nutrients levels tolerance range is the most fundamental biological information required for assessing the suitability of a particular shrimp species for aquaculture in a particular region. The abundance of shrimp larvae in sea grass habitats depends on the physico-chemical parameters such as temperature, salinity

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ion on salinity and temperature tolerance range is the most fundamental physico-chemical data required for assessing the suitability of a shrimp species for lagoon in a particular environment (Robert and Bricel, 1989).

Seasonal variations of favorable water quality conditions in shrimp larvae living in sea grass habitats. Sea grass habitats are productive threatened ecosystems providing a nursery and breeding ground for a variety of brackish water organisms including many economically and ecologically important species.

The rapid expansion of shrimp fishery in the Negombo Lagoon has increased the demand for shrimp juveniles. The lagoon and adjacent boundary areas function as the major nursery and sheltering ground for many finfish and crustacean groups during the juvenile phase of their life cycle. The present work assesses the juvenile resources of shrimps which are favorable for fluctuating environmental conditions of Negombo Lagoon. Physical changes in the water source as a result of activities related to shrimp fishery include siltation, sedimentation and high concentrations of total suspended solids levels.

2.6 Sea grass ecosystem management

Sea grass beds play a vital role in sustaining the fisheries in the Negombo estuarine system. Besides beings agents in removing excess nutrients entering the lagoon through various effluents the sea grass beds act as breeding and nursery grounds for fish shrimp and other important organisms. The use of drag nets and cast nets in the sea grass beds not only

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tacean and other organisms, but also destroys the sea grasses. Due to the damage caused to sea grass beds and juvenile fish, shrimp and other benthic marine organisms, it is necessary to ban the use of drag net and cast nets. The fishermen affected by the ban should be assisted through the fisheries cooperatives to take up fishing in the coastal waters, using alternative fishing gears.

In view of its vital importance for productivity and the maintenance of water quality and the limited knowledge available formulated to promote better understanding of the extent, species composition and status of sea grass ecosystem.

2.7 Shrimp Fishery Resources in Negombo Lagoon

The Negombo lagoon is the source of nearly half of all fisheries production in shrimpôs resources in Sri Lanka and shrimp production of one half of all shrimp landing sites. Although several estuarine ecological factors determine the biological productivity of the Negombo lagoon fisheries, the most important production mechanisms underlying these fisheries is thought to be the combination of lagoon with costal vegetation of sea grass which provide the ideal habitat as breeding grounds and nurseries. Although several commercial fish species are thought to be dependent on the sea grass habitat of Negombo Lagoon as a breeding and nursery ground, shrimp is considered to be the most economically important species. For example, in 2001 year 298 MT total annual shrimp catches accounted for over the total production tonnage of the sea grass dependent fisheries

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by far the most income generating commercially valuable species.

In so far the fisheries are concerned, the lagoon function as a breeding and nursery ground for a number of commercially important shrimp species, a source of protein supply to the community, a source of employment and an anchorage for marine and lagoon fishing craft. Shrimps are the most important organisms to the lagoon fishery. Today they are exploited in a manner that is not sustainable. Therefore the development of fisheries based upon enhanced production is not possible. Management should include the prohibition of all fishing methods that destroy nursery areas such as sea grass habitats. Most of the existing fisheries are exploited and some of the critical habitats of sea grass beds are destroyed in the process.

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CHAPTER - 3

METHODOLOGY

In order to achieve the two objectives mentioned in the objective in the research different methodologies have been adopted. This chapter describes each method in detail.

3.1 Study Site

This study was carried out in the eight sampling locations were chosen within the lagoon, north shore of lagoon in Negombo Pitipana and Kadolkelle, western part of Aluthkuruwa, Thalahena and Sethapaduwa and eastern part of Liyanagemulla, Katunayeke and Kurana area. Negombo Pitipana, Kadolkele, Aluthkuruwa area were located near the sea mouth and Thalahena, Kurana and Katunayeke are located in middle and Liyanagemulla and Sethapaduwa area is located in the southern part of the Muthurajawella marsh. Water samples and number of shrimp larvae catch were collected twice a week for a period of one year period during from July 2007 to July 2008. Sea grass distribution and sampling location was determined using Garmin Software Global Position System (GPS) locations (**See Annex 1**). The water depth where the measurements were carried out was less than 01 m at all sites. (**See Annex 2**).

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3.2.1 Shrimp larval catch

Relative abundance of different species of sea grasses and their coverage at each sampling site was estimated twice a weekly using a one square meter (1m X 1m) quadrate samples, which was subdivided into 25 squares of equal sizes using nylon nets, randomly collected in number of shrimp larval catch were counted.

3.3 Environmental Factors

3.3.1 Water Quality

This study recorded the salinity and nutrient measurements of the Negombo Lagoon at eight sampling locations for periods of one year. The following environmental parameters which were expected to influence the distribution and abundance of shrimps were determined in the eight sampling sites.

3.3.2 Salinity and Nutrient Measurement

Physico - chemical parameters such as Temperature, Salinity and Nutrients measurement were monitored using a Mercury Filled Celsius Thermometer (0^0 C -100^0 C), Refractometer (0 ppt - 100 ppt), Ammoniacal-Nitrogen (Phenate method), Nitrate-Nitrogen (Copper-

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, Nitrite-Nitrogen (Colorimetric-diazotization method) and Phosphate-Phosphorous (Ascorbic acid method) analyzes for APHA standard methods (**See Annex - 6, 7, 8, 9**) were used for the determine to the Ultra - Violet Spectrophotometer.

All samples were immediately put on ice for transport to the research station to be frozen until analyzed. Samples for the determination of nutrients were collected using a polyethylene bottle and immediately stored in ice. All samples were filtered using pre combusted 0.45 µm GF/F Whatman membrane filters to produce precipitate (>0.45µm) and dissolved (<0.45µm) fractions. Aliquots of filters samples were stored in polythene bottles (Pre washed with HCl 1:1 rinsed 3 times with distilled water and filter water) and stored frozen prior to analysis.

3.4 Data Analysis

The data collected was analyzed statistically using a range of methods. These included regressions, one way Analysis of Variance (ANOVA) followed by the software, Minitab version 14 was used in the statistical analysis.

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CHAPTER - 4

RESULTS

The results of the present study indicate that the (Table 1) carried out from July 2007 and July 2008 was diagnosed to analyze the monthly variations of the mean statistical values physico - chemical characteristics of the Negombo Lagoon.

Table 1 Summary of the mean statistical values of water quality parameters in eight sampling location during the study period from July 2007- July 2008

Month Parameter	**July 2007**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July 2008**
Temperature ^{0}C	30.25	29.9	30.41	27.79	27.5	28.0	29.0	29.94	30.56	29.95	28.96	28.0	29.8
Salinity (ppt)	23.4	24.56	25.74	18.88	16.3	18.1	20.0	30.0	31.85	26.43	18.2	20.40	23.48
Ammoniacal -N (mg/l)	0.222	0.321	0.274	0.216	0.19	0.12	0.16	0.159	0.083	0.314	0.223	0.27	0.225
Nitrate-N (mg/l)	0.250	0.305	0.378	0.542	0.437	0.30	0.240	0.389	0.406	0.339	0.553	0.419	0.256
Nitrite-N(mg/l)	0.044	0.065	0.065	0.042	0.02	0.050	0.020	0.144	0.162	0.115	0.05	0.14	0.06
Phosphate-P(mg/l)	0.089	0.138	0.148	0.321	0.232	0.16	0.11	0.087	0.127	0.096	0.239	0.303	0.099

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Table 2) carried out from July 2007 and July 2008 was diagnosed to analyze the monthly variations of the mean statistical values of the no of shrimp larval catch and water depth of the Negombo Lagoon.

Table 2 Summary of the mean statistical values of shrimp larval catch data in eight sampling location during the study period from July 2007- July 2008

Month Parameters	**July 2007**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul 2008**
Depth (ft)	2.125	2.125	2.45	2.95	3.365	2.09	1.656	1.6	1.835	1.77	2.0	2.013	2.125
Number of Shrimp Larva e	173	153	295	523	341	157	358	142	197	303	333	347	174

4.1 Shrimp larval catch

The data shows (Table 2) that the Shrimp larval catch occurrence was high in October to November and January, April to June (Figure 3). Among the eight stations the shrimp larval catch occurrence was low in Negombo Piptipana and Sethapaduwa sites and highest in Kadolkele, Liyanegemulla and Thalahena (**See Annex 3**).

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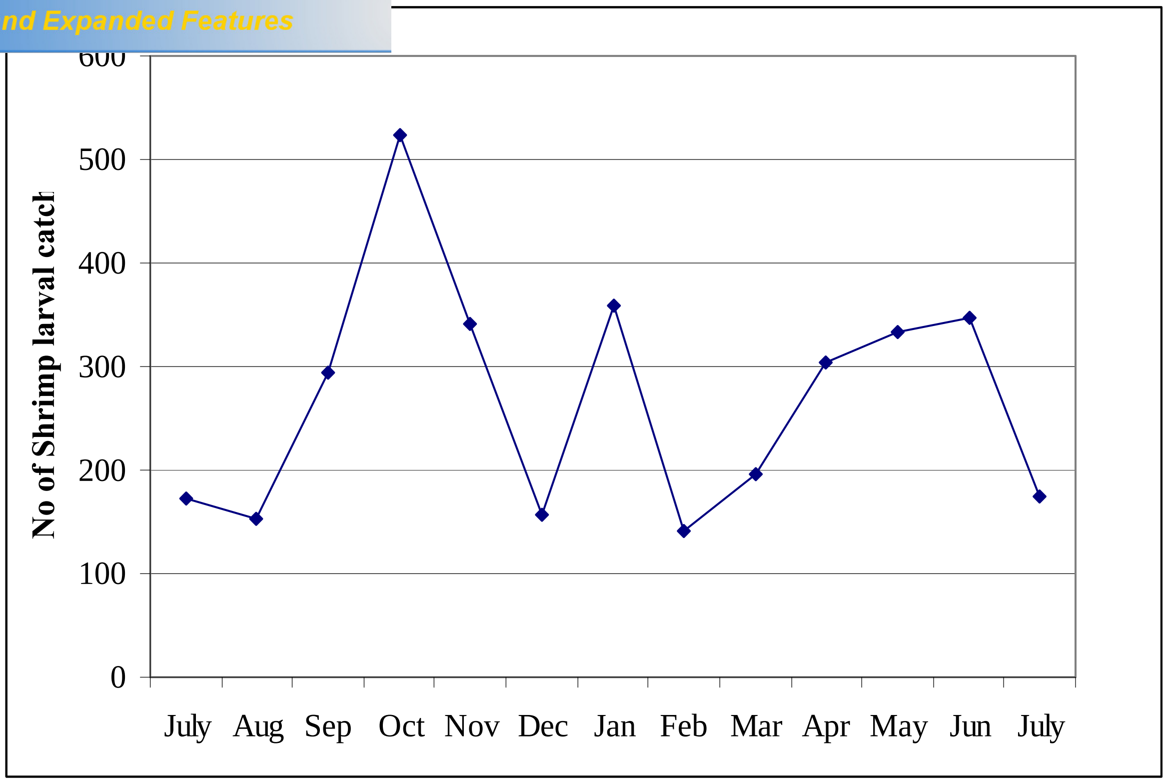

Figure 3 Monthly variations of number of shrimp larval catch (1m x 1m)

Monthly variations of shrimp larval catch in the Negombo Lagoon reached a maximum during October, November, January and May to June during the South West monsoon season. Lowest level found it August and February during the dry season month (Figure 3).

4.2 Water Quality Parameters

The results of the study indicate that (Table 1) carried out from July 2007 and July 2008 was diagnosed to analyze the monthly variations of the physico - chemical characteristics of the Negombo Lagoon.

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The mean monthly water temperature values for each site are given in Table 1. The mean of water temperature at the eight sampling sites during the study period are shown in Figure 4. Temperature in sea grass ecosystem in the tropic is always influenced by air temperature and thermal conditions, which are often variable due to the mixing of water of varying temperature and the diurnal and seasonal variations of total incoming radiation. The seasonal variation of the day temperature of the surface water of the Negombo Lagoon at different locations was reported during this study period (**See Annex 4**).

The data show (Table 1) in some instances surface water temperature range from 27^0 C - 30^0 C and the lagoon water temperature becomes highest in September, January and March (Figure 4). The water temperature dropped slightly in October and November with the onset of the south west monsoonal rainfalls. The diurnal variation in temperature of the Negombo Lagoon had been reported for the daily time variations. The average temperature variation in all location was in the range of 27^0 C - 32^0 C.

4.2.2 Salinity

The mean monthly salinity values for each sampling site are given in table 1. The data show that (Table 1) variation of salinity levels of the Negombo lagoon sea grass habitat was highest in sea mouth area of Negombo Pitipana and Kadolkele site (**See Annex 5**).

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mporal and spatial variations in salinity. There was a uniform pattern in the monthly variations of salinities at all locations of the lagoon.

Monthly variations of salinity in the Negombo Lagoon reached a maximum during September and February to April dry season and lowest value in October to January and May to July during south west monsoon season. The salinity attained its maximum during the first inter monsoon (February to April) and it led to a condition where the lagoon converted almost into fresh water with the onset of the south west monsoon (May - June). During the intermediate rainy season, pronounced salinity gradient was developed in the lagoon. (eg. January, July and December) with a range of salinity varying from 20 ppt to 30 ppt at the mouth to less than 5-10 ppt at the southern part of the lagoon. The salinity gradient was well established during August and September from the fresh water outfall to the sea mouth and vice versa. Relatively higher salinities were reported in March (32 ppt). This pattern changed markedly once again with the onset of the second inter monsoon on October, November combined with changing wind pattern (Figure 4). This resulted in converting the entire water body into fresh water again. The acceptable range of salinity values reported for shrimp growth and production is 10-32 ppt (CEA, 2001) (**See Annex 20**).

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Temperature and Salinity

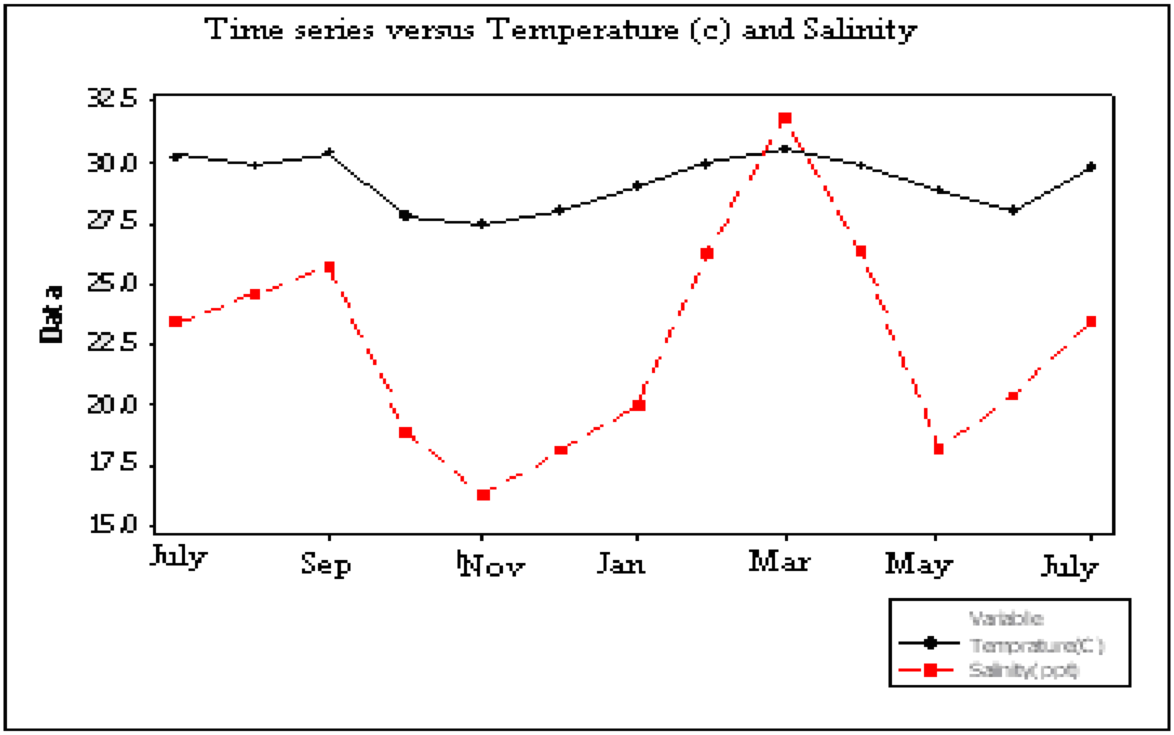

Figure 4 Time series vs. Temperature and Salinity level

One-way ANOVA: Temprature(C), Salinity (ppt)

Source	DF	SS	MS	F	P
Factor	1	286.8	286.8	27.72	0.001
Error	24	248.3	10.3		
Total	25	535.1			

S = 3.217 R-Sq = 53.59% R-Sq (adj) = 51.66%

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ations and of Temprature and Salinity

Level	N	Mean	St Dev
Temperature(C)	13	29.230	1.089
Salinity (ppt)	13	22.588	4.417

Pooled StDev = 3.217

4.3 Nutrient

4.3.1 Nitrate - Nitrogen

The concentration of micro-nutrient levels of Nitrate is a primary nutrient in lagoon environment brackish water with moderate to high salinity; diatoms are the dominant planktonic organisms. They require fairly large amounts of nitrogen and limiting nutrients than phosphorous received in fertilizer.

Nitrate-Nitrogen in the Negombo Lagoon reached a maximum during October-November and May-June during the South West monsoon season. Lowest levels were found in January and July during the dry season month (Figure 5). Nitrate-Nitrogen levels were highest in Kadolkelle, Liyanagemulla and Thalahena area (**See Annex 10**). The proposed acceptable range of Nitrate-Nitrogen for shrimp larvae is less than 01mg/l, recommended by Central Environmental Authority in Sri Lanka (CEA, 2001) (**See Annex 20**).

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orous

Phosphate-Phosphorous is considered to be one of the important primary nutrients in lagoon. Monthly variations of Phosphate-Phosphorus in the Negombo Lagoon reached a maximum during October, November during South West monsoon season. The lowest Phosphate levels were observed in February and July (Figure 5). Phosphate-Phosphorous levels were highest in Kurana, Liyanagemulla, Negombo Pitipana and Kadolkele areas. (**See Annex 11**). The proposed acceptable range of Phosphate-Phosphorous for shrimp larvae is less than 01mg/l, recommended by Central Environmental Authority in Sri Lanka (CEA, 2001), (**See Annex 20**).

4.3.3 Ammoniacal -Nitrogen

Ammonia is an important nutrient of phytoplankton. It is also the major end product of protein catabolism excreated by aquatic animals. Ammonia in water consists of a unionized (NH_3) and ionized form (NH_4^+). Unionised ammonia can be toxic to fish. Monthly variations of Ammoniacal-Nitrogen in the Negombo Lagoon reached a maximum during August and April before monsoon season and lowest level in December and March (Figure 5). Ammoniacal-Nitrogen level was observed to be significantly higher in Negombo, Kodolkele and Thalahena sites (**See Annex 12**). The proposed acceptable range of Ammoniacal -Nitrogen for shrimp larvae is less than 01mg/l, recommended by Central Environmental Authority in Sri Lanka (CEA, 2001) (**See Annex 20**).

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Nitrite-Nitrogen is an intermediate product in the nitrification of ammonia to nitrate. It is toxic to fish and therefore is important for aquatic organisms. Monthly variations of Nitrite-Nitrogen in the Negombo Lagoon reached a maximum during February, March and June and minimum was found in October, November, January and May (Figure 5). The proposed acceptable range of Nitrite-Nitrogen for shrimp larvae is less than 01mg/l, recommended by Central Environmental Authority in Sri Lanka (CEA, 2001) (**See Annex 20**).

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r Nutrients

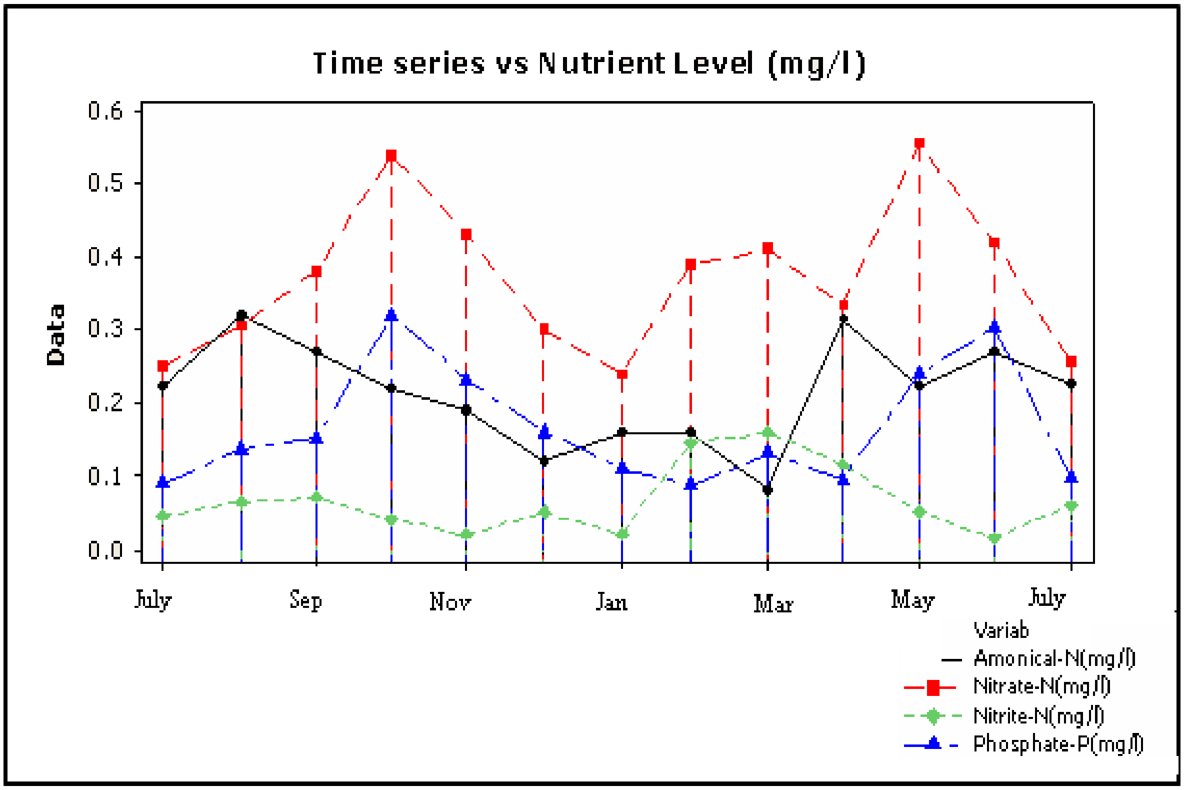

Figure 5 Time series vs. Nutrients levels (mg/l) in the sea grass habitat

One-way ANOVA: Ammoniacal-N (mg/l, Nitrate-N (mg/l, Nitrite-N (mg, /l, Phosphate-P (mg/l)

Source	DF	SS	MS	F	P
Factor	3	0.62675	0.20892	34.28	0.05
Error	48	0.29252	0.00609		
Total	51	0.91927			

S = 0.07806 R-Sq = 78.18% R-Sq (adj) = 76.19%

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ations of Nutrients levels

Level	N	Mean	St Dev
Ammoniacal-N (mg/l)	13	0.21338	0.07149
Nitrate-N (mg/l)	13	0.36977	0.10246
Nitrite-N (mg/l)	13	0.06554	0.04653
Phosphate-P (mg/l	13	0.16562	0.08126

Pooled St Dev = 0.07806

ANOVA results from nutrient analysis showed (Figure 5) that there is considerable variation in the total concentration of both dissolved inorganic and organic nutrients between the sea grass communities and the surrounding water column. All sites showed considerable nutrient pooled Standard Deviation of 0.078.

4. 4 Contribution of water quality parameters to abundance of shrimp productivity

4.4.1 Correlation coefficient

In order to investigate the contribution of water quality parameters towards the sea grass habitats and shrimp larval catch, the correlation coefficients between abundance of shrimp larvae and environmental factors were derived. The following section provides the results.

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orrelation coefficients between the abundance of shrimp Larvae and Environmental factors

Water quality parameters and shrimp larvae catch	**Standard values of correlation coefficients Pearson correlation P-Values**					
	Temperature (^{0}C)	Salinity (ppt)	Ammoniacal-N (mg/l)	Nitrate-N(mg/l)	Nitrite-N(mg/l)	Phosphate-P (mg/l)
Salinity (ppt)	0.874 0.000					
Ammoniacal-N (mg/l)	0.034 0.912	-0.037 0.904				
Nitrate-N(mg/l)	-0.374 0.208	0.230 0.449	-0.006 0.985			
Nitrite-N(mg/l)	0.688 0.009	0.851 0.000	-0.256 0.398	0.026 0.932		
Phosphate-P (mg/l)	-0.765 0.002	-0.593 0.033	0.117 0.703	0.761 0.003	-0.520 0.069	
Shrimp larvae	-0.545 0.054	-0.482 0.096	0.181 0.555	0.599 0.031	-0.464 0.738	0.738 0.004

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In order to investegate the contribution of water quality parameters towards the sea grass habitats and shrimp larval catch was expressed as a productivity of the different water quality parameters measured. The best fitting regression model state that,

The regression equation is

Shrimp larval catch = - 59 + 6.9 Salinity (ppt) + 34 Ammoniacal-N (mg/l)

+ 638 Nitrate-N (mg/l) - 1550 Nitrite-N (mg/l)

+ 175 Phosphate- P (mg/l)

Table 6 Probability values of Salinity and Nutrients levels

Water Quality Parameters	N	Coef	SE Coef	T	P
Salinity (ppt)	13	6.93	15.30	-0.19	0.858
Ammonical-N (mg/l)	13	33.9	433.8	0.45	0.940
Nitrate-N (mg/l)	13	638.5	719.0	0.08	0.404
Nitrite-N (mg/l)	13	-1550	1919	-0.89	0.446
Phosphate-P (mg/l)	13	175.5	974.2	0.81	0.862

S = 93.8394 R-Sq = 60.3% R-Sq (ad) = 31.9%

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Source	DF	SS	MS	F	P
Regression	5	93445	18689	2.12	0.017
Residual Error	7	61641	8806		
Total	12	155086			

The nitrogen levels at all sites existed in the form of ammonia, which occurred in concentration +34 mg/l, while there was nitrate + 638 mg/l, Phosphate concentration +175 mg/l and less nitrite concentration of -1550 mg/l.

According to the results of the regression analysis,the equation is significant and the Shrimp larval catch for the sea grass habitats indicate that Nitrite-Nitrogen (**See Annex 15**) contribute negatively for the shrimp larval catch while Nitrate ï Nitrogen (**See Annex 16**), Phosphate-Phosphorous (**See Annex 17**) and Ammoniacal-Nitrogen(**See Annex 18**), contribute positively to the larval catch Significantly $p<0.05$.

Ammoniacal-Nitrogen level played the greatest role in altering the total dissolved nutrient levels observed and in 2007, they accounted for the difference in nitrogen levels. With regard to phosphorous, statistical analysis of the 2007 to 2008 period data showed the mean concentrations from phosphate-Phosphorous levels pools with the same means, than higher phosphate concentrations.

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CHAPTER - 5

DISCUSSION

This chapter discusses the research findings of the study. Even though the scope of the studies on salinity and nutrients levels relationships between to survival of shrimp larvae in sea grass ecosystem in Negombo Lagoon.

5.1 Salinity and Nutrients Measurements

The abundance of shrimp larvae in sea grass habitats depends on the physico-chemical parameters such as temperature, salinity and nutrients levels. Information on salinity and temperature tolerance range is the most fundamental physico- chemical data required for assessing the suitability of a shrimp species for lagoon in a particular environment (Robert and Bricel, 1989).

The salinity level of the water in the eastern part of the lagoon is fairly low (around 15 -29 ppt) compared to the southern part since fresh water inlets fall on to the eastern side of the Lagoon. The salinity level in the north western part of the lagoon is considerably high (22-34 ppt). Usually estuarine organisms live in relatively constant environmental conditions with respect to salinity and temperature. It is known that salinity changes in sea water affect the brackish water animals physiologically and ecologically and they are unable to maintain

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he salinity is below 30 ppt (Nagabhushanam and Bidarkar, 1975). Most of the commercially important shrimps occur in estuarine environments and are therefore, naturally subject to changes in salinity resulted by due to seasonal changes. It has been found that environments with low and fluctuating saline conditions support fewer crustacean species than those with higher but stable saline conditions.

As mentioned in the introduction, the major aims of this study were to determine the role of the major physico - chemical parameters of salinity and nutrient levels of Negombo Lagoon on sea grass community productivity of shrimp larval stages and to see if sea grass beds varied spatially throughout the lagoon. The sea grass community production and water quality parameters recorded for all of the study sites was within the range reported in the literature for similar sea grass communities. However the values observed were at the low levels of critical limits. This may be due to natural variation between ecosystems; the results also suggest that in Negombo Lagoon it may in partly be due to human inputs.

The Negombo town area of sampling site is highly polluted due to sewage discharged from the households further, the circulation of water at this part of the lagoon was also observed to be very poor, Sea grass habitats are reported to be rare in heavily polluted waters.

One factor that is likely to play an important role in determining sea grass community production levels is nutrient availability primarily nitrogen and phosphorous. A comparison of the data obtained here showed that significant correlation between water column nutrient concentrations and community production despite the fact that there were high levels of

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gen and soluble reactive phosphorous at all sites. A factor which could explain this difference in 2008 is the initially low concentration of Nitrogen and Phosphorous of dry season months of 2008 January to March and 2007 July to September. High nutrient loads of sites in Negombo Pitipana, Sethapaduwa and Aluthkuruwa area. Because of the fish landing centers high number of FRP boats release of engine oil in water.

Despite its location outside the major town of Negombo Pitipana location site 7 had the highest ambient concentrations of soluble reactive phosphorous and dissolved inorganic nitrogen. Negombo town discharge large percentage of sewage directly into the lagoon. However, even the lowest ambient concentrations observed were relatively high for tropical ecosystems and so it appears that the sea grass communities are not nutrient limited at any of the sites studied.

The primary factors directly affecting primary production in the Negombo Lagoon sea grass communities in year 2007 and 2008 appear, therefore to be salinity and nutrients levels giving higher production in shrimp larval stage. The substrate is a significant ecological factor that influences the distribution of benthic organisms by providing places for attachment, shelter and nourishment (Wise and Molles, 1979).

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elationship between to salinity and nutrient levels

The results of the present study reveal that changes in water quality in the Negombo Lagoon area do not have any effect on the abundance of shrimp larvae. Fluctuations in water quality in the localities studied are not great and perhaps therefore doing not exceed the tolerance limits for the shrimp larvae stages.

Regression gives the relationship between salinity and nutrient levels and shrimp larvae show that - 59 + 6.9 Salinity (ppt) + 34 Ammoniacal-Nitrogen (mg/l) + 638 Nitrate-Nitrogen (mg/l) - 1550 Nitrite -Nitrogen (mg/l) + 175 Phosphate-Phosphorous (mg/l). Results of the present study indicate that the abundance of shrimp larvae in Negombo Lagoon is negatively correlated with salinity and nitrite nitrogen content in the water and is positively correlated with nitrate, ammonia and phosphate content in the habitat. Toxic metabolites of Ammonia and Nitrites are above favorable ranges for shrimp larvae during the study period of this year.

In the sampling sites in the lagoon area, the abundance of shrimps were the highest possibly due to the stable salinity values (30 ppt-36 ppt) when compared to the sampling sites of Kadolkele and Negombo Pitipana. The Shrimp catch was highest in Kadolkele site where the sea grass cover is also dense (Peterson *et al,* 1984). Results indicate that higher abundance of sea grasses in northern side Kadolkele area has increased shrimp larval catch. Values for shrimp larval catch of sea grasses also have changed in seasonal variation during study period and this would have contributed to changes in abundance of this ecosystem.

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ring the beginning of the northeast monsoon and south west monsoon from mid 2007 and to mid 2008.

Sea grass communities are very important as nurseries, food sources and shelter, ground of Negombo Lagoon. Negombo Lagoon fishery is of great significance for the adjacent local shrimp fishery production. The importance of the lagoon fishery for the local communities is very evident and any loss of integrity in these sea grass communities could have deleterious impacts on both the fishery and community welfare. Therefore, enhanced understanding of the role of the sea grass communities could thus provide a useful management tool in this much taxed ecosystem.

In the present study it was found that the abundance of shrimp larvae in vegetated areas is higher than in non vegetated areas. Fishers may have known this through experience and therefore concentrate most of their fishing effort in the sea grass habitats. As such environmental parameters prevailing in Negombo Lagoon area are suitable for the existence of the sizable population of shrimp which help to sustain an artisanal fishery.

This study has been carried out during the periods of January, April, June, September and October which could be considered as the high levels of shrimp larval catch. These coincide with the south - western and north - eastern rainy seasons of the island. Salinity levels in the lagoon decline with the inter - monsoonal rainy seasons and this might be emigration of shrimps to the sea. Although these factors are yet be investigated properly, measures to maintain the present patterns of the salinity changes in the lagoon are

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terns results in salinity changes. High shrimp yields can be seen as the major outcome of resource sharing practice in the fishery of Negombo Lagoon as they are directly responsible for the living standards of fishing community. Use of some types of fishing gear such as encircling nets has been reported to affect the macro benthic community structure by destroying the sea grass beds (Anon, 1994). In the present study, sea grass beds were not found in some of the sampling sites, where the encircling nets are used. The critical habitats within this system such as sea grass beds are being threatened due to human activities including destructive fishing methods such as drag nets.

This study was mainly focused on the sea grass habitat water quality affected on commercially important shrimp larvae in the Negombo Lagoon. The shrimp fishermen in the study area also catch substantial amount of by catch, which mainly consists of shrimp juveniles. It was noted that the juveniles of shrimp utilizing Negombo Lagoon as nursery ground form considerable portion of the by catch. Although shrimp juveniles seemed to supplement the economy of the shrimp fishermen in the study area especially during the lean season of the fishery, so far considerable attention has not been paid in view of management of this component. The present study indicated that the destructive fishing methods used in the lagoon destroy critical habitats and the extensive removal of larval shrimps from the nursery environment.

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CHAPTER - 6

CONCLUSION

The present study intended to investigate the monthly variations of favorable water quality conditions for shrimp larvae living in the sea grass ecosystem. The lagoon and adjacent boundary areas function as the major nursery and sheltering ground for many finfish and crustacean groups during the juvenile phase of their life cycle. The range of salinity levels from 15-32 ppt, Ammoniacal-Nitrogen levels from 0.12-0.321 mg/l, Nitrite-Nitrogen ranged from 0.03 -0.163 mg/l, Nitrate-Nitrogen range from 0.25-0.553 mg/l and Phosphate-Phosphorous range from 0.089-0.321 mg/l. The observed range of Salinity is acceptable for the survival and growth of shrimp larvae. The observed levels of Nitrate, Phosphorous, Ammonia and Nitrites were low, acceptable for the survival and growth of shrimp larvae. The relative abundance of shrimps in Negombo Lagoon was found to be higher and their distribution was positively correlated to Nitrate-Nitrogen, and negatively correlated to dissolve inorganic Nitrite-Nitrogen in the water. Shrimp larvae were found consistently in considerable numbers all the shrimp larvae of different species were more abundant in the second inter monsoonal months.

Investigation of the suitability of the sea grass habitats water quality as breeding and nursery ground could be considered within the acceptable limits recommended by the Central Environmental Authority Standard (2001). Kodolkele, Thalahena and Kurana had

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rass communities. It was found that the abundance of shrimp catch in seagrass habitats areas is higher than in without seagrass habitats areas.

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CHAPTER - 7

RECOMMENDATIONS

During the past several decades there has been a visible degradation of environment in northern part of the lagoon due to human activities including inadequately planned settlement, municipal pollution and intensification of fishing; consequently the shrimp resources and these critical habitats are being threatened.

Southern part of the lagoon during the last two decades of after establishment of the Ekala industrial zone and the Katunayake free trade zone may have direct or indirect waste water discharge into the Dandugam Oya and Ja-ela canal polluting water of the Negombo Lagoon. It is necessary therefore to enforce existing environmental regulations to overcome unpermitted and unregulated discharge of solid waste/debris by the local people into the natural water bodies which result in pollution of the natural water bodies.

As such it appears that the sea grass is a significant factor that influences the abundance of the shrimp larvae in the Negombo Lagoon. Therefore, for the sustainability of these shrimp resources, much emphasis should be made to conserve the sea grass ecosystem.

In order to minimize damage to the lagoon environment from fishing activities it is advisable that the consideration be given to prohibiting the use of drag nets targeting

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perated in the areas where there are sea grass beds which are the principle nursery grounds for the early juvenile stages providing both shelter and feeding grounds.

If these operations are to be continued, attention should be paid to introduce suitable mesh regulations to limit the exploitation of considerable proportions of undersized shrimps. In addition measures should be taken to prohibit the use of drag nets in the areas of the lagoon where there are sea grass beds; either exists or is being re-established. The might be achieved by the placement of marked poles to indicate the boundaries of the areas to be protected, preventing the use of drag net inshore of the poles. There is an urgent need to make a meaningful assessment of the water quality of the Negombo Lagoon prior to implementing regulatory measures in order to maintain the quality of water and to conserve its sea grass and shrimp resources.

Better management of the shrimp fishery to control over exploitation may be the only short term policy to bring production back to respectable levels, as well as being essential for realizing the more long term economic benefits of protecting sea grass habitat. This conclusion holds also for fisheries elsewhere, which are supported by sea grass or other estuarine and coastal wetlands that provide breeding habitats and nurseries for the fishery for income generation is an activity that is embedded within a complex system comprising of ecological and economic dimensions.

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ANNEXURE

ANNEX 1

Table 1 GPS Location

Sampling Location	Latitude and Longitude
Negombo Pitipana	N 07^{0} 12 277ô
	E 079^{0} 49 644ô
Kadolkele	N 07^{0} 12 503ô
	E 079^{0} 50 230ô
Aluthkuruwa	N 07^{0} 12 523ô
	E 079^{0} 50 290ô
Thalahena	N 07^{0} 10 286ô
	E 079^{0} 49 944ô
Sethapaduwa	N 07^{0} 06 602ô
	E 079^{0} 53 818ô
Liyanagemulla	N 07^{0} 06 602ô
	E 079^{0} 53 818ô
Katunayeke	N 07^{0} 08 534ô
	E 079^{0} 51 805ô
Kurana	N 07^{0} 09 685ô
	E 079^{0} 53 459ô

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Table 2 Monthly variations of Depth (ft) in selected sea grass habitat in Negombo Lagoon during the study period from the July 2007-July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	1.5	1.5	2.0	2.36	2.9	1.2	1.1	1.0	1.2	1.55	1.7	1.8	1.6
Katunayake	1.5	1.5	2.1	2.54	2.76	1.41	1.45	1.3	1.5	1.5	1.65	1.4	1.5
Kurana	2.0	2.0	2.1	2.5	2.73	1.54	1.6	1.5	1.6	1.6	2.3	2.5	2.0
Kadolkele	2.0	2.0	2.5	3.1	3.8	2.2	1.4	1.4	1.4	1.5	1.85	1.9	2.0
Aluthkuruwa	2.0	2.0	2.0	3.13	3.8	1.63	1.5	1.5	1.6	1.5	1.8	1.8	2.0
Sethappaduwa	2.0	2.0	1.8	2.8	3.2	2.6	1.4	1.4	2.1	1.52	1.5	1.5	2.0
Negombo/ piti	2.9	2.9	3.2	3.7	3.63	3.2	2.4	2.4	2.9	2.35	2.5	2.5	3.0
Thalahena	3.1	3.1	3.9	3.5	4.1	3.0	2.4	2.4	2.4	2.65	2.7	2.7	2.9
Statistical Ave	2.13	2.13	2.45	2.95	3.37	2.098	1.66	1.61	1.83	1.77	2.0	2.01	2.12

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Table 3 Monthly variations of Number of shrimp larval catch (1m x 1m) in Sea grass habitat in Negombo Lagoon during the study period from the July 2007-July 2008

Month / Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	185	150	245	598	344	130	424	115	200	351	374	347	204
Katunayake	100	130	450	601	243	130	354	82	160	263	377	336	142
Kurana	190	143	278	416	345	121	376	135	210	238	326	265	253
Kadolkele	225	151	340	700	690	345	586	173	325	502	567	578	274
Aluthkuruwa	169	179	379	534	322	131	226	179	199	365	192	243	163
Sethappaduwa	185	120	200	582	234	103	306	831	155	205	289	387	164
Negombo/ piti	126	125	274	371	285	75	265	26	126	194	193	138	142
Thalahena	200	222	190	378	265	218	328	244	200	306	348	483	253
Statistical Ave	173	153	295	523	341	156.6	358	142	196.9	303	333	347	174

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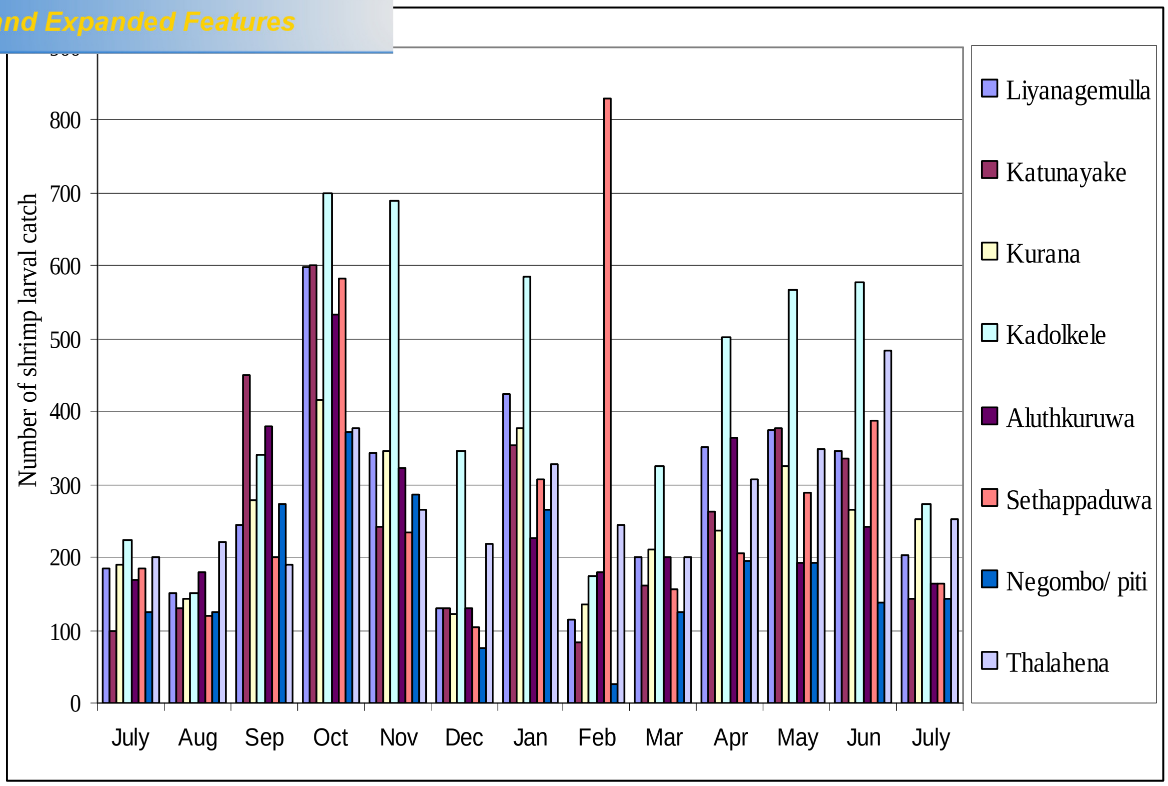

Figure 1 Comparison of number of shrimp larval catch (1m x 1m) in sites

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Table 4 Monthly variations of water Temperature in Sea grass habitat in Negombo Lagoon during the study period from the July 2007- July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	29.0	29.0	30.5	26.0	27.0	30.0	30.0	29.0	30.0	29.4	29.0	28.9	29.0
Katunayake	29.0	28.5	30.5	27.0	27.0	29.5	30.0	30.0	30.5	30.1	28.5	28.95	29.0
Kurana	30.0	30.0	30.0	27.3	27.8	30.0	31.0	30.5	30.5	29.3	28.45	28.5	29.5
Kadolkele	30.0	30.0	29.5	28.0	27.9	30.0	30.0	30.0	30.5	30.2	28.5	29.0	30.0
Aluthkuruwa	30.0	30.2	31.0	28.0	29.0	30.0	32.0	30.0	31.25	30.2	29.3	28.55	30.0
Sethappaduwa	30.5	30.0	29.8	28.0	29.0	30.0	31.0	30.0	30.75	30.2	29.25	28.5	30.0
Negombo/ piti	31.5	30.0	31.0	29.0	29.0	30.0	32.0	30.0	30.75	30.1	29.3	28.65	30.5
Thalahena	32.0	31.5	31.0	29.0	29.0	30.0	32.0	30.0	30.25	30.1	29.4	30.2	31.0
Statistical Ave	30.3	29.9	30.4	27.8	28.2	29.94	31.0	29.92	30.56	30.0	29.0	28.9	29.88

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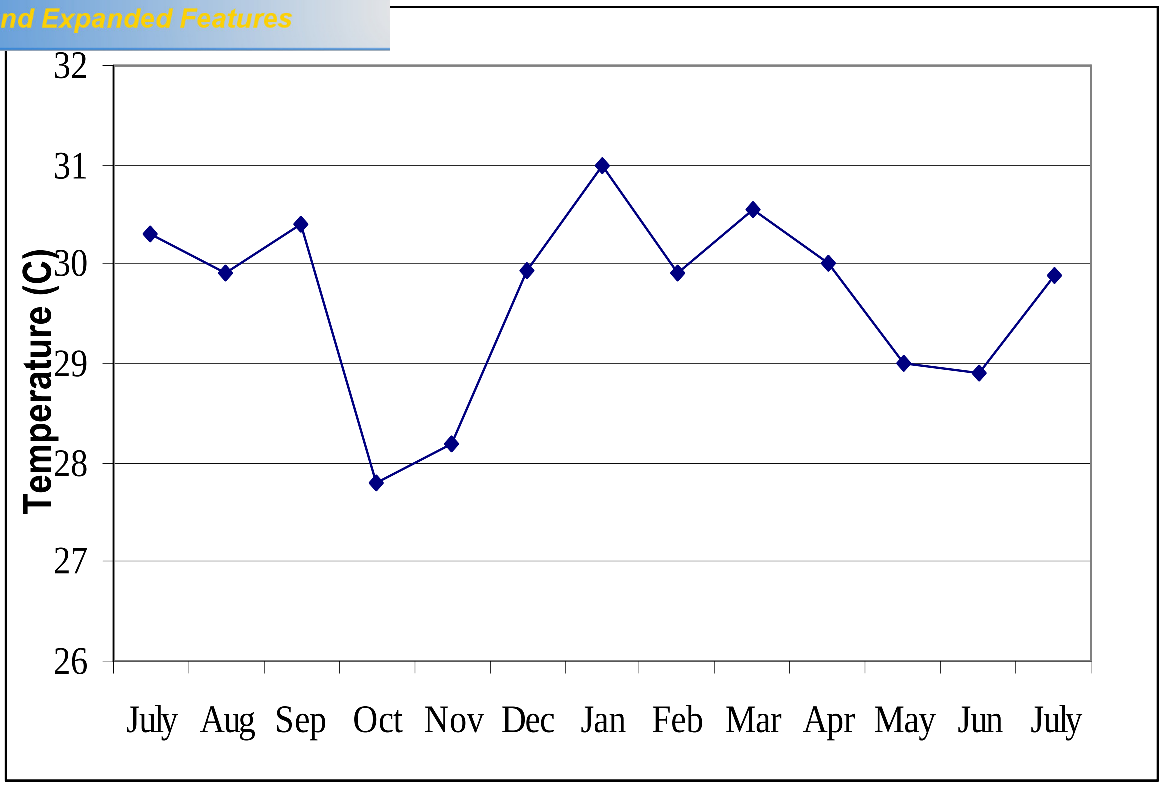

Figure 2 Monthly variations of water Temperature in sea grass habitat

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Table 5 Monthly variations of Salinity (ppt) levels in Sea grass habitat in Negombo Lagoon during the study period from the July 2007-July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	19.2	17.0	21.4	15.0	13.2	13.13	13.4	29.0	28.7	28.5	19.3	18.9	19.5
Katunayake	18.3	14.7	13.5	16.0	12.4	14.2	16.0	30.0	26.5	27.0	15.5	17.9	19.4
Kurana	19.8	30.9	29.2	17.0	16.26	19.2	18.0	28.1	33.5	29.2	19.0	18.5	19.9
Kadolkele	28.8	30.8	31.9	17.0	12.46	21.0	16.3	29.1	33.4	29.1	28.0	29.0	30.0
Aluthkuruwa	22.6	23.5	29.7	17.0	16.6	17.26	20.0	28.0	34.5	28.0	25.0	22.0	24.0
Sethappaduwa	23.0	24.0	20.9	19.0	18.6	19.16	18.0	21.8	30.75	21.8	20.4	30.5	23.5
Negombo/ piti	27.5	29.6	30.3	25.0	20.8	20.26	22.35	23.0	34.5	23.0	29.0	28.0	28.0
Thalahena	28.0	26.0	29	25.0	20.3	21.0	21.5	21.6	33.0	21.6	25.0	25.0	23.6
Statistical Ave	23.4	24.6	25.7	18.9	16.3	18.15	18.2	26.3	31.86	26.0	22.7	23.7	23.49

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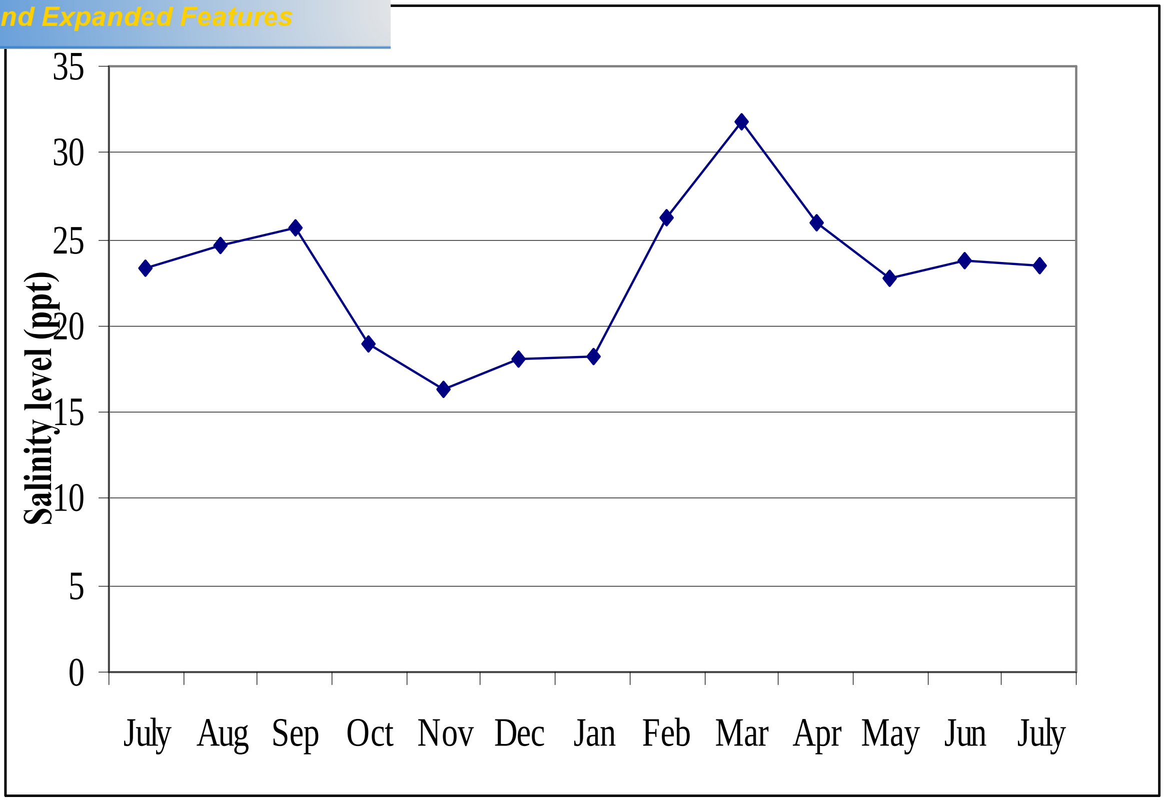

Figure 3 Monthly variations of Salinity (ppt) levels in sea grass habitat

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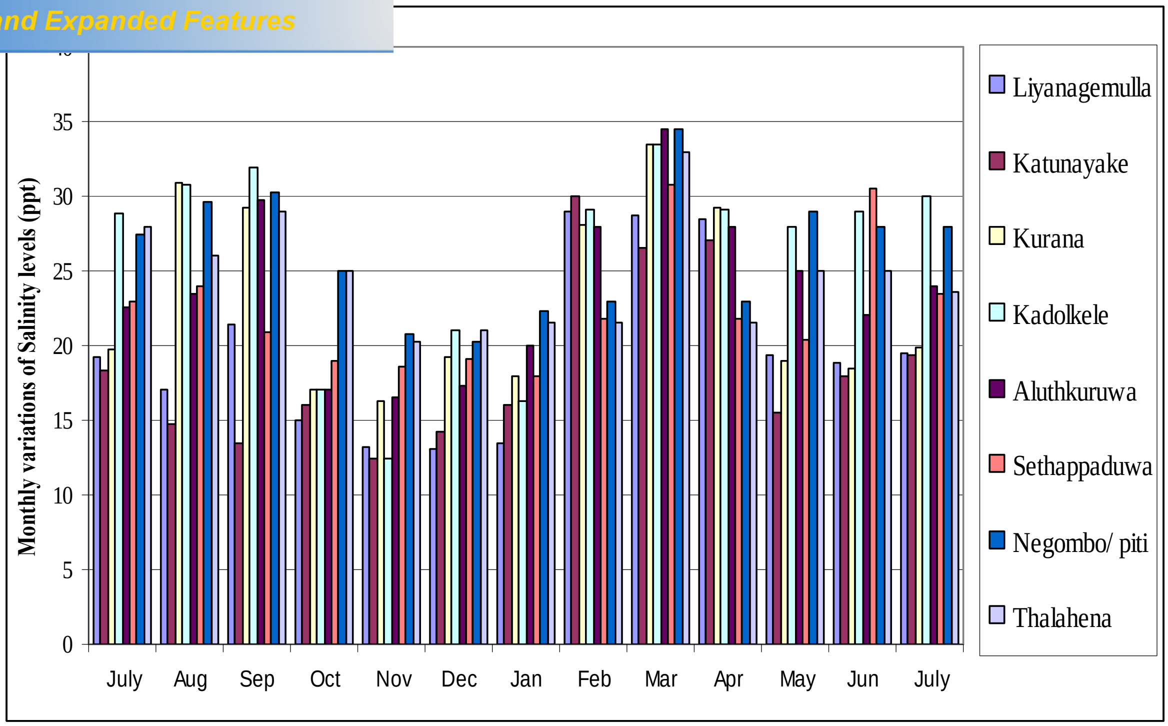

Figure 4 Comparison of Monthly Salinity (ppt) variations in selected sites

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Standard Method for Nutrient Analysis

Ammoniacal Nitrogen - (Phenate Method)

Principle

Ammonia reacts with phenol and hypochlorite in alkaline solution to give indophenol blue. Sodium nitroprusside is used to intensify the blue color at room temperature.

Reagents

1. Phenol solution: Dissolve 20g phenol in 200 ml of 95% v/v ethyl alcohol.
2. Sodium nitroprusside solution: Dissolve 1.0 g sodium nitroprusside in 200ml of distilled water. Store in an amber bottle in the refrigerator. The solution is stable for at least one month.
3. Alkaline reagent: Dissolve 100 g sodium citrate and 5 g sodium hydroxide in 500 ml distilled water.
4. Sodium hypochlorite: Commercial bleach solution.
5. Oxidizing solution: Mix 100 ml of reagent (3) and 25 ml of reagent (4). This solution should be made up fresh before use and is stable for less than one day.

3. Ammonia stock solution: Dissolve 0.9433 g of ammonium sulphate, $(NH_4)_2SO_4$ (A.R.dried in desiccator) in 1 litre distilled water. This solution contains 200.0 mg/l and should be stored in a glass vessel in refrigerators.

Procedure

To 10 ml sample add 0.4 ml phenol solution (1), mix by swirling and then add 0.4 ml sodium nitroprusside solution (2) and 1 ml oxidizing solution (5). Cover the top of flask and keep the sample out of direct sunlight. Read the absorbance at 640 nm after one hour at room temperature.

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Nitrate - Nitrogen (Copper / Cadmium reduction method)

Principle

Nitrate is reduced to nitrite by cadmium copper couple and the nitrite is then determined using the sulphanilamide/NED method follows the Nitrite methods.

Reagents

1. 2 M hydrochloric acid: Add 16.7 ml concentrated (12 M) Hal to 50 ml distilled water and make up to 100 ml.
2. Copper sulphate solution: Dissolve 20 g copper sulphate Cu So_4 .$5H_2O$ in 1 litre distilled water.
3. Buffer solution : Dissolve 100 g ammonium chloride,NH_4Cl 20 g sodium borate,$Na_2B_4O_7$ and 1g ethylenediamine tetra acetic acid,disodium salt (Na $_2$EDTA) in distilled water and make up to 1 litre.
4. Cadmium metal flings: Use filling that passes through a 2.0 mm mesh sieve but is retained on a 0.5 mm mesh size.

Preparation of Column

Prepare the column by washing 20g cadmium filings (4) with 100 ml 2M HCl (1) and then rinsing with distilled water. Add 40 ml copper sulphate solution (2) and swirl the contents until the blue colour disappears. Plug the base of the column with glass wool, fill with water and then add treated cadmium to a point level with the outlet (see diagram).Make sure there are no trapped air bubbles. Flush the column twice with 50 ml distilled water plus 5 ml buffer solution (3) and adjust the stopcock until the outflow rate is 25 ml per 240 ± 10 seconds.

Procedure

Place 50 ml of sample, blank or standard in a 50 ml measuring cylinder and add 5 ml of buffer solution (3). Mix well and then place 40 ml of this solution on the column and allow it to run through to waste. Add the

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Nitrite - Nitrogen

Principle

In a strongly acid medium nitrite reacts with sulphanilamide to from a diazonium compound which reacts with NED to from a strongly colored azo compound.

Reagents

1. Sulphanilamide solution: Dissolve 5 g sulphanilamide $NH_2.C_6H_4.SO_2.NH_2$ in a mixture of 50 ml concentrated (12M) HCl and 300ml distilled water. Dilute to 500 ml with distilled water. The solution is stable for several months.
2. N-(1 ï naphthyl) rethlenediamine dihydrochloride (NED) solution: dissolve 0.50 g of NED in 500 ml distilled water. Store in a dark bottle in a refrigerator where it is stable for approximately one month.
3. Nitrite standard solution: Dissolve 1.064 g potassium nitrite, KNO_2 (A.R., dried at 105^0C for 1 hour) in distilled water. Add 1 ml 5M NaOH and dilute to 250 ml. This solution contains 700 mg/l NO_2-N and should be stored in a borosilicate glass vessel in a refrigerator.

Procedure

Add 0.2 ml of sulphanilamide solution to 10 ml sample, mix and after two to eight minutes add 0.2 ml of NED solution. Leave for 10 minutes and then measure the absorbance of the samples and standards against a reagent blank at 540 nm. The Colour is stable for 2 h.

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Phosphate Phosphorous

Reagents

1. Sulphuric Acid- Antimony solution: Mix 53.3 ml concentrated sulfuric acid,H_2SO_4 with 500 ml distilled water and cool. Dissolve 0.748 g potassium antimony tartrate, K $(SbO)C_4H_4O_6$ 1/2 H_2O in the H_2SO_4 solution and dilute to 1 litre with distilled water. Store in refrigerator.
2. Molybdate solution: Dissolve 10.839 g sodium molybdate,$Na_2MoO_4.2H_2O$ in 500 ml distilled water and dilute to 1 litre with distilled water. Store in refrigerator.
3. 1.8 M Sulphuric acid solution: Mix 100 ml concentrated (18 M) H_2SO_4 with 500ml distilled water and dilute to 1 litre.
4. Ascorbic acid
5. Mixed reagent A: Mix 25 ml each of (1) and (2) and 10 ml of (3) and 0.2 g ascorbic acid and dilute to 100 ml with distilled water. This solution should be prepared fresh each day.
6. Phosphate standard solution: Dissolve 0.1757 g potassium dihydrogen orthophosphate KH_2PO_4 (dry A.R) in distilled water. Add a few drops of chloroform as a preservative and dilute to 1 litre. This solution contains 40 $mgl^{-1}PO_4$ - P and should be stores in refrigerator.

Procedure

To 25 ml of sample add 5.0 ml of mixed reagent a (5). Allow 15 minutes for colour development and measure the absorbance of standard and samples against a reagent blank at 882 nm. The colour is stable for 2 hours.

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Table 6 Monthly variations of Nitrate - Nitrogen (mg/l) levels in sea grass habitat in Negombo Lagoon during the study period from July 2007 - July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	0.110	0.066	0.079	0.198	0.342	0.322	0.102	0.148	0.062	0.16	0.184	0.105	0.116
Katunayake	0.085	0.336	0.352	0.453	0.432	0.045	0.075	0.563	0.246	0.39	0.453	0.413	0.09
Kurana	0.216	0.834	0.649	0.643	0.532	0.37	0.263	0.261	0.693	0.20	0.543	0.49	0.043
Kadolkele	0.532	0.185	0.354	0.286	0.342	0.868	0.737	0.821	0.494	0.86	0.367	0.293	0.632
Aluthkuruwa	0.116	0.159	0.313	0.578	0.232	0.068	0.147	0.432	0.186	0.43	0.583	0.254	0.114
Sethappaduwa	0.115	0.525	0.706	0.954	0.675	0.009	0.157	0.153	0.426	0.15	0.953	0.854	0.114
Negombo/ piti	0.72	0.176	0.265	0.653	0.643	0.249	0.27	0.285	0.293	0.24	0.984	0.214	0.85
Thalahena	0.098	0.162	0.307	0.764	0.412	0.544	0.243	0.452	0.849	0.30	0.335	0.228	0.092
Statistical Ave	0.250	0.310	0.38	0.542	0.457	0.309	0.25	0.39	0.406	0.34	0.553	0.419	0.256

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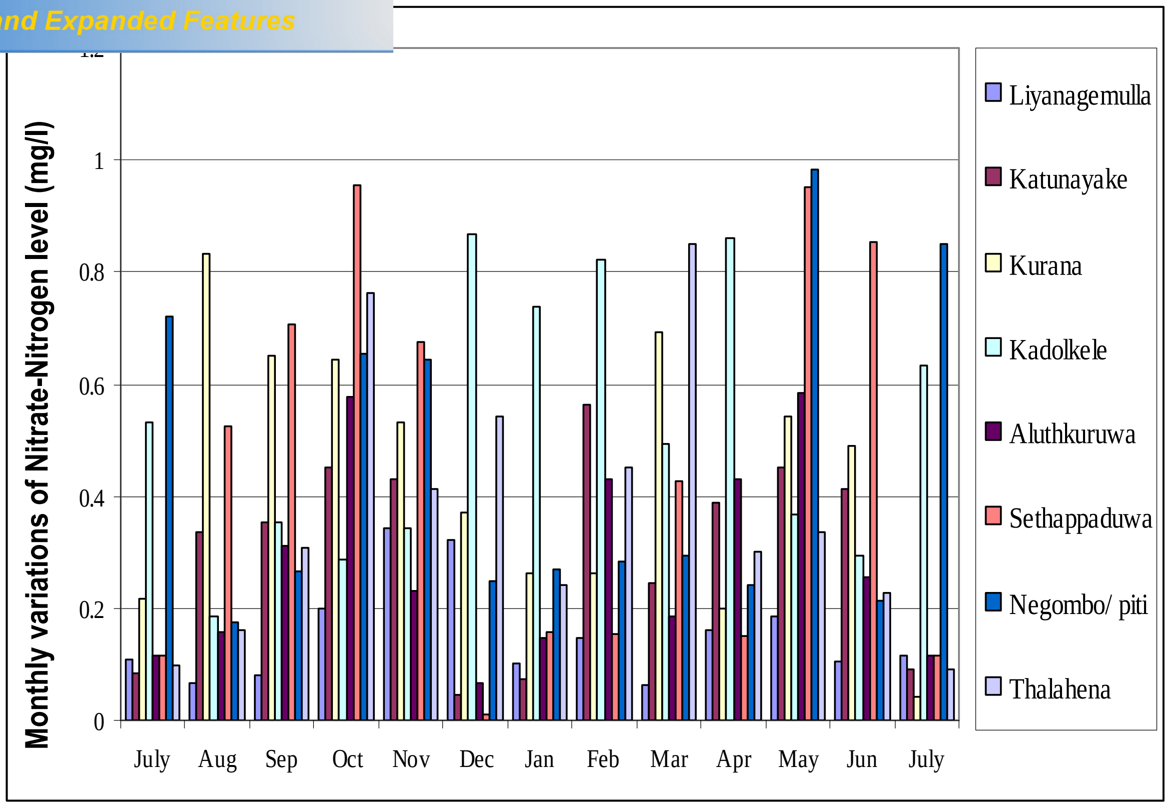

Figure 5 Comparison of Nitrate -Nitrogen (mg/l) variations in selected sites

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Table 7 Monthly variations of Phosphate -Phosphorous (mg/l) levels in sea grass habitat in Negombo Lagoon during the study period from July 2007-July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	0.096	0.096	0.084	0.132	0.132	0.056	0.093	0.087	0.101	0.09	0.135	0.345	0.012
Katunayake	0.085	0.071	0.053	0.217	0.217	0.066	0.089	0.074	0.065	0.08	0.345	0.332	0.076
Kurana	0.096	0.088	0.059	0.243	0.243	0.562	0.037	0.041	0.047	0.05	0.116	0.234	0.078
Kadolkele	0.10	0.153	0.138	0.459	0.459	0.136	0.015	0.092	0.056	0.09	0.232	0.336	0.142
Aluthkuruwa	0.071	0.092	0.068	0.467	0.467	0.236	0.022	0.145	0.263	0.18	0.453	0.143	0.086
Sethappaduwa	0.091	0.062	0.086	0.453	0.453	0.056	0.052	0.024	0.087	0.05	0.336	0.454	0.094
Negombo/ piti	0.123	0.258	0.253	0.321	0.321	0.167	0.097	0.134	0.302	0.14	0.228	0.142	0.153
Thalahena	0.048	0.287	0.436	0.321	0.321	0.065	0.509	0.095	0.099	0.09	0.044	0.435	0.046
Statistical Ave	0.09	0.14	0.15	0.327	0.232	0.168	0.11	0.09	0.128	0.1	0.239	0.302	0.099

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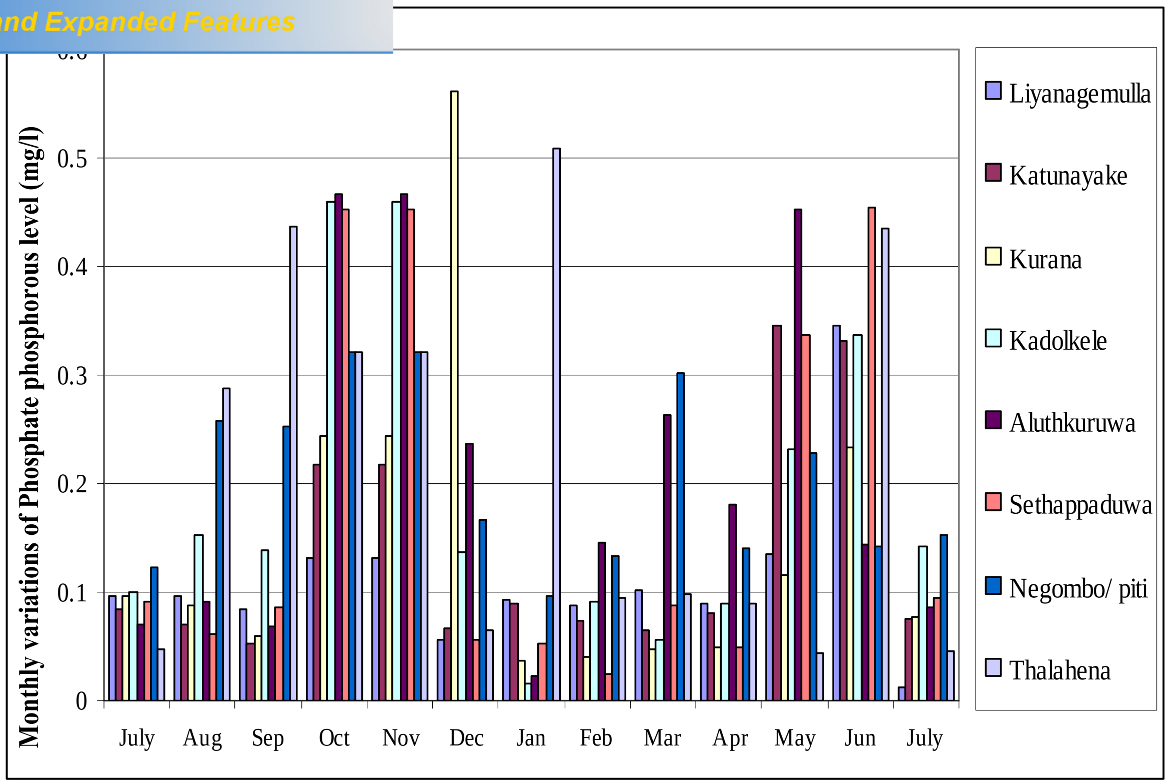

Figure 6 Comparison of Phosphate-Phosphorous (mg/l) variations in selected sites

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Table 8 Monthly variations of Ammonical - Nitrogen (mg/l) levels in sea grass habitat in Negombo Lagoon during the study period from July 2007-July 2008

Month / Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	0.053	0.042	0.049	0.005	0.035	0.036	0.043	0.094	0.087	0.82	0.006	0.049	0.057
Katunayake	0.251	0.231	0.241	0.251	0.021	0.038	0.129	0.23	0.226	0.24	0.196	0.162	0.242
Kurana	0.385	0.371	0.336	0.354	0.028	0.044	0.057	0.116	0.029	0.12	0.171	0.102	0.42
Kadolkele	0.074	0.053	0.087	0.045	0.052	0.053	0.051	0.077	0.069	0.53	0.061	0.67	0.078
Aluthkuruwa	0.117	0.143	0.178	0.173	0.156	0.147	0.172	0.177	0.054	0.16	0.367	0.404	0.119
Sethappaduwa	0.265	0.217	0.300	0.202	0.152	0.026	0.206	0.232	0.029	0.17	0.205	0.205	0.302
Negombo/ piti	0.584	0.785	0.905	0.29	0.239	0.132	0.022	0.023	0.083	0.18	0.375	0.205	0.532
Thalahena	0.047	0.732	0.096	0.405	0.876	0.489	0.653	0.321	0.091	0.29	0.402	0.407	0.053
Statistical Ave	0.22	0.32	0.27	0.22	0.19	0.121	0.17	0.16	0.084	0.31	0.22	0.28	0.225

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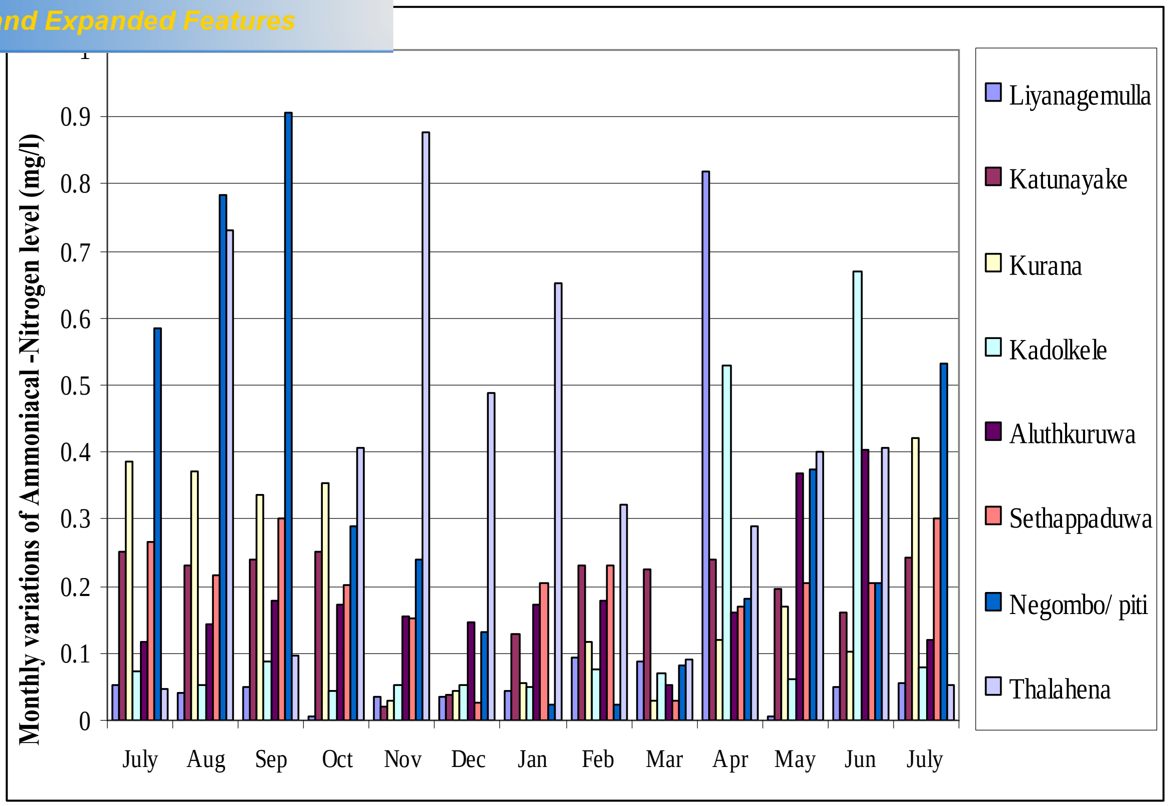

Figure 7 Comparison of Ammoniacal -Nitrogen (mg/l) variations in selected sites

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Table 9 Monthly variations of Nitrite- Nitrogen (mg/l) levels in sea grass habitat in Negombo Lagoon during the study period from July 2007- July 2008

Month Location	July 2007	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July 2008
Liyanagemulla	0.036	0.037	0.037	0.04	0.023	0.029	0.055	0.036	0.024	0.04	0.018	0.266	0.039
Katunayake	0.031	0.041	0.048	0.032	0.01	0.032	0.03	0.021	0.036	0.03	0.176	0.332	0.042
Kurana	0.025	0.02	0.042	0.007	0.023	0.003	0.02	0.078	0.588	0.09	0.008	0.115	0.034
Kadolkele	0.008	0.045	0.037	0.023	0.043	0.003	0.007	0.007	0.107	0.06	0.03	0.128	0.007
Aluthkuruwa	0.149	0.153	0.159	0.216	0.043	0.120	0.015	0.014	0.019	0.01	0.128	0.051	0.243
Sethappaduwa	0.008	0.058	0.032	0.006	0.009	0.004	0.008	0.009	0.065	0.01	0.004	0.154	0.004
Negombo/ piti	0.052	0.073	0.07	0.005	0.008	0.007	0.009	0.008	0.176	0.08	0.03	0.109	0.063
Thalahena	0.046	0.093	0.097	0.004	0.043	0.21	0.072	0.98	0.287	0.59	0.009	0.018	0.053
Statistical Ave	0.04	0.07	0.07	0.04	0.03	0.051	0.03	0.14	0.163	0.11	0.05	0.15	0.061

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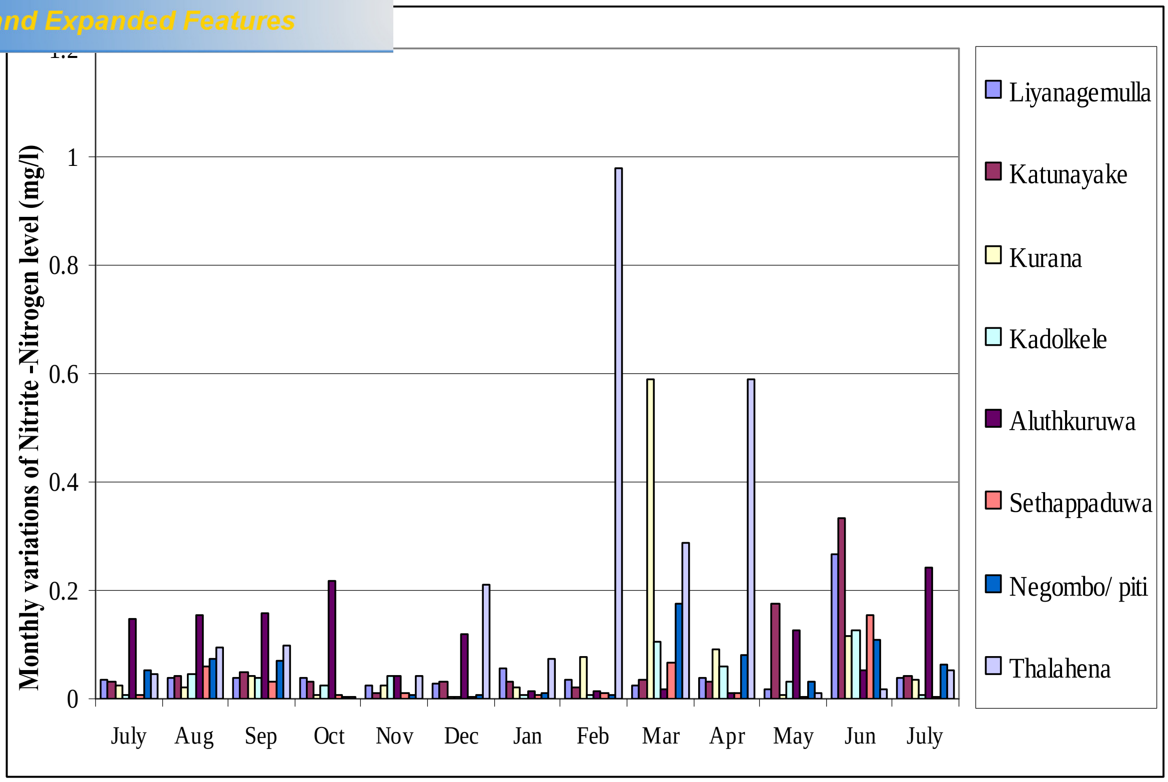

Figure 8 Comparison of Nitrite - Nitrogen (mg/l) variations in selected sites

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Shrimp larval catch versus Temperature (^{0}C)

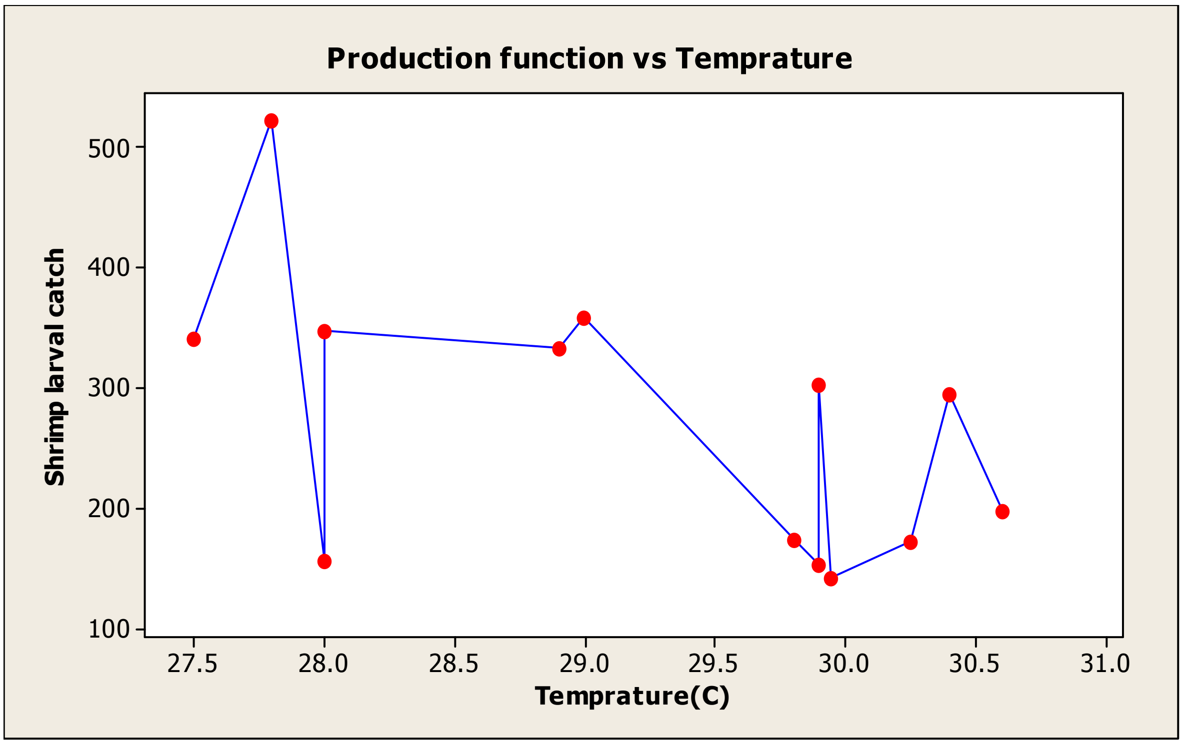

Figure 9 Monthly variation of Shrimp larval catch versus Temperature (^{0}C)

One-way ANOVA: Shrimp larval catch versus Temperature (^{0}C)

Source	DF	SS	MS	F	P
Temperature (^{0}C)	10	125616	12562	0.85	0.651
Error	2	29470	14735		
Total	12	155086			

S = 121.4 R-Sq = 81.00% R-Sq (adj) = 0.01%

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Shrimp larval catch versus Salinity

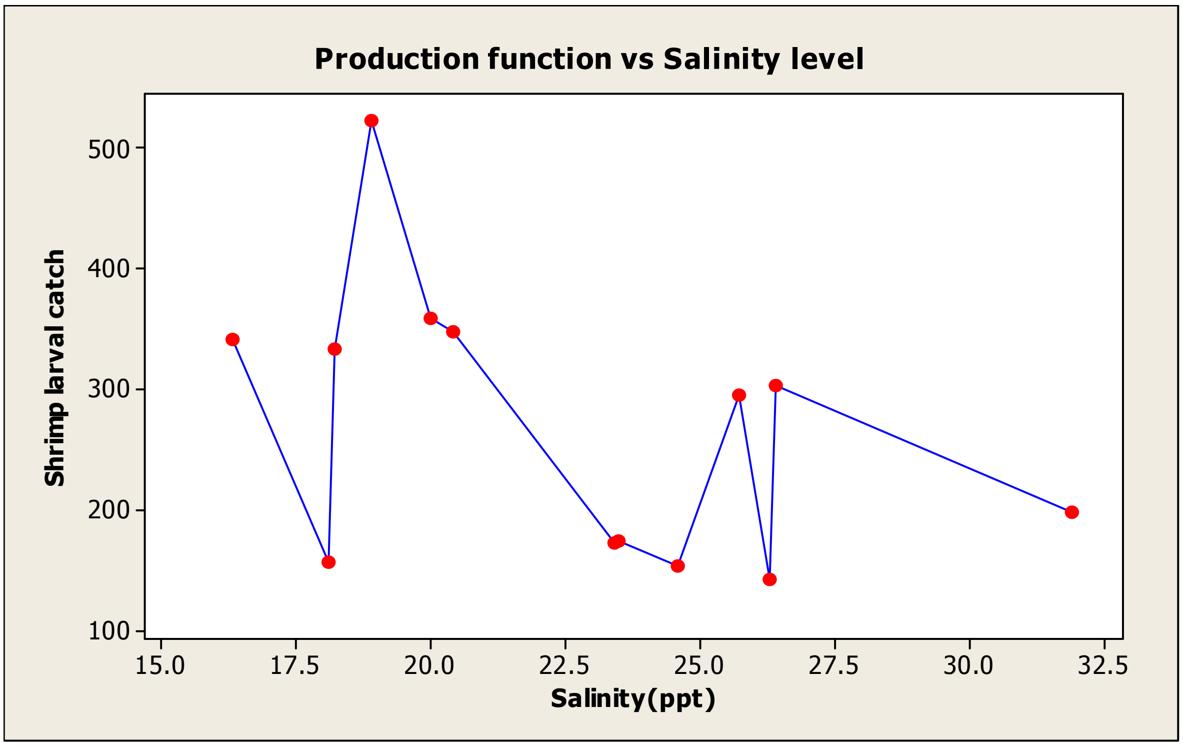

Figure 10 Monthly variation of Shrimp larval catch versus Salinity (ppt)

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Shrimp larval catch versus Nitrate -Nitrogen

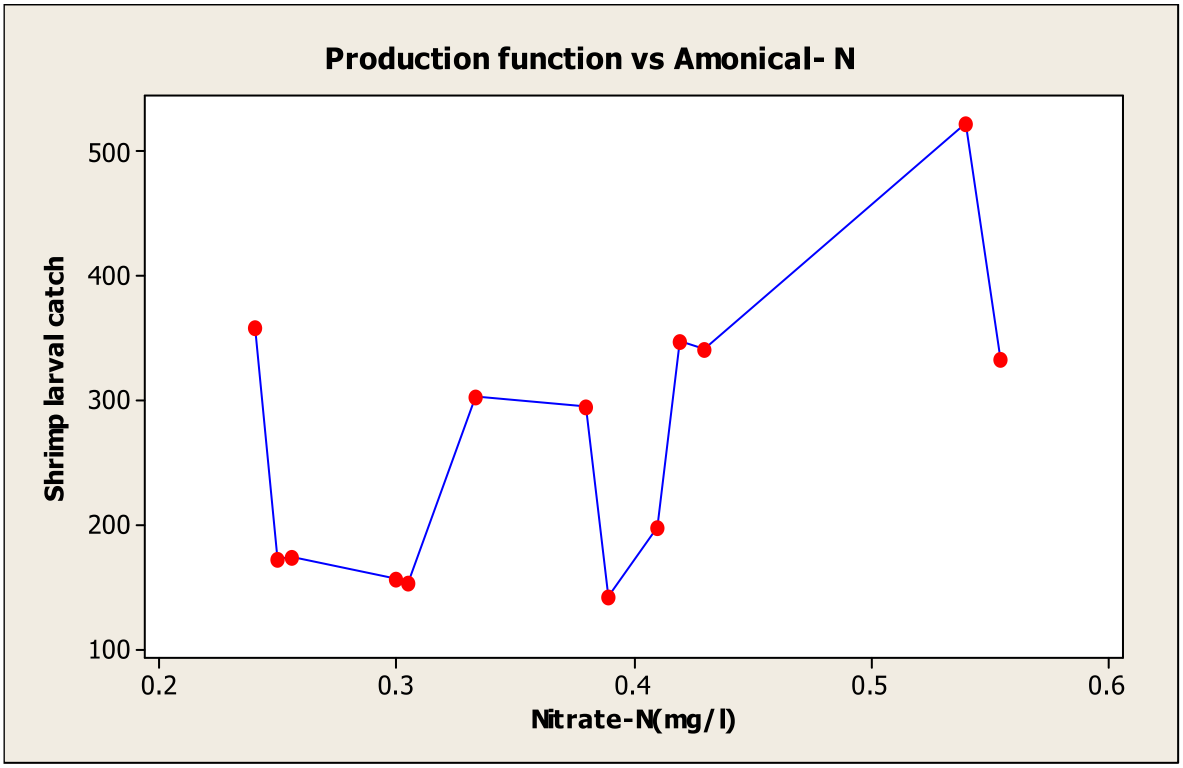

Figure 11 Monthly variation of Shrimp larval catch versus Nitrate -Nitrogen

One-way ANOVA: Shrimp larval catch, Nitrate-N (mg/l)

Source	DF	SS	MS	F	P
Factor	1	468238	468238	72.46	0.001
Error	24	155086	6462		
Total	25	623324			

S = 80.39 R-Sq = 75.12% R-Sq (adj) = 74.08%

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Shrimp larvae catch versus Phosphate - Phosphorous

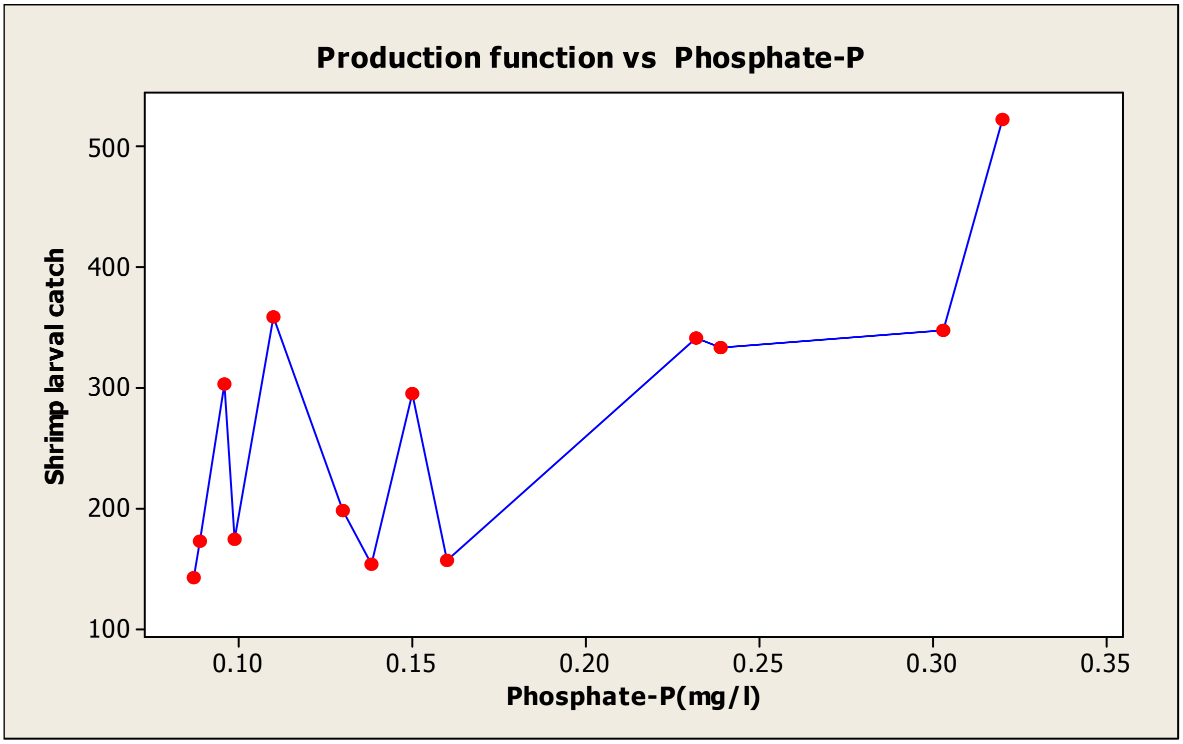

Figure 12 Monthly variations of Shrimp larvae catch versus Phosphate - P

One-way ANOVA: Shrimp larval catch, Phosphate-P (mg/l)

Source	DF	SS	MS	F	P
Factor	1	468951	468951	72.57	0.001
Error	24	155086	6462		
Total	25	624037			

S = 80.39 R-Sq = 75.15% R-Sq (adj) = 74.11%

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Shrimp larvae catch versus Ammoniacal -Nitrogen

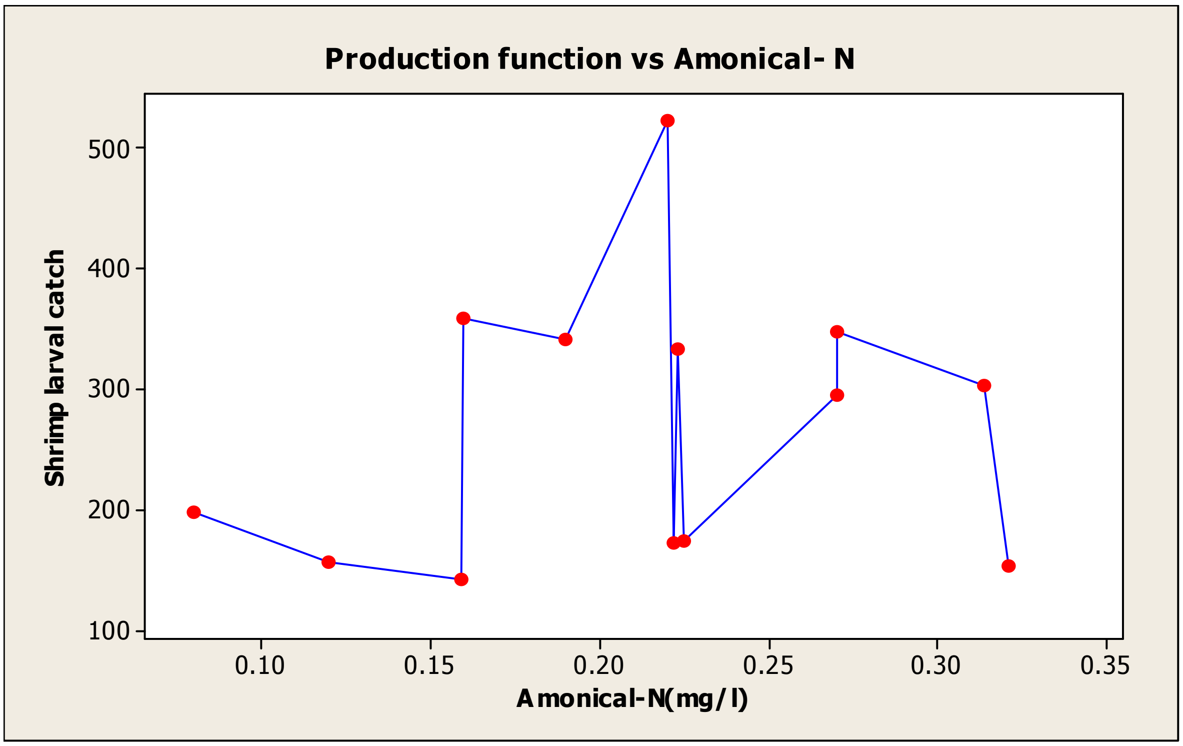

Figure 13 Monthly variations of Shrimp larvae catch versus Ammoniacal-N

One-way ANOVA: Shrimp larval catch, Amonical-N (mg/l)

Source	DF	SS	MS	F	P
Factor	1	468784	468784	72.55	0.001
Error	24	155086	6462		
Total	25	623870			

S = 80.39 R-Sq = 75.14% R-Sq (adj) = 74.11%

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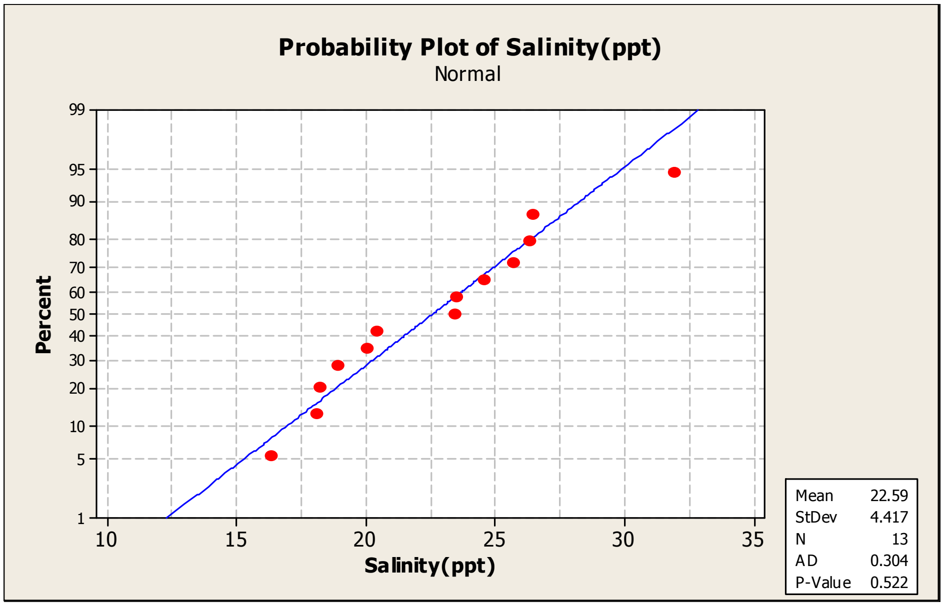

Figure 14 Normal Probability Plot of Salinity (ppt)

One-way ANOVA: Shrimp larva, Salinity level

Source	DF	SS	MS	F	P
Factor	5	760742	152148	70.53	0.005
Error	72	155321	2157		
Total	77	916063			

S = 46.45 R-Sq = 83.04% R-Sq (adj) = 81.87%

Result from salinity concentration was lower probability value P= 0.005. P values are often used in hypothesis tests, either reject or fail to reject a null hypothesis. The smaller the P value, the smaller is the probability rejecting the null hypothesis. The corresponding ANOVA result obtained from F value computed for 70.53 and the P value associated with The P value is 0.005. There for the null hypothesis of no interaction is rejected at P =0.005. Thus it can be concluded that, effect of salinity vary depending on the shrimp larvae stages.

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Table 11 Water Quality Standard for brackish water Shrimp culture

Parameters	**Tolerance Limits**
Temperature (^{0}C)	<35
Salinity (ppt)	10-32
Nitrite (mg/l)	<1.0
Nitrate (mg/l)	<1.0
Phosphate (mg/l)	<1.0
Ammonia (mg/l)	<1.0

Source: Central Environmental Authority (2001)