Small Scale Multispecies Demersal Fishery Off Negombo, Sri Lanka, A Study of Their Biology and Socio-economics.

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DEDICATED TO MY LOVING MOTHER

DECLARATION

The work reported in this thesis is the result of my own investigations carried out at the National Aquatic Resources Research and Development Agency (NARA), Colombo, Sri Lanka. It has not been and not will be submitted concurrently in candidature for any degree, in this or any other university. All sources of information and citations in this thesis have been duly acknowledged.

R. R. P. Maldeniya

ABSTRACT

The present multidiciplinary study on the demersal fishery in the Negombo area on the west coast of Sri Lanka was based on the data collected from 1992 to 1999. The prime objective of this study was to identify an appropriate management strategy for the sustainable development of the resources and the fishery. Assessments of fishery, fishery resources, economics of fishing, marketing and the social aspects of the fishing community were studied in detail. The status of economically important fish stocks in the shallow and deep waters were assessed through indicator species, *Lethrinus lentjan* and *Lethrinus nebulosus*.

The demersal fishery in the area is highly diverse and the highest fishing effort is deployed by handline combined with drift gillnet boats followed by bait cage traditional handline with outboard motor boats, bottom trammel net, bottom longline, bait cage handline with inboard motor boats, and a more limited effort by bottom set gillnet and spear fishing. Handline with inboard motor boats, bottom set gillnets and spear fishing only operate during the non-monsoon season, but fishing effort is high during this period by all gears. The multigear demersal fishery in the area is predominately conducted in the shallow waters of less than 40 m and only handline and bottom longline fishing are deployed in depths greater than 40m. The CPUE realised from shallow waters are low for all gears but improved with increasing fishing depth.

A total of 139 fish species belonging to 68 families have been recorded in the catches but the most important families are Lethrinidae, Carangidae, Lutjanidae, Serranidae and Scombridae. *L. nebulosus* and *L. lentjan* are the dominant species. Recently the contribution of squid and cuttlefish to the total demersal catch has increased. Lethrinds replaced the catches of Carangids as dominant fish. The three important gears, traditional bait cage handline, bottom longline and bottom trammel net fisheries are highly interactive, harvesting the same stocks of economically important species of different but overlapping sizes. Both traditional handline and bottom trammel nets catch large quantities of juveniles of the indicator species inhabiting the shallow waters while bottom longlines catch adults in deeper waters. A decline of CPUE of these interactive gears has been observed over the years.

The present fishing effort of the multispecies demersal fishery has come close to the optimum, which produces the maximum sustainable yield (MSY), but has long exceeded the maximum economic yield (MEY). The economically important fish resources in the shallow waters are being overexploited and have long exceeded the optimum exploitation of 0.5 by all three main gears. The exploitation of bottom longline fishing has exceeded the optimum effort which produces MSY for *L. nebulosus* and both handline and bottom longline has exceeded the optimum effort for *L. lentjan*. The economics of exploitation of these two species has exceeded the MEY by all gears. The yield or the value of the catch of these two indicator species could only be improved by a 50% reduction of current effort of either bottom trammel nets or traditional handline fishery, but over 60% of the households engaged in these fisheries depend entirely on fishing income.

All boat/gear combinations involved in demersal fishing exhibited good performance and generated a positive net profit, but the economic performance among them is highly variable. Profitability is highest for modern gears rather than traditional bait cage handline fishing. The seasonal change in fishing, according to the seasonal abundance of resources, is economically rewarding. Relatively low fixed costs plus a competitive market, high demand and low indebitness to middlemen results in a high net profit.

Contents

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LIST OF SYMBOLS AND THEIR DEFINITIONS

1) Symbols Used in the Text

BLL	Bottom longline fishing with OBM boats
BSN	Bottom set gillnet with OBM boats
BTN	Bottom trammel net fishing with OBM boats
CPUE	Catch per unit effort
DFEO	District Fisheries Extension Office
EEZ	Exclusive Economic Zone or the sea area with exclusive rights
F	Female
FAO	Food and Agriculture Organisation of the United Nation
FL	Fork length
GNP	Gross National Production
HL	Traditional handline fishing or bait cage handline fishing with OBM boats
HL*	Seasonal handline fishing or seasonal bait cage handline fishing with IBM boats
HL/DN	Handline fishing or drop handline fishing combined with drift gillnets with OBM boats or combination boats
i. e.	That is
IBM	In board motor boat
Lat	Latitude
LL	*Lethrinus lentjan*
LN	*Lethrinus nebulosus*
Long	Longitude
M	Male
N-E	North-East monsoon
OBM	Out board motor boat
RV	Research Vessel
Sig	Significance
SL	Standard length
SPF	Spear fishing with OBM boats
S-W	South-West monsoon
TL	Total length
U	Unisex
VPA	Virtual population analysis
X-factor	Fishing mortality array

2) Mathematical and Statistical Expression

ϕ'	Growth performance index
χ^2	Chi-squire
a	Intercept on the Y axis of the straight line graph
D	License fee
B	Biomass at any exploited state
b	Slope of a straight line graph
$B\alpha$	Maximum biomass of the carrying capacity level
BF	Batch fecundity
BW	Fresh eviscerated body weight
C	Number of fish
CF	Confidence limit
d	Depreciation
Df	Degree of freedom
dt	Time taken for the species to grow through a particular length
E	Exploitation rate
e or exp	Exponential value
Ξ'	Bio-economic equilibrium
f	Fishing effort

F	Fishing mortality coefficient or fishing mortality rate
FC	Fixed cost
GSI	Gonosomatic index
GW	Fresh Gonad weight
ln	Natural logarithm
k	Economic life
K	Growth coefficient or growth constant
L	Total length of fish
$L\alpha$	Asymptotic length
M	Natural mortality coefficient or natural mortality rate
MEY	Maximum economic yield
MSY	Maximum Sustainable Yield
N	Number of fish in the population
p	Price one kilogram of fish
P'	Average purchase price
P	Probability
q	Catchability coefficient
r	Rate of increase of biomass
S	Salvage value
SLRS/Rs	Sri Lankan rupee
t	Age or time
T	Temperature C^0
t0	Age at zero length
TC	Total cost
TR	Total revenue
V	Value of the yield
VC	Variable cost
vi	The volume of sample counted number of ova of diameter i
Vi	Total displaced volume of all ova in diameter i
W	Total fresh weight of fish
xi	Number of ova counted in diameter i
Xi	Total number of ova (eggs) in the ovary of diameter i
Y	Yield
Z	Total mortality coefficient or total mortality rate

Chapter 1

Introduction and an Overview of Fisheries in Sri Lanka

1. 1 INTRODUCTION

The importance of the fisheries sector to the Sri Lankan economy is widely acknowledged. Its significance as a primary source of animal protein, employment opportunities and foreign exchange earner for the country is well established. Fisheries provide 65% of the animal protein consumed in Sri Lanka, sustain full time employment to around 120,000 persons and account for 2.63% for the Gross National Production (GNP) of the country, while exports of fish and aquatic products were valued at around Rs. 6750 million in foreign exchange in 1998 (Anon, 1999a).

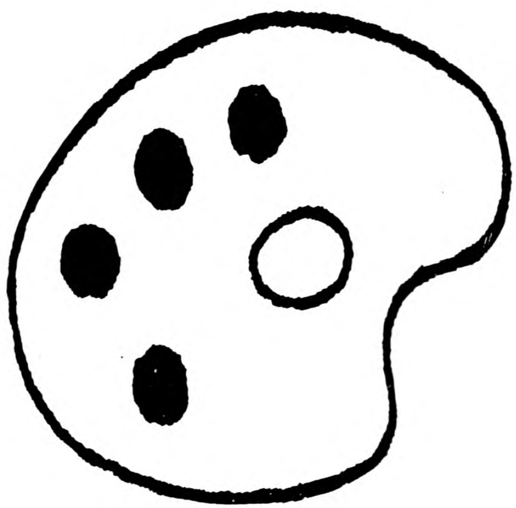
In recognizing the importance of the fisheries sector to the national economic development and food security, the Sri Lankan Government has announced a number of development policies to promote the exploitation of aquatic resources on a sustainable basis with the main objectives being to increase fish production, generate employment opportunities, increase foreign exchange, uplift the socio-economic conditions of the fishing communities and ensure conservation and management of the resources and environment (Anon, 1998).

Marine fisheries are the mainstay of fish production in Sri Lanka. They contributed over 90% to the total national fish production of 242,000 t in 1997, the backbone being the coastal fisheries which contributed 152,750 t, about 71% of the total marine landings (Anon, 1999a). The offshore fisheries are still in a developing stage. Coastal fisheries are confined to waters of the relatively narrow continental shelf and slope area, and in contrast to the offshore fisheries use little capital and less technology while providing employment for a significant portion of the coastal population.

1. 2 MARINE ENVIRONMENT

Sri Lanka is an island in the Indian Ocean situated close to the southeastern corner of the Indian subcontinent. India and Sri Lanka are separated by the shallow Palk Strait, Palk Bay and the Gulf of Mannar. The island has a land area of 65,525 sq. km. Since the declaration of the Exclusive Economic Zone (EEZ) in 1978, the country has sovereign rights over 517,400sq. km of sea area. The coastline, 1700 km long, meanders along

NUMEROUS ORIGINALS IN COLOUR



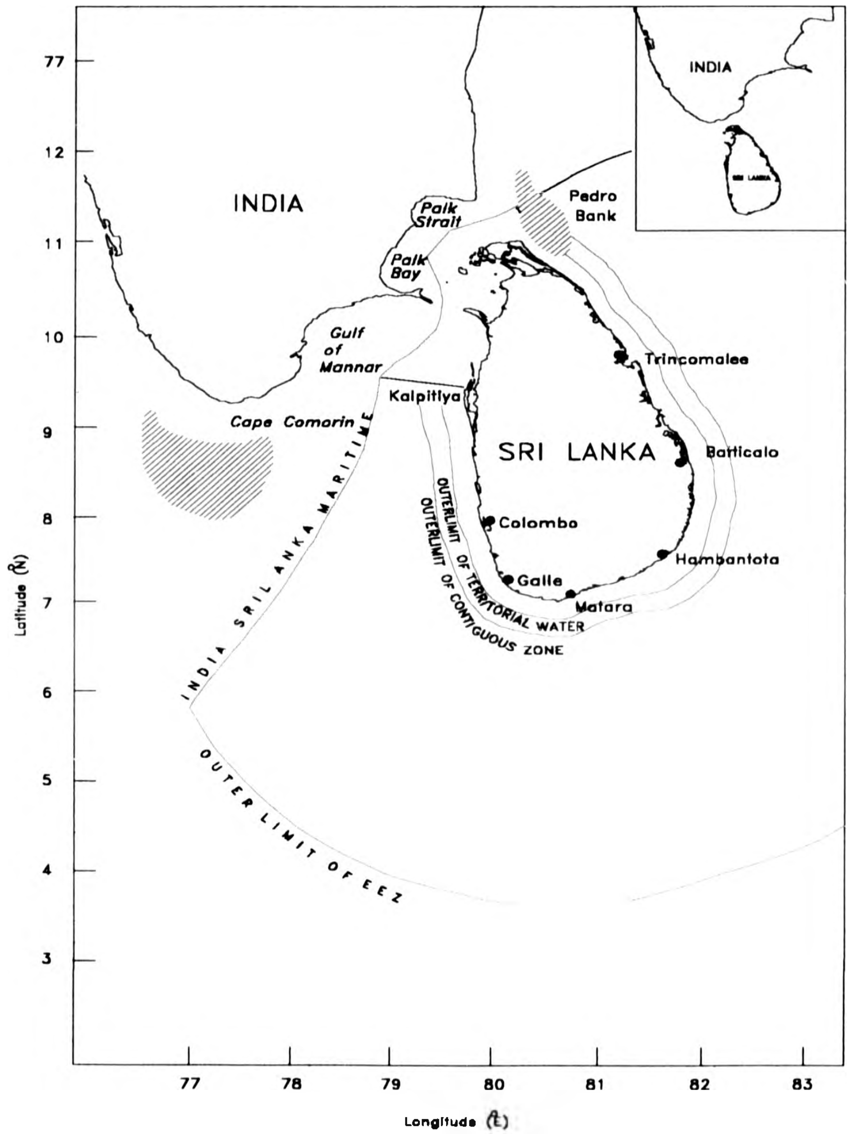


Fig. 1.1. Location of Sri Lanka and its EEZ.

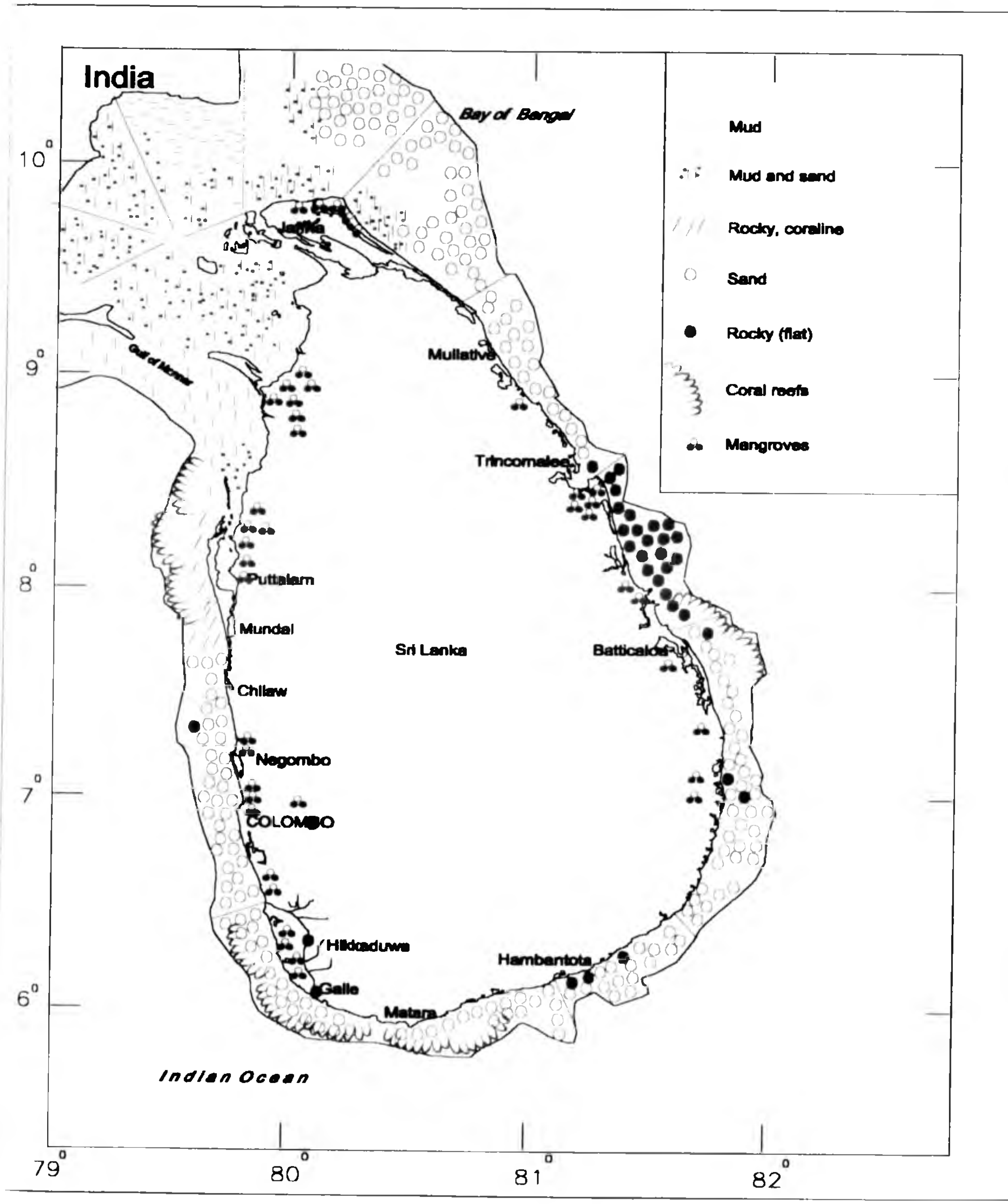


Fig. 1.2. Bottom sediment structure in the continental shelf of Sri Lanka

sandy beaches, extensive lagoons and estuaries, mangroves, coastal marshes and dunes. Seawards lie reefs of sandstone or coral and shallow beds of coastal and estuarine sea-grass. The better known fringing coral is located around Hikkaduwa, Galle, Batticaloa, Trincomalee, Mannar, Negombo and around the Jaffna peninsula (Anon, 1991, Anon, 1999a) (Fig. 1.1).

The shelf is narrow, rarely exceeding 40 km and averaging around 22 km in width, with a total area of some 26,000 sq. km., equivalent to about 5% of the country's EEZ (Anon, 1991). To the north and northwest, the shelf widens to an extensive shallow bank where it forms the Gulf of Mannar, Palk Bay, Palk strait and Pedro Bank. With the exception of a few areas in the Gulf of Mannar, off Pedro Bank and southwest of Hambantota, the edge of the continental shelf falls off rapidly from 50-65 m to 1500-3500 m. The bottom sediment in the shelf area is generally rocky, particularly between Colombo to Batticaloa and is basically non-trawlable. The bottom of the northern shelf, particularly the Palk Strait, is predominantly muddy or muddy sand and hence trawlable (Fig. 1.2).

Sri Lanka is subjected to the influence of a monsoonal wind system. The South-West monsoon occurs from May to September causing heavy rains, mainly in the western part of the country. The North-East monsoon occurs from November to January with the heaviest rainfall in the north and east and on the northeastern slope of the central hills. The sea surface currents are influenced by the monsoons, and are often strong at the beginning (April-June) and at the end (August-September) of the South-West monsoon, and during the North-East monsoon. During the South-West monsoon the general oceanic circulation is from west to east with current velocities of up to 2-3 knots near the shelf edge. During the North-East monsoon, the circulation is reversed, and the current velocity is about 1-2 knots. The depth of the thermocline also varies with the monsoon, reaching 100-125 m on the west coast during the North-East monsoon and 40-60 m during the South-West monsoon. Upwellings are not observed but monsoon winds and currents influence the mixing of waters down to about 100 m depth. The tides around Sri Lanka are predominantly semidiurnal and micro-tidal, with the highest amplitudes in the Colombo area and the lowest around Jaffna and Trincomalee (Dassanayake, 1994; De

Bruin, 1994).

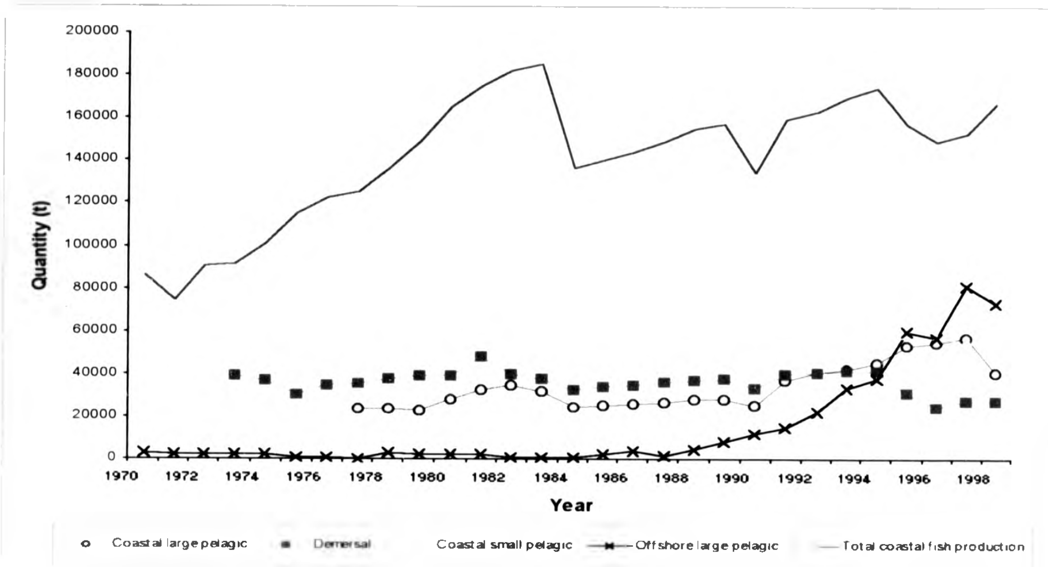
1. 3 MARINE FISHERY RESOURCES

The acoustic survey by the RV 'Dr. Fridjof Nansen' in 1978-1980 estimated the potential yield from coastal fish resources within the continental shelf to be 250,000 t per year of pelagic and demersal species. Pelagic fish were estimated to have a maximum sustainable yield of 170,000 t per year and demersal species 80,000 t (Blindheim and Foyn, 1980).

Preliminary estimates of Sri Lanka's offshore pelagic resources indicate that 50,000-90,000 t per year could be taken without risk of over exploitation (Sivasubramanium, 1978). The species include tunas, billfishes, spanish mackerels and pelagic sharks etc. The total marine fisheries resources, including Sri Lanka's offshore area, could thus yield up to 350,000 t per year.

1. 4 MARINE FISHERIES

The marine fisheries industry in Sri Lanka has a long history. During the early stages of development, traditional methods of fishing using canoes and gear such as beach-seines, hand-lines, nets made out of coir and stake nets were used in coastal area. The coastal inhabitants were mostly engaged in exploiting resources in close vicinity to the shore in and around their settlements. The fish production in the 1940s was in the region of 40,000 t (De Zylva, 1954). A high percentage of this production came mainly from beach-seines (Canagaratnam and Medcof, 1956). Sheltered bays and naturally protected areas were used to beach the traditional crafts, and markets developed around the landing centers. The stage of rapid development and highest rate of growth in the fisheries began in late 1950s with a significant impact of motorization and the introduction of modern craft and methods (Joseph, 1993). This revolutionized the industry and increased fish production markedly. The technological inputs increased coastal fish production from 84,400 t in 1962 to 152,750 t in 1999, and the fisheries now target both small and large pelagic fish, demersal fish and shell fish such as prawns, lobsters and crabs.



Source: Ministry of Fisheries and Aquatic Resources Development

Fig. 1. 3. Marine fish production in Sri Lanka 1970 – 1998.

A stable phase of the coastal fisheries development, with little increase in production has led to a levelling off of the fishery outputs since the 1980s (Fig. 1.3). Observations and assessments have revealed that there is over exploitation of some of the targeted small pelagic fish species (e.g. *Amblygaster sirm*) in areas like Negombo where there is a large concentration of fishing effort (Karunasinghe, 1990). During the early 1980s the most important development has been the introduction of multiday fishing boats for the expansion of fishing effort towards offshore waters. Around 1,700 such boats of size range in 32-60 ft are currently fishing in and off the EEZ, contributing around 100,000 t (Anon, 1999a).

1. 5 DEMERSAL FISHERIES IN SRI LANKA

In the Sri Lankan fisheries literature, the category demersal fish is used in a broad sense to encompass fish, which are vulnerable to bottom fishing gear, where fishing activities are described as demersal fisheries. These include a wide range of reef-associated fish including snappers (family Lutjanidae), groupers (family Serranidae), emperors (family Lethrinidae) etc., and many reef-associated pelagic or semi-pelagic types such as barracudas (family Sphyraenidae), jacks and trevallys (family Carangidae), spanish mackerel (family Scombridae), sharks, skate etc.

Total demersal fish production averaged 30,000-40,000 t in the 1970s, and reached almost 48,000 t in 1981. It has declined since the early 1980s (Fig.1. 3), mainly due to civil disturbance in the north and east area which previously contributed over 80% of the demersal fish landed (Maldeniya, 1985). Since the early 1980s the fishable area has been reduced but the demersal catch, although below the predicted MSY (maximum sustainable yield), is now concentrated on a much restricted area, mainly western and southern parts of the island which previously produced about 20% of the annual catch. In recent years the annual demersal fish production has stabilized at around 25,000 t.

Sri Lanka had an offshore commercial trawl fishery on the Wadge Bank during the period 1920 to 1975 as well as some sporadic activity on the Pedro Bank during the same period. The loss of these trawling grounds with the establishment of Indo-Sri Lanka maritime boundary led to the suspension of this fishery in 1976. Trawling is now carried out only for prawns along the north, east and limited inshore areas in the west coasts. The by-catch contains substantial amount of small varieties of low value fish (Sivasubramanium, 1985). The motorization of craft and introduction of synthetic nets, the loss of Wadge Bank and Pedro Bank trawlable grounds in late 1970s, and increased popularity of gillnets etc., has all resulted in the demersal fisheries receding to a position of lower significance (Maldeniya, 1997). The present demersal fish production is 27,200 t, which is about 16% of the total coastal fish production (Anon, 1999a).

1. 5. 1 Fishing Crafts

Demersal fisheries in Sri Lanka are carried out at an artisanal level. Except in north, and east, and a few other places, Negombo, Chilaw in the western and Hambanthota on the southern coasts, fishing is seasonal. During the season a variety of craft, including >34 ft inboard powered multiday boats which generally conduct offshore pelagic fishing spending several days at sea, 28-34 ft inboard powered day or multiday fishing boats, outboard-powered 17-22 ft boats, motorized and non-motorized outrigger canoes and log rafts, and sailing canoes, participate in the fishery. There is significant regional variation in the type and number of vessels operating in the fishery. On the southern and southwestern coasts motorized outrigger canoes are common while 17-22 ft outboard motor (OBM) boats are more popular among western and northwestern fishermen engaged in demersal fisheries. Some of the multiday boats are operated for demersal fishing only from November to April, which is a lean season for large pelagic fisheries, (Maldeniya, 1997).

1. 5. 2 Fishing Methods

Fishing methods used to catch demersal fish include handlines, bottom set gillnets, bottom longlines, bottom trammel nets, traps and spears (Anon, 1995). Hand lining is the traditional method and is the most important in all areas. Bottom longlining is popular among fishermen in the northwest, west and southwest while the use of bottom set gillnets is popular in the northwest and south. Bottom trammel netting for demersal finfish is used extensively by fishermen in the northwest and west and shows rapid expansion. Traps operate only on the east coast, mainly in Trincomalee and Batticaloa. Spear fishing for demersal finfish came into practice only recently (Maldeniya, 1997). Spear fishing is not listed as a illegal fishery under the Fisheries Act 1996 but possession or use of spear gun has however been made unlawful since 1993 under the Flora and Fauna Protection Act No. 49 (Anon, 1993). Some of the fishing methods used are seasonal in nature, with fishing seasons in many cases being more or less diametrically opposed on different sides of the island due to the varying effects of the North-East and South-West monsoons.

In addition to target fishing, some demersal fish is landed as by-catch from prawn trawling. The northern part of the country was formerly the most important area for trawling, but the civil disturbances have significantly reduced demersal fish landings from this source. It has been also noted that most of the small-mesh gillnetters operate handline fishing throughout the year as an ancillary gear (Maldeniya, 1997).

1. 5. 3 Species Composition

Demersal catches are highly diverse in terms of number of species found, but catches are dominated only by a few species (Sivasubramaniuam, 1985). About 55 families representing some 215 species of demersal and semi-demersal fishers were identified during RV 'Lilla' trawl survey (1920-23) (Pearson and Malpas, 1926). The trawl catches made by RV 'Dr Fridtjof Nansen' (1978-80) listed 238 species belonging to 81 families (Sætersdal and De Bruin, 1978, Blindheim, *et al.*, 1979, Blindheim and Foyn, 1980). About 30 species are the most common. Emperor fishes (family Lethrinidae), snappers (family Lutjanidae), jacks and trevallys (family Carangidae), groupers (family Serranidae), grunts and sweetlips (family Haemulidae), ponyfishes (family Leiognathidae), surgeon fishes (family Acanthuridae), requiem sharks (family Carcharhinidae), eagle rays (family Myliobathidae), guitar fishes (family Rhinobatidae), and sting rays (family Dasyatidae) are the major varieties.

1. 5. 4 Distribution of Resources

Demersal fish resources are distributed in the inshore waters and along the continental shelf and slope areas around the country. In general the smaller short-lived species such as pony-fishes predominate in the north and northwest while the larger, long-lived species such as snappers, emperors, groupers, sharks and rays predominate in the other areas of the continental shelf (De Bruin, 1978). It has been noted that the changes in species composition vary in accordance with differences in bottom conditions and the depth. The depth of 20-60 m range is the most productive for demersal fish (De Bruin *et al.*, 1994). Analysis of the composition of the trawl catches made by RV 'Dr Fridtjof Nansen' (Sivasubramanium, 1985) showed that the lethrinids were the most frequently occurring fish group on the west coast, followed by carangids, skates and leiognathids. In the south, lethrinids were replaced by serranids, followed by lutjanids and lethrinids. On the east coast lujanids was the dominant family followed by carangids, pomadasyids, lethrinids and serranids in the order of abundance.

1. 5. 5 Stock Status

Although a number of bottom trawl surveys have been carried out around Sri Lanka over the years in order to study the distribution and abundance of demersal resources, it was only the 'Dr Fridtjof Nansen' acoustic survey (1978-80) that estimated the total biomass of demersal resources in the coastal waters (Sivasubramanium, 1985). But this investigation could not make separate estimates for species or species groups. The potential yield of demersal fish from the continental areas was estimated to be about 80,000 t per annum (35,000 t from the shallow Palk Bay/Palk Strait area in the north and 45,000 t from the rest of the continental shelf (Blindhieim and Foyn, 1980). More detailed analysis of data of the 'Dr Fridtjof Nansen' survey has produced an estimation of maximum sustainable yield (MSY) of the more valuable varieties of large demersals such as emperors, snappers and carangids in the order of 28,000-29,000 t (Sivasubramanium, 1985).

1. 6 FISHERIES MANAGEMENT

As in other tropical countries the coastal fisheries in Sri Lanka are both multispecies and multigear in nature. Except for a few cases of traditional management systems (beach seine and stake-net fishery), the fish and the ocean are common property, and open-access to the coastal fisheries prevails (Atapattu, 1994). It is the open access nature of fisheries that has accelerated the fishing effort over the years, both by increasing fishing power and fishing units. In addition the state has provided incentives in the form of subsidies on capital goods and institutional credit (De Silva *et al.*, 1996). Despite increasing fishing effort, the coastal fish production has been at a stabilized level since the early 1980s (Fig. 1. 3), leading to a reduction in the fishing income which has increased the conflict between fishermen engaged in traditional fisheries and those using modern methods (Fernando, 1996). At the same time, population growth in the country and the lack of alternative income generating opportunities has led to more and more fishing boats going to sea, putting more and more pressure on coastal fisheries. The involvement of around 120,000 fishermen in mostly small scale fishing has forced the government to consider, as an important management objective, how to improve the socio-economic status of these fishermen, whilst preventing over exploitation of fish stocks. International agreements in fisheries emphasize responsible fishing and the adoption of a precautionary approach (United Nations 1992, FAO, 1995). The development and management of fisheries in Sri Lanka was based on the Fisheries Ordinance promulgated in 1940. The fisheries industry has developed into a complex situation over the years, but the provisions of the Fisheries Ordinance have not changed, and were no longer adequate for efficient management. Therefore a new Fisheries and Aquatic Resources Act No 2 with complete legislation for fisheries management was promulgated in 1996 (Atapattu, 1996).

The need for better management has shown the inadequacy of information for the provision of scientific advice (Dayaratne, 1996) and that there was a lack of expertise in the appropriate fields. The problems of tropical small scale fisheries are usually complex, comprising socio-economic and political issues as well as biological issues. It is unlikely that the objectives of management can be described solely by biological bases such as maximum sustainable yield (MSY) and optimum effort which produces MSY (f_{MSY}). Past experience has shown that biological assessment alone has not helped much in the management of fishery resources in Sri Lanka (Alexander, 1975, 1976, Fernando, 1996, De Alwis, 1996). The small scale fisheries sector in Sri Lanka is a priority target for poverty relief. Fisheries are amongst the most complex of human activities, linking people with the aquatic environment and its renewable resources. The formation of management and development schemes need to take account of these multiple objectives and the multifaceted nature of the system, in order to achieve the aim of reducing poverty. The lack of information pertaining to the resources, the technology and socio-eonomic aspects of the small scale fisheries has hindered the planning and development of an effective management scheme. Studies conducted on bio-socio-economics of small scale fisheries in Sri Lanka are so far limited. A study on bio-socio-economics of fishing for small pelagics along the southwest coast of Sri Lanka was undertaken with an objective to build an information base for policy formulation to solve the conflict between the purse seine fishermen and the small scale fishermen targeting the same small pelagic resources (Dayaratne and Sivakumaran, 1994). Vidanage and Wimalasena (2000) undertook a socio-economic study to fill the gaps of the understanding of small tuna fishery conducted through ring nets and gillnets in the southern coast with a similar objective.

The management problems are highly localized so that the information needed is dependent on the specific type and state of the fishery concerned. There is little published information relating to the management of demersal fisheries in Sri Lanka. The general impression given by the literature is that these resources are widely considered to be under-exploited and most research and development effort has gone into promotion of new or efficient fishing methods (Weerasooriya *et al.*, 1985; Hammerman, 1986) to improve the extraction capacity of fisheries. The technological and socio-economic impacts of the various fishery development projects that have been carried out to increase catches have not been evaluated. It is noteworthy that the 'study of innovation in a cultural vacuum' by Alexander (1975) precisely describes the end result of many fishery developments carried over the past years in Sri Lanka.

The demersal fishery resources consist of a number of quite distinct biological, geographic and economic components. Grouping these together, as is commonly done, masks the considerable internal variation that exists in the fishery. This could lead to over-exploitation of some of the valuable large demersal fish, which are both limited in abundance and have a discrete distribution. In addition, fishing effort shows a patchy distribution. High concentration of fishing effort is found in a few places like Chilaw, Negombo and Hambantota (Fig. 1.1) in the western and southern coasts respectively. Some of the fishing methods have broader environmental effects (Rajasoriya *et al.*, 1995; Dayaratne *et al.*, 1997). The use of these environmentally unfriendly gears are mostly found in the areas where the fishing effort is high (Maldeniya, 1997) and there the conflicts are generally reported. Fishermen as well as resources do not move long distances in demersal fisheries. The approach must favour the intensive, independent study of selected areas providing a unit stock, which in turn support a unit fishery, as opposed to the more conventional broad view of the entire national fishery.

The present study focused its attention on the demersal fishery in the west coast of Sri

Lanka, off Negombo, which is the largest coastal fishing area in Sri Lanka. Of the total number of coastal small scale fishing crafts registered in 1998 (26,908) about 13.3% (3,806) were operating in this area (Anon, 1998). The area is highly accessible and connected to the roads leading to the most populated cities. Most of the fishing is carried out within a 20-25 km coastal stretch and the area is extremely productive due to the influence of Negombo lagoon and river runoff, mangroves, coral reefs and seagrass which line the coastal fringes of the shelves (Anon, 1994). The small pelagic fishery which is the major coastal fishery in this area has reached a maximum production level (Karunasinghe, 1990) but fishing effort is steadily growing. Population growth and economic changes in the country has intensified the growth of fishing effort. The decline of seasonal migration of fishermen to the north and east coast during the lean season, due to prevailing civil disturbances in these areas since early 1980s, has directed fishing effort to other fishery resources in the area. These increased efforts have been borne mainly by demersal fisheries because the other fisheries such as prawn trawling, stake netting and beach seining are managed through traditional systems. The effort of demersal fisheries has thus steadily increased as a result of their open access nature. At present many types of fishing gears are being used in the area throughout the year despite the heavy monsoon winds. Some of the gears used are non-selective and destructive. The small pelagic and shrimp fisheries in the areas have been studied in detailed, and management issues have been identified (Karunasinghe, 1990; Sanders *et al.*, 2000), but there is a lack of research activities regarding demersal resources in this area.

The high levels of fishing pressure exerted on demersal resources in the area have led to a growing concern regarding the sustainability of the harvest of resources and an awareness that effective steps must be taken to manage fishery resources exploitation. The effective management methodology of planning, evaluation and adjustment in the early development process before a critical situation is reached is the more desirable approach to implement strategy, but as mentioned earlier the problems of tropical multispecies small scale fisheries are generally complex, comprising of biological, economical, social and political issues. Multidisciplinary research, which provides information on bio-socio-economic aspects of fisheries, is therefore of fundamental importance. Proper management needs first to identify the problems pertaining to the fishery and then plan and implement the strategies to remove the causes of such problems.

1. 7 AIMS AND OBJECTIVES OF THE STUDY

The present study aims to provide quantitative information for the resource base and on the technology and economy of the exploitation, marketing strategy and the social status of the fishing community engaged in demersal fisheries in the Negombo area for the primary purpose of developing an effective management scheme.

The objectives of the study are as follows:

- Assessment of the present status of the demersal fishey.
- Assessment of demersal fish stocks and their exploitation.
- Examination and evaluation of the income distribution among fishing gears and of different user groups.
- Examination and evaluation of marketing strategy and identify the factors affect the income of fish sales.
- Examination and evaluation of the socio-economic status of different user groups and identify socio-economical management issues.
- Identification of appropriate management strategies for the demersal fisheries in Negombo area based on the bio-socio-economic status.

1. 8 ORGANIZATION OF THE THESIS

The thesis consists of nine chapters including this chapter.

- Chapter 1,

Presents a general description of marine fishery resources, their environment and the status of small scale fisheries in Sri Lanka. Most emphasis is given to demersal fisheries.

- Chapter 2,

Presents the assessment of demersal fisheries, identifying crafts and gear engaged and dynamics of fisheries. Provides estimates of fishing effort, catch in volume, catch composition and size composition data of major species.

- Chapter 3,

Provides information on reproductive biology of commercially important species *Lethrinus nebulosus* and *Lethrinus lentjan* in the demersal catch off the Negombo area

- Chapter 4,

Provides information on length-weight relationship and vital statistics of *Lethrinus nebulosus* and *Lethrinus lentjan* which are needed to develop single species stock assessment models.

- Chapter 5,

Undertakes stock assessment through single species and multispecies models and estimates the maximum sustainable yield (MSY) and the fishing effort which produces MSY. Discusses the biological management strategy under multispecies and single species situations.

- Chapter 6,

Presents cost structures and profitability of demersal fishing with different boat/gear combinations and performs economic modeling under single species and multispecies situation

- Chapter 7,

Presents marketing strategies of demersal fish catches in the area and identify constrains which affect fish price

- Chapter 8,

Presents the socio-economic structure of fishing households engaged in demersal fishing with different boat/gear combinations and identifies the demographic and socio-cultural condition in Negombo area.

- Chapter 9,

Presents the general discussion and provide conclusions and recommendations, and also discusses the limitation of this study and future research needs

This thesis is based on original field research carried out as a part of an ongoing research project into bio-socio-economics of demersal fisheries in Sri Lanka of the National Aquatic Resources, Research and Development Agency (NARA) and the Sida/SAREC (Swedish International Development Agency/Swedish Agency for Research Co-operation) Coastal fisheries management Program

Chapter 2

Assessment of Demersal Fisheries in the West Coast of Sri Lanka

2. 1 INTRODUCTION

Demersal fish production in the west coast of Sri Lanka has always been greater than of the southwest coast but second to the northwest coast of the country (Maldeniya, 1985). Two District Fisheries Extension Offices (DFEO) administer the west coast fisheries. The Negombo DFEO area extends between the Maha Oya and Kelani river estuaries (Fig. 2. 1) contributed over 79% to the total demersal finfish production in 1985 and the balance came from Colombo DFEO area, extends between the Kelani river and Bolgoda lake estuaries (Maldeniya, 1985). The recent innovations in the west coast fishery, such as introduction of new and more efficient demersal fishing methods (Weerasooriya, *et al.*, 1985; Maldeniya, 1987), the arrival of additional fishing vessels from the northern and eastern parts of the country during the political upheaval of mid 1980s and the decline of seasonal migration of fishermen from Negombo area to northern and eastern coasts during the lean fishing season have increased demersal fishing activities in the Negombo area. These changes have resulted in an increased fishing effort through an increase in the number of units, an improved efficiency and an extension of fishing operations over time and space (Maldeniya, 1997). At present, demersal fish account for one of the major groups of fish landed in the Negombo area.

The objective of this chapter is to assess the present status of the fishery and to obtain reliable estimates of fishing effort, volume of the catch, catch composition, and the production trends by boat/gear combination, with the final objective of utilizing these data to assess the potential yield and to evaluate possible management strategy for the multispecies demersal fishery in the Negombo area.

2. 2 MATERIALS AND METHODS

In response to the rapid growth of demersal fisheries in the Negombo area, a sampling programme to monitor the bio-economic activities of demersal fisheries was started in 1992 by the National Aquatic Resources Research and Development Agency (NARA). Sampling was conducted on 5-6 days per month during the initial phase (January 1992 to December 1996), at 4 selected major landing centers, Pitipana, Kuttiduwa, Palagathurai and Kammaltota (Fig 2. 1). In the second phase sampling was increased to 9-10 days per month and an additional two centers, Hendala and

Kepungoda were also sampled with the financial assistance of Sida/SAREC (Swedish International Development Agency/Swedish Agency for Research Cooperation) coastal fisheries management programme from January 1997 to December 1999. Additional weekly visits were also made to collect information on fishing effort by boat/gear combination made in other landing centers, which are not covered by the sampling programme. Sampling sites were selected to be as representative as to cover possible landings of all demersal fisheries. The assessment of fisheries in the present study utilized the data collected in both phases.

The number of boats landed, volume and composition of the catch, effort by different boat/gear combination and the size frequency of major species were collected as statistical data. The collection of length data was given high priority because of its value in the estimation of population and fishery parameters (Chapter 4) and stock assessment (Chapter 5) of demersal species. The collection of length data of all species would be impossible and hence work was concentrated on certain indicator species chosen to cover the main groups of demersal fish and whose size composition range was sufficiently wide to provide an early measure of any effect of fishing. In addition, information on fishing area and depth, time spent on fishing, number of fishing units used, number of crew, type of boat used, price of fish species, income, expenditure, ancillary catch, number of days engaged in fishing per week etc. were also collected from boats engaged in demersal fisheries. These data were collected by either random sampling of fishing boats or by interviewing fishermen. Fishermen generally use a calibrated rope with an attached eight (Maiyama) to measure the fishing depth and also get some idea about the sea-bed. The by-catch in the prawn trawl fishery was not sampled, as the present study focused mainly on large demersal resources. Information on the production of by-catch of prawn trawl is already available for this area (Sanders *et al.*, 2000). The juvenile forms of large demersal fish are rarely encountered in trawl catches. Pelagic fisheries were not sampled, as there is no substantial contribution to the total demersal fish production through the use of pelagic gear.

The FAO Species Identification Sheets for Fishery Purposes – West Indian Ocean (Fishing Area 51) (Fischer and Bianchi, 1984), the FAO Species Identification Field

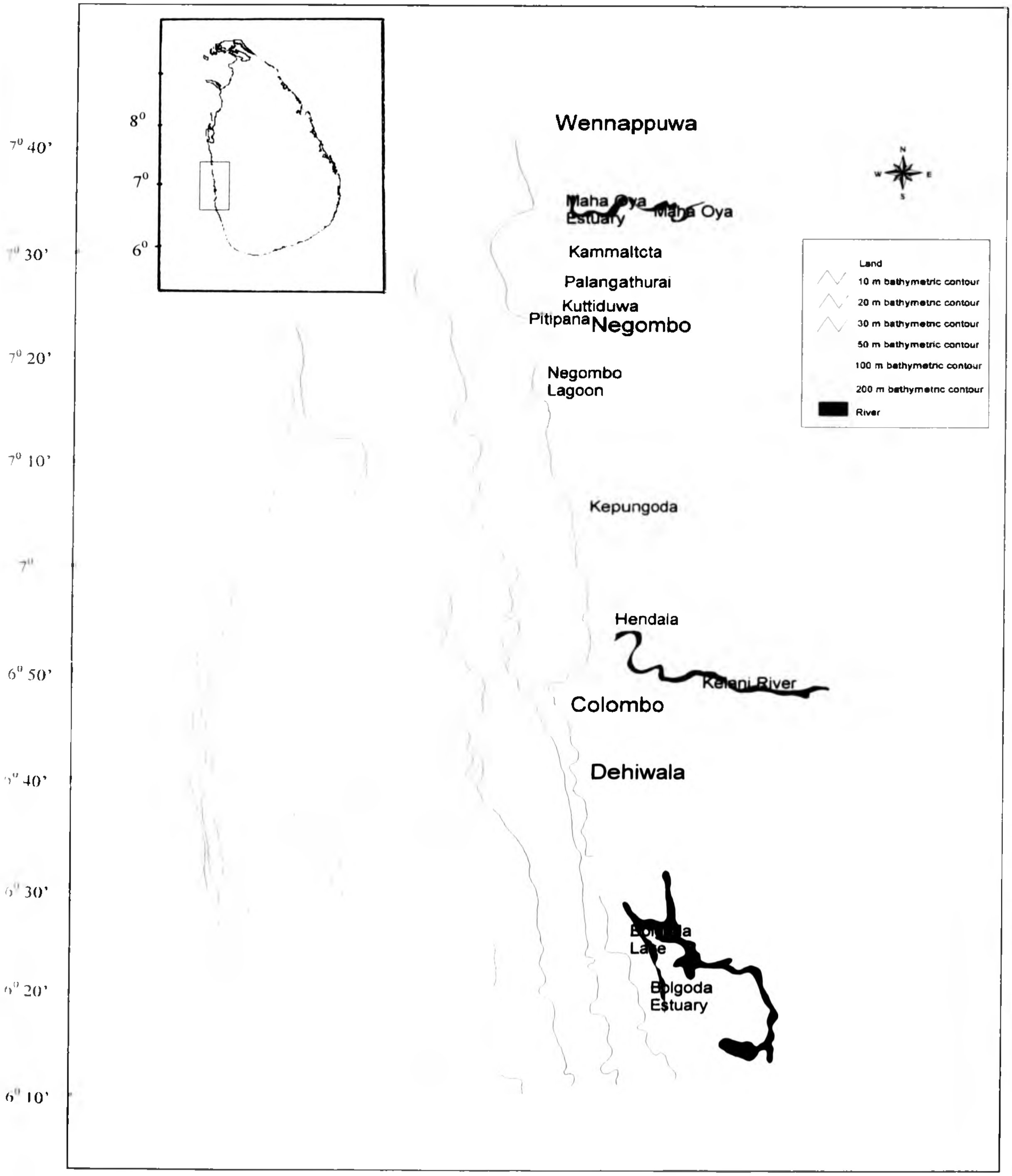


Fig. 2.1. Fishing area and major fish landing sites

Guild for Fishery Purposes (De Bruin *et al.*, 1994), The Marine and Fresh Water Fishes of Ceylon (Munro, 1982), Commercial Sea Fishes of India (Talwar and Kacker, 1984), Sea Fishes (Smith and Heemstra, 1977), the FAO Species Catalogue, Emperor Fishes and Large Eye Breams of the World (family Lethrinidae) (Carpenter and Allen, 1989), the FAO Species Catalogue, Snappers of the World (family Lutjanidae) (Allen, 1985), the FAO Species Cataloge, Nemipterid Fishes of the World (Russe, 1990), the FAO Species Catalogue, Groupers of the World (Heemstra and Randall, 1993), the FAO Species Catalogue Part I and Part II, Sharks of the World (Compagno, 1984a and 1984b), the FAO Species Catalogue, Cephalopods of the world (Roper *et al.*, 1984) were used to identify species. Most of the bony fishes (Teleosts) of economical importance were identified to species level but cartilaginous fishes (Elasmobranchs) (shark, skate, ray etc.), shell fish (prawns, lobsters, crabs) and molluscs (squid, cuttlefish and octopus) were not identified in such detail.

2. 2. 1 Fishing Ground

Sampling showed that the demersal fishing operations are primarily confined to the area between Wennappuwa and Dehiwala (Lat 6.50 – 7.25 N^0 and Long 79.30 – 79.55 E^0). It has a coastline of approximately 110 km in length with complex mangrove fringed lagoon and estuarine embayments (Fig. 2.1) (Anon, 1994). The continental shelf here covers a total of about 72,500 ha down to the 50 m depth contour of which around 7330 ha is located between the shore line to 10 m depth, 21770 ha between 10 – 20 m depth, 29440 ha between 20-30 m depth and 13960 ha between 30-50 m depth.

The topography of the fishing area is mostly uneven and associated with rocky or coralline areas. Limited sandy or muddy-sand areas are found close to the shore where prawn trawling takes place (Fig. 1.2).

2. 2. 2 Fishing Gear

Fishing methods presently used to target demersal fish resources are, handline, bottomset gillnet, bottom longline (Fig. 2.1), bottom trammelnet (Ballo del) (Fig. 2.3) and spear fishing using either snorkels or scuba. The fishermen use two types of handline. Boats, which operate handline fishing alone generally conduct bait cage

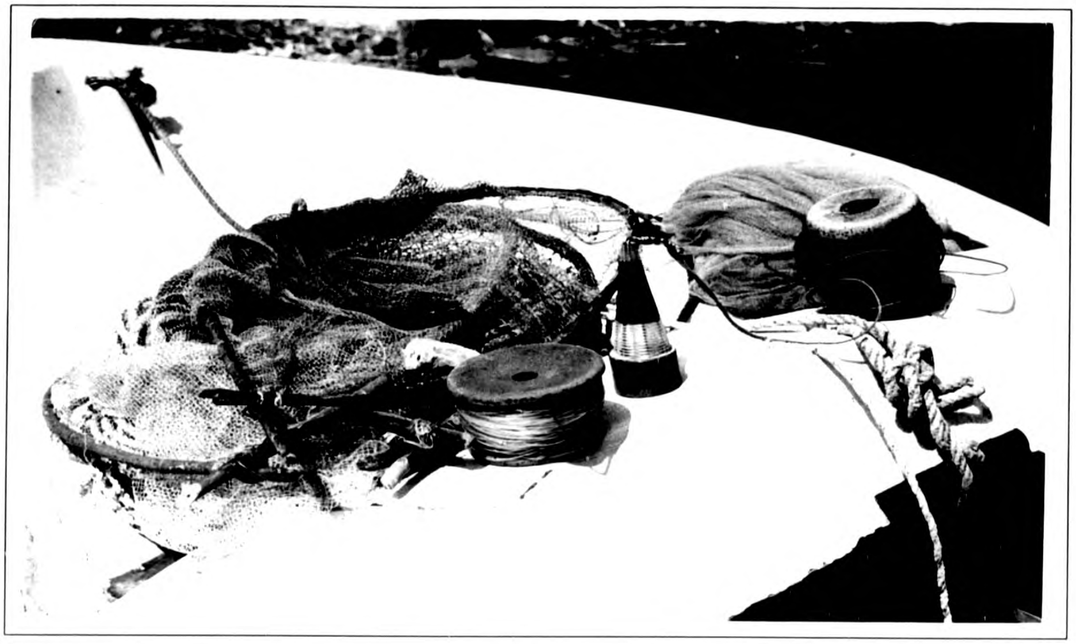


Fig. 2.2. Bait cage handline.

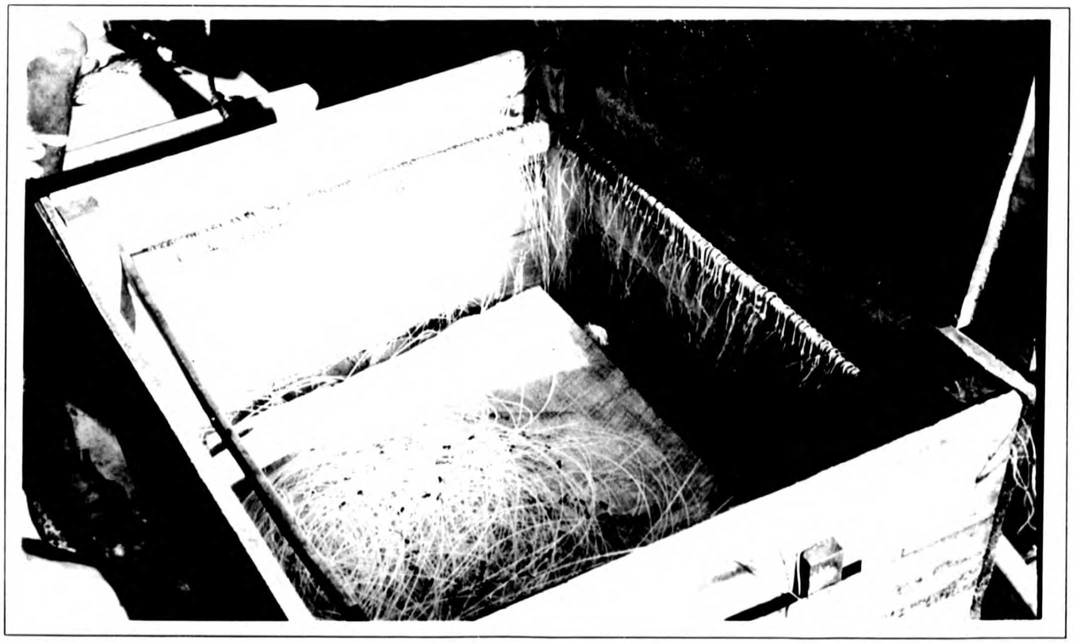


Fig. 2.3. Bottom longline.

Fig. 2.4. Bottom trammel net.

handline fishing (Fig. 2. 4), and the boats which operate handline in combined with small mesh drift gillnets conduct drop handline fishing. During the lean season for trawling some of the 3.5 t (28-32 ft size class) inboard motor boats (IBM) conduct bait cage handline fishing with trawl caught prawns (HL*). In addition about 100-150, 17 –22 ft size class outboard motor boats (OBM) operate bait cage handline (HL) purchasing live prawns from lagoon stake net catches. Fishermen generally use a wide range of hook sizes or mesh sizes and non-selective gears to ensure the catch of a wide size range. The operational characteristics and specifications of the fishing gear used for demersal fishing in the Negombo area are listed in Table 2.1

2. 2. 3 Fishing Craft (Boat)

On average 250-300 craft are engaged exclusively in demersal finfish fisheries in Negombo area. They are basically 17 –22 ft size class boats, powered with 15-25 hp outboard motors (OBM) (Fig. 2. 5) and use a variety of fishing gear, such as bottom longline (BLL), bottom set gill net (BSN), bottom trammel net (BTN), spear fishing (SPF) and bait cage handline (HL). During the non-monsoon (October to April) period some of the 3.5 ton type (28-32 ft) inboard motor (IBM) (Fig. 2. 6) prawn trawlers also operate for bait cage handline fishing (HL*). In addition some of the 17 –22 ft OBM boats which operate pelagic small-mesh gillnet also conduct drop handline fishing with gillnets (HL/DN) or shift to demersal fisheries during the lean season of pelagic fisheries (October to April). Monthly variation of the number of boats of different categories which operated in the different fisheries for the period 1992-1999 are listed in Tables 2 . 2a to 2. 2h.

Fig. 2.5. 17-28 ft outboard motor boat (OBM boat).

Fig. 2.6. 28-32 ft inboard motor boat (IBM boat).

Table 2.1. Specifications and operational characteristics of demersal fishing gears used in the Negombo area.

Fishing gear	Gear specification	Operational characteristics
Drop handline fishing (HL-DN)	200-300 m monofilament mainline carrying 2-3 ft or 1-1.5 m monofilament branch lines above the sinker. Cut pieces of fish or squid are used for bait. Hooks of the size range of No. 3 – 12 are used.	Fishing mainly in daytime or at night mainly without light attraction. Most of the HL-DN combination boats use this method year round to catch large demersal fish.
Bait cage handline fishing (HL) (HL*)	As above but uses a small conical cane or wire cage 570-90 mm in diameter and 200-250 mm high containing live prawns to attract fish. Hooks of the size range of No. 8-17 are used	The cage is lowered on a length of monofilament and fishing carried on around it, usually in the daytime. Both IBM boats (HL*) and OBM boats (HL) use this method.
Bottom longline (BLL)	4 mm kuralon main-line with 1 m long monofilament branch lines attached at 2 m intervals. Floats are attached to each end of the line using 6 mm polypropylene rope. 300-1000 hooks of the size rang of No. 5-10 are generally used. Bait is squid, cuttlefish or cut pieces of fish.	This fishery is conducted year round but effort is high during nonmonsoonal period as some of the boats which generally operated drift gillnets for small pelagics shift to operate this gear during non-monsoon period (October – April).
Bottom trammel net (BTN)	Inner net is 4 ply and 50-70 mm mesh size, typically 1,500 meshes long and 40 meshes deep. Outer net is 6-9 ply and 380-410 mm mesh size, typically 1500-1600 meshes long and 70-80 meshes deep. An inner and two outer panels are hung to a 7-8 mm dia. Polypropylene head rope with floats at 3-5 m intervals and a 3-4 mm dia. Foot rope with 10-20 g lead sinkers attached at intervals of 30-40 cm by 1.5-2 mm dia. Pieces of sinker rope. A cement sinker of about 750 g is attached at the joint between each pair of adjacent net pieces. Usually about 25 net pieces are used.	This has been introduced into Sri Lanka quite recently and is used to target most inshore demersal fish as well as lobsters. Generally operate near shore area
Bottom set gillnet (BSN)	8-12 pieces of 4-27 ply net (normal size 1500 meshes long by 40-60 meshes deep) of 60-125 mm mesh size hung to a 3-5 mm dia. Polypropylene head rope rigged with small floats at 4-6 intervals. 200-300 g sinkers of 100 mm dia. are attached to the 3 mm polypropylene foot rope every 4 - 5 m. For skate, up to 12 pieces of 27-36 ply 360-460 mm mesh net hung to a 8 mm dia. Polypropylene head rope with floats attached every 10-15 m and a 3 mm dia. Foot-rope with 500-600 g circular cement sinkers of 110-120 mm dia. Attached.	The main variation is for bony fish and for skate, with the mesh size of the nets varying according to the fish being targeted. Nets are laid in areas of the soft bottom, usually during the months when seas are calm. Fishermen often select used pelagic drift nets for bottom set nets.
Spear fishing (SPF)	Fishing is mainly done by those engaging in SCUBA diving in the coastal areas. Fishing is conducted during non-monsoonal period, diving to a maximum of about 20-25 m.	Spear guns are imported to Sri Lanka illegally. About 6-8 skilled fishermen in Negombo participate in the fishery.

Table 2.2a. Number of boat operated by different boat/gear combination for demersal fishing in 1992.

Year	IBM boats	OBM boats						Total
1992	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	10	121	23	33	12	1	205	405
Feb	9	98	36	29	8	2	286	468
Mar	12	111	21	42	17	2	392	597
Apr	7	115	15	49	19	2	396	603
May	10	84		63	6	1	402	566
Jun		72		58	7	1	377	515
Jul		103		41		1	412	557
Aug		131	1	46		1	269	448
Sep	6	154	8	59	2	1	304	534
Oct	15	148	21	43	9	2	272	510
Nov	17	135	33	39	16	2	311	553
Dec	11	129	19	42	18	2	228	449
Av.	10.8	116.8	19.7	45.3	11.4	1.5	321.2	517.1

Table 2.2b. Number of boat operated by different boat/gear combination for demersal fishing in 1993.

Year	IBM boats	OBM boats						Total
1993	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	8	135	27	28	11	2	238	449
Feb	10	122	31	37	10	2	312	524
Mar	19	106	28	41	9	2	473	678
Apr	12	125	18	58	21	2	421	657
May	9	76		54	6	1	484	630
Jun		64		61	2	1	471	599
Jul		83		53		1	425	562
Aug	3	102		48		1	303	457
Sep	2	138	12	57	8	2	381	600
Oct	13	159	19	36	13	2	316	558
Nov	12	141	23	42	15	2	358	593
Dec	7	115	21	39	17	2	253	454
Av.	9.5	113.8	22.4	46.2	11.2	1.7	369.6	563.4

Note: Abbreviation as per Table 2.1.

Table 2.2c. Number of boat operated by different boat/gear combination for demersal fishing in 1994.

Year	IBM boats	OBM boats						
1994	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	Total
Jan	11	123	36	36	6	2	249	463
Feb	13	135	48	49	9	2	326	582
Mar	17	117	47	36	11		456	684
Apr	19	129	33	52			440	673
May	5	97		63	21		506	692
Jun	1	57		69	17		495	639
Jul		81	8	57	8		444	598
Aug		105	15	77	3		316	516
Sep		134	36	68	2	2	398	640
Oct	9	157	31	52	7	2	330	588
Nov	15	161	22	43	6	2	374	623
Dec	16	146	28	51	5	2	264	512
Av.	11.8	120.2	25.3	54.4	8.6	2.0	383.2	600.8

Table 2.2d. Number of boat operated by different boat/gear combination for demersal fishing in 1995.

Year	IBM boats	OBM boats						
1995	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	Total
Jan	7	121	43	52		2	264	489
Feb	15	107	38	59		2	347	568
Mar	9	152	45	76	5		485	772
Apr	17	146	26	64	17		467	737
May	6	86	4	85	11		537	729
Jun	9	101		51	5		523	689
Jul		88		57	8		472	625
Aug		123	12	86	2	1	336	560
Sep	11	128	14	93		2	423	671
Oct	7	147	30	90		2	351	627
Nov	18	155	32	72	5	2	379	663
Dec	12	132	35	63	8	2	280	532
Av.	11.1	123.8	23.3	70.7	7.6	1.9	405.3	638.5

Note: Abbreviation as per Table 2.1.

Table 2.2e. Number of boat operated by different boat/gear combination for demersal fishing in 1996.

Year	IBM boats	OBM boats						Total
1996	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	19	121	54	65	2	2	275	538
Feb	22	119	56	79	3	2	360	641
Mar	18	132	58	72	2	2	504	788
Apr	12	113	42	80	5	2	486	740
May	11	82	19	91	4		559	766
Jun	8	87	7	85	7		544	738
Jul	2	117	3	93	9		491	715
Aug		99	8	95	6		349	557
Sep	7	120	21	102			440	690
Oct	10	147	38	77	2		365	639
Nov	18	155	47	87	1	2	413	723
Dec	15	142	39	60	2	2	292	552
Av.	12.9	119.5	32.7	82.2	3.9	2.0	423.2	673.9

Table 2. 2f. Number of boat operated by different boat/gear combination for demersal fishing in 1997.

Year	IBM boats	OBM boats						Total
1997	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	16	143	49	68	2		285	563
Feb	11	137	54	79	3	1	374	659
Mar	19	144	56	72	2	1	523	817
Apr	21	96	68	83	3		504	775
May	8	112	36	106	4		580	846
Jun	9	72	17	92	7		564	761
Jul	3	91	22	116	9		509	750
Aug		127	42	125	6		362	662
Sep	4	142	39	112			457	754
Oct	16	161	31	79		1	379	667
Nov	17	155	38	87		1	429	727
Dec	19	147	36	61	1	1	303	568
Av.	13.0	127.3	40.7	90.0	1.0	1.0	439.1	712.4

Note: Abbreviation as per Table 2.1.

Table 2.2g. Number of boat operated by different boat/gear combination for demersal fishing in 1998.

Year	IBM boats	OBM boats						Total
1998	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	18	81	61	56	5	1	296	518
Feb	13	98	55	78	11		388	643
Mar	23	86	72	69	9	1	542	802
Apr	19	69	66	86	13	1	523	777
May	11	111	25	103	7	1	601	859
Jun		84	11	84		1	585	765
Jul		95	17	95	1		528	736
Aug		87	28	87	4		376	582
Sep		139	48	99	5		473	764
Oct	4	128	37	77	6	1	393	646
Nov	19	121	54	82	3		445	724
Dec	14	94	59	42	8	1	314	532
Av.	15.1	99.4	44.4	79.8	21.7	1.0	455.3	695.7

Table 2.2h. Number of boat operated by different boat/gear combination for demersal fishing in 1999.

Year	IBM boats	OBM boats						Total
1999	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
Jan	27	73	58	52	2		303	515
Feb	19	85	76	43	9		397	629
Mar	24	93	69	55	10	1	465	717
Apr	17	123	73	79	13	1	535	841
May	11	91	71	115	1	1	615	905
Jun	2	101	23	102			599	828
Jul		76	14	75			540	705
Aug		88	19	93			385	585
Sep		113	36	101	7		484	741
Oct	1	146	44	62	9	1	361	624
Nov	14	122	49	79	2	1	405	672
Dec	17	124	63	45	2	1	321	573
Av.	14.7	102.9	49.6	75.1	26.9	1.0	450.8	694.6

Note: Abbreviation as per Table 2.1

2. 2. 4 Unit of Fishing Effort

Crafts engaged in demersal fishing generally operate once a day with one gear type The fishing operations last for about 5 –10 hours Most fishermen set off to the fishing grounds early in the morning and return before noon. Bottomset gillnets on the other hand, are set in the evening and the catch is collected the next morning Fishermen in gear combination boats shoot their pelagic nets first and conduct handline fishing for about 5-7 hours until hauling the nets Manning of fishing craft varied from 2 to 4 crewmen Generally 4 fishermen are involved in bait cage handline fishing while 2-3 fishermen are involved in bottom longline. The bottom set gillnet, bottom trammelnet, spear fishing and gear combination boats manned with two fishermen. Though demersal fishing in the study area was conducted with varied gear, involving a variety of man-hours, the unit of fishing effort is considered in terms of number fishing days

2. 2. 5 Estimation of Fishing Effort

The monthly fishing effort of the study area made by the various gears was estimated through a series of steps as below

(i) *Estimation of daily effort*

Daily effort of a particular fishery in each sampling day at each sampling site was estimated as

Daily effort (site) = Number of boats sampled of a particular gear × Daily raising factor,

Where, Daily raising factor = Total number of boat landed / Total number of boats sampled (all gears)

(ii) *Estimation of monthly effort*

Monthly effort was estimated by multiplying effort of all sampling days at each sampling site by the monthly raising factor

Monthly effort (site) = Daily effort of all sampling days × Monthly raising factor,

Where, Monthly raising factor = Number of days boats landed per month / Number of days sampled

In this process it was assumed that fishing took place on 25 days in each month

(iii) *Estimation of monthly effort of the study area*

Monthly total effort in the study area for each fishery was estimated as:

Monthly total effort (area) = Σ Monthly effort at all sampling sites $\times$ Monthly raising factor

Where, Monthly raising factor = Monthly total effort in the study area/Σ Monthly total effort at all sampling sites

Information on the total number of boats of different types operated in the study area was taken from the Statistical Division of the Ministry of Fisheries and Aquatic Resources Development.

2. 2. 6 Estimation of Catch per Unit Effort (CPUE)

There was no difference (in terms of catch composition and volume) between landings of similar gear in different landing centers because in most instances they fish in the same fishing ground. Therefore catch per unit effort (CPUE) by gear was obtained by direct monitoring of the fishing activities of the particular gear. Monthly average CPUE in the study area for each fishery was estimated as:

CPUE = Σ Catch of all sample boats in a month/ No. of boats sampled

2. 2. 7 Estimation of Fish Production

The total monthly fish production in the study area for a particular gear (i) was estimated as:

Production (gear i) = monthly average CPUE (gear i) $\times$ monthly fishing effort (gear i)

The total monthly fish production in the study area by all gears was estimated as:

Production (month) = $\sum_{i}^{n}$ (CPUE (gear i) $\times$ monthly total effort (gear i)).

The monthly fish production estimates were pooled for the year to get at the total annual production.

2. 2. 8 Estimation of Size Frequency Distribution

Total length measurements (TL) were taken for all specimens of the randomly selected sample of two major species (*L. nebulosus* and *L. lentjan*) caught separately in each gear type. Length was measured from the tip of snout to the end of the longest caudal fin ray with a measuring board to the nearest unit (mm) below. The length data sample was then compiled to the size frequency distribution for species in 2 cm length intervals. The daily length frequency data of each gear in the study area were pooled for the month and the results were given as plots of monthly and annual length frequencies for each species separately for each gear or as a combination for all gears. The monthly length frequency distribution was used to estimate growth and fishery parameters (vital statistics) of these two species (Chapter 4).

2. 3 RESULTS

2. 3. 1 Fishing Effort

The total fishing effort (number of fishing days) by all gears increased steadily by about 38% from 1992 to 1997 and then slightly declined over the last two years during 1998 and 1999 (Fig. 2. 7).

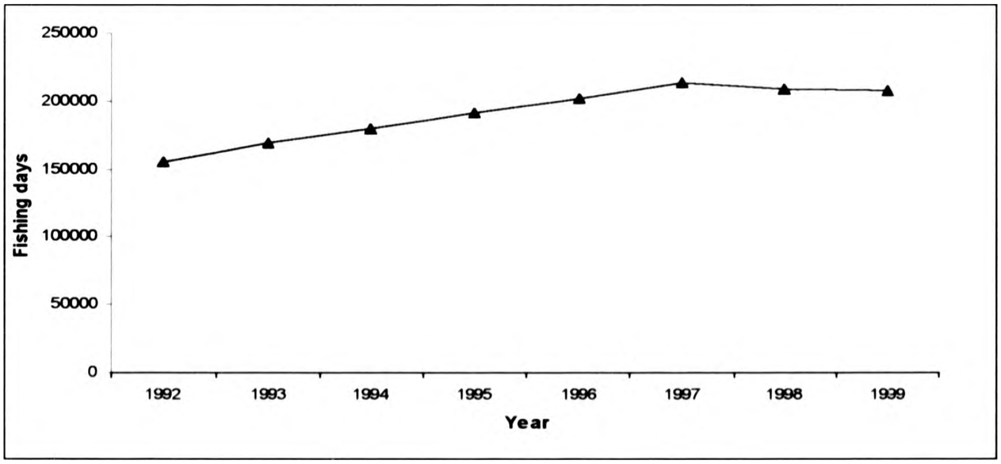


Fig. 2. 7. Estimated total annual fishing effort by all gears.

The contribution of fishing effort by boat/gear combination to the total fishing effort is illustrated in Fig. 2. 8. Drop handline fishing combined with drift gillnet was the most important fishing method in the exploitation of demersal resources in the area. On average it contributed about 64% of the total fishing effort by all gears during the period 1992-1999. The second most important fishing method (about 18% of the total effort) was bait cage handline fishing conducted with out board motor (OBM) boats. A considerable amount of fishing effort also occured through bottom trammel net (11%) and bottom longline (5%). Fishing effort through bottom set gillnet (1%) and spear fishing (0.2%) with OBM boats were relatively lower than other gears and showed a declining trend over the years. The seasonal handline fishing effort with inboard motor (IBM) boats was also low (1.5%) and has remained more or less unchanged over the period as there was little change in the number of IBM boats engaged in handline fishing (Table 2. 2a to 2.2h).

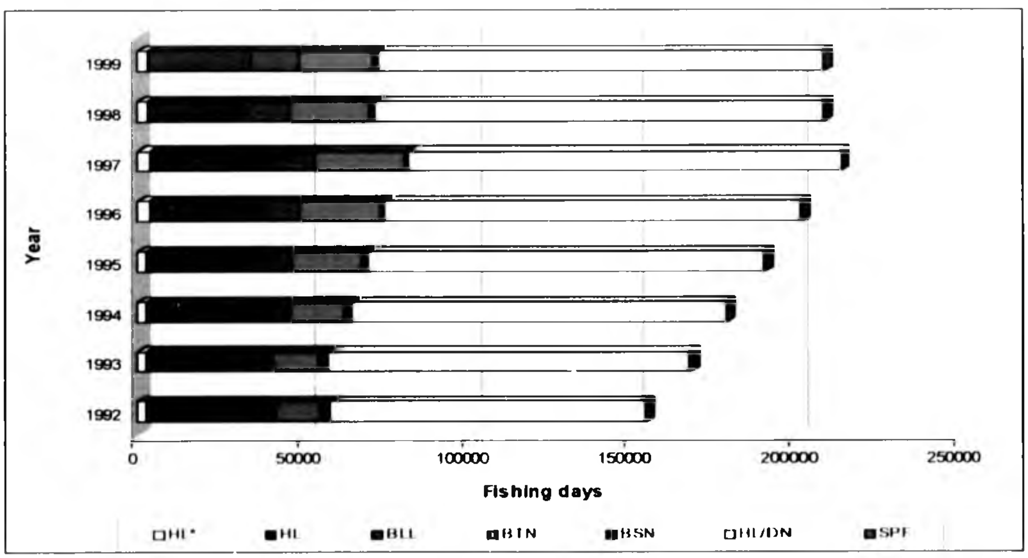


Fig. 2. 8. Estimated annual fishing effort by boat/gear combination

Note: (HL*) bait cage handline fishing with inboard motor (IBM) boats, (HL) bait cage handline fishing with out board motor boats (OBM); (BLL) bottom longline fishing with OBM boats; (BTN) bottom trammel net with OBM boats; (BSN) bottom set gillnet with OBM boats; (SPF) spear fishing with OBM boats , (HL/DN) handline fishing combined with drift gillnet with OBM boats.

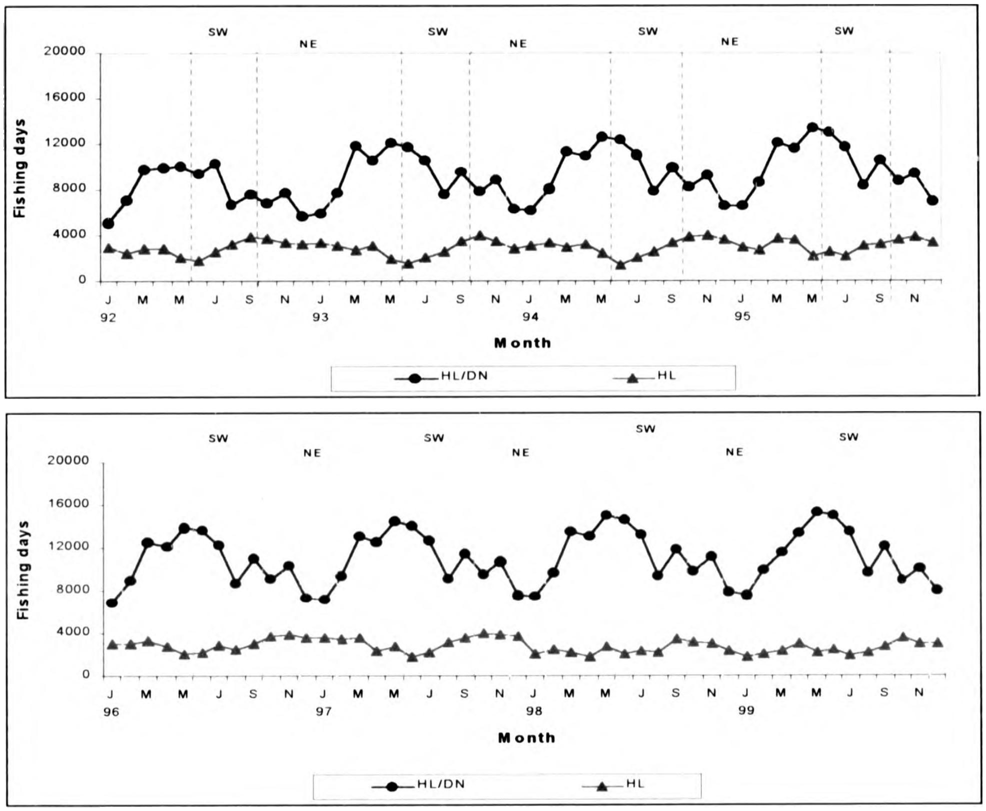
The relative importance of the fishing effort of various gears has changed over the past two years. Through bait cage hand line fishing with OBM boats has remained a popular fishing method throughout all these years, the effort has declined by about

13% and the effort of bottom set gillnet and spear fishing has also declined by 52% and 61% respectively. Meanwhile the use of bottom longline, bottom trammel net and handline fishing combined with drift gillnet has gained popularity and have shown increases of 70%, 40% and 29% respectively over the years 1992 to 1999. The amount of fishing effort directed at present through bottom trammel netting was second only to drop handline fishing combined with drift gill net and bait cage handline fishing with OBM boats.

2. 3. 1. 1 Seasonal Variation of Fishing Effort

The estimated monthly fishing effort by gear engaged in demersal finfish fisheries are given in Fig 2.9a to 2.9c.

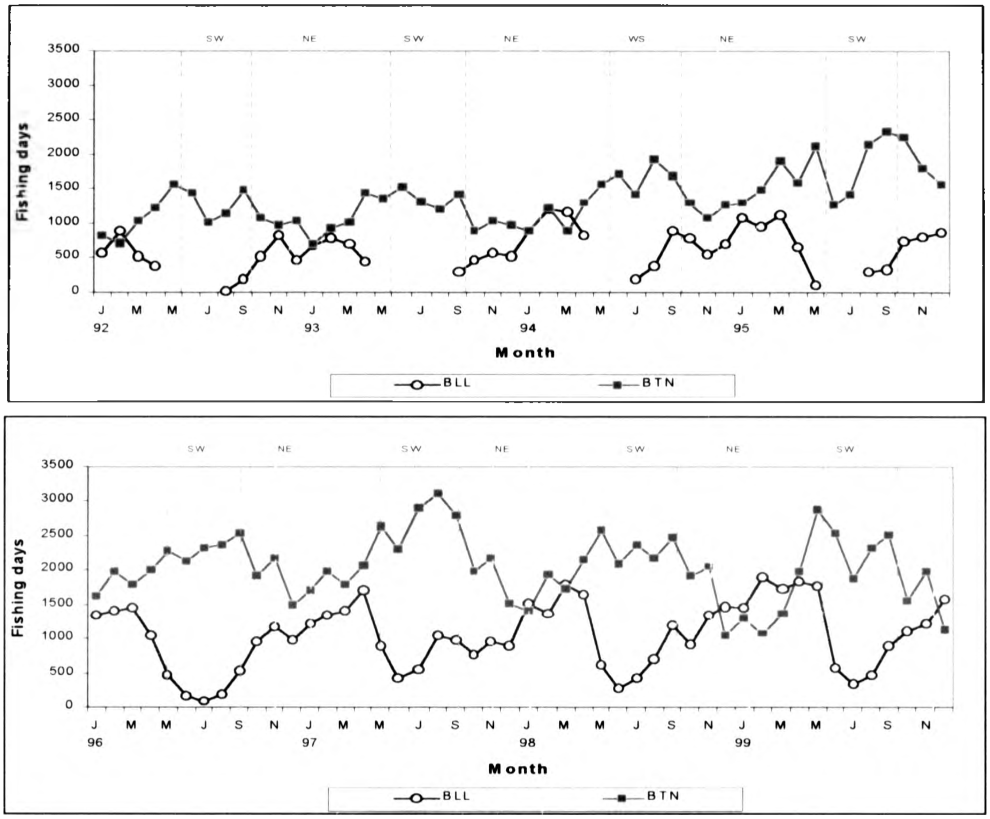
The variations of fishing effort of handline fishing (drop handline) combined with drift gillnet followed similar pattern in all years. Fishing effort increased during the inter-monsoon period from February to April and declined during the monsoon months May to September (South-West monsoon) and November to January (North-East monsoon). While the effort of handline fishing (bait cage handline) conducted by OBM boats increased towards the end of the South-West monsoon (July to September) and during the inter-monsoon period February to April. Both drop handline fishing combined with drift gillnets and traditional bait cage handline fishing with OBM boats operated year round but the fishing effort declined with the onset of monsoons (Fig. 2. 9a).



Note: SW South-West monsoon; NE North-East monsoon

Fig. 2. 9a. Seasonal variation of fishing effort of handline fishing combined with drift gillnet by OBM boats (HL/DN) and handline fishing by OBM boats (HL).

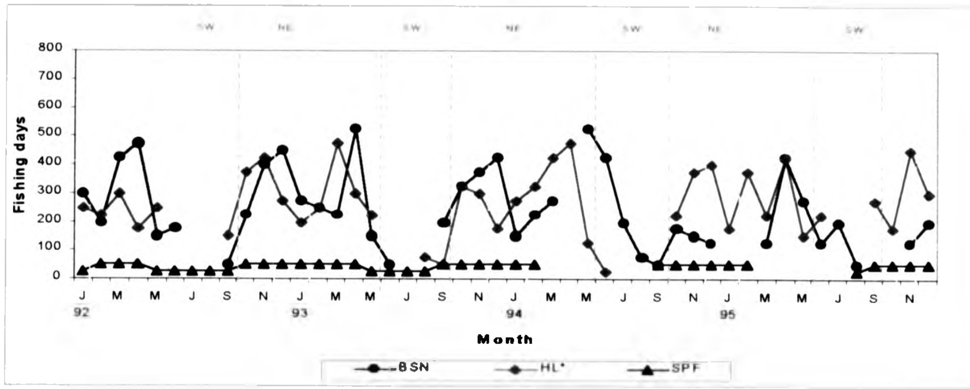
Bottom longline and bottom trammel net fishing are also conducted year round but bottom longline operated seasonally during the early 1990s (1992 to 1995) (Fig. 2. 9b). Fishing effort of bottom longline steadily increased with the decline of South-West monsoon and maximized during the inter-monsoon period from March to April. The fishing effort of bottom trammel net increased with the onset of South-West monsoon, the maximum effort being mostly reported at the later months July to September of the monsoon period and the minimum level of effort observed during North-East monsoon period.

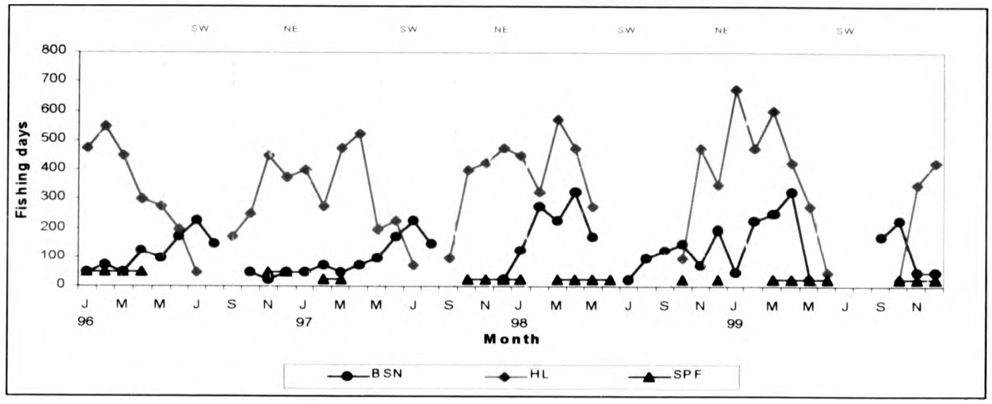


Note: SW South-West monsoon; NE North-East monsoon

Fig. 2. 9b. Seasonal variation of fishing effort of bottom longline with OBM boats (BLL) and bottom trammel net (BTN) fishing with OBM boats.

Bottom set gill net fishing and spear fishing with OBM boats and hand line fishing with IBM boats are more seasonal and commence with the decline of South-West monsoon period and reaches highest levels during the non-monsoon period (March/April). However, some increase in fishing effort of bottom set gill net has been observed with the onset of South-West monsoon winds (April/ May) (Fig. 2. 9c).





Note: SW South-West monsoon; NE North-East monsoon

Fig 2. 9c. Seasonal variation of fishing effort of handline fishing with IBM boats (HL*),bottom set gillnet (BSN), and spear fishing with OBM boats (SPF).

2. 3. 1. 2 Fishing Effort in Relation to Fishing Depth

The fishing activities of different boat/gear combinations have been performed in different depth ranges. The distribution of fishing effort in relation to fishing depth is given in Fig. 2. 10. Fishing activity of all boat/gear combinations were predominantly conducted within the 11- 40 m depth range. Only bait cage handline fishing with OBM boats, bait cage handline fishing with IBM boats and bottom longline fishing with OBM boats have conducted fishing in depths exceeding 40 m. Fishing effort of about 46% of bottom longline, 11% of handline with OBM boats and 27% of handline with IBM boats extended beyond 40 m depth. Bottom trammel netting, bottom set gillnet and spear fishing with OBM boats operate in shallow waters, mainly confined to the 11-20 m depth range while the effort of handline combined with drift gillnets, handline with IBM boats, handline with OBM boats and bottom longline was mainly confined to the intermediate depth zone (20-40 m).

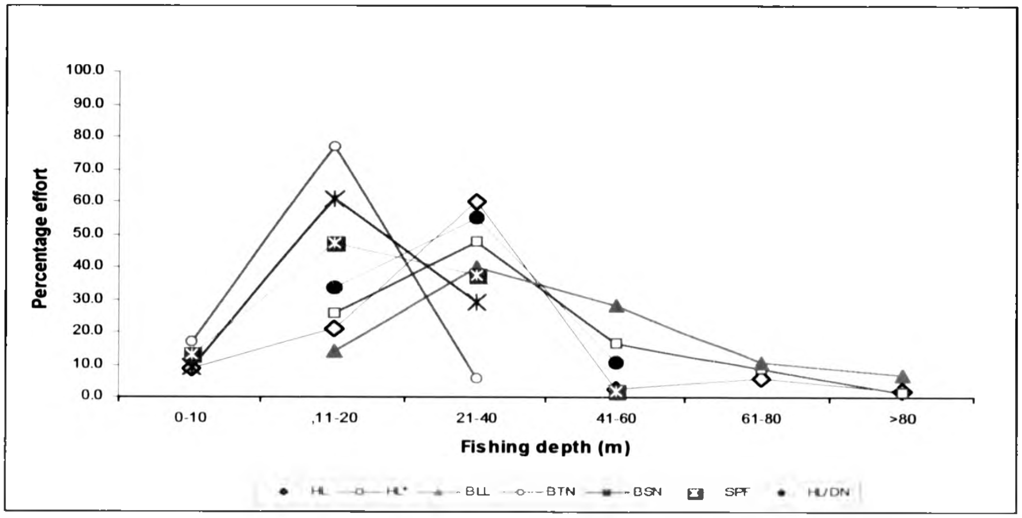


Fig. 2. 10. Percentage distribution of fishing effort by boat/gear combination in different depth ranges in 1999.

Note: BLL = bottom longline fishing with OBM boats. HL = handline fishing with OBM boats. HL* = handline fishing with IBM boats. BSN = bottom set gillnet fishing with OBM boats. BTN = Bottom trammel net fishing with OBM boats. HL/DN = handline fishing combined with drift gillnet with OBM boats. SPF = spear fishing with OBM boats.

2. 3. 2 Inter Annual Variation of Catch per Unit Effort (CPUE)

The estimated average annual CPUE of all species by different fishing boat/gear combinations are given in Table 2. 3.

The highest annual average CPUE was reported for handline fishing operated with IBM boats followed by bottom longline fishing, spear fishing and bottomset gillnets with OBM boats. The CPUE realized by handline drift gillnet combination boats were relatively lower than any other gear. The annual average CPUE realized by bait cage handline and bottom trammel net fishing with OBM boats were quite close to each other. Except for handline fishing combined with drift gillnet, there were no large differences in CPUE among fishing gears operated for demersal resources in the area.

The limited amount of time and space available for operation of handlines limit the CPUE of handline combined with drift gillnet fishery.

The of CPUE by bait cage handline, bottom longline and bottom trammel nets fishing with OBM boats have shown a declining trend while CPUE of handline fishing combined with drift gillnet has shown an increasing trend over the years from 1992-1999.

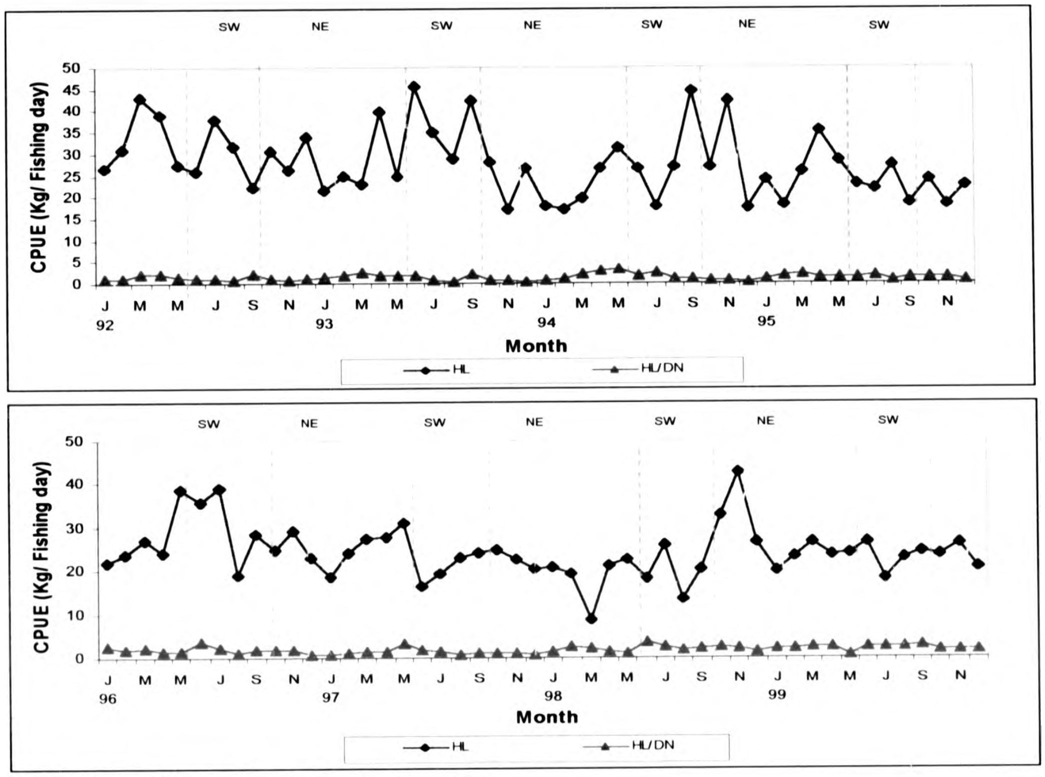
Table 2. 3. Annual variation of CPUE by boat/gear combination.

Year	Catch per unit effort (kg/fishing day)						
	IBM boats	OBM boats					
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN
1992	39.64	31.34	55.97	33.62	55.41	35.97	1.35
1993	37.95	29.81	44.19	28.21	30.55	25.80	1.34
1994	36.30	26.34	39.63	28.42	26.03	39.08	1.57
1995	36.44	24.01	37.74	23.37	22.91	27.40	1.45
1996	36.63	27.85	36.49	24.98	30.39	46.68	1.87
1997	42.07	23.34	35.25	27.84	31.49	55.97	1.39
1998	41.11	22.77	26.63	17.56	24.86	30.92	2.14
1999	36.34	23.40	29.66	18.70	40.41	27.17	2.17
Average	38.31	26.11	38.20	25.46	32.76	36.12	1.66

2. 3. 2. 1 Seasonal Variation of CPUE

Average monthly CPUE of all species by different boat/gear combination is shown in Fig. 2. 11a to 2. 11c.

The CPUE of bait cage handline fishing with OBM boats generally decline with the onset of monsoon winds, April/May and November/December but increase with the improvement of weather conditions towards the end of monsoon (Fig. 2. 11a). The seasonal variation of handline fishing combined with drift gillnet was not as clear as bait cage handline fishing with OBM boats alone. However, some increase was observed with the onset of the South-West monsoon and again at the decline of the monsoon. Although the monsoon periods appear as regular intervals on the graphs the onset of strong winds may vary from year to year. Thus the seasonal pattern of CPUE varies from year to year (Fig. 2. 11a).



Note: SW = South-West monsoon; NE = North-East monsoon

Fig. 2. 11a. Seasonal variation of CPUE of handline fishing with OBM boats (HL) and handline fishing combined with drift gillnet by OBM boats (HL/DN)

The CPUE of bottom longline fishing increase during the latter part of the monsoon or mainly during the non-monsoon months while in bottom trammel net fishery relatively higher CPUE is generally reported during the monsoon months (Fig. 2. 11b).

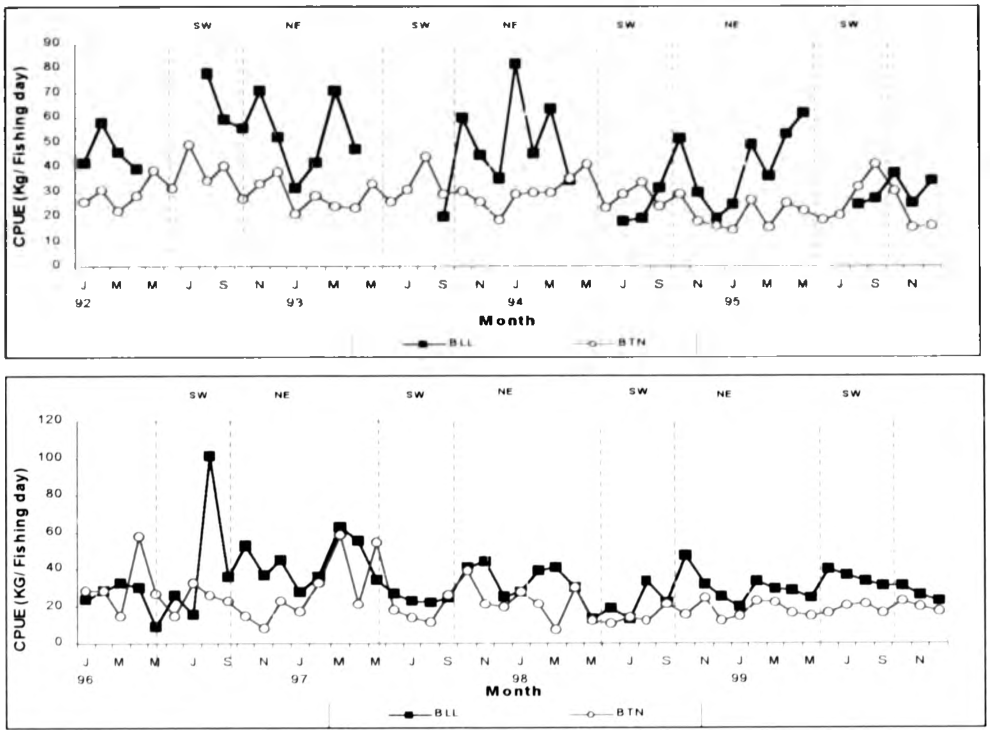


Fig. 2. 11b. Seasonal variation of CPUE of bottom longline fishing with OBM boats (BLL) and bottom trammel net fishing with OBM boats (BTN).

The operation of bottom set gillnets, spear fishing and seasonal handline fishing with IBM boats were seasonal in nature. Relatively higher CPUE for all three fisheries were reported during non monsoon months (Fig. 2. 11c).

The CPUE of bait cage handline with OBM boats (Fig. 2. 11a), bottom longline (Fig. 2. 11b) and bottom set gillnet (Fig. 2. 11c) fishing generally followed the monsoon pattern. An increase of CPUE was observed at the end of the South-West monsoon, September to November and in the inter monsoon months but declined during strong monsoon months, May to July in most years. In the bottom trammel net fishery high CPUE were reported mostly in the monsoon months, May to July. Seasonal variation was not indicated in the handline fishery made by the combination boats.

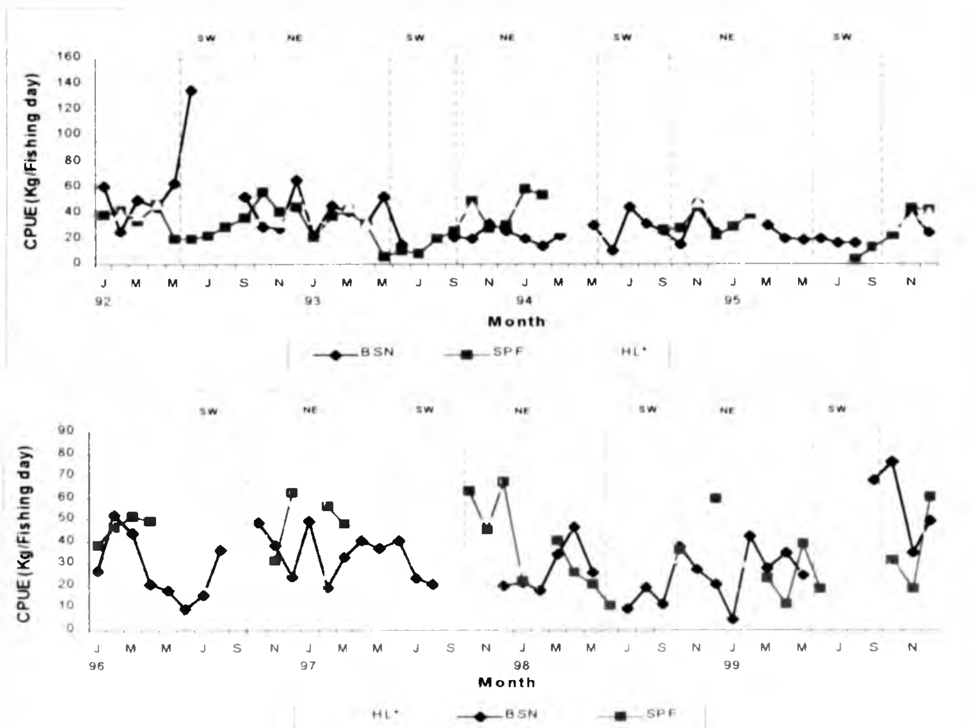


Fig. 2. 11c. Seasonal variation of CPUE of bottom set gillnet (BSN), spear fishing (SPF) and handline fishing with IBM boats (HL*)

2. 3. 2. 2 Variation of CPUE in Relation to Fishing Depth

The CPUE of different boat/gear combinations appears to be maximal at different depths (Fig. 2. 12). The highest CPUE was reported for bottom trammel net at shallow depths (10-20 m) while bottomset gillnet, spear fishing and handline fishing combined with drift gillnets were maximized at intermediate depths, 21- 40 m. The CPUE of bait cage handline fishing with IBM boats, bait cage handline fishing with OBM boats and bottom longline fishing improved progressively with increasing depth and the CPUE of bottom longline was maximal at 61-80 m depth range.

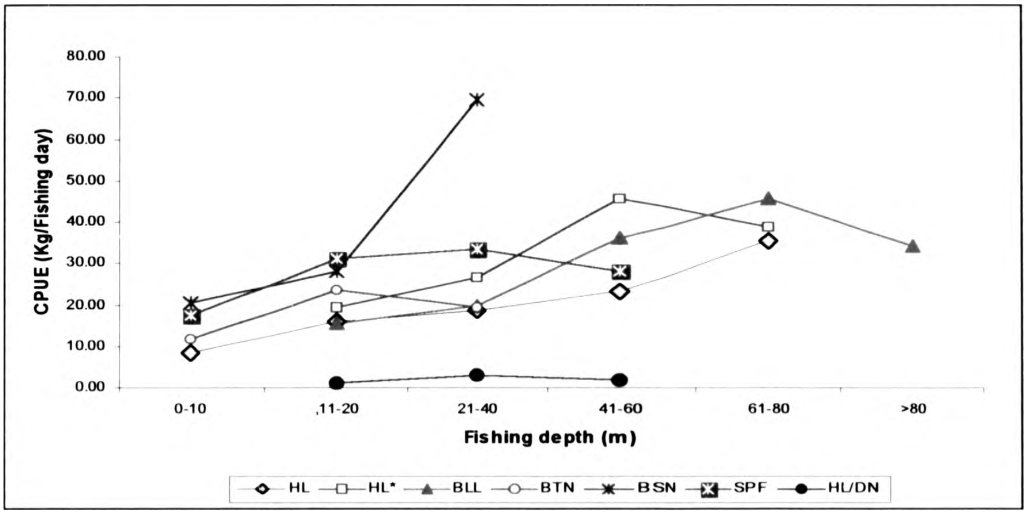


Fig.2. 12. Variation of CPUE by boat/gear combination in different depth ranges for 1999

Note: BLL = bottom longline fishing with OBM boats. HL = handline fishing with OBM boats. HL* = handline fishing with IBM boats. BSN = bottom set gillnet fishing with OBM boats. BTN = Bottom trammel net fishing with OBM boats. HL/DN = handline fishing combined with drift gillnet with OBM boats. SPF = spear fishing with OBM boats.

2. 2. 3 Fish Production

The estimated annual landings of demersal fish by different gears in the study area for the period 1992 to 1999 are shown in Fig. 2. 13. The demersal fish production has fluctuated over the years. In recent years (between 1995 to 1997) the production has increased from 1,994,555 kg in 1995 to 2,481,280 kg in 1997 and then declined to 2,021,630 kg and 2,041,602 kg in 1998 and 1999 respectively. The reduction in the fish catch is due to the decline in the effort since 1998.

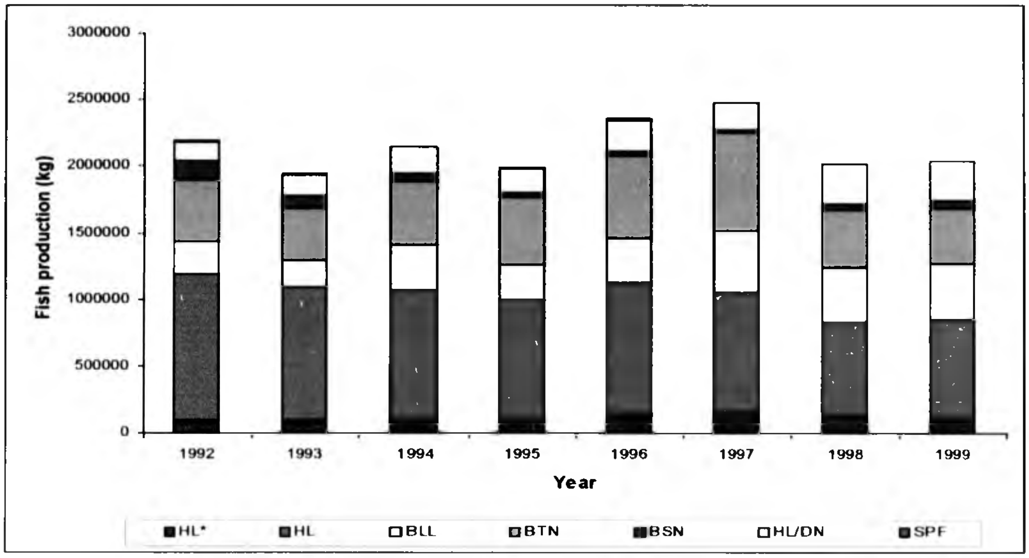


Fig. 2. 13. Demersal fish production (kg) in the Negombo area – West coast of Sri Lanka, 1992-1999.

Bait cage handline with OBM boats formed the largest proportion of the catch followed by bottom trammel-net, then bottom longline (Fig. 2. 13). The contribution of bait cage handlines with OBM boats and bottom set gillnet has declined while the contribution from bottom longline has increased over the period 1992 -1999. The bottom trammel-net catch increased at a steady rate up to 1997 (from 463,631 kg to 733,196 kg) and then declined to 411,891 kg in 1999. The IBM boats operating seasonal bait cage handline fishing contributed a fairly consistent production. The percentage contribution of spear fishing to the total production was insignificant due to the low fishing effort. The maximum catch of 17,416 kg of spear fishing was reported in 1992 and it declined to 5,104 kg in 1999.

2. 3. 4 Dynamic of Demersal Fishery

Average monthly catch, effort and CPUE of all species in three main gears, bait cage handline with OBM boats, bottom longline and bottom trammel net operated with OBM boats during 1992-1999 are shown in Fig. 2. 14. Intra-annual dynamics of fishing effort and CPUE of bottom longline and bottom trammel net seem linked to catch while in the bait cage handline fishery with OBM boats catch and effort seem

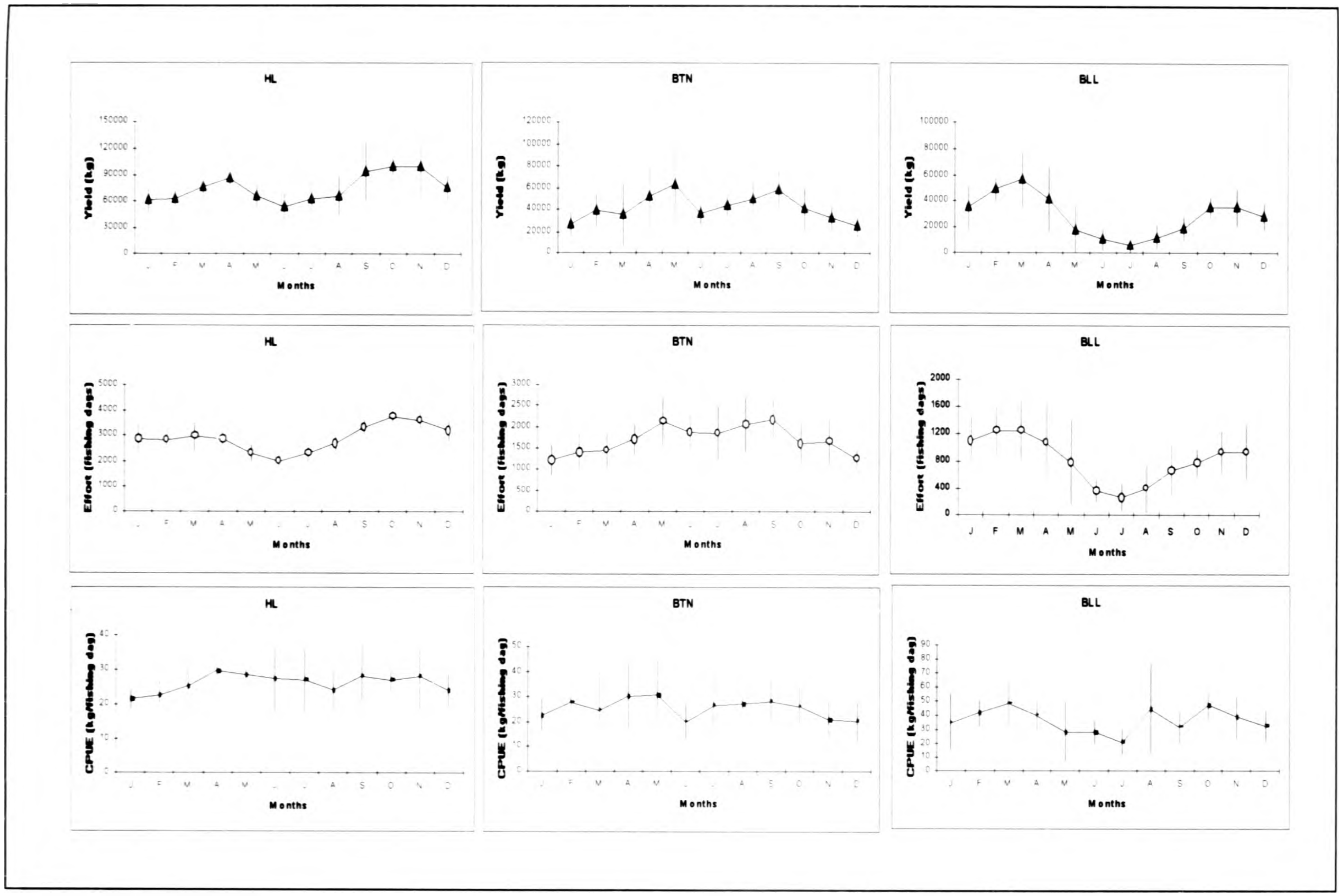


Fig. 2. 14. Average monthly catch (kg), effort (fishing days) and CPUE (kg/fishing day) of different fisheries from 1992-1999. Vertical bars indicates the monthly range of the estimates.

linked but CPUE is relatively steady. It indicates that the pattern of fishing effort follows the availability of fish by bottom longline and bottom trammel net fisheries. Hand line fishing effort, catch and CPUE was high in February to April and again in September to November coinciding with inter-monsoon periods. Similarly bottom longline has shown a higher effort, a higher catch and increased CPEU in September to April. Relatively high catch, effort and CPUE for bottom trammel net was reported in March to May and again in July to October coinciding with the strong rains prevailing at the beginning and at the end of the South-West monsoon.

2. 3. 5 Catch Composition

The relative contributions of major 'fish' categories to the total demersal catch over the period 1992 – 1999 in the study area are given in Table 2.4. An increase in the relative contribution of Cephalopods (squids and cuttlefish) has been observed over the period but particularly in the year 1999. The contribution of Elasmobranchs (sharks and skates) to the total demersal catch has shown a gradual decline from 7.9% in 1992 to 2.7% in 1999. Teleost (bony fish) fish contribution has remained the major component of the catch throughout the period.

Table 2.4. Percentage contribution of major 'fish' categories to the total demersal fish landings in 1992-1999.

Major fish categories	Percentage composition							
	1992	1993	1994	1995	1996	1997	1998	1999
Crustaceans	0 5	0 3	0 3	0.4	0 1	0 1	0.1	0.2
Cephalopods	0.2	0.5	0.1	0 6	0.9	0.8	1 9	3 4
Elasmobranchs	7 9	8.2	7 5	1 8	5.9	2 9	3.3	2.7
Teleosts	91 4	90.0	92 1	97.2	93 1	96.2	94 9	93.7

2. 3. 6 Species Composition

A total of 139 species belonging to 68 families of bony fishes were identified in the demersal catches in Negombo area. The species identified are given in Table 2. 5. Annual species composition in percentage by weight of demersal fish caught in all gears in different years are illustrated in Fig. 2. 15.

Table 2. 5 List of species identified in the demersal fish catches in the Negombo area during 1992-1999

Division/Order	Family	Species	Common/ English name	Local name
Shrimps and prawns	-	-	Shrimp and prawns	Issa
Lobsters	Palinuridae	-	Lobster	Pokirissa
Crabs	Portunidae	*Portunus pelagicus*	Sea crabs/Blue swimming crabs	Mudu kakuly
Cephalopods	Loliginidae	-	Squids	Bothal della
	Ommistophoridae	-	Squids	Yak della
	Onychoteuthidae	-	Squids	Gini gella
	Sephidae	*Sepia pharaonis*	Cuttlefish/ Pharaoh cuttlefish	Gebi della
	Octopodidae	-	Octopus	Buwalla
Sea cucumber	Holothuriidae	-	Beache-de-mer/sea cucumber	Mudu kudella
Batoid fishes	Rhinobatidae	-	Shovel nose ray	Baloliya
	Narkidae	-	Numb fish	Hirimaduwa
	Rajidae	-	Skate	Pihatu maduwa
	Dasyatididae	-	Sting rays	Welli maduwa
	Gymnuridae	-	Gymnuridae	Nelum maduwa
	Myliobatididae	-	Cow nose ray	Sangosa
	Mobulidae	-	Devil ray	Aga maduwa
Sharks	Hemiscyllidae		Bamboo shark	Kurakkan mora

Continuation- sheet2

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Acanthuridae	*Acanthurus sp.*	Surgeon fishes	Detta
		Acanthurus xanthopterus	Yellow surgeon fish	Detta
		Naso annulatus	Banded unicorn fish	Buruwa
	Albulidae	*Albula sp.*	Bone fish	Meeya
	Ambassidae	*Ambassis gymnocephalus*	Glass fish	Kattilla
	Ariidae	*Arius sp.*	Sea cat fish	Aguluwa
		Arius thalassinus	Giant cat fish	Thora aguluwa
	Balistidae	*Balistoides viridescens*	Bluefin trigger fish	Kukula
		Odonus niger	Redtoothed trigger fish	Kalu potubari/Kakaka
	Belonidae	-	Needle fishes	Habarali/Theliya
	Caesionidae	*Caesio tere*	Yellow and blueback fusilier	Anil bolla
		Diterygonotus balteatus	Mottled fusilier/Red bait	Higura
	Carangidae	*Alectis ciliaris*	African pompano	Kannadi parawa
		Alectis indicus	Indian thread fish	Kannadi parawa
		Alepes sp.	Scad	Thelmalla
		Atule mate	Yellowtail scad	Ginnati parawa
		Carangoides Caeruleopinnatus	Coastal trevally	Pihati parawa
		Carangoides fulvoguttatus	Yellow spotted trevally	Thumba parawa
		Carangoides gymnostethus	Bludger	Vetti parawa
		Carangoides sp.	Whip trevally	Penna parawa
		Caranx heberi	Black-tip trevally	Kahaparawa/Guru parawa
		Caranx ignobilis	Giant trevally	Atanagul parawa
		Caranx melampygys	Blue- fin trevally	Nil parawa
		Caranx sexfasciatus.	Big-eye trevally	Hora parawa
		Decapterus sp.	Mackerel scad	Linna/Bolla
		Elagatis bipinnulata	Rainbow runner	Lenaparawa

Continuation –sheet 3

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Carangidae	*Gnathanodon speciosus*	Golden trevally	Kabara parawa
		Megalaspis cordyla	Torpedo scad	Kiralawa/Venkadaya
		Scombroides sp.	Queen fish	Kattawa
		Selar crumenophthlmus	Big-eye scad	Asgedi bolla
		Selaroides leptolepis	Yellow-stripe scad	Sura parawa
		Seriola rivoliana	Almaco jack	Keeli parawa
		Trachinotus sp.	Dart	Kukulamaha
		Uluma mentalis	Long-rakered trevally	Katakaluwa
		Uraspis helvola	White-tongue trevally	Ha parawa
	Centropomidae	*Lates calcarifer*	Barramudi/Sea perch	Moda
	Chaetodontidae	-	Butterfly fish	Gal lella
	Chanidae	*Chanos chanos*	Milk fish	Wekkaya
	Chirocentridae	*Chirocentrus sp.*	Wolf herring	Katuwalla
	Clupeidae	*Amblygaster clupeoides*	Bleeker`s soomthbelly sardinella	Gal hurulla
		Amblygaster sirm	Spotted sardinella	Hurulla
		Nematalosa sp.	Gizzard shad	Koiya
		Sardinella sp.	Sardinella	Salaya
	Congridae	-	Conger eels	Mudu arndha
	Coryphaenidae	*Corypaena hippurus*	Dolphin fish	Vanna
	Diodontidae	-	Spiny puffers	Peththaya
	Drepanidae	*Drepane punctata*	Spotted sickle fish	Pasinthiya
	Echeneidae	*Remora sp.*	Remoras	Sapaththuwa
	Elopidae	*Elops machnata*	Tenpounder	Mannawa
	Engraulididae	*Stolephorus indicus*	Indian anchovy	Hedella

Continuation –sheet 4

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Ephippidae	*Ephippus orbis*	Spade fish	Thirali
		Platax sp.	Bat fish	Kotadora
	Exocoetidae	-	Flying fish	Piyamessa
	Fistulariidae	*Fistularia sp.*	Cornet fishes	Bombili
	Gerreidae	*Gerres filamentosus*	Whip-fin silverbiddy	Thirali
		Gerres sp.	Silverbiddy	Thirali
	Haemulidae	*Plectorhinchus sp.*	Sweet-lips	Boraluwa
		Plectorhinchus vittatus	Oriental sweet-lips	Iri boraluwa
		Pomadasys sp.	Grunter	Bataya
	Hemiramphidae	-	Half-beaks	Moralla
	Holocentridae	-	Squirrel fishes	Balal maruwa
	Istiophoridae	*Istiophorus platypterus*	Indo-Pacific sail-fish	Thalapatha
		Makaira indica	Black marlin	Koppara
	Kyphosidae	*Kyphosus cinerascens*	Blue seachub	Gal siliththa/Paramuwa
	Labridae	-	Wrasses. Coris	Girawa
	Lactariidae	*Lactarius lactarius*	False trevally	Pulunna
	Leiognathidae	-	Pony fishes	Karalla
	Lethrinidae	*Gymnocranius sp.*	Large eye bream	Makuna
		Lethrinus conchyliatus	Redaxil emperor	Meewatiya
		Lethrinus crocineus	Yellow-tail emperor	Meewatiya
		Lethrinus harak	Thumbprint emperor	Meewatiya
		Lethrinus lentjan	Pink-ear emperor	Meewatiya
		Lethrinus mahasena	Sky emperor	Meewaltiya/Katta deliya

Continuation – sheet5

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Lethrinidae	*Lethrinus mahasenoides*	Maldive emperor	Meewatiya
		Lethrinus microdon	Small-tooth emperor	Meewatiya
		Lethrinus nebulosus	Spangled emperor	Meewatiya
		Lethrinus obsoletus	Orange-striped emperor	Meewatiya
		Lethrinus olivaceus	Long-face emperor	Uru hota
		Lethrinus ornatus	Ornate emperor	Meewatiya
		Lethrinus rubrioperculatus	Spot-cheek emperor	Meewatiya
	Lobotidae		Triple-tails	Korali
	Lutjanidae	*Aphareus sp.*	Job fish	Kalamiya
		Aprion virescens	Green job fish	Dhiulawa
		Etelis sp.		Ragamuwa
		Lutjanus argentimaculatus	Mangrove red snapper	Thambuwa
		Lutjanus bengalensis	Bengal snapper	Ranna
		Lutjanus bohar	Twospot snapper	
		Lutjanus decussatus	Cheackered snapper	Ranna
		Lutjanus fulviflamma	Black-spot snapper	Ranna
		Lutjanus fulvus	Black-tail snapper	Ranna
		Lutjanus gibbus	Humpback red snapper	
		Lutjanus johnii	John's snapper	
		Lutjanus kasmira	Common blue-stripe snapper	Ranna
		Lutjanus lemniscatus	Yellow-streaked snapper	
		Lutjanus lunulatus	Lunar-tail snapper	
		Lutjanus lutjanus	Big-eye snapper	Ranna
		Lutjanus madras	Indian snapper	Ranna
		Lutjanus malabaricus	Malabar blood snapper	Gola
		Lutjanus quinquelineatus	Five-lined snapper	Ranna
		Lutjanus rivulatus	Blubber-lip snapper	Badawa
		Lutjanus russelli	Russell's snapper	Ranna
		Lutjanus sanguineus	Hump-head snapper	Kondagola
		Lutjanus sebae	Emperor red snapper	
		Lutjanus vitta	Brown-stripe snapper	Ranna
		Paracaesio sp.	Blue snapper	
		Pinjalo sp.	Pinjalo	
		Pristipomoides filamentosus	Crimson job fish	Kalamiya

Continuation – sheet6

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Lutjanidae	*Pristipomoides multidens*	Goldbanded job fish	Kalamiya
		Pristipomoides sp.	Job fish	Kalamiya
	Menidae	*Mene maculata*	Moon fish	Hadapana
	Monacanthidae		Leather-jacket	Paramanadan
	Monodactylidae		Moonies	Kapuhenda
	Mugilidae	*Liza sp.*	Mullet	Godaya
		Valamugil sp.	Mullet	Serayawa
	Mullidae		Goat fish	Nagari
	Muraenidae		Morays	Gal-gulla
	Nemipteridae	*Nemipterus sp.*	Thread-fin bream	Sudda
		Parascolopsis sp.	Monocle breams	Pulutta
		Scolopsis bimaculatus	Thumbprint monocle bream	Pittuwa
		Scolopsis sp.	Monocle breams	
		Scolopsis vosmeri	White-cheek monocle bream	
	Paralichthyidae		Short pelvic flounders	Pathamedi
	Pinguipedidae		Sand-perches	Katussa
	Platycephalidae		Spiny flatheads	Eriyalaya
	Plotosidae		Stinging cat fishes	Mudu hunga
	Polynemidae		Thread-fins tassel fishes	Kalawa
	Priacanthidae		Big-eyes	Gal pulunna
	Pristigasteridae		Iiishas	Puvali

Continuation – sheet7

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Psettodidae		Spiny turbot	Pathamedi
	Rachycentridae	*Rachycentron canadum*	Cobia	Mudilla
	Scaridae		Parrot fishes	Girawa
	Scatophagidae		Scats	Ilathi
	Sciaenidae		Croakers	Pannawa
		Protonibea diacanthus	Spotted croaker	Kurala
	Scombridae	*Acanthocybium solandri*	Wahoo	Gal thora
		Auxis rochei	Bullet tuna	Kombaya
		Auxis thazard	Frigate tuna	Alagoduwa
		Euthynnus affinis	Kawakawa	Athawalla
		Katsuwonus pelamis	Skipjack tuna	Balaya
		Rastrelliger kanagurta	Indian mackerel	Kumbalawa
		Sarda orientalis	Striped bonito	Thorabalaya
		Scomberomorus commerson	Narrowbarred spanish mackerel	Thora
		Scomberomorus guttatus	Indo-Pacific king-mackerel	Mal thora
		Scomberomorus lineolatus	Streaked seer fish	Sekkal thora
		Thunns albacares	Yellowfin tuna	Kelawalla
		Thunnus tonggol	Longtail tuna	Howalla
	Srranidae	*Cephalopholis sp.*	Hind	Thabuwa
		Epinephelus sp.	Grouper	Kossa
		Epinephelus coioides	Orange-spotted grouper	Kossa
		Epinephelus fasciatus	Blacktip grouper	Kossa
		Epinephelus faveatus	Barredchest grouper	Mal kossa
		Epinephelus malabaricus	Malabar grouper	Gal kossa
		Epinephelus undulosus	Wavylined grouper	Lawaya
		Variola louti	Yellow edged lyretail	Sangaththa
	Siganidae	*Siganus sp.*	Rabbit fish	Orawa
	Sillaginidae	*Sillago sp.*	Sillagos	Kalanda

Continuation – sheet8

	Family	Species	Common English name	Local name
Bony fish/Teleosts	Sparidae	*Acanthopagrus sp.*	Seabream	Thirali, Mattiyawa
		Argyrops sp.	Seabream	Seriya
	Sphyraenidae	*Sphyraena barracuda*	Great barracuda	Kadarala
		Sphyraena sp.	Barracuda	Jeelawa/Ulawa
	Stromateidae	*Pampus sp.*	Butter fishes	Vaovalaya
	Synodontidae	*Synodus sp.*	Lizard fish	Kattussa
	Terapontidae	*Terapon sp.*	Terapon	Keeli
	Triacanthidae		Tripod fishes	Thunkatta
	Trichiuridae		Hair-tail fishes	Sawalaya

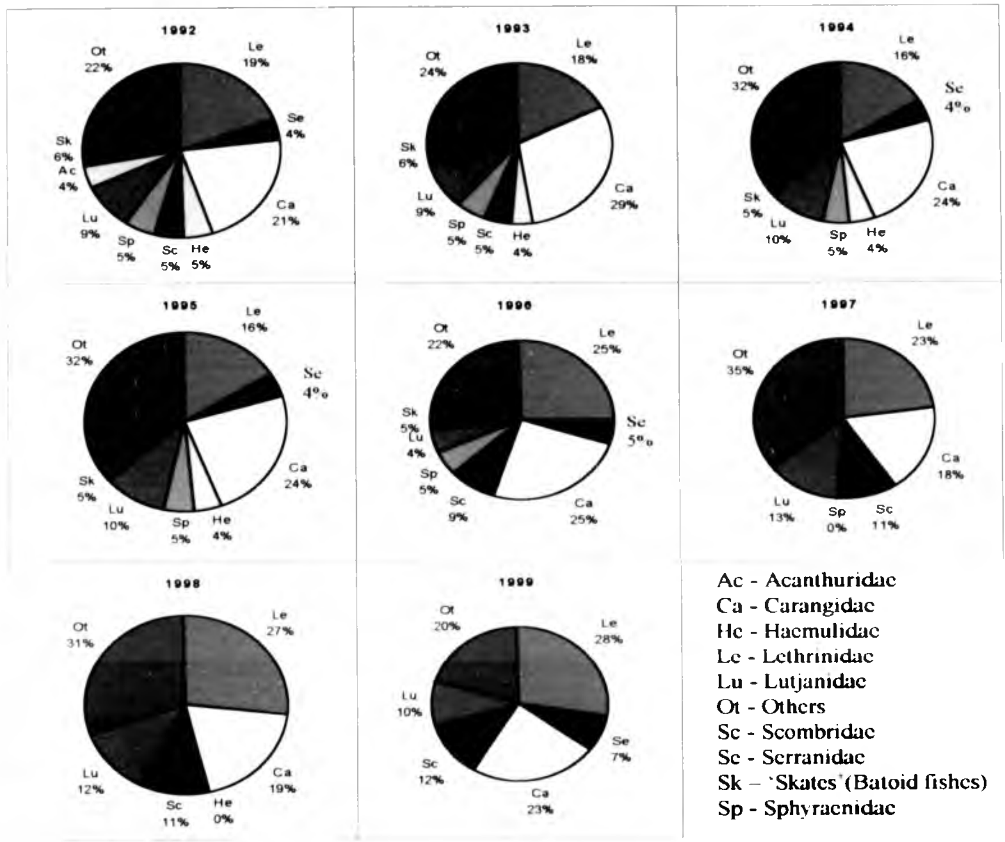


Fig. 2.15. Annual variation by weight of important group or principal families of fishes to the demersal catch off Negombo from 1992 to 1999.

Though demersal fish catches are highly diverse in terms of number of species, a few families dominate the catches. Only about 4-8 groups or families of fish are found to dominate the catches. Jacks and trevallies (family Carangidae) was the largest single group in all years from 1992 to 1995 (18% - 29%) closely followed by emperor fishes (family Lethrinidae) (16% - 28%). In 1996 both groups contributed equally and since 1997 lethrinids have been the biggest group in the catch and have shown a steady increase over the years. During the early 1990s about 7-8 fish families or groups contributed a considerable amount (> 4%) to the total catch but there has been a decline to about 4-5 fish families or groups in late 1990s, each of which consisted of a large number of species. The most important families represented in the demersal catch over the period 1992-1999 were Carangidae, Lethrinidae, Lutjanidae, Scombridae, Serrenidae Haemmulidae and Sphyrinidae.

In 1992, eight families and sharks contributed 78% and all the other species collectively contributed 22% by weight to the total demersal catch while in 1999 only 5 families contributed in bulk (80%) and the contribution of all other species was only 20%.

2. 3. 6. 1 Variation of Species Composition by Gear

The contribution of fish categories or families to the catch of different fisheries in 1999 is shown in Fig. 2. 16. Except for bottom set gillnet, all other fisheries operating in the Negombo area may considered to be interactive because they target common important species belonging to the family Carangidae, Serranidae, Lethrinidae, Lutjanidae, Scombridae and the category Cephalopods (squid and cuttle fish). Bottom longline and bottom set gillnets target limited species or families while bottom trammel net and spear fishing exploit a wide range of species. Bait cage handline fishing with OBM or IBM boats target mainly on carangids, lethrinids and lutjanids and the drop handline fishing conducted combine with drift gillnets target on scombrids and lethrinids. Fisheries employing bottom longline, bottom trammel net, bait cage handline with OBM or IBM boat and handline combined with drift gillnet have been identified as being substantially interactive in exploiting Lethrinids.

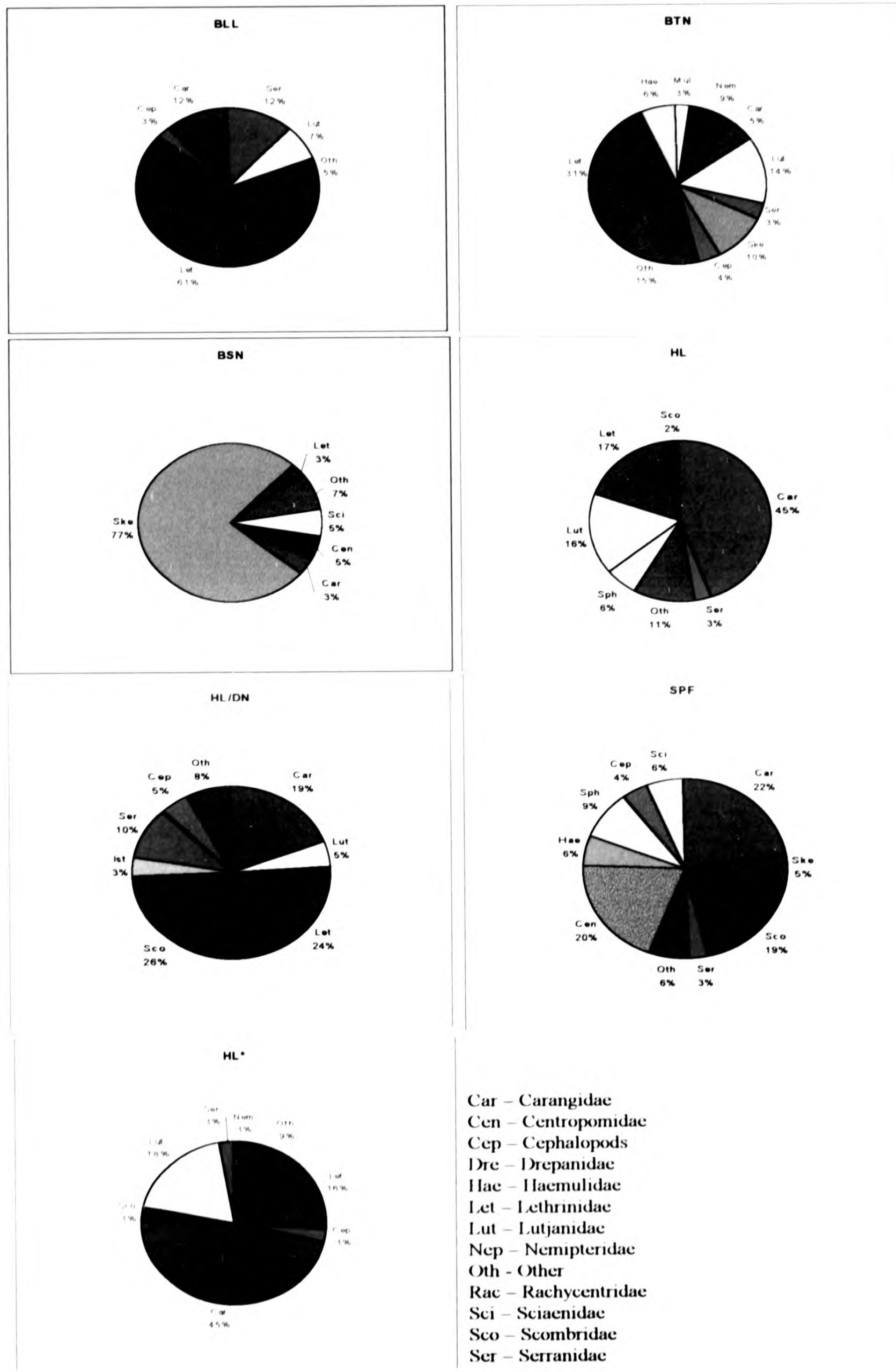


Fig. 2. 16. Contribution of important species by weight to the total catch by different boat/gear combination in the Negombo area in 1999.

2. 3. 6. 2 Variation of Species Composition by Fishing Depths

The contribution of important fish species or families/group by weight to the total catch of different depths is given in Fig. 2.17. In shallow waters (0-10 m depth) catches consisted of a large number of species but only a limited number contributed in large volume to the total catch. Smaller varieties or juvenile fish of Lutjanids- *Lutjanus fulvus* (LUFL) and *Lutjanus fluviflamma* (LUFU), Carangids- *Carangoides caeruleopinnatus* (CARCA) and *Caranx heberi* (CARHE), Lethrinids - *Lethrinus lentjan* (LETLE) and *Lethrinus nebulosus* (LETNE) and Nemipterids – *Scolopsis bimaculatus* (SCOBI) dominated in this shallow depth range. As the fishing depth increased the number of species encountered in the catches declined while the contribution of individual species increased.

In the depths of 11-20 m, Lethrinids – *Lethrinus elongatus* (LETEL), *Lethrinus mahasen* (LETMA), *Lethrinus lentjan* and *Lethrinus nebulosus*, Carangids - *Carangoides gymnostethus* (CARGY) and *Carangoides fulvoguttatus* (CARFU), Lutjanids – *Lutjanus madars* (LUTMD), Serranids – *Epinephelus sp.* (EPISP) and Siganids – *Siganus sp.* (SIGSP) dominated the catches.

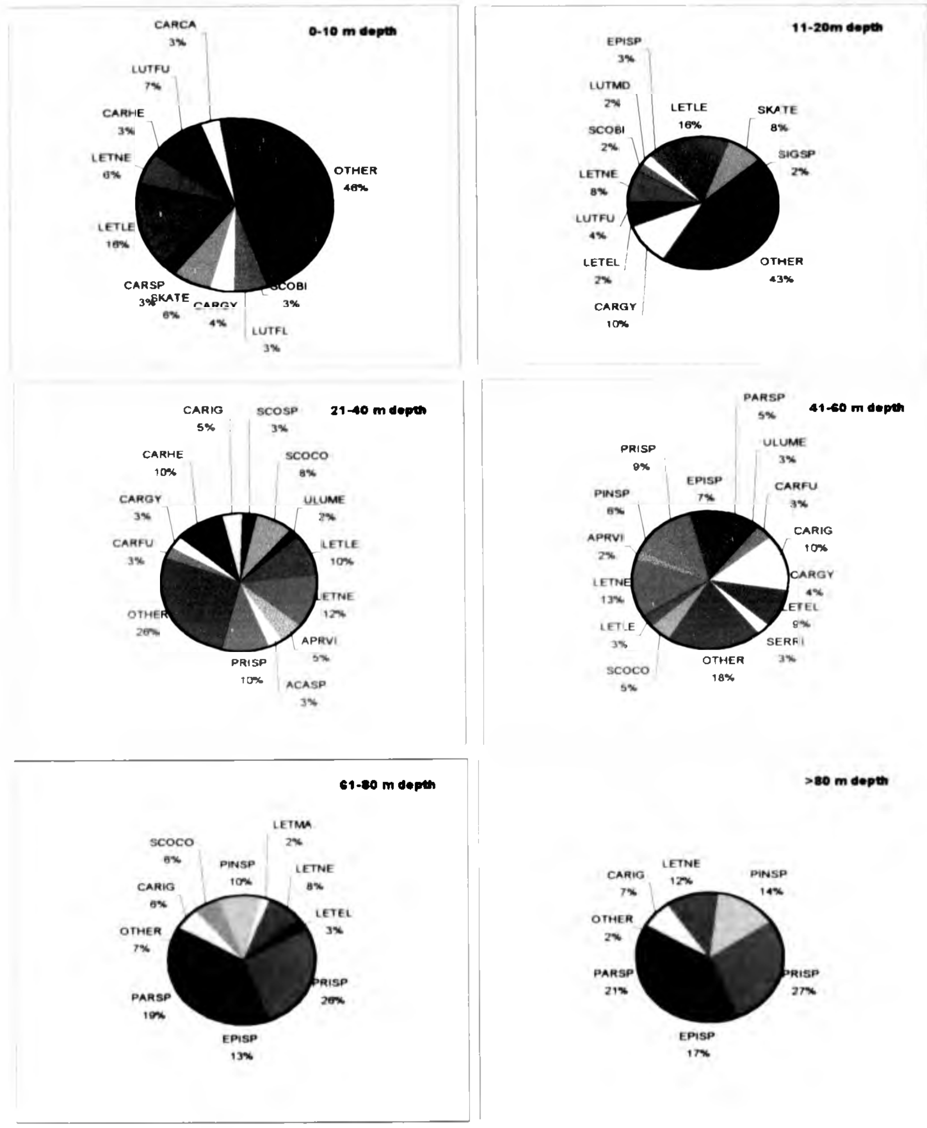


Fig. 2.17. Percentage contribution of species by weight to the total demersal fish catch of Negombo area obtained in different depths during 1999

Note:

APRVI – *Aprion virescens*, PARSP *Parascolopsis sp.*
CARCA – *Carangoides caeruleopinnatus*, LETLE – *Lethrinus lentjan*, LETNE – *Lethrinus nebulosus*
CARGY – *Carangoides gymnostethus*, CARFU – *Carangoides fulvogattatus*, LUTMD – *Lutjanus madars*
EPISP – *Epinephelus sp.*, SIGSP – *Siganus sp.*, CARIG – *Caranx ignobilis*, ULUME – *Uluma mentalis*
LUFL – *Lutjanus fulvus*, LUFU – *Lutjanus fluviflamma* ,CARHE – *Caranx heberi*,
SCOBI – *Scolopsis bimaculatus*, LETEL – *Lethrinus elongatus*, LETMA – *Lethrinus mahasen*,
SCOCO – *Scomberomorus commerson*, PRISP – *Pristipomoides sp.*, PINSP – *Pinjalo sp.*,

Towards deeper waters (21-80 m depth) larger varieties of Carangids - *Caranx heberi*, *Carangoides fulvoguttatus*, *Carangoides gymnostethus*, *Caranx ignobilis* (CARIG), *Ulums mentalis* (ULUME), Lethrinids – *Lethrinus nebulosus*, *Lethrinus lentjan*, *Lethrinus elongatus*, Scombrids - *Scomberomorus commerson* (SCOCO), Lutjanids - *Aprion virescens* (APRVI), *Pristipomoides sp.* (PRISP), *Pinjalo sp.* (PINSP), Serrenids - *Epinephelus sp.* and Nemipterids - *Parascolopsis sp.* (PARSP) dominated the catches.

The species reported from the shelf slope area (depths >80m) were limited. They were mostly large varieties. The most important species were *Caranx ignobilis* (Family Carangidae), *L. nebulosus* (family Lethrinidae), *Pinjalo sp.*, *Pristipomoides sp.* (family Lutjanidae), *Parascolopsis sp.* (family Nemipteridae) and *Ephinephelus sp.* (family Serranidae).

2. 2. 7 Species Composition of Family Carangidae and Lethrinidae

Carangidae and Lethrinidae were the most important fish families in the demersal fisheries of the Negombo area (Figs. 2. 15-17). Both families are notably heterogeonus. A total of 23 species belonging to family Carangidae and 13 species belonging to family Lethrinidae were collected and identified in the demersal catches off Negombo (Table 2. 5). These species contributed varying percentages to the total catch of different fishing gears. The contribution of species to the total catch of Carangidae and Lethrinidae in 1999 is shown in Table 2. 6.

Table 2.6. Species composition by weight of family Carangidae and Lethrinidae in the demersal catch in 1999.

Carangidae		Lethrinidae	
Species	%	Species	%
Alectis ciliaris	1.6	*Gimnocaranius sp.*	1.9
Alectis indicus	0.8	*Lethrinus conchyliatus*	0.3
Alepes sp.	0.9	*Lethrinus crocineus*	0.1
Atule mate	3.9	*Lethrinus decustatus*	0.6
Carangoides caeruleopinnatus	6.9	*Lethrinus elongatus*	9.8
Carangoides fulvoguttatus	6.8	*Lethrinus harak*	0.2
Carangoides gymnostethus	26.2	*Lethrinus lentjan*	35.7
Carangoides sp.	6.1	*Lethrinus mahasen*	6.9
Caranx heberi	10.1	*Lethrinus microdon*	1.9
Caranx ignobilis	22.8	*Lethrinus nebulosus*	37.6
Caranx melampygys	1.2	*Lethrinus obsolatus*	2.7
Caranx sexfasciatus	1.0	*Lethrinus ornatus*	0.7
Decapterus sp.	0.6	*Lethrinus rubrioperculatus*	1.8
Elagatis bipinnulata	0.4		
Gnathanodon speciosus	3.9		
Megalaspis cordyla	1.1		
Scombroides sp.	3.6		
Selar crumenophthalmus	0.3		
Selaroides leptolepis	0.2		
Seriola rivoliana	0.9		
Trachinotus sp.	0.4		
Uluma mentalis	0.2		
Uraspis helvola	0.0		
Total catch (kg)	506214		604540

The dominant species encountered in the family Carangidae were ***Carangoides gymnostethus*** (26.2%) and ***Caranx ignobilis*** (22.8%), ***Caranx heberi*** (10.1%) and those in the family Lethrinidae were ***L. nebulosus*** (37.6%), ***L. lentjan*** (35.7%) and ***L. elongatus*** (9.8%). The contribution of other species to the total catch of Carangids and Lethrinids were substantially low.

2. 2. 8 Production of family Lethrinidae

The estimated total Lethrinid catch in the Negombo area is given in Fig. 2. 18. It is clear that the catches have steadily increased from 1994 and have exceeded 605,540 kg in 1999. The contribution of the two main species of the family Lethrinidae, *L. nebulosus* and *L. lentjan* has also increased. *L. nebulosus* dominated the catches from 1992 to 1994 and again in 1998 and 1999 while the contribution of *L. lentjan* was greater between 1995-1997.

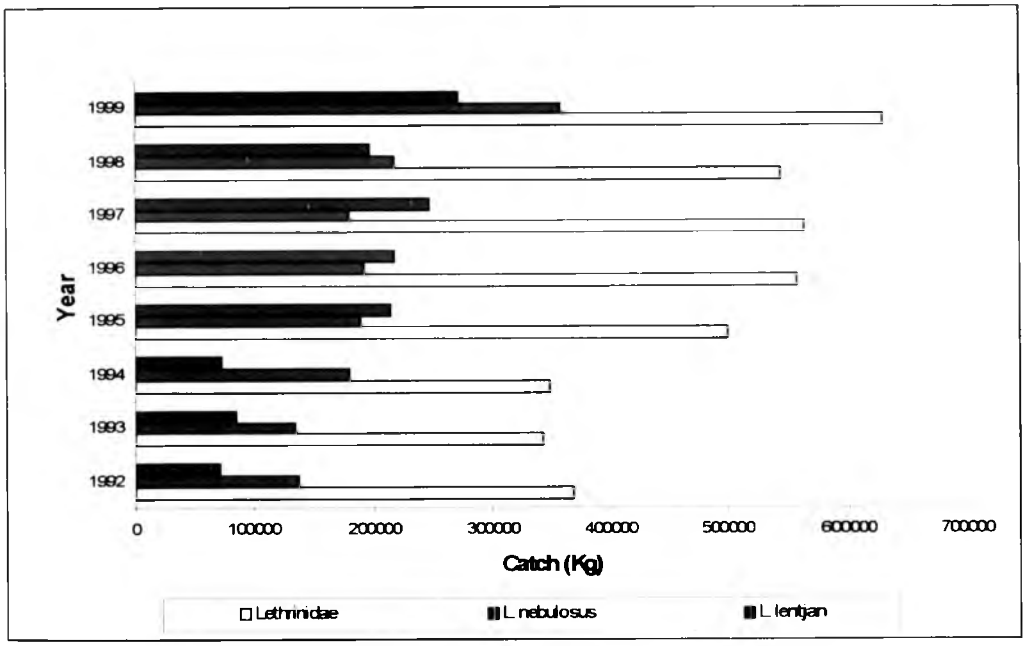


Fig. 2. 18. Catch of Lethrinids in the Negombo area from 1992-1999.

2. 2. 9 Sequential Exploitation

The length frequency distributions of the two major species of the family Lethrinidae, *L. nebulosus* and *L. lentjan* caught by different gears are shown separately in Figs. 2. 19 and 2.20.

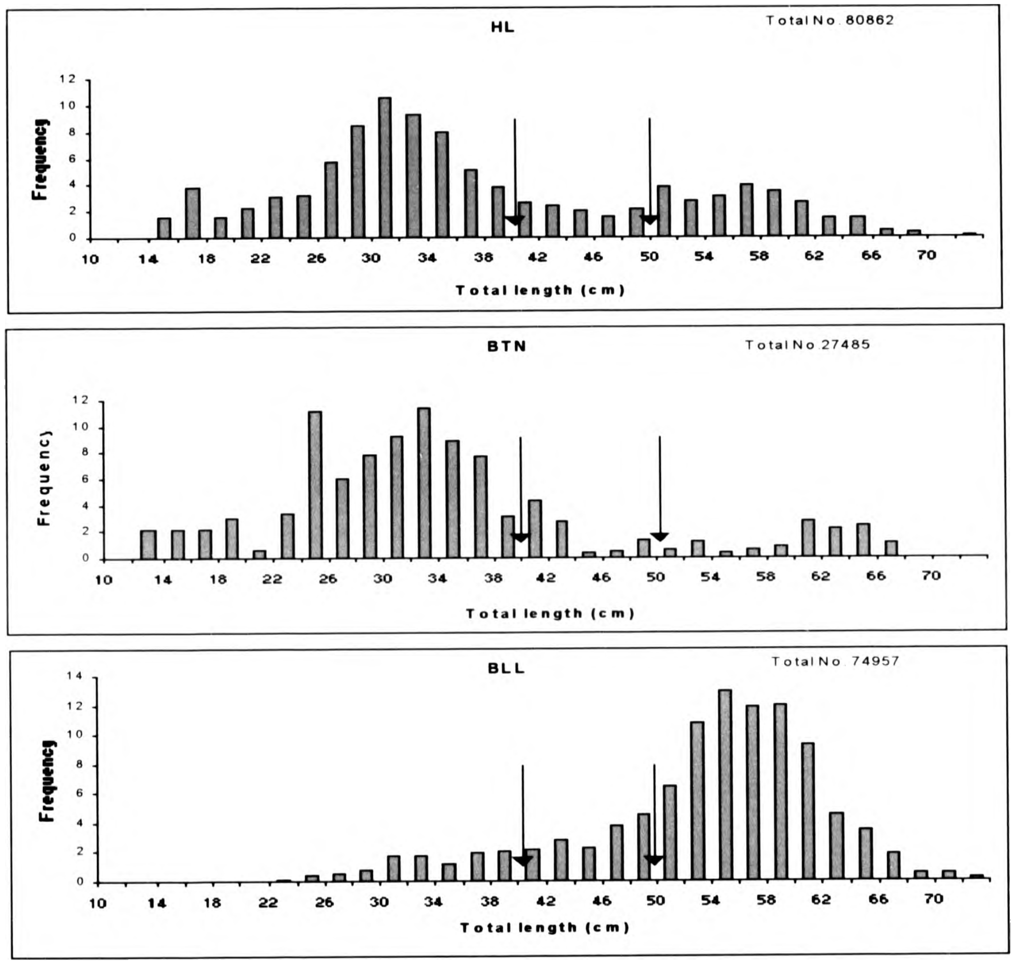


Fig. 2. 19. Length frequency distribution of *L. nebulosus* caught by different fishing gears. The arrows indicate length group which was the least represented in the catch of different gears.

Except for bottom longline (BLL) fishery the length frequency distributions of *L. nebulosus* in bottom trammel (BTN) and handline (HL) fisheries were bimodal (Fig. 2.19) while the distribution of *L. lentjan* was unimodel for all the gears investigated (Fig. 2.20). Owning to the low abundance of *L. lentjan* in deeper waters less fish were sampled from longline catches.

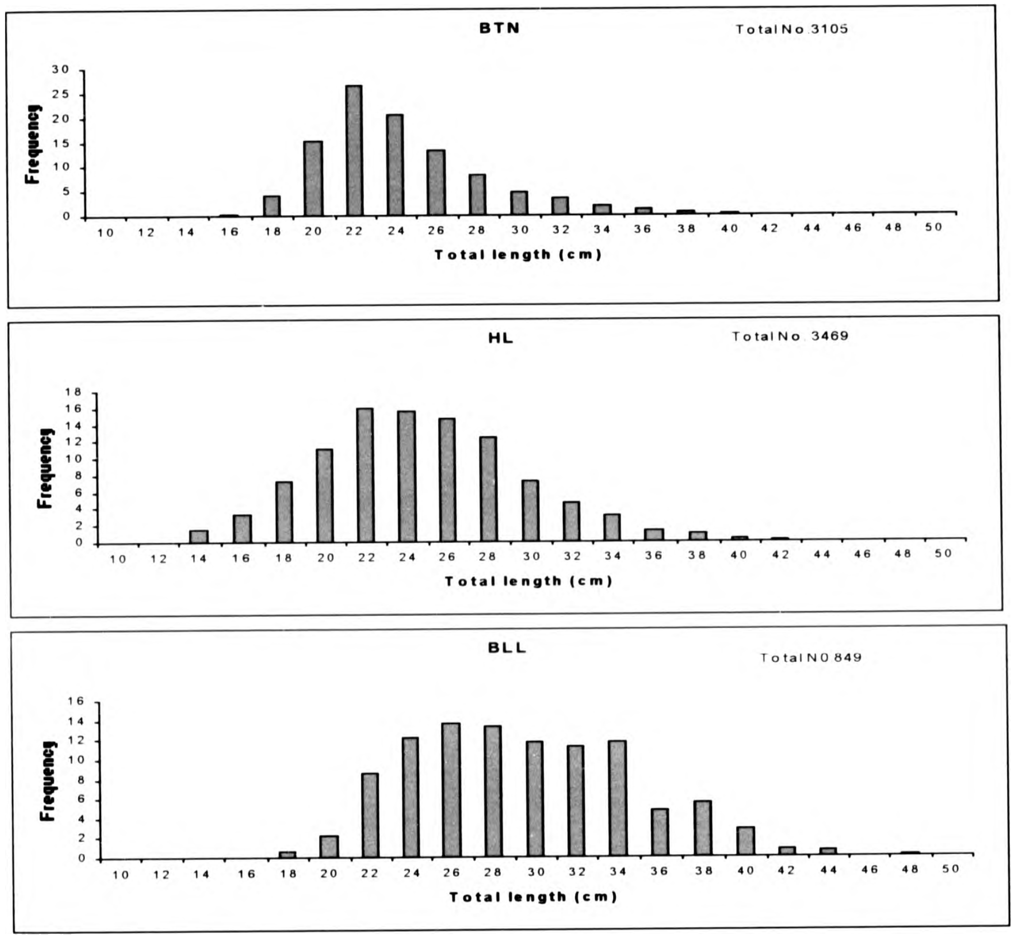


Fig. 2. 20. Length frequency distribution of *L. lentjan* caught by different fishing gears.

Different fisheries target different life stages of fish at separate times or at the same time in different depths. Bottom trammel nets operate in shallower waters and apparently catch smaller sized fish of both species. A wide size range of fish was found in the handline catches while large fish were reported from bottom long line catches. There is some overlap in size of *L. nebulosus* but much more of a overlap was found for *L. lentjan* caught by the three types of gear. It was observed that the intermediate size group, 40-50 cm of *L. nebulosus* were harvested relatively less by all fisheries (indicated in arrows) (Fig.2. 19). This may be due to the effect of gear selectivity or due to migration of this size group or both. If they move out of fishing range they may be found in deeper waters or at a different geographical location where lower fishing intensity takes place at present.

2. 2. 10 Size Distribution by Different Depths

The length frequency distribution of *L. nebulosus* (Fig. 2. 21) and *L. lentjan* (Fig. 2. 22) at different depths show small individuals of both species in the shallower waters and larger fish in deep waters.

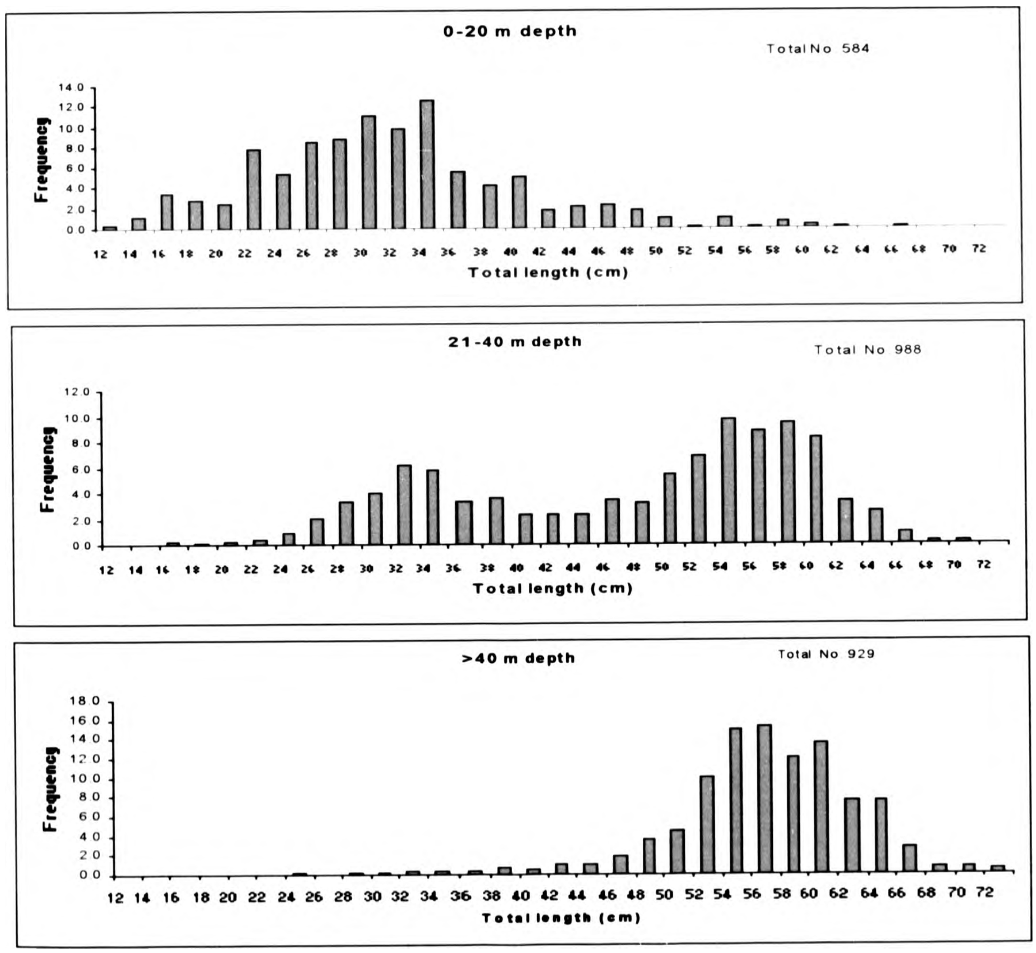


Fig. 2. 21. Length frequency distribution of *L. nebulosus* caught at different depths.

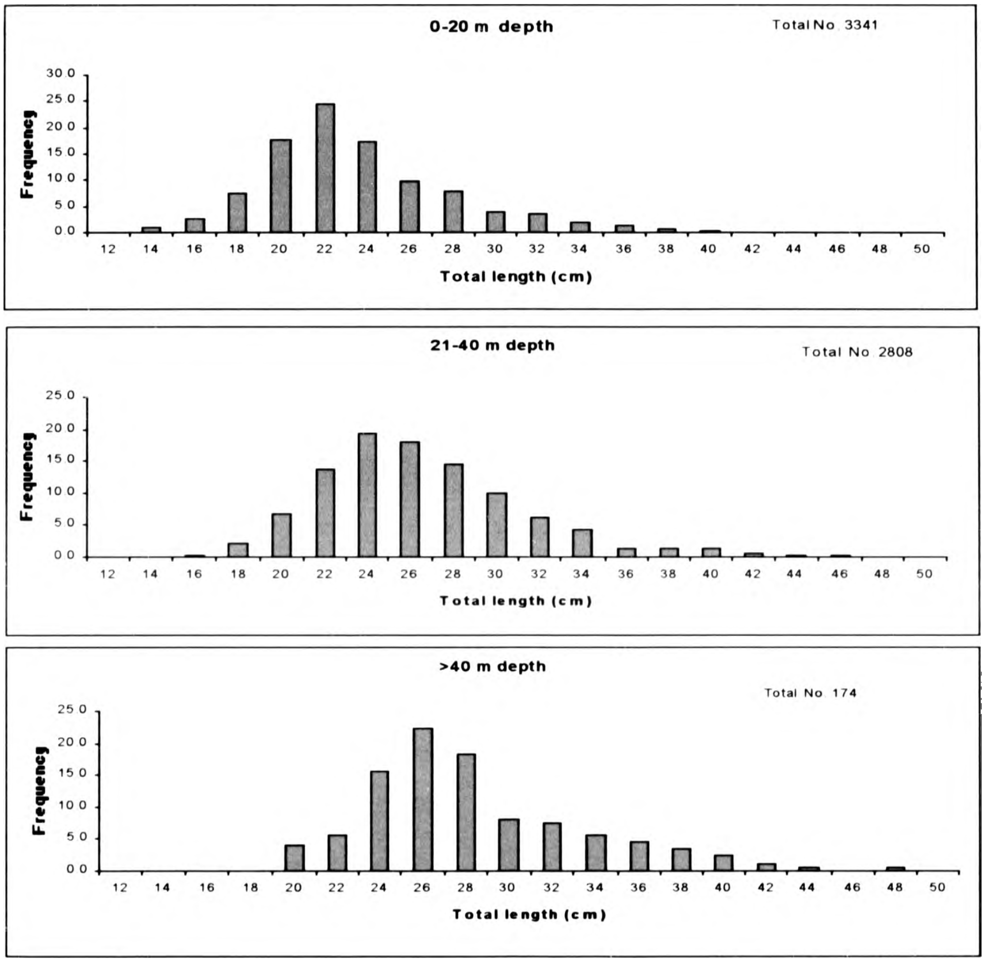


Fig. 2. 22. Length frequency distribution of *L. lentjan* caught at different depths

L. nebulosus was distributed over the full range of depth from 0 to > 40m while *L. lentjan* is limited to the 0-40 m depth range. The modal size caught in the shallow (0-20 m) waters were 32 cm and 22 cm respectively for *L. nebulosus* and *L. lentjan*. In the intermediate depths (21-40 m) both small (modal size of 34 cm) and large fish (modal size of 58 cm) of *L. nebulosus* were observed while the modal size of 26 cm for *L. lentjan*. In the deeper waters (>40 m) the adult *L. nebulosus* of modal size 58 cm and *L. lentjan* of 26 cm was reported.

2. 4 DISCUSSION

The rough bottom reef areas and adjacent shallow sandy areas off Negombo support a diverse fish community which form the basis of an artisanal demersal fishery in the area. About a decade ago demersal fisheries in Negombo were mainly carried out by 28-32 ft class 3.5 IBM boats using handline, bottomset gillnets and bottom longline (Maldeniya, 1985). Now the fishery is mainly carried out by17-22 ft OBM boats using a greater variety of fishing gear. Only a few IBM boats, on the other hand engage in handline fishing during the lean season for prawn trawling which is their primary activity. The fishing effort in demersal fisheries has increased over the past two decades with a greater involvement of small boats and new fishing methods such as bottom trammel net and bottom longline. Another development is the increased fishing effort by most gears during the inter-monsoon periods (October to April). The catches from of small mesh drift net and prawn trawls are poorer during these months and so effort shifts to demersal fishing during this period. Fishermen from this area would have previously migrated to the north and east coast, during this lean season to continue pelagic fisheries, but the civil disturbance in these areas has forced them to stay out and change their effort to other fisheries, mainly the demersal fishery. Fishermen are thus presently immobile and operate from their home-ports and use landing sites close to their dwellings. Demersal resources in the area were naturally managed until early 1980s, with a distinct pattern characterized by a seasonal fishing effort. The operational limitations arising out of monsoon weather conditions still result in a lower fishing effort of most fishing gear, with the exception of trammel netting.

Handline is the well established traditional demersal fishing method in many parts of Sri Lanka including Negombo area (Maldeniya, 1997) and it is practiced with a high degree of variation and expertise. Basically two handline fishing methods have been identified in the Negombo area. Drop handlines operate with single hook for larger demersal varieties such as lethrinids, carangids, scombrids and serranids while bait cage handline fishing mainly target small varieties or juveniles of large varieties of carangids, lethrinids, lutjanids etc. During the past two decades interest has been aroused in using modern efficient gears for the exploitation of fish resources which are seasonal abundant but these species have not been targeted by the traditional methods to exploit more efficiently. Fishing effort of bottom longline and bottom trammel net has thus increased and spear fishing came into operation. On the other hand the effort of traditional bait cage handline fishing and bottom set gillnet has declined. The fishing effort of spear fishing remains at a low level (0.1% of the total fishing effort in 1999) because having a spear gun is an illegal activity in Sri Lanka and banded in 1993.

By measuring fishing effort it is possible to estimate the optimum effort, which will produce the maximum yield from any given fish population. It also indicates whether or not the current fishing effort is over exploiting the fish stocks. Some of the demersal fishing boats operated on a seasonal basis and the number of operated days for individual boat varies. The assessment of fishing effort is thus of critical importance for management the demersal fishery in the Negombo area. The aggregate fishing effort of the demersal fishery in the Negombo area has steadily increased from 1992 with the popular use of bottom longline, bottom trammel net, handline fishing with OBM boats and handline fishing combined with drift gillnets and reached a maximum in 1997 (213,725 fishing days). Thereafter it slightly declined in 1998 and 1999 mainly due to decline of bait cage handline fishing with OBM and bottom trammel net fishing. In 1999 the highest fishing effort (65%) was through handline fishing combined with drift gillnets followed by bait cage handline with OBM boats (15%), bottom trammel net (11%) and bottom longline (7%) fishing.

Relatively low catch rates were recorded for all gears operated in the shallow waters (0-10 m) during the span of the present study, indicating that the stocks are quite heavily exploited by the present fisheries but higher catch rates reported in deeper depths indicate promising prospects for handline and bottom longline fishing gear. The highest annual average CPUE was reported for seasonal bait cage handline fishing operated with IBM boats while the lowest CPUE was reported for drop handline fishing conducted combined with drift gillnets. Operational limitations such as limited time, space and the number of fishermen engaged in fishing activity has caused a low catch in fishing operations. The average annual CPUE of bait cage handline with OBM boats, bottom longline and bottom trammel net fishing has shown a declining trend over the period 1992 to 1999 while CPUE of other fisheries remained more or less unchanged. However, the average CPUE of handline fishing with OBM boats for the period 1992-1999 (26.1 kg/fishing day) has improved above that reported during the early 1980s (11 kg/fishing day) by IBM boats (Maldeniya, 1985), but the catch rates of bottom longlining (54 kg/ fishing day in 1980s and 38.2 kg/fishing day in 1990s) and bottomset gillnets (53 kg/fishing day in 1980s and 32.7 kg/fishing day in 1990s) has declined over the past years. The expansion of fishing operations over time and space, using small OBM boats which are more speeder than IBM boats, are the most important feature in increasing the catch rates of the handline fishery. Bottom longline fishing during the time of fishery promotion (early 1980s) was conducted with a larger hook size (No. 5-7) and with squids or cuttlefish as bait (Weerasooriya *et al.*, 1985, Maldeniya, 1994). At present fishermen use a wide size range of hooks (No. 5-10) and mostly cut pieces of sardines and herrings as bait. These bait varieties have proved not to be as effective as squids or cuttlefish (Pajot and Weerasooriya,1980) and this may be the main reason in declining performance of bottom longline fishing. Further, limited knowledge of good fishing grounds, limited number of gear units used due to the limited carrying capacity of the small boats or an increase of competition for the limited resource may also have contributed to the decline of CPUE of both bottom longline and bottomset gillnet fisheries.

The demersal fish catch has increased from 2,194,160 kg in1992 to 2,481,280 kg in 1997 and then slightly declined to 2,021,608 kg in 1998. The fish catch trend followed the fishing effort trends over the period. Bait cage handlines by both OBM and IBM boats reveal the highest production accounting for 41.3 % of the catch in 1998 (2,021,608 kg). Next in importance was bottom longline which accounted for 20.5 %. Ancillary catch (296,455 kg) of drop handline of combined gear contributed 14.7 % to the total production. The estimated annual by-catch production of prawn trawling in 1998 by IBM boats and non-mechanized traditional crafts was 104,429 kg and 134,621 kg for respectively (Sanders *et al.*, 2000). Thus the demersal fish production including the prawn by-catch in the Negombo DFEO area was estimated as 2,260,658 kg for the year 1998. This shows that the production of demersal fishes in Negombo area has doubled during the 17 years starting from 1,032,520 kg in 1982. The fish yield within the 50 m depth contour in the study area with intensive fisheries for all demersal species (including prawn by-catch) and large demersal species appears to be about 31.2 kg/ha and 27.9 kg/ha respectively. This is substantially higher than reported in reef fisheries in Cuba (6.0 kg/ha) and Jamaica (15.0 kg/ha) where intensive fishing takes place with traps, hook and lines, nets and spear fishing (Munro, 1983b). The high production rate reported in the present study may be due to vulnerability of many varieties of fish in the shallow waters, demersal, semi-demersal and some pelagic species for the fishing gears currently used in demersal fisheries (Table 2. 5). However, the nutrient discharge from Negombo lagoon (Anon, 1994) and perennial rivers (Fig. 2.1) and the adjacent coral reefs and mangroves may also influence the high natural productivity of the inshore waters off Negombo.

A change of catch composition, with an increase of squids and cuttlefish and a decrease in the contribution of carnivorous fish species notably such as sharks, skates and carangids has been seen in the demersal catches over the period (Table 2.3). Similar observations have been reported from Jamaica (Koslow *et al.*, 1988, Koslow *et. al.*, 1994), Philippines (Amar *et al.*, 1996), Fiji (Russ, 1985, Russ and Alcala, 1989) and Mauritius (Paul, 1987). The decrease in the abundance of carnivorous species are considered to be the most readily detectable effect of high fishing pressure in multispecies fisheries (Russ, 1985). However, decline of shark and skate catches may also be due to declining fishing effort of bottom set gillnets over the years. Overexploitation of apex predators may result in an increase of pray species such as squid and cuttlefish. It was observed with the increase of fishing effort the catch changed from being dominated by large herbivorous species such as acanthurids to small predatory lethrinids, and then to small herbivorous siganids in the Tigak Island, Papua New Guinea (Wright and Richards, 1985). The increase of lathrinids in the Negombo area may also be a similar effect of high fishing pressure.

A large number of demersal species inhabit the Negombo area. Among them a total of 139 fish species belong to 68 families of bony fishes (teleost) have been identified in the present study. Most of these species were either captured occasionally or in low numbers. The number of fish species, which contributed a significant part by weight of the catch, is much more limited. They are thus susceptible and in most danger of overexploitation. The species of major importance include the families: Lethrinidae, Lutjanidae, Carangidae, Serranidae, Haemulidae, Sphyreanidae and Scombridae. It was noted that all the dominant families were notably heterogeneous but only a few species dominated the catch of each family. The family Carangidae which has been found to be the principal family, contributing the maximum weight to the total demersal catch from 1992 to 1995 was closely followed by Lethrinidae. From 1997 family Lethrinidae however, has come to dominate the demersal catch in the Negombo area. The analysis of the composition of earlier demersal trawl catches made by RV'Dr Fridtjof Nansen' however, revealed that lethrinids were the dominant group on the west coast, followed by carangids, skate and leiognathids (Sivasubramanium, 1985).

Lethrinids (emperors) are tropical marine perciforms found entirely in the Indo-Pacific, except for one species that occurs only in the eastern Atlantic (Carpenter and Allen, 1989; Kulbicki, 1995). Out of 32 species reported in the Indian Ocean 20 have been found in the waters around Sri Lanka (De Bruin *et al.*, 1994) and 13 have been identified in the demersal catches off Negombo. They are fished commercially by most gears targeting demersal fish in the area. The spangled emperor (*Lethrinus nebulosus*) and pinkear emperor (*Lethrinus lentjan*) are the two most dominant species of lethrinids in the catch and contribute 11.1% and 10.6% of the total demersal fish landed in the Negombo area in 1999 respectively. They also make an important contribution to the demersal fish catches of many countries such as the Sudan and Saudi Arabia (Sanders and Morgan, 1989). Red Sea (Wray, 1979; Randall, 1983), Gulf of Aden (Aldonov and Druzhinin, 1978), Southern Indian waters (Toor, 1968b), Saya de Malhs (Bertrand, 1988), New Caledonia (Loubens, 1980a).

One of the most salient features of demersal fisheries off Negombo is the relatively high exploitation of inshore resources extending to a depth of 40 m from the coast. Resources beyond this depth still remain under exploited. Thus the fishing effort beyond 40 m and 60 m depth counters was only 14% and 5% of the total effort respectively, in spite of the fact that economically attractive larger species, such as snappers (*Pinjalo sp*. *Pristipomodes sp*.), Carangids (*Caranx ignobilis*), groupers (*Ephinephaelus sp.*) dominate the catches from these depths. Fishing for such deep dwelling fish is under developed in Sri Lanka because few local fishermen have the necessary skills to locate productive and exploitable fishing grounds on the continental slope. Fishermen locate and mark the fishing grounds purely by experience. Deep-water fishing can be carried out only during non-monsoonal months from December to April when conditions for fishing with small vessels and gear such as handline or bottom longline are most suitable. High winds and strong waves of the monsoon current usually does not permit such operations. Though catch rates in deeper waters were high (Fig. 2.6) they tend to be highly variable compare to those in the shallow waters which were low but tended to be more constant and regular. In view of low exploitation, high catch rates and high economic value of the above resources, emphasis should be placed on increasing the exploitation beyond 40 m. It might be an economically viable alternative to improve the CPUE of bait cage handline fishery. However, extensive research must be under taken to assess the stock densities and species interaction of the intended zone of operation, identify suitable fishing method and obtain an assessment of the financial viability before such fishing operations are planned for.

Most demersal species appear to be confined to a limited depth range and only a few were found with wide distribution. Both *L. nebulosus* and *L. lentjan* were found distributed over a wide depth range with *L. nebulosus* having the deeper range. It was observed that the juveniles of most demersal species normally inhabit shallow waters and appear to move towards deeper waters with the onset of maturity (Wheeler, 1961 *in* Paul, 1987; Munro, 1983a). Observations on the length frequency distribution of *L. nebulosus* and *L. lentjan* in different depth zones indicated such a movement of fish from shallow waters to deeper area as they grow (Fig. 2.16 and Fig. 2.17). It appears likely that shallow habitats are essential for settlement and survival of juveniles of these species, but in the Negombo area the non-selective and destructive fishing gears like bottom trammel net, bottom set gillnets operate in these shallow waters which will have a detrimental influence on recruitment. In fact Rajasuriya *et al* (1995) and Jayawardane and Dayaratne (1995) have stated that bottom set gillnet and bottom trammel nets should be banned, not only as a fishery conservation measure but to protect areas considered to be over-harvested from the physical damage this type of gears causes to coral and other organisms of the marine ecosystem. The operation of bottom trammel nets in the coral reef areas has been made an illegal activity under New Fisheries Act No. 2 (Anon, 1996).

Demersal fisheries in Negombo area seem to target different sizes of fish of the same stock of principal species such as *L. nebulosus* and *L. lentjan*. Gears operating in shallow depths target juvenile fish which are still growing and may not have attained maturity while the gears operating in deeper waters target adult fish with the potential consequences of reducing the spawning biomass. Wheeler (1961 *in* Paul, 1987) observed that most of the commercially important adult fish of lethrinids migrated to deeper waters in Mauritius to reproduce and become highly susceptible to capture because their migration consistent with time and space. The increase of bottom longline fishing effort in the nonmonsoon period may target such spawning migrations of lethrinids in deep waters. There is no information available of the spawning behaviour or the spawning seasons of these important lethrind species in Sri Lanka to enforce management measures to protect the adult fish. The knowledge of the key aspects of their reproductive biology such as spawning seasons, sexuality, length at maturity, fecundity etc. are prime important for sustainable management of these important species.

The demersal fisheries in the Negombo area show some signs of overexploitation. For example, the recent CPUE of all the major fishing gears have declined and the catch composition has changed. On the other hand a high fishing effort has been deployed on catching smaller varieties or the juveniles of larger varieties inhabiting in shallow waters. It is therefore important to study the impact of fisheries on fish stocks and manage the fisheries to ensure their sustainability. Demersal fishery in the Negombo area is a multispecies fishery, which simultaneously exploits large number of species. It is never feasible to perform stock assessments and study the impact of fisheries on all major species encountered in the catches. However, the stock assessment of indicator species to determine the health of the resource base as a precautionary fishery management has been recommended by recent international agreements (FAO Code of Conduct for Responsible Fisheries) (FAO, 1995). To start with, substantial work must be done on the biology and behavior of species, which constitute the mainstay of the fishery. Due to limited manpower, facilities and time available, biological studies of only the two commonly exploited species with all major gears were undertaken. *L. nebulosus* (Fig. 2. 23) was considered to be the deep water

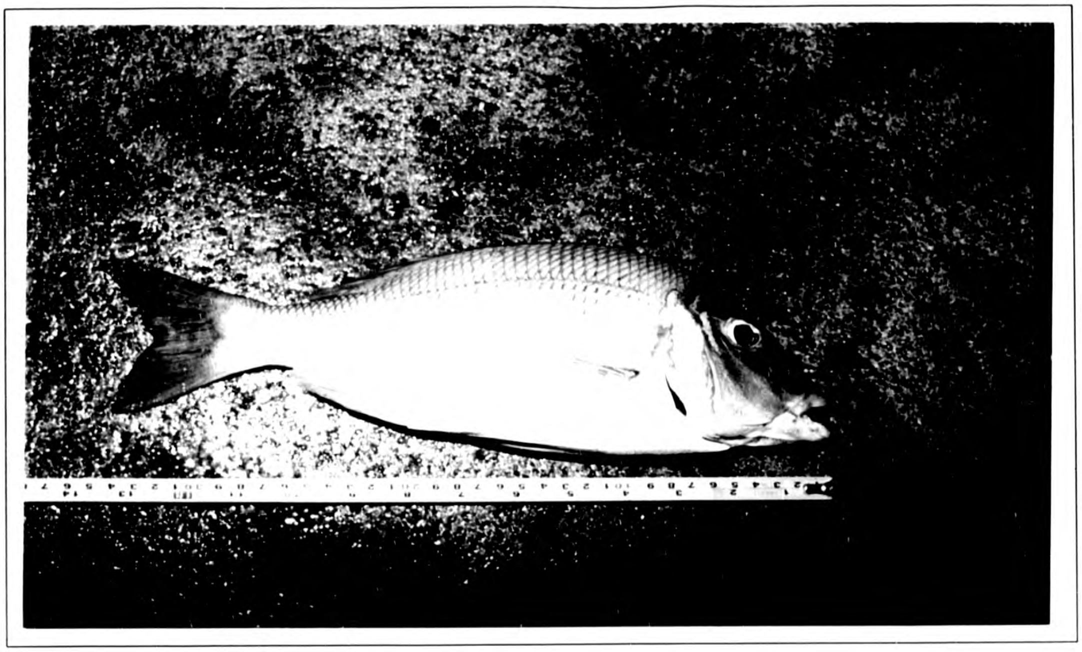


Fig. 2.23. *Lethrinus nebulosus.*

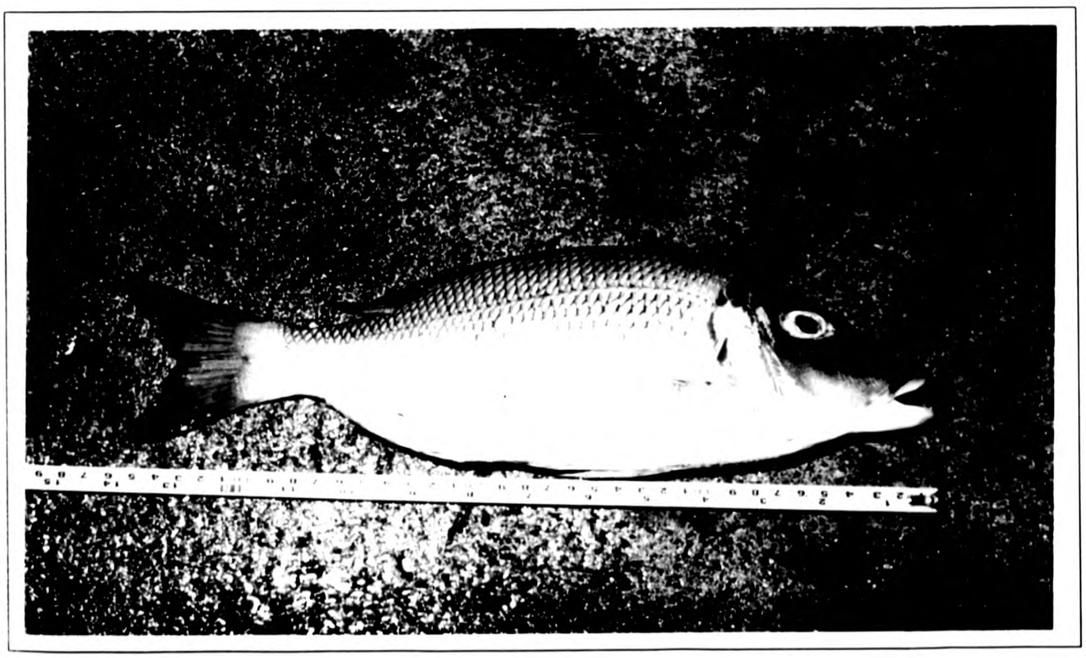


Fig. 2.24. *Lethrinus lentjan.*

indicator species while *L. lentjan* (Fig. 2. 24) was considered to be the shallow water indicator species.

Chapter 3

Reproductive Biology of *Lethrinus nebulosus* and *Lethrinus lentjan*

3. 1 INTRODUCTION

Of the various aspects of the biology of fish populations, especially those that support important fisheries, the measure of reproductive potential is of primary importance as a basic determinant of recruitment and thus productivity. Maturation rates in particular, along with the rate of growth and mortality are essential to the characterization of the population dynamics of fish stocks (Scott, 1979; Wootton, 1979) and thereby biological management of fisheries. From a fishery perspective, it is clearly important to maintain reproductive output in an exploited population. It has been noted that the decline of many fisheries has been due to reduced recruitment caused by low levels of spawning stocks (Cushing, 1975, Cushing, 1998).

L. nebulosus and *L. lentjan* in the Negombo area are exploited in varied quantities across wide size range at all depths with a variety of fishing gears of different selectivity (Chapter 2). The present fishing pattern could disrupt the reproductive activities of both species, therefore, it is important to study how this multigear fishery affects the spawning stock of these two indicator species for better biological understanding. Stock management involving the control of exploitation of mature adults therefore requires knowledge of key aspects of their reproductive biology such as fecundity, maturity and sexuality of the species. There is no study on reproductive biology of *L. nebulosus* or *L. lentjan* that has been done in Sri Lanka.

Although these two species make an important contribution to the demersal catches in many countries (Aldonov and Druzhinin, 1978; Loubens, 1980a; Bertrand, 1988; Sanders and Morgan, 1989; Kulbicki, 1995) their reproduction remains one of the least studied problems in the biology of *L. nebulosus* and *L. lentjan*. So far the most important contributions to the understanding of their reproduction are those of Kuo and Sen (1990) and Ebisawa (1990) on *L. nebulosus* in Northwestern Australian and Okinawa (Japan) and Toor (1968a) and Kedidi (1984) on *L. lentjan* in Southern India and Red Sea respectively. During their studies some of the aspects of spawning habits, sexuality, size of maturity and fecundity have been investigated.

This chapter provides information on aspects of reproduction, particularly about age/length at sexual maturity, sex ratio in different age groups, fecundity and its relation to size, spawning pattern and annual spawning seasons of *L. nebulosus* and *L. lentjan* population off Negombo – west coast of Sri Lanka.

3. 2 MATERIALS AND METHODS

Fish from each species were collected from the commercial catches shortly after landing. Monthly samples of *L. nebulosus* were obtained from January to December 1999 and for *L. lentjan* from October 1998 to September 1999. A total of 387 specimens from 23.6 cm to 68.2 cm total length and weighing between 183.2 g and 3950.4 g of *L. nebulosus*, and a total of 458 specimens from 8.2 cm to 49.3 cm total length and weighing between 9.3 g and 1923.9 g of *L. lentjan* were collected. Specimens were immediately chilled with ice and brought into the laboratory for dissection.

In the laboratory, total length (TL) and weight of each fish were measured to the nearest 0.1 cm and 0.1 g respectively. To determine gonosomatic index (GSI) the gonads were carefully removed, damped and accurately weighed to 0.01g. The eviscerated body weight (guts removed) of fish was then measured to nearest 0.1g to obtained somatic weight. The length of body cavity was taken as the distance from the apex of the heart to the anus and the gonad length was measured to nearest millimeter. Ovaries were preserved in modified Gilson's fixative (Bagenal, 1978) for about 2-3 months to facilitate separation of eggs.

3. 2. 1 Gonad Structure

The paired gonads of both species are suspended below the swim bladder from the dorsal body wall. The testes first appear as slender, thread-like short structures in the abdomen near the vent. As maturity advances they appear as two prominent strips and when fully mature they extend to the anterior of the body cavity. The paired ovaries are more or less symmetrical although sometimes the left lobe of the ovary is slightly longer in both species. The two lobes form a 'U'-shaped loop and open to the outside by a short common oviduct. Eggs were visible to the naked eye in all developed and mature ovaries (all stages other than Stage I and Stage II).

3. 2. 2 Sex Determination and Maturity Stage

Since it was not possible to determine the sex and level of maturity by external features in both species, sex determination and gonad maturity were determined from both macroscopic and microscopic characteristics of gonads after dissection. Representative samples of gonads at different stages of maturity were taken for preparation of maturity scale. As there is not much variation in the macroscopic structure of the gonad, a common maturity scale was adopted for both species. A seven stage maturation scale based mainly on visual inspection of ovary, GSI, the length of ovaries in relation to the body cavity length and ova development was used to adapt the maturity scale to classify the maturity status of ovaries (Table 3. 3). An appropriate six stage maturity scale was used to determine the maturity status of males (Table 3. 4).

3. 2. 3 Gonosomatic Index

Gonosomatic index (GSI) was calculated for females and males according to the formula,

$GSI = GW/BW \times 100$

Where, GW = fresh gonad weight (g) and BW = freshly eviscerated body weight (g).

3. 2. 4 Development of Ova

The preserved ovarian sample, for each fish was placed in 1 to 4 liters of water, depending on the size of the ovary. The supporting connective tissue was dissected away and the remaining eggs were thoroughly stirred into a suspension. Three 1 ml sub-samples were then removed by pipette on to 1 ml micrometer slide. All eggs > 3 μm in diameter in each sub-sample were counted using a compound microscope with ocular micrometer at 10 × magnification. One micrometer division of the ocular micrometer corresponded to 0.0012 mm (81 m. d. = 1 m.m). The total ova count by diameter size of each μm units was estimated as the average number of ova in each diameter in the 1 ml sub-sample extrapolated to total volume using the formula,

$$\frac{Xi}{xi} = \frac{Vi}{vi}$$

Where, X = total number of ova in the ovary, x = number of ova counted in sample, V = total displaced volume of all ova, v = volume of the sample, i = ova diameter of each μm unit.

The ova (oocyte) diameter frequency polygon with total ova count for each ovary was presented and the modes of the ova diameter distribution pattern were separated into their component batch using the method described by Hasselblad's NORMSEP programme in the FiSAT package (Gayanilo *et al.*, 1996), which is widely used to separate the modes in a frequency distribution. This programme estimates the number of ova underline in each mode (in each normally distributed batch of ova) and mean of the mode. These information has also been used in estimation of batch fecundity as well as to identify the modal progression of ova at different maturity stages. The development pattern of ova was traced through modal progression in different maturity stage of ovaries.

3. 2. 5 Spawning Season

The seasonal changes of the relative proportion of mature, ripe and spent fish (Stage V-VII for females and Stage IV- VI for males) were used to establish the reproductive season (Toor, 1968a). The average duration for spawning season was identified as the time when at least 50% of the adult female population has reached maturity Stage V (mature) or higher, up the time when 50% of the adult population becomes Stage VII (spent) (Wassef and Bawazeer, 1992) and for the male Stage IV to Stage VI. The frequency of spawning was determined from the size frequency distribution of intra-ovarian ova (Toor, 1968a; Grimes, 1987; West, 1990).

3. 2. 6 Length at Maturity

Size at first maturity for the two sexes of both species was calculated by plotting the percentage of mature fish (Stage V and above for female and Stage IV and above for male) in each size group during spawning season (Newman and Pollock, 1974).

3. 2. 7 Fecundity

In this study, Stage IV (late stage) and Stage V fish were used for fecundity estimates. The batch fecundity was estimated either as the number of ova that was initially separated from the general ova (eggs) stock or as the number of ova that are ready to be shed. The batch fecundity is proportional to body size as shown in the following equation:

$BF = a L^{b}$

Where, BF = batch fecundity, a = constant, b = exponent, L= total length (cm)

3. 3 RESULTS

3. 3. 1 Sex Ratio

Of the 387 specimens collected of *L. nebulosus*, there were 221, 134 and 32 females, males and visually sex undeterminants respectively. While 436 of specimens of *L. lentjan*, there were 250, 186 and 22 were respectively females, males and visually sex undeterminants. The sex ratio (male:female) of *L. nebulosus* was 1:1.65 and for *L. lentjan* was 1: 1.34. The estimated χ^2 values for both species showed a significantly different ($p>0.05$) of the ratio from expected 1:1 for both species, indicating the general predominance of female over male.

3. 3. 1. 1 Seasonal Variation of Sex Ratio

The percentage occurrence of sexes in different months for each species is given in Figs. 3.1 and 3.2 respectively. The percentage occurrence of females was found to be higher than males in most months in both species. A higher proportion ($p>0.1$) of females of *L. nebulosus* were reported in months, January, April and May coinciding with the end of the North-East monsoon (November to January) and with the onset of South-West monsoon (May-September) but a significantly high proportion of females was reported in April and May ($p>0.05$) (Table 3.1). The sex ratios were close to unity during the South-West monsoon (June to October).

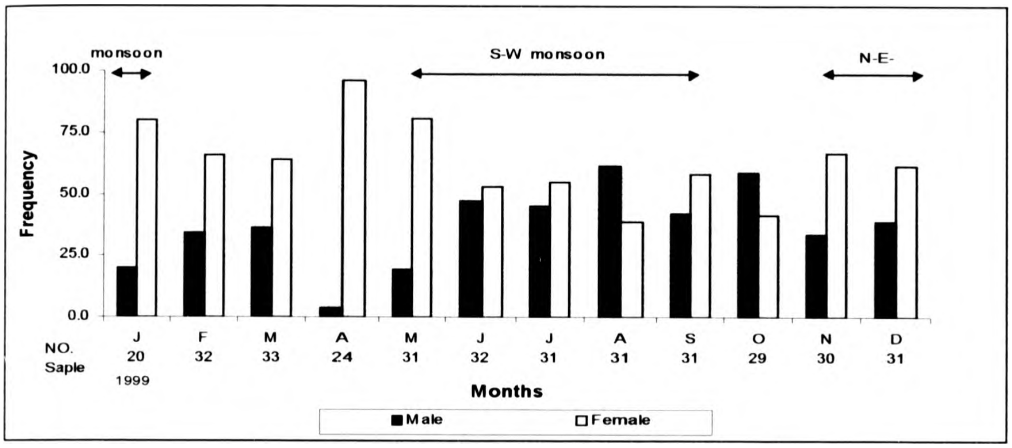


Fig. 3.1. Monthly variation of the proportion of male : female of *L. nebulosus* (January to December 1999)

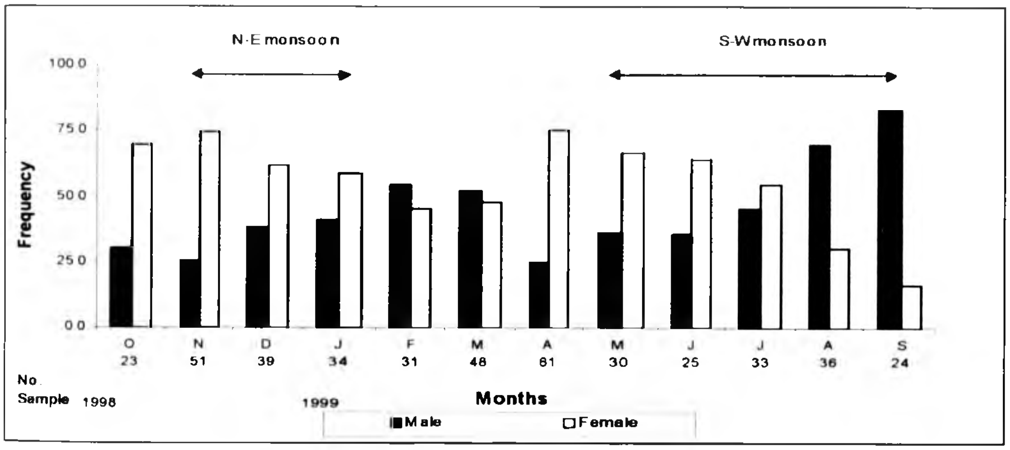


Fig 3. 2. Monthly variation of the proportion of male : female of *L. lentjan* (October 1998 to September 1999).

In *L. lentjan*, a high proportion ($p>0.1$) of females were reported in November, April, August and September (Fig. 3.2) but a significantly higher proportion ($p>0.05$) of females was reported in November, April and September with the onset of South-West and North-East monsoon and at the and of South-West monsoon.

Table 3. 1. Monthly variation of χ^2 value of the sex ratio of *L. nebulosus* and *L. lentjan*.

Species	χ^2 Value											
	Jan 1999	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
L. nebulosus	3.60	1.56	1.23	10.08	5.82	0.06	0.15	0.79	0.40	0.43	1.67	0.79
	Oct. 1998	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
L. lentjan	1.76	6.13	1.04	0.53	0.15	0.04	7.88	1.31	0.98	0.14	2.72	5.33

$\chi^2_{0.1}$ 1df = 2.71, $\chi^2_{0.05}$ 1df 3.84

3. 3. 1. 2 Variation of Sex Ratio by Size

The variations in sex ratio of *L. nebulosus* and *L. lentjan* with size are illustrated in Figs. 3.3 and 3.4 respectively.

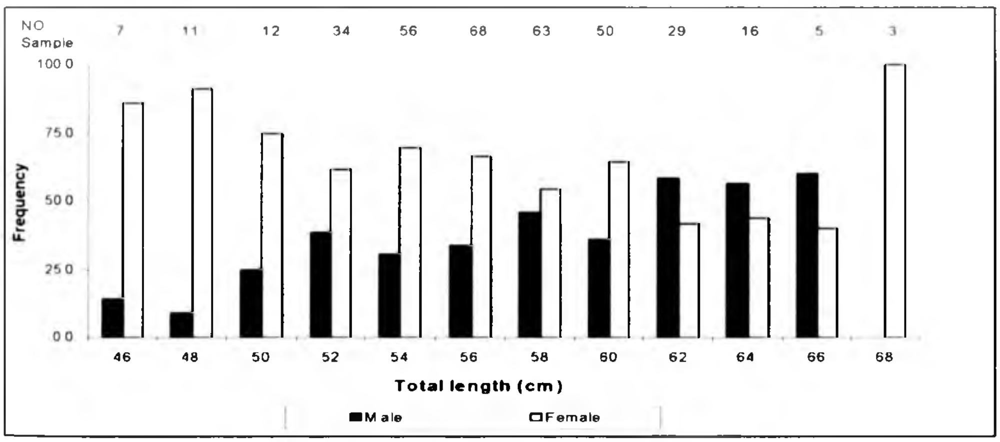


Fig. 3.3. Variation of the proportion of female: male of *L. nebulosus* by size.

Table 3. 1. Monthly variation of χ^2 value of the sex ratio of *L. nebulosus* and *L. lentjan.*

Species	χ^2 Value											
	Jan 1999	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
L. nebulosus	3.60	1.56	1.23	10.08	5.82	0.06	0.15	0.79	0.40	0.43	1.67	0.79
	Oct. 1998	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
L. lentjan	1.76	6.13	1.04	0.53	0.15	0.04	7.88	1.31	0.98	0.14	2.72	5.33

$\chi^2_{0.1}$ 1df = 2.71, $\chi^2_{0.05}$ 1df 3.84

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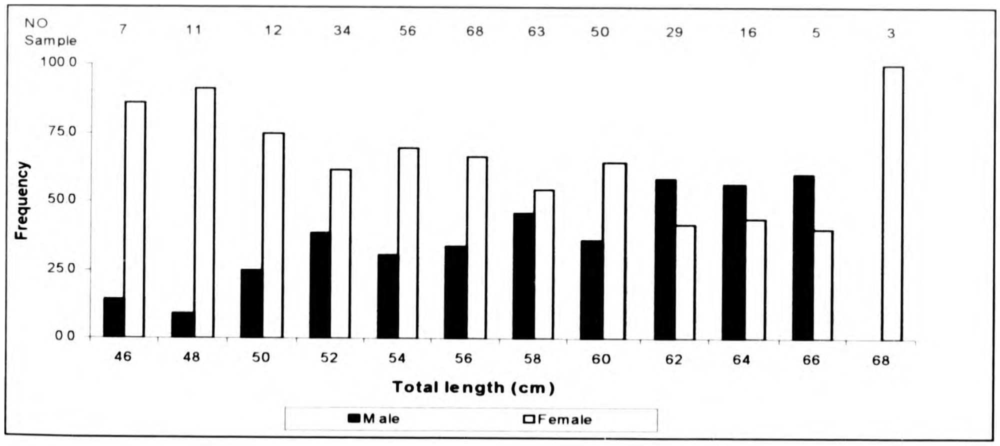


Fig. 3.3. Variation of the proportion of female: male of *L. nebulosus* by size.

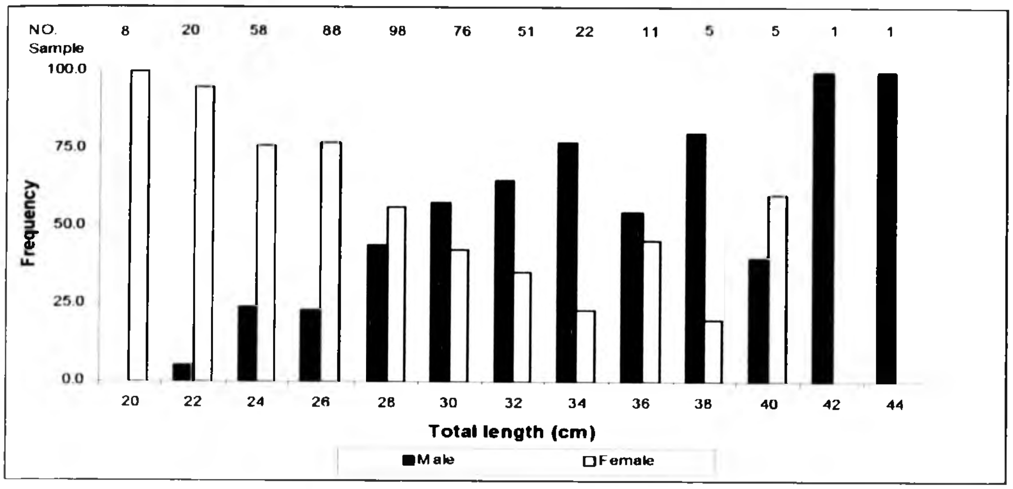


Fig. 3.4 Variation of the proportion of female: male of *L. lentjan* by size

Females dominated in the smaller size classes while males were dominant in the large size classes of both species (Figs. 3.3 and 3.4). A higher proportion ($p>0.1$) of female *L. nebulosus* were observed at 48, 54-56 and 60 cm in total length (Table 3.2) or at an age of 4 years (Chapter 4) but a significantly high proportion ($p>0.05$) of females was not observed at any length class. Females of *L. lentjan* were significantly dominant at size of 20 to 26 cm total length ($p>0.05$) or at an age of 1 years and males were dominated at size of 32- 34 cm (Table 3.2) or of 2 years. (Chapter 4).

Table 3. 2. Size variation of χ^2 value of the sex ratio of *L. nebulosus* and *L. lentjan.*

Species	χ^2 Value												
	46	48	50	52	54	56	58	60	62	64	66	68	
L. nebulosus	1.04	2.03	1.00	0.76	3.10	2.69	0.18	1.53	0.52	0.14	0.13	0.75	
	20	22	24	26	28	30	32	34	36	38	40	42	44
L. lentjan	4.00	8.10	7.76	13.09	0.76	0.95	2.21	3.27	0.05	0.90	0.10	0.50	0.50

$\chi^2_{0.1}$, 1df = 2.71, $\chi^2_{0.05}$, 1 df = 3.84

3. 3. 2 Seasonal variation of Gonosomatic Indices (GSIs)

The variation of mean monthly GSIs by sex of each species is given separately in Figs.3. 5 and 3. 6.

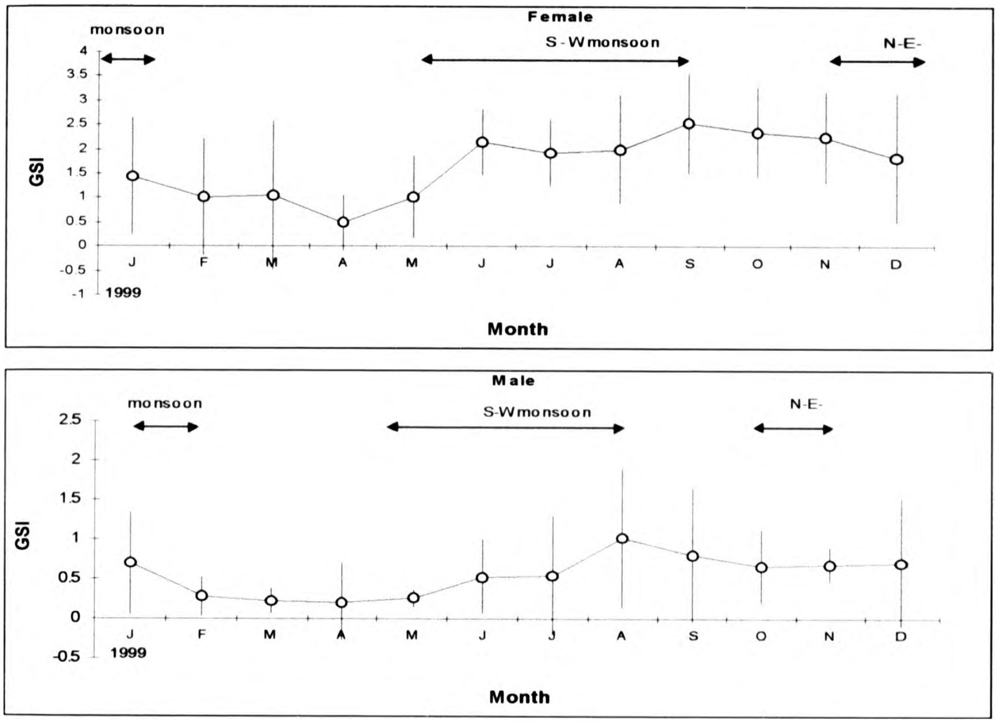


Fig.3. 5. Seasonal changes of GSIs by sex of *L. nebulosus*. Vertical bars indicate ± standard deviation.

The monthly mean ovary GSIs for *L. nebulosus* increased along with the South-West monsoon from May (1.02) and reached the maximum in September (2.54) and gradually declined (Fig. 3.5). The minimum ovary GSI was reported in April (0.48). A similar pattern of development was shown for the testis GSI but in this case the maximum was reported in August (1.02).

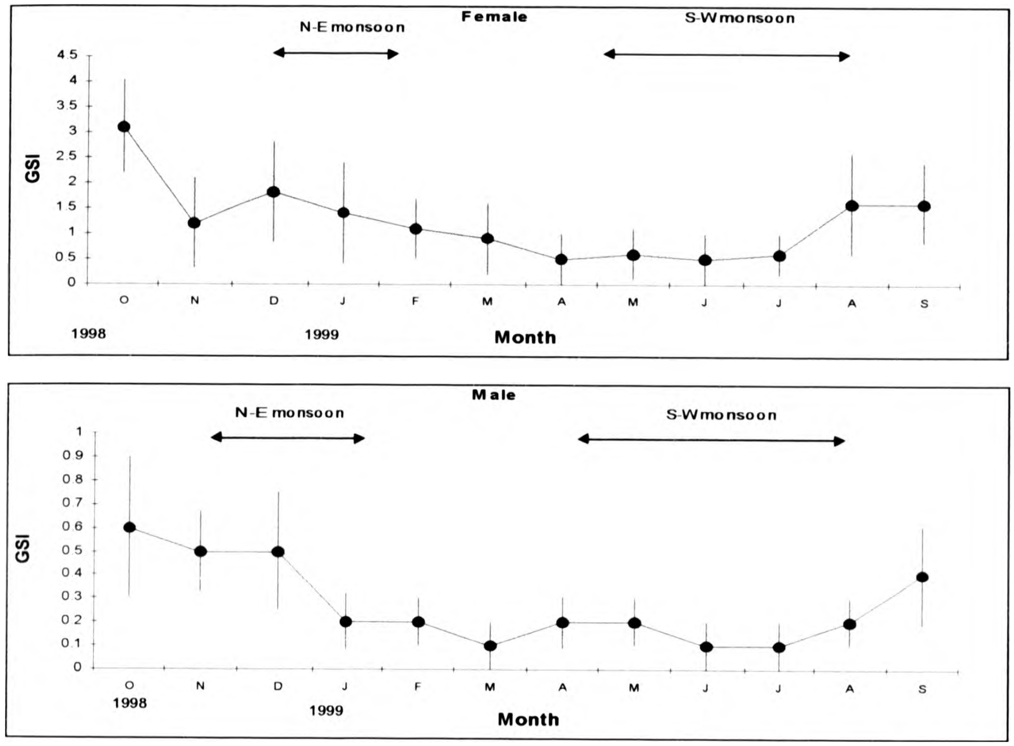


Fig. 3.6. Seasonal changes of GSIs by sex of *L. lentjan*. Vertical bars indicate the ± standard deviation

The increase in the mean GSI of the ovary of *L. lentjan* started from July (GSI was 0. 6), rising to 1.6 in August and peaking in October (GSI was 3.1), and thereafter the GSI gradually declined (Fig. 3.6). The lowest mean value of GSI for the ovary (0.5) was reported in April. The seasonal variation of mean testis GSI followed a similar pattern. The increase of GSI started in August and prevailed until December. A maximum mean value was reported in October (GSI was 0.6) and the minimum was reported in March (GSI was 0.1).

3. 3. 3 Development of Ova to Maturity

A seven stage of maturity scale was selected to describe the development of ova of the two species (Fig. 3. 7). In Stage I, the size range of ova was 3 - 7 µm with a modal value of 3 µm but it is not so clear in Fig. 3.7 due to counting of eggs > 3 µm. By Stage II, ova diameter increased and formed an advance group with a mode at 6 µm divisions in both species. This is known as the 'egg mass'. In Stage III, a batch of ova with a mode at 11 µm in *L. nebulosus* and 10 µm in *L. lentjan* had become clearly separated from the general 'egg mass' and they represented the developing ova. In Stage IV, ova diameter of the developing batch had increased and another new batch of ova developed with a mode at 18 µm and 16 µm respectively for *L. nebulosus* and *L. lentjan*. They represented the maturing ova. In Stage V, the newly developed maturing ova mode progressed rapidly to occupy at 26 µm and 24 µm respectively for *L. nebulosus* and *L. lentjan* and they represent the mature ova which is ready to be shed shortly. In Stage VIa, the batch of mature ova has been shed or is being shed while remaining maturing ova advanced to 16 µm in *L. nebulosus* and 14 µm in *L. lentjan* while the remaining hydrated and degenerating ova form a less prominent mode at around 32 µm in both species. In Stage VIb, the mode of maturing ova progressed to occupy a mode at 24 µm in *L. nebulosus* and 22 µm in *L. lentjan* and this represented the second batch of mature ova. In Stage VII, in addition to the general egg mass some hydrated and degenerating ova were observed. It was observed that redevelopment of ovaries started from Stage III of both species.

Note: to highlight the most advance mode ova, the small sizes of ova 3–10µm were not entered in Stage V and VIa (Fig. 3.7).

3. 3. 4 Variation of Gonosomatic Indices (GSIs) in Different Maturity Stages

The relationship of ovary and testis GSI to maturity stages of each species is illustrated in Figs 3. 8 and 3. 9.

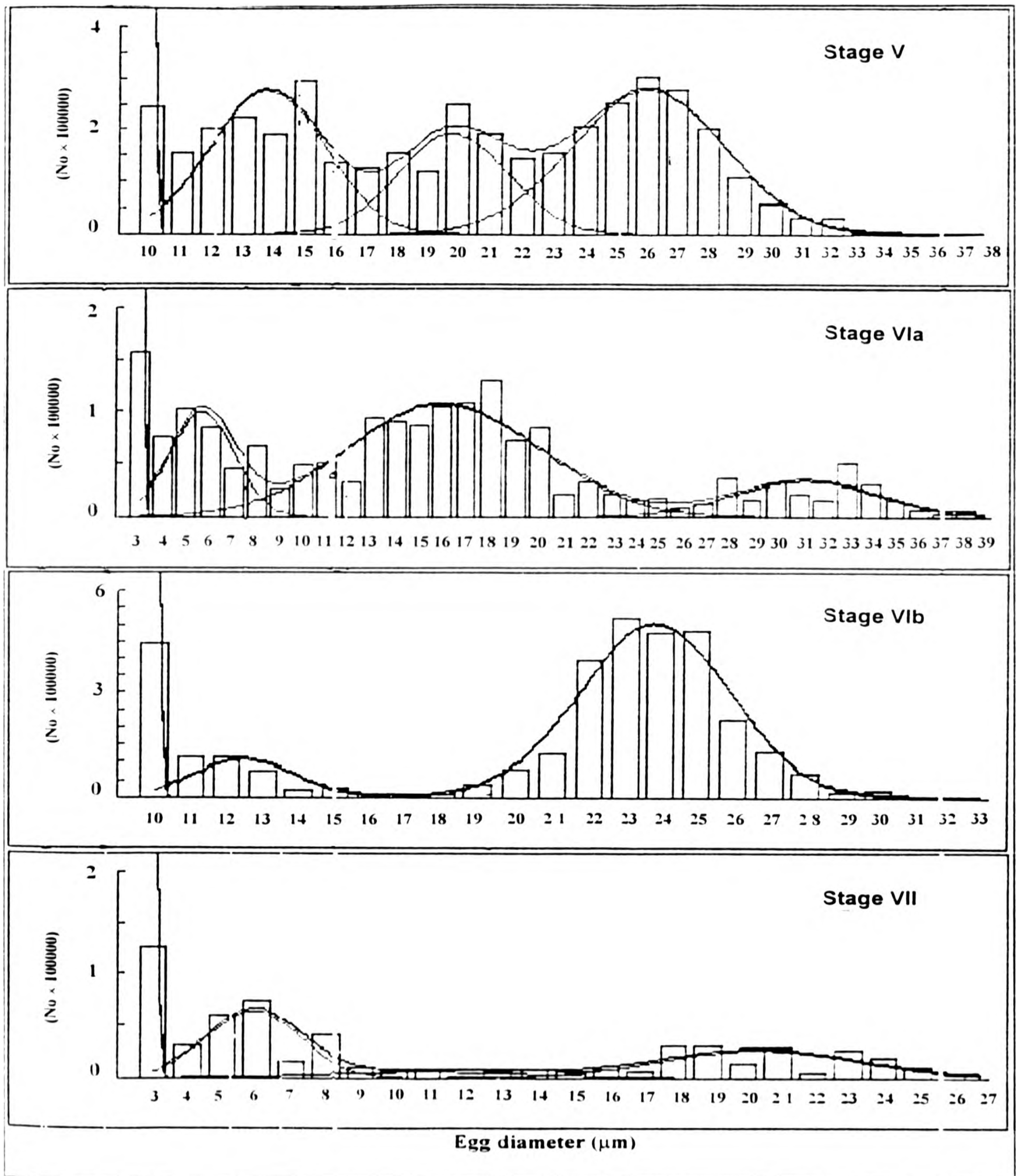


Fig. 3.7 Egg diameter frequency polygon representing the growth of eggs in different stages of maturity of *Lethrinus nebulosus*.

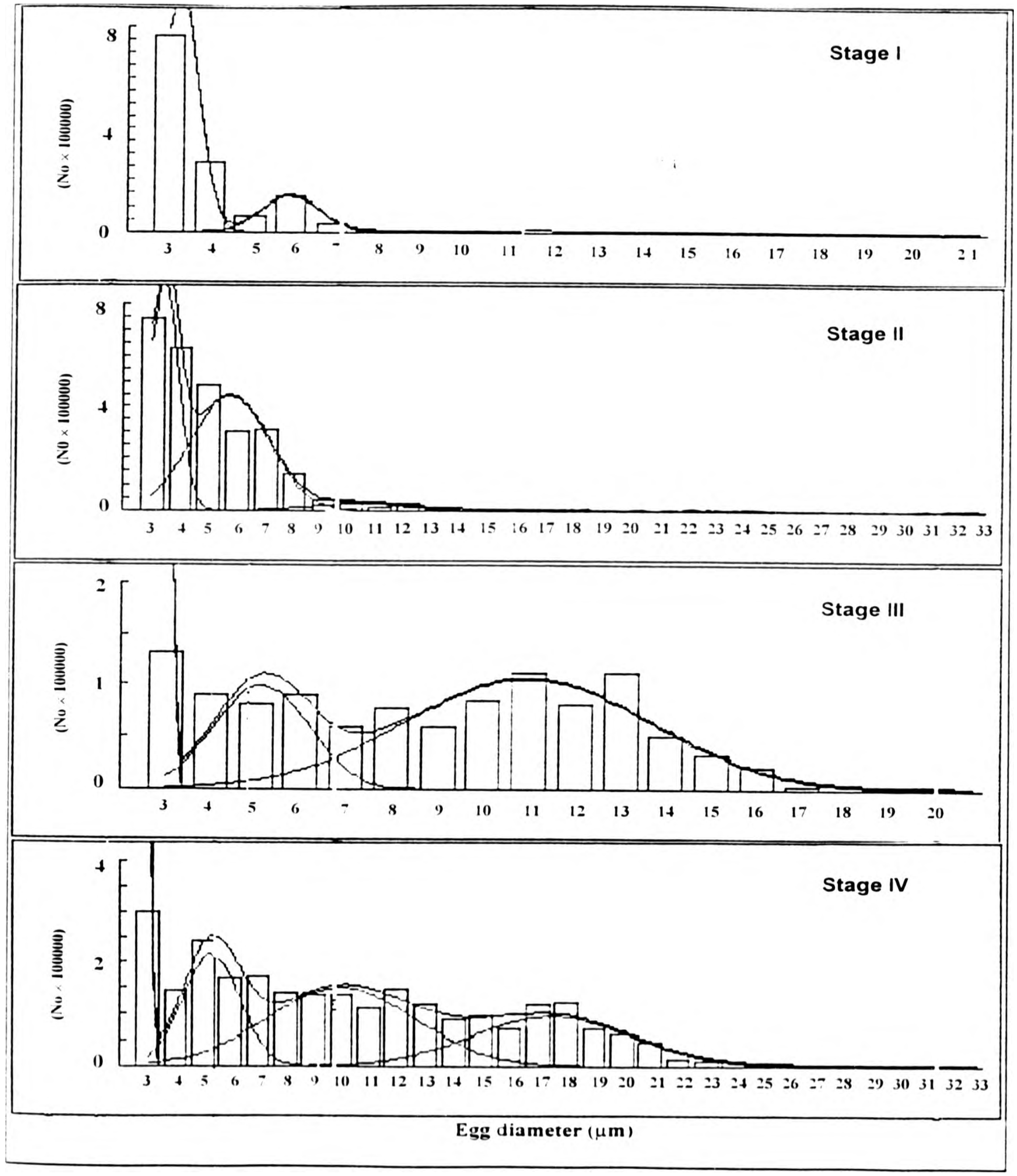


Fig. 3.7. Egg diameter frequency polygon representing the growth of eggs in different stages of maturity of *Lethrinus nebulosus*.

Continued

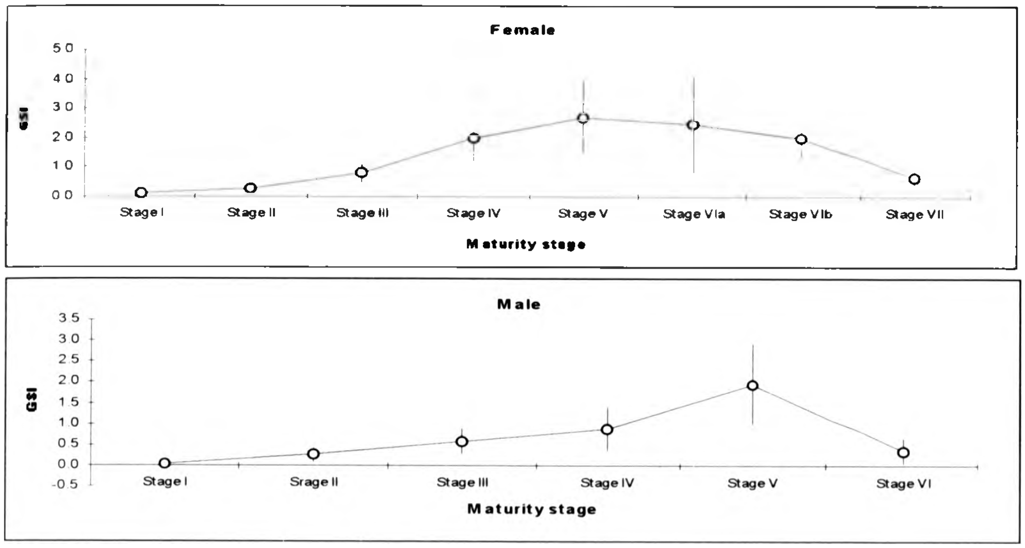


Fig. 3.8. Relationship of ovary and testis GSIs of *L. nebulosus* in different maturity stages.

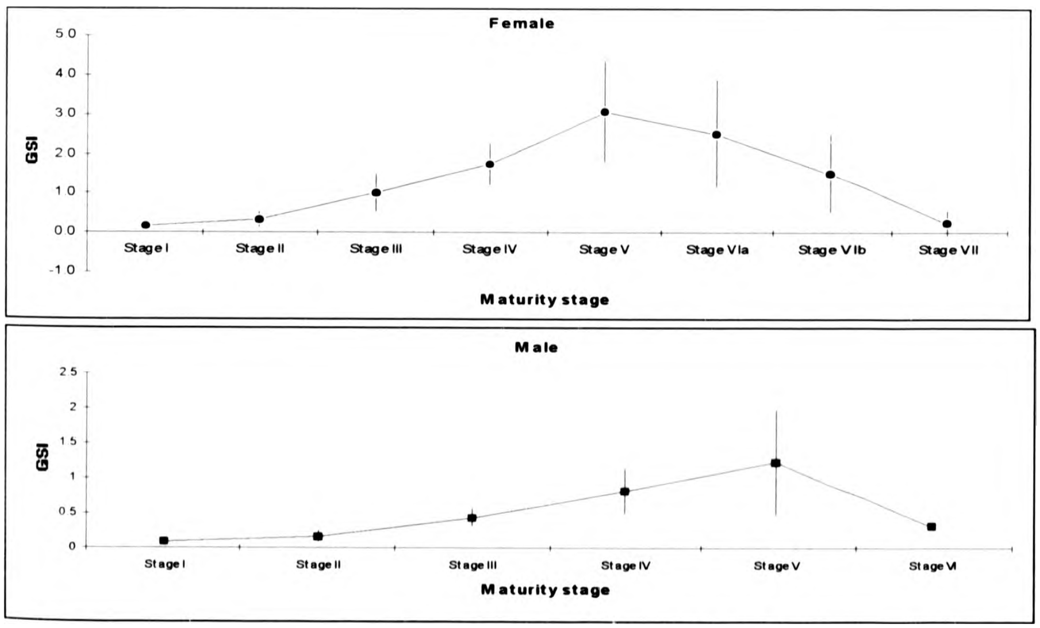


Fig. 3. 9. Relationship of ovary and testis GSIs of *L. lentjan* in different maturity stages.

The mean GSI for both ovaries and testes increased with increasing maturity stage and was maximal at Stage V in both sexes and species and then declined. The development of yolk and milt is the most probable explanation for increase gonad weight in Stage V. GSI can provide an objective measure of the progression of maturation of the gonads of both sexes and species (Figs. 3.8 and 3.9) but according to morphological features there is marked variance at the higher maturity stages.

3. 3. 5 Maturity Stages in the Development of Gonads

Maturity stages were classified on the base of macroscopic and microscopic characteristics of both the testes and ovaries are summarized in Tables 3. 3 and 3. 4 respectively. Maturity stages of gonad development are studied based on a number of complementary criteria. The macroscopic staging of gonads may be subjective and the resolution may be limited, thus both macroscopic and microscopic criteria (visual observation, GSI, ovarian ova development and gonad length to body cavity length ratio) were used in this study. Microscopic characters like ova development enable the identification of two separate sub-stages in the active or ripe-running stage of the ovary (Stage VIa and Stage VIb) providing a greater resolution than macroscopic features. GSI can also provided an objective measure of staging development of gonad but GSI of higher maturity stages shows high variance. Although each set of criteria has its limitation when used in combination, the reliability of the staging system is greatly improved.

Table 3. 3. The maturity scale of testes.

Maturity stage	Description
Stage I (immature virgin)	Testes are strap-like, translucent and almost colourless. GSI – LN range 0.01-0.05 mean 0.038 LL range 0.08-0.16 mean 0.10 Gonad length/body cavity ratio – LN range 42.3-63.0 mean 49.9 LL range 26.9-70.3 mean 50.6
Stage II (developing)	Testes have become thicker, translucent and white. The main body of the testes show numerous translucent regions and the lobes tending to be opaque off-white and rough in texture. GSI – LN range 0.09-0.47 mean 0.256 LL range 0.11-0.45 mean 0.174 Gonad length/body cavity ratio – LN range 45.1-74.4 mean 59.3 LL range 36.8-76.4 mean 56.0
Stage III (developed)	Testes have increased further in size; the main body has become opaque and white, and lateral margins and the tips of the lobes appear creamy white. GSI – LN range 0.25-1.71 mean 0.577 LL range 0.21-0.73 mean 0.44 Gonad length/body cavity ratio – LN range 46.4-95.3 mean 67.0 LL range 46.8-91.2 mean 63.7
Stage IV (mature)	Testes have become opaque, and creamy white, and hard in texture throughout. GSI – LN range 0.61-1.40 mean 0.877 LL range 0.73-0.96 mean 0.82 Gonad length/body cavity ratio – LN range 56.7-89.7 mean 71.2 LL range 53.8-93.6 mean 66.9
Stage V (ripe and spawning)	Testes have become enlarge, opaque and white, and sometime milt can be extruded by applying pressure to the abdominal wall. GSI – LN range 1.12-3.72 mean 1.94 LL range 1.03-1.48 mean 1.23 Gonad length/body cavity ratio – LN range 54.8-106.2 mean 82.6 LL range 57.0-101.5 mean 79.0
Stage VI (Spent)	Testes have become thin and flaccid, wrinkled and generally translucent although some regions can remain opaque and white. GSI – LN range 0.02-0.94 mean 0.329 LL range 0.10-0.54 mean 0.32 Gonad length/body cavity ratio – LN range 34.7-95.6 mean 56.9 LL range 60.0-76.3 mean 65.7

Note: LN = *L. nebulosus* LL = *L. lentjan*

Table 3. 4. The maturity scale of ovary

Maturity stage	Description
Stage I (immature virgin)	Ovaries are narrow and small, colourless and generally translucent. Eggs are not yet visible to naked eye. GSI – LN range 0.02-0.13 mean 0.09 LL range 0.10-0.40 mean 0.158 Gonad length/body cavity ratio – LN range 27.2-64.9 mean 49.7 LL rang 41.2-73.1 mean 60.1 Modal distribution of ova diameter- LN 3μm LL 3μm
Stage II (early developing)	Ovaries have become round, the ovarian wall thinner and red or pink in color. Large eggs are still not visible. GSI – LN range 0.13-0.49 mean 0.29 LL range 0.10-0.80 mean 0.328 Gonad length/body cavity ratio – LN range 41.7-77.9 mean 60.5 LL range 35.4-77.8 mean 62.3 Modal distribution of ova diameter- LN 3, 6μm LL 3, 6μm
Stage III (late developing)	Ovaries have increased in size, offers yellow or creamy in colour with blood capillaries, the ovary wall remains translucent, eggs are now visible and being creamy white. GSI – LN range 0.38-1.5 mean 0.78 LL range 0.20-2.1 mean 1.002 Gonad length/body cavity ratio – LN range 54.0-83.8 mean 64.8 LL range 42.1-89.8 mean 65.6 Modal distribution of ova diameter- LN 3, 5, 11μm LL 3, 5, 10μm
Stage IV (maturing)	Ovaries appear bright yellow or orange with blood capillaries. Eggs of large size are opaque and yellow and distinct from smaller eggs. GSI – LN range 1.14-2.96 mean 1.96 LL range 1.0-2.8 mean 1.744 Gonad length/body cavity ratio – LN range 64.4-90.0 mean 75.5 LL range 46.6-93.2 mean 73.3 Modal distribution of ova diameter- LN 3, 5, 10, 18 μm LL 3, 5, 10, 16 μm
Stage V (mature)	Ovaries become orange-yellow in colour, the ovarian wall has become fully vascular, thin and translucent. Large eggs are yellow and translucent. GSI – LN range 1.05-4.61 mean 2.72 LL range 1.5-4.1 mean 3.07 Gonad length/body cavity ratio – LN range 62.7-92.9 mean 79.1 LL range 56.9-95.6 mean 79.1 Modal distribution of ova diameter- LN 3, 5, 13, 26 μm LL 3, 5, 12, 24 μm

Continued

Stage VI a (Gravid or running)	Ovaries are similar to the of the previous stage, but ova can be easily extruded by gently pressing the abdomen. Large eggs, mostly hydrated. GSI – LN range 1.55-3.62 mean 2.45 LL range 1.5-3.5 mean 2.51 Gonad length/body cavity ratio – LN range 65.8-111.4 mean 81.3 LL range 62.8-96.9 mean 79.5 Modal distribution of ova diameter- LN 3, 6, 16, 32 µm LL 3, 5, 14, 32 µm
Stage VI b (Partially spawned)	Ovaries have partially filled, the ovary wall slightly wrinkled, reddish-yellow in colour, residual large eggs present. GSI – LN range 0.99-3.97 mean 1.99 LL range 0.9-2.2 mean 1.51 Gonad length/body cavity ratio – LN range 62.6-117.1 mean 77.7 LL range 57.5-93.7 mean 75.4 Modal distribution of ova diameter- LN 3, 6, 24 µm LL 3, 6, 23 µm
Stage VII (Spent)	Ovary wall has become thick and wrinkled, ovaries flaccid, elongated and narrow and brown-red in colour, residual eggs present. GSI – LN range 0.12-0.96 mean 0.628 LL range 0.1-0.9 mean 0.244 Gonad length/body cavity ratio – LN range 45.1-71.8 mean 60.0 LL range 47.3-90.8 mean 69.3 Modal distribution of ova diameter- LN 3, 6 µm LL 3, 6 µm

3. 3. 6 Spawning seasons

Full maturation of ovaries of *L. nebulosus* was deemed to have been reached in June, when about over 50% of females studied were mature (>Stage V) and a high percentage maturity continued until December. The running fish (Stage VIa and VIb) also first appeared in June and were present until March (Fig. 3.10A). Spent fish were present in most months during the spawning season but the highest percentage (28.6%) was reported in March. The spawning period of female *L. nebulosus* extended over a long period, about 9 months, but within this period two pulses were identified. The principal pulse extended from July to November while a second minor pulse peaked in February. Mature males (>Stage IV) were reported from June to January and again in March (Fig. 3. 10B). The maximum number of mature male fish (>Stage IV) was reported in November and spent fish (Stage VI) was in December and in March. Thus the spawning pattern of male *L. nebulosus* was similar to that of the females.

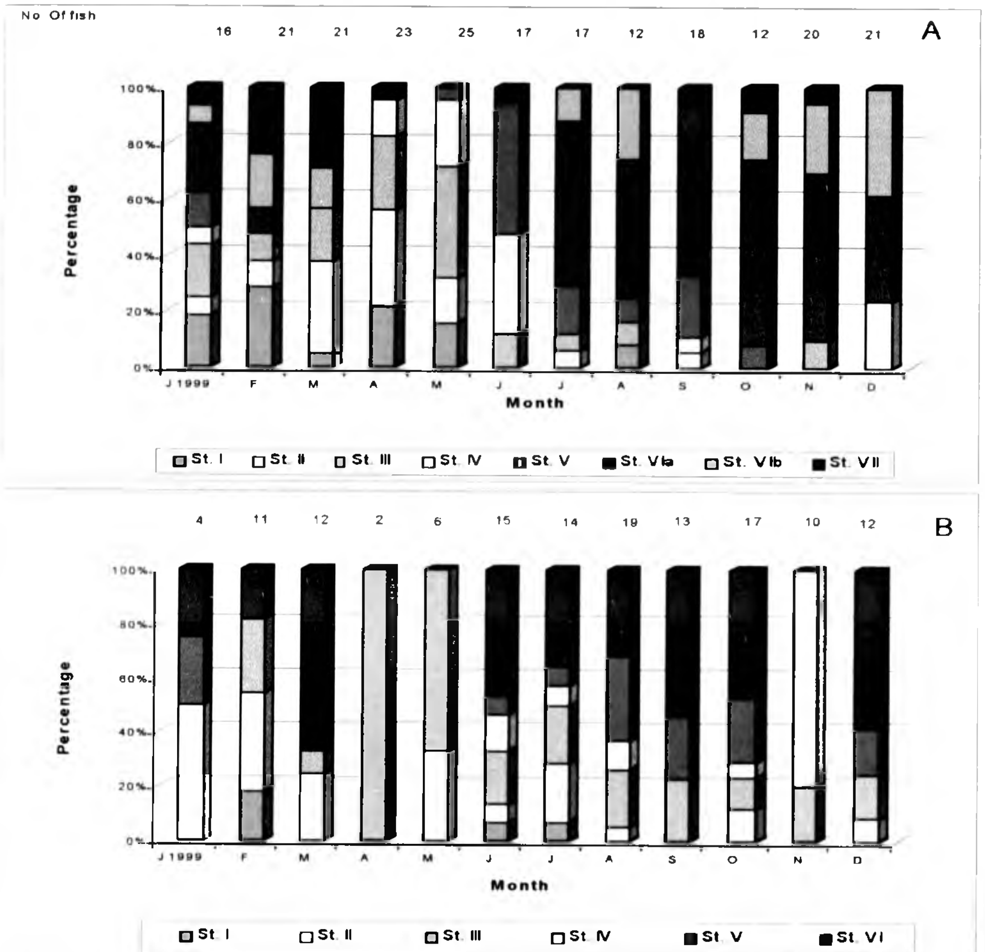


Fig. 3.10. Monthly variation of percentage maturity stages for female (A) and male (B) *L. nebulosus*.

The spawning season of female *L. lentjan* extended for about 3-4 months. Maturation of mature ovaries started in October and continued until December (Fig.3. 11A). A high percentage of running (Stage VIa and VIb) individuals were reported in October and December. The spawning season of male *L. lentjan* was not so clear as for females. The mature testes were initiated in October and maturation continued until December. The highest number of spent fish (Stage VI) was reported in November (Fig. 3. 11B).

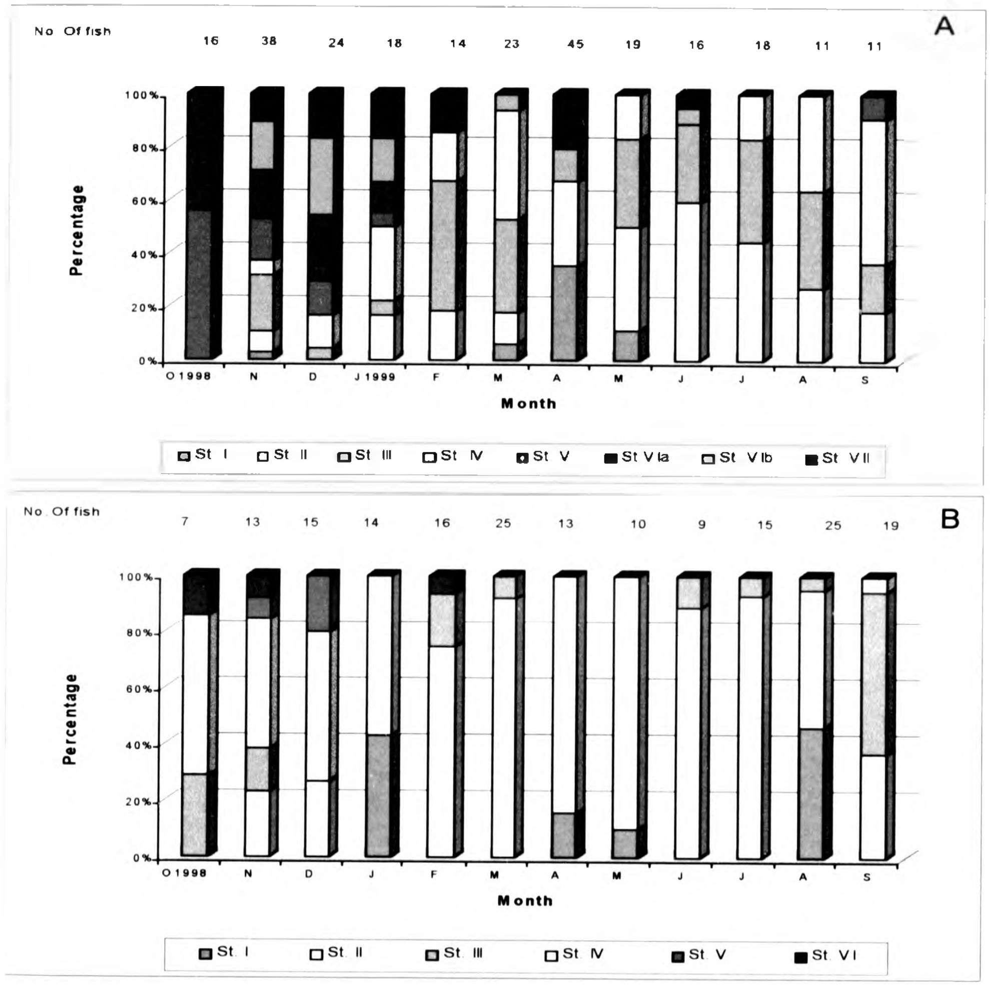


Fig. 3. 11. Monthly distribution of different maturity stages for female (A) and male (B) *L. lentjan*.

3. 3. 7 Size at Sexual Maturity

The frequency distribution of mature (Stage V to Stage VII for female and Stage IV to Stage VI for male) male and female fish of *L. nebulosus* and *L. lentjan* by size are illustrated in Figs 3. 12 and 3. 13 respectively.

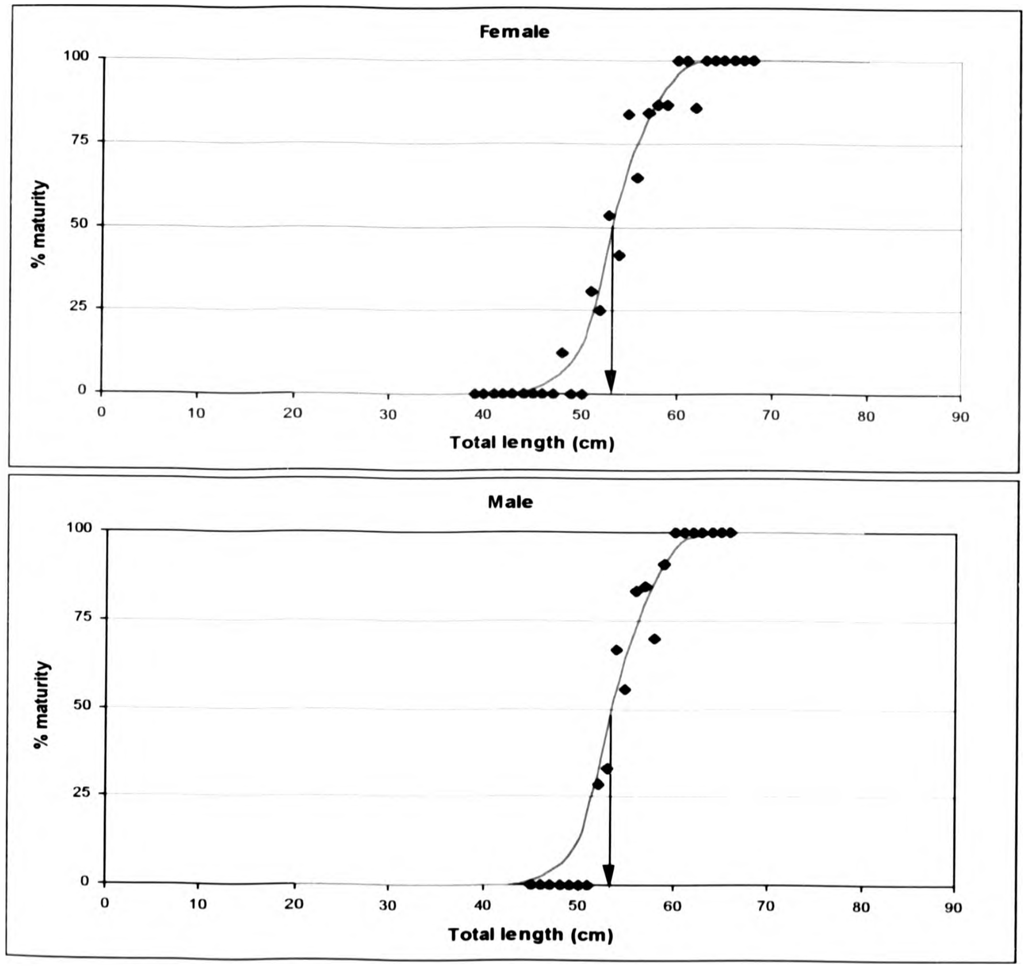


Fig 3. 12. Percentage maturity of female (stage IV to VII) and male (IV to VI) *L. nebulosus* by size class.

The size of 50% maturity of both female and male *L. nebulosus* was estimated at around 53 cm. The minimum sizes of mature female and male fish were reported as 48 cm and 52 cm respectively. All fish exceeding 60 cm, both male and female, were mature. This indicates that *L. nebulosus* attains maturity at about 48 –50 cm and will spawn when larger than 50 cm.

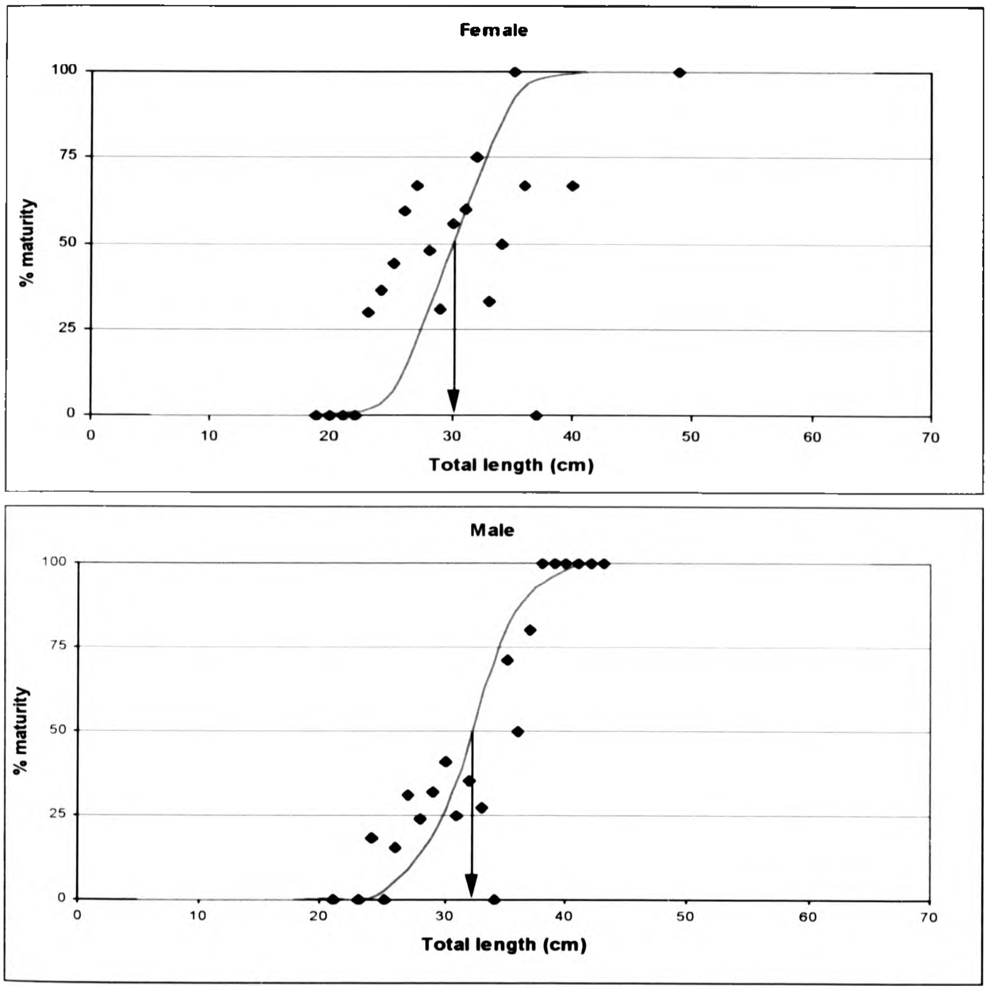


Fig 3. 13. Percentage maturity of female (Stage IV to Stage VII) and male (Stage IV to Stage VI) *L. lentjan* by size class

The size of 50% maturity of female *L. lentjan* was estimated at around 30 cm and male at around 33 cm. The minimum sizes of mature female and male fish were reported as 20 cm and 24 cm respectively. All fish exceeding 38 cm, both male and female, were mature. Thus *L. lentjan* was found to attain maturity at above 20 cm and will spawn when larger than 30 cm total length. Converting these lengths to corresponding ages

(Chapter 4) show that *L. nebulosus* would mature during their fourth year of life while *L.lentjan* would mature earlier, in the second year (see Chapter 4, Table 4. 4).

3. 3. 8 Fecundity

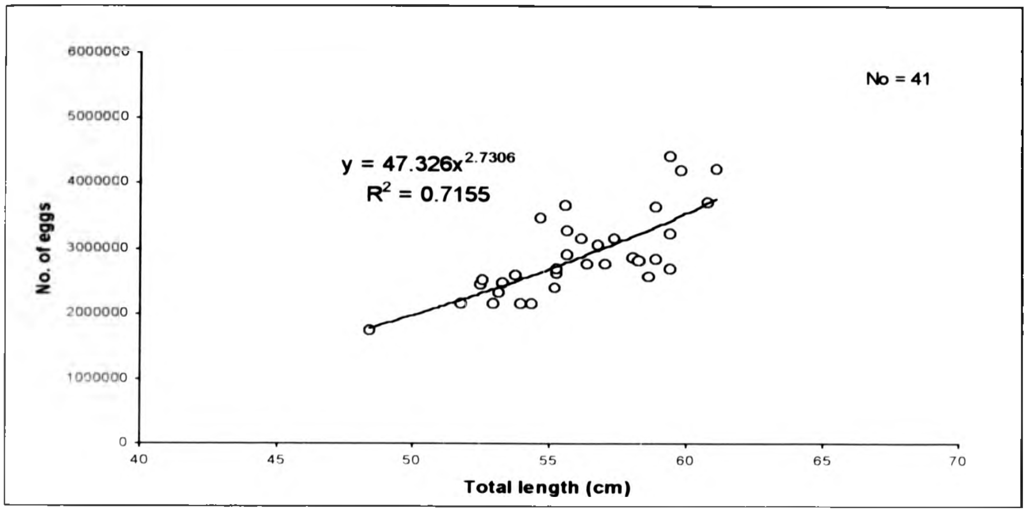


Fig 3. 14. Relationship of batch fecundity and total length of *L. nebulosus*

Batch fecundity was found to increase exponentially with size in both species Figs. 3. 14 and 3. 15. The relationship between total length (TL) and batch fecundity of *L. nebulosus* was; Fecundity = 47.326 L $^{2.73}$ (Fig. 3. 14).

The relationship is highly significant (p>0.05). The number of eggs estimated to be released during each spawning ranged from 1,886,855 to 3,565,036 for the size range of 48.4 to 61.1 cm.

A similar high significant relationship (p>0.05), and batch fecundity was shown for *L. lentjan*. Fecundity = 83.407L$^{2.58}$ (Fig. 3.15).

The number of eggs estimated to be released during each spawning ranged from 282,407 to 1,978,056 for the size range of 23.1 to 49.0 cm.

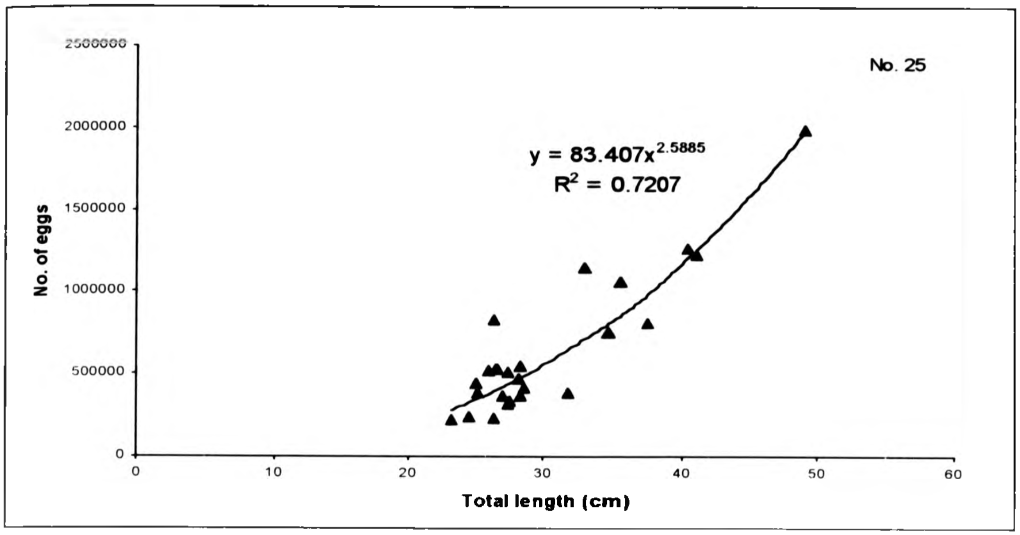


Fig. 3. 15. Relationship of batch fecundity and total length of *L. lentjan*

3. 4 DISCUSSION

Knowledge of the sex ratio is considered to be essential in the management of the demersal fishery in the Negombo area, as it changes in relation to season and size of indicator species (Fig. 3.1, 3.2, 3.3 and 3.4). Stock assessment and management strategies are usually developed under the assumption of equal proportions of males and females in the population. The considerable increase in the proportion of females in the spawning season of both species indicates some congregation during the spawning season. Similar observations have been noted by other workers such as Toor (1968a) for *L. lentjan* and Salem (1976 *in* Wassef and Bawazeer, 1992) and Aldonov and Druzhinin (1978) for some members of Lethrinids including *L. lentjan* and *L. nebulosus*. The fishing effort in this study area by most gear, bottom longline especially increased with the decline of South-West monsoon from September/October and continued until the return of South-West monsoon winds in April/May. This fishery targets the large demersal varieties mainly Lethrinids (Chapter 2, Fig. 2.4b) and the effort, mainly through bottom longline may be exploiting the spawning aggregations identified in this study.

The predominance of females at younger ages and males in older ages in both species could indicate either some change of sex or differential behavior of male and female fish during their life span. Male domination of the smaller size classes has been observed in some of the demersal fish belonging to families Serranidae (Smith, 1965 *in* Thresher, 1984), Lactaridae (Moore, 1979), Labridae (Reinboth, 1975; Warner and Roberton, 1978), Pomacanthidae (Fricke and Fricke, 1977) and Scaridae (Reinboth, 1968 *in* Thresher, 1984). This has been attributed to sex change at a certain size class or age. Such a change of the gonadal tissues has not been seen in the present study in any of the size classes of fish. However, there is some supporting evidence for the sex change of Lethrinids, including *L. nebulosus* and *L. lentajn,* in the literature (Lebeau and Cueff, 1975; Loubens 1980a; Young and Martin, 1982; Ebisawa, 1990). Lebeau and Cueff (1975) in which the sexual transformation was found to occur over a wide range of size (protogynous hermaphroditism), resulting in a considerable overlap in the size distribution of the male and female components of the population. Ebisawa (1990) reported that *L. nebulosus* exhibited juvenile hermaphroditism in which sex was determined as 24-30 cm fork length and other Lethrinid species, such as *L. nematacanthus*, *L. variegatus* and *L. lentjan,* were mostly functional protogynous hermaphroditism. He further observed that both male and female germinal tissues were in a mixed form during the transformation of sex. In the present study *L. nebulosus* were sampled between 23.6 to 68.2 cm total length but only 16 fish were sampled from the 20-30 cm length group. This may be why neither of hermaphroditism nor sex change was observed in *L. nebulosus* in the present study. As no histological work has done during the present study, the hypothesis that protogynous hermaphroditism exists in this species was based upon comparative length distributions of male and females captured during the spawning period. Males have been observed in all length classes of both species. This indicates that males may develop directly or be derived from adult females through sex change.

Lebeau and Cueff (1975) has suggested that the size difference in the sexes in related species of, *L. enigmaticus* in the Indian Ocean, was due to sexually different growth. Loubens (1980a), Kuo and Lee (1986) and Baillon (1991) estimated growth parameters of *L. nebulosus* separately by sex (see Chapter 4, Table 4.7) but found that the difference of growth rate between the sexes was very low. This minor difference in the growth rate would not influence such variation in the size distribution of both male and female of *L. nebulosus*. Wyatt (1983) observed a high proportion of females in some coral reef fish in shallow waters in contrast to equivalent ratios in fish inhabiting in deeper waters. He suggested that the most likely explanation was selective capture of the large males by the intensive fishing in the shallow waters. The predominance of males among larger size class of both species may also be the result of the size related offshore migration with increasing size.

The gonad maturity of *L. nebulosus* and *L. lentjan* in this study is based on three methods. The most commonly used method classifies the maturity stages on changes in the general appearance of gonads (Aldonov and Druzhinin, 1978; Kedidi, 1984; Kuo, 1988; Nizioka, 1979). The characters generally used to define maturity stages of gonads include size, color etc. or the gonosomatic index. Macroscopic characteristic of gonads may be subjective and Gonad index may also be biased due to high variance at higher maturity stagers. A few classification schemes have been based on histological examination of gonad tissues of *L. nebulosus* (Loubens, 1980a; Ebisawa, 1990), but none have been reported for *L. lentjan*. Histological description can provide the most complete information but is time consuming and costly. Toor (1968a) used the description of ova development in combination with the general appearance of the gonad to identify the maturity stages of *L. lentjan*. In the present study maturity stages in gonad development were classified based on microscopic characters (ovarian ova development), GSI and several macroscopic characters. The development pattern of ova allowed the identification of certain additional stages (Stage VIa and Stage VIb) which have not be reported in other studies conducted on *L. lentjan* and *L. nebulosus* (Toor, 1968a; Aldonov and Druzhinin, 1978; Loubens, 1980a, Ebisawa, 1990). These partially spawned stages superficially resemble Stages IV and V depending on the species, but compactness and colour of the ovaries were different. Therefore, maturity scales developed primarily for temperate fishes, which have a definite spawning season, are not suitable for iteroparous tropical fishes which produce successive batches of ova which are released in multiple spawning. In such fishes, the maturity scale should be based more on the modal position of different batches of ova or on histological examination. However, characteristics like protogynous hermaphroditism, have not been identified with characters used in the present study. Therefore it is more appropriate to identify sexual maturity stages based on various morphological and histological features of gondal development.

All the stages of maturity were found in the catches of both species indicating that spawning take place in the coastal waters off Negombo. The principal spawning season of female *L. nebulosus* extended over a long period from July to December with a second minor in February. *L. lentjan* on the other hand spawned from October to January with a major peak in October, and a second minor peak was in March. These results confirm the general observations of an extended spawning seasons by other authors (Toor 1968a; Kedidi, 1984; Ebisawa 1990; Kuo and Sen, 1990).

The spawning seasons of *L. nebulosus* and *L. lentjan* reported in different localities (Table 3. 5) indicate that their spawning season may have some latitudinal variation.

Table 3. 5. Spawning season of *L. nebulosus* and *L. lentjan* in different localities.

Source of information	Locality	Peak spawning season
L. nebulosus		
Sanders *et al.* (1984)	North Red Sea	April to July
	Gulf of Aden	March to May and September
	North Arabian Gulf	May to June
Kuo and Sen. (1990)	North-west Australia	July to August/September and March to June
Ebisawa (1990)	Okinawa –Japan	
Egretaud (1992)	New Caledonia	March to June
Present study	Negombo, Sri Lanka	July to December and February
L. lentjan		
Toor (1968a)	South India	December to February
Aldonov and Druzhinin (1978)	New Caledoniya	September to December
Kedidi (1984)	Red Sea	January April and August
Present study	Negombo, Sri Lanka	October to January and March

In populations of *L. nebulosus* in the countries at higher latitudes of the tropical region (Red Sea, Arabian Gulf area and Okinawa), spawning begins earlier, than in the equatorial region. The influence of some environmental character may cause this. Loubens (1980a) and Bertrant (1986) indicated that the elevation of water temperature was the breeding stimulus of Lethrinids.

There has been no study on the spawning frequency of *L. nebulosus* or *L. lentjan* made through direct observation of spawning. In the present study spawning frequency was estimated by an indirect method based on ova development. The evidence derived from ova maturity suggests that both species are batch spawners (Fig. 3.7). Considering the number of graphical modes of mature eggs developed during the spawning season and assuming batch of mature eggs spawned at once, female spawns at two times during the spawning season. Presumably detailed analysis of the size distribution of modal eggs may reveal more than two modes of size classes in the ovaries at any stage of maturity (Fig. 3.7) suggesting that more than two spawning events is possible. De Vlaming (1983) reported that most species with asynchronous oocyte development have protracted spawning seasons with multiple spawning. However, Toor (1968a) concluded, based on the poly modal distribution of ova diameter, that *L. lentjan* spawns twice during the spawning season.

A difference in the size at sexual maturity between sexes was observed with *L. lentjan* in the present study. Female fish of *L. lentjan* mature around 30 cm (2 year) while males mature at around 33 cm total length (2 year). Both male and female fish of *L. nebulosus* mature at around 53 cm (4 year) total length. Different observations have been made for *L. nebulosus* in the northern Red Sea where the males sexually appear to mature earlier at around 4.6 years than females which mature at around 5.9 years of age (Sanders and Morgan, 1989). The minimum length at maturity of *L. nebulosus* was observed at around 40 cm folk length in Okinawa, Japan (Ebisawa, 1990) and 38 cm fork length in New Caledonia (Egretaud, 1992). The size and age at maturity of *L. lentjan* in southern Indian waters was estimated as 30 cm standard length and three years respectively (Toor, 1968a). Kedid (1984) estimated that the Red Sea population of *L. lentjan* mature at 3.8 years. This shows that females of *L. lentjan* mature at a relatively young age in the Negombo area. Grimes (1987) concluded that Lutjanids in continental and shallow habitats mature at smaller lengths than those species and populations in insular and deep habitats. The present results confirm his findings but no comparative data are available for these two species. However, generally high fishing mortality and selection pressure favors high fecundity with rapid development, growth and maturity (Grimes *et al.*, 1988).

Few studies have been completed on the fecundity of *L. nebulosus* and *L. lentjan*. In the present study batch fecundity of *L. nebulosus* was estimated as 1,886,855 to 3,565,036 eggs per fish ranging in size from 48.4 to 61 cm total length and for *L. lentjan* fecundity varied from 282,407 to 1,978,056 eggs ranging in size of fish from 23 to 49 cm. Tawada *et al.*(1984 *in* Ebisawa, 1990) estimated that fully matured *L. nebulosus* of average of 49.7 FL spawned approximately 11,000,000 eggs within 122 days during the spawning period in the tanks and Ebisawa (1990) found that the fertilities counted in tanks were two times larger than those in natural condition. Kedidi (1984) found that an average female *L. lentjan* lay 12,000-78,000 eggs per year. Different relationships have been found to exist between length and fecundity in different species of fish. Studies have demonstrated that the fecundity and the length of fish has a cube or close to the cube relation (Bagenal, 1957). The findings of the present study shows that the fecundity of both *L. nebulosus* and *L. lentjan* increased at a rate of 2.7 and 2.6 times the length increase respectively and was also close to the rate of increase of body weight in relation to length (Chapter 4). A linear relation between fish length and fecundity has been reported by Wassef and Bawazeer (1992) but for *L. nebulosus* and *L. lentjan* this ratio was observed to generally confirm the cube relation.

Chapter 4

Length-Weight Relationship and Vital Statistics of *Lethrinus nebulosus* and *Lethrinus lentjan*

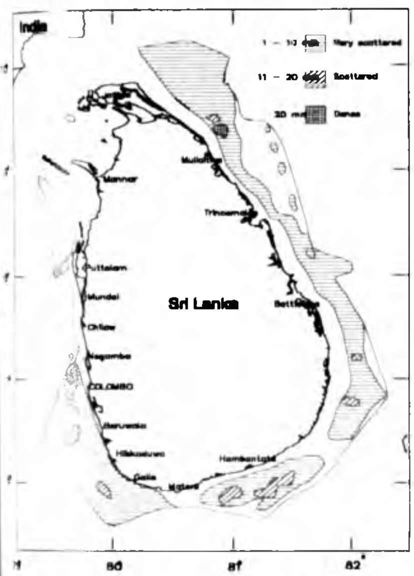
4.1 INTRODUCTION

Reliable estimates of length-weight relationship and vital statistics such as growth and mortality and selectivity parameters of exploited populations of *L. nebulosus* and *L. lentjan* are essential for the biologically sustainable management of these species. In fact analytical stock assessment models depend on the accuracy and reliability of these parameters for evaluations and projections of fish stocks (Gulland, 1969; 1983; Hilborn and Walters, 1992).

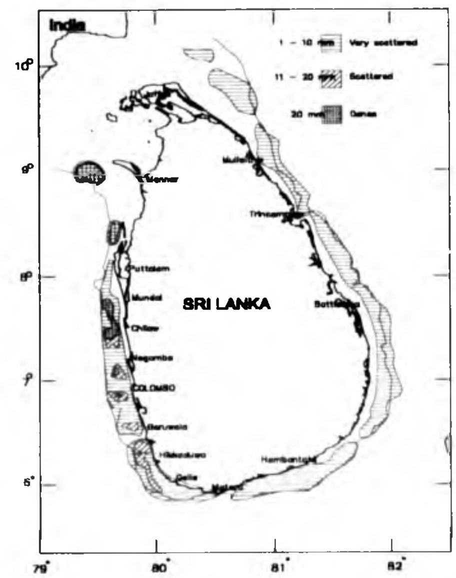
Despite the commercial importance of the two species in demersal fisheries, their population dynamics has not been studied in Sri Lanka. This investigation of the key population and fisheries parameters of *L. nebulosus* and *L. lentjan* is the first of this kind in Sri Lanka. The results are later used in the stock assessment studies in Chapter 5.

4. 1. 1 POPULATION/STOCK STRUCTURE

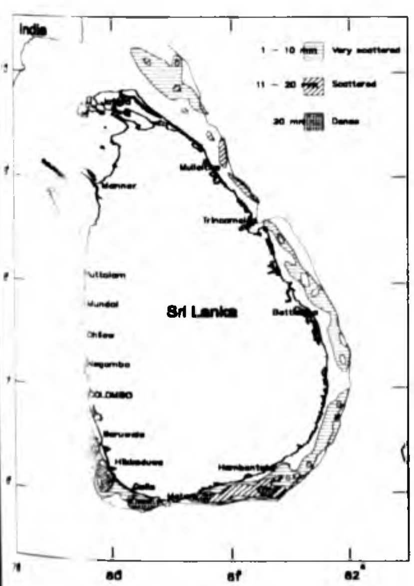
The population parameters differ from species to species, but they may also vary from stock to stock within the species. The theory of stock assessment is based on the unit stock concept (Sparre *et al.*, 1989). Thus it is important to know the geographical distribution and movement of fish stocks. In the tropics, diversity of species is high, but their geographic range is generally smaller than at high latitudes (Stevens, 1989). Tagging experiments carried out in the Gulf of Thailand have shown that most demersal species migrate over short distances or within limited areas (Vadhanakul, 1980). Although there is no direct evidence on the distribution and movement of demersal fish resources off Negombo, there is some information which indicates that the movements of local demersal fish populations are restricted. The resource survey conducted by RV 'Dr. Fridtjof Nansen' (1978-80) inferred high and discrete concentrations of demersal resources off Negombo in all the three periods of investigation (Fig. 4.1) (Sætersdal and De Bruin, 1978, Blindheim *et al.*, 1979, Blindheim and Foyn, 1980). There may be some exchange of fish between adjacent areas but the survey indicated that the populations in the study area were rather isolated. Thus in this investigation, it is assumed that each component species of the demersal resources in the Negombo area form a 'unit stock'



1978



1979



1980

Fig. 4.1. Distribution of echo intensity of recordings classified as demersal and semi-dimersal fish

Costal Fish resources surveys with the R.V. " Dr Fridtjof Nanson"

a. Aug – Sep 1978

b. April – May 1979

c. Jan – Feb 1980

4. 2 MATERIALS AND METHODS

4. 2. 1 Length-weight relationship

Data from a total of 387 *L. nebulosus* and 458 *L. lentjan*, collected over the period of 1998-1999, have been used to study the length-weight relationships. Total lengths were measured to the nearest 0.1 cm and total body weight (with gonads and viscera intact) to the nearest 0.1 g. The length-weight relationships were studied without considering sex of fish by the least square method, using the following logarithmic form of the general formula: $W = aL^b$, ... (1)

$\log_{10} W = \log_{10} a + b \log_{10} L$

Where, W = weight of the fish (g), L = total length (cm), and a and b (regression coefficient) are parameter constants.

The 95% confidence limits of the regression coefficient (b) of the linear regression were estimated.

4. 2. 2 Growth Parameters

Growth is the change of size, either as body weight or length, as a function of age (time). Though a number of growth models such as von Bertalanffy, Gompertz, Logistic (Beverton and Holt, 1957 *in* Sparre and Venema, 1992, Ursin 1968; Allen, 1971; Ricker, 1975; Gulland, 1983; Pauly, 1984a; Pauly and Morgan, 1987) are available, the von Bertalanffy model (Bertalanffy, 1934 *in* Sparre and Venema, 1992) was used in this study because the consistent physiological concepts fit a wide range of species and to represent growth over the full range of life span. Further more this model can be incorporated into the widely used fisheries yield equation of Beverton and Holt (1957 *in* Sparre and Venema, 1992) (Gulland, 1983). However, imprecisely defined asymptotic length ($L\infty$) or weight ($W\infty$) parameter in this model has been subject to criticism (Knight, 1968; Roff, 1980; Moreau and Moreau, 1987). The asymptotic length is defined as the mean size of a cohort of fish population if they lived and grew indefinitely (Ricker, 1975). The von Bertalanffy growth equation based on length measurements is expressed as:

$L_t = L_\infty (1 - e^{-K (t-t_0)})$ .... (2)

Where, Lt = predicted length at time t, L_∞ = asymptotic length, e = base of natural log, t = time, t_0 = age of the organism at length 0, K = the growth coefficient (instantaneous growth rate).

Three methods are generally used to estimate t or the age of fish, 1) recovery of marked fish of a known size and estimation of the incremental growth over the released period. This is an expensive and time consuming method. 2) using the modal progression (Peterson method) (Petersen, 1892 *in* Sparre and Venema, 1992). This method requires the measurement of the length of a large number of fish in a population and it is based on the supposition that the lengths of fish in a year class (cohort) will distribute normally around a mean. When length data are plotted as a series of normal distributions, cohorts can be separated. 3) counting marks that develop periodically in various hard parts such as otoliths, scales, bones etc. or analysis of daily otolith rings (Panella, 1971 *in* Gjøsæter *et al.*, 1984).

Despite the limitations on the analysis of length frequency data it is however a widely used method in the determination of age of tropical species primarily because lengths can easily measured in the field and also more refine methods have now been developed to over-come many problems dealing with length based estimation of population parameters specially applicable to tropical conditions (Pauly and Munro, 1984; Pauly, 1986a; 1986b; 1986c, 1987 and Pauly and Morgan, 1987). Graphical (Cassie, 1954; Bhattacharya, 1967 *in* Sparre and Venema, 1992) or computer-based statistical methods (NORMSEP- Hasselblad, 1966; ELEFAN I- Pauly and David, 1981; Pauly, 1986a; 1986b; 1986c) have been used to separate mixtures of year (age) classes in length frequency distributions of various tropical fish.

The ELEFAN I programme incorporated in FiSAT software package (Gayanilo *et al.*, 1994) was used for the estimation of parameters of the von Bertalanffy growth model for the two species during the present study. FiSAT software package brings together a series of ELEFAN programs and is perhaps the best known method (Complete ELEFAN) for stock assessment from length data (Pauly, 1987). A representative length sample of the population is the prime requirement in the length based assessment methods. The demersal fishery in the study area is a multigear fishery and both *L. nebulosus* and *L. lentjan* are vulnerable to most gears. Among them handline, bottom longline and bottom trammel net are the most important. Thus during this population dynamic and stock assessment study only these three main fishing gears were considered. All handline methods conducted with different craft gear combination (bait cage handline fishing with IBM boats, bait cage handline fishing with OBM boats and drop handline fishing combined with drift gillnet) were pooled and as common handline fishing data as they operate in the same depth zone and use common hook sizes. The three major gears exploit different size groups of fish due to gear selectivity and/or because they operate in different depth zones (Chapter 2). In order to obtain a representation of the entire length distribution of the population the monthly length data sample of different gears were pooled and were used to prepare total length distributions for the two species from January to December 1999. In addition, prior to estimation of the population parameters, the original length frequency data were corrected using the probabilities of capture, described by Pauly (1986b) to minimize the effect of the gear selection on the length data sample. The methodology of collection of length frequency data has been discussed in Chapter 2

The 'Powell-Wetherall' plot in the FiSAT package was used to obtain a preliminary estimate of $L\infty$. Powell (1979 *in* Sparre and Venema, 1989) and Wetherall *et al.* (1987) suggested the use of a special application of length-based Beverton and Holt (1957 *in* Sparre and Venama, 1992) Z-equation to estimate both $L\infty$ and Z/K values:

$$Z = K \times \frac{L\infty - \bar{L}}{\bar{L} - L'} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where, L' = any length equal or above the smallest length under full exploitation (cutoff length), $\bar{L}$ = mean length of fish of length L' and longer, Z = total mortality coefficient (total mortality rate), K = growth constant

As L' can be any value equal to and above the smallest length under full exploitation, the above equation can give a series of estimates of Z, namely one for each choice of L'. This makes it possible to transfer equation (3) into a regression analysis with L' as the independent variable. A series of algebraic manipulations shows that the Beverton and Holt (1957 *in* Sparre and Venema, 1992) Z equation based on length data is equivalent to:

$$L - L' = a + b \times L' \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where, $b = -K/(Z+K)$ and $a = -b L\infty$ or $Z/K = -(1+b)/b$ and $L\infty$ as $-a/b$

The plotting L -L' against L' gives a linear regression from which a and b can be estimated and hence L∞ and Z/K. This method is especially suitable for situations where little or nothing is known about the fish stock in question. However, it should be remembered that this method is based on the assumption of a constant parameter system.

The analysis of growth parameters with ELEFAN I routing of FiSAT package was performed as follows,

1) The 'response surface' routing of 'ELEFAN I' was used to refine the preliminary estimate of L∞ and to obtain the corresponding estimate of K by ignoring seasonal growth oscillation (setting $C = 0$)
2) The estimated growth parameters were then used to construct a length converted catch curve from which the approximate probabilities of capture by length were derived.
3) The original length frequency data were corrected for incomplete selection (and/or incomplete recruitment) using probability of capture by length obtained in step 2 and outlined in Pauly (1986b). This corrected data were then run through ELEFAN I to obtain final estimates of growth parameters.
4) The optimum combination of K an L∞ was chosen through maximization of Rn values (the highest value of the goodness of fit index) which can range from 0-1.
5) Comparison of growth performance in terms of length of various stocks of each species were performed based on the φ' index of Pauly and Munro (1984),

$$\phi' = \log_{10} K + 2 \log_{10} L\infty \quad \ldots\ldots\ldots\ldots\ldots (5)$$

Where, L∞ = asymptotic length (total length) (cm), K = growth constant, φ'= species specific value.

6) The length at age was calculated with von Bertalanffy growth model, assuming t_0 to be zero.

4. 2. 3 Estimation of Total Mortality Rates (Z)

The loss of individuals in a cohort from fishing and natural processes over a particular time t, is called total mortality rate. The mortality rate over a very short time interval $\frac{dN}{dt}$, is proportional to the number of individuals present at any time t (Nt) and this can be written,

$$\frac{dN}{dt} \quad Z\,Nt \quad \ldots\ldots\ldots\ldots \quad (6)$$

Where, Z = instantaneous total mortality coefficient

Z= F + M

Where, F = Fishing mortality coefficient, M =natural mortality coefficient

The equation (6) can be rearranged and integrated to give the number from t = 0 to t,

$$\frac{Nt}{N0} = \exp\left[- Z\,t\right] \quad \ldots\ldots\ldots\ldots \quad (7)$$

This is called exponential decay model or population equation

Where, N0 initial number of individual at time = 0, Nt = number remaining at time t

Or

$$N(t2) = N(t1) \times \exp\left[-Z \times (t2-t1)\right] \quad \ldots\ldots\ldots\ldots \quad (8)$$

Where, N(t1) = number of fish in t1, N(t2) = number of fish in t2

The total number of deaths during the time interval t1 to t2 = N(t1)-N(t2)

In the present study Z was estimated using length based method. Although wide range of length based methodologies to estimate Z is available (Pauly, 1984b, Pauly and Morgan, 1987, Sparre, 1987), Z in the present study was estimated using the length converted catch curve method (Pauly, 1984a, 1984b). Hampton and Majkowsky (1987) and Isaac (1990) suggested that the length converted catch curve for derive Z will be free of bias when the fish are either long life or not showing seasonal growth oscillation and also little growth variability between individuals. The length converted catch curve for *L. nebulosus* and *L. lentjan* was constructed with length frequency data by different gears collected over the period January to December 1999 under the following assumptions (Pauly, 1984b).

- Z is same in all length groups used in the plot
- all length groups used in the plot were recruited with the same abundance and that the recruitment fluctuations were small and random
- all length groups used were large enough and wide enough to effectively represent the average population structure over the period of the time considered.

The length converted catch curve also involves the following steps:

- pooling of monthly length frequency sample for each gear to obtain a single, length frequency sample representative of the population for the period under consideration. This was made to reduce the effect of seasonal recruitment pulses on the population structure. Also the various samples were given the same weight by converting to percentage length/frequency samples to prevent the effect of different sample size on the pooled samples.
- construction of catch curves using the pooled length frequency sample and growth parameters, using the procedure is given below.

The total number of deaths due to fishing, during the time t1 to t2 is:

$$C(t1, t2) = \frac{F}{Z} \times [N(t1) - N(t2)] \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

This is called catch equation

Where, C(t1, t2) = total catch in number during the time period (t1 to t2), F = fishing mortality coefficient.

Inserting Eq. (8) into Eq. (9) gives:

$$C(t1, t2) = N(t1) \times \frac{F}{Z} \times [1 - \exp(-Z \times (t2 - t1))] \quad \ldots\ldots\ldots\ldots \quad (10)$$

In the length converted catch curve, the length distribution of each species was first converted to age frequency distribution using the estimated growth parameters.

In the equation (10), C(t1, t2) was replaced by the frequency (number of individuals), (C) between length L1 and L2 and t became the relative age at the length group midpoint.

The equation therefore become,

$\ln [C (L1 - L2)/dt] = \text{constant} - Z\, t\, (L1 + L2)/2$ .... (11)

or

$\ln [C/dt] = \text{constant} - Zt$

Where, C = number of individuals in each length group, t = mean age, dt = time taken for the species to grow through a particular length group.

A length converted catch curve is thus the plot of ln [C/dt] against t. The relative age (t) at the lower limit of the length group is calculated using the inverse of the von Bertalanffy equation with t_0 set at zero as only a relative age is required,

$t = (-1/K) \ln [1 - Lt/L\infty]$ .... (12)

The value dt, the relative time taken for the species to grow through a particular length group, is estimated as the age at L2(t2) minus the age at L1(t1). Mean ages, used as the independent variable (X value) in the length converted catch curve, are approximated to the age at mid point of length group, (L1 + L2)/2.

The mean age of the length group is also calculated using the inverse of the von Bertalanffy equation,

$t((L1 + L2)/2) = (-1/K) \ln [1 - ((L1 + L2)/2)/L\infty]$ .... (13)

Finally the natural logarithms of the frequency (number) divided by the change in age, ln [C (L1-L2)/dt] are plotted against mean age, t as a length converted catch curve separately for each gear.

The regression line was fitted through the data in such a way as to exclude:

- The initial ascending data points representing groups of individuals which are either not fully recruited or too small to be totally vulnerable to the fishing gear.
- Data points close to L∞, where the relationship between length and age become uncertain.

The length converted catch curve method is incorporated into the ELEFAN II in the FiSAT software package (Gayanilo *et al.*, 1996).

4. 2. 4 Estimation of Natural Mortality Coefficient (Rate) (M), Fishing Mortality Coefficient (Rate) (F) and Exploitation Rate (E)

The natural mortality coefficient (M) for these species was estimated using empirical equation of Pauly (1980):

$\log M = -0.0152 - 0.279 \log L\infty + 0.6543 \log K + 0.463 \log T$ .... (11)

Where, T = mean seawater temperature (28 C^0)

The estimation of fishing mortality coefficients (F) of *L. nebulosus* and *L. lentjan* for different gears were obtained by subtracting the estimated natural mortality coefficient (M) from the respective total mortality coefficient (Z).

Exploitation rate (E) of two species by gear were estimated as,

$Ei = Fi / Z$ .... (12)

Where, Ei = exploitation rate by gear i, Fi = fishing mortality by gear i, Z =total mortality

4. 2. 5 Determination of Probability of Capture and the Mean Length at First Capture

The probability that a certain size of fish will be caught is dependent on the following:

1) The probability that the fish is present on the fishing ground (recruitment).
2) The probability that the fish is retained by the gear once it has entered the gear (gear selection).
3) The product of the probabilities of above two (recruitment and gear selection).

The lengths at 25%, 50% and 75% probability of capture (L^{25}, L^{50} and L^{75}) of *L. nebulosus* and *L. lentjan* exploited by different gears were estimated using the ascending part of the length converted catch curve, assuming that the selection curve of each gear is similar to that of a trawl. The following procedure in ELEFAN II is used to estimate the probability of capture in each length class (i).

In the ascending part of the catch curve the fish are not fully exploited either by not being fully recruited or due to gear selectivity. The equation (10) was used to estimate the number of fish that ought to have been caught in each length groups in the ascending part of the catch curve.

The difference between expected numbers and the actual numbers gives the resulting combined effect of incomplete recruitment and gear selection.

The probability of capture can thus be calculated as the ratio of numbers observed over the numbers available,

Pi = ln (Ci/dt)/ ln (Cai/dt) .... (16)

Where, Pi = probability of capture for each length class, Ci = number of fish caught at length group i, Cai = number of fish available at length group i.

4. 3 RESULTS

4. 3. 1 Length-Weight Relationship

The scatter plot of length weight data pairs of *L. nebulosus* and *L. lentjan* are illustrated in Figs. 4.2 and 4.3 respectively. The results of the analysis of the length-weight relationships and related statistics are summarized in Table 4.1. In both species the length exponent were close to 3 as might be expected and the 'a' intercept are also quite similar (Table 4.1).

Table 4.1. Length - Weight Regression Statistics.

Parameters	Species	
	L. nebulosus	*L. lentjan*
Length range (cm)	23.6 – 68.2	8.2 – 43.1
Weight range (g)	183.21 – 3950.21	9.31 – 1923.89
No. of fish (n)	379	455
R^2	0.862	0.755
Length-weight relationship		
'*a*'	0.0197	0.0169
'*b*'	2.9046	2.9741
95% Confidence limit of -*b*	2.7975	2.9329
+*b*	3.0117	3.0153

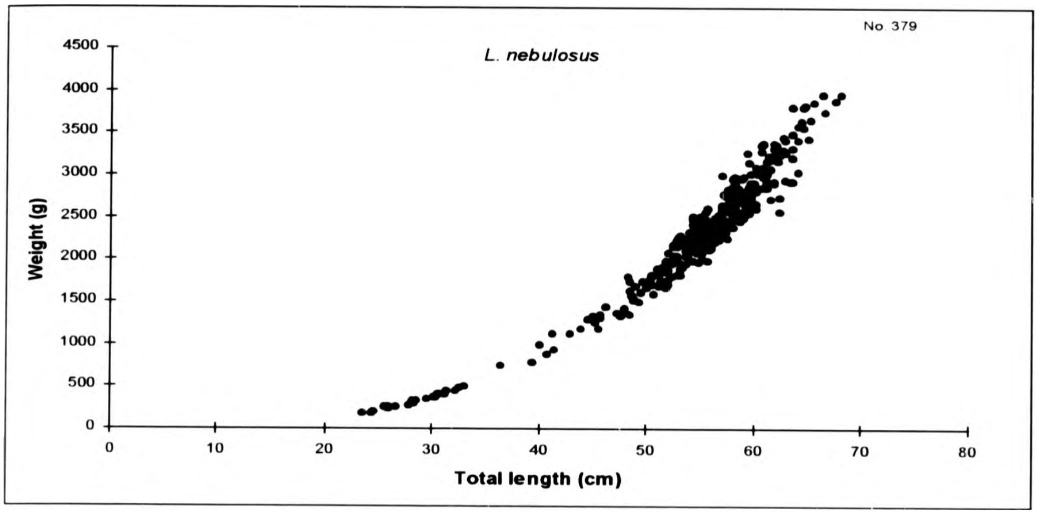


Fig. 4.2. Length – Weight relationship of *L. nebulosus*.

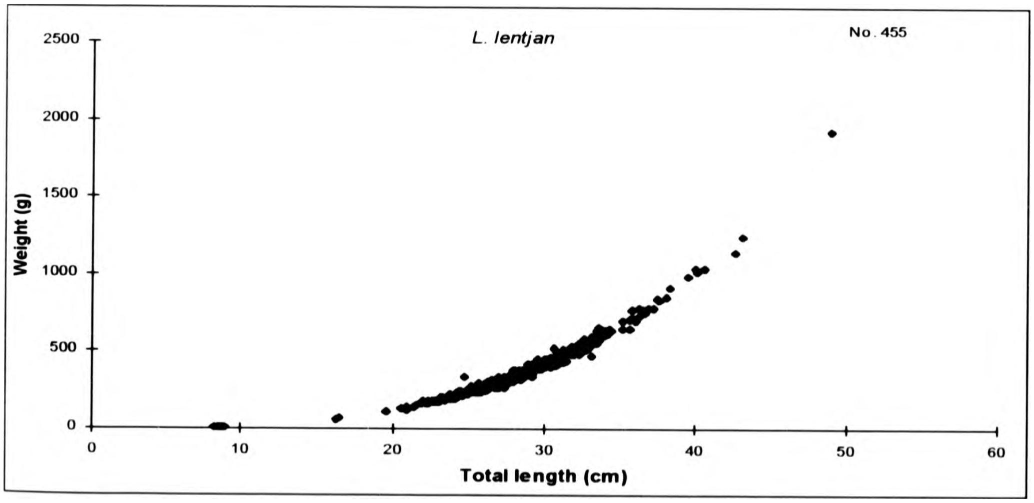


Fig 4.3. Length – Weight relationship of *L. lentjan*.

The estimated length-weight relationship for the two species are,

L. nebulosus $W = 0.0197 L^{2.90}$

L. lentjan $W = 0.0169 L^{2.97}$

Where, W = total weight (g) and L = total length (cm)

4. 3. 2 Growth Parameters

The preliminary estimates of asymptotic length ($L\infty$) for *L. nebulosus* and *L. lentjan* made using a 'Powell-Wetherall' plot, were 87.7 cm and 56.5 cm respectively (Table 4.2).

Table 4.2. Results of 'Powell-Wetherall' plot. Estimates of asymptotic length ($L\infty$) and the value of the ratio total mortality coefficient/growth coefficient (Z/K).

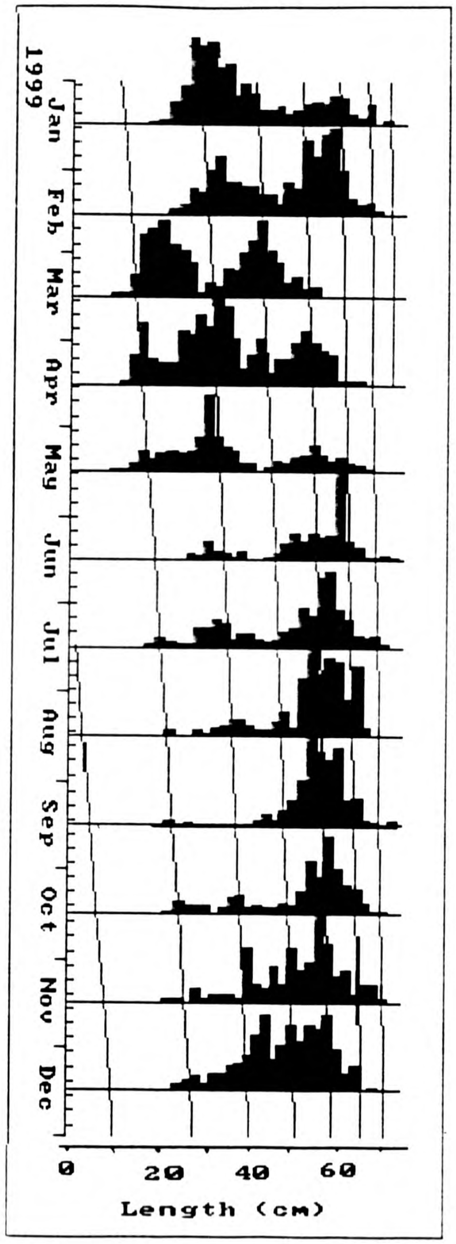
Species	Year	$L\infty$ (cm)	Z/K
L. nebulosus	1999	87.72	8.381
L. lentjan	1999	56.48	6.587

The population growth parameters estimated together with growth performance index (ϕ') by ELRFAN I are summarized in Table 4.3 for the two species. The estimated value of asymptotic length ($L\infty$) and growth constant (K) for *L. nebulosus* were 89.0 cm total length and 0.24 year^{-1} and for *L. lentjan* 61.5 cm total length and 0.33 year^{-1} respectively.

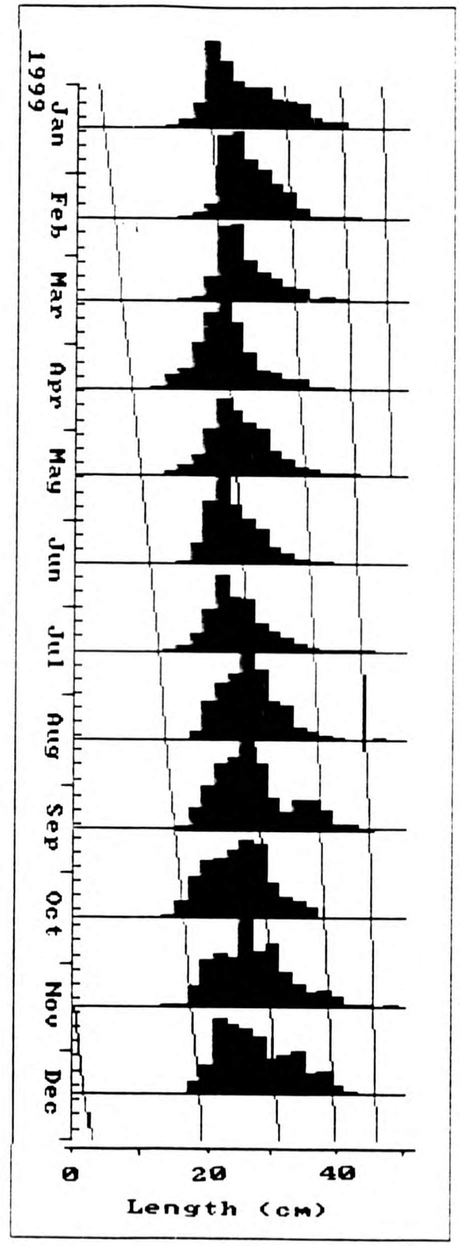
Table 4. 3 Growth parameters ($L\infty$ = asymptotic length, K = growth coefficient) and performance index (ϕ') of *L. nebulosus* and *L. lentjan* with ELEFAN I.

Species	Year	$L\infty$ (cm) TL	K (year^{-1})	ϕ'
L. nebulosus	1999	89.0	0.24	3.28
L. lentjan	1999	61.5	0.33	3.10

The estimates $L\infty$ with 'Powell-Wetherall' is slightly lower than the estimates with ELEFAN I because the analysis depend on the maximum size of fish in the length frequency sample and the underline assumption of constant parameter system would also affect the estimates of $L\infty$.



L. nebulosus
$L\alpha$ = 89.0 cm
K = 0.24 $Year^{-1}$
Rn = 0.111



L. lentjen
$L\alpha$ = 61.5 cm
K = 0.33 $Year^{-1}$
Rn = 0.174

Fig. 4. 4. Length frequency distribution of *L. nebulosus* and *L. lentjan* fitted with best possible growth curve.

The above estimated growth parameters suggest the following best fit growth curves for the two species.

L. nebuosus Lt = (89.0 (1 – exp (- 0.24 (t – t_0)))

L. lentjan Lt = (61.5 (1 – exp (- 0.33 (t- t_0)))

Where, Lt = total length (cm) at age t (years), t_0 = the theoretical size at age 0.

The length frequency distribution (pooled length frequency distribution for all gear) fitted with the best growth curve estimated by the ELEFAN I routing for *L. nebulosus* and *L. lentja* are shown in Fig. 4. 4.

4. 3. 3 Length at Age

The length at age estimates of the two species and the proportion of fish in the catch of each age group are presented in Table 4. 4.

Both *L. nebulosus* and *L. lentjan* are slow growing and relatively long lived species. Thus *L. nebulosus* attained its maximum length ($L\infty$) at about 40 years but they grow about 85 cm or 96% of $L\infty$ in 13 years. *L. lentjan* reached its maximum length at about 29 years of age but grow rapidly when they are young and reached about 60.7 cm in size or 99% of $L\infty$ in 13 years (Table 4. 4).

The juveniles of *L. nebulosus* of age 0 were found to be less vulnerable to all the gear deployed in the study area, consisting only 1.1% of the catch in number (Appendix Table 4.1). Fish of age 1 were more vulnerable than the 2 and 3 age groups representing 21.8%, 16.3% and 16.5% respectively. The majority of *L. nebulosus* in the catch was of 4 years age fish consisting 34.9% of the catch. Maximum age of *L. nebulosus* was 7 years represented <1% of total catch. In the case of *L. lentjan* most of the catch belonged to the first year group. The maximum age of fish in the catches was 3 years. (Appendix Table 4. 2).

Table 4. 4 Length at age and the proportion of fish in each age group of *L. nebulosus* and *L. letjan*.

L. nebulosus			*L. lentjan*		
Age (years)	Total length (cm)	% of catch (in numbers)	Age (years)	Total length (cm)	% of catch (in numbers)
0	0.0	1.1	0	0.0	2.5
1	19.0	21.8	1	17.3	78.5
2	33.9	16.3	2	29.7	16.8
3	45.7	16.5	3	38.7	2.2
4	54.9	34.9	4	45.1	0.0
5	62.2	8.2	5	49.7	0.0
6	67.9	0.9	6	53.0	0.0
7	72.4	0.2	7	55.4	0.0
8	76.0	0.0	8	57.1	0.0
9	78.7	0.0	9	58.3	0.0
10	80.9	0.0	10	59.2	0.0
11	82.7	0.0	11	59.9	0.0
12	84.0	0.0	12	60.3	0.0
13	85.1	0.0	13	60.7	0.0

4. 3. 4 Natural and Fishing Mortality Coefficient (Rate) and Exploitation Rate

The estimated values of the instantaneous natural mortality coefficient (M) using the Pauly's empirical formula (Pauly, 1980) for *L. nebulosus* and *L. lentjan* were 0.52 year^{-1} and 0.71 year^{-1} respectively.

The estimated values for instantaneous total mortality coefficients (Z), fishing mortality coefficients (F) and the exploitation rates (E) of *L. nebulosus* and *L. lentjan* for different gear are summarized in Table 4. 5.

Table 4. 5 Estimated total (Z) and fishing (F) mortality coefficient and exploitation rates (E) for *L. nebulosus* and *L. lentjan*.

Species	Year	Gear	Mortality coefficient (year $^{-1}$)		Exploitation rate (E)
			Total mortality rate (Z)	Fishing mortality rate (F)	
L. nebulosus	1999	HL	1.65	1.13	0.68
		BTN	0.91	0.39	0.43
		BLL	1.92	1.40	0.73
L. lentjan	1999	HL	2.88	2.17	0.71
		BTN	3.14	2.43	0.77
		BLL	1.73	1.02	0.59

HL = handline fishing. BLL = bottom longline fishing. BTN = bottom trammel net fishing

Except with the exploitation of bottom trammel net fishing for *L. nebulosus*, fishing mortality (F) and exploited rates (E) of both species have been maintained at a higher level than the accepted exploitation level of 0.5 in all fisheries during the present investigation. The highest values of fishing mortality and exploitation rate were recorded for *L. lentjan* in the bottom trammel net fishery while the highest value of fishing mortality and exploitation rate were recorded for *L.nebulosus* in the bottom longline fishery.

4. 3. 5 Probability of Capture

The estimated lengths at 25%, 50% and 75% probability of capture of *L. nebulosus* and *L. lentjan* by different gears separately are summarised in Table 4.6.

Table 4.6. Length derived at different probability of capture levels in different gears.

Species	Year	Gear	Mean length (cm) TL		
			L 25%	L 50%	L 75%
L. nebulosus	1999	HL	24.1	26.7	28.7
		BTN	20.3	22.7	24.9
		BLL	52.8	55.2	57.3
L. lentjan	1999	HL	20.1	21.8	23.6
		BTN	19.1	20.9	22.7
		BLL	21.9	23.5	25.4

HL = handline fishing. BLL = bottom longline fishing. BTN = bottom trammel net fishing

The larger fish of both species were caught by bottom longline while the smaller were caught by bottom trammel net and handline fisheries.

4. 4 DISCUSSION

The length-weight relationship of *L. nebulosus* and *L. lentjan* for the combined sexes in the present study were very close relationship to cube for both species, *i. e.* b = 2.90 and 2.97 respectively for *L. nebulosus* and *L. lentjan*. Sanders *et al.* (1984) and Egretaud (1992) found similar values of 2.97 and 2.93 for *L. nebulosus* in the Gulf of Suez and New Caledonia respectively. Also from the length-weight relationship for *L. lentjan* in the Red Sea area values for 'b' of 2.94 and 3.09 were estimated by Wassef (1991) and Kedidi *et al.* (1984). The latter author has interpreted the value of 3.09 for 'b' as indicating optimal living conditions for the fish in the Red Sea area.

In many applications of population dynamics and stock assessment models, it is necessary to estimate the age of fish. The conventional methods of ageing of temperate species are not appropriate for tropical species because of the inherent technical difficulties associated with tropical species. The length based ageing method is thus commonly used as the 'second best' option for tropical fish. This method is more reliable in younger year classes because it is easier to separate cohorts. Older fish grow in length more slowly and variation among individuals tends to obscure variation between year classes (Westerheim and Ricker, 1978). Many fish populations in tropical waters have extended spawning period and thus distinct year classes can be difficult to recognize in the length frequency distribution. The difficulty of using otoliths for ageing tropical long living bottom species (Morales-Nin, 1988) and the validation of the otolith derived age, encouraged the use of length based method for studying the population dynamics of these two species in this study.

L. nebulosus and *L. letjan* are both long living and slow growing species compared to small pelagic species (Karunasinghe, 1990). They are also batch spawners and have an extended spawning period (Chapter 3, Figs. 3.10-3.11). Size selection occurs in most gears used in the capture of these species (Table 4.6). Thus the use of length based methods to estimate growth parameters of these species might not be expected to be appropriate. However, the use of pooled length frequency data of all gears has made a good representation of both populations. Further, the effects of gear selection on the catch samples were reduced by correcting these prior to the estimation. It has been shown that ELEFAN I and methods, similar in concept, are most effective when one of the parameters of the growth equation, generally $L\infty$, can be estimated or approximated to a narrow range (Basson *et al.*, 1988). The estimates of growth parameters in the present study were based on the approximation of L∞ values, which were determined by the Wetherall method (Wetherall *et al.*, 1987; Pauly, 1986a). The approximate estimates of L∞ by Wetherall method is higher than the maximum size of fish encountered for both species (*L. nebulosus* 72 cm and *L. lentjan* 49 cm) in the present study. It is recommended, however, that an alternative method of ageing be undertaken for comparative purposes.

To assess the validity of the growth parameters obtained in this study, similar estimates for the two species in different localities were compared (Table 4.7). The results are show high variance in both species. The growth constants (K) estimated for *L. nebulosus* by interpretation of scales or otoliths in Fiji (Baillon, 1991), Kuwait (Baddar 1987), New Caledonia (Loubens, 1980b) and Yemen (Aldonov and Druzhinin, 1978) varied from 0.1 to 0.22 $year^{-1}$ and suggested that *L. nebulosus* is growing faster in Sri Lankan waters. The values of asymptotic length (L∞) range from 57.9 to 96.7 (cm) FL and the present value is at the top end of the range. Only the growth parameters estimated for *L. nebulosus* in Gulf of Aden, Yemen based on otoliths reading is quite close to the present estimates (Aldonov and Druzhinin, 1978).

The estimated growth constant (K) counting with periodical rings in otoliths and scales for *L. lentjan* in India (Toor, 1968b) and in Red Sea (Wassef and Bawazeer, 1990) varies from 0.48 to 0.27 $year^{-1}$ and the asymptotic length (L∞) from 43.9 to 64 (cm) TL. The estimate of Toor (1968b) for *L. lentjan* population in the south Indian waters is quite close to the present estimates but is of a faster growth rate and a higher asymptotic length than reported in many studies. It is likely that the observed variability is merely a reflection of the different environmental conditions in different habitats. However, the size range in the catches of both species in the present study was mainly of small/young fish, which would be expected to grow faster. The studies above mentioned were based on cyclical growth patterns in scales or otoliths validated with length frequency data. Gjøsæter *et al.* (1984) emphasized the practical difficulties in ageing of coral reef fish by counting of rings in otoliths. Thus the accuracy of those estimates should be used with caution.

Table 4.7. Growth and mortality estimates in various stocks of *L. nebulosus* and *L. lentjan*. L∞ = asymptotic length, K = growth coefficient, ϕ' = performance index, M = natural mortality coefficient.

Locality	L∞ (cm)	K (year^{-1})	ϕ'	Sex	M	Source
L. nebulosus						
Northwest Australia	61.1 FL	0.106	2.59	M		Kuo and Lee (1986)
Northwest Australia	52.7 FL	0.127	2.547	F		Kuo and Lee (1986)
Northwest Australia	58.5 FL	0.743	3.405	M		Baillon (1991)
Northwest Australia	57.6 FL	0.588	3.290	F		Baillon (1991)
Great Barrier Reef- off Queensland Australia	48.0 SL	0.39	2.954	U		McPherson (1985)
Gulf of Suez, Egypt	86.0 TL	0.11	2.910	U		Sanders and Morgan (1989)
Fiji	96.7 FL	0.162	3.180	U		Baillon (1991)
Fiji	80.0 FL	0.23	3.168	U		Carpenter and Allen (1989)
Central Division, Fiji	64.6 SL	0.16	2.825	U		Dalzell *et. al.* (1992)
Western Division, Fiji	62.3 SL	0.17	2.819	U		Dalzell *et. al* (1992)
Western Division, Fiji	61.5 FL	0.36	3.134	U	0.73	Sharma (1990)
Central division, Fiji	61.4 FL	0.34	3.108	U	0.71	Sharma (1990)
Northern Division, Fiji	50.2 SL	0.21	2.724	F		Dalzell *et. al* (1992)
Northern Persian Gulf, Kuwait Kuwait	62.7 TL	0.19	2.873	M		Carpenter and Allen (1989)
New Caledonia	62.7 TL	0.19	2.873	U		Baddar (1987)
New Caledonia	61.7 FL	0.21	2.903	U		Loubens (1980b)
New Caledonia	57.9 FL	0.22	2.868	U		Loubens (1980b)
Kavieng, Papua N Guin	55.5	0.22	2.831	U	0.56	Baillon (1991)
Gulf of Aden, Yemen	55.8 FL	0.31	2.985	U		Sharma (1990)
Gulf of Eden, Yemen	87.0 FL	0.09	2.833			Sanders and Morgan (1989)
Gulf of Aden, Yemen	85.9 FL	0.101	2.872			Aldonov and Druzhinin (1978)
Present study (Sri Lanka)	71.6 FL	0.21	3.032			Aldonov and Druzhinin (1978)
	89.0 TL	0.24	3.28	U	0.52	
L. lentjan						
Gulf of Mannar, India	64.0 TL	0.27	3.044	U		Toor (1968b)
New Caledonia	33.6 FL	0.33	2.571	U		Loubens (1980b)
Tuwwal, Saudi Arabia	51.1	0.174	2.657	U		Sanders and Morgan (1989)
Gulf of Aden, Yemen	42.6 FL	0.48	2.94	U		Aldonov and Druzhinin (1978)
Red Sea	43.9 TL	0.29	2.75			Wassef and Bawazeer (1990)
Present study (Sri Lanka)	61.5 TL	0.33	3.10	U	0.71	

Source: Fish Base, ICLARM Manila, Philippines

The values of L∞ and K obtained for the two species in the present study lead to the growth performance index ϕ'. Although presently estimated values are higher than that of estimates in most areas (Table 4.7) they still fall within the 95% confidence limit, and therefore suggest that the estimates are biologically reasonable and are acceptable for future stock assessment analysis.

Pauly's empirical equation (Pauly, 1980) was used to estimate natural mortality coefficient (M) in the present study. It is believed to be a useful method of estimation of M and has been used successfully for a large number of independent estimates of natural mortality of a wide range of sizes, taxa and habitats of fish (Pauly, 1980). The present estimated values of M for both species are thus considered to be reasonably accurate for the use of further stock assessment analysis. Values of M in the literature are only available for *L. nebulosus* (Table 4. 7) and vary from 0.56 $year^{-1}$ (Sharma, 1990, Kavieng, Papua New Guinea) to 0.73$year^{-1}$ (Sharma, 1990 – central division, Fiji). The present estimate of 0.52 $year^{-1}$ is within the range and is close to that by Sharma (1990) for the population in Kavieng, Papua New Guinea.

The natural mortality coefficient (M) of *L. lentjan* is much higher compared with *L. nebulosus* in the present study. This may be an indication of higher interaction than *L. nebulosus*. The perdition or cannibalism may be higher with *L. lentjan*. Generally, high natural mortality reduce the older cohorts, and would favour high fecundity with rapid development and growth (Grimes *et al.* (1988). These characteristics all seem apparent with *L. lentjan* but need more studies to come to a conclusion.

The total mortality coefficient (Z) in this study has been estimated from regression analysis of the length converted catch curve. This method is based on the assumption of a constant parameter system (Sparre and Venema, 1992) *i.e.* recruitment remains constant every year and also that F and M remain constant. The assumption of a constant parameter system is however never strictly fulfilled in reality. It has been shown earlier that *L. nebulosus* between 40-50 cm contribute only low quantities to the catches made by any gear (Chapter 2, Fig. 2. 19). They may not be available in the fishing area or are not caught due to selectivity of gears. This may affect the uniformity of availability of each cohort to the fishing gear. This violation of steady state assumption could affect the accuracy of the estimation of the total mortality. The occurrence of a nearly straight right-hand limb in the length converted catch curve of *L. nebulosus* in each fishery has however given confidence to use this method. The accurate estimation of Z and M are important because in turn they affect the estimations made on the fishing mortality coefficient (F) and exploitation rate (E) of the two species.

The exploitation levels of both *L. nebulosus* and *L. lentjan* in Negombo area have currently reached a high level. *L. nebulosus* has far exceeded the optimal exploitation rate of 0.5 (Gulland, 1971), except for bottom trammel nets. In fact the overall exploitation rate was 0.68 for all the gears used to exploit the species. In the case of *L. lentjan* the exploitation rate has exceeded 0.5 for all gears and the overall exploitation rates has reached to 0.71. The exploitation rate of stock when above 0.5 is considered as overexploited and when it has long exceeded 0.7 the stocks are in extremely high risk. Thus a reduction of fishing effort and careful monitoring of the fishery is important to rehabilitate these stocks and generate a long term catch increase.

The mean size selection (L^{50}) of *L. nebulosus* by the three main gear, bottom longline, handline and bottom trammel net in 1999 was respectively 55.2, 26.7 and 22.7 cm total length, while for *L. letjan* it was respectively 23.5, 21.8 and 20.9 cm total length. This indicates that, except for the bottom longline fishery for *L. nebulosus*, other gears target juvenile fish of both species. At present handline and bottom trammel nets which target the small individuals account for 30% and 6% of the total landings of *L. nebulosus* by number. The situation is even more severe for *L. lentjan* where handline and bottom trammel nets account for 40% and 40% respectively of the catch by number (Chapter 2 and Appendix Table 4. 2). It is very clear that the current fishing strategy will affect highly the *L. lentjan* population, with over 80% of the catch consisting of juveniles while 64% of the catch of *L. nebulosus* consists of adult spawners (Chapter 2 and Appendix Table 4.1). It shows the danger of growth overfishing for *L. lentjan* and recruitment overfishing for *L. nebulosus*.

It is advisable, therefore to make arrangements as soon as possible to reduce the fishing effort of gears deployed in targeting juveniles of these species, especially bottom trammel nets and handline fishing, which are exploiting large quantities of juvenile fish of both species. Further to make a close season for the bottom longline fishery during the spawning season. However, the demersal fishery in the Negombo area is a multispecies multigear fishery. This exercise has to be practiced very carefully as such an initiative may adversely affect the quantities of total landings. Both handline and bottom trammel nets are used all year round and a large number of fishermen are engaged in these fisheries. As such any reduction on theses fisheries will have severe socio-economic consequences. Thus before such initiative is implemented likely effects of the socio-economic conditions of the fishing community have to be studied and alternative income sources identified.

Appendix Table 4.1. Number of *L. nebulosus* sampled by gear in 1999

Length (cm)	No. of fish			
	BLL	BTN	HL	Total
10	0	0	1	1
12	0	2	0	2
14	0	2	11	13
16	0	2	29	31
18	0	5	12	17
20	0	1	24	25
22	1	5	37	43
24	7	13	37	57
26	8	10	72	90
28	12	19	95	126
30	21	26	124	171
32	25	25	92	142
34	18	19	80	117
36	23	13	56	92
38	25	5	54	85
40	28	6	38	72
42	33	3	24	60
44	40	1	22	63
46	43	3	23	69
48	61	5	31	97
50	86	3	45	134
52	148	4	39	193
54	209	3	49	269
56	182	2	63	250
58	199	3	63	274
60	200	2	50	253
62	79	0	25	110
64	66	0	29	96
66	29	0	9	40
68	10	0	6	16
70	10	0	0	10
72	6	0	1	7

Appendix Table 4.2. Number of *L. lentjan* sampled by gear in 1999

Length (cm)	No. of fish			
	BLL	BTN	HL	Total
12	0	0	3	3
14	0	1	53	54
16	0	10	115	125
18	5	125	254	384
20	19	471	388	878
22	73	822	556	1451
24	103	635	539	1277
26	116	408	511	1035
28	113	258	430	801
30	100	148	251	499
32	96	104	162	362
34	100	59	108	267
36	40	35	44	119
38	47	19	30	96
40	24	6	13	43
42	7	2	9	18
44	5	1	2	8
46	0	1	0	1
48	1	0	1	2

Chapter 5

Stock Assessment and Modelling of Fish Stocks

5.1 INTRODUCTION

The main objective of the assessment of exploited fish stocks is to predict the outcome of future yield and biomass levels if the level of existing fishing effort is maintained or changed in one way or other. The benefit of fishing could be sustained to perpetuity if the harvesting is guided by a proper assessment of optimum yields and optimum effort. Biological fisheries management concerns the maximum yield, which can be taken from a stock without adversely affecting future reproduction and recruitment. This quantity is termed the maximum sustainable yield (MSY) and the corresponding fishing effort is denoted by f_{MSY}.

In tropical waters, fisheries tend to exploit a large number of species simultaneously, with a variety of gears, even though a particular fishery may target one or a few species. Assessment of such exploitation of stocks on a species-by-species approach, does not take into account neither the different degrees of exploitation to which the individual species are subjected at a given level of aggregate effort by the fishery nor the interactions among the species (Gulland 1971). In such situations a multispecies approach of assessment has many advantages. The problems of multispecies assessment, caused by technological interactions between fisheries and biological interaction between species have been raised at previous discussions of fisheries management (May *et al.*, 1978; Mercer, 1982; FAO, 1978). Decreases in the abundance of economically important carnivorous species (apex species) are considered to be the most readily detectable effects of biological interaction due to high fishing pressure in many multispecies fisheries (Pauly, 1979; Russ 1985; Russ and Alcala, 1989; Koslow *et al.*, 1994; Jennings and Polunin, 1995; Amar *et al.*, 1996). The evidence in declining of important fish groups, primarily carangids has been observed in the demersal fishery in the Negombo area. When the multispecie approach does not allow for species interaction, separate assessments of commercially important species/groups are considered preferable as a precautionary approach because they are the target species (Appoldorn and Lindeman, 1985).

The principal matters considered in this chapter are the current status of the resources exploitation and the estimation the optimum fishing effort, producing the maximum sustainable yield (MSY) of demersal resources in the Negombo area and thereby to identify most appropriate biological management strategy. This has been undertaken by conducting two separate analyses. The first is a single species assessment of the important indicator species, *L. nebulosus* and *L. lentjan*, which comprised, respectively 17% and 13% of the total demersal fish landed in the study area during 1999. The second will provide an assessment of all the demersal species combined, and utilizes annual landings and catch per unit effort (CPUE) data.

5. 1. 1 Assessment Models

5. 2. 1. 1 Single species models

Fishery assessment models are the tools of fishery science that provide a quantitative evaluation of the condition of exploited stocks and a means of measuring the impact of various exploitation patterns. Two general types of models are commonly used in single species stock assessment; descriptive stock models or 'surplus production models' and analytical models or 'dynamic pool models'. In surplus production models the stock is the basic unit. The key process modeled by surplus production models is biomass regeneration. Graham (1935) and Schaefer (1954) described the best known classical model and subsequently Pella and Tomlinson, (1969), Fox (1970 *in* Sparre and Venema, 1992) and Schnute (1977; 1985) developed models of this type with some improvements. The theory behind the surplus production models has been reviewed by Ricker (1975), Caddy (1980), Galland (1983) and Pauly (1984a). Conceptually, classical production models only deal with changes of the population level and thus do not make explicit reference to the age distribution of the stock. The narrow focus of the production models overlooks many biological processes such as growth, mortality and reproduction, which occur at the level of the individual fish. The underlying assumptions, advantages and disadvantages of the Schaefer model were discussed broadly by Megrey and Wespestad, (1988). The analysis and derivation of MSY assume that the stock has stabilized to the current fishing effort, but fishing effort regularly changes and stabilization will take some years. In practice data seldom comes from a fishery in equilibrium. Further the model assumes that the catchability does not change with stock size or time. This assumption can be violated as a result of technological changes with time. Therefore, Larkin (1977) and Gulland (1978) suggest that MSY derived from surplus production models should no longer be a goal of fisheries management.

In the dynamic pool models the individual is the basic unit and the stock size is a function of the number, growth and mortality of individual recruits to the stock. Baranov (1918 *in* Gulland, 1971) was the first to use these principles in fish population dynamics and later Ricker (1958) developed more sophisticated models of this kind. Today the yield per recruit model introduced by Beverton and Holt (1957 *in* Sparre and Venema, 1992), is most generally applied in fish stock assessment. For Beverton and Holt yield per recruit model to work a great deal of biological data is needed, particularly on recruitment rate, growth rate and the probability of death from natural causes.

Virtual Population Analysis (VPA) or cohort analysis (Pope, 1972) are also grouped under analytical models. VPA are used to analyze the effect that fishing has had on a particular year class of a stock in the past and are used to predict the future effect of different fishing effort. The method dealing with the future on the other hand, is called the 'predictive model' or the'Thompson and Bell model', and was first developed by Thompson and Bell (1934 *in* Sparre and Venema, 1992). Sparre and Venema (1992) incorporated the value of the catch in the 'Thompson and Bell model' and consequently developed a bio-economic model. The original VPA is based on catch at age data, but Jones (1974, 1984) modified the Thompson and Bell model to include length data. VPA methods gives good estimates of stock size and recruitment in past years when accurate data on catch in number by age/length are available but depend on the input of the values of natural mortality which is critical for an accurate outcome. The more heavily the stock is fished the more useful cohort analysis is because most of the removals from the stock are accounted for by fishing and the less the accurate estimate of natural mortality. This modified 'Thompson and Bell model' uses the time series data on number of fish caught by length together with biological and fishing information, such as estimates of growth parameters, length-weight relationship, the ratio of natural mortality to growth and terminal fishing mortality. The 'Jones' model assumes that the stock is in static condition and that the growth parameters do not vary with age or size of the adult stock and that the rate of fish caught is proportional to the number present in the population. The underlining assumptions, advantages and disadvantages of this model were discussed by Megrey and Wespestad (1988). Generally the analytical models give the best and most reliable estimates of production for optimal management of the stock, but have a greater demand for input data. The complexity and high level of computation in 'Thompson and Bell model' made it unpopular until the introduction of modern high efficiency computers. It is now widely used in tropical fisheries assessment and has largely replaced the use of Beverton and Holt yield per recruit model.

5. 1. 1. 2 Multispecies Models

The multispecies models can either be an extension to the descriptive or analytical model or they can be based on other approaches such as prey/predator type models or 'ecosystem models'. The most common multispecies model is the Schaefer surplus production model which relates total catch of all species to the total effort by all fleets, assuming each stock conforms to the Schaefer surplus production model. This has been termed the 'total biomass production' model. The application of a single species production model by treating the multispecies community as a single unit may obscure changes in the fishery due to species interaction or the variable catchability and desirability of different species (Koslow *et al.*, 1988). Initially at low fishing pressure, apex predators, typically the larger and more valuable fishes, will be taken. As fishing pressure increases and species at the top of the food chain are removed, species at lower trophic levels will be harvested. Thus, a total biomass model will fit the general relationship between total catch and total effort but it will not reflect the changes in species composition.

In multispecies fisheries it is also common practice to apply single species Beverton and Holt yield per recruit models to individual species. The yield curves for each species are then combined to give a total curve (Pauly and Murphy 1982; Munro and Thompson, 1983; Huntsman and Waters, 1986). Maximum sustainable yield and the corresponding level of fishing mortality for the multispecies groups in the Beverton and Holt yield per recruit model are computed from the pooled yield equation (Polovina and Ralston, 1986; Lee and Al-Baz 1989).

In prey/predator type models, a matrix of the probability that one species will be eaten by other species is used to simulate the biomass variation in the stock involved. Riffenburg (1969) was the first to develop a multispecies model of this type to assess the interactions among hake (*Merluccius productus*), anchovy (*Engraulis mordax*), and sardine (*Sardinops sagax*) on the Pacific coast of North America. Agger and Nielsen (1972 *in* Mercer, 1982) and Andersen *et al.* (1977 *in* Mercer, 1982) have also used models of this type to assess the North Sea fish resource. Recent trends in ecosystem modelling aimed at describing the ecosystem including the fish stocks have produced more complex models, but are very data intensive. As in the prey/predator type models food consumption is an important part of these models, but many other components of the ecosystem are also incorporated (Andersen *et al.*, 1977 *in* Mercer, 1982; Laevastu and Larkins, 1981). The ECOPATH model, for example, is an analytical procedure to estimate mean annual standing biomass, annual biomass production, and annual biomass consumption of the user specified species groups in a static situation under the assumption that the ecosystem is at equilibrium condition The model requires the input biomass of different trophic levels and total mortality rates and diet composition data of fish species in different trophic levels This model has been field tested with coral reef frigate shoals, Hawaii (Polovina, 1984), coral reef ecosystem in the Hawiian Archipelago (Atkinson and Grigg, 1984) and tropical shallow water demersal ecosystem in Malaysia (Heng and Chark, 1986 *in* Pitcher *et al.*, 1998).

5. 1. 1. 3 Choice of Stock Assessment Models

The choice of a fish stock assessment model depends on the type of management advice needed and the available data. When a stock is unexploited or lightly exploited, the management advice required is some basic biological reference point such as maximum sustainable yield (MSY) and the corresponding level of fishing effort for use in planning. Models derived from yield-per-recruitment and surplus production can provide these estimates. When a stock is heavily fished, management advice is needed relative to three types of overfishing, 1) growth, 2) recruitment, and 3) ecosystem with a view to the conservation of fish stocks.

Growth overfishing occurs when the size of fish on entry to the fishery does not produce the maximum yield per recruit to compensate for high fishing mortality. Growth overfishing represents an inefficient use of the resource but will not by itself cause a stock collapse. The yield-per-recruit model is an appropriate approach to identify growth over-fishing and to estimate the size of entry which will lead to efficient harvesting the stock for a given fishing mortality.

Recruitment overfishing occurs when the spawning stock has been reduced to a level such that the average recruitment and thus the yield from the fishery decline. Cohort analysis models in the case offer better estimates of the fishing mortality, better avoiding recruitment overfishing than the yield-per-recruit model can even, when combined with some information on the sustainable level of spawning stock biomass

Ecosystem overfishing occurs when there is a change in the species composition and abundance in an ecosystem making it inefficient from the standpoint of an economically viable fishery. Ecosystem models, multispecies surplus production, cohort analysis models are addressed by the ecosystem overfishing question.

5. 2 MATERIALS AND METHODS

5. 2. 1 Single Species Stock Assessment

Single species stock assessment was made using the length-based 'Thompson and Bell' model (Thompson and Bell, 1934 *in* Sparre and Venema, 1992). The input data for the two species (*L. nebulosus* and *L. lentjan*) consisted of:

1) total number of fish by species, exploited by all gears and also the numbers caught by the different gears in each length group over a one year period (1999) (Appendix Table 5.1 and 5.2),
2) growth parameters,
3) length-weight relationship,
4) natural mortality by length group.

The monthly length-frequency sample of each species from each fishery were used to obtain the total number of fish in the catch of each length class. This was done by raising the number of fish in the monthly length frequency samples in the following manner:

1) The number of fish of each species of a particular length group per sample were multiplied by a raising factor. Which was the ratio of the total weight of the species caught by the sampled boats in a month to the weight of the actual sample taken from the boats during the same month.

2) The number of fish calculated in step (1) was raised again by a second raising factor which was the ratio of the total catch in all the boats of the fleet during the month to the weight of the total catch of the sampled boats in that month.

The Thompson and Bell model predicts the effect of different fishing level on yield based on historical data or the inference of cohort analysis. Thus the first step is to perform length-based cohort analysis for each species separately in order to obtain an estimate of the current fishing pattern exerted on each species by all gears.

The length-based cohort analysis has been described by Jones (1984) and Pauly (1984a). The cohort analysis involved the application of both the population and catch equations (Chapter 4) as in VPA. The age corresponding to length groups is estimated with the inverse von Bertalanffy growth equation. The length-based cohort analysis is incorporated as VPA II in the FiSAT software package (Gayanilo *et al.*, 1996).

The number of fish surving from one age group (Nt) to the next (Nt +1) is estimated with population equation:

$N_{t+1} = N_t \exp[-(F_t + M)]$ .... (1)

Where, Ft = fishing mortality coefficient at time t and M = natural mortality coefficient

The catch at time t (Ct) is the proportion dying due to fishing and is estimated with catch equation:

$C_t = [F_t/Z]\, N_t\, (1 - \exp[-(F_t+M)])$ .... (2)

Where, Z = total mortality coefficient

By rearranging equation (2) and dividing equation (1) by equation (2) produces Gulland's equation (Gulland, 1965) allows the estimation of the number of fish caught, thus:

$N_{t+1}/C_t = (F_t + M) \exp[-(F_t + M)] / F_t (1 - \exp[-(F_t + M)])$ .... (3)

Or

$C_t = N_{t+1} (F_t/Z_t) (\exp(Z_t) - 1)$

This equation can be generalized for any time interval,

$C_{\Delta t} = N_{t+\Delta t} (F/Z) (\exp Z \Delta t - 1)$ .... (4)

The length groups of the catch sample are converted into age classes by the inverse von Bertalanffy equation,

$t_{Li} = t_0 - ((1/K) \times \ln[1 - L_i/L_\infty])$ .... (5)

This can be written as,

$\Delta t = t_{L1} - t_{L2} = 1/K \times [L_\infty - L_1 / L_\infty - L_2]$

Where, K = growth constant, L_∞ asymptotic length, t_{Li} = age at any length, t_{L1} = age at length L1, t_{L2} = age at length L2 and t_0 = age of fish at length 0.

Using the above equation (4), starting from a guessed terminal fishing mortality of the largest length group and known M value, estimate the Nt, the number of fish there must have been accounted in a particular catch. Fishing mortality and stock number could be obtained for the small length groups by backward calculating with catch-at-length data for a steady state population. In the equation (4), F can not be solved algebraically but by using an iterative method requiring using a computer. Different terminal F values were used in the iteration and the F value which gave consistency in estimates of M in different length groups was selected as terminal F.

Having selected the total fishing mortality by length group (F_{total}) it is possible to calculate the fishing mortality by gear using the catch proportion for each gear, thus:

$F_{iX} = F_{total\,i} \times C_{iX}/C_{total\,X}$ .... (6)

Where, F_{iX} = fishing mortality in particular length group (x) by gear i, $F_{total\,X}$ = total fishing mortality coefficient in particular length group x, C_{iX} = catch in numbers in particular length group (x) by gear i, C_{totalX} = total catch in number in particular length group (x) by all gears.

This provides the assumptions on F arrays (fishing mortality pattern) of each gear for prediction with different fishing mortality rates.

The prediction of yield for each species with different fishing mortality is done with the length-based Thomson and Bell model. This model takes input data from length based cohort analysis (Tables 5. 1 and 5.3 for *L. nebulosus* and Tables 5.2 and 5.4 for *L. lentjan*).

The input data consists of:

- the fishing mortality by length,
- the F at length array,
- the number of fish in the lowest length group,
- growth parameters,
- natural mortality coefficient by length group (M'),
- length-weight relationship (a and b constant),
- average price/kg by length group (used in estimation of value of the catch for bio-economic model).

The outputs from the model for each length group are:

- the number of surviving fish in each length group,
- the catch in numbers,
- the yield in weight,
- the total yield, mean biomass at Δt and value of the catch.

The calculations are repeated for a range of F- arrays (X-Factor)

The length based Thompson and Bell analysis is based on an approximation, which consider the catch is taken instantly at the middle age of the length group. The first and the second halves of the age group fish suffer only by natural deaths (Sparre and Venema, 1992).

The number of survivors at fist half of the age;

$N(L1, L2)/2 = NL1 \times \exp -M(L1, L2)$ .... (7)

Where, $N(L1,L2)/2$ = number of fish survive at first half of length group (L1,L2), NL1 = number of fish at length L1.

When instantaneously, the catch is taken and the number of survivors becomes;

$NL2 = NL1 \times \exp -M(L1,L2) - C(L1, L2)$ .... (8)

Where, $C(L1, L2)$ = number of fish in the length group (L1, L2), NL2 = number of fish at length L2.

So the survivors at the end of each length group;

$NL2 = [NL1 \times \exp -M(L1,L2) - C(L1, L2)] \times \exp -M(L1,L2)$ .... (9)

This can be rearranged as

$NL1 = [NL2 \times \exp M(L1,L2) + C(L1, L2)] \times \exp M(L1,L2)$ .... (10)

In the eq. (10) catch of a particular length group was estimated with;

$$C(L1,L2) = [NL1 - NL2] \times \frac{F(L1,L2)}{Z(L1,L2)} \quad \text{................} \quad (11)$$

Where, F (L1-L2) = fishing mortality of the length group (L1-L2), Z(L1-L2) = total mortality of the length group (L1-L2).

Then it is inserted to eq. (10), which gives;

$$NL1 = [NL2 \times \exp M(L1,L2) + = [NL1 - NL2] \times \frac{F(L1,L2)}{Z(L1,L2)}] \times \exp M(L1,L2) \text{.........} (12)$$

When equation (12) is rearranged;

The number of surviving fish is given,

$$NL2 = NL1 \times \frac{1/M\,(L1 - L2) - F(L1 - L2)/Z(L1 - L2)}{M\,(L1 - L2) - F(L1 - L2)/Z(L1 - L2)} \quad \text{.................} \quad (13)$$

M (L1-L2) = the fraction of NL1 which survive from natural deaths during time period from tL1 to $tL1+\Delta t/2$

In the eq. (13), M(L1-L2) is estimated from;

$$M(L1\text{-}L2) = (L\infty - L1 / L\infty - L2)^{M/2K} \text{ ....} \quad (14)$$

It should be noted that the analysis assumes the natural mortality of each species is constant throughout the different length groups.

In the eq. (13), F(L1-L2) is derived from;

$$F(L1\text{-}L2) = \frac{M \times F(L1 - L2)/Z(L1 - L2)}{1 - (F(L1 - L2)/Z(L1 - L2)} \text{ ....} \quad (15)$$

F/Z is derived from;

$$F(L1\text{-}L2)/Z(L1\text{-}L2) = C\,(L1\text{-}L2)/(N\,(L1) - N(L2))$$

The catch in weight (yield) by length group is calculated by multiplying catch (number) in each length group by weight of length group, W (L1-L2)

W(L1-L2) is estimated from,

$$W(L1\text{-}L2) = a \times ((L1+L2)/2)^{b} \text{ ....} \quad (16)$$

Where, a and b = constant of the length weight relationship.

Then the catch (yield) of the length group is given by;

$$Y(L1\text{-}L2) = C(L1\text{-}L2) \times W(L1\text{-}L2) \text{ ....} \quad (17)$$

Where, Y(L1-L2) = catch in weight (yield) of the length group

The value of the yield is estimated as,

$$V(L1\text{-}L2) = Y(L1\text{-}L2) \times V(L1\text{-}L2) \text{ ....} \quad (18)$$

Where, V (L1-L2) = the average price of one kilo of fish between length L1 and L2 during the time Δt (L1-L2) and this is the time that a cohort takes to grow from L1 to L2, during that time the number of survivors decreases from N (L1) to N (L2).

The mean number of survivors of that length group is estimated,

$$N\,(L1\text{-}L2) \times \Delta t = (N\,(L1)\text{-}N\,(L2))/Z(L1\text{-}L2) \text{ ....} \quad (19)$$

The corresponding mean biomass at Δt is,

$$B\,(L1\text{-}L2) \times \Delta t\,(L1\text{-}L2) = N\,(L1\text{-}L2) \times \Delta t\,(L1\text{-}L2) \times W\,(L1\text{-}L2) \text{ ....} \quad (20)$$

Where, B (L1-L2) = biomass of the length group (L1-L2).

Summation of all length groups gives the total estimates.

5. 2. 2 Multi Species Stock Assessment

The 'total biomass production model' was applied to the demersal finfish fishery in Negombo area in order to estimate the optimum level of fishing effort required to produce the MSY. These parameters were estimated by means of the Schaefer and Fox models described in Sparre and Venema (1992). The time series data on annual catch and effort of demersal finfish fisheries collected through the period 1992 –1999 were used (Chapter 2).

In fact in the Schaefer model the yield per unit effort (annual CPUE) is assumed to decline linearly with an increase in fishing effort (annual standardized fishing effort), while in the Fox model the decline is summed to occur exponentially. The Schaefer model assumes that the increase in stock biomass conforms to a symmetrical 'S' shape or logistic curve. In the model of Fox used an asymmetric curve was used in place of Schaefer symmetrical one. The logistic equation describes that the rate of increase of biomass is more rapid until the stock is at one half of the maximum biomass and thereafter it increase at a reduce rate and stabilize at carrying capacity ($B\infty$). This suggest that if the stock is exploited, productivity and therefore yield would be maximized when the stock is at the half of the maximum biomass or carrying capacity. The logistic equation;

$$\frac{dB}{dt} = r\,B\left[1 - \frac{B}{B\infty}\right] \qquad (21)$$

Where, $B\infty$ = maximum biomass of the carrying capacity level, B = biomass at any exploited state, r = rate of increase, $\frac{dB}{dt}$ = rate of biomass growth

If the stock is exploited, the catch rate usually catch or yield (Y) per year is deducted.

$$\frac{dB}{dt} = r\,B\left[1 - \frac{B}{B\infty}\right] - Y \qquad (22)$$

In equilibrium condition where the rate of fishing has been maintained exactly by biomass growth. *i.e.* $\frac{dB}{dt} = 0$

$$Y = rB\left[1 - \frac{B}{B\infty}\right] \quad \ldots\ldots\ldots\ldots \quad (23)$$

The yield of stock $Y = afB$ or $\frac{Y}{f} = qB$ .... (24)

Where, Y = yield, q = catchability coefficient (constant), f = fishing effort

$$\frac{Y}{f} = CPUE$$

$$CPUE = qB \quad \text{or} \quad B = \frac{CPUE}{q} \quad \ldots\ldots\ldots \quad (25)$$

Substituting equation (25) to equation (24) gives,

$Y = f\,CPUE = r\,(CPUE/q)\,[1 - (CPUE/q)/(CPUE\infty/q)]$ .... (26)

Where, $CPUE\infty$ = catch per unit effort at the maximum biomass ($B\infty$) of the stock

Dividing equation (24) by CPUE gives,

$F = r/q\,[1 - CPUE/CPUE\infty]$

Or

$CPUE = CPUE\infty - [CPUE\infty\, q/r]\, f$ .... (27)

Which is a straight line with a slope, $b = [1\text{-}CPUE\infty\, q/r]$ and an intercept $a = CPUE\infty$

$CPUE = Y/f = a + bf$ .... (28)

Where, a and b = constant

Multiplying equation (28) by fishing effort (f),

$Y = af + bf^2$ .... (29)

Which is the equation for Schaefer's model and suggests that the yield is related to fishing effort by a symmetrical parabola

The model of Fox use an asymmetric curve in place of Schaefer's symmetrical one In this model CPUE decrease in a curve with increasing fishing effort rather than the straight line assumed under the Schaefer model

The curve is transformed to a straight line by using natural logarithms,

$\ln[CPUE] = \ln[Y/f] = c + df$ .... (30)

In practice, the approach of Schaefer and Fox models is to use a long time series of annual catch and effort data. CPUE/ ln CPUE graphed against fishing effort (f) and the value of a or c = intercept and b or d = slope is substituted to equation (29) and (30) respectively.

From the constants a and b of equation (29) and c and d of equation (30) the MSY and corresponding f_{Msy} considered to be the biologically optimum effort, are estimated by the following expressions.

Schaefer : $MSY = -a^2/4b$ .... (31)

$f_{Msy} = -a/2b$ .... (32)

Fox : $MSY = (1/d)\, e^{(c-1)}$ .... (33)

$f_{Msy} = -1/d$ .... (34)

Using the estimated values of a and b of Schaefer and c and d of Fox models, adjusted the time series values of Y are adjusted (adjusted CPUE) corresponding to each of the f values. The area based total biomass production model assumes that the fish assemblages, their habitats and productivity do not differ within the area, the relationship between catch and effort is at equilibrium in the area and that the fish stocks and effort are contained within the designated fishing area.

5. 2. 3 Standardization of Fishing Effort

Demersal fishery in Negombo is a multigear fishery (Chapter 2) and the fishing effort extended by each gear varies from each other because either they are target species specific or differ in efficiency. Therefore the fishing effort of each gear should be made into a common unit of measurement before combining all the effort measures into a total effort in the application of 'total biomass production model'. The fishing effort was therefore standardized to the fishing power which is the quantity proportional to yield and effort and expressed in a common measure. Thus the handline with bait cage fishing with OBM boat effort was selected as the common unit (standard unit) in the present study because it is the single dominant fishing gear used in the area and is also has been operated all year round during the study period. The monthly fishing effort of the other gear was therefore standardized to the bait cage handline gear with OBM boat by using the ratio of average monthly catch rates of the particular gear to the handline gear assuming all gears were operating under the same conditions (at the same time and in the same area). This method works with the concept of 'relative fishing power' (Robson, 1966) and considers the fishing power of a given effort unit to standard fishing power of the bait cage handline unit.

Standardized effort = monthly fishing effort fleet i × Raising factor

Raising factor = monthly mean CPUE i/ monthly mean CPUE (HL)

$$\text{Standardized monthly total effort } E_{month} = \sum_{i}^{n} \text{monthly fishing effort of fleet i}$$

$$\text{Standardized annual total effort } E_{annual} = \sum E_{month}$$

5. 3 RESULTS

5. 3. 1 Jones Length-Based Cohort Analysis

The total number of fish of each species (*L. nebulosus* and *L. lentjan*) caught by each gear over the period January to December 1999 were used as input data for the cohort analysis. In addition the estimates of asymptotic length (L∞), growth constant (K), natural mortality coefficient (M) and the constants of the length-weight relationship (a and b) made for each species in Chapter 4 were also utilized in the analysis. Length based cohort analysis was performed with pooled length-frequency data obtained from all gears in all months during the year 1999. The results for *L. nebulosus* and *L. lentjan* are summarized in Tables 5.1 and 5. 2 respectively. The fishing mortality was relatively high over mid length from 54 cm to 70 cm for *L. nebulosus* 20 to 44 cm total length for *L. lentjan*. The maximum and minimum fishing mortalities of 2.15 and 0.046 $year^{-1}$ respectively were recorded for the mid lengths of 12 cm and 64 cm for *L. nebulosus* and 2.45 and 0.002 $year^{-1}$ respectively 12 cm and 34 cm for *L. lentjan*. A summary of the analysis is given below (Table 5. 3).

Table 5. 1. The results of the Jones length based cohort analysis of *L. nebulosus*.

Mid length (cm)	Catch (number)	Population (number)	Natural mortality coefficient (M) Year⁻¹	Fishing mortality coefficient (F) Year⁻¹	Total mortality coefficient (Z) Year⁻¹	Exploitation rate (E)
12	587	775290.00	0.52	0.0072	0.5272	0.0137
14	1791	732291.00	0.52	0.0227	0.5427	0.0418
16	3618	689437.81	0.52	0.0475	0.5675	0.0837
18	2024	646189.31	0.52	0.0276	0.5476	0.0504
20	1950	605964.63	0.52	0.0270	0.5470	0.0494
22	3500	567187.38	0.52	0.0510	0.5710	0.0893
24	6022	582274.25	0.52	0.0924	0.6124	0.1509
26	6626	488378.56	0.52	0.1069	0.6269	0.1705
28	9479	449512.81	0.52	0.1616	0.6816	0.2371
30	12412	409540.28	0.52	0.2261	0.7461	0.3030
32	11866	368577.00	0.52	0.2325	0.7525	0.3090
34	9740	330174.31	0.52	0.2056	0.7256	0.2834
36	7644	295796.94	0.52	0.1735	0.6935	0.2502
38	5473	265237.56	0.52	0.1331	0.6531	0.2038
40	4960	238386.30	0.52	0.1292	0.6492	0.1990
42	4690	213464.02	0.52	0.1312	0.6512	0.2015
44	3385	190183.97	0.52	0.1017	0.6217	0.1636
46	4263	169497.25	0.52	0.1382	0.6582	0.2100
48	5520	149194.97	0.52	0.1956	0.7156	0.2733
50	8109	128996.73	0.52	0.3214	0.8414	0.3820
52	10534	107766.66	0.52	0.4849	1.0049	0.4825
54 ↑	12235	85935.21	0.52	0.6879 ↑	1.2079	0.5695 ↑
56	12229	64451.70	0.52	0.8932	1.4132	0.6320
58	12094	45102.97	0.52	1.2538	1.7738	0.7068
60	9200	27993.12	0.52	1.5089	2.0289	0.7437
62	4618	15622.61	0.52	1.2410	1.7610	0.7047
64	3819	9069.70	0.52	1.8181	2.3381	0.7776
66	1693	4158.44	0.52	1.6124	2.1324	0.7561
68	655	1919.45	0.52	1.1822	1.7022	0.6945
70 ↓	382	976.35	0.52	1.2923 ↓	1.8123	0.7131 ↓
72	216	440.64	0.52	0.5000	1.0200	0.4902

Note: double head arrow indicates the length range which has subjected to high fishing mortality and exploitation rate

Table 5. 2. The results of the Jones length based cohort analysis of *L. lentjan.*

Mid length (cm)	Catch (number)	Population (number)	Natural mortality coefficient (M) Year $^{-1}$	Fishing mortality coefficient (F) Year $^{-1}$	Total mortality coefficient (Z) Year $^{-1}$	Exploitation rate (E)
12	480	2049162.38	0.71	0.0020	0.7120	0.0028
14	8984	1878070.25	0.71	0.0393	0.7493	0.0524
16	17714	1706808.63	0.71	0.0821	0.7921	0.1036
18	60264	1535878.13	0.71	0.3019	1.0119	0.2983
20	145774	1333885.13	0.71	0.8358	1.5458	0.5407
22 ↑	206811	1064282.75	0.71	1.4922 ↑	2.2022	0.6776 ↑
24	161652	759069.81	0.71	1.5757	2.2857	0.9894
26	124910	524579.56	0.71	1.7011	2.4111	0.7055
28	90419	347534.75	0.71	1.7869	2.4969	0.7156
30	58631	221188.44	0.71	1.7251	2.4351	0.7084
32	42557	138426.97	0.71	1.9400	2.6500	0.7321
34	31270	80295.19	0.71	2.4532	3.1632	0.7755
36	12883	39975.73	0.71	1.7996	2.5096	0.7171
38	9062	22010.17	0.71	2.2926	3.0036	0.7636
40	3837	10141.78	0.71	1.8934	2.6034	0.7273
42	1532	4865.96	0.71	1.3757	2.0857	0.6596
44 ↓	1097	2543.31	0.71	1.8872 ↓	2.5972	0.7266 ↓
46	192	1033.59	0.71	0.6072	1.3172	0.4610
48	255	617.10	0.71	0.500	1.2100	0.4132

Note: double head arrow indicates the length range which has subjected to high fishing mortality and exploitation rate.

Table 5. 3. Summary of the Length cohort analysis for *L. nebulosus* and *L. lentjan*.

Parameters	*L. nebulosus*	*L. lentjan*
Mean fishing mortality	0.254	0.649
Mean exploitation rate	0.328	0.477
Maximum fishing mortality	2.1495	2.4532
Minimum fishing mortality	0.0463	0.0020
Recruitment number	241,261	2,049,162
Population	8,659,012	11,720,370

The VPA analysis indicated that both *L. nebulosus* and *L. lentjan* are recruited at a total length of 12 cm. The fishing moralities were initially quite low for both species but increased as they grew in size. When *L. nebulosus* exceeded > 50 cm there was a marked increase in fishing mortality because of increased vulnerability to all gears, specially to handline and bottom longline. *L. lentjan* showed a similar increase in fishing mortalities above 20 cm for the same reason but there was a decline at length greater 46 cm as they vulnerability to fishing gear appeared to decrease.

Fishing mortality partitioned between gears obtained through Jones cohort analysis (Tables 5.1 and 5.2) is given in Tables 5. 4 and 5. 5 for *L. nebulosus* and *L. lentjan* respectively.

Table 5. 4. Estimated fishing mortality of *L. nebulosus* by different fishing gear obtained by partitioning the fishing mortality estimates of Jones cohort analysis.

Mid length (cm)	Fishing mortality (F) ($Year^{-1}$)			
	Bottom longline (BLL)	Bottom trammel net (BTN)	Handline (HL)	All gears
12	0.0	0.007	0.0	0.007
14	0.0	0.007	0.015	0.023
16	0.0	0.008	0.040	0.048
18	0.0	0.011	0.016	0.028
20	0.0	0.002	0.025	0.027
22	0.001	0.014	0.037	0.051
24	0.005	0.047	0.040	0.092
26	0.006	0.027	0.074	0.107
28	0.009	0.037	0.116	0.162
30	0.023	0.047	0.157	0.226
32	0.025	0.061	0.146	0.233
34	0.019	0.051	0.135	0.206
36	0.032	0.048	0.093	0.174
38	0.038	0.020	0.075	0.133
40	0.043	0.031	0.055	0.129
42	0.058	0.021	0.052	0.131
44	0.051	0.003	0.048	0.102
46	0.092	0.004	0.042	0.138
48	0.120	0.013	0.062	0.196
50	0.191	0.007	0.123	0.321
52	0.370	0.015	0.100	0.485
54	0.543	0.006	0.138	0.688
56	0.646	0.013	0.234	0.893
58	0.933	0.025	0.293	1.254
60	1.138	0.125	0.341	1.509
62	0.918	0.156	0.321	1.241
64	1.220	0.319	0.55	1.818
66	1.270	0.277	0.338	1.612
68	0.718	0.0	0.464	1.182
70	1.292	0.0	0.000	1.292
72	0.345	0.0	0.153	0.500

Table 5. 5. Estimated fishing mortality of *L. lentjan* by different fishing gear obtained by partitioning the fishing mortality estimates of Jones cohort analysis.

Mid length (cm)	Fishing mortality (F) (Year^{-1})			
	Bottom longline (BLL)	Bottom trammel net (BTN)	Handline (HL)	All gears
12	0.0	0.0	0.002	0.002
14	0.0	0.001	0.038	0.039
16	0.0	0.008	0.074	0.082
18	0.003	0.122	0.177	0.302
20	0.008	0.524	0.303	0.836
22	0.066	0.870	0.556	1.492
24	0.128	0.773	0.675	1.576
26	0.208	0.684	0.810	1.701
28	0.247	0.602	0.938	1.787
30	0.404	0.514	0.807	1.725
32	0.587	0.547	0.806	1.940
34	0.956	0.618	0.879	2.453
36	0.475	0.740	0.584	1.800
38	0.908	0.627	0.759	2.294
40	1.028	0.367	0.498	1.893
42	0.446	0.235	0.694	1.376
44	1.096	0.274	0.518	1.887
46	0.00	0.607	0.000	0.607
48	0.167	0.0	0.333	0.500

The estimated mean fishing mortality of *L. nebulosus* and *L. lentjan* for different gears are summarized below in Table 5. 6

Table 5. 6 Mean fishing mortality coefficient for estimated *L. nebulosus* and *L. lentjan* by gear.

Fishing gear	Mean fishing mortality coefficient (F) (Year^{-1})	
	L. nebulosus	*L. lentjan*
Bottom longline	0.389	0.448
Bottom trammel net	0.050	0.477
Handline	0.143	0.497

The mean F is very variable across gears for *L. nebulosus*. The highest value was reported for bottom longline and the lowest value was for bottom trammel net while for *L. lentjan* highest mean fishing mortality was recorded for handline and lowest for bottom longline, however, the mean fishing mortalities of this species for each of the gear are quite close.

5. 3. 2 Single Species Stock Assessment - Thompson and Bell Model

The projected annual yield/biomass of *L. nebulosus* and *L. lentjan*, for different levels of effort by different fishing gears using Thompson and Bell model, are shown in Figs 5.1 and 5.2 respectively. The results are summarized in Table 5.7.

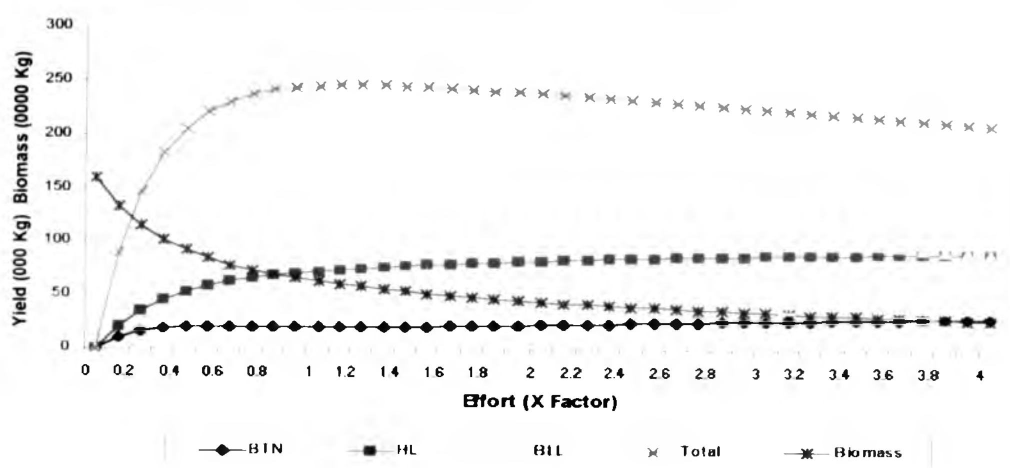


Fig. 5.1. Projected annual yield/biomass of *L. nebulosus* when the fishing effort of all gears is changed. The present fishing effort is 1.0.

The maximum sustainable yield (MSY) for the overall fishery were estimated at 246.51 t and 262.27 t for *L. nebulosus* and *L. lentjan* respectively (Table 5. 7). The estimated optimum effort to achieve this MSY was 1.2 times the 1999 effort for *L. nebulosus* and 0.6 times or 60% of the fishing effort of 1999 for *L. lentjan*. This shows that *L. lentjan* has been overexploited and to obtain MSY the present fishing effort should be reduced by 40%, but a reduction of this order would result in only small increase of yield (5.4% or 13.4 t). The 1999 effort was producing a yield close to or slightly below MSY with respect to *L. nebulosus*. Although a 20% increase in fishing effort would achieve the MSY but only a marginal increase in yield (<1 t) would result. Furthermore increase in fishing effort of this scale would also increase the fishing cost and reduce the CPUE.

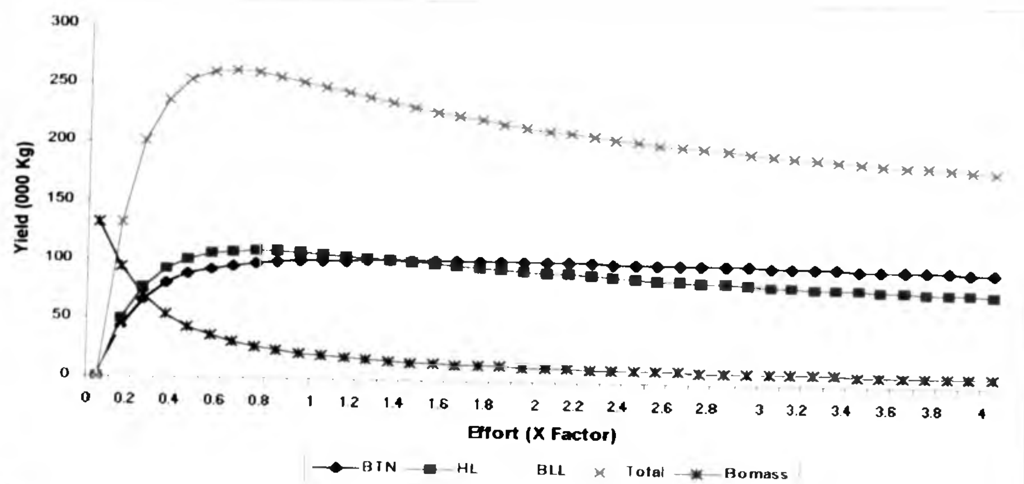


Fig. 5.2. Projected annual yield/biomass of *L. lentjan* when the fishing effort of all gears is changed. The present fishing effort is 1.0.

The maximum sustainable yield of *L. nebulosus* for bottom longline, bottom trammel net and handline were estimated at 152.7 t, > 26.6 t and > 88.1 t respectively. The yield of *L. nebulosus* for handline and bottom trammel net was found to increase over the entire range of fishing effort analyzed but the effort of bottom longline in 1999 has exceeded the optimum (X – factor 0.9), which produces the MSY. Therefore the fishing effort of the bottom longline at present would have to be reduced by about 10% to attain the MSY, but the resulted improvement in the yield is insignificant (from 152.5 t to 152. 6 t) (Table 5.7). Both bottom trammel net and handline fishing are conducted more in shallow waters and catch more young fish which have not attained the appropriate size for generating maximum yield. Thus an increase of fishing effort of these fisheries would enhance the growth overfishing.

The maximum sustainable yields of *L. lentjan* for bottom longline, handline and bottom trammel net were estimated at 64.7 t, 108.6 t and 102.2 t respectively. The fishing effort in 1999 of both handline and bottom longline has been shown to have exceeded the optimum fishing effort by 30% and 60% respectively, but the effort in 1999 of bottom trammel net could be increased by 1.6 times to produce the MSY (Table 5.7). In the multispecies situation, since stock assessment of other species has not been done, any increase in the fishing effort must be viewed with extreme caution.

Table 5.7 Summarized results of the Thompson and Bell Model analysis.

Species	Fishing Gear	Annual total effort (fishing days in 1999)	Annual stan Fishing effort in 1999	MSY (t)	F factor corresponding to MSY	Yield in 1999 (t)
L. nebulosus	Bottom trammel net	22525	17620	≥29.7	≥4	12.9
	Bottom longline	14875	17844	152.6	0.9	144.6
	Handline	169425	48673	≥90.7	≥4	42.6
	Total	206825	84137	246.6	1.2	200.1
L. lentjan	Bottom trammel net	22525	17620	102.2	1.6	87.1
	Bottom longline	14875	17844	64.7	0.4	41.2
	Handline	169425	48673	108.6	0.7	84.1
	Total	206825	84137	262.2	0.6	212.4

5. 3. 3 Projections of Yield Performance Under Different Fishing Strategies

Three hypothetical scenarios of different fishing strategies for each species were tested using the Thompson and Bell model. In each scenario the effort of one fishing gear was increased while the effort of the other gears were maintained at the contemporary level or at the effort level in the year 1999.

In the case of *L. nebulosus*:

1) Changing the effort of bottom trammel net fishery

The increase of fishing effort of bottom trammel net could increase its catch (yield) from a present yield of 20.7 t to 63.1 t if, in the extreme case, the present effort were increased by four times (Fig. 5. 3). However, the associated decline in the estimated catch from other gears at this extreme case is predicted to be substantial, specially for bottom longlineing. The estimated decline in the catch of handline would be from 72.9 t to 57.9 t while in bottom longline fishery catch would decline from 152.3 t to 114.1 t. The total catch would decline from 245.8 t to 235.1 t.

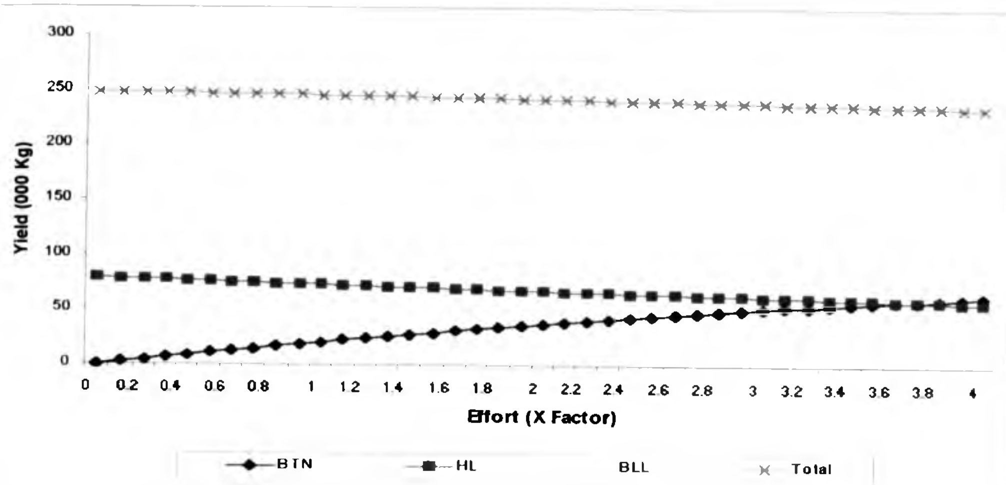


Fig. 5. 3. **Predicted changes in annual catches (yield) when the fishing effort of bottom** trammel net is changed. The present fishing effort is 1.0

2) Changing the effort of bottom longline fishery.

An increase of fishing effort of bottom longline would improve its catch from 152.3 t to 205.8 t, at the extreme case if the 1999 effort were increased by four times (Fig. 5.4). However, the associated decline of catch in the bottom trammel net and handline fishery at the extreme fishing effort level would be highly substantial. The predicted catch of bottom trammel net would decline from 20.7 t to 11.4 t while that of handlining would from 72.9 t to 38.7 t. The total catch would only improve slightly from 245.8 t to 255.9 t.

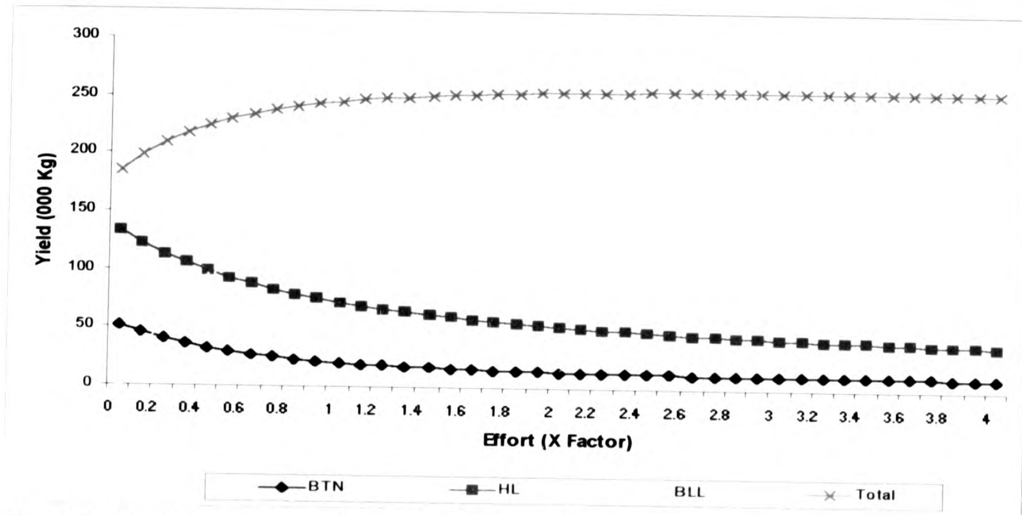


Fig. 5.4. Predicted changes in annual catches (yield) when the fishing effort of bottom longline is changed. The present fishing effort is 1.0.

3) Changing the effort of handline fishery.

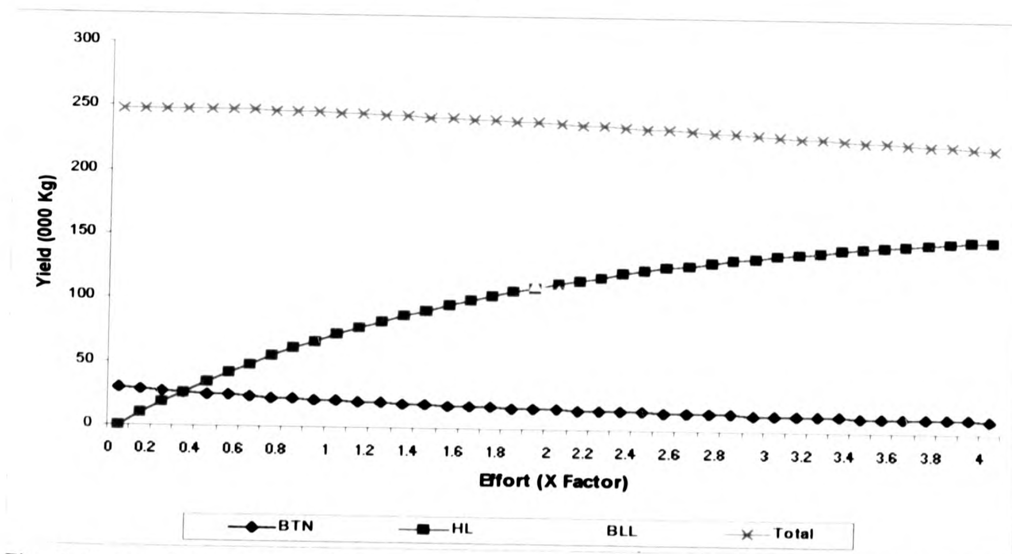


Fig. 5. 5. Predicted changes in annual catches (yield) when the fishing effort of handline is changed. The present fishing effort is 1.0.

It is observed that the catch of handline would increase from 72.9 t to 150.5 t with increasing effort by four times the 1999 effort (Fig. 5.5). The increase the effort of handline would reduce the catch of other gears. The associated decline in the catch of bottom longline would be from 152.3 t to 61.1 t while in the bottom trammel net catch would decline by two times, from 20.7 t to 10.5 t. The total catch by all gears would reduce from 245.8 t to 222.1 t.

In the case of *L. lentjan*:

1) Changing the effort of the bottom trammel net fishery.

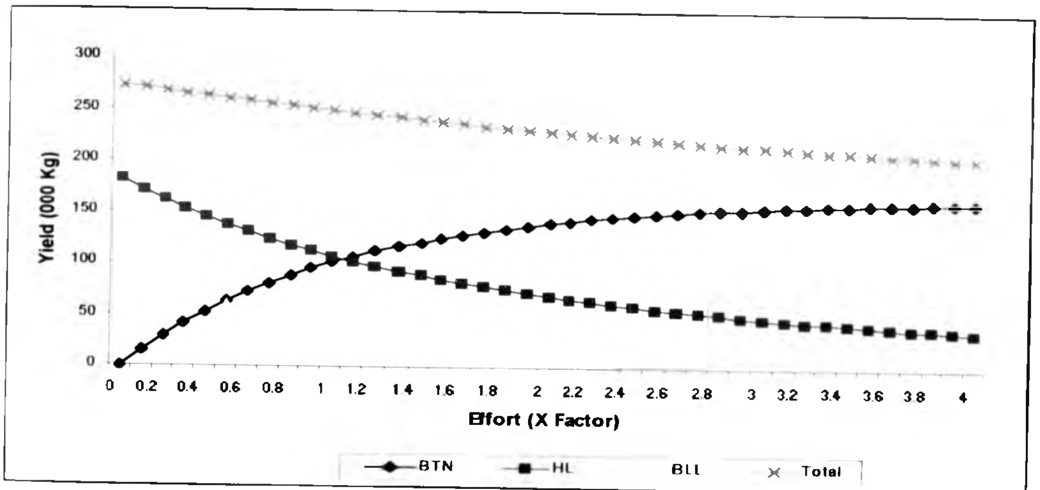


Fig. 5. 6. Predicted changes in the annual catches (yield) when the fishing effort of bottom trammel net is changed. The present fishing effort is 1.0.

The increase of fishing effort of bottom trammel net would increase the catch (yield) from 100.9 t to 161.8 t at the extreme case of increasing the 1999 effort by four times (Fig. 5. 6). However, the associated decline in the estimated catch from other gears at the extreme level of fishing effort is very substantial. The estimated decline in the catch of handline would be from 106.6 t to 35.8 t while the bottom longline fishery catch would decline from 41.3 t to 6.6 t. The total catch would decline from 248.8 t to 204.13t.

2) Changing the effort of the bottom longline fishery.

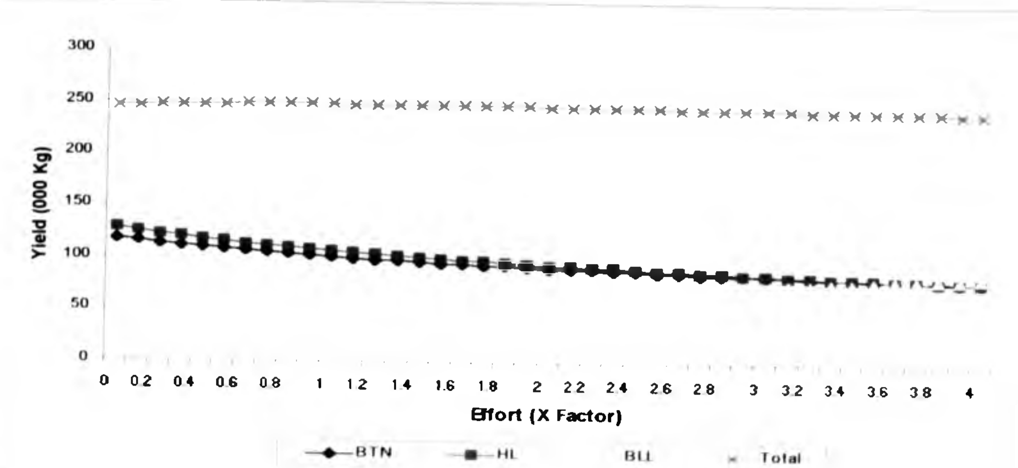


Fig. 5.7. Predicted changes of the annual catches (yield) when the fishing effort of bottom longline is changed. The present fishing effort is 1.0.

The increase of fishing effort of bottom longline would increase the catch and double it from 41.3 t to 83.7 t at the extreme case of increasing the 1999 effort by four times (Fig. 5.7). However, the associated decline of catch in the bottom trammel net and handline fishery at the extreme fishing effort level is substantial. The catch of bottom trammel net would decline from 100.9 t to 79.5 t while the catch of handline would decline from 106.6 t to 79.0 t. The total catch would only reduce from 248.8 t to 242.2 t.

3) Changing the effort of the handline fishery.

It was observed that the catch of handline is increased with increasing effort (Fig. 5.8). The present catch would be increased two times, from 106.6 t to 154.9 t with increasing the effort by four times the present effort. The increase the effort of handline reduces the total catch of other gears. The associated decline in the catch of bottom longline will be from 41.3 t to 6.8 t while in the bottom trammel net catch will decline by two times, from 100.9 t to 43.8 t. The total catch reduces from 248.8 t to 205.5 t.

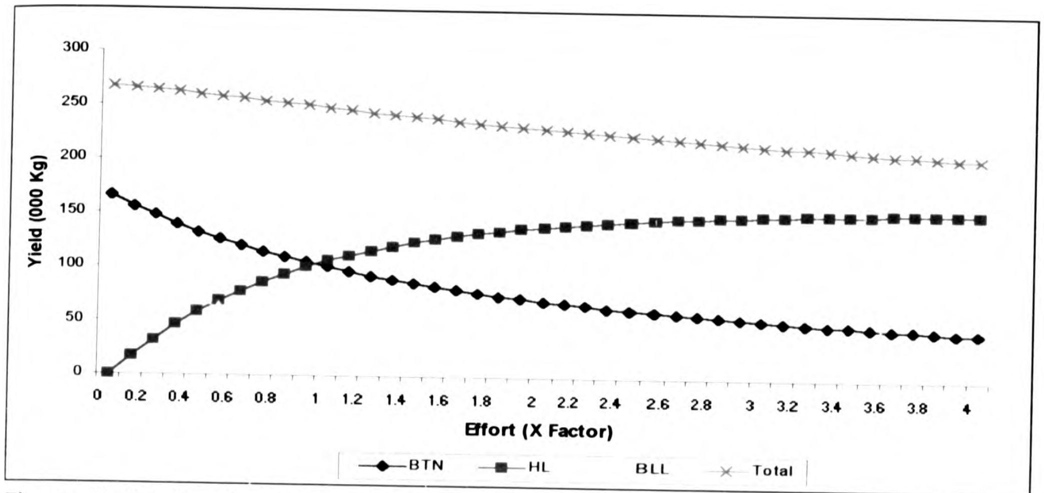


Fig. 5. 8. Predicted changes of the annual catches (yield) when the fishing effort of handline is changed. The present fishing effort is 1.0

The likely consequences on future yields under different fishing strategies obtained from Thompsom and Bell model are summarized in Table 5. 8.

Table 5. 8 Summary of performance projections under different development options

Development option	Total catch (000 Kg)			
	0.5 (X Factor)	1.0 (X Factor)	2.0 (X Factor)	4.0 (X Factor)
L. nebulosus				
BLL vary	230.6	245.8	254.8	255.9
BTN vary	247.3	245.8	242.5	235.1
HL vary	247.7	245.8	239.1	222.1
BLL, BTN, HL vary	221.2	245.8	238.8	209.8
L. lentjan				
BLL vary	248.6	248.8	247.0	242.2
BTN vary	260.5	248.8	229.3	204.3
HL vary	258.9	248.8	230.5	205.5
BLL, BTN, HL vary	261.1	248.8	214.4	183.4

It is very clear that the catch of *L. nebulosus* would slightly improve either by reducing the 1999 effort of handlining or bottom trammel netting by half (50%) or by doubling the effort of bottom longline fishing. While the total yield of *L. lentjan* would not be improved by an increase in effort of any fishing gear. The only improvement, which could be done, is by reducing the effort of handline or bottom trammel net by 50%.

5. 3. 4 Standardized Fishing Effort

The total standardized fishing effort steadily increased over the study period from 1992 reaching a maximum in 1997, (Table 5. 9), after which it declined. The gear which contributed most to the fishing effort were the bottom trammel net fishing and handline fishing with OBM boats, the effort of which declined most significantly in 1998 and 1999.

Table 5. 9. Standardized annual total fishing effort of all demersal gear and the overall total effort from 1992-1999.

Year	IBM boats	OBM boats						Total
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
1992	3110	35025	8060	15701	4767	556	4399	71618
1993	3891	34150	8379	13692	3600	541	5451	69704
1994	4594	36050	15941	19021	2263	520	8217	86605
1995	4545	37150	10891	22451	1324	461	4686	84507
1996	5603	35850	13654	23281	1069	575	8573	88605
1997	6613	38175	19038	30132	1342	298	8585	104181
1998	7446	29825	23269	19692	2783	295	15589	98898
1999	5186	30875	17844	17620	2590	189	12611	86915

HL* = handline fishing with IBM boats. HL= handline fishing with OBM boats. BLL = bottom longline fishing with OBM boats. BTN = bottom trammel net fishing with OBM boats. BSN = bottom set gillnet fishing with OBM boats. SPF = spear fishing with OBM boats. HL/DN = handline fishing combined with drift gillnet.

5. 3. 5 Total Biomass Production Model

The data utilized for the development of total biomass production model are;

1. Estimated annual total standardized fishing effort (Table 5. 9) covering the above period.
2. Estimated annual demersal fish catch (yield) by all boat/gear combination in the Negombo area from years 1992 to 1999 (Table 5. 10).

The linear relationships from the Schaefer and Fox models between annual average CPUE of all species and standardized fishing effort are illustrated separately in Figs. 5. 9 and 5. 10. From the relationships values of constants were provided to model the relationship between annual catch and standardized effort in Schaefer and Fox models.

Table 5. 10 Input data for Schaefer and Fox models

Year	Total catch (actual) (kg)	Fishing effort		CPUE	
		Total fishing effort (actual) (fishing days)	Total fishing (standardized) (standardized fishing days)	Schaefer model (CPUE)	Fox model (lnCPUE)
1992	2194.160	155.125	71.618	30.63	3.422
1993	1946.261	169.025	69.704	27.92	3.329
1994	2152.114	180.250	86.605	24.85	3.213
1995	1994.555	191.550	84.507	23.60	3.161
1996	2364.996	202.175	88.605	26.69	3.284
1997	2481.280	213.725	104.181	23.82	3.170
1998	2021.630	208.700	98.898	20.44	3.018
1999	2041.602	208.375	86.915	23.49	3.157

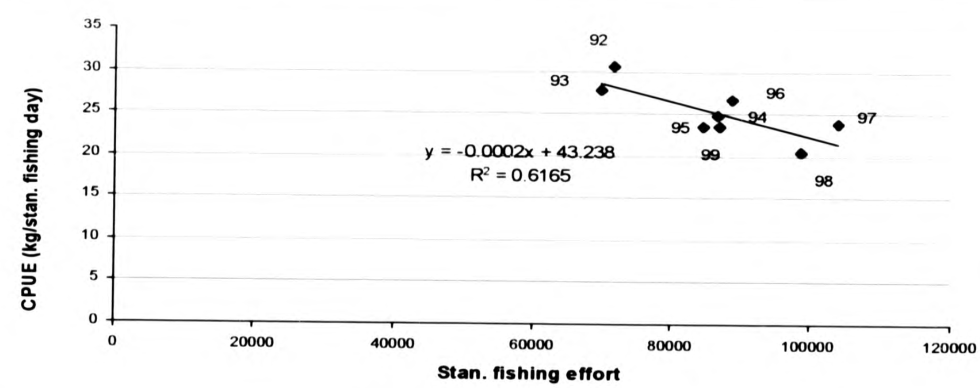


Fig. 5. 9. Linear regression for Schaefer model.

These linear relationships were found to be highly significant with $R^2 = 0.616$ and $R^2 = 0.607$ for Schaefer and Fox models respectively. However, the slightly higher level of significance obtained with the Schaefer model suggests it may be more effective in predicting CPUE from effort than the Fox model.

The annual sustainable catch for different levels of fishing effort (Table 5.11) was calculated using the regression equations generated by the Schaefer and Fox models (Figs. 5.9 and 5.10).

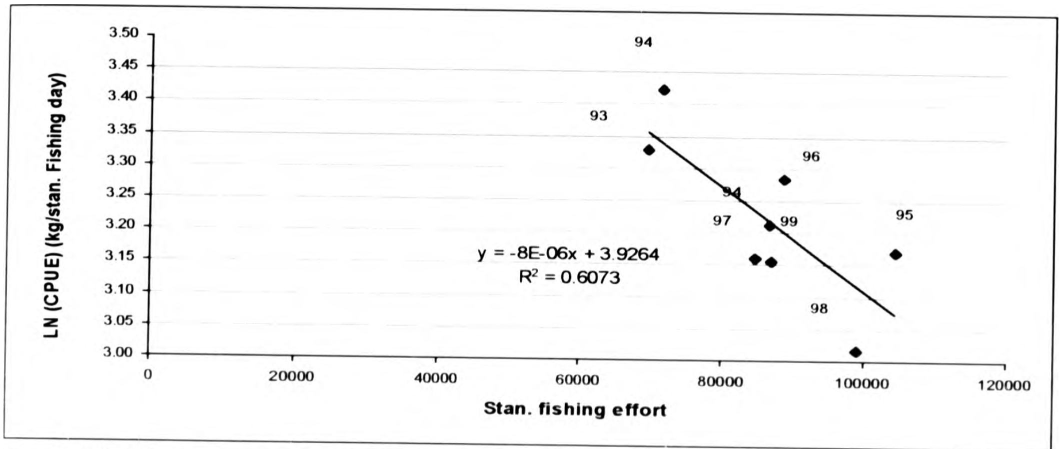


Fig. 5. 10. Linear regression for Fox model.

Table 5. 11 Predicted sustainable yield at different effort levels in Schaefer and Fox models

Effort (standard fishing days)	Predicted sustainable yield (kg)	
	Schaefer model $Y = af + bf^2$	Fox model $Y = f \times \exp(c + d \times f)$
0	0	0
1500	601.533	672.963
30000	1108.999	1190.405
45000	1522.399	1579.281
60000	1841.731	1862.393
75000	2066.998	2058.992
90000	2198.197	2185.291
105000	2235.330	2254.911
120000	2178.396	2279.264
135000	2027.395	2267.882
150000	1782.328	2228.698

Note: a = 43.2377511 b = -0.000209 c = 3.92642998 d = -8.186E-06

The outcomes from the Schaefer and Fox models for the evaluation of the associated MSY and F_{MSY} values, together with regression statistics are given in Table 5. 12. The associated graphical respresentation of Schaefer and Fox models, showing the relationships between annual sustainable catches and standardized fishing effort are given in Fig 5. 11. The sustainable catch (yield) curves of both Schaefer and Fox model increased with increasing fishing effort (standard effort) at low levels of fishing effort as would be the case in the early development stages of the fishery. This increase tapers off and reaches a maximum (MSY), and eventually begins to fall as effort increases, reducing the fish stock below the maximum sustainable yield. In the Schaefer model MSY is estimated as 2,236 tons per annum produced at the level of 103,421 standard fishing effort day per annum (f_{MSY}). According to the Fox model MSY is very close to this at 2,280 tons per annum from a f_{MSY} of 122,160 standard fishing effort day per annum.

Biological overfishing is said to occur whenever sustainable yield falls below MSY. Thus the demersal fish production in Negombo area exceeded the predicted MSY levels in both 1996 and 1997 and optimum effort (f_{MSY}) in 1997. A considerable decline in the fish production was noted immediately after 1997 without much decline of fishing effort. In 1999 fishing effort has further declined but the production was not improved as predicted. This effect is related to the time taken for stocks to recover biologically from the effect of overfishing and for a new equilibrium to be reached. The present yield (2,042 tons) and effort (86,915 standard fishing days) are very close to the predicted maximum (Fig. 5.11), and that a sustained increase in yield would not result from increasing the effort. The most likely consequence of a high increase of effort would be for yields to decrease, along with the CPUE and fishery profits.

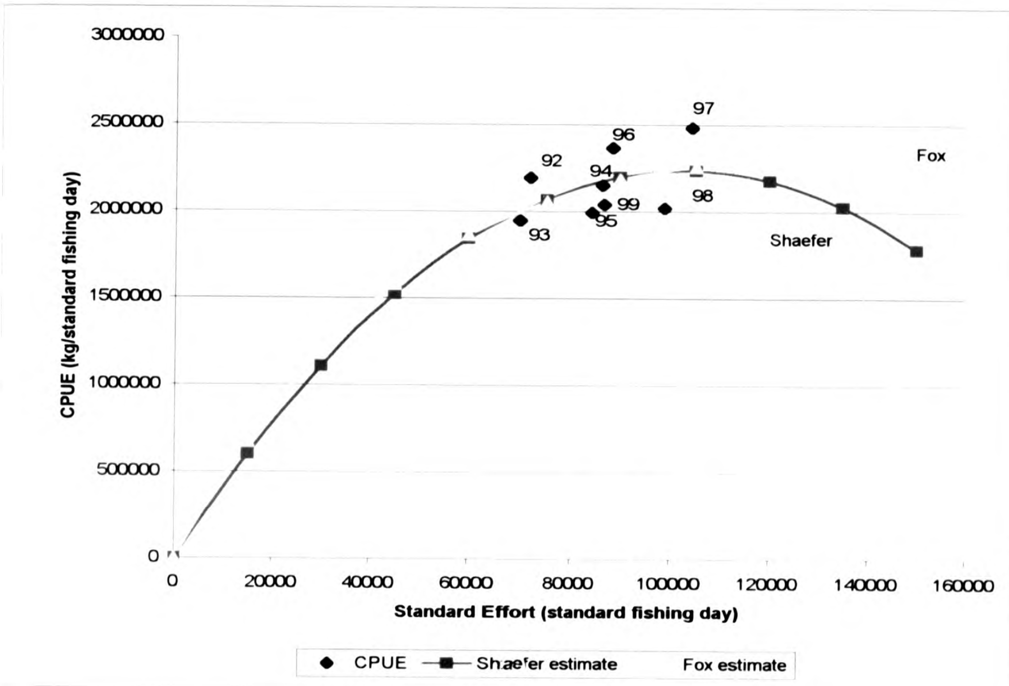


Fig.5. 11. The derived relationship between yield and standardized effort of Schaefer and Fox model. It also includes the actual annual yield for 1992 - 1999.

The total annual standardized effort over the period 1992 to 1999 varied from 69,704 to 104,181 standard fishing days and the catch varied from 1,994,555 kg to 2,481,280 kg. This shows since 1992 to 1999 the standardized fishing effort and the annual catch has not increased much and thus the catches of most years are clustered around MSY (Fig. 5.11).

Table 5. 12 Outcomes and regression statistics of Schaefer and Fox models

Item	Schaefer	Fox
Intercept (a) (c)	43.237751	3.92643
Standard error of intercept	34 357669	-8 19000000
95% CF (a+) (c+)	57.580943	4.4990518
(a-) (c-)	28.894559	3.3538082
Slope (b) (d)	-0.000209	0.0547606
Standard error of slope	4.53000000000	7.21000000000000
95% CF (b+) (d+)	-4 4300000	-1.61000000
(b-) (d-)	-0.000374	-1 4800000
Regression		
Multiple R	0.785	0.779
R square	0 616	0.607
Adjusted R square	0.553	0.542
Analysis of variance		
Regression		
Sum of squares	42.752	0.06556
Df	1	1
Mean square	42.752	0.06556
F	9.645	9.280
Sig	0 021	0.023
Residual		
Sum of squares	26 595	0.04239
Df	6	6
Mean square	4.433	0.007065
Total		
Sum of squares	69.347	0 108
Df	7	7
MSY (kg)	2235850 8	2279624 8
f_{MSY} (fishing days)	103421.2	122160.6

5. 4 DISCUSSION

The history of fisheries resource surveys in Sri Lanka dates back to the beginning of the 20th century (Pearson and Malpas, 1926). Although a number of demersal fishery surveys have been conducted over the past years, except for the 'Dr. Fridtjof Nansen' survey (1978-1980), none has attempted to make stock assessment or population study on demersal resources (Sivasubramaniam, 1985). The 'Dr Fridtjof Nansen' survey was aimed at an estimation of the total biomass of fish resources in the coastal waters based on acoustic information, but was not able to make separate estimates by taxonomic groups. That survey indicated very high abundance of demersal resources off Chilaw, Negombo, Hanbantota (Fig. 4.1). The present study is the first attempt to estimate the demersal fish stocks off Negombo in the west cost of Sri Lanka with some accuracy.

The general lack of an adequately detailed time series of catch and effort statistics and a lack of knowledge of the biology, distribution, extent and interdependence of many of the major commercial species has prevented the use of conventional fish stock assessment methods. Despite criticism of the methods and models developed primarily for temperate long lived species, these models adapted for use in tropical fast turnover multispecies fisheries (Gulland, 1982; Ursin, 1984; Sugihara *et al.*, 1984; Pauly and Morgan, 1987) have been used in the present study. The data available for this study had limitations on the use of stock assessment models and procedures. Analytical models demand large amounts of biological data and cannot be used in multispecies fishery.

The 'total biomass production model' has been used in managing many tropical multispecies fisheries (Pope, 1979; Ralston and Polovina, 1982, Munro and Thompson, 1983, Sugihara *et al.*, 1984; Wright and Richards, 1985) largely because it is based only on catch and effort data, which are relatively easy to obtain. This model allows species to be combined but may not ensure conservation of individual species because neither interspecific interaction nor climatic variables have been considered in the analysis. Pooling of fisheries data for modelling purposes is sometimes also recommended in a multispecies situation (FAO, 1978, Pauly, 1984a, Gulland and Garcia, 1984), but problems arises when the individual stocks have different productivity, so that the effort required to maximize yield in the mixed stock will ultimately overexploit the least productive species.

In the present study however the aggregate CPUE showed higher correlation coefficients with the standardized effort in both Schaefer and Fox models. This clearly illustrates that the holistic characteristic of the resource. The total biomass production model was applied to a small area in the present study as suggested by Pope (1979) to minimize the possible bias overcoming from the presence of many stocks which could be present in a larger area. This procedure has also been adopted by Sommani (1983) with the application of the Schaefer model to a small area within the Gulf of Thailand, the results from which implied the possibility of local stock. The main disadvantage is that the Schaefer model ignores the biological processes affecting the stock biomass and also assumes that stocks are stabilized to the current rate of fishing. Kirkwood (1982) stated that in the application of the biomass production model, the estimated MSY will be less than the sum of the MSY of single species. Also the sensitivity of the system to environmental fluctuations will increase as the level of exploitation increased. Further he emphasized the limitation of applications of the model with strongly interactive species.

In the present study Schaefer model was selected as more appropriate than Fox model based on the high correlation between CPUE and standard effort data. However, Larkin (1982) suggested that tropical multispecies yield model is mostly a flat-topped yield model rather than a Schaefer parabolic yield model or a Fox skewed model. If the yield/effort relationship of the multispecies demersal fishery in the Negombo area is more or less flat-topped, the increase or decrease of fishing effort would not lead to considerable change of yield but increase of effort would influence the change in species composition in favour of low value fast growing species which could affect the value of the catch.

A comparison of the historical trends in the demersal fishery in the Negombo region with the outputs from the production model shows that the fishery has reached its maximum sustainable yield level in terms of total fisheries (Fig 5. 11) and therefore the fishing effort should not be increased. Further increase of fishing effort would decrease the

CPUE (Fig. 5. 9) and thereby the fishing income. The situation calls for optimization and delimitation of the demersal fleet to exploit alternative species or under exploited species in deeper waters (>50m) such as red mullets (*Pristipomis sp.*) (Chapter 2). The biological justification for an expansion of fishing range off shore to >50 m is doubtful since the knowledge of species distribution and interaction between offshore and inshore is limited. It is erroneous even to assume that a given level of fishing effort allows a certain surplus yield to be maintained indefinitely, irrespective of environmental condition (Hilborn 1979) because not only fisheries, the environmental changes and fluctuations would also affect biological productivity of the resource base.

At present fishing effort is operating below the f_{MSY} but an increase of population with a probable increase in consumer demand could enhance the fishing effort if the open access nature of the fishery is not controlled. If the effort increased beyond f_{MSY} (103,421 standard fishing days) the level of biomass overexploitation would increase and the sustainable yield would be reduced and a suboptimal sustainable yield would result. The demersal fishing effort in the Negombo area has exceed the f_{MSY} in 1997 but it has declined in subsequent years both in 1998 and 1999 but yield has not recovered over the period. The management from suboptimal sustainable yield level to the optimal one is only possible in the long run when the fish stocks have been built up. During the stock rebuilding period, the harvest will have to decrease. The adjustment period from suboptimal to optimal may take many years. Hence in this fishery rationalization of fishing effort at the f_{MSY} level is important in the long term.

The application of total biomass production models to the multispecies fisheries in most instances has found that the actual current mean catch was always very close to the predicted MSY (Marshall *et al.*, 1982, Moyo, 1990 *in* Kolding, 1998, Hillborn and Walters, 1992). They encountered a problem only when fitting surplus production models to fisheries with data points only on the ascending side of the yield-effort curve and concluded that it is simply not possible to find the MSY without overexploiting the stock. Clearly the distribution of data points in the present study is not restricted to the ascending part of the yield-effort curve. However, uncertainty and the biological limitations behind the analysis of MSY as management objective is highly questionable but still the MSY concept is deeply rooted in management process (Barber, 1988). The use of a biomass production model for stock assessment in the present study was considered worthwhile. It may be over optimistic to make any prediction without some consideration of the interaction between species or the uncertainty of the estimates. Much more information about the variability and randomness of fish stocks and fishery is required to check the present assessment values. In particular it would be informative to obtain estimates through independent methods such as acoustic or trawl survey.

Over fishing in multispecies stocks is hard to define in terms of 'growth overfishing' or 'recruitment overfishing' (Cushing, 1975) which are concepts pertaining to single species stocks. 'Ecosystem overfishing' has been defined by Pauly (1979) as 'what takes place in a mixed fishery when the decline of the originally abundant stocks is not fully matched by the contemporary or subsequent increase of the biomass abundant component of the area'. The multispecies fishery in Negombo area may not be severely over fished ecologically if the definition given above is used, but there are some changes in the composition of the catch over the years (Chapter 2) which are of interest. The catch composition of shark, skate and carnivorous species like carangids has declined while the contribution of squids and cuttlefish has increased. The changes in species composition has sustained the notion of ecosystem over fishing of some degree in the demersal fisheries of Negombo. These changes in the catch composition would affect the fishing income. This leads on the concept of economic overfishing (Chapter 6).

Detailed assessments of the indicator species, *L. nebulosus* and *L. lentjn* in the demersal fisheries in the Negombo area was carried out with length based analytical model, the Thompson and Bell model. This allowed some consideration of the likely consequences on future yields and values of altering the magnitude of the fishing effort. It was observed that the present 1999 fishing effort by all gears produces lower catches (yield) than the predicted maximum sustainable yield (MSY) with respect to both *L. nebulosus* and *L. lentjan*. An increase in catch of *L. nebulosus* could be achieved by an increase of effort by 20% while for *L. lentjan* a 40% reduction of effort would be required. At present *L. lentjan* is over exploited. *L. lentjan* inhabit relatively shallow waters than *L. nebulosus* (Aldonov and Druzhinin, 1978; Carpenter and Allen, 1989) and only few *L. lentjan* were encountered in gears operated in the deeper waters (Chapter 2). This indicates that commercially important demersal species in the shallow waters are presently overexploited. The 1999 fishing effort of bottom long line fishery has long exceeded the required effort to achieve the predicted MSY for *L. lentjan* and slightly exceeded it for *L. nebulosus*. Meanwhile handline effort has exceeded the predicted MSY of *L. lentjan* and the effort in 1999 of bottom trammel was below the optimum for both species because they catch small size fish. The effort would have increased to 1.6 times and >4 times to achieve MSY *L. nebulosus* and *L. lentjan* respectively. This indicates the complexity of a common management strategy which can be adapted to maintain a sustainable fishery on these species.

The projected performance in different combinations of fishing strategies (Table 5. 8) shows that except for bottom longline fishing for *L. nebulosus*, increase of fishing effort of any fishery would reduce the present total catch but reducing the present fishing effort by 50% either handline or bottom trammel net would slightly increase (about 0.8%) the aggregate of catch of *L. nebulosus* and can cause some increase of *L. lentjan* (4.7%). Both bottom trammel net and handline catch small fish and reducing the effort would allow time until they grow bigger and become vulnerable to bottom longline fishing at later stage.

The aim of conservation of fish resources through biological management is not only to achieve a maximum sustainable yield (MSY) but also to provide a necessary conditions to ensure viability of resources. How then should biological management policies be adjusted to take account of the information revealed from biological and stock assessment studies? The decision should be a balance between losses in short term and gain in long term. Reduction of fishing effort will reduce the yield but it would influence the rebuilding of the resources.

When the intensity of fishing effort on a fish stock is increased beyond a certain level, the biological system is thrown out of balance in two ways. First, the young recruits entering the fishery may be caught before they have grown to a commercially acceptable size (growth overfishing). Second, and more important, the adult stock may be reduced to the extent that insufficient offspring are produced to maintain the population. The production of *L. nebulosus* by handline and bottom trammel net fishing was 80,830 kg which is about 36% of the total production in 1999 and the catch consisted of juveniles. While bottom longline produced the rest, 144,596 kg (Chapter 2) of the catch consisted of adult fish. The catch of *L. lentjan* by all gears are mainly juveniles (Chapter 3).

In the context of future management with respect to biological consideration, it is most important to reduce the fishing effort of handline and bottom trammel net to reduce growth over fishing and recruitment over fishing of the two species. The reduction of fishing effort of handline and bottom trammel would allow fish to grow until maturity which would improve the yield as well as potential recruitment. The increase of bottom longline effort would affect the spawning biomass of both populations and therefore it is advisable to reduce the effort of bottom longline. The analysis showed that the present effort of bottom longline has exceeded optimum effort, which produce MSY of *L. nebulosus* by 10% and *L. lentjan* by 60%. Therefore fishing effort of bottom longline should also be reduced by 10-60% to ensure minimum size of spawning biomass.

Fishing is not only providing protein to the Sri Lankan population, it also provides livelihood for many people. A higher level of fishing effort would put the stock at a high risk of overfishing but on the other hand would provide more employment with lower economic returns. Likewise lower effort level ensures sustainability of fish stock but provides limited employment with high economic returns. It is thus important to study how such a reduction of fishing effort would effect fishing income and the social well being of the fishing community. As Beverton (1990) puts it "......*fisheries cannot be driven to extinction because fishing will disappear before the fish*"..... This indicates the importance of fishermen in fisheries. Therefore, studies on the economics of exploitation and socio-economic and cultural factors should play an equally important role when designing management scheme for the demersal fishery in Negombo area.

Appendix Table 5.1. Total number of *L. nebulosus* exploit by different gears in 1999.

Length (cm)	Total number of fish exploited			
	BLL	BTN	HL	Total
10	0	0	12	12
12	0	587	0	587
14	0	587	1204	1791
16	0	587	3031	3618
18	0	820	1204	2024
20	0	164	1786	1950
22	52	931	2516	3500
24	356	3072	2594	6022
26	393	1661	4571	6626
28	552	2144	6783	9479
30	1261	2556	8596	12412
32	1257	3136	7472	11866
34	895	2432	6412	9740
36	1421	2109	4114	7644
38	1565	842	3065	5473
40	1640	1199	2121	4960
42	2065	751	1875	4690
44	1706	90	1589	3385
46	2851	119	1294	4263
48	3396	367	1756	5520
50	4829	172	3108	8109
52	8038	326	2162	10534
54	9658	109	2455	12235
56	8843	179	3201	12229
58	8999	242	2826	12094
60	6939	760	2081	9200
62	3415	581	1193	4618
64	2563	671	1166	3819
66	1334	291	355	1693
68	398	0	257	655
70	382	0	0	382
72	149	0	66	216

Appendix Table 5.2. Total number of *L. lentjan* exploit by different gears in 1999.

Length (cm)	Total number of fish exploited			
	BLL	BTN	HL	Total
12	0	0	480	480
14	0	196	8788	8984
16	0	1651	16064	17714
18	561	24414	35289	60264
20	1450	91437	52887	145774
22	9163	120630	77019	206811
24	13117	79275	69260	161652
26	15238	50220	59452	124910
28	12494	30467	47459	90419
30	13722	17482	27428	58631
32	12875	11997	17686	42557
34	12190	7882	11198	31270
36	3400	5298	4184	12883
38	3588	2476	2999	9062
40	2084	743	1010	3837
42	497	262	773	1532
44	637	159	301	1097
46	0	192	0	192
48	85	0	170	255

Chapter 6

Cost Structure, Profitability and Economic Modelling of Fishing

6.1 INTRODUCTION

The stock assessment of this multispecies multigear fishery revealed that it has reached the maximum sustainable yield (MSY) and that the economically important large species have been overexploited. These species are at risk of recruitment and growth overfishing (Chapter 5). Thus the economic value of the harvest may decline in the future. Various types of fishing boat and gear are used in the demersal fishery, which exploit a variety of resources. Expanded use of efficient modern technologies has mainly been responsible in creating problems of overfishing. Increasing fishing pressure in a multispecies fishery will lead to a shift in species generally, giving way to less valuable species. Signs of declining valuable species have already been shown in this study. This would clearly affect the economic value of the harvest.

Among the many objectives of fisheries management, economic returns, efficiency and equity are most important, because fishing operations account for the major part of a fishing household's income in Sri Lanka (Fernando 1985a, Dayaratne and Sivakumaran, 1994). The effectiveness of fisheries management and development depends on the identification of an economically viable production system. Thus a clear assessment of cost, earnings, and profitability of different combinations of boat and gear in a comparable format with resource exploitation is required to guide the rational allocation of resources, and to design and improve the productivity of fisheries in the future. In Sri Lanka microeconomic data on the economic performance of small scale multigear fisheries are not presently available. This is the first attempt to provide an analysis of the microeconomic performance of multigear small scale fishery in Sri Lanka.

The present study examines the economic performance, and endeavors to determine the economically optimum yield and effort both for the short term and the long term sustenance of the demersal fishery in the Negombo area. The boat/gear specific costs, earnings and profitability levels are compared and factors responsible for their variation are identified and explained.

6. 2 MATERIALS AND METHODS

Data on operational costs such as oil, bait, food, ice, marketing (auction) commission and the sale/price of fish species have been collected along with the fisheries data from 1992 until 1999 (Chapter 2). Sample data on capital investment of fishing assets, their age and maximum economic life, maintenance costs and crew sharing systems were collected through the use of a questionnaire together with social data of randomly selected boat owners engaged in different fisheries from March – December 1999 and by interviewing fishermen and book-keepers of co-operative societies. The English draft of the questionnaire was translated into Sinhalese, pre-tested outside the sample settlement, and then modified and improved. A total of 5 villages in 2 divisional secretariats of Negombo DFEO (District Fisheries Extension Office) area were selected to use the questionnaire to represent all technologies involved in demersal fisheries in the Negombo area. The same 5 villages were used for the questionnaires of marketing and the socio-economics of crew members. This helped in the comparison of biological and economic, marketing and social data. The following methodology was adopted to establish the linkage between biological and economical studies.

- The stratification followed in biological assessment of fisheries was also followed to assess the economics of fisheries.
- The economic performance of fisheries was assessed by different boat/gear combination.
- The economic assessment of exploitation of demersal fish stocks was also performed under multispecies and single species situation and the same species were considered in both studies.

A total of 106 boat owners and 127 crew members were interviewed at Kuttiduwa, Pitipana, Palagathurai, Kammalthota and Hendala (Fig. 2.1). The number of boat owners and crew members interviewed are given in Table 6.1.

Table 6.1. Number of boat owners and crew members interviewed at different sampling centers.

Villagers	Secretariat Division	Boat/gear combination	Total no. Sampled	
			Boat owners	Crew members
Hedala	Je-ela	HL*	4	5
Pitipana. Kuttiduwa. Palagathurai	Negombo	HL	27	31
Pitipana. Kuttiduwa	Negombo	BLL	19	24
Palagathiari. Kamalthota	Negombo	BTN	21	26
Kuttiduwa. Palagathurai	Negombo	BSN	4	5
Kuttiduwa	Negombo	SPF	1	1
Pitipana. Kuttiduwa. Palagathuri	Negombo	HL/DN	30	35

The economic analysis has been undertaken by converting variables such as assets, operational regimes and technical efficiency into a single comparable numerator, the Sri Lankan rupee (SLRS or Rs) value. The basic unit of analysis was the fishing day (unit of fishing effort). The maximum number of fishing days per year was considered to be 300 fishing days. Fishing operations were distinguished according to the type of boat/gear combination, assuming that all fishing operations were made within the study area and that the changes in effort and adjustments in the stocks could be made instantaneously. Fishing units using more than one type of fishing gear form a separate group of 'combined gear' and are treated as a separate technology.

6. 2. 1 Cost Structure

Costs are differentiated into fixed costs and variable costs. Fixed costs (FC) constituted those items that in the short run cannot be varied by the fishermen. This includes the cost of depreciation of the fishing assets (boat, engine and gear), license and insurance fee. Depreciation is an input cost for the use of durables and was computed using the straight-line method.

Annual depreciation (d) was estimated as:

$d = (P' - S)/k$ .... (1)

Where, P' = average purchase price of fishing asset, economic life = k, S = salvage value.

Salvage value is assumed to be zero because the fishing assets have very little or no salvage value after their economic life.

Fishing boats engaged in small scale fishing are rarely insured but licensing was started in 1998. The license fee for all gears was Rs. 50 per annum. The payment of the license is usually borne by the owner.

The boats, engines and gear involved in demersal fishing activities fall into different age groups running up to twenty years. The mean age of these assets used in 1999 was estimated from the age profile of the fishing assets obtained from the sample data on demersal fisheries. The same pattern of age structure was assumed to be found over the previous years. The purchase price of the fishing assets was taken according to the mean age of fishing assets involved in each year (Appendix Table 6.1 to 6. 4). The average lifetime and the purchasing price of fishing assets were obtained by interviewing fishermen and co-operative managers.
Fixed cost was estimated as:

$FC = d + D$ .... (2)
Where, d = depreciation, and D = license fee.

Purchasing of fishing assets by the fishermen engaged in demersal fishing was generally made with their own savings. No one in the sample has received any subsidy or other assistance with purchasing their fishing equipment over the past 10 years (Chapter 8). Therefore interest on capital investment was not considered when estimating fixed cost.

Variable costs (VC) are the sum of costs of all inputs that are incurred only when the fishing unit operates. There are three kinds of variable costs, operational costs (fuel, oil, ice, food, cigarettes, maintenance etc.) labour costs (wages, crew share) and shore costs (landing, transport, commission). The crew are generally paid a share of the value of the catch after operational costs and shore costs have been deducted from revenue. This encourages crew members to participate actively in fishing because the risk is shared by all crew members. The total operational cost was estimated using the amount spent per fishing day multiplied by total fishing effort (total fishing days). The annual fishing effort estimated by craft gear combination (Chapter 2, Fig. 2. 3) is listed below in Table 6.2.

Table 6.2. Annual fishing effort by craft gear combination (as fishing days).

Year	3.5 t IBM boat	17-22' OBM boat						Total
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
1992	2425	35025	4425	13600	2850	450	96350	155125
1993	2375	34150	4475	13850	2800	500	110875	169025
1994	2650	36050	7600	16325	2375	300	114950	180250
1995	2775	37150	6975	21200	1525	325	121600	191550
1996	3550	35850	9800	24650	1075	300	126950	202175
1997	3575	38175	12200	27000	925	125	131725	213725
1998	3025	29825	13325	23950	1800	175	136600	208700
1999	3300	30875	14875	22525	1375	175	135250	208375

HL* = handline fishing with 3.5 t IBM boats. HL = handline fishing with OBM boats BLL = bottom long line fishing with OBM boats. BTN = bottom trammel net fishing with OBM boats. BSN = bottom set gillnet fishing with OBM boats. SPF = spear fishing with OBM boats. HL/DN handline driftnet combination fishing with OBM boats.

The commission charge was computed based on a percentage of catch value (fish sale) with the rate being provided by the co-operative societies managed by the church or local governments. Generally, the commission charge is 1% of the fish sales and is paid before sharing. Landing or transport charges are not relevant to demersal fishing in the Negombo area because fishing boats land at their home-port. The crew subsequently take the catch to the auction place or beach markets themselves which enables them to save labour charges otherwise they have to pay for labour in cash or in kind.

Thus total cost (TC) can be written as;

$TC = FC + VC$ .... (3)

Where, VC (variable cost) includes operational, labour and shore costs, FC (fixed cost) includes depreciation cost and license fee.

Generally, cost items are calculated on an annual basis but the fishing gear operated in the Negombo area changes seasonally. Some boats operate for small mesh gillnetting or prawn trawling, then shift in the short term to operate for demersal species only during the lean season. Therefore all costs of operating demersal fisheries were assigned in proportion to the fishing effort (fishing days). The total cost items (depreciation, operational, license, repairs and maintenance, labour, opportunity etc.) of the fleet was estimated by multiplying the daily cost item by the total annual fishing effort (total number of fishing days per annum). The operational cost of the handline component of the combination boats was estimated in proportion to the catch of drift net to handline, assuming total volume of the catch ≈ cost because their major fishery is drift gillnetting. The average annual handline catch proportion to the drift gillnet catch in the combination boats is given in Table 6.3.

Table 6. 3. Proportion of handline catch to the drift gillnet catch of combined boats.

Year	1992	1993	1994	1995	1996	1997	1998	1999
Handline catch proportion	3.2	3.1	3.4	3.0	5.0	3.5	6.2	5.9

6. 2. 2 Revenue

The revenue is the monetary value derived from the catch. The demersal fishery in the Negombo area is multispecies and multigear in nature. The total catch is made up of an aggregate catch from all gears. The catch consisted of a variety of species, of different sizes due to the different selectivities of the gears. Thus the unit price of the catch varies among the gears used. Hence the total revenue (TR) was estimated by multiplying the catch of each gear by its unit price, summing up over all gears, and expressing the resulting aggregate value as the total revenue.

$TR = pi_1 Yi_1 + pi_2 Yi_2 + \ldots + pi_n Yi_n$ .... (4)

Where, Yi = catch (yield) of gear i, pi = unit price of fish of gear i

The price variation according to the variety of fish was not considered in the estimation of TR (total revenue) because in Negombo in most instances fish are auctioned in a mixed form. The average annual unit price of fish for each gear was calculated by dividing catch values reported in sampling days in all months by the corresponding volume of the catch (yield). This would reduce the seasonal variation of unit price of fish. The annual average fish production by boat/gear combination (Chapter 2, Fig. 2.8) is given below in Table 6.4.

Table 6. 4. Annual demersal fish production (kg) by boat/ gear combination from 1992-1999.

Year	3.5 t IBM boat	17-22' OBM boat						Total
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
1992	95657	1092003	242599	463631	148745	17416	134109	2194160
1993	93930	994615	204477	396168	85097	14351	157623	1946261
1994	103935	968362	341554	469148	58117	17723	199275	2152114
1995	103230	895415	252501	517806	33537	9493	182573	1994555
1996	143535	981974	337743	615885	27093	14005	244790	2364996
1997	153189	897249	463564	733196	28221	6997	198866	2481280
1998	129833	705740	413552	420012	50626	5412	296456	2021630
1999	122237	728225	419464	411891	62151	5104	292531	2041602

HL* = handline fishing with 3.5 t IBM boats. HL = handline fishing with OBM boats BLL = bottom long line fishing with OBM boats. BTN = bottom trammel net fishing with OBM boats. BSN = bottom set gillnet fishing with OBM boats. SPF = spear fishing with OBM boats. HL/DN handline driftnet combination fishing with OBM boats.

6. 2. 3 Sharing System

The income of crew is derived from divisible income (revenue minus running cost and auction/marketing charges) according to the prevailing share system. The share system is generally based on acceptable norms by boat owners and crew. Except for the handline fishery, a uniform share system is practiced among all demersal fisheries in the Negombo area. The accepted tradition is by dividing equal proportions of the divisible income amongst owner, crewmembers, boat and gear. The boat owner generally owns the gear and is also engaged in fishing. Thus the boat owner gets three portions of the share while a crewmember gets a single portion. Boat owners pay the crew share in cash after every fishing trip. Generally, most of the catch is sold but sometimes a few kilos are for consumption by the boat owner and crew members. We were told that fish worth Rs. 75 to Rs. 200 were shared daily among the crew members. It was thus assumed that an additional average income of Rs.30 was given to a crew member for every fishing day during the study period.

6. 2. 4 Labour and Employment

The number of crew and the average amount of man-hours engaged in a fishing operation is summarized in Table 6. 5. There is little variation in the average number of working hours per day across gear types. In general, most of gear types have been operated for 6-8 hours/day.

Table 6. 5. Average number of crew and the man-hours engaged in fishing by different boat/gear combination.

No. Crew members	Fishing gear						
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN
Crew members	4	4	2.3	2	2	2	2
Man hour/day	28	28	18	12	12	12	12

HL* = Handline fishing with IBM boat. HL = Handline fishing with OBM boat. BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat. BSN = Bottom set gillnet fishing with OBM boat. SPF = Spear fishing with OBM boat. HL/DN = Handline fishing combine with gillnet with OBM boat.

6. 2. 5 Repairs and Maintenance

The repair and maintenance of boat and gear was borne by the boat owner. In the handline fishery a share was not allocated for the gear, instead a nominal sum (Rs 30-Rs100) was allocated for repairs and maintenance of the gear. The information on average repair and maintenance of boat and gear are only available for the year 1999 from the sample data on demersal fisheries. The same pattern of cost structure was assumed to be found over the previous years. The ratio of boat owner's gross income (share from fish sales) to repairs and maintenance cost was assumed to be constant over the years studied. The figures used as repair and maintenance were therefore estimates based on this assumption. The average daily repair and maintenance cost of fishing assets reported in 1999 and the ratio of owner's gross income to repair and maintenance cost is given in Table 6. 6.

Table 6. 6. Ratio of owner's gross income to repair and maintenance

Cost (Rs)/ Fishing day	Fishing gear						
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN
Repairs and maintenance	79.74	32.11	67.86	44.67	42.71	31.24	9.34
Ratio	8.28	6.31	4.76	6.13	2.59	1.69	5.94

HL* = Handline fishing with IBM boat. HL = Handline fishing with OBM boat. BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat. BSN = Bottom set gillnet fishing with OBM boat. SPF = Spear fishing with OBM boat. HL/DN = Handline fishing combine with gillnet with OBM boat.

The highest ratio of gross income to repair and maintenance cost was reported from bait cage handline fishing with IBM and OBM boats. The average age of IBM boats engaged in demersal fishing was about 9 years and they are quite old. Thus the repairs and maintenance of boat may be very high and also the replacement of gear is more frequent in the handline fishery. The lowest was reported with spear fishing and bottom set gillnets. In the case of bottom set gillnets, instead of repairing them fishermen replaced the nets frequently with secondhand large mesh pelagic gillnets. The boats engaged in bottom trammel net fishing do short trips that are less wearing on engine parts and the boat hull.

6. 2. 6 Profitability and Efficiency Parameters

Profitability indicates focus on the implications of the margin between revenue and cost. The profitability measures used include: gross profit (operating profit) and net profit (financial profit).

Gross profit (or operating profit) is defined as,

$$\text{Profit}_{gross} = TR - VC \quad \text{.................} \quad (5)$$

Where, TR = total revenue and VC = variable cost

Net profit (or financial profit) is defined as,

$$\text{Profit}_{net} = TR - TC \quad \text{................} \quad (6)$$

Where, TC = total cost

A fishing unit is expected to continue operating as long as a positive gross profit is earned (Panayatou, 1985a). Positive net profit is a prerequisite for the long-term viability of a fishing unit In addition, the levels of profitability of different types of fishing operations were also analyzed and compared using alternative indices of profitability The alternative indices are operating ratios and return on cost and investment These are;

1 Financial profit (net profit) to variable cost ratio (Financial profit/Total variable cost)

This is the measurement of how much profit per unit of variable cost It is an indication of the profitability in relation to current variable operational cost (how much costs need be incurred to earn a rupee) The closer this ratio is to one means that fishermen are more capable of financing the next fishing trip assuming all other things remain constant

2 Financial profit (net profit) to total revenue ratio (Financial profit per fishing day/Total revenue per fishing day)

This is the measurement of the profit to turnover/sales ratio and details how much profit is earned for a unit of sales

3 Rate of return to total financial cost per fishing day (Financial profit per fishing day/Total financial cost of a fishing day)

The rate of return to total financial cost per fishing day shows how much of the financial cost (capital cost) of fishing day can be recovered by the financial profit of a fishing day It determines whether the activity can be carried out by borrowing and what the maximum cut off and the surplus is

4 Pay back period of financial cost per fishing day (Average financial costs per fishing day/ Average financial profit per fishing day)

Pay back period is the time taken to recover the financial cost per day of the project using the cash/profit generated

5 Rate of return to investment (Annual financial profit/Total investment)

The rate of return to investment shows how much of the initial investment can be recovered per annum

6. Pay back period of investment (Total investment/Annual financial profit)
Pay back period shows how soon investment could recover the initial investment cost of the project using the cash/profit generated.

The profitability of a particular fishing unit depends on both cost and earnings. In the context of multigear fishery all methods have their own advantages and disadvantages in relation to their cost of operation and in respect of their earnings. The effectiveness of multispecies fisheries development and management depends on the economical viability of different boat/gear combinations. The analysis of these profitability indices provides insights for the planning of future development and management to improve productivity within the demersal fisheries sector in the Negombo area.

The efficiency indicators measure the productivity of specific factors of production such as labour and capital. Labour productivity is the ratio of total revenue to crew member days. The average number of crew members involved in fishing in different boat/gear combinations are varied (Table 6. 5). The number of crew member day per year was estimated by multiplying total annual fishing effort (total annual fishing days) (Table 6. 2) by the average number of crew members engaged in fishing. The capital productivity is the ratio of total revenue to total investment. Another measure of productivity is capital intensity. This is the ratio of capital invested per crew member. The capital invested was estimated by multiplying average capital invested in each craft gear unit by the average number of boat operated in each year (Appendix Tables 6.2 and 6.4). The average number of crafts operated by gear is shown in Tables 2.2a-2.2h.

6. 2. 7 Pure Economic Profit and Resource Rent

The pure economic profit from the fishery was estimated by deducting opportunity cost of labour and capital from the net income earned by the owners and crew. The opportunity cost of an owner's capital is the income that can be derived by an owner from the most profitable investment, next to fishing. As there was no information available on such an investment, the prevailing interest rate on bank fixed deposit was used as the opportunity cost of the owner's capital. Though the interest rate of savings varied from

10% to 15% per annum over the years 1992-1999, the opportunity cost of capital investment was computed using the prevailing interest rate for fixed deposits of 12% as in 1999 (Central Bank report - Sri Lanka 1999) multiplied by the total investment cost (Appendix Tables 6.2 and 6.4). In the demersal fishery sector, owners also function as crew members. Thus part of pure profits of labour is captured by the owner. The opportunity cost of an owner's labour is the income foregone by managing the fishing instead of working in another job. According to the education level of the boat owners (Chapter 8), the average daily wage rate they could get was the average skilled labour wage rate in the Negombo area. It varied over the period as follows (Table 6. 7). The information on labour cost was gathered by interviewing labour managers of different enterprises in Negombo area.

Table 6. 7. Average annual skilled labour wage rate in Negombo area during 1992 to 1999

Year	1992	1993	1994	1995	1996	1997	1998	1999
Daily wage rate (Rs)	175	175	200	200	250	250	300	300

The pure profit of boat owner = net income – (opportunity cost of capital + opportunity cost of labor).

Where, net income = (crew share + boat share + gear share + fish share) – (license and insurance fee + repairs and maintenance cost).

The opportunity cost of crew labour was calculated using the average wage rate for un-skilled labour in the Negombo area. It varied over the period as follows (Table 6. 8).

Table 6. 8. Average annual unskilled labour wage rate in Negombo area during 1992 to 1999

Year	1992	1993	1994	1995	1996	1997	1998	1999
Daily wage rate (Rs)	125	125	150	150	175	175	200	200

The pure profit of a crew = (net income) – (opportunity cost of labor).

Where, net income = crew share + fish share

The economic or resource rent was estimated by adding the boat owner's and crew member's pure profits.

The standard of fishing income by different boat/gear combination was compared with the defined national per capita income or with other groups in the country (per capita income) to identify the position of demersal fishing income in the Negombo area within the society. However, a more appropriate comparison would be between the incomes of fishermen and those who engaged in vocations with similar risk. As there was no information in such vocations, comparison was made between different land based vocation of different educational categories.

6. 2. 8. Economic Model

6. 2. 8. 1 Bio-Economic Modelling of Multigear Fisheries on Economically Important Species

An analytical approach has been used, based on the Thompson and Bell model (Thompson and Bell, 1934) to assess the economic performance of the economically important indicator species, *L. nebulosus* and *L. lentjan*. The bio-economic model developed by Sparre and Venema (1992), incorporating the values of the catch to the Thompson and Bell prediction model assuming prices do not change at any effort level, was used in this study. Generally, price is inversely proportionate to the total volume of the catch. Change of effort would change the volume of the catch and thereby change the catch value. The values were incorporated for all length classes and estimated the value of the catch of each length class. The total value of the catch was the product of all length classes. The same procedural flow was followed as with the length-based Thompson and Bell stock assessment model in Chapter 5. It has been chosen because of its flexibility and mathematical simplicity. It can easily incorporate data on catch at length as well as value at length.

6. 2. 8. 2 Bio-Economic Modeling of Multigear Multispecies Fishery

Gordon's bio-economic fixed price model for open access fishery (Gordon, 1954) was applied with the time series data (1992 to 1999) on total revenue (TR) and fishing effort (standardized fishing effort). This model is based on the parabolic sustainable yield–effort production model (Schaefer, 1954). Multiplying each point on the sustainable yield curve by a constant price produced a sustainable revenue curve having the same general shape as the sustainable yield curve (Chapter 5). The time series data (1992 to 1999) on total cost (TC) of fishing was also modeled as a line arising from the origin and intersecting the total revenue curve (TR). Cost being assumed to be proportional to fishing effort. The revenue curve was constructed assuming that the price per kg of fish in the market is constant at all levels of effort and the cost of fishing rose at a rate as effort increased. These models depict cost and revenue as a function of fishing effort (standardized effort). The data on standardized fishing effort used in the analysis is given in Table 5. 9.

The constant price (the average for the entire period from 1992 to 1999) was estimated by dividing the total revenue by total catch regardless of boat/gear combination. The fixed price total revenue curve was constructed by multiplying total annual catch by the fixed price. If the catch is a parabola against effort (Schaefer 1954), then the revenue also will be a parabola. Since the total cost depends on the effort, the total cost for the period 1992 to 1999 was divided by the total effort resulting in an average value total cost for the above period. The cost line was estimated by multiplying the total yearly effort (standard) by the average value of total cost. The input data for the Gordon-Schaefer economic model is given in Table 6. 9.

Table 6. 9. Input data for the Gordon-Schaefer economic model

Year	Standardized annual effort (fishing days)	Total cost (Rs)	Av. cost per unit effort (Rs)	Adjusted total cost (RS)	Total revenue (Rs)	Total catch (Kg)	Average fish price (Rs)	Adjusted revenue (Rs)
1992	71618	102896320	1553.73	111275040	119748695	2194160	73.91	162172691
1993	69704	106248771	1553.73	108301201	123172545	1946261	73.91	143850213
1994	86605	120765829	1553.73	134560793	141418110	2152114	73.91	159065027
1995	84507	123613824	1553.73	131301067	143960077	1994555	73.91	147419674
1996	88605	151297846	1553.73	137668253	179836136	2364996	73.91	74799361
1997	104181	163862738	1553.73	161869153	198171474	2481280	73.91	183394034
1998	98898	147830555	1553.73	153660797	177378283	2021630	73.91	149420816
1999	86915	157162871	1553.73	135042449	187333463	2041602	73.91	150896967

The main predictions of the Gordon-Schaefer model are the bio-economic equilibrium (E'), the effort where total revenue equals total cost (where the total cost curve intersects the total revenue curve) and the maximum economic yield (MEY), and the optimum level of effort (f_{MEY}) where the difference (vertical distance) between revenues and cost is maximized (Clark, 1985, Anderson, 1986 , Hannesson, 1993). The actual position of E' is determined by relative price and costs. The underlying assumptions of the economic model are;

1. Price of fish is constant with the time and the quantity supplied.
2. The cost per unit effort remained the same at all effort levels.
3. Considered that all species react as a single population
4. The individual fishing units operate in perfect competition with each other.

In addition, all the assumptions made for the Schaefer surplus production model (Chapter 5) are also applied for this model.

A second degree curve was fitted to the total revenue as a function of effort (standardized effort). The concept of the relationship of yield (revenue) and effort was described in Chapter 5.

$TR = af + bf^2 \times$ fixed price .... (7)

Where, TR = total revenue, f = standardized effort (Chapter 5, Table 5.9), a = intercept (43.237751), b = slope (-0.000209) of the Schaefer model estimated in Chapter 5.

This equation, generally used to describe the fishery production function (Schaefer, 1954), also fits well with the revenue function in fisheries (Gordon, 1954). Therefore the values 'a' and 'b' estimated for the Schaefer Model (Chapter 5) was used for the economic model.

In order to find the relationship of total cost as a function of effort (standardized effort) a straight-line was fitted to the data of total cost and effort.

At the bio-economic equilibrium (E ') point where the fishery is open access, fishing cost equal fishing revenue. Thus,

$f_{(E')} \times$ cost (average cost) = $(af_{(E')} + bf^2_{(E')}) \times$ fixed price .... (8)

When it simplified fishing effort at bio-economic equilibrium (E') is given,

$f_{(E')}$ = [(cost / price) – a] / b .... (9)

The fishing effort (f_{MEY}) which produces maximum economic yield (MEY) is one half of the value of $f_{(E')}$. The value of MEY is estimated as,

MEY = ($af_{MEY} + bf_{MEY}^2$) × fixed price .... (10)

Net profit or economic rent is the distance between the revenue curve and fishing line. So that,

Net profit = MEY – fishing cost .... (11)

6. 3 RESULTS

6. 3. 1 Fixed Cost

Total annual fixed cost of the fishing fleet operated for demersal fishing is illustrated in Fig. 6.1. The worksheets depicting the analysis of fixed cost are given in Appendix Tables 6.5 – 6.7. Total fixed cost steadily increased from 1992 to a maximal in 1997 and then declined in 1998 and slightly increased in 1999. The depreciation cost of fishing boats is much greater than the gear. On average the depreciation cost of fishing boats is about 83% of the fixed cost and the gear was 17% across all gears for the period 1992-1999. The licensing cost was added to fixed cost only from 1998 and it is relatively very low (0.3%)

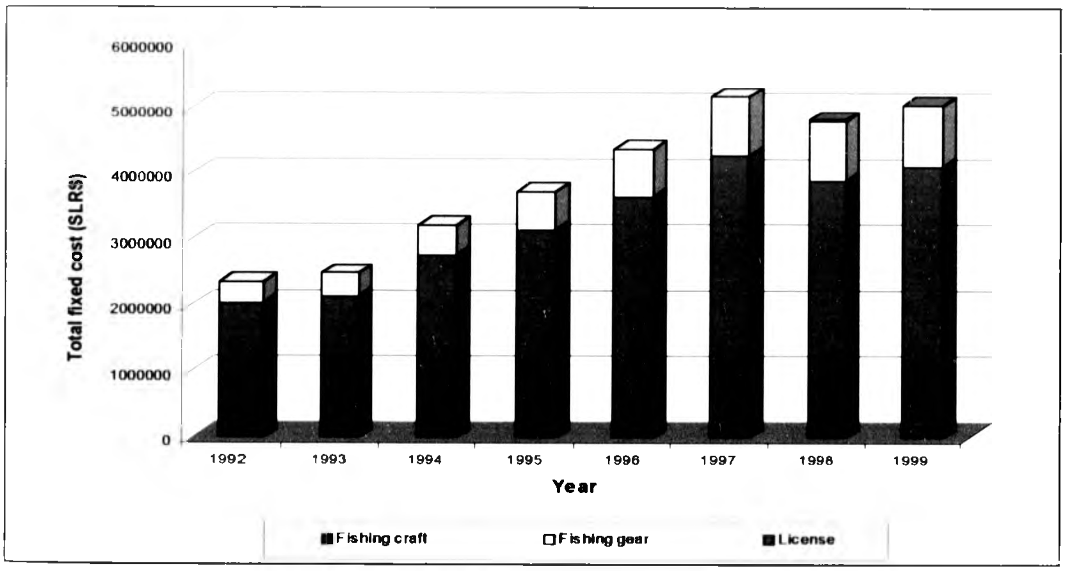


Fig. 6.1 Total annual fixed cost of the fishing fleet engaged in demersal fisheries in the Negombo area from 1992-1999.

6. 3. 2 Operational Cost of Fishing

Average annual operation cost of a fishing day of different boat/gear combinations are given in Fig. 6. 2. The details of the cost items in different fisheries are depicted in Appendix Table 6. 8 to 6.14. The average annual operational cost of a fishing day has increased with all gears without much annual fluctuation from 1992 to 1999. The highest operational cost was reported from OBM boats operated with bottom longline and it was notably higher than the other gears. Bait cage handline fishing with OBM and IBM boats and spear fishing with OBM boats have also shown high operational costs and their costs were quite close. The minimum was reported for handline fishing combined with drift gillnets because a large proportion of the cost was covered by drift gillnet fishery. The operational costs of both bottom trammel net and bottom set gillnet fishing with OBM boats were also low and close to each other.

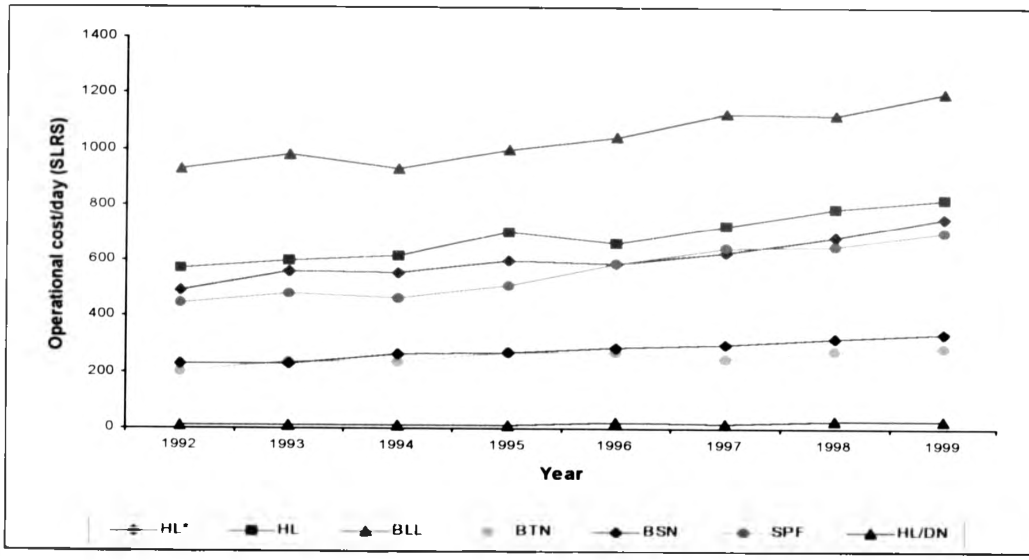


Fig. 6. 2 Average annual operational cost per fishing day for different boat/gear combination from 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

The itemized average daily operational cost for the period of 1992-1999 is given in Figs. 6.3 A and B. Fuel was the most important cost in bait cage handline fishing with IBM boats. It accounted for 69% of the cost and the remaining 16% was for the crew's food and 15% for gear maintenance. The fisherman used prawns as bait which they catch themselves by trawling. This enabled them to reduce operational costs to lower than bait cage handline fishing with OBM boats.

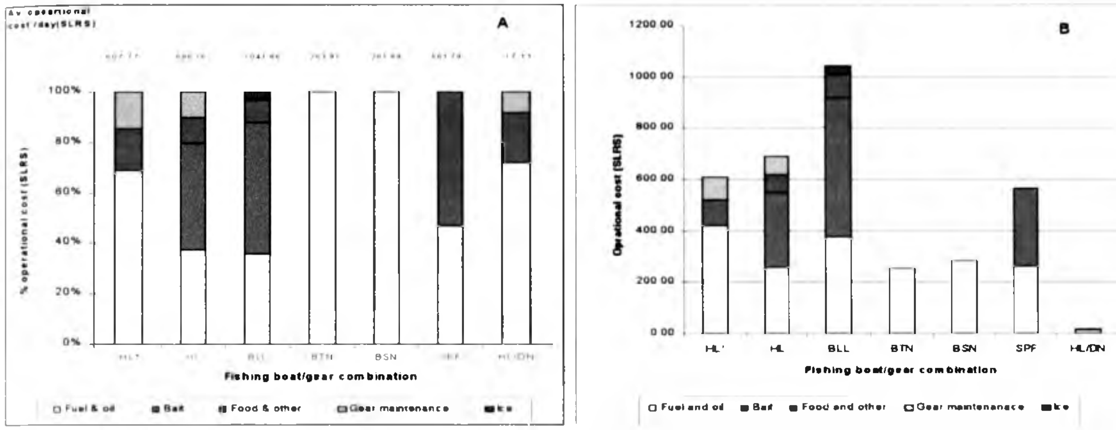


Fig. 6. 3. Itemized average operational cost per fishing day for different boat/gear for the period 1992-1999. A- in percentages B- in values (SLRS).

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat.

Bait cost was the most important input of handline fishing with OBM boats. The cost incurred for purchasing bait was about 42% of the total operational cost. The fishery was highly dependent on live bait (small live prawns) which were purchased from the lagoon stake net fishermen. Fuel accounted for 36% of the operational costs. The remaining was for crew's food, gear maintenance and sometimes to purchase ice (Fig. 6.3A).

Bait was also the most important cost for bottom longline fishery followed by fuel, which accounted for about 52% and 36% of the operational costs respectively. The longlines incur extra costs to purchase ice to keep the fish in good quality because they travel a longer distance than other fishermen. Fishing operations heavily depend on squids or cuttlefish as bait and these are more expensive than shrimps (Fig. 6.3A).

Fuel was the only input for bottom trammel net and bottom set gillnet fisheries. Fishing with trammel nets take place for a few hours in inshore waters. As such food and ice are not carried on the fishing run. In the bottom set gillnet fishery fishermen go to the fishing ground only to shoot their nets or collect the catch. Relatively higher fuel costs are incurred compared to trammel net fishing as they travel twice to the fishing ground to shoot the nets and then return later to collect the catch (Fig. 6. 3A).

The hiring cost of compressed air cylinders, diving equipment and food was the most important input, and accounted for 53% of the operational costs of the spear fishery. Fuel cost was about 47%. They spend a considerable amount for food as they need quick and high energy food for diving (Fig. 6.3B). Fuel was the main input in the combination fishery and about 72% of the total cost was spent on fuel. The operational cost (cost proportion) incurred for the handline fishing by the combination boat was very low in proportion to the gillnet catch because the bulk of the catch came from gillnets (Fig. 6.3A).

Fig. 6.3B shows how the fuel cost varied between different boat/gear combinations. Except handline fishing with IBM boats, bottom longline fishing and handline combined with drift gillnets for all other gears incur similar fuel cost in operations. The highest fuel cost was reported from handline fishing with IBM boats because they run on diesel. Bottom longline fishermen travel long distance in searching good fishing grounds and thus fuel consumption is high. The lowest fuel cost was reported for handline fishing combined with drift gillnets because a large proportion of the fuel cost was covered by drift gillnet fishery.

Total annual operational cost steadily increased from 1992 to 1999 but a slight decline was observed in 1998. The highest operational cost was reported in the fleet of OBM boats operating bait cage handline fishing and on average constituted 54% of the total operational cost over the period 1992-1999 followed by bottom longline fleet (23%) and bottom trammel net (12%). The minimum (0.4%) was reported for the spear fishing fleet.

The total annual operational cost of the fishing fleet engaged in the different fisheries is shown in Fig. 6. 4.

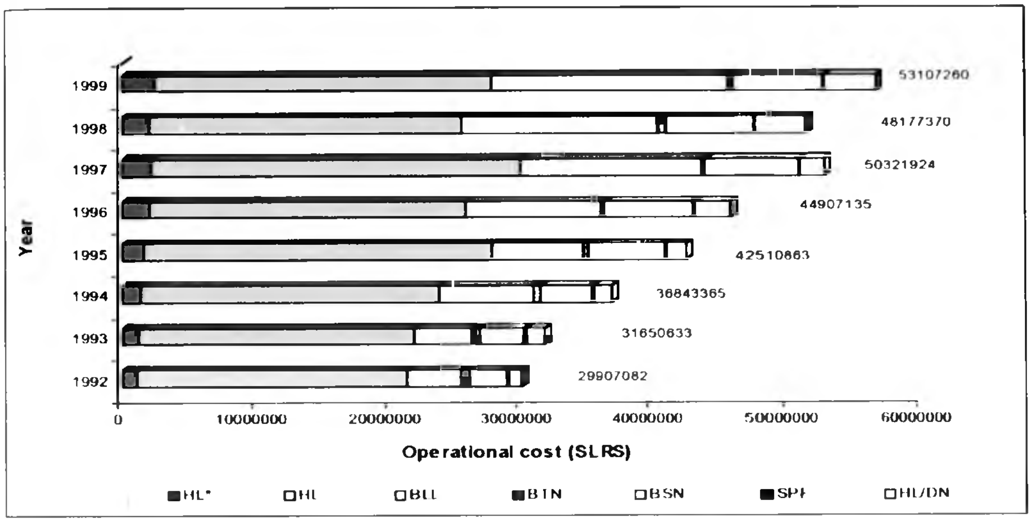


Fig. 6. 4. Total annual operational cost of the demersal fishing fleet for 1992 to 1999

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

6. 3. 3 Fish price

Fish prices varied depending on the total volume of the demersal fish catch, surplus supply of fish, type (species), size of the fish, quality or due to spatial and temporal variations. The volume of the catch, type, size of the fish and quality in turn depend on the type of gear used. The averaging of fish prices over the year would minimize the spatial and temporal variation of the fish prices and the effects due to surplus supply of other fish species. Variation of annual fish price during the study period was examined in relation to each fishery. The results are illustrated in Fig. 6. 5. Average unit price of all fisheries increased from 1992 to 1999. The intra-annual variation of fish price was higher in bottom trammel net, bait cage handline with OBM boat, handline fishing combined with drift gillnet and spear fishing and low in bottom set gillnets, bottom longline and

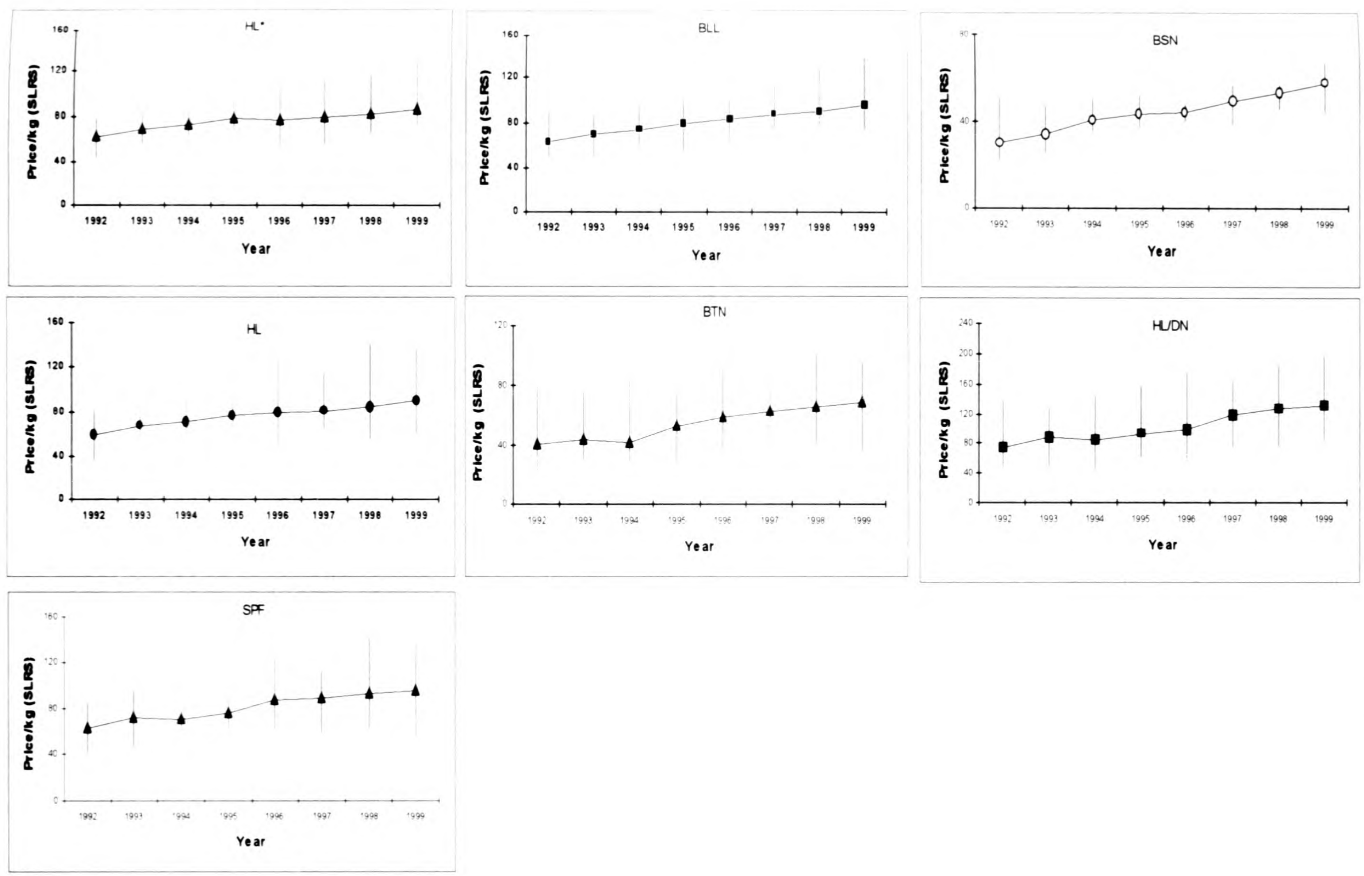


Fig. 6. 5. Annual average fish price of all varieties in different fisheries. Vertical bars show the price range.

bait cage handline with IBM boats. Bottom trammel net are successfully operated during the monsoon period. This is the lean season for most demersal fisheries in the area (Chapter 2, Fig. 2.4a-c) while drop handline combined with drift gillnets and spear fishing target on large valuable semi-demersal species, which are more seasonal in the shallow waters. The seasonal variation of the landings of these fisheries may influence the high intra-annual variation of the average fish price. Non grading of fish catch and also seasonal variation of species composition of the catch may influence the intra-annual price variation of bait cage handline fishing with OBM boats.

The average fish price of all varieties in different fisheries for the period 1992-1999 is shown in Fig. 6. 6.

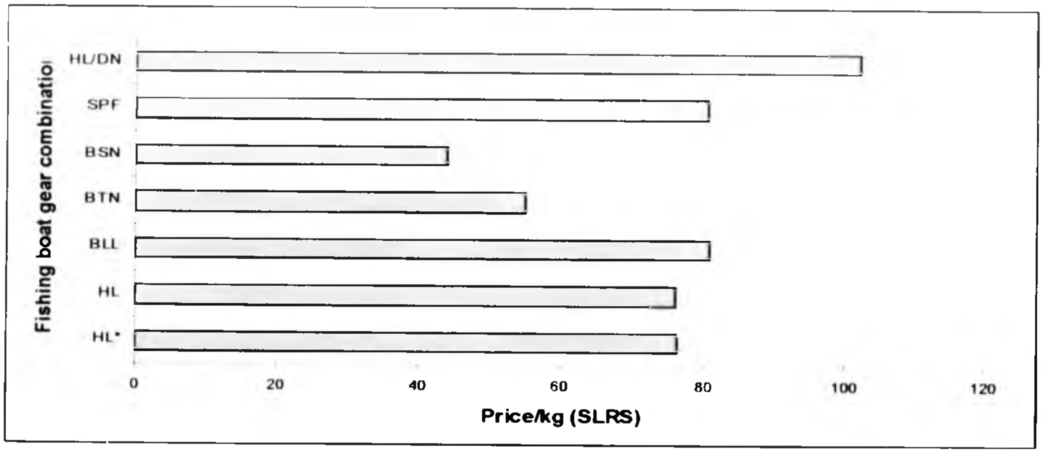


Fig. 6.6. Average fish price of all varieties in different fisheries from 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

The value shows that handline fishing in a combination boat enjoys the highest price per kilogram because the drop handline targets valuable large species such as seer fish (*Scomberomorus commerson*), sail fish (*Istiophorus platypterus*), large carangids (*Caranx ignobilis*, *Carangoides gymnostethus*) etc. Bottom longline and spear fishing received a high price due to catching large size fish such as Lethrinid, Serranids, Carangids, Sphyrinids and Scombrids, which fetch a high price at the markets. The lowest price was recorded for bottomset gillnet catchers followed by bottom trammel net (Fig. 6.6). The quality of bottomset gillnet catches were generally poor due to the long immersion period and the catch consisted mostly of skates which received a low price at markets (Chapter 7). The catch of bottom trammel net consisted of low value fish or juvenile forms of valuable species as they operate in the near shore area, therefore they also received low prices.

6. 3. 4 Revenue

Average annual revenue was the product of the total volume of the fish catch by different boat/gear combinations (Table 6.3) and the average fish price (Fig. 6.6). The estimates of annual total revenue of the demersal fishery by different boat/gear combination are given in Fig. 6.7.

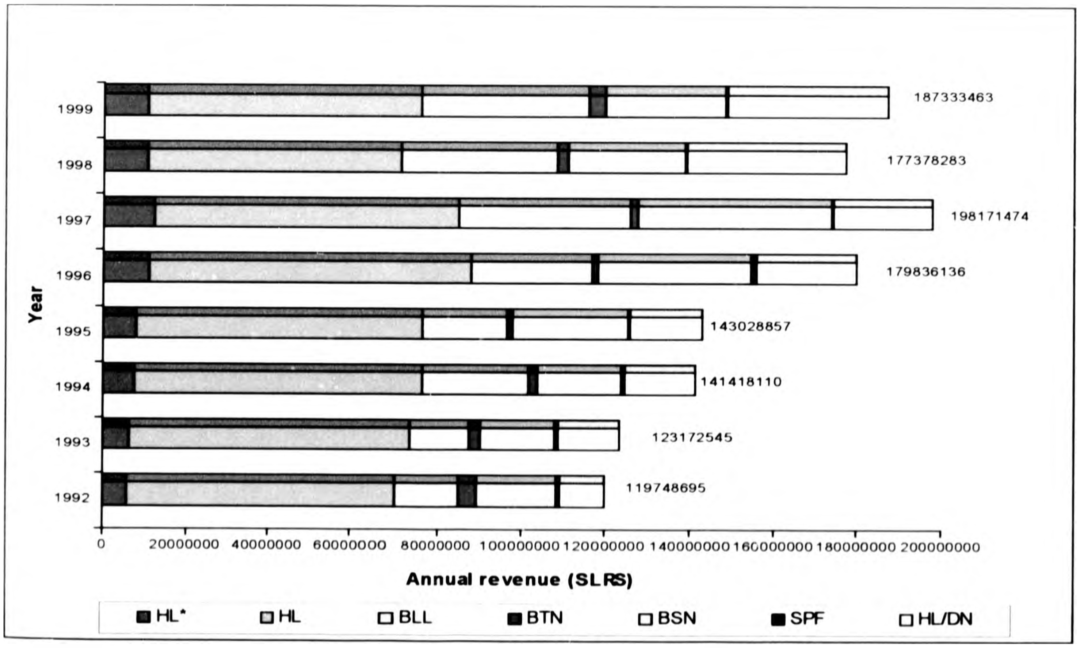


Fig. 6. 7. Total annual revenue of demersal fishing fleet from 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat.

Total annual revenue has also increased from 1992 to a maximal in 1997 and then declined in 1998 and slightly increased in 1999. The revenue of all fisheries except bottom set gillnets and spear fishing has shown an increasing trend from 1992. The maximum revenue for handline fishing with OBM boats was reported in 1996, while for bottom longline and bottom trammel nets in 1997. Handline combined with drift gillnets was maximal in 1999. Bait cage handline fishing with OBM boats contributed the highest average to the total revenue, accounting for 42.7% across all gears over the period 1992-1999. Bottom longline and bottom trammel net contributed equal proportions (17.5%), followed by handline combined with drift gillnet fishery (13.9%) and handline fishing with IBM boats (5.7%). The contribution of spear fishing and bottom set gillnets were very low over the years because the total catch landed by this fishery was low due to low fishing effort.

6. 3. 5 Operational Profit, Income and Income Distribution

Operational profit of a fishing day is the amount of income after deduction of scale commission (auction charges) and operational cost and this is divided among crew members according to the sharing system. The average annual operational profit per fishing day of different boat-gear combinations is shown in Fig. 6. 8. The worksheets showing the estimations are given in Appendix Tables 6.15 - 21.

The operational profit per fishing day of handline fishing with IBM, spear fishing, bottom trammel net and handline with OBM boats have progressed from 1992 with some fluctuations. But spear fishing and bottom trammel net have declined since 1997, handline with IBM boats since 1998 and handline fishing with OBM boats since 1996. Bottom longline has steadily declined with some recovery in 1994 and 1997, while bottom set gillnet fishing and handline combined with gillnet fishery has increased from 1998 and 1997, respectively (Fig. 6. 8). On average the highest operational profits were reported for handline fishing with IBM boats, bottom longline and spear fishing, while the lowest was reported in handline fishing combined with drift gillnets because most of the profits were covered by drift net operations.

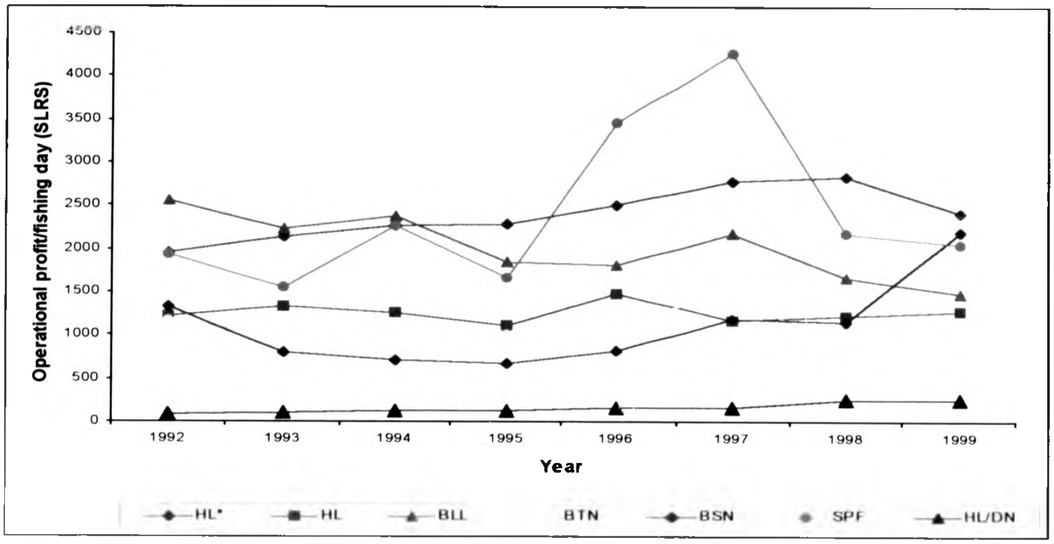


Fig. 6. 8. Average operational profit per fishing day of different boat/gear combination from 1992 to 1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

A crew member's net income was estimated considering both cash income (crew share) and non-cash income (fish share). The fish share received by handline drift net combination fishing was estimated in proportion to drift net to handline catch ratio given in Table 6. 2. The boat owner's net income was estimated by deducting repairs and maintenance cost from gross income (cash income fish sales + non-cash income from fish share) (Appendix Tables 6. 15-21). The average net income per fishing day for crew member and boat owner engaged in different fisheries over the period 1992 - 1999 is shown in Fig. 6. 9. The maximum average net income per fishing day for a crew member was reported from spear fishing followed by bottom longline, and handline with IBM boats. The lowest average value of Rs. 281.76 was reported for handline fishing conducted by OBM boats and bottom set gillnets and bottom trammel net also received a low income. The owner of the combination boats received an additional average income of Rs. 99.84 while crew members got Rs. 53.70, above the income from pelagic fish caught by the drift gillnet fishing. The boat owner's income is much higher than the crew member's except in handline fishery because no share is allocated to the gear. The owner received two portions of share, one is as a crew member and the other for boat.

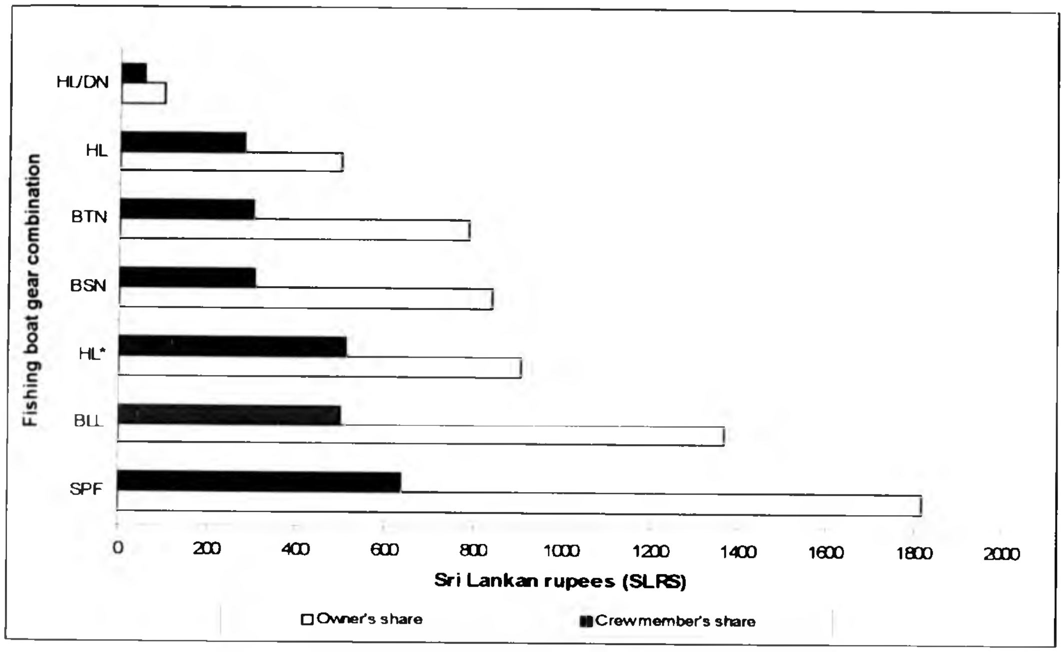


Fig 6. 9 Average net income of boat owner and crew-member for the period 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing wit OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat.

6. 3. 6 Variable Cost

The variable costs of demersal fishing in the Negombo area include operational cost, labour cost of fishing, repair and maintenance cost and commission of fish sales as auction/marketing charges. The annual average variable cost of a fishing day by boat/gear combination is illustrated in Fig. 6. 10. The worksheets depicting the estimation are given in Appendix Tables 6.15-21. The variable cost of handline fishing with OBM boats, handline combined with drift gillnets, bottom trammel nets and bottom set gill nets has maintained a steady level over the years but some increase has been observed in bottom set gillnet fishery from 1998 and a decline in bottom trammel net fishery from 1997. The variable cost of handline with IBM boats increased from 1992 and was highest in 1998 and then declined while in the bottom longline fishery variable cost has declined from 1992 to 1999.

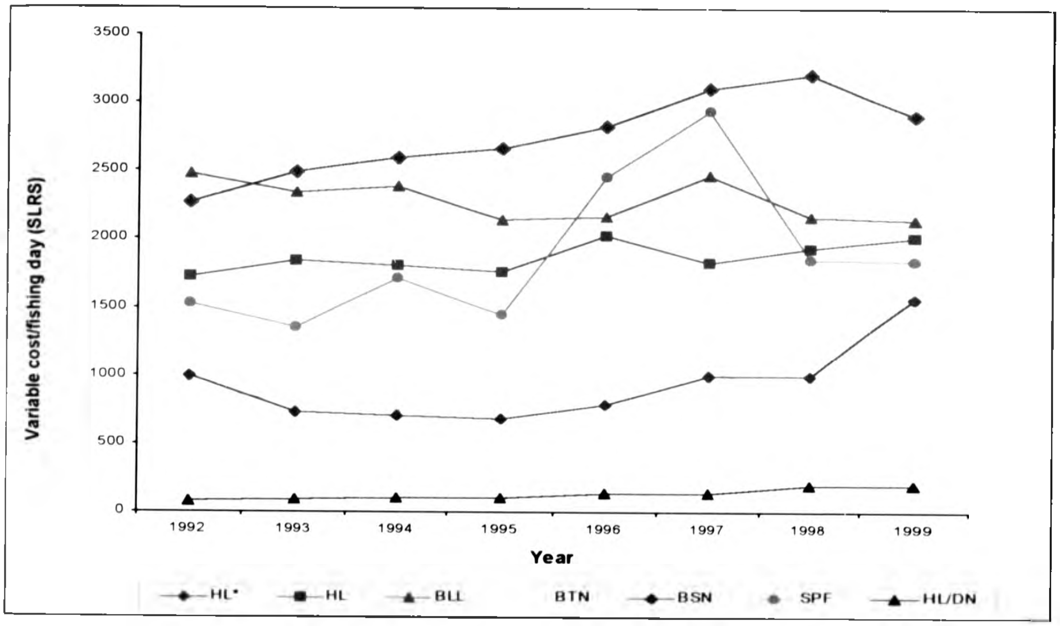


Fig. 6. 10. Total variable cost per fishing day by different boat/gear combination from 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN – Handline fishing combine with gillnet with OBM boat

On average, variable cost of handline with IBM and OBM boats, bottom longline and spear fishing was higher than the bottom trammel net and bottom set gillnet fishery. The notable feature is that the handline with IBM boats, bottom longline and spear fishing have a high operational profit as well as a high variable cost while bottom trammel net and bottom set gillnet have low operational profits as well as low variable costs but handline with OBM boats has low operational profit and high variable cost.

The average variable cost per fishing day by different boat/gear combination over the period 1992-1999 is shown in Fig. 6.11. The labour cost was the most important component of the variable cost of all fisheries and it varied between 81% to 50% across all gears. The maximum was reported for handline combined with drift gillnets and the minimum for bottom longline because in relation to the fish sale, cost of operation is low and thus crew share is high in handline fishing in combination boats. Operational cost was the second important component and it varied between 13% to 46%. The maximum was reported for bottom longline fishery and the minimum was for handline fishing combined with drift gillnets. The lowest component of the variable cost was the sales commission and it varied between 1.1% to 1.6%.

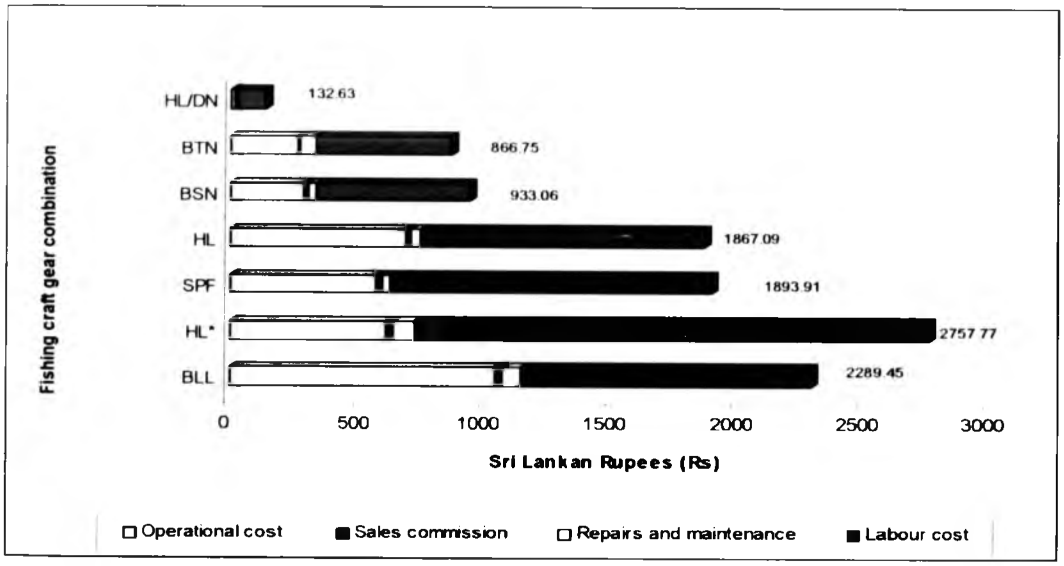


Fig. 6. 11 Average annual variable cost per fishing day by different craft gear combination

Note – Total variable cost is given in values

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

6. 3. 7 Total Variable Cost

The total annual variable costs of the fishing fleet operated for demersal fisheries in the Negombo area is given in Fig. 6. 12. Total annual variable cost followed a similar pattern as total operational cost, increased from 1992 and was maximal in 1997 then declined in 1998 and slightly increased in 1999.

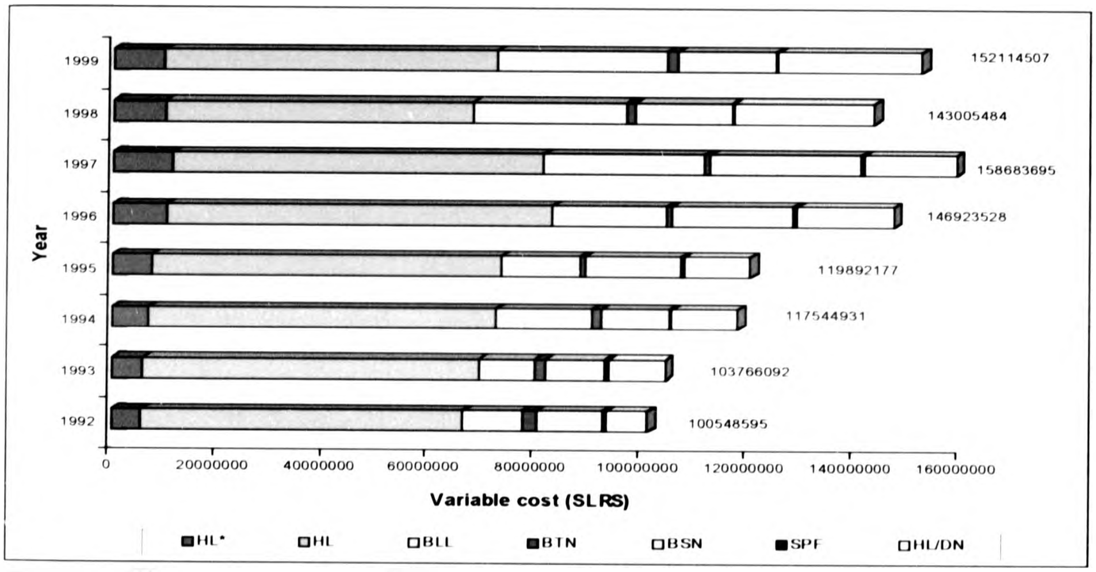


Fig. 6. 12. Total variable cost of the demersal fishing fleet in the Negombo area from 1992 to 1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL = bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat.

On average the fleet of bait cage handline with OBM boat contributed the highest amount (50%) to the total variable cost of the demersal fishing fleet followed by bottom longline (16%), bottom trammel net (14%) and handline combined with drift gillnet fleet (13%). The spear fishing fleet contributed the minimum amount (0.4%).

6. 3. 8 Total cost

The annual total costs of fishing is estimated by adding both variable and fixed cost and is given in Fig. 6. 13. Annual variation of total cost of fishing followed the similar pattern as total fixed cost and total variable cost, increased from 1992, was highest in 1997 then declined in 1998 and slightly increased in 1999.

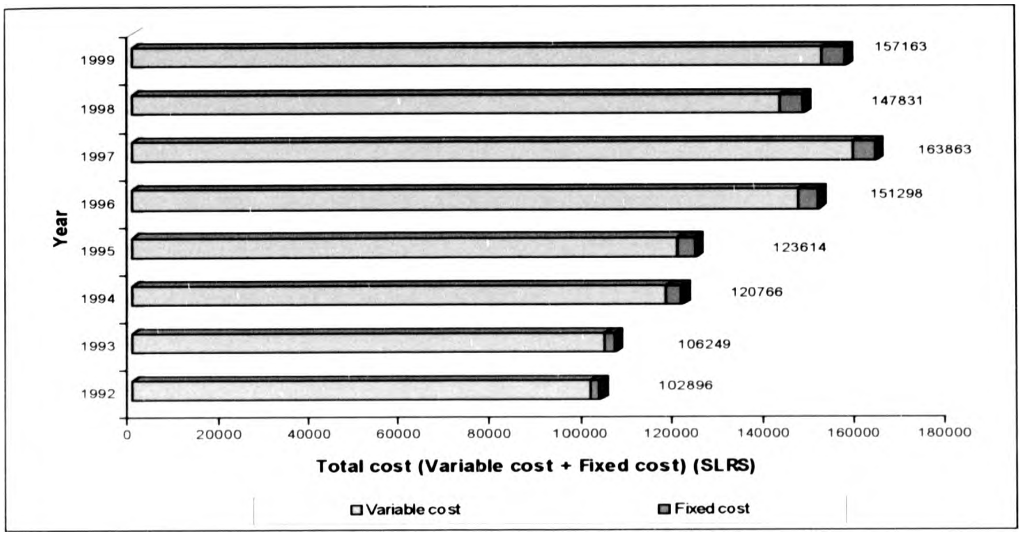


Fig. 6. 13. Annual average total cost of demersal fishing operation from 1992-1999.

The total cost to fixed cost varied between 2.3% and 3.3% while variable cost to fixed cost also varied between 2.3% and 3.3% over the period 1992 to 1999. This indicates that the variable cost is clearly the major component of the total cost.

6. 3. 9 Cost of Production

Table 6. 10. shows the different cost items associated with the production of one kilo of fish by different boat/gear combinations. The highest total cost of production per unit weight of demersal fish was reported from drop handline fishing in combination boats followed by bait cage handline fishing with IBM boats and OBM boats and bottom longline fishing. In the bottom longline and bait cage handline fishing with OBM boats, labour costs and bait costs were mainly responsible for the high cost of production, while in the bait cage handline fishing with IBM boats fuel costs and labour cost influenced the high operational cost. The lowest production cost was reported in bottom set gillnet

fishing with OBM boats. Bottom trammel net and spear fishing also maintained low variable costs (labour and fuel) thus resulting in a lower cost of production (Table 6. 10).

All boat/gear combinations have maintained the average sale price per kilo greater than the cost of production. The profit margin was high in relation to production cost for spear fishing (62%), bottom set gillnet (53%), bottom trammel net (44%), handline combined with drift gillnet (30%) and bottom longline fishing (27%), and low in handline fishing conducted with IBM boats (3%) and handline fishing conducted with OBM boats (5%).

Table 6. 10. Average production cost of fish over the period 1992-1999 (Rs/kg).

Craft gear combination	Operational cost (Rs/kg)	Variable cost (Rs/kg)	Fixed cost (Rs/kg)	Total cost (Rs/Kg)	Av. Price (Rs/kg)
Handline with IBM boat (HL*)	15.39	69.92	4.00	73.92	76.17
Handline with OBM boat (HL)	26.07	71.06	1.45	72.51	75.98
Bottom longline with OBM boat (BLL)	29.67	62.34	1.48	63.82	80.91
Bottom trammel net with OBM boat (BTN)	10.47	3.55	2.55	38.04	54.76
Bottomset gillnet with OBM boat (BSN)	8.10	27.00	1.81	28.81	43.97
Spear fishing with OBM boat (SPF)	14.69	48.58	1.08	49.66	80.47
Handline in combination fishing with OBM boat (HL/DN)	10.03	77.52	0.97	78.50	102.40

6. 3. 10 Profitability

All boat/gear combination engaged in demersal fishing in the Negombo area earned positive gross profit (operational profit) and net profit (financial). Maximum average net profit was reported by spear fishing followed by bottom longline. Relatively low net profit was reported by bait cage handline fishing with OBM and handline fishing in combination boats but in the combination boats the profit earned by driftnet fishing for pelagic fish could be higher than the handline component of demersal fishing (Fig. 6. 14).

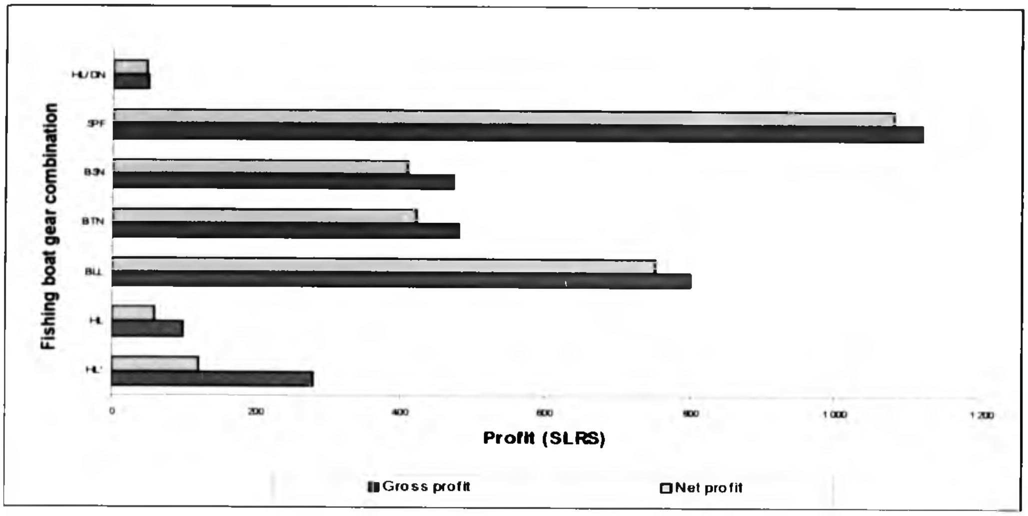


Fig 6 14 Average gross and net profit per fishing day of different boat/gear combination engaged in demersal fishing in the Negombo area for the period 1992-1999

The annual variation of average net profit per fishing day by different boat/gear combination is given in Fig 6. 15

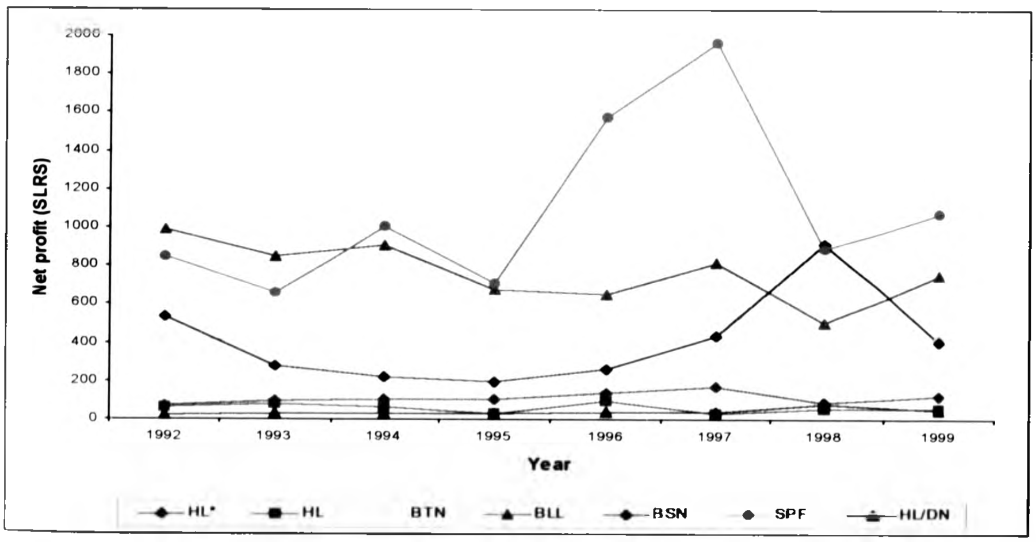


Fig 6 15 Annual variation of average net profit per fishing day of different boat/gear combination for 1992 to 1999

Net profit per fishing day of spear fishing, bottom trammel net, bait cage handline with IBM and OBM boats and drop handline fishing of combination boats increased from 1992 and was highest in 1998 for bait cage handline fishing with IBM boats, for handline fishing of combined boats, trammel net and spear fishing in 1997, for bait cage handline fishing with OBM boats in 1996. It then declined but a slight improvement has observed in spear fishing and bottom trammel net in 1999.

The other profitability indicators (financial profit to variable cost, financial profit to total revenue, rate of return to total financial cost and rate of return to investment) for multigear fishing operations is illustrated in Fig. 6. 16.

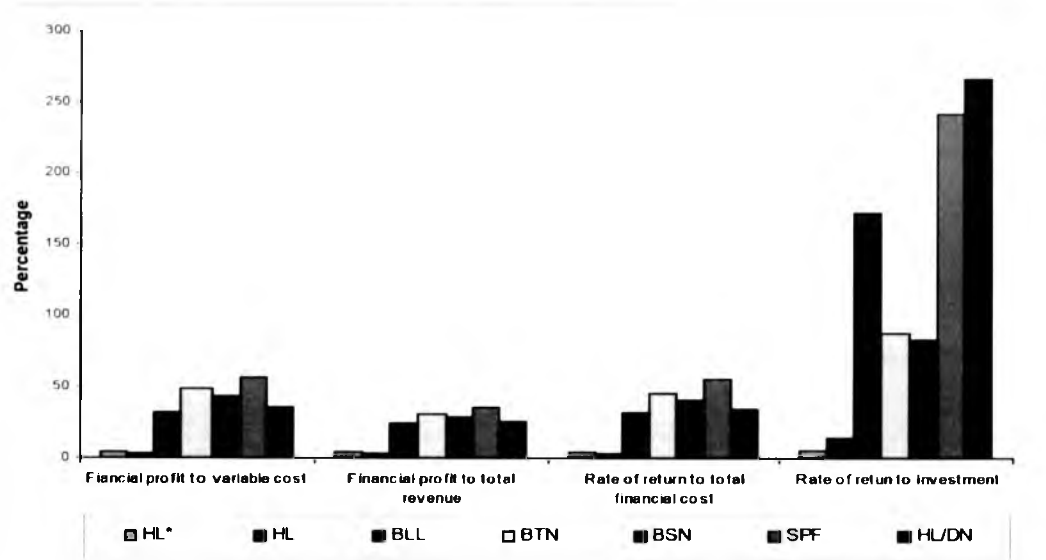


Fig. 6. 16. Profitability of demersal fishing with different boat/gear combination over the period 1992-1999

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat.

The ratio of average daily financial profit (net profit) to average daily variable cost indicated that the fishermen who operate spear fishing, bottom trammel net fishing, bottom set gillnet, handline fishing combined with drift gillnet and bottom longline fishing with OBM boats are relatively more capable of financing the next fishing trip than those operating bait cage handline fishing with OBM or IBM boats (Fig. 6. 16). The highest value was reported in spear fishing while the lowest was reported in bait cage handline fishing with OBM boats. The ratio of average daily financial profit to average daily revenue showed that the spear fishing obtained maximum financial profit from the revenue of fishing operation followed by bottom trammel net, bottom set gillnet, handline fishing in combined with drift gillnet and bottom longline fishing with OBM boats. Again the minimum financial profit was gained by bait cage handline fishing with OBM boats.

The rate of return on financial profit to total financial cost (capital investment) of operation indicates that spear fishing, bottom trammel net, bottom set gillnet, handline fishing combined with drift gillnet and bottom longline fishing with OBM boats had relatively higher profits than handline fishing with OBM or IBM boats. This ratio of net profit to total investment provides a measure of the return to total investment. Handline fishing combined with drift gillnet, spear fishing and bottom longline fishing with OBM boats show highest average rates of return to investment. The lowest was reported by handline fishing with OBM and IBM boats. All four profitable indices estimated (Fig. 6. 16) show that fishing with bait cage handline especially with OBM boats is not as rewarding as other gears. The most profitable gear was spear fishing which shows maximum ratios for all four indices tested.

The pay back period of financial cost per fishing day and to the total investment is given in Fig. 6. 17. The pay back period of financial cost of a fishing day with financial profit for the above mentioned highly profitable gears, spear fishing, bottom longline, bottom trammel net, drop handline fishing of combined boats and bottom set gillnets varied between 2 to 4 days. The minimum period of 2 days was reported for spear fishing. While the less profitable bait cage handline fishing with OBM or IBM boats required 25 and 34 days respectively. The pay back period of investment implies that handline fishing combined with drift gillnet, spear fishing and bottom longline fishing with OBM boat would be able to recover their investment within a year while handline fishing with IBM boats and handline fishing with OBM boats require about 21 and 8 years respectively.

The high investment cost of IBM boats made the pay back period of investment long and this period is more than the lifetime of IBM boat. IBM boats are principally prawn trawlers, but some IBM boats were engaged for 8-9 months in prawn trawling, and only shift to handline fishing during the lean season for prawn trawling because they get a better net income from handline fishing than prawn trawling at that time. As prawn trawling is much more profitable than operating for fish, because of the high price paid for prawns they could recover their investment cost during the period of prawn trawling.

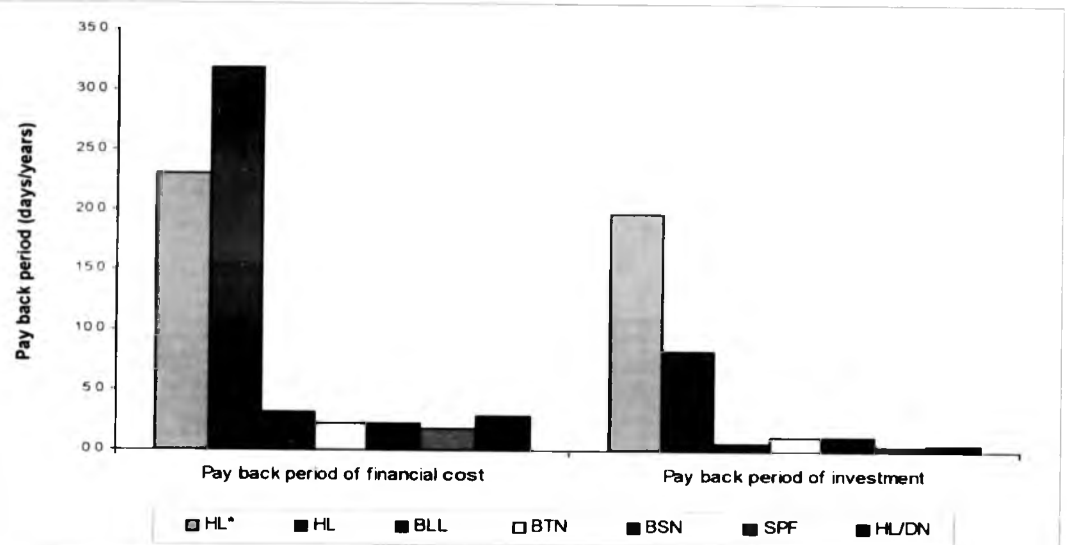


Fig. 6. 17. Average pay back period of financial cost and investment for different boat/gear combination engaged in demersal fisheries over the period 1992-1999.

6. 3. 11 Efficiency Parameters

The efficiency indicators measure the productivity of specific factors of production. The average labour and capital productivity of fishing by different boat/gear combination for the period from 1992 -1999 is given in Fig. 6. 18. Labour productivity indicates how much revenue can be extracted by a crew member in a fishing day. The higher the value of labour productivity the higher the amount that a crew member gets in a fishing day. The bottom longline and spear fishing with OBM boats are more labour productive than other gears (Fig. 6. 18). The lowest value was reported in drop handline fishing combined with drift gillnet and bait cage handline fishing with OBM boats but when considering both drift gillnet and handline in combined gear operation it could be more profitable than indicated only for the handline component.

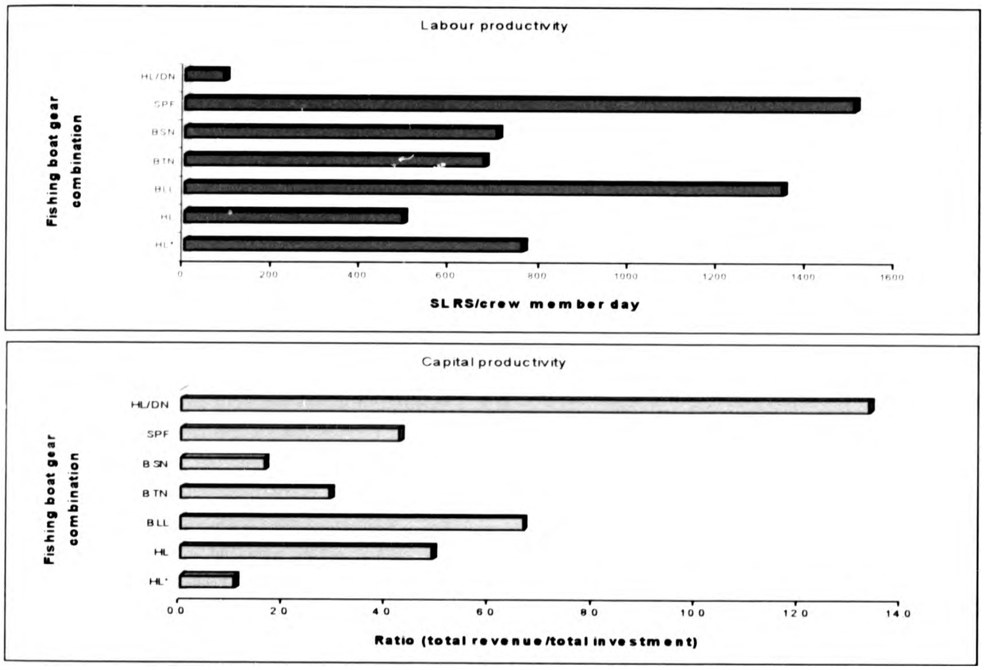


Fig. 6. 18. Labour productivity and capital productivity of different boat/gear combination engaged in demersal fishing in the Negombo area over the period 1992-1999.

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

Capital productivity is the total revenue to total investment made for different boat/gear combination. The highest capital productivity reported in drop handline fishing with drift gillnets followed by bottom longline, bait cage handline with OBM boat and spear fishing with OBM boat and lower values were reported in bait cage handline fishing with IBM boat because of the high investment cost (Fig. 6. 18).

The relationship between capital intensity and labour productivity is given in Fig 6.19.

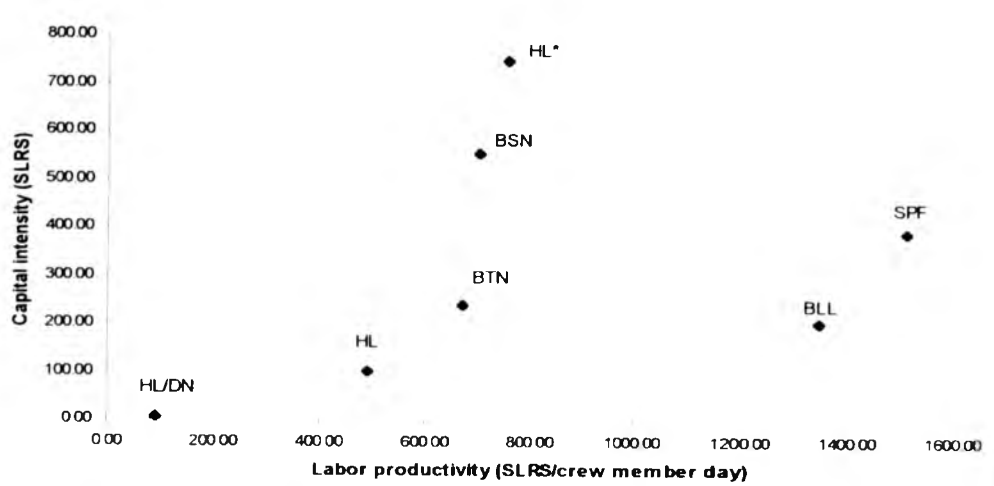


Fig 6. 19 Capital intensity of demersal gears as a function of labor productivity

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL = bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

On average, labour productivity and capital intensity increased with the scale of operation. Handline fishing with OBM boats are less capital intensive and moderately labour productive while bottom longline with OBM boats and spear fishing with OBM boats are more labour productive and moderately capital intensive. Bottom set gillnet fishing with OBM boats and handline fishing with IBM boats are more capital intensive than labour productive. Drop handline fishing combined with drift gillnets are less labour productive and less capital intensive. It seems that bottom trammel net fishing with OBM is moderately labour productive and capital intensive

6. 3. 12 Return to Capital and Labour

Return to boat owner's capital and labour per fishing day of different boat/gear combinations is shown in Fig. 6. 20.

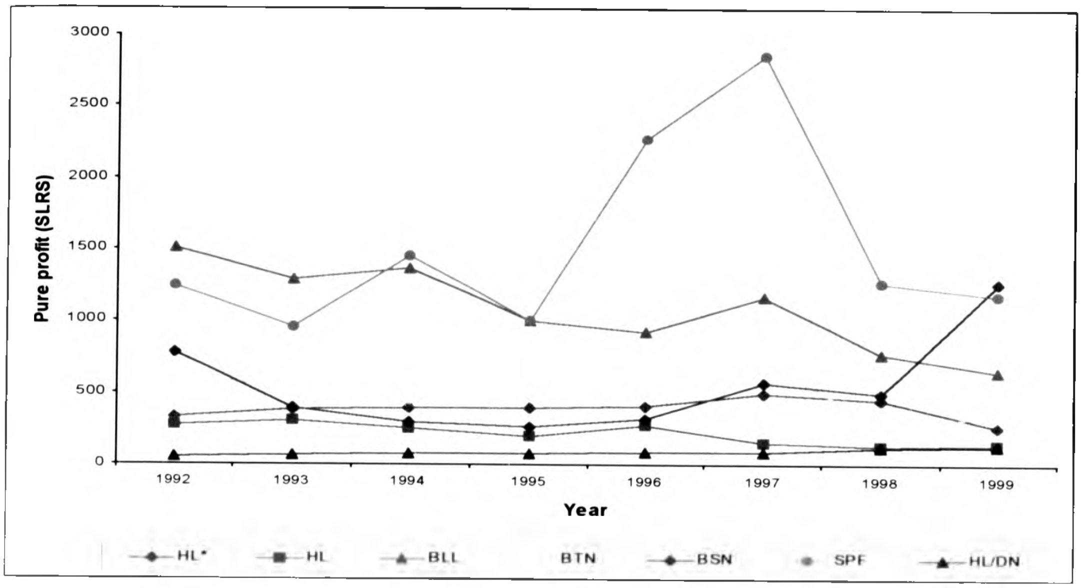


Fig. 6. 20. Return to boat owner's capital and labour per fishing operation by different boat/gear combination.

HL* = Handline fishing with IBM boat. HL = Handline fishing with OBM boat. BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat. BSN = Bottom set gillnet fishing with OBM boat. SPF = Spear fishing with OBM boat. HL/DN = Handline fishing combine with gillnet with OBM boat.

Returns of boat owner's capital and labour of all fisheries has declined from 1992 to 1999 except in the bottom set gillnet fishery, where improvement was seen in 1999, but that could have been an unusual year. High returns were observed only for spear fishing and bottom longline fishery. Boat owners of bottom trammel nets have maintained a relatively higher return than bait cage handline fishing with OBM or IBM boats or bottom set gillnets, but all declined from 1997 onwards. The bait cage handline fishing was the lowest next to handline operation of combined boats.

The returns to crew member's labour per fishing operation in different craft gear is shown in Fig. 6. 21.

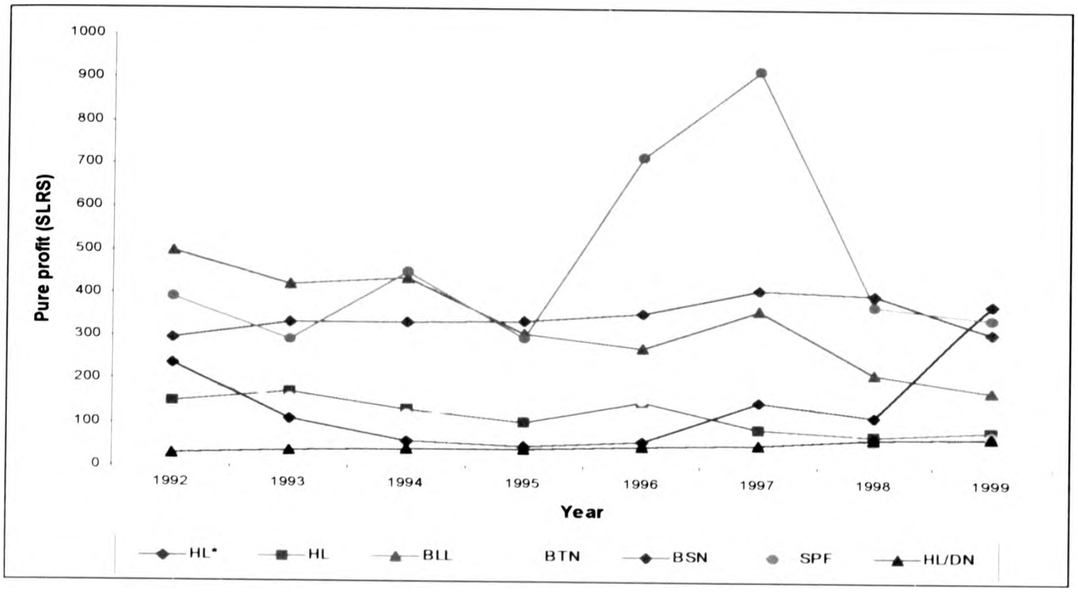


Fig 6 21 Return to crew member's labour per fishing operation by different boat/gear combination from 1992-1999

A crew member's average annual pure profit per fishing day follows a similar pattern as that boat owner's Profit of all fisheries shows a declining trends except for bottom trammel net and bottom set gillnets in 1999 Relatively higher profits were reported for crew members engaged in bottom longline, spear fishing and bait cage handline fishing with IBM boats compared to crew members engaged in bottom trammel net, bottom set gillnet or bait cage handline fishing with OBM boats.

Average pure profit of the crew members are lower than boat owners in all fisheries, but closer in bait cage handline fishery with IBM boats because the opportunity cost of fishing capital invested was higher than the OBM boats involved in other fisheries In the bait cage handline with OBM boats and handline fishing of combination boats, boat owner's pure profit was about two times higher that of the crew members In the bottom longline, spear fishing, and trammel net fishery it was about three times higher and in bottom set gillnets about four times higher than of the crew members.

6. 3. 14 Resource rent

The resource rent was estimated by summing up the boat owner's and the crew members' pure profits of all fishing days of each year. Total annual resources rent of demersal fishing in Negombo area is given in Fig. 6. 22.

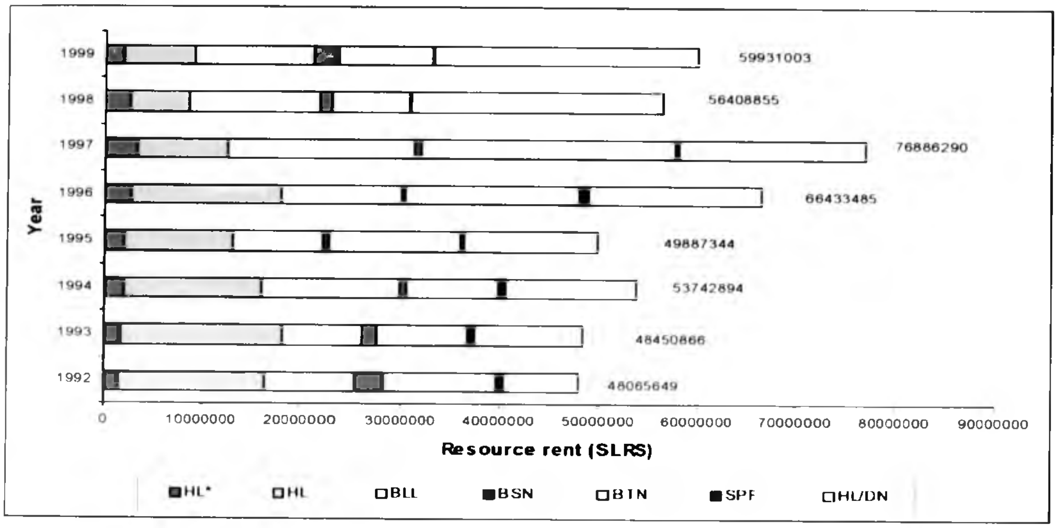


Fig. 6. 22. Annual resource rent of demersal fishing in the Negombo area from 1992 to 1999

HL* = Handline fishing with IBM boat. HL = Handline fishing with OBM boat. BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat. BSN = Bottom set gillnet fishing with OBM boat. SPF = Spear fishing with OBM boat. HL/DN = Handline fishing combine with gillnet with OBM boat.

The annual average resource rent of demersal fishing varied from Rs. 48 million in 1992 to Rs. 60 million in 1999. The highest resource rent (of approximately Rs. 77 million) was reported in 1997. On average, over the period 1992 to 1999 the highest contribution to the total resource rent was reported from drop handline combined with drift gillnets (29%), followed by bottom trammel net (22.5%), bottom longline (20.7%) and bait cage handline fishing with OBM boats (20.6%), while the lowest was reported from spear fishing (0.9%).

6. 3. 15 Economic Model

6. 3. 15. 1 Thompson and Bell Bio-Economic Model

The projected economics of exploitation of economically important indicator species, *L. nebulosus* and *L. lentjan* using the Thompson and Bell model when fishing effort of all gears changes are shown in Figs. 6. 23 and 6.24, respectively. The maximum economic yield (MEY) or maximum value of the catch by all fisheries were estimated at Rs. million 26.64 and Rs. million 18.44 for *L. nebulosus* and *L. lentjan* and the estimated optimum effort which produce MEY is 0.5 or 50% and 0.8 or 80% of the effort level in 1999 respectively. The current fishing effort is indicated as X factor = 1. This indicates that *L. lentjan* has long exceeded the MEY compared to *L. nebulosus* and to obtain MEY the fishing effort in 1999 should be reduced by 20% and 50% for *L. nebulosus* and *L. Lentjan*, respectively. Such reduction however would result in only a small increase of the catch value of *L. nebulosus* (about 1%) but a considerable improvement (about 14%) for *L. lentjan* (Fig. 6. 24).

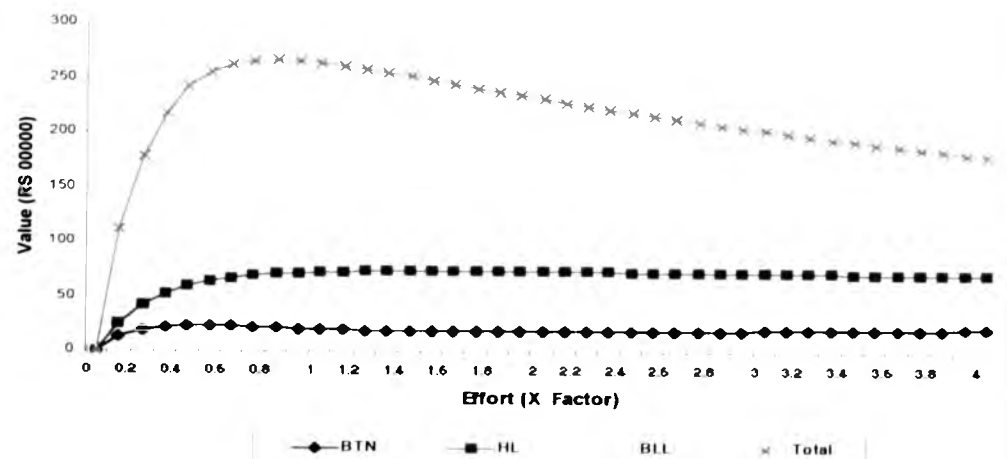


Fig. 6. 23. Projected annual catch value of *L. nebulosus* when the fishing effort changes. Present effort = 1.

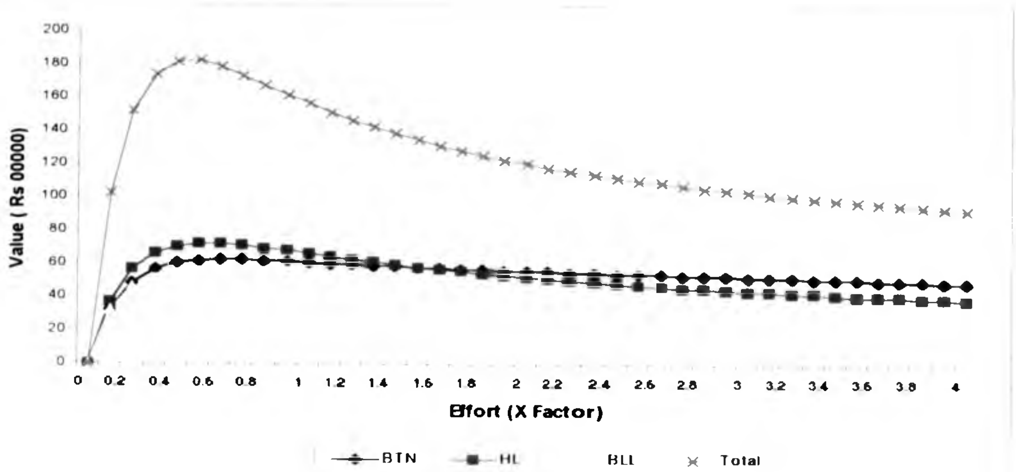


Fig 6 24 Projected annual catch value of *L. lentjan* when the fishing effort of all gears changes Present effort = 1

The MEY of *L. nebulosus* exploited through bottom longline and bottom trammel nets were estimated as Rs million 17.42 and 2.35, respectively and it would achieve this at the effort level of 0.7 (70%) and 0.5 (50%) times of the 1999 effort level. This shows that both fisheries have exceeded the MEY and therefore effort should be reduced by 30% and 50% to attain the MEY in bottom longline and bottom trammel net fisheries respectively. At present the value of the *L. nebulosus* realized through handline is below the MEY and can be increased by about 60%. However, such an increase would improve the value only by 1.8% (Rs. million 7.24 to Rs. million 7.37) (Fig. 6. 23).

The MEY of *L. lentjan* for botton longline, bottom trammel net and handline were estimated at Rs. million 5.12, 6.27 and 7.24, respectively. The 1999 effort of all three gears, bottom longline, bottom trammel net and handline has exceeded the optimum effort by 70%, 40% and 50%, respectively (Fig. 6. 24). A summary of the results is given in Table 6. 11.

Table 6. 11. Results of the Thompson and Bell bio-economic model analysis.

Species	Fishery	Annual effort (fishing days)	MSY (t)	MEY in Rs. Million	X factor corresponding to MSY	X factor corresponding to MEY	Yield (t) obtained with the X factor corresponding to MEY
L. nebulosus	HL	169425	≥90.67	7.37	≥4	1.6	80.15
	BLL	14875	152.66	17.42	0.9	0.7	150.66
	BTN	22525	≥29.71	2.35	≥4	0.5	20.58
	All	206825	246.63	26.63	1.2	0.8	241.79
L. lentjan	HL	169425	108.65	7.24	0.7	0.5	105.84
	BLL	14875	64.74	5.12	0.4	0.3	64.29
	BTN	22525	102.16	6.27	1.6	0.6	96.12
	All	206825	262.27	18.24	0.6	0.5	261.07

HL = handline fishing, BLL = bottom long line fishing, BTN = bottom trammel net fishing

6. 3. 15. 2. Projections of Economic Performance Under Different Fishing Strategies

Three hypothetical scenarios of different fishing strategies for each species were tested using the Thompson and Bell bio-economic model. In each scenario the effort of one fishing gear was increased while the effort of the other gears were maintained at the contemporary level.

In the case of *L. nebulosus*:

1) Changing the effort of the bottom trammel net fishery

The increase of fishing effort of bottom trammel net could increase its catch value from a present value of Rs. million 2.02 to Rs. million 5.78 if, in the extreme case, the present effort were increased by four times (Fig. 6. 25). However, the associated decline in the estimated value of the catch of other gears at the extreme case is predicted to be substantial, especially in bottom longline fishing. The estimated decline in the value of the catch of handline would be Rs. million 7.24 to Rs. million 5.58 while bottom longline would decline from Rs. million 17.08 to Rs. million 12.61. The total value of the catch would decline from Rs. million 26.35 to Rs. million 23.97.

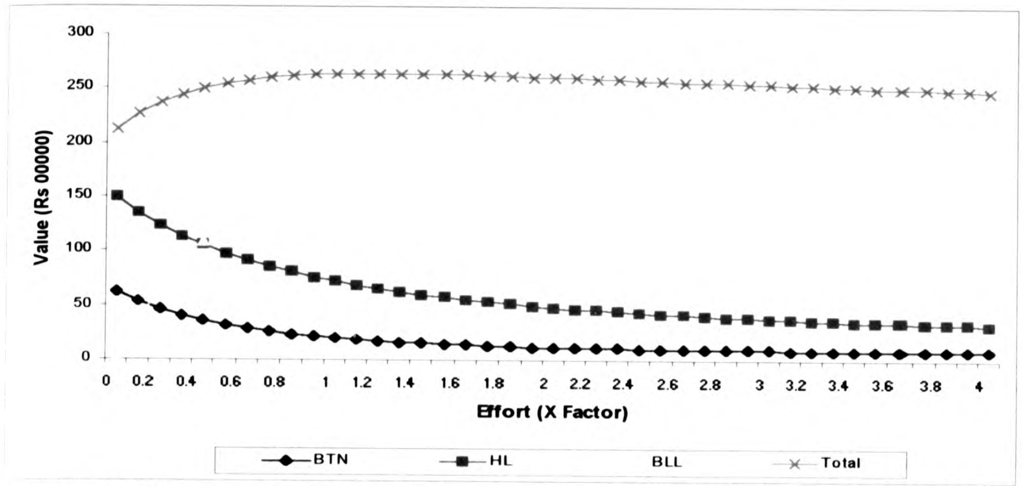


Fig. 6. 25. Change of the annual value of the catch when the fishing effort of bottom trammel net (BTN) is changed. Present effort = 1.

2) Changing the effort of the bottom longline (BLL) fishery.

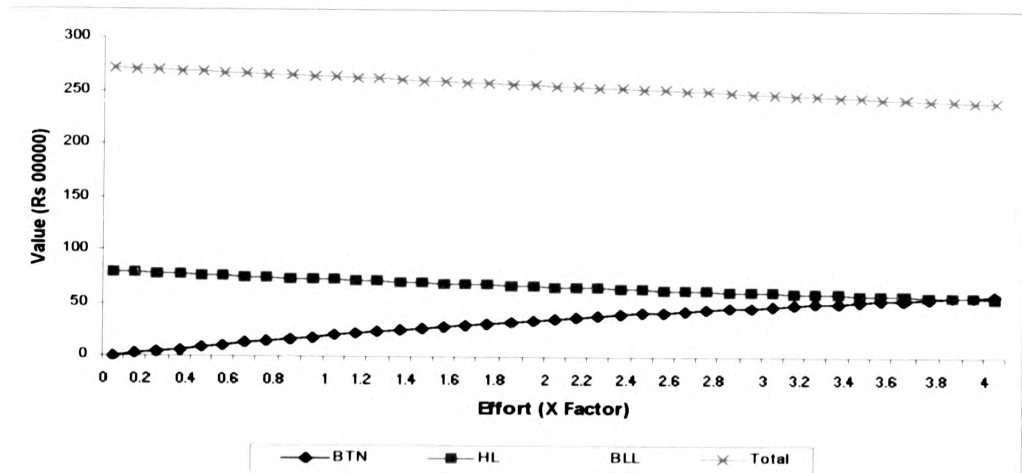


Fig. 6. 26. Change of the annual value of the catch when the fishing effort of bottom longline (BLL) is changed. Present effort = 1.

The increase of fishing effort of bottom longline would improves the value of its catch from Rs. million 17.08 to Rs. million 20.71 at the extreme case of increasing the present effort by four times (Fig 6 26) However, the associated decline of the value of the catch in the bottom trammel net and handline fishery at the extreme effort level is highly substantial The catch of bottom trammel net would decline from Rs million 2 02 to Rs million 0 85, while the catch value of the handline fishery would decline from Rs million 7 24 to Rs million 3 24 The total value of the catch will decline from Rs million 26 35 to Rs million 24 80

3) Changing the effort of the handline (HL) fishery

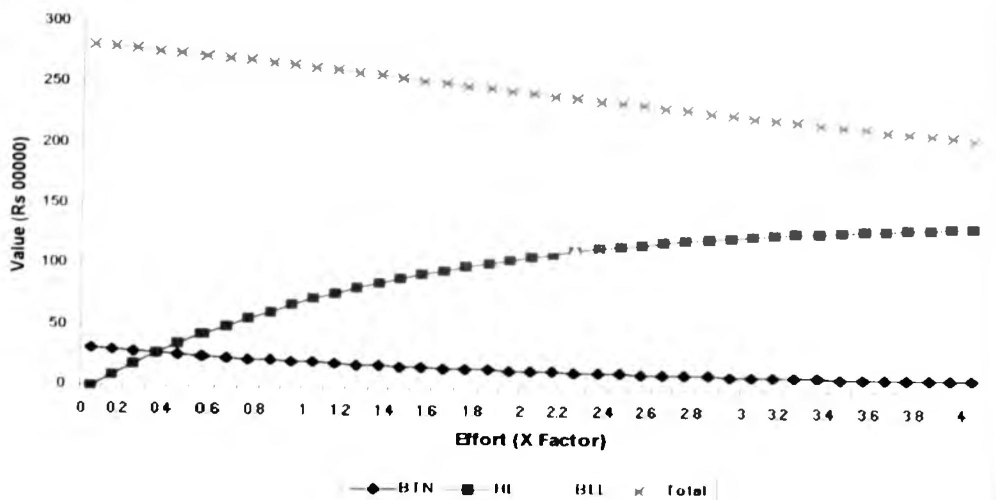


Fig 6 27 Change of the annual value of the catch when the fishing effort of handline (HL) is changed Present effort = 1

The value of the catch of the handline fishery increased with increasing its effort (Fig 6 27) from Rs million 7 24 to Rs million 13 42 at the extreme level of effort, *ie* at four times effort in 1999 The increase effort of the handline fishery drops the value of the catch of other gears The associated decline in the catch value of bottom longline would be from Rs million 17 08 to Rs million 6 51 million While in the bottom trammel net would decline from Rs million 2 02 to Rs million 0 85 Then the total catch drops from Rs million 26 35 to Rs million 20 78

In the case of *L. lentjan*:

1) Changing the effort of the bottom trammel net (BTN) fishery.

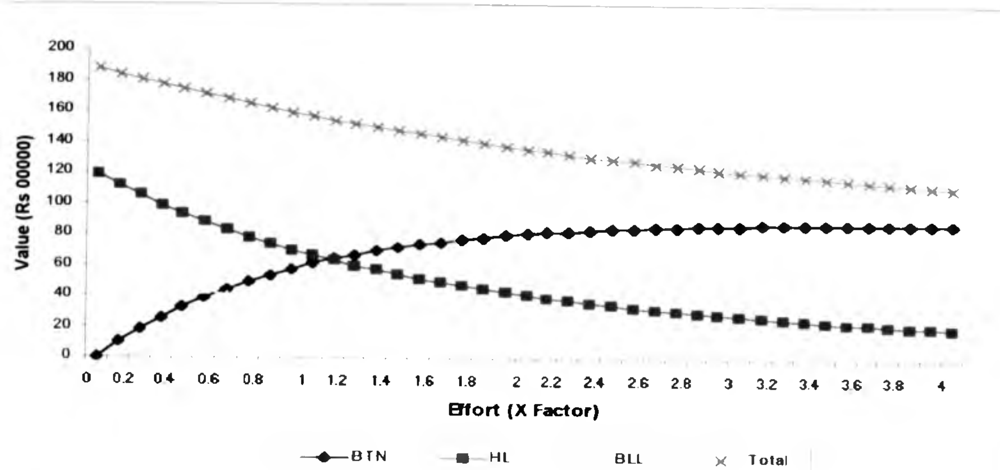


Fig. 6. 28. Change of the annual value of the catch when the fishing effort of bottom trammel net (BTN) is changed. Present effort = 1.

The increase of the fishing effort of bottom trammel net would increase the value of the *L. lentjan* catch from Rs. million 6.10 to Rs. million 8.74, at the extreme case of increasing the present effort by four times (Fig. 6. 28). However, the associated decline in the estimated value of the catch of other gears at this extreme level is substantial. The estimated decline in the value of the catch of handline would be Rs. million 6.65 to Rs. million 1.96, while bottom longline would decline from Rs. million 2.92 to Rs. million 0.41. The total value of the catch would decline from Rs. million 15.67 to Rs. million 11.11.

2) Changing the effort of the bottom longline (BLL) fishery.

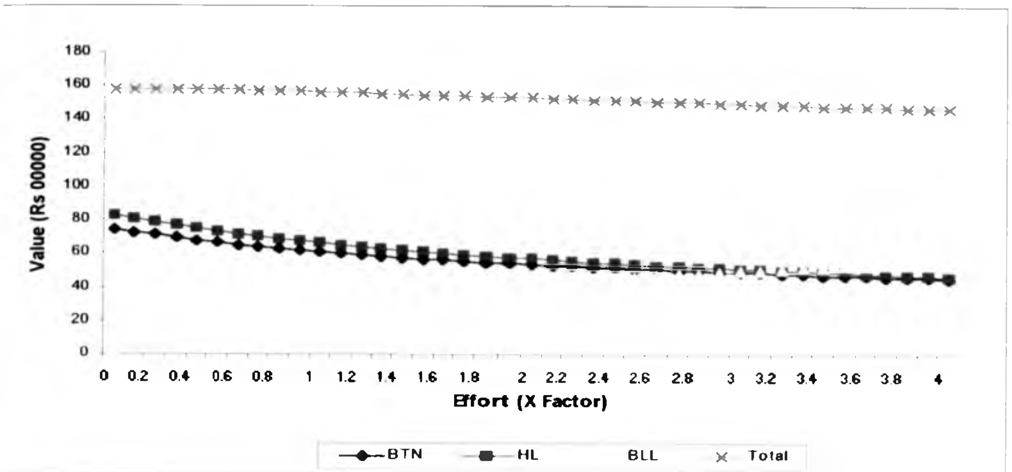


Fig. 6. 29. Change of the annual value of the catch when the fishing effort of bottom longline (BLL) is changed. Present effort = 1.

The increase of fishing effort of bottom longline would improve the value of its catch from Rs. million 2.92 to Rs. million 5.45, at the extreme case of increasing the present effort by four times (Fig. 6. 29). However, the associated decline of the value of the catch in the bottom trammel net and handline fishery at the extreme fishing effort level is substantial. The catch of bottom trammel net would decline from Rs. million 6.10 to Rs. million 4.55, while the catch value of handline would decline from Rs. million 6.65 to Rs. million 4.65. The total value of the catch would fall from Rs. million 15.67 to Rs. million 14.66.

3) Changing the effort of the handline (HL) fishery.

The value of the catch of handline increases with increasing effort (Fig. 6. 30) from Rs. million 6.65 to Rs. million 8.48 at the extreme level of 4 times of the present effort. The increase in effort of handline reduces the value of the catch of the other gears. The associated decline in the catch value of bottom longline would be from Rs. million 2.92 to Rs. million 0.41, while the bottom trammel net would decline from Rs. million 6.10 to Rs. million 2.37. Then the total catch drops from Rs. million 15.67 to Rs. million 11.27.

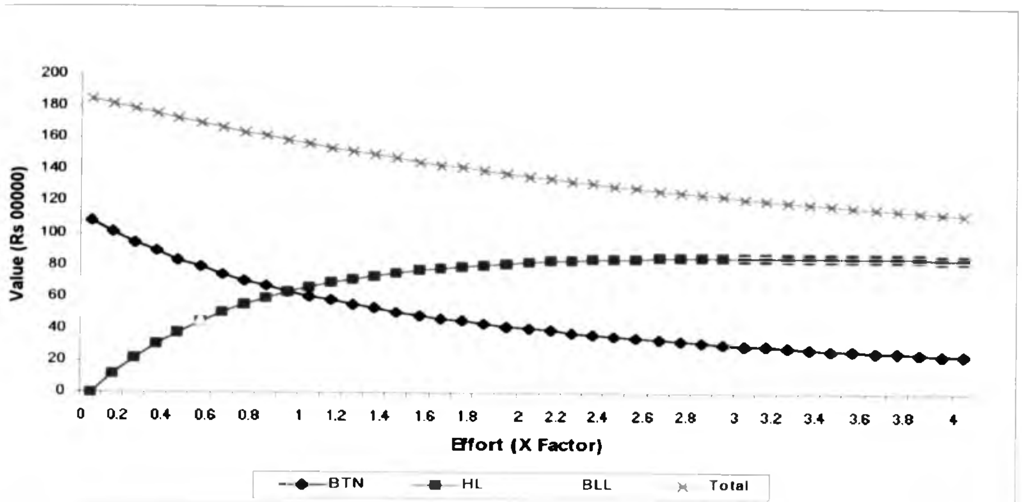


Fig. 6. 30. Change of the annual value of the catch when the fishing effort of handline (HL) is changed. Present effort = 1.

The likely consequences on the future value of the total catch of *L. nebulosus* and *L. lentjan* under different development options (magnitude of fishing effort) obtained through the Thompsom and Bell bio-economic model are summarized in Table 6. 12.

Table 6. 12. Summary of performance total values projected under different development options.

Development option	Total Value (Rs.00,000)			
	0.5 (X Factor)	1.0 (X Factor)	2.0 (X Factor)	4.0 (X Factor)
L. nebulosus				
BLL vary	25.51	26.35	26.07	24.08
BTN vary	26.73	26.35	25.56	23.97
HL vary	27.31	26.35	24.37	20.78
BLL, BTN, HL vary	25.51	26.35	23.13	17.91
L. lentjan				
BLL vary	15.81	15.67	15.31	11.27
BTN vary	17.08	15.67	13.55	11.11
HL vary	17.00	15.67	13.66	11.27
BLL, BTN, HL vary	18.24	15.67	12.05	9.32

0.5 (X Factor) = 50% of the effort level in 1999
1.0 (X Factor) = effort level in 1999
2.0 (X Factor) = tow times of the effort level in 1999
4.0 (X Factor) = four times of the effort level in 1999

Increase of the value of the total catch of neither *L. nebulosus* nor *L. lentjan* could be achieved by an increase in effort of any fishing gear. The value of *L. nebulosus* catch could be slightly improved by reducing the present effort of handline or bottom trammel net by half (50%). While the higher value for *L. lentjan* could be achieved by reducing the effort of all gears by 50% or reducing effort of bottom trammel net or handline by 50%.

6. 3. 15. 3. Economic Model of Multi-Species Fishery

Gordon's bio-economic model for open access fishery was applied to the multispecies multigear demersal fishery in the Negombo area with the time series data (1992 to 1999) addressing the total annual revenue, annual total cost and the total annual standard fishing effort. The price adjusted actual data on total annual revenue and annual total cost inputted to the model are given in Table 6. 9 (under materials and methods). The total annual revenue and total annual standard fishing effort and the annual total cost and total annual standard fishing effort were modelled to estimate maximum net revenue of fishing (maximum economic yield MEY), the maximum level of effort (f_{MEY}) where the net revenue maximized (MEY). The bio-economic equilibrium (E') is the point where the total revenue equals total cost. The estimated total revenue and total cost data at a given effort level used for the construction of multispecies, multigear economic model are given in Table 6. 13.

Table 6. 13. Predicted cost, revenue and profit at different effort levels in the Gordon-Schaefer multispecies economic model

Estimated effort Standard fishing days	Predicted values		
	Revenue (Rs)	Total cost (Rs)	Net profit curve (Rs) (Revenue-Total cost)
0	0	0	0
15000	46125	23306	22819
30000	85500	46612	38888
45000	118125	69918	48207
60000	144000	93224	50776
75000	163125	116530	46595
90000	175500	139836	35664
105000	181125	163142	17983
120000	180000	186448	-6448
135000	172125	209754	
150000	157500	233060	
165000	136125	256365	
180000	108000	279671	
195000	73125	302977	
210000	31500	326283	

Relation ship of revenue $TR = af + bf^2 \times$ fixed price a= 43.237751, b = -0.000209 Schaefer model (Chapter 5).

Relationship of cost TC = total effort × average cost of unit effort.

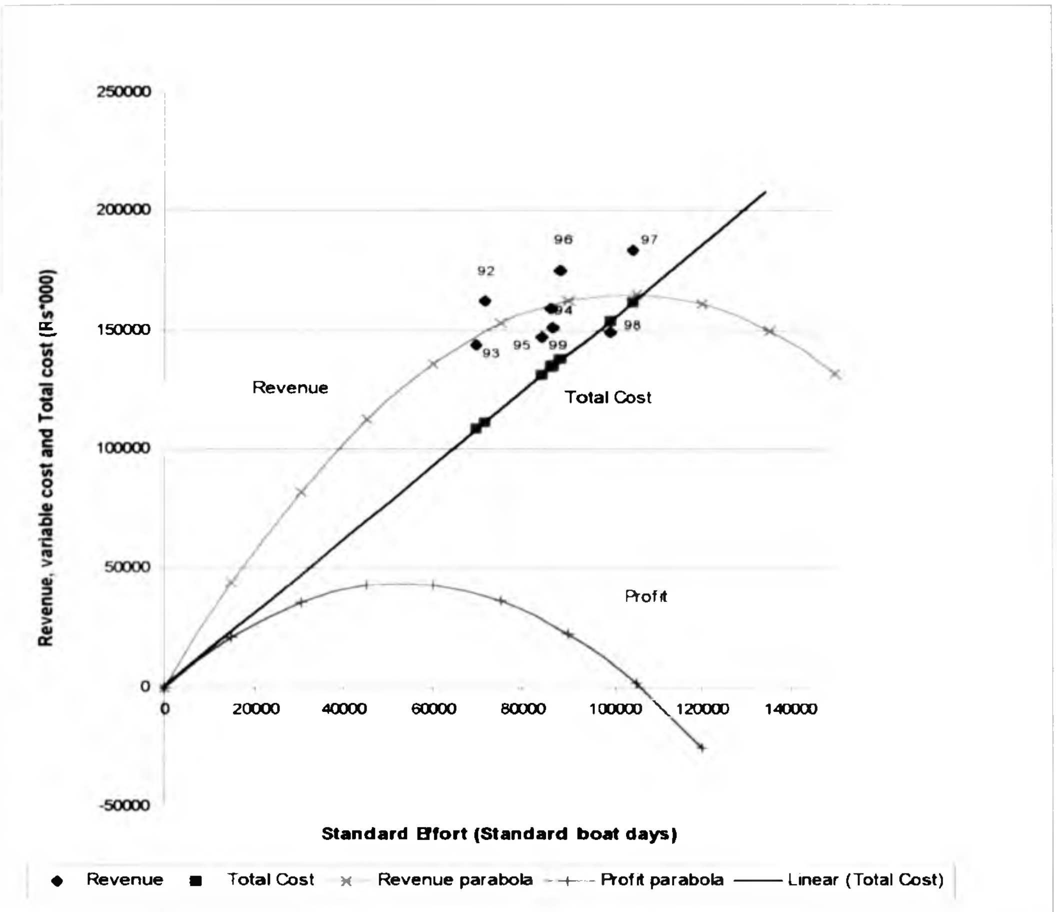


Fig. 6. 31. The static Gordon – Schaefer economic model for multispecies demersal fishery from 1992-1999.

The revenue (value of the landed catch) of fishing increases with increasing effort according to the relationship given in the equation, TR = $af + bf^2 \times$ fixed price. The total revenue is maximized at the level corresponds to the MSY. Thereafter revenue increases but at a decreasing rate. The total cost of fishing steadily increases as the effort increases. In an open access fishery, fishing effort (total cost of fishing) increases until it equals the total revenue. This level of effort represents the bio-economic equilibrium (E'), which is about 106,297 standard fishing days (Table 6. 13). Generally, in the long run, fishing effort can not go beyond this level because the cost would exceed their revenue. The net revenue or profit of fishing gives the revenue (landed value) less total cost. All fisheries combined produced a catch worth approximately Rs. 158.9 million per annum and an average resource rent of Rs. 57.5 million over the period 1992-1999. The point of revenue which maximizes the profit is called the maximum economic yield (MEY) (Rs million 123), where the vertical distance between cost line and the revenue curve is maximized (Fig. 6. 32). The present fishing effort for demersal resources exploitation is about 86,915 standard fishing days. But the maximum economic yield comes at 53,149 standard fishing days. This shows that the present effort level has exceeded the maximum effort level by about 40%. The results of the Gordon –Schaefer model are summarized in Table 6. 14.

Table 6. 14. Outcome of the Gorden – Schaefer multispecies economic model

MEY (Rs million)	Stan Effort correspond to MEY	Present revenue (Rs million)	Present stan. Effort level	Revenue correspond to MSY (Rs million)	Sta Effort correspond to open-access equilibrium
123	53,149	160	86915	165	106,297

The costs involved in demersal fishery in the Negombo area is relatively high. It is clear that the total cost curve meets the total revenue curve close to the maximum revenue (Fig. 6. 31). In such a situation the level of biomass over exploitation at the bio-economic equilibrium point is relatively low and the sustainable yield is high. Thus the economics of fishing itself controls overfishing below MSY. In this situation the rationalization of fishing effort to achieve maximum economic yield would reduce the yield corresponding to 86915 effort level (2100 t) to the yield corresponding to 53149 effort level (1600 t).

6. 4. DISCUSSION

Demersal fisheries provides a livelihood to a large segment of the fishing population in the Negombo area, since the fishery is undertaken with labour intensive gears. Some of the fishermen are exclusively engaged in demersal fishing, while others are seasonal or are engaged in combination with other gears to maximize their profit. Fishing boats operate for the maximum number of working days (6 days) per week. The outboard motor (OBM) boats mainly used in small scale fisheries in the area are readily adaptable for any kind of fishing method, which has allowed them to change fishing traditions seasonally to obtain a better income. The relatively low capital cost of fishing gear is an added advantage to small scale fishermen to allowing them to shift their technology seasonally in order to target different resources. Except for the boat, engine and gear, no other equipment is used in demersal fisheries.

The average operational cost of a fishing day varied from Rs. 17.12 to Rs. 1041.85 over the period 1992 to 1999. The lowest operational cost was reported from handline fishing combined with drift gillnet because the major part of the operation cost was borne by the drift gillnet operation. When considering a single gear operation, lowest average operational cost was reported from bottom trammel net with OBM boat and bottom set gillnet and the highest average cost for bottom longline fishing with OBM boat. In other coastal fisheries, such as large mesh gillnet and ring nets targeting on large pelagic resources, the daily operational cost varied between Rs. 656.8 and Rs. 1007 in 1999 (Vidanage and Wimalasena, 2000). The largest component of running cost was fuel, which accounted for an average of 58.6 % of costs across all gears. The IBM boats run on diesel and OBM boats need kerosene and petrol. In Sri Lanka both kerosene and diesel are subsidized for all the public. Other than fuel, bait is an important constituent of the running expenses of handline with OBM boats and bottom longline fishing, where compressed air tanks and diving equipment being important in spear fishing.

Labour costs were the most important input of variable costs, accounting for an average of 57% across all gears. The maximum percentage of labour cost was reported from handline fishing combined with drift net followed by handline fishing with IBM boats and handline fishing with OBM boats. The low operational cost in relation to revenue from fish sales resulted in a higher crew cost in the handline operation combined with drift nets, while in the handline fishing with OBM boats or IBM boats, high crew costs were due to a higher labour intensity, because the average crew size was four members.

The fish sale price from all gears has been maintained at a higher level than the production cost in all years (Table 6. 10). This is mainly because of the high quality of fish due to the short time spent on fishing and strong local demand (Chapter 7). The low cost of operation and high revenue makes demersal fishing a profitable venture. All types of fishing gears operating in demersal fishing gained positive net profit (financial profit) indicating their viability but it varied among gear types. The maximum resource rent was reported for spear fishing and the minimum was for handline fishing with OBM boats. The existence of pure profit (resource rent) or 'quasi rent' is critically dependent on the opportunity cost. The biggest economic gain is generated when the opportunity cost of labour is set at a value above the poverty level or when it is moved towards zero, but the risk of fishing can not be devalued by setting a low opportunity cost.

Resource rent may not however be obtained where the fishery is open access in nature. In an open access fishery, positive resource rent is a temporary feature, as it attracts new entrants into the fishery until the rent is dissipated. How do these fisheries maintain positive resource rent over the period without diminishing it? The operation of spear fishing is an illegal activity under the Flora and Fauna Act of Sri Lanka (1993) (Anon, 1993), thus the number of units operated has not increased. The few units operating in the area maintained 'quasi rent' without erosion. Bottom longline generally operates more in deeper waters than other gears and maintains a high profit mainly due to operating in these less exploited areas. While bottom trammel net earned a pure profit mainly due to monopolistic power of operation and non-selectivity of fishing. The use of the non-selective bottom trammel net has led to unrest among fishermen, mainly among handline fishermen, in the belief that the laying of nets on coral reefs disturbs the habitat and disperses the fish schools which they are targeting. It has turned into a conflict situation on several occasions.

Under the new Fisheries and Aquatic Resources Act No. 2. 1996, regulations have been enforced on the operation of trammel nets in coral reef areas (The Gazette of the Democratic Socialist Republic of Sri Lanka 1996). This regulation has restricted the rapid increase of fishing effort along all the coastal waters in the Negombo area. At present bottom trammel net operation is limited to areas to where prawn trawling and drift netting are mainly taking place. Fishing gear such as bottom longline, bottom set gillnets and handline can normally be successfully operated only during the non-monsoon period. Operation of bottom longline and handline needs both the knowledge of resource distribution and the skill of locating fishing grounds. The operational cost and the risks of operation are relatively high and the gears are highly dependent on specific types of bait varieties. The supply of baits such as live bait for bait cage handline, and squids and cuttlefish for longline are limited. Bottom set gillnets target mainly on skates which are low value species and their abundance has now declined. The present situation thus prevents an influx of other fishermen from entering and competing for these profits.

Fernando (1985a) stated while the fishery resources are open access in a legal sense in Sri Lanka, their operation is constrained by many social factors. Fishing communities in Sri Lanka are closed and localized and do not entertain outsiders fishing in their waters (Munasinghe, 1985; Atapattu, 1994). It is therefore important to identify the factors that effectively maintain the proprietary rights in the area over the years. Some form of restrictions on entry need to be maintained for a positive pure profit and a high economic return on capital and labour. Though fishing in Negombo area is effectively closed to outsiders through socio-cultural or technological barriers or both, it is open access within the community. With the increase in population, additional fishermen may therefore be attracted to the fishery unless new entry is prevented. To maintain the best possible use of the fishery by ensuring sustainability of resources, an effective management plan is needed in the future.

For demersal fisheries in Negombo area, the crew are always paid a share of the value of the divisible income according to the prevailing sharing system, and, in addition some amount of fish after every fishing trip is taken for their own consumption. The values of all these items together comprise their total earnings. The sharing system of labour remuneration has an important bearing on the amount of risk born by the two factors of capital and labour. Under a fixed wage system all risk arising from the vagaries of nature as well as from fluctuations of market and the benefits arising from windfall harvests are born by the owner, while the crew members get a steady income, not lower than the opportunity cost for their labour. Under the sharing system, on the other hand, crew members also share part of the risk, the risk of a low catch and the risk of low market prices, but then enjoy part of the benefits arising from windfall profits. Generally crew paid on a share basis enjoy higher average earnings than crew paid on a fixed wage rate because the earnings from a share basis incorporate a premium for risk taking. The prevailing share basis in the area values equally both the functions and tasks of all the crew members including boat owner or skipper.

The fishing gears deployed in demersal fisheries in Negombo area can be broadly categorized as traditional and modern gears. The economic efficiency as well as productivity is higher with the modern fishing gear than the traditional handline fishery (Figs. 6. 16 - 19). A similar observation was made by Kurien and Willmann (1982) in small pelagic fisheries in Kerala, India, in small pelagic fisheries in the Philippines (Trindad *et al.*, 1993) and in San Miguel Bay fishery in the Philippines (Smith and Mines, 1982b). These new technologies yield a higher rate of return than the traditional methods and thereby generate high revenue relative to the cost of operation. The economic reward of these gears is sufficiently high to attract continued investment. The traditional bait cage handline fishing realized a low CPUE (Chapter 2, Table 2.3) because they are full time fishermen and not targeting seasonal abundance resources with different methods and therefore receive low revenue. The high operational (bait cost and fuel cost) and labour cost (Figs. 6.3 and 6.9) limit their net income. Traditional handline fishermen purchase live bait from the lagoon stake net fishery which is managed by a traditional system. The IBM boats seasonally conduct bait cage handline fishing but catch bait themselves by trawling and thus reduce their operational cost. The high catch rates realized by them compensates for the fuel cost of fishing. However, the application of modern gears is mostly limited to the seasons as the target fish are seasonally available resources. The multispecies nature of demersal fisheries and seasonal availability of certain species typically precludes the gears operating profitably throughout the year. This encourages gear diversification for better profit, which requires additional investment. However, the capital cost of demersal fishing gears is relatively low.

The fishermen in the Negombo area are generally enterprising and have easily adapted to modern fishing methods as they have realised the economic gain of those fishing methods. Owning an additional gear for traditional handline fishermen who operate the same gear throughout the year would enable them to operate during the off-season for another resource. In Sri Lanka, the owner of the fishing unit generally owns the boat as well as the fishing gear and if they can divide the ownership of fishing assets among crew members they may get a higher income than at present. The present sharing system commonly defines a particular share for fishing gear. This system allows individual fishermen to contribute part of the cost of an individual fishing gear to obtain a return from such an investment. This important element of flexibility of the sharing system can take advantage of the seasonal shift of fishing. In most instances crew members are either sons, or relatives of the boat owners (Chapter 8). Thus such a system can be easily operated in the fishery and this helps to reduce income difference between boat owner and crew member. The species composition of bait cage handline and bottom trammel net fisheries are high (Chapter 2, Fig. 2.11) and consisted of large amount of low value fish and also the catch consisted of smaller fish than other fisheries. Non grading of fish catch may affect the price of valuable species and in turn the total revenue of the catch. Grading of fishing can improve the value of the resource and thereby income of fishing. Detailed study on this aspect should be made in future.

A substantially high profitability and productivity has been observed in handline fishing combined with drift net. Though the present study was limited to the handline component, it has indicated a high efficiency of this dual fishing act. The highest percentage of fishing effort on demersal resources was directed through handline fishing of combination boats. The dual fishing has many advantages. It is not necessary to employ additional labour and capital or time, on operation of the additional gear but limited time and space of handline operations can limit the catch. The financial efficiency of this dual act was estimated separately by utilizing information collected on catch and price of drift net fishery during the sampling period. The average catch per fishing day and unit price of the drift net component is given below (Table 6. 15).

Table 6 15 Average annual CPUE (kg per fishing day) and the unit price of fish in handline drift gillnet combined fishery

Item	Year								Average
	1992	1993	1994	1995	1996	1997	1998	199	
Drift gillnet catch (kg) per fishing day	42.19	43.23	46.18	48.33	37.4	39.71	34.52	36.78	41.04
Handline catch (kg) per fishing day	1.35	1.34	1.57	1.45	1.87	1.39	2.14	2.17	1.66
Price of a kg of drift gillnet catch	30 51	32.07	35.24	37.75	38 83	41 16	45 73	49.65	38 87
Price of a kg of handline catch	75.25	89 15	84 36	93 12	98 25	119 53	127 84	131 66	102 40

The estimated monthly net income, of boat owner and crew member is given below (Table 6 16)

Table 6 16 Average monthly net income of boat owner and crew member engaged in handline combined with drift gillnet fishing

Labour	Average monthly net income (Rs)								Average
	1992	1993	1994	1995	1996	1997	1998	1999	
Boat owner									
Drift gillnet	27163	27786	34328	38233	28601	33355	31890	36937	32287
Handline	1491	1800	2098	2001	2639	2598	3599	3745	2496
Total (Rs)	28654	29586	36426	40234	31240	35953	35489	40682	34783
Crew member									
Drift gillnet	6791	6947	8582	9558	7150	8339	7972	9234	8072
Handline	804	968	1128	1075	1422	1394	1936	2013	1343
Total (Rs)	7595	7915	9710	10633	8572	9733	9908	11247	9415

This shows that boat owners' total monthly net income of handline combined with driftnet fishing is very high, second only to spear fishing. This explains why this combined fishery is the most popular method among fishermen in the Negombo area

The analysis of monthly income assuming that the boats were continuously engaged in demersal fishing, showed that the boat owner's income was far ahead of crew members' income for all craft gear combination The owner's share typically constitutes a return on investment and provides enough income to allow for reinvestment in a new fishing unit once the existing unit has reached the end of its useful life As the owner also takes an active part in fishing he earns a crew share

Both boat owner's and crew member's income however is very much higher than any other similar vocation or employment in Sri Lanka. The crew member's net income by all craft gear combinations is higher than the national per capita income. A comparison is given below (Table 6. 17).

Table 6. 17. Comparison of monthly net income of boat owners and crew members engaged in different craft gear combinations and wages received in salaried employment.

Craft gear combination	Monthly net income (Rs)					
	Boat owner	Crew member	National av Income per person	National poverty level	Graduate school teacher	Av. Skill labor
HL*	22675	12736				
HL	12496	7044				
BLL	34233	12481				
BTN	19724	7504				
BSN	20997	7685				
SPF	45375	15885				
HL/DN (handline only)	2496	1343				
HL/DN (total)	34783	9415				
			5,500*	3000*	6,500*	4,500*

*Source: Central Bank of Sri Lanka (Annon, 1999c)
HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combine with gillnet with OBM boat

The generation of relatively high monthly income by coastal fishing has also been observed in earlier studies (Fenando, 1985a, Atapattu, 1994, Wimalaena and Rupamoorthi, 1998, Vidanage and Wimalasena, 2000). A crew member engaged in demersal fisheries gets a higher monthly income than crew members engaged in offshore multiday fisheries (Wimalasena and Rupamoorthi, 1998). It is thus clear why the boats engaged in other fisheries such as prawn trawling or drift netting, seasonally shift to demersal fishing with these profitable gears and also manage to purchase fishing assets with their savings. This clearly shows advantages of technical innovations in demersal fisheries on the economics of fishing

The financial conditions of fishermen engaged in demersal fisheries are not as bad as commonly claimed by small scale fishermen (Bailey, 1994, Munasinghe, 1985, Panayotou, 1985b). This is confirmed here by the continuous immigration of youth to demersal fisheries in this area and not seeking employment outside fishing. However, fishing is an inherently risky occupation, both physically and economically. Fishermen are less risk-averse than land-base salaried employees. The conditions under which the fishermen derive their income are quite different from those who are engaged in land-based employment. They work long and irregular hours at sea and the conditions under which this income is earned are very trying and risky. Their income varies from day to day and seasonally, and they have to invest the operational cost. Fuel price is now increasing markedly and as the Sri Lanka rupee value is depreciating against the US dollar, the prices of all imported items (*e.g.* boat engines, gear material) are increasing. The Government may remove the fuel subsidy with the depression of country's economy. The fishermen have to replace fishing assets quite often. Moreover they do not have much participatory social life because their social acceptance is quite low and their social amusements differ from other communities.

Economists argue that the purpose of fishery is to produce income rather than fish (Crutchfield, 1962, 1975). Economic overfishing was evident in the multispecies demersal fishery in the Negombo area. The economic performance under the multispecies situation showed that the present fishing effort in the Negombo area has long exceeded the maximum economic yield (MEY) of Rs. million 123 and for this to be obtained the fishing would have to be restricted to 53,149 standard days effort, but that such an effort reduction would reduce the total annual revenue of the fishing as well as the total catch. During 1999 the demersal fishery in the Negombo area produced a revenue of about Rs. 160 million and Rs. 30 million of profit. At the level of MEY, the fishery would produce about Rs. 48 million profit. But to achieve the forgone profit of about Rs. 18 million a large number of fishermen would have to be removed from the fishery and provided with alternative employment. Reduction of total catch by reduction of effort would also affect a large number of people who are engaged in post-harvest activities such as marketing.

When considering the economically important species, the situation is critical, as they are biologically as well as economically overexploited. Bio-economic assessment for single species showed that the level of fishing effort by all fisheries has exceeded the level at which the MEY is produced for both *L. nebulosus* and *L. lentjan*. It needs a 20% and 50% reduction of fishing effort, respectively, to achieve MEY for *L. nebulosus* and *L. lentjan* and this indicates that the fishing effort in 1999 has exceeded the MEY more for *L. lentjan* than *L. nebulosus* The financial gain of effort reduction is about Rs million 2 5 for *L. lentjan* and about Rs millon 0 28 for *L. nebulosus* The different management options tested with the bio-economic model showed that by a 50% reduction of handline or bottom trammel net fishing, the catch value of both species could be improved Proper management systems should be biologically sound and economically efficient, and require the bio-economic optimal management reference points The different management reference points obtained by stock assessment and economic assessment fishing in the present study are summarized below (Table 6 18)

It appears that economic optimization is more conservation minded than fishing based on maximizing the sustainable yield, since the economically optimal effort is less than the effort needed to maximize the sustainable yield It demands reducing the effort in 1999 by 60% to achieve MEY from multispecies fishery (Table 6 18) From a biological point of view, effort reduction also seems to be the key issue at present for the sustainability of the economically important species It demands a reduction of overall fishing effort by 40% to maintain the production of *L. lentjan* at MSY level to ensure sufficient residual biomass, thereby avoiding recruitment overfishing It also showed that a reduction of fishing effort of bottom trammel net or handline in 1999 by 50% would improve the annual catch of both species, and that both fishing gears exploit juvenile fish in large quantities, which indicated the danger of growth overfishing

Table 6. 18. Biological and economical management reference points for demersal fisheries in Negombo area

Resources	Biological management reference points		Economical management reference points	
	MSY (t)	f_{MSY} Stan. Fishing days	MEY (Rs. Million)	f_{MEY} Stan. fishing days
Single species condition				
L. nebulosus	246	104.298 (250.050)	26.63	60.799 (166.700)
L. lentjan	262	52.149 (125.025)	18.24	26.075 (104.188)
Multispecies condition	2236	130.421 (212.166)	123	53.149 (106.305)

Note. Actual fishing effort is indicated in parenthesis

Although rationalization of fishing effort would result in high income and ensure sustainability of resources, the reduction of fleet capacity will cause large social problems and create unrest and increase unemployment. The demersal fishery in the Negombo area at present provides a substantial income to the fishing community, which is well above comparable earning levels in other sectors of Sri Lankan society. Thus there may be little option of outside economic activities comparable to fishing. In most instances their skills are fishing or fishery related activities. There are few existing economic activities that fishermen can avail of without assistance (Chapter 9). Rationalization of effort would not only affect the fishermen it will also affect the wealth created in other productive enterprises downstream. These productive activities induce commerce and trade in the local economy. In a practical sense it is very difficult to rationalize or halt the flow of new entrants into demersal fishery as long as it is a profitable activity. Thus government must be consider what realistic alternatives exist before rationalizing the effort or access to a fishery is denied. This emphasizes the importance of a socio-cultural knowledge of fishermen before planning the management and development strategies. Future policies should consider not only biology or economics or both, but also the social and political elements. Irrespective of social implication however, the renewable resource must be conserve or it will colapse.

The most important question which has arisen out of economic analysis of multispecies demersal fishery in the Negombo area is what allowances a high profit from this fishery even though it is economically overfished? Is it a temporary feature or is it specific to this area? The main determinant of profit is the sale price of fish as the mode of fishing operation has been shown to be maintained at a low cost. It is therefore important to study how fishermen sell their catches with a high profit margin and this will be discussed in the next Chapter.

Appendix Table 6.1. Age profile and economic life of boats and engines in demersal fisheries.

Year of purchased	28-32 ft size class IBM boat	17-22 ft size class OBM boat	
		Engine	Hull
1986	1	0	0
1987	0	1	1
1988	0	0	0
1989	2	1	2
1990	4	2	1
1991	2	4	1
1992	3	2	2
1993	4	6	5
1994	2	6	4
1995	1	5	5
1996	1	6	7
1997	0	7	9
1998	0	11	8
1999	0	15	21
Average year of purchase	1991.9	1995.9	1996.4
Average purchasing year	1991	1995	1996
Economic life (years)	15	10	12

Appendix Table 6. 2. Estimated average year of purchase and average purchase price of boats and engines engaged in demersal fisheries.

Year	IBM boat		OBM boat			
			Engine		Hull	
	Average purchasing year	Price (Rs)	Average purchasing year	Price (Rs)	Average purchasing year	Price (Rs)
1992	1984	600,000	1988	51,000	1989	42,500
1993	1985	620,000	1989	53,750	1990	45,000
1994	1986	650,000	1990	66,500	1991	48,500
1995	1987	688,000	1991	69,500	1992	50,250
1996	1988	710,000	1992	77,500	1993	53,000
1997	1989	750,000	1993	84,000	1994	58,600
1998	1990	800,000	1994	79,167	1995	60,750
1999	1991	855,000	1995	82,000	1996	62,500

Appendix Table 6. 3. Age profile and economic life of fishing gear.

Year	Fishing gear			
	BLL	BTN	BSN	SPF
1996		2	2	
1997	3	12	8	
1998	18	17	9	1
1999	9	5	4	
Average year of purchase	1998.2	1997.7	1997.7	1998
Average purchasing year	1998	1997	1997	1998
Economic life (Years)	2	3	3	10

BLL = bottom lobgline fishing with OBM boats, BTN = bottom trammel net fishing with OBM boats, BSN = bottom set gillnet fishing with OBM boats, SPF = spear fishing with OBM boats

Appendix Table 6. 4. Estimated average age and average purchasing price of fishing gear used in demersal fisheries.

Year	Fishing gear							
	BLL		BTN		BSN		SPF	
	Average purchasing year	Price (Rs)	Average purchasing year	Price (Rs)	Average purchasing year	Price (Rs)	Average purchasing year	Price (Rs)
1992	1991	5,600	1990	14,875	1990	14,230	1991	6,500
1993	1992	6,055	1991	15,625	1991	18,700	1992	7,000
1994	1993	6,875	1992	17,875	1992	20,457	1993	7,000
1995	1994	7,225	1993	19,320	1993	22,075	1994	8,000
1996	1995	7,600	1994	20,936	1994	24,345	1995	10,000
1997	1996	8,500	1995	23,385	1995	26,750	1996	13,000
1998	1997	8,775	1996	24,890	1996	30,023	1997	15,000
1999	1998	9,245	1997	26,115	1997	30,575	1998	15,000

BLL = bottom longline fishing with OBM boats, BTN = bottom trammel net fishing with OBM boats, BSN = bottom set gillnet fishing with OBM boats, SPF = spear fishing with OBM boats.

Appendix Table 6. 5. Annual and daily depreciation cost of a boat and engine (SLRS)

Year	Annual depreciation cost (Rs)			Daily depreciation cost (Rs)		
	IBM boat	OBM boat		IBM boat	OBM boat	
		Engine	Hull		Engine	Hull
1992	40,000.00	5,100.00	3,541.67	133.33	17.00	11.81
1993	41,333.33	5,375.00	3,750.00	137.78	17.92	12.50
1994	43,333.30	6,650.00	4,041.67	144.44	22.17	13.47
1995	45,866.66	6,950.00	4,187.50	152.89	23.17	13.96
1996	47,333.33	7,750.00	4,416.67	157.78	25.83	14.72
1997	50,000.00	8,400.00	4,883.33	166.67	28.00	16.28
1998	53,333.33	7,916.70	5,062.50	177.78	26.39	16.88
1999	57,000.00	8,200.00	52,08.33	190.00	27.33	17.36

Appendix Table 6. 6. Annual and daily depreciation cost of fishing gear (SLRS)

Year	Annual depreciation cost (Rs)				Daily depreciation cost (Rs)			
	BLL	BTN	BSN	SPF	BLL	BTN	BSN	SPF
1992	2,800.00	4,958.33	4,743.33	650.00	9.33	16.53	15.81	2.17
1993	3,027.50	5,408.33	6,233.33	700.00	10.09	18.03	20.78	2.33
1994	3,437.50	5,958.33	6,819.00	700.00	11.46	19.86	22.73	2.33
1995	3,612.50	6,440.00	7,358.33	800.00	12.04	21.47	24.53	2.67
1996	3,800.00	6,978.67	8,115.00	1,000.00	12.67	23.26	27.05	3.33
1997	4,350.00	7,795.00	8,916.67	1,300.00	14.50	25.98	29.72	4.33
1998	4,387.50	8,296.67	10,007.7	1,500.00	14.63	27.66	33.36	5.00
1999	4,622.50	8,705.00	10,191.7	1,500.00	15.41	29.02	33.97	5.00

BLL = bottom longline fishing with OBM boats, BTN = bottom trammel net fishing with OBM boats, BSN = bottom set gillnet fishing with OBM boats, SPF = spear fishing with OBM boats.

Appendix Total 6. 7. Total depreciation cost of fishing assets diploid in different demersal fisheries (SLRS).

Year	Depreciation cost (Rs)							Total
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
1992	323325	1009070	127484	391816	82109	12965	88827	2035596
1993	327228	1038843	136130	421317	85176	15210	104557	2128461
1994	382766	1284822	270864	581823	84645	10692	139292	2754904
1995	424270	1379380	258982	787156	56623	12067	225750	3144228
1996	560119	1453718	397390	999558	43591	12165	180174	3646715
1997	595845	1690389	540216	1195560	40959	5535	204147	4272651
1998	537785	1290528	576573	1036317	77886	7572	366462	3893123
1999	627000	1379804	664764	1006642	61449	7821	356615	4104095

HL* = Handline fishing with IBM boat. HL = Handline fishing with OBM boat. BLL= bottom long line fishing with OBM boat. BTN = Bottom trammel net fishing with OBM boat. BSN = Bottom set gillnet fishing with OBM boat. SPF = Spear fishing with OBM boat. HL/DN = Handline fishing combine with gillnet with OBM boat.

Appendix Table 6.8. Average annual operational cost of a fishing day of handline fishing by IBM boat (HL*).

Craft gear combination	Item	Average cost (SLRS)							
		1992	1993	1994	1995	1996	1997	1998	1999
Handline with IBM boat (HL*)	Fuel & oil	352.67	385.39	392.40	405.23	421.33	437.85	460.12	497.92
	Food & other	78.00	102.15	85.72	111.56	75.65	88.27	115.76	136.18
	Gear maintenance	60.00	73.25	75.00	85.96	92.05	104.34	108.02	117.35
	Total	490.67	560.79	553.12	602.75	589.03	630.46	683.90	751.45

Appendix Table 6. 9. Average annual operational cost of a fishing day of handline fishing by OBM boat (HL).

Craft gear combination	Item	Average cost (SLRS)							
		1992	1993	1994	1995	1996	1997	1998	1999
Handline with OBM Boat (HL)	Fuel & oil	228.92	225.77	262.21	245.33	268.86	253.90	277.05	296.34
	Bait	232.80	247.19	237.62	302.13	275.86	325.45	334.07	355.79
	Food & other	58.16	78.25	46.84	85.33	59.90	67.45	80.15	76.25
	Gear maintenance	54.50	50.00	72.56	69.75	57.90	80.36	94.50	92.80
	Total	574.38	601.21	619.23	702.54	662.52	727.16	785.77	821.18

Appendix Table 6. 10. Average annual operational cost of a fishing day of bottom longline fishing by OBM boat (BLL).

Craft gear combination	Item	Average cost (Rs)							
		1992	1993	1994	1995	1996	1997	1998	1999
Bottom longline with OBM boat (BLL)	Fuel & oil	306.74	315.35	325.60	355.40	370.54	387.75	437.90	481.24
	Bait	514.78	560.70	480.50	522.88	540.18	603.19	535.67	569.50
	Food & other	86.65	75.80	102.35	83.14	100.56	95.35	110.26	105.16
	Ice	20.00	26.50	22.25	38.13	32.30	42.15	37.75	48.50
	Total	928.17	978.35	930.70	999.55	1043.58	1128.44	1121.58	1204.40

Appendix Table 6. 11. Average annual operational cost of a fishing day of bottom trammel net fishing by OBM boat (BTN).

Craft gear combination	Item	Average cost (Rs)							
		1992	1993	1994	1995	1996	1997	1998	1999
Bottom trammel net with OBM (BTN)	Fuel & oil	201.76	236.70	235.38	272.46	271.10	249.95	276.04	287.90
	Total	201.76	236.70	235.38	272.46	271.10	249.95	276.04	287.90

Appendix Table 6. 12. Average annual operational costs of a fishing day of bottom set gillnet fishing by OBM boat (BSN).

Craft gear combination	Item	Average cost (Rs)							
		1992	1993	1994	1995	1996	1997	1998	1999
Bottom set gillnet with OBM boats (BSN)	Fuel & oil	234.56	232.96	264.25	269.80	287.96	302.17	320.73	342.65
	Total	234.56	232.96	264.25	269.80	287.96	302.17	320.73	342.65

Appendix Table 6. 13. Average annual operational cost of a fishing day of spear fishing by OBM boat (SPF).

Craft gear combination	Item	Average cost (Rs)							
		1992	1993	1994	1995	1996	1997	1998	1999
Spear fishing with OBM boats (SPF)	Fuel & oil	215.60	234.63	222.80	263.24	278.45	282.05	275.12	321.74
	Food & other	232.50	246.32	239.15	246.78	308.66	366.41	378.36	382.47
	Total	448.10	480.95	461.95	510.02	587.11	648.46	653.48	704.21

Appendix Table 6. 14. Average annual operational cost of a fishing day of handline fishing combined with drift net by OBM boat (HL/DN).

Craft gear combination	Item	Average cost (Rs)							
		1992	1993	1994	1995	1996	1997	1998	1999
Handline combined with drift net operated by OBM boat (HL/DN)	Fuel & oil	232.54	293.38	272.66	295.36	311.50	300.76	287.35	331.32
	Food & other	56.00	73.35	65.70	75.90	75.63	78.52	100.60	92.75
	Gear maintenance	25.50	22.70	28.00	34.19	42.00	34.95	38.25	47.04
	Total cost	314.04	389.43	366.36	405.45	429.13	414.23	426.20	471.11
		314.04							
	Handline catch proportion	3.2	3.1	3.4	3.0	5.0	3.5	6.2	5.9
	Total cost of Handline fishing	10.05	12.07	12.46	12.16	21.46	14.50	26.42	27.80

Appendix Table 6. 15. Worksheet – Handline fishing with IBM boat (HL*)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	6001504	2425	2474.85	24.75	2450.10	490.67	1959.43	5	391.89	30.00	421.89	783.77	30.00	813.77	67.38	746.39
1993	6462384	2375	2721.00	27.21	2693.79	560.79	2133.00	5	426.60	30.00	456.60	853.20	30.00	883.20	73.13	810.07
1994	7548799	2650	2848.60	28.49	2820.12	553.12	2267.00	5	453.40	30.00	483.40	906.80	30.00	936.80	77.57	859.23
1995	8109749	2775	29922.43	29.22	2893.21	602.75	2290.46	5	458.09	30.00	488.09	916.18	30.00	946.18	78.34	867.84
1996	11082337	3550	3121.79	31.22	3090.57	589.03	2501.54	5	500.31	30.00	530.31	1000.61	30.00	1030.61	85.33	945.28
1997	12310248	3575	3443.43	34.43	3408.99	630.46	2778.53	5	555.71	30.00	585.71	1111.41	30.00	1141.41	94.51	1046.90
1998	10769627	3025	3560.21	35.60	3524.61	683.90	2840.70	5	568.14	30.00	598.14	1136.28	30.00	1166.28	96.57	1069.71
1999	10528251	3300	3190.38	31.90	3158.48	751.45	2407.03	5	481.41	30.00	511.41	962.81	30.00	992.81	82.20	910.61

Appendix Table 6. 16. Worksheet – Handline fishing with OBM boat (HL)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	63598240	35025	1815.80	18.16	1797.64	574.38	1223.26	5	244.65	30.00	274.65	489.30	30.00	519.30	32.77	486.54
1993	66788380	34150	1955.74	19.56	1936.18	601.21	1334.97	5	266.99	30.00	296.99	533.99	30.00	563.99	35.59	528.40
1994	68676233	36050	1905.03	19.05	1885.98	619.23	1266.75	5	253.35	30.00	283.35	506.70	30.00	536.70	33.87	502.83
1995	68176879	37150	1835.18	18.35	1816.83	702.54	1114.29	5	222.86	30.00	252.86	445.71	30.00	475.71	30.02	445.70
1996	77428650	35850	2159.79	21.60	2138.20	662.52	1475.68	5	295.14	30.00	325.14	590.27	30.00	620.27	39.14	581.13
1997	72910474	38175	1909.90	19.10	1890.80	727.16	1163.64	5	232.73	30.00	262.73	465.46	30.00	495.46	31.26	464.19
1998	6039172	29825	2024.82	20.25	2004.57	785.77	1218.80	5	243.76	30.00	273.76	487.52	30.00	517.52	32.66	484.86
1999	65307218	30875	2115.21	21.15	2094.06	821.18	1272.88	5	254.58	30.00	284.58	509.15	30.00	539.15	34.02	505.13

Appendix Table 6. 17. Worksheet – Bottom longline fishing with OBM boat (BLL)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	15560300	4425	3516.45	35.16	3481.29	928.17	2553.12	4.3	593.75	30.00	623.75	1781.24	30.00	1811.24	86.22	1725.03
1993	14468793	4475	3233.25	32.33	3200.92	978.35	2222.57	4.3	516.88	30.00	546.88	1550.63	30.00	1580.63	75.24	1505.39
1994	25456020	7600	3349.48	33.49	3315.98	930.70	2385.28	4.3	554.72	30.00	584.72	1664.15	30.00	1694.15	80.64	1613.51
1995	20043529	6975	2873.62	28.74	2844.89	999.55	1845.34	4.3	429.15	30.00	459.15	1287.45	30.00	1317.45	62.71	1254.73
1996	28218428	9800	2879.43	28.79	2850.64	1043.58	1807.06	4.3	420.25	30.00	450.25	1260.74	30.00	1290.74	61.44	1229.30
1997	40826081	12200	3346.40	33.46	3312.94	1128.44	2184.50	4.3	508.02	30.00	538.02	1524.07	30.00	1554.07	73.97	1480.09
1998	37505031	13325	2814.64	28.15	2786.49	1121.58	1664.91	4.3	387.19	30.00	417.19	1161.57	30.00	1191.57	56.72	1134.85
1999	40323074	14875	2710.79	27.11	2683.69	1204.40	1479.29	4.3	344.02	30.00	374.02	1032.06	30.00	1062.06	50.55	1011.51

Appendix Table 6. 18. Worksheet – Bottom trammel fishing with OBM boat (BTN)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	Crew share (Rs)	Crew member's fish share (rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	18906872	13600	1390.21	13.90	1376.31	201.76	1174.55	4	293.64	30.00	323.64	880.91	30.00	910.91	55.84	855.07
1993	17415523	13850	1257.44	12.57	1244.86	236.70	1008.16	4	252.04	30.00	282.04	756.12	30.00	786.12	48.19	737.93
1994	19737056	16325	1209.01	12.09	1196.92	235.38	961.54	4	240.38	30.00	270.38	721.15	30.00	751.15	46.05	705.11
1995	27536910	21200	1298.91	12.99	1285.92	272.46	1013.46	4	253.37	30.00	283.37	760.10	30.00	790.10	48.43	741.66
1996	36632840	24650	1486.12	14.86	1471.26	271.10	1200.16	4	300.04	30.00	330.04	900.12	30.00	930.12	57.02	873.10
1997	46345288	27000	1716.49	17.16	1699.33	249.95	1449.38	4	362.34	30.00	392.34	1087.03	30.00	1117.03	68.47	1048.56
1998	27649390	23950	1154.46	11.54	1142.92	276.04	866.88	4	216.72	30.00	246.72	650.16	30.00	680.16	41.69	638.47
1999	28647002	22525	1271.79	12.72	1259.07	287.90	971.17	4	242.79	30.00	272.79	728.38	30.00	758.38	46.49	711.89

Appendix Table 6. 19. Worksheet – Bottom set gillnet fishing with OBM boat (BSN)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	4503999	2850	1580.35	15.80	1564.55	234.56	1329.99	4	332.50	30.00	362.50	997.49	30.00	1027.49	26.61	1000.88
1993	2957112	2800	1056.11	10.56	1045.55	232.96	812.59	4	203.15	30.00	233.15	609.44	30.00	639.44	16.56	622.88
1994	2359540	2375	993.49	9.93	983.56	264.25	719.31	4	179.83	30.00	209.83	539.48	30.00	569.48	14.75	554.73
1995	1447122	1525	948.93	9.46	939.44	269.80	669.64	4	167.41	30.00	197.41	502.23	30.00	532.23	13.78	518.45
1996	1201845	1075	1118.00	11.18	1106.82	287.96	818.86	4	204.71	30.00	234.71	614.14	30.00	644.14	16.68	627.46
1997	1389590	925	1502.26	15.02	1487.24	302.17	1185.07	4	296.27	30.00	326.27	888.80	30.00	918.80	23.80	895.00
1998	2665472	1800	1480.82	14.81	1466.01	320.73	1145.28	4	286.32	30.00	316.32	858.96	30.00	888.96	23.02	865.94
1999	3525798	1375	2564.22	25.64	2538.57	342.65	2195.92	4	548.98	30.00	578.98	1646.94	30.00	1676.94	43.43	1633.51

Appendix Table 6. 20. Worksheet – Spear fishing with OBM boat (SPF)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	1086077	450	2413.51	24.14	2389.37	448.10	1941.27	4	485.32	30.00	515.32	1455.95	30.00	1485.95	25.11	1460.84
1993	1028285	500	2056.57	20.57	2036.00	480.95	155.05	4	388.76	30.00	418.76	1166.29	30.00	1196.29	20.22	1176.07
1994	829601	300	2765.34	27.65	2737.68	461.95	2275.73	4	568.93	30.00	598.93	1706.80	30.00	1736.80	29.35	1707.45
1995	713494	325	2195.37	21.95	2173.41	510.02	1663.39	4	415.85	30.00	445.85	1247.54	30.00	1277.54	21.59	1255.95
1996	1224317	300	4081.06	40.81	4040.25	587.11	3453.14	4	863.28	30.00	893.28	2589.85	30.00	2619.85	44.28	2575.58
1997	619400	125	4955.20	49.55	4905.65	648.46	4257.19	4	1064.30	30.00	1094.30	3192.89	30.00	3222.89	54.47	3168.42
1998	499721	175	2855.55	28.56	2826.99	653.48	2173.51	4	543.38	30.00	573.38	1630.13	30.00	1660.13	28.06	1632.08
1999	487456	175	2785.46	27.85	2757.61	704.21	2053.40	4	513.35	30.00	543.35	1540.05	30.00	1570.05	26.53	1543.51

Appendix Table 6. 21. Worksheet –Handline combined with drift gillnet fishing (HL/DN)

Year	Total revenue (Rs)	Fishing effort (fishing days)	Revenue per fishing day (Rs)	Auction chargers (Rs)	Net revenue per day (Rs)	Operational cost per fishing day (Rs)	Net profit per fishing day (Rs)	No. of shares	Crew share (Rs)	Crew member's fish share (rs)	Total crew member share (Rs)	Boat owner's share (Rs)	Boat owner's fish share (Rs)	Total boat owner's gross income (Rs)	Repairs and maintenance cost per day (Rs)	Boat owner's total net income (Rs)
1992	10091702	96350	104.74	1.05	103.69	10.05	93.64	3	31.21	0.96	32.17	62.43	0.96	63.39	3.77	59.62
1993	14052068	110875	126.74	1.27	125.47	12.07	113.40	3	37.80	0.93	38.73	75.60	0.93	76.53	4.55	71.98
1994	16810860	114950	146.24	1.46	144.78	12.46	132.32	3	44.11	1.02	45.13	88.22	1.02	89.24	5.30	83.93
1995	17001174	121600	139.81	1.40	138.41	12.16	126.25	3	42.08	0.90	42.98	84.17	0.90	85.07	5.05	80.02
1996	24047719	126950	189.43	1.89	187.53	21.46	166.07	3	55.36	1.50	56.86	110.71	1.50	112.21	6.67	105.55
1997	23770393	131725	180.45	1.80	178.65	14.50	164.15	3	54.72	1.05	55.77	109.43	1.05	110.48	6.56	103.92
1998	37898871	136600	277.44	2.77	274.67	26.42	248.25	3	75.59	1.86	77.45	151.18	1.86	153.04	9.09	143.95
1999	38514664	135250	284.77	2.85	281.92	27.80	254.12	3	78.73	1.77	80.50	157.47	1.77	159.24	9.46	149.78

Appendix Table 6. 22. Annual and daily opportunity cost of capital invested for a boat and engine (SLRS).

Year	Annual opportunity cost (Rs)			Daily opportunity cost (Rs)		
	IBM boats	OBM boats		IBM boats	OBM boats	
		Engine	Hull		Engine	Hull
1992	72,000.00	6,120.00	5,100.00	240.00	20.40	17.00
1993	74,400.00	6,450.00	5,400.00	248.00	21.50	18.00
1994	78,000.00	7,980.00	5,820.00	260.00	26.60	19.40
1995	82,560.00	8,340.00	6,030.00	275.20	27.80	20.10
1996	85,200.00	9,300.00	6,360.00	284.00	31.00	21.20
1997	90,000.00	10,080.00	7,032.00	300.00	33.60	23.44
1998	96,000.00	95,00.04	7,290.00	320.00	31.67	24.30
1999	102,600.00	98,40.00	7,500.00	342.00	32.80	25.00

Appendix Table 6. 23. Annual and daily opportunity cost of capital invested for fishing gear unit (SLRS).

Year	Annual opportunity cost (Rs)				Daily opportunity cost (Rs)			
	BLL	BTN	BSN	SPF	BLL	BTN	BSN	SPF
1992	672.00	1,785.00	1,707.60	780.00	2.24	5.95	5.69	2.60
1993	726.60	1,875.00	2,244.00	840.00	2.42	6.25	7.48	2.80
1994	825.00	2,145.00	2,454.84	840.00	2.75	7.15	8.18	2.80
1995	867.00	2,318.40	2,649.00	960.00	2.89	7.73	8.83	3.20
1996	912.00	2,512.32	2,921.40	1,200.00	3.04	8.37	9.74	4.00
1997	1,020.00	2,806.20	3,210.00	1,560.00	3.40	9.35	10.70	5.20
1998	1,053.00	2,986.80	3,602.76	1,800.00	3.51	9.96	12.01	6.00
1999	1,109.40	3,133.80	3,669.00	1,800.00	3.70	10.45	12.23	6.00

Appendix Table 6. 24. Estimated opportunity cost of fishing assert (boat and gear) per fishing operation (SLRS).

Year	Opportunity cost (Rs)							Total
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN	
1992	240.00	37.40	39.64	43.35	43.09	40.00	1.20	444.68
1993	248.00	39.50	41.92	45.75	46.98	42.30	1.22	465.67
1994	260.00	46.00	48.75	53.15	54.18	48.80	1.56	512.44
1995	275.00	47.90	50.79	55.63	56.73	51.10	1.44	538.59
1996	284.00	52.20	55.24	60.57	61.94	56.20	2.61	572.76
1997	300.00	57.04	60.44	66.39	67.74	62.24	2.00	615.84
1998	320.00	55.97	59.48	65.93	67.98	61.97	3.47	634.80
1999	342.00	57.80	61.50	68.25	70.03	63.80	3.41	666.79
Average	283.63	49.23	52.22	57.38	58.58	53.30	2.11	556.45

HL* = Handline fishing with IBM boat, HL = Handline fishing with OBM boat, BLL= bottom long line fishing with OBM boat, BTN = Bottom trammel net fishing with OBM boat, BSN = Bottom set gillnet fishing with OBM boat, SPF = Spear fishing with OBM boat, HL/DN = Handline fishing combined with gillnet with OBM boat.

Chapter 7

Marketing of Fish Catch

7. 1 INTRODUCTION

The amount of net profit from fish sales is determined by sale price relative to the cost of operation. We have understood how the fishermen have maintained 'quasi property' rights over fishery resources through the mode of operation (Chapter 6). Such conditions protect net profits to some extent by preventing over-capitalisation and over-exploitation. We have also shown how the fishermen have maintained the cost of operation at a low level (Chapter 6). On the other hand, profits also depend on the revenue of fish sales and which in turn depends on the fish price. It is therefore, important to study the marketing patterns of fish catch which influence the fish price.

Since fish is a highly perishable commodity, speedy marketing is a very important aspect. In Sri Lanka fish marketing is handled largely by private traders. The Government has taken up a certain amount of intervention in the marketing of fish especially of the large scale fish catches through the Ceylon Fisheries Corporation (CFC). It is government policy not to control the activities of private traders but rather to encourage more persons and organisations to enter this trade and thereby strengthen the competition. The fish marketing net work in Sri Lanka is highly complex and involves a number of intermediates (Jayasuriya, 1980; Anon, 1988). The efficiency of distribution of products though these complex chains also determines the price that fishermen ultimately get. Good roads, available cold storage facilities, ice plants in the area and proximity to major city centres influence rapid movement of products through these chains. Furthermore seasonal variation of quantities landed, size, species, quality of fish and marketing practices directly influence the fish price.

In Sri Lanka, as in other developing countries, fish traders are mostly moneylenders and constitute the prime source of finance for small scale fishermen. In most instances fishermen depend on these moneylenders because their income varies daily as well as seasonally. They provide immediate cash without any security or explicit interest rates or repayment schedules, but under the condition of delivering fish as long as the debt is outstanding. Loans provided by banks or co-operatives are far less flexible than credit offered by local traders. In such conditions traders can exploit the fishermen by paying a lower price than the prevailing market price (Sutinen *et al.*, 1981; Smith and Mines, 1982b; Fernando, 1985b; Librero, 1985; Bailey *et al.*, 1987). In addition the monopsonistic (single buyer) or the oligopsonistic (few buyers) characteristics of fish marketing structures may result in a low price received by the fishermen. Fish marketing pattern may thus constrain the income of fishermen due to preventing a competitive market for their goods and service (Smith and Mines, 1982b, Fernando, 1985b, Librero, 1985).

The present study has been very restricted in scope, and only attempts to provide some descriptive account on the demersal fish marketing systems prevailing in the Negombo area, and to identify the marketing pattern and obligations and constraints which affect fish price. It does not attempt to compare technical efficiency of different marketing systems. In this study marketing of fish refers solely to the disposal of the fish catch by the fishermen.

7. 2 MATERIALS AND METHODS

Information on fish marketing was collected together with economic and social data through the use of a questionnaire during the period March to December 1999, which included both lean and peak seasons (monsoon and intermonsoon) for all small scale fisheries in the area. To facilitate comparison of biology, economics, social and marketing data, the same boat owners who were interviewed to gather economics and social data were interviewed at the same sampling centers, Kuttiduwa, Pitipana, Palagathurai, Kammalthota and Hedala. A total of 106 boat owners engaged in different fisheries were interviewed during this period. The number of boat owners interviewed by different boat/gear combination is given in Table 6.1. The questionnaire focused on obtaining information on the mode of disposal of the fish catch, marketing practices, the producers' obligations to fish traders and to identify the marketing constraints in the area. In addition, information was collected through interviews of different fish buyers to identify the marketing links in the Negombo area. The number of different buyers interviewed at each sampling centre is listed in Table 7.1.

Fig. 7. 1. Fish displayed on plastic sheets

Fig. 7. 2. Fish displayed on the ground

Table 7.1. Number of different buyers interviewed at each sampling centres.

Landing center	Assemblers	Retailers					Consumers
		Bicycle venders	Motorcycl e venders	Venders on foot	Venders in fixed location	Venders in suburb area	
Hedala	2	-	2	-	3	1	6
Kuttiduwa	6	1	2	2	15	11	36
Pitipana	3	2	3	2	13	4	22
Palagathurai	-	5	2	6	4	-	14
Kammalthota	-	5	1	4	2	-	9

7. 3 RESULTS

7. 3. 1 Marketing Systems

The demersal fish in the Negombo area are all marketed locally in fresh condition (without chilling) in lots without weighing which facilitates quick disposal of the catch and minimises handling. Fish being a perishable commodity it is important to dispose of them steadily and efficiently otherwise fishermen have to preserve them in ice to keep the fish in good quality. Selling fish without weighing is the traditional marketing system in the Negombo area.

The demersal fish in the area land at different landing centres scattered along the coast. Fishermen dispose of their catches at the landing point immediately after landing. Two types of marketing systems have been identified in the area,

1. Open markets
2. Fish auctions

All the landing sites are generally open markets. Local governments in the area control open beach markets and charge 1% of the total fish sales as a rental. Kuttiduwa is the only large open market found in the Negombo area, other landing sites being relativel small in physical size. No infrastructure facilities such as ice factories, cold storage facilities, stall or shed to display the fish etc. exist to support fish traders in these open markets except Kuttiduwa. Fishermen display their catches on plastic sheets or just on the ground which is possibly polluted (Fig. 7.1). Open markets prevail only in the morning hours, mostly about 2-4 hours (6-10 am) but the open market in Kuttiduwa prevails until noon. The number of different types of buyers coming to these open markets are limited and therefore fishermen have less access to a wide range of possible buyers. There is no mode of communication of information on fish prices with other major marketing centres where the marketing is more competitive. However open markets allow them to sell their catches direct to the traders or consumers without transporting fish to major marketing centres. This enables then to save transport, loading and unloading charges, and time and also reduces the amount of handling but haggling over price is common in open markets. However, payments are settled on the spot. The fishermen who are not bound to fish traders can derive an advantage from this situation. The interviews revealed that there were no contractual arrangement of trading. This type of arrangement is undermined when there is an informal credit transaction between fishermen and traders. The fishermen are compelled to accept the given price because of the dependency relationship, which binds them to the traders.

Fish auctions for small scale fisheries are found in only a few places in the Negombo area such as Pitipana, Katunayake and Hedala because the cost of constructing auction centre, staffing and managing an auction centre in small communities is difficult. Moreover organising an effective auction in a small community where low quantities of fish are landed and only a few buyers are present would be difficult as the basis for competitive bidding does not exist under such circumstances. Except for the evening fish auction at Pitipana, all other auction centres are run in the morning. Fishermen, mainly in Pitipana and Kuttiduwa area, who operate handline or bottom longline fishing in the offshore areas or who have spent more time on fishing or engaged in troll fishing for large pelagic species generally arrive later in the morning. They sell their catches in the evening auction at Pitipana action centre. Having an evening auction is important to the demersal fishermen in the Negombo area and thus enables them to spend more time on fishing. Towards the end of the day few traders remain at the open markets and thus a competitive market does not prevail but stocks have to disposed of in order to save on ice or cold storage and to avoid losses due to spoilage.

Fish auctions are managed either by the church or local government. The Catholic church in the Negombo area is historically involved in managing small scale fisheries and fish marketing in the area because Negombo is a Christian dominated area (Chapter 8). Most of the auction centres were organised under the auspices of the church as a welfare service to the Christian society. At present the church only manages Pitipana auction centre and others are managed by local governments. The auction centres are generally located in major ports close to city centres where large quantities of fish are landed and ice plants and cold storage facilities are available. Thus a large number and a wide variety of buyers are involved in auctions. The prevailing practice is sale of the total catch by lots through auction where buyers compete by bidding. Fishermen display their catches in separate lots on the floor and weighing is not done. Each lot mostly consists of mixed species. As explained in Chapter 6 the multispecies demersal catch consists of a large portion of low value fish and fewer high price varieties. When low value fish is mixed with high price fish fishermen expect price improvements to the low value fish and it also ensures quick disposal. Buyers are forced to buy the whole lot because of the prized fish varieties in the lot. However, the present studies reveal that grading would improve overall revenue of the fish catch.

Bidding is open and done in ascending order simply by verbally declaring the bids of all the prospective buyers for a particular fish lot. The highest bidder receives the fish lot. This practice allows a price increase through trader competition. Generally 1% of the total fish sales is taken as auction charges for the registered people. Payment is made on spot and is guaranteed that the settlement is made at the bid price. There is no doubt that the auction system is advantageous to the fishermen (producer), with about 87% of the boat owners interviewed showing their willingness to have the auction system rather than open market system. The auctions are less important overall than open beach markets for demersal fish marketing in the Negombo area (Fig. 7.2). Only two auction centres in the area, Pitipana, Hedala are involved in demersal fish marketing and only Pitipana auction centre is principally involved in demersal fish marketing. IBM boats who conduct handline fishing generally sell their catches at Hedala auction centre and the handline and bottom longline fishermen in Pitipana and Kuttiduawa areas sell their catches at Pitipana auction centre. All the others sell at different open markets. On average 35% of the demersal fish landed in the Negombo area in 1999 was marketed through auctions. The relative importance of auction marketing was higher during the North-West monsoon period from November to January. The open market was important in the South-West monsoon period, April to September, because landings of bottom trammel nets are high in that period (Fig. 7.2) and marketed mainly in open markets in Palagthurai, Kammalthota and Kuttiduwa.

Fig. 7. 3. Kuttiduwa open fish market

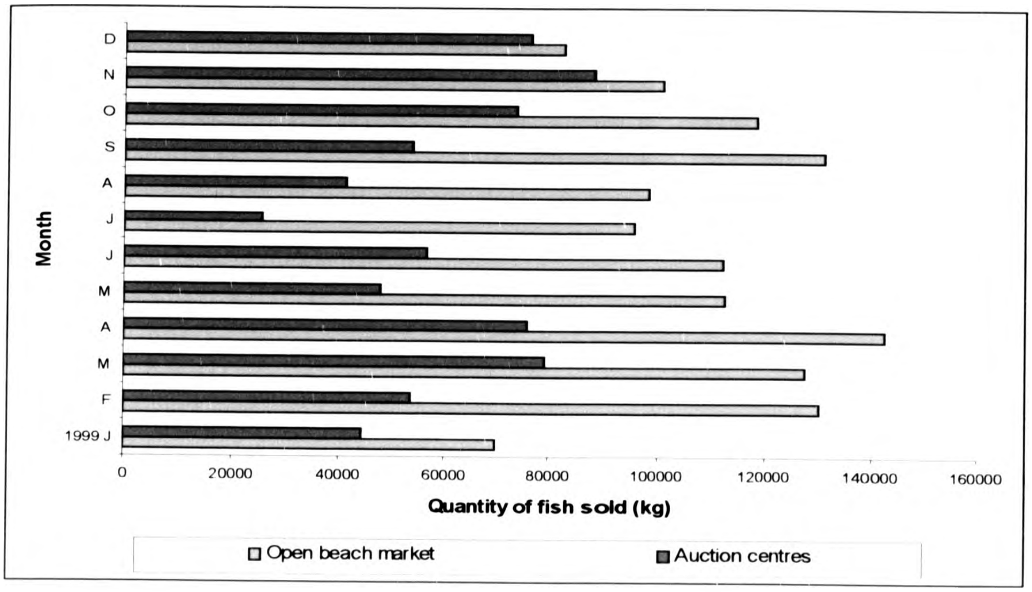


Fig 7.2 Total quantity of demersal fish sold in the open markets and auction centres in 1999

7. 3. 2 Categories of Buyers, and Market Net Work

Demersal fish marketing in the Negombo area is in the exclusive hands of the private sector. The buying units comprising the fish marketing system can be categorised into three according to the type of activity and mode of business,

1) Assemblers
2) Retailers
3) Consumers

All the traders interviewed carry out business as individual enterprises and trading is the family business of most assemblers and retailers. Their involvement in fish marketing is a matter of circumstance, not of choice. As in most fishing communities, the source of livelihood is limited to fishing and fishery related activities.

The assemblers who assemble demersal fish generally assemble high price varieties of fish or squid and cuttlefish. Such assemblers operate in small numbers, mainly in the principal market centres like Pitipana, Kuttiduwa and Hedala where a large amount of fish landed. They obtain their supplies of fish through auction and open markets. They sell their stocks mainly to the retailers in the interior of the country after retaining 8 - 10% profit. Others supply fish, squid or cuttlefish to the tourist hotels and tourist resorts in the area or sometimes send fish to the wholesalers operating in Colombo Central fish market (St. John's Market). When fish is supplied to tourist hotels it is usually a direct sale where as the supplies to the Colombo central fish market is a commission transaction based on the final selling price at Colombo. Generally assemblers buy selected varieties and quantities on request. The interview evidence indicated that the assemblers purchased about 31% of the demersal catch.

Among the demersal fish buyers, fish retailers dominated in the Negombo area. They obtain supplies directly from auctions or open markets but local retailers occasionally obtain fish from assemblers. It was found that retailers purchased about 52% of the total catch landed (2,041,602 kg) in the area in 1999. Two types of retailers were identified during this study, mobile retailers and retailers of fixed locations. Mobile retailers are motorcyclists, cyclists and box/basket carriers and the retailers of fixed locations are roadside slab owners and market retailers. Except for a few mobile and market retailers, others sell only demersal fish. A distinct feature in the retail trade of Negombo is the large number of women. They sell mainly in fixed locations either at same open beach market or at retail markets where the fish were landed in the Negombo town or they carry the fish in baskets a short distance from landing centres. Their clienteles are mainly in the urban areas. They still practice the traditional way of selling without weighing and by lots. Selling fish in temporary huts is a common feature in Kuttiduwa open market (Fig. 7.3). On the whole, trading at fixed locations seems to be important to retailers. Assemblers only invest in purchasing fish but retailers have to buy ice, carrying boxes and baskets and for the mobile retailers a vehicle. Most consumers obtain their requirements from fish retailers.

Direct producer to consumer links are quite common for the trade in demersal fish in the Negombo area. People who live close to Negombo, when they need to purchase a large quantity of fish (generally more than 2-3 kilos), often come to auctions or open markets, but consumers who need small quantities buy from retailers. The interview evidence indicated on average about 17% of the demersal catch is sold direct to the consumers. It was noted that handline and bottom trammel net fishermen sell a relatively higher proportion of their catch directly to the consumers because they catch relatively small quantities (Chapter 2) and also their catches consisted of low value small varieties which most consumers can afford. The main types of transaction and flow pattern are illustrated in Fig. 7. 4.

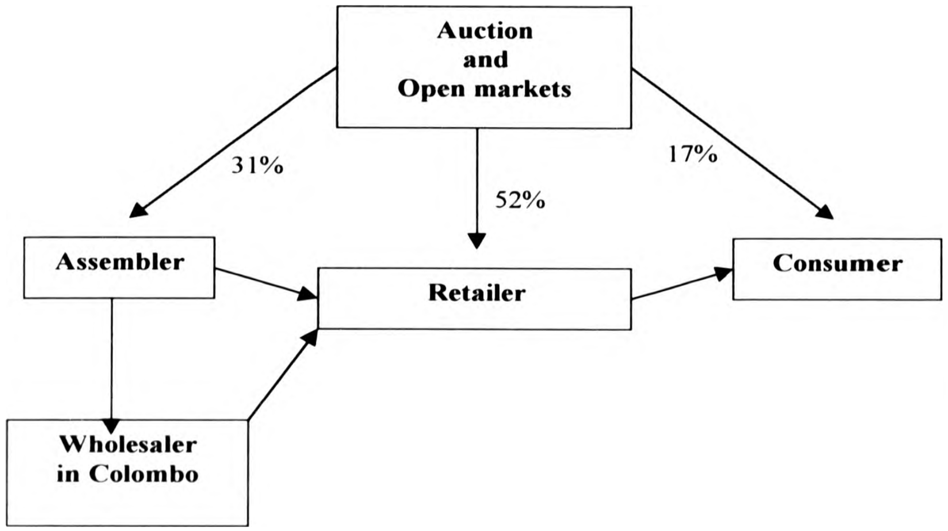


Fig. 7. 4. Demersal fish market network in Negombo area

7. 3. 3 Fish Distribution

The distribution of demersal fish shows three distinct patterns. Fish trading by women is a highly localised distribution. Basket/box carriers cover about 3-5 km distance from each landing centre retailing fish on foot. The retailers sell their fish at fixed locations such as in the retail market at Negombo town or at beach markets which also cater for local population. The mobile retailers sell the catch in the peripheral areas of Negombo and travel about 5-20 km distance. Both these retailers sell their fish direct to consumers.

The assemblers link to the retailers more from the interior, 30-60 km distance, who visit the landing centres in their own vehicle or visit in groups organised by one whose vehicle is used to transport fish to inland areas. One of those interviewed was an intermediate retailer who distributes the fish to consumers through other retailers. This pattern of distribution meets the regional requirements for fish. These retailers are more established and organised traders and all of them have fish stalls or slabs in interior towns. They purchase large quantities of different varieties of fish, demersal, pelagic or prawns. Thus they are found in major open markets like Kuttiduwa where all types of fish are landed in large quantities. The assemblers otherwise send the fish to wholesalers in the Colombo central fish market and some retailers in the interior areas purchase their requirements from Colombo fish market. The present system improves the trade efficiency and reduces the market losses and allows traders to cater their services to different area.

In general, short market links are found between fishermen to consumer within the demersal fish marketing system in the Negombo area. In most cases, producers channel their catch through retailers to consumers. This indicates the high demand for demersal fish. Short market channels benefit both fishermen (producer) and consumer. When there are more marketing links the consumer price is increased. The consumer price reflects the value addition at each point involving ice, packing, loading, transport and include risk and profit margin. It also takes more time to reach the consumer and thus the quality deterioration is very high. This affects consumer demand and in turn the fishermen's price.

What brings a large domestic market demand for fresh demersal fish in the Negombo area as well as in suburbs? Among demersal species lethrinds, lutjanids, carangids, serranids, scombrids, squids and cuttlefish are considered prime commercial species and they are 'white fish' (white flesh), less oily, easy to fillet and thus used in quality preparations. Market preference, quality of fish (freshness) and the resulting demand are the main reasons for the comparatively high price commanded by such varieties. The majority of the population believes that fish has less cholesterol than meat, and eating of fish has no religious prohibition among majority of Buddhists and Hindus.

7. 3. 4 Fish Price

Fish price varies by size, species, quality, and seasonal and daily availability of the fish. In addition it also varies from place to place and quantity sold. The fish price variation due to seasonal variation is shown in Fig. 7.5. Seer fish (*Scomberomorus commerson*) dominated the price of all species and was highly varied between months, with a relatively low price reported in February, May, July, September and October. carangids also fetched a high price but frequent price variation was not as marked as for seer fish.

A seasonal decline of price was reported from July to October. Emperor fishes reported the next highest price to carangids and seasonal price increases were reported in July to September. The average price of snappers was low and they did not show marked seasonal price variation. Fish categorised as 'other' are low valued fish and the seasonal price variation of them was not prominent as for snappers.

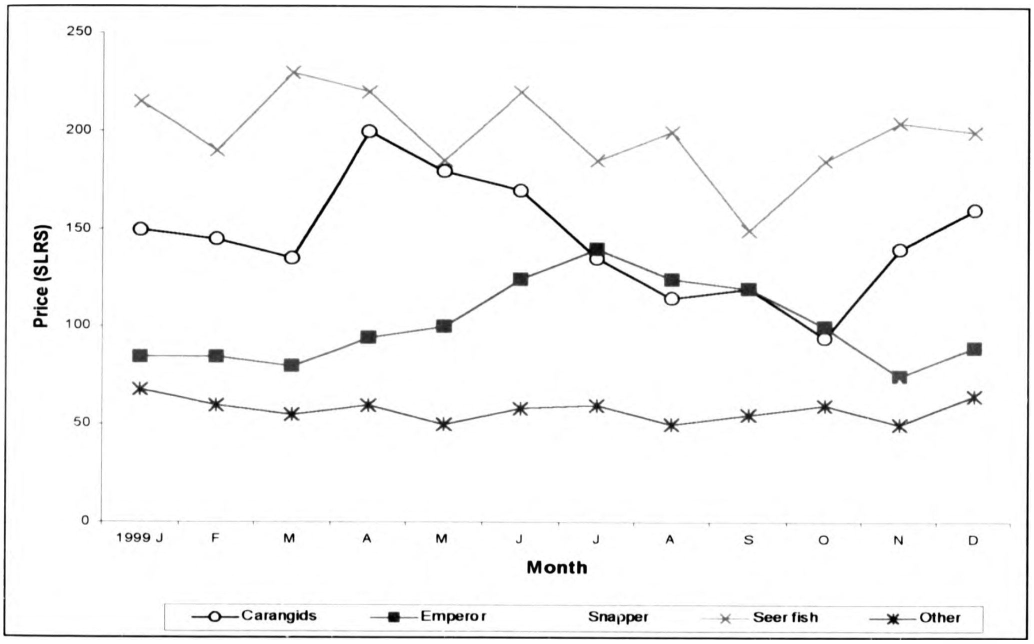


Fig. 7.5. Monthly average fish price (Rs/kg) reported in Pitipana fishing auction in Negombo in 1999.

Market preference and the resultant demand and scarcity are the main reasons for comparatively high price commanded by seer fish, carangids (travelly) and emperors. The overall production of these varieties influences the price variation received by the fishermen. The fishing price variations by quantity sold in different markets are given in Table 7. 2.

Both fishermen and wholesalers always demand or fix a higher price for small quantity sales because consumers when buying a small quantity always discriminate quality fish according to their choice by variety, size or quality. This indicates that the consumer is willing to pay a higher price for quality fish. The average wholesale fish price of most varieties is higher in Negombo than at Colombo central fish market (Table 7.2).

Table 7. 2 Average selling fish price of demersal species in different markets in 1999.

Place	Buyers	Fish price (Rs)				
		Emperors	Snappers	Carangids	Seer fish	Other
Negombo Auction/open market	Assemblers Retailers	101.70	77.30	145.40	185.40	65.00
	Consumers	125.00	100.00	190.00	250.00	75.00
*Colombo central fish market	Wholesale	75.00	70.00	130.00	200.00	60.00
	Retail market	100.00	85.00	210.00	282.00	70.00

*Sources: Ceylon Fisheries Co-operation * Sri Lanka Fisheries Year Book 1999

Colombo central fish market receives fish from all parts of the island and they always receive catches of the previous day chilled in ice. When considering the average consumer buying price at auctions or at open markets, it was higher than the consumer buying price from retail markets or the wholesale market at Colombo central fish market. This indicates the price gain by the Negombo fishermen for producing better quality fish.

7. 4 DISCUSSION

Negombo is a metropolitan area as well as a tourist area and in close proximity to the major city centres including the capital city Colombo. All kinds of sea fish are landed in Negombo and infrastructure facilities such as ice plants, storage facilities and efficient transportation provide a large domestic market for fresh fish, in which a wide range of fish are sold.

There are two types of demersal fish markets in Negombo area where the performance of business activities directs the flow of goods and services from producer to consumer. Monopoly and perfect competition are the two theoretical extremes of capitalism, but neither of the two exists under empirical conditions. All empirical markets fall somewhere between the two extremes. The auction system promotes competition among the traders thereby increasing the price. The skill of negotiation is a prime factor in open markets but it also promotes some competition among traders. Both systems allow the fishermen a price commensurate with the supply and demand for the day. In this way they largely eliminate the middlemen's profit.

However, there are considerable marketing inefficiencies which emerged from this study. It was observed that the buyers involved in demersal fish marketing are mostly local traders. At Negombo though traders are free to enter the auction or open market there appears to be some entry barrier to the outsiders of the community. Retailers from suburban areas always buy their stocks through assemblers. This shows that some control of marketing system is exercised by local traders in the area. Their capacity to buy large quantities of fish depends on their links with the market network. This prevents outsiders from entering this trade even though they have capital to dispose. This could reduce the competition in the market and thereby penalise the fishermen. However, both auction centres and open markets are controlled by the church or local governments and are not controlled by the traders. It was noted during the survey that the fishermen have no liability or obligation to the auction staff, who are paid by the church and have no liability to traders.

Though there is some competitive market prevailing in the Negombo area it can be more developed for the benefit of all three sectors, producer, consumer and the trader involved in the system. In the development of the marketing system, a few basic features have to be considered. Fish handling is extremely poor and leaves much to be desired. It appears both fishermen and traders are little concerned with the losses attendant on fish quality due to poor handling. Fish land mostly without ice and are just displayed on the floor. Due to the absence of sheltered sheds in the open markets fish tend to be exposed to direct sunlight until they are sold, which reduces the quality of the product and thereby affects the price. The fishermen need to dispose of the catch quickly and they are satisfied with the present marketing system because it allows quick disposal. Though quick disposal is the essence of the operation, spoilage losses, shrinkage and pilferage inexorably adds to cost. Packing of fish by traders is still primitive and little ice is used because of the lack of ice supply especially to open markets, which are far from major centres, and to minimise the processing cost. They pack fish in wooden or fiber-glass boxes or cane baskets, which are easily subject to bacterial contamination. Quality losses affect the fish price by reducing consumer demand and thereby deprive the fishermen of income.

With regard to the trade in demersal fish in the Negombo area direct fishermen (producers) to consumer links are quite common. Direct sale of the catch to the consumer is possible because of the high local demand and the lack of obligations to sell the catch to particular local buyers. Consumers generally buy small quantities and even at auction competitive bidding will increase the price offered for small quantities. There is no doubt that selling small quantities directly to consumers is advantageous to the fishermen but consumers are selective and discriminate the catch according to their choice. This shows that the consumer is willing to purchase quality fish at a high price.

Negombo has a good reputation for producing good quality fish and this has made a high demand for Negombo fish because they do short fishing trips and land fresh fish. Thus comparison of the average purchasing prices of fish at the landing sites in the Negombo area and those at Colombo central fish market in a comparable period reveals that for most varieties, buyers and consumers in the Negombo area are paying more than the price paid by the wholesalers or consumers from the retail outlets at Colombo central fish market. This emphasis the importance of quality assurance of fish catches, and the opportunities for price enhancement.

Value addition to the catch can also be made by grading either by variety or size or both. It has been shown that the consumers discriminate fish not only by quality but also by size and variety. The price of prawn of different grades varies up to a factor of eight (personal observations). At present there is no such grading system practised in the marketing of demersal catches. The absence of such a system especially affects fish price of the handline fishery which exploit a large variety of species of a wide size range (Chapter 2) which could be graded both by size and variety. The size differences of the catches of other fisheries are not marked as for handline fishery and they can be graded according to species. This is an important opportunity to enhance the fishermen's income. It is further evident that some of the retailers sell their stocks at the same open market where they purchased and gain profits. Value addition could further be enhanced by developing packet fish for super markets for the middle class and by exploring foreign trade for squid and cuttlefish.

In the natural resource sector, because of the scarcity of the resources, marketing pressures influence the exploitation of these resources and may present major constraints upon the achievement of sustainable development. Fish provide income not only to fishermen but also to traders. Fisheries management therefore must identify means and measures to offset these market forces which otherwise might have serious implication on the sustainability of resources. In all these systems, fish price is the critical factor. Price reflects the relative scarcity of resource and changes in response to variation in supply and demand. Price therefore, is a market force, which could be used to support management objectives. The price instability inherent in auction and beach markets sales can be reduced by increasing market transparency, information and measures which allow control of the quantity of the product in the market at a given point in time. The diffusion of price information is of specific relevance in order to increase competition particularly in open markets but there is no such a system available to communicate marketing information where open markets are scattered and far from major centres

Chapter 8

Socio-Economics of Fishing Households

8. 1 INTRODUCTION

Development of demersal fisheries in the Negombo area over the past two decades has been associated with increased extractive capacity (Weerasooriya, *et al.*, 1985; Maldeniya, 1997). The social effects of these developments have been largely neglected compared with biology of harvesting or economics of exploitation. These development activities were borne out of the perception of open access, which has lead to a rapid increase in fishing effort with modern efficient technology that has resulted in traditional fishermen competing on unequal technical terms for limited resources. In this situation, the resource base has become overfished and economically a dualism has developed as modern efficient fisheries attempt to co-exist with traditional fisheries.

Implementation of management measures based only on bio-economic assessment would not consider the impact of regulatory actions on the livelihood of fisherfolk. Socio-economic studies integrated with stock assessment and economics of fishery resources exploitation have thus been given a higher priority in the context of fisheries management in recent years, mainly in developing countries (Bailey *et al.*, 1987, Smith *et al.*, 1980, Paul, 1987). The integration of these components provides a better picture how the management strategies affect the livelihood of fisherfolk and provide additional benefits in the interpretation of the well being of fishing communities. Application of socio-economic research to improve fisheries development and management is not a common feature in Sri Lanka. Research activities have only recently began to shed some light on the socio-economic aspects of fishermen and fishing communities (Dayaratne and Sivakumaran, 1994; Dayarantne *et al.*, 1997; Vidanage and Wimalasena, 2000).

The main objective of this chapter is to generate baseline information on social and economic conditions of fishing households engaged in demersal fisheries in the Negombo area, particularly their socio-demographic profile and employment, income and income distribution characteristics, expenditure, investment pattern, debt and liabilities, in order to identify the important socioeconomic issues of concern for the management of the fisheries.

8. 2 MATERIALS AND METHODS

Social data of boat owners were collected together with economic data and the crew members social data were separately collected through the use of another questionnaire during the same period from March to December 1999. Both questionnaires consisted mostly of closed questions. The English draft was translated into Sinhalese, pre-tested outside the sampled settlements, and then modified and improved. All the information was recorded in Sinhalese. Information on all expenditure was gathered in monetary terms. The amount of expenditure and income was collected on a monthly basis and the annual expenditure and income were constructed assuming there was no monthly variation in values of expenditure and income.

As explained in Chapter 6 the same 5 villages in 2 divisional secretariats of Negombo DFEO (District Fisheries Extension Office) area were selected for sampling to represent all technologies, marketing patterns, ethnic composition and religious affiliations involved in demersal fisheries in Negombo area. Households were sampled from Kuttiduwa, Pitipana, Palagathurai, Kammalthota and Hedala, including both boat owners and crew members on a random basis as respondents to provide information on the socio-economics of households. More than 70% of the fishermen engaged in demersal fisheries live in these 5 villages. A total of 233 households were sampled of which 45.5% belonged to boat owners and 54.5% belonged to crew members. These provided a reasonable representation (8%-25%) of different boat/gear combinations involved in demersal fisheries in the area. The number of households sampled by boat/gear combination is listed in Table 6. 1.

The basic unit of analysis is the household by boat/gear combination. The standard of living was measured by income, saving and expenditure on food as a proportion of total expenditure, known as the Engel's coefficient. Engel's coefficient was estimated as,

Engel's coefficient = [Total food expenditure/ Total household income]$\times$ 100

Where, total food expenditure = food expenditure + fish share for consumption (non-cash income from fishing) + food stamp (National welfare)

The larger the percentage of total expenditure going to food, the poorer the household is considered to be. As the measure of living standard the net household income from all sources (fishing and non-fishing) and in all forms (cash and non-cash) whether earned by the head of household or other family members was used. The proportion of expenses and savings were assessed in relation to the disposable income. As the boats operating in demersal fisheries in the area seasonally change the target fishery and in some households more than one member has been engaged in income generation, the annual average disposable income (fishing income) was obtained through interviews. It was however noted that the average disposable income reported by the households which depend only on fishing was close to the income values estimated for different boat/gear combinations in Chapter 6.

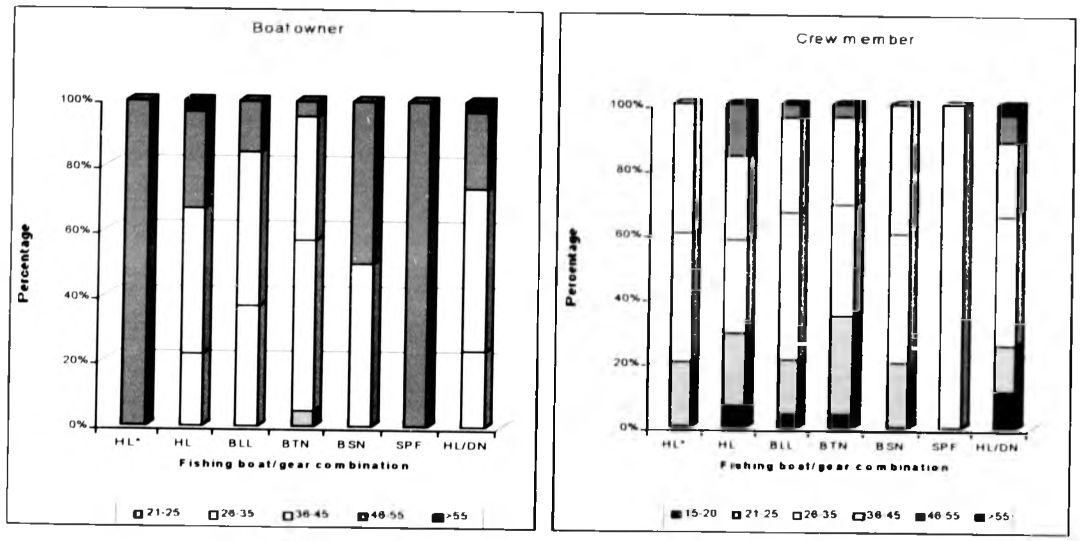
The following methodology was adopted to establish the linkage between bio-economic and socioeconomic findings.

- The stratification for the bio-economic sampling was also applied to the socioeconomic survey of the households, including income distribution.
- The average annual net cash income (average annual disposable income), expenditure and savings were estimated by different boat/gear combination.
- Income from particular boat/gear combinations was correlated with income from fishery related and /or non-fishery activities of each category of household.

8. 3 RESULTS

8. 3. 1 Socio-Demographic Profile

The age of the boat owners in the sample varied from 24 years to 58 years. The average age was 40 years and varied among the technology used but the majority of them were between 26-45 years (Fig. 8.1). The highest age of 58 years was reported of a boat owner operating handline fishing with OBM boats while the lowest age (24 years) was reported in the bottom trammel net fishery. Except for bottom trammel net fishery boat owners engaged in all other demersal fisheries were above 26 years. The boat owners who were above 55 years of old but still engaged in fishing were reported from handline fishing with OBM boats and handline fishing combined with drift gillnets. Crew members are younger than the boat owners, with an average age of 33 years. Their age ranged from 16 to 57 years but the majority of them were between 26-35 years. The young recruits to the fishing industry represent the age group of 15-20 years and were reported in handline fishing with OBM boats, bottom longline, bottom trammel net and handline fishing combined with drift gillnet while the oldest age group (> 55years) was reported in handline fishing combined with drift gillnet. There was little difference in the average age of the crew members engaged in different fisheries (Fig. 8.1).

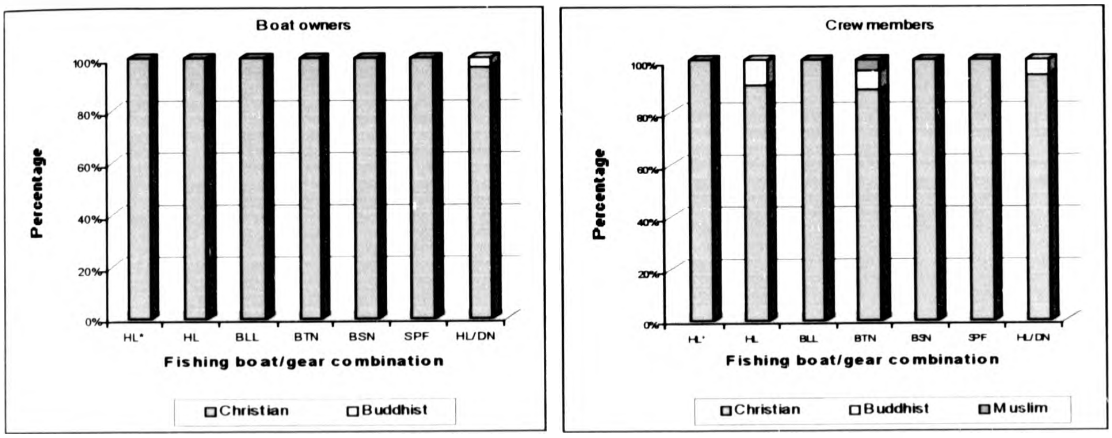


Note: sample size of both boat owners and crew members by different boat/gear combinations are as Table 6.1.

Fig. 8.1 Age profile of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

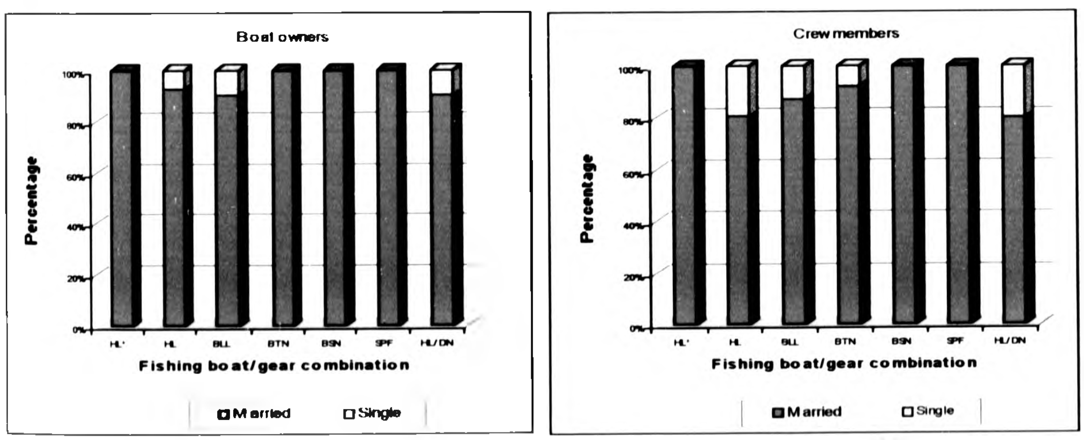
Of the 106 boats owners sampled, almost all of them were Christian and the sample of 127 crew members 94% were Christians and a few Buddhist (6%) and Muslims (<1%) (Fig. 8.2). Buddhist and Muslims were engaged in handline combined with drift gillnet fishing, bottom trammel net and handline fishing with OBM boats.

When considered their civil status, the majority of boat owners were married (93%). Among crew members the number of unmarried members was higher than boat owners (Fig. 8.3). On average 86% of the crew members sampled were married.



Note: sample size of both boat owners and crew members by different boat/gear combinations are as Table 6.1.

Fig. 8.2 Boat owners and crew members belong to different religion engaged in demersal fisheries in Negombo in 1999

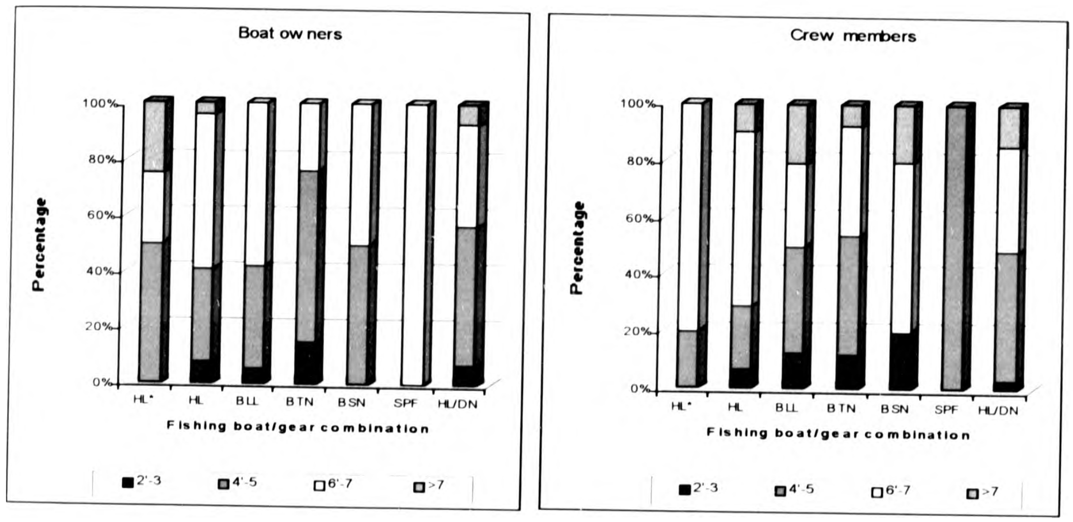


Note: sample size of both boat owners and crew members by different boat/gear combinations are as Table 6.1.

Fig. 8. 3. Civil status of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

HL*= Handline fishing with inboard engine (IBM) boats, HL=Handline fishing with outboard engine (OBM) boats, BLL= Bottom longline fishing with OBM, BTN= Bottom trammel net fishing with OBM boats, BSN= Bottom set gill net fishing with OBM boats, SPF = Spear fishing with OBM boats, HL/DN = handline fishing combined with drift gill net fishing with OBM boats.

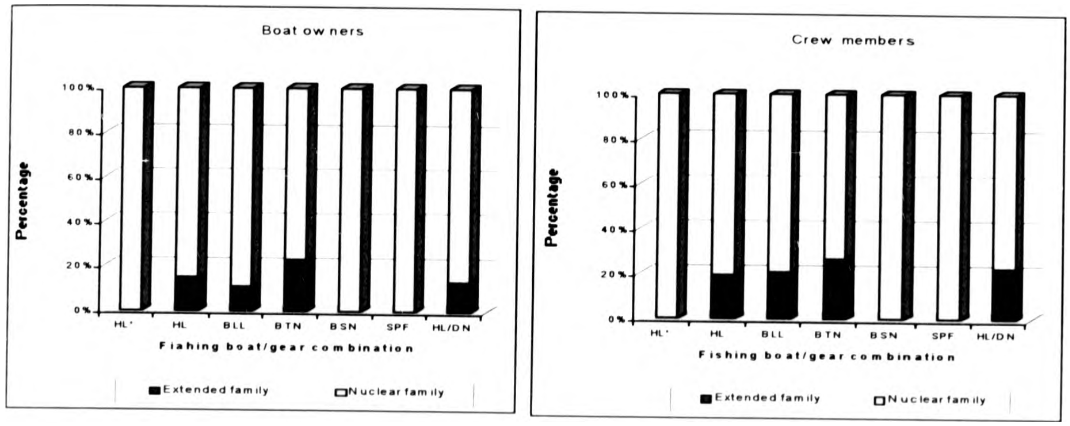
The size of the boat owner's family varied from 2 to 9 members and the average was 5.3 members per family. The lowest average family size was reported among households engaged in bottom trammel net fishing while the highest average was reported among handline fishing operate with IBM boats and handline combined with drift gillnet fishing (Fig. 8. 4). The crew members family size was slightly larger than boat owners, about 5.7 members per household and the number varied from 2-11 (Fig. 8. 4).



Note: sample size of both boat owners and crew members by different boat/gear combinations are as Table 6.1

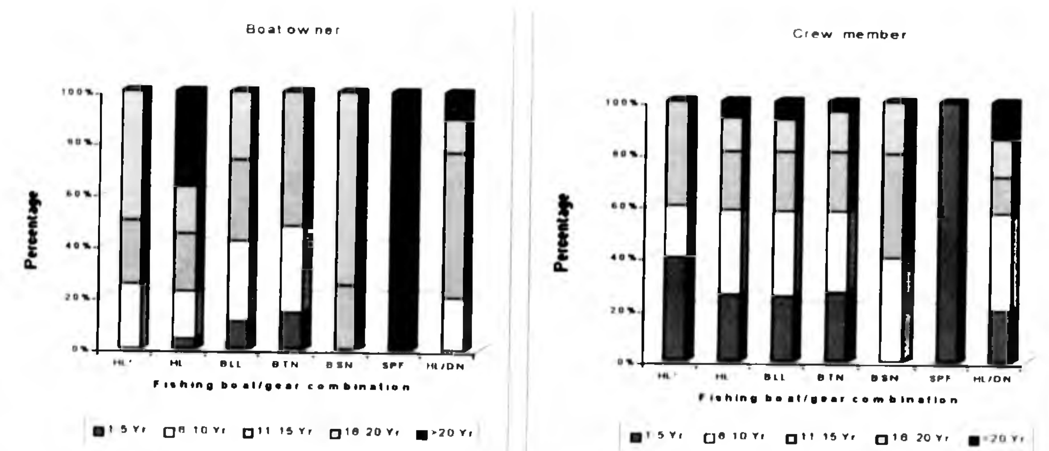
Fig. 8.4. Family size of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

The majority of boat owners (86%) and crew members (80%) live in their own house (nuclear family) and only a few of them live with their relatives (extended family) (Fig 8.5). The boat owner's participation in fishing activities was 100% in all boat/gear combinations. They have considerable years of experience in fishing. Some of them have devoted more than half of their life time (about 32 years) to this occupation. On average most of them have 15 years experience in fishing. The highest average experience of demersal fishing was reported by the boat owners engaged in spear fishing and handline fishing with OBM boats (Fig. 8. 6). The crew members have somewhat less experience in their occupation. On average most of them have 6-10 years of fishing experience. The crew members engaged in modern fishing methods were relatively less experienced than crew members engaged in handline (bait cage handline or drop handline fishing) fishing with OBM boats.



Note: sample size of both boat owners and crew members by different boat/gear combinations are as Table 6.1

Fig. 8.5. Family status of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

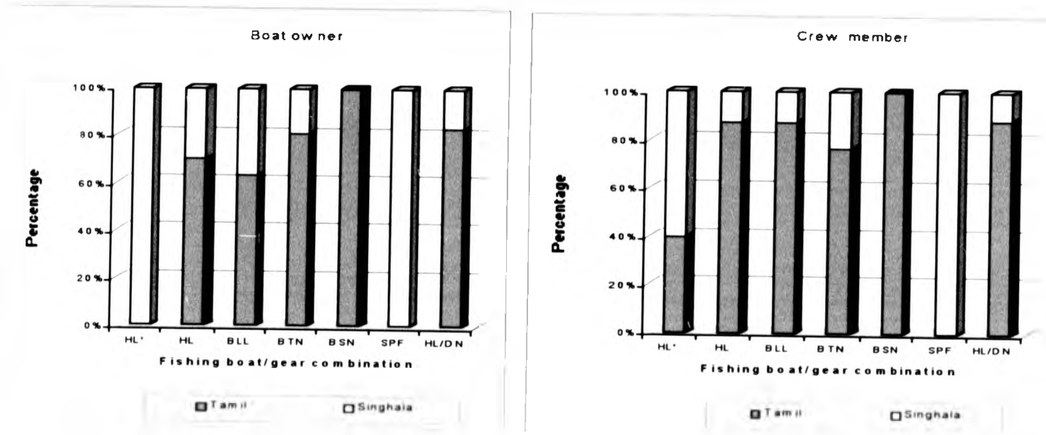


Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig. 8. 6. Year of fishing experience of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats

The majority of boat owner's (73%) mother tongue is Tamil while 83% of the crew members interviewed speak Tamil and the rest speak Sinhala (Fig. 8.7). All the boat owners sampled had ownership of a single boat.



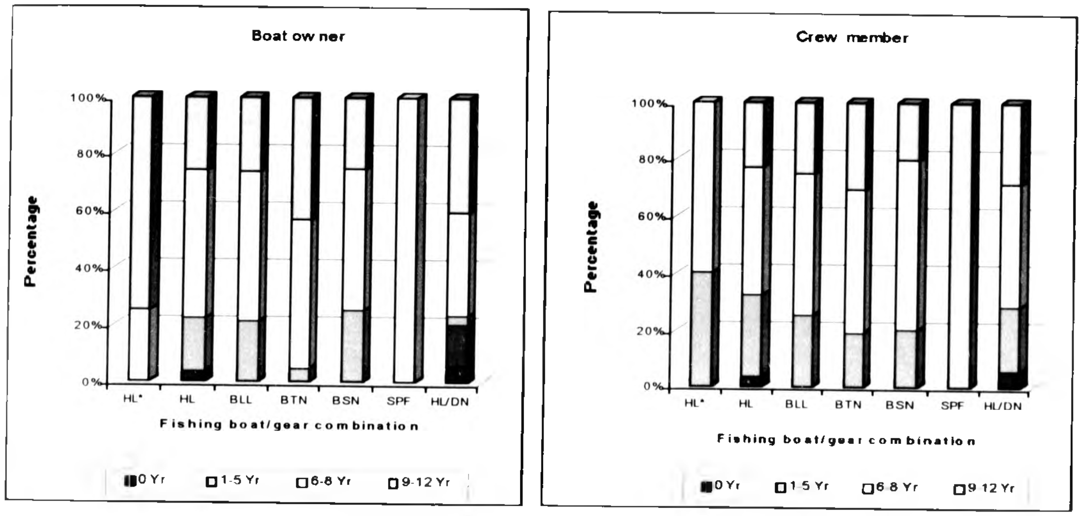
Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig. 8. 7. Mother tongue of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

HL* Handline fishing with inboard engine (IBM) boats. HL Handline fishing with outboard engine (OBM) boats. BLL Bottom longline fishing with OBM. BTN Bottom trammel net fishing with OBM boats. BSN Bottom set gill net fishing with OBM boats. SPF Spear fishing with OBM boats. HL/DN handline fishing combined with drift gill net fishing with OBM boats

8. 3. 2 Literacy and Education Attainment

The term literacy implies the ability of people to read and write a language. A person who can write their name and address and read and understand a newspaper was considered literate. All the boat owners are literate. Except for seven in the sample all have received formal school education (Fig. 8. 8). Among them only 12% have only had primary education and about 49% have attained up to 5-8 years of secondary education while 32% of them have gone to tertiary school education level (9-12 years). The high educational attainment of boat owners was particularly evident among bottom trammel net and handline fishing combined with drift gillnets operators. Among crew members sample only 3 members did not obtain formal secular education but all members are literate. The level of education attained by crew members was similar to boat owners (Fig. 8. 8). On average about 26% acquired 9-12 years formal tertiary education or reached at least 2 years of high school (tertiary education) and over 47% have secondary education. The lowest level of schooling was found among the crew members engaged in handline fishing with IBM boats. The average educational attainment of both boat owners and crew members was above the national average in all levels (Fig. 8.9).



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1

Fig. 8.8. Education attainment of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

The present study clearly shows that a substantial number of boat owners as well as crew members engaged in demersal fisheries in the Negombo area have progressed beyond primary education. In Sri Lanka school education is free to the public. The fishing villages are close to the city centres. Thus the fishermen have taken this advantage to educate themselves to some extent.

In addition to school education all boat owners have technical skills, mainly in fishery related activities. Boat owners were more technically competent than crew members and most of them have skills in engine repairing and gear rigging. Thus they can save the labour cost of engine and gear repairing and rigging. One of them has formal fisheries training obtained from the Fisheries Training Institute at Negombo (Fig. 8. 10). Except for a few, the technical skills of crew members were also at a high level.

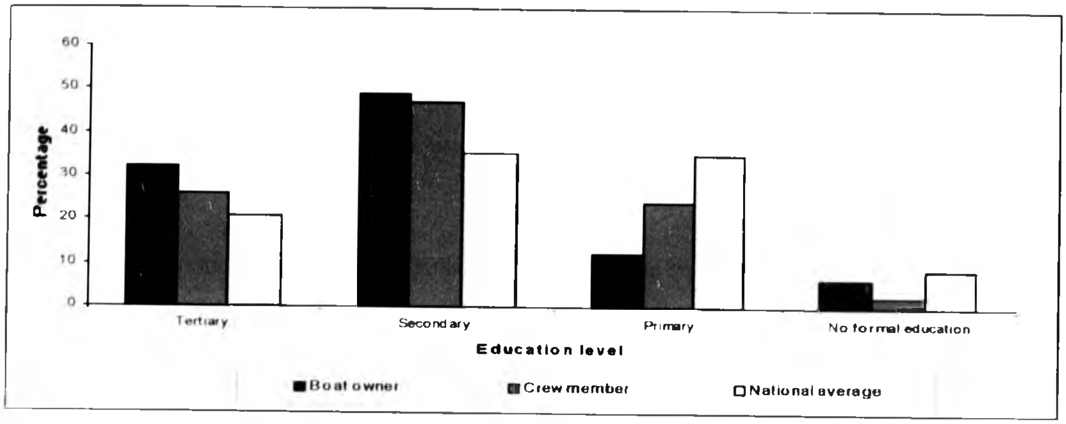
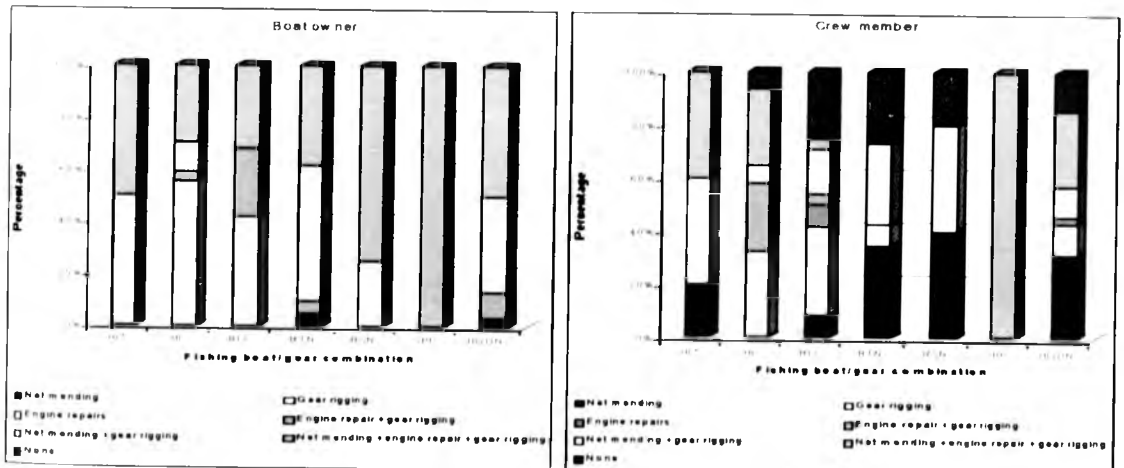


Fig. 8.9. Average educational attainment of boat owners and crew members engaged in demersal fisheries in Negombo in 1999 and the national average of educational attainment.



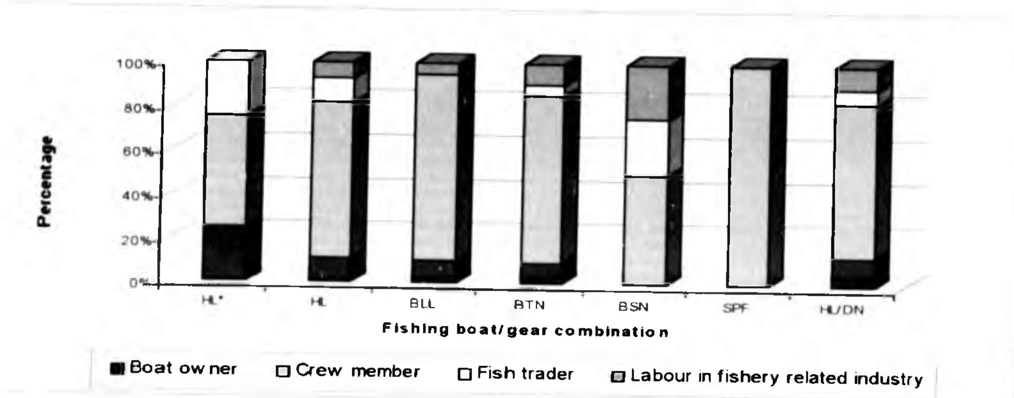
Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig. 8. 10. Skills of boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

HI*: Handline fishing with inboard engine (IBM) boats, HI: Handline fishing with outboard engine (OBM) boats, BLL: Bottom longline fishing with OBM, BTN: Bottom trammel net fishing with OBM boats, BSN: Bottom set gill net fishing with OBM boats, SPF: Spear fishing with OBM boats, HL/DN: handline fishing combined with drift gill net fishing with OBM boats.

8. 3. 3 Career Development of Boat owners

Over 72% of the boat owners sampled started their career as a crew member. In addition some of them, about 11% of the total sample, directly entered with the ownership of boat and gear, while others started their career as a fish seller or hired labour in fishery related industry. Relatively higher numbers of crew members have become the boat owners engaged in bottom longline or bottom trammel net fishing (Fig. 8. 11) which indicates the profitability of these fisheries.



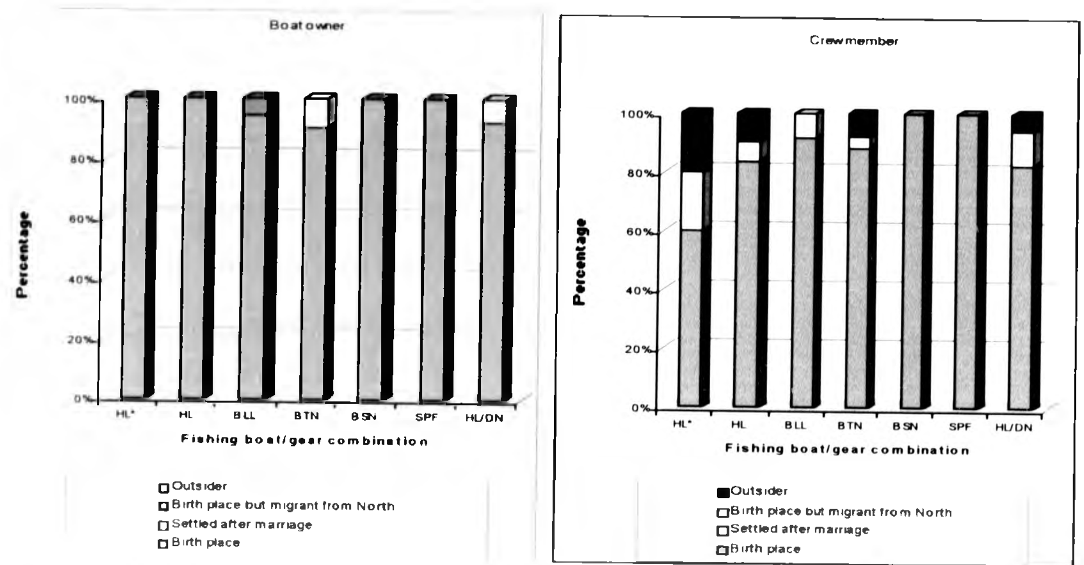
Note: sample size of both boat owners by different boat/gear combination are as Table 6.1.

Fig. 8.11. Career development of boat owners engaged in demersal fisheries in Negombo 1999.

HL*= Handline fishing with inboard engine (IBM) boats, HL=Handline fishing with outboard engine (OBM) boats, BLL= Bottom longline fishing with OBM, BTN= Bottom trammel net fishing with OBM boats, BSN= Bottom set gill net fishing with OBM boats, SPF = Spear fishing with OBM boats, HL/DN = handline fishing combined with drift gill net fishing with OBM boats.

8. 3. 4 Relationship to the Fishing Area - Negombo

Negombo area is the birthplace of the majority of boat owners as well as crew members. On average over 92% of boat owners and 86 % of crew members sampled gave their birth place as Negombo (Fig. 8.12). A few of them were settled after marriage or migrated from the east coast but their birthplace was Negombo. No outsiders were reported among the boat owners but there were few outsiders working as crew members.



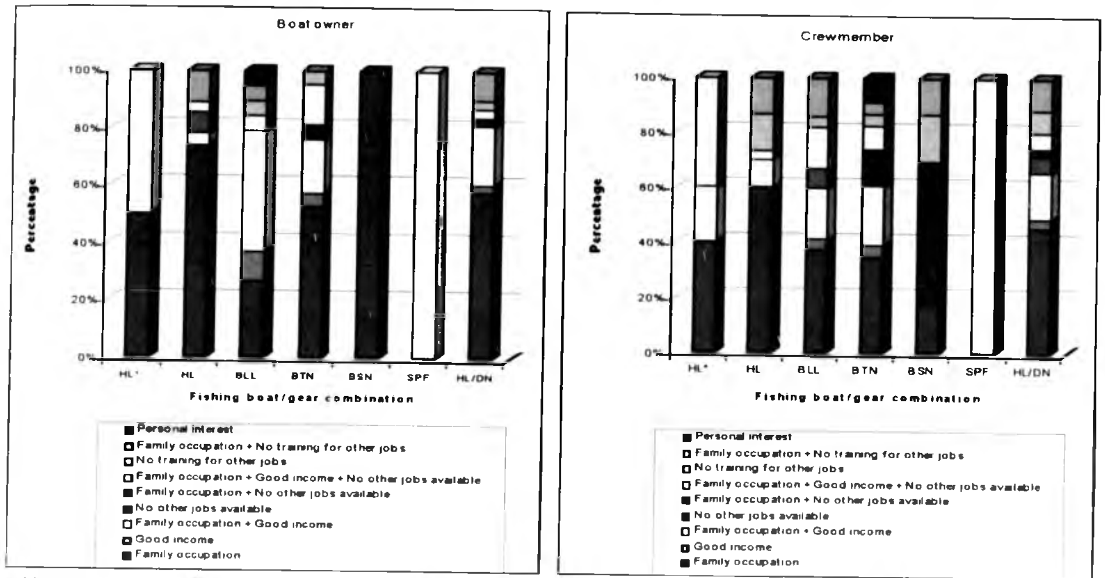
Note sample size of both boat owners and crew members by different boat/gear combination are as Table 6 1

Fig 8 12 Relationship of boat owners and crew members to the fishing area, Negombo

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats

8. 3. 5 Selection of Fishing as a Vocation

The majority of the boat owners interviewed have stated that they selected fishing because it is their family occupation while another substantial number of owners stated that they selected fishing because it is their family occupation as well as a good income source. However, some of them realized that their lack of formal education disqualified them from other employment. On average only 3% were expressed concern about the inadequacy of available jobs and about 1% selected fishing for personal interest. The majority of boat owners as well as crew members engaged in handline fishing with OBM boats expressed their dissatisfaction with the fishing income and stated that they continue fishing as it is their family occupation and they have a lack of skills with other fishing gears (Fig 8 13). The boat owners engaged in spear fishing, bottom longline fishing, bottom trammel net fishing and handline fishing with IBM boats generally expressed satisfaction with the income they received from fishing and this confirms the economic assessment of different fisheries (Chapter 6).



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1

Fig. 8. 13 Selection of fishing as a vocation by boat owners and crew members engaged in demersal fisheries in Negombo in 1999.

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats

A relatively lower percentage (85%) of crew members than boat owners (91%) have come from fishing families. The crew members engaged in bottom longline, bottom trammel net and seasonal handline fishing conducted with IBM boats generally expressed satisfaction with their present fishing income (Fig. 8. 13). Some of them, mainly crew members engaged in handline fishing with OBM boats complained that no adequate alternative jobs were available in and around the area while others realized that the lack of educational qualifications limited their occupational opportunities.

8. 3. 6 Labour Hiring Relations

Crew members in most instances were related to boat owners. In the sample, about 60% of the crew members were either boat owners' sons or relatives (Table 8. 1). Some of them were friends or neighbours and only a few were unrelated.

Table 8. 1. Relationship of crew members to boat owner in 1999

% Relationship				
Son	Relative	Friend	Neighbour	No relationship
24.4	34.6	15.7	12.6	12.6
Sample size	127			

8. 3. 7 Household Occupational Structure

In most of the fishing households only the headman was engaged in income generating activities. On average 66% and 73% of the households of boat owners and crew members respectively depended only on the headman's income (Fig. 8. 14). About 19% of spouses of boat owners and 12% of spouses of crew members were engaged in income generating activities. In addition to the headman or his wife and other house members, especially children (15%), were also engaged in different occupations in both boat owners and crew members' households. In the present study one house was found with all three *i.e* headman, spouse and family members engaged in income generating activities

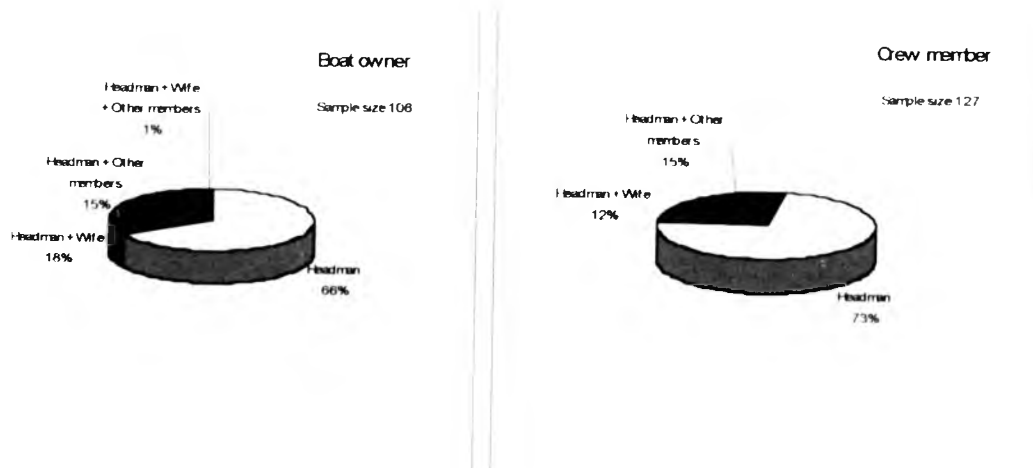


Fig. 8. 14. Occupational structure boat owners and crew members households engaged in demersal fisheries in Negombo in 1999

8. 3. 8 Participation of Women in Economic and House Keeping Activities

Table 8. 2. Women participation in economic activities.

Employment structure	Sample size	% contribution Boat owner's wife	Sample size	% contribution Crew member's wife
Fish marketing	2	1.9	2	1.6
Fish processing	2	1.9	0	0.0
Money lending	1	0.9	0	0.0
Factory worker	6	5.7	7	5.5
Other self employment	5	4.7	4	3.1
Housemaid in Middle East	3	2.8	2	1.6
House wife	87	82.1	112	88.2
Total	106	100.0	127	100.0

The majority of wives of both boat owners and crew members are house wives but assist them as unpaid family labour in selling the catch, processing, cleaning nets etc. Among working women only a few of them engaged in fishery related activities as an income generating occupation. A number of spouses were working in factories in nearby areas and a few were working as house maids in Middle East countries (Table 8. 2).

8. 3. 9 Occupation Structure of Headmen

The boat owners and crew members are mainly engaged only in fishing (Table 8. 3). However, a few of them undertake a variety of ancillary occupations in addition to fishing, including fishery related activities, or other business.

Table 8. 3. Occupational structure of headmen

Employment structure	Sample size	Boat owner % contribution	Sample size	Crew member % contribution
Fishing only	97	91.5	114	89.8
Fishing + other fishery related activity	4	3.8	6	4.7
Fishing + other business	5	4.7	7	5.5
Total	106	100.0	127	100.0

8. 3. 10 Ancillary Economic Activities of Headman

The ancillary economic activities of headman of fishing households are listed in Table 8. 4. Among fishery related activities, fish processing, boat engine and gear repairing are the most important. Relatively few boat owners engaged in these activities as an income source but some crew members undertook these activities.

Table 8. 4. Ancillary economic activities of headmen.

Vocation	Sample size Boat owner	Sample size Crew member
Fish processing	1	-
Supply of fish to hotels	2	-
Distillation of illicit liquor	-	1
Ferrying tourists	1	-
Engine repairing	2	-
Gear repairing	-	5
Animal husbandry	2	1
Motor bicycle repairing	1	-
Unskilled labour	-	6
Total	9	13

The boat owners engaged in a variety of other businesses. Some of them were supplying fish, mainly squid and cuttlefish, to nearby tourist hotels and guest houses while others engaged in technical vocations such as motorcycle engine repairing. One was running a small piggery. Crew members mostly engaged in temporary unskilled labour jobs.

8. 3. 11 Economic Activities of Other Family Members of Fishing Households

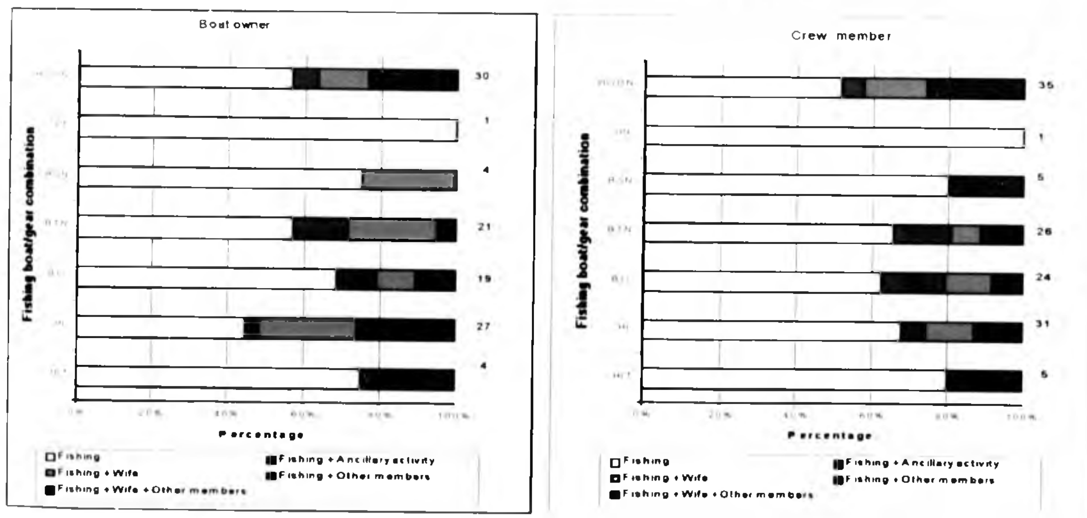
Other family members of both boat owner's and crew member's are mainly engaged in fishing (Table 8.5). The family members of boat owner's generally work as a crew member of their own boat and in crew member's family members work with different parties engaged in fisheries. It was noted that family members of both boat owners and crew members engaged in bait cage hndline fishing with OBM boats and handline fishing combined with drift gillnets were mostly engaged in fishing while family members of boat owners and crew members engaged in trammel net and bottom longline were engaged in salaried jobs either as hired labour or in Government service.

Table 8. 5. Economic activities of family members other than household heads and wives.

Occupation	Sample size	% contribution Boat owner's family members	Sample size	% contribution Crew member's family members
Fishing	13	76.5	14	73.7
Hired labour	2	11.8	4	21.1
Government service	2	11.8	1	5.3
Total	17		19	

8.3.12 Total and Disposable Income and Income Distribution of fishing Households

The annual average disposable household income of boat owner's and crew member's vary between boat/gear combination used in demersal fisheries as well as with the number of members engaged in income generating activities. The profile of the number of members involved in income generating activities of boat owners and crew members engaged by different boat/gear combinations are given in Fig. 8. 15.



Note: sample size by different boat/gear combination are indicated in the figure.

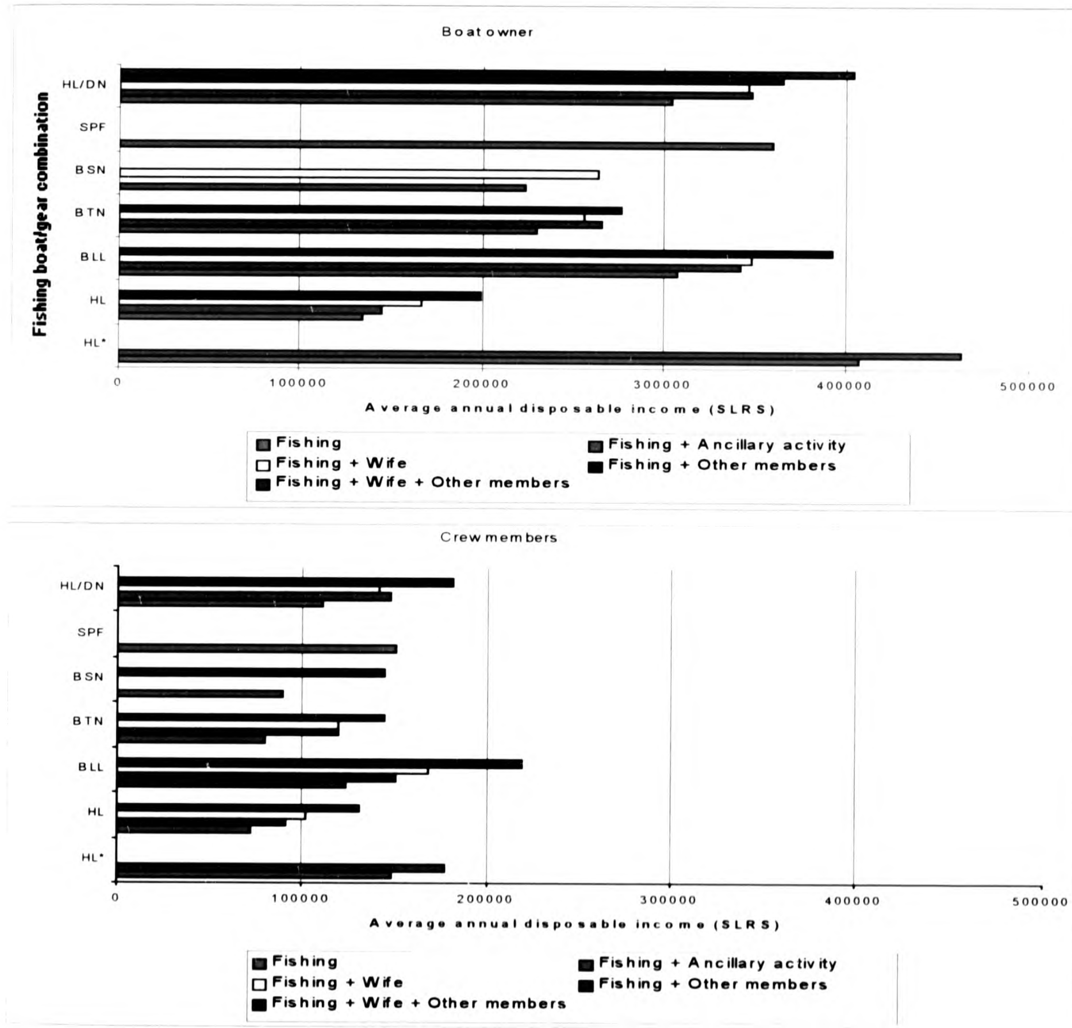
Fig. 8. 15. Number of members engaged in income generating activities in boat owners and crew members household in Negombo in 1999.

The highest proportion of average number of members involved in income generation was reported in both boat owners and crew members households engaged in handline fishing with OBM boats and handline combined with drift gillnet and the lowest was from households engaged in spear fishing and handline fishing with IBM boats. On an average in the boat owners and crew members households about 1. 4 and 1.3 members engaged in income generation respectively.

The majority of boat owners (58%) and crew members (63%) households depend only on fishing income. A high proportion of headman engaged in ancillary activities were reported from both boat owners and crew members engaged in handline fishing with IBM boats, bottom trammel net and bottom longline fisheries while low proportion was reported from both boat owners and crew members engaged in handline fishing with OBM boats and handline fishing combined with drift gillnets. The participation of spouses in income generation was high in the boat owners households engaged in handline fishing with OBM boats, bottom longline and bottom trammel net fishing while in the crew members households engaged in handline fishing with OBM boats, bottom longline and handline combined with drift gillnets. The other members participation in income generation was high among the boat owners and crew members households engaged in handline fishing with OBM boats and handline fishing combined with drift gillnets. Only one boat owners household was reported with both wife and other members of the family engaged in income generating in addition to the house headman.

The annual average disposable income distribution patterns of boat owners and crew members households engaged in different fisheries are shown in Fig. 8. 16. The annual average income generated by boat owners through fishing varied from Rs. 133,000 to Rs. 410,000. The highest average amount was reported from households engaged in seasonal handline fishing with IBM boats and the minimum was from households engaged in handline with OBM boats. In addition to fishing through ancillary activities they earned monthly income of Rs. 1,500 to Rs 7,000. Generally people who supplied fish to the tourist hotels and guest houses in nearby areas received the highest extra income. The annual average income generated through ancillary activities varied from Rs. 11,000 to

Rs. 54,000 or 8-16% of their disposable fishing income. The maximum ancillary income was earned by boat owners engaged in bottom trammel net fishing because they were engaged in supplying fish to the tourist resorts. The minimum was earned by the boat owners of handline fishing with OBM boats.



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig. 8. 16. Average annual disposable income of boat owners and crew members fishing households engaged indifferent boat/gear combination in 1999.

The income generated through ancillary activities in the crew members households varied from Rs. 19,000 to Rs. 38,000 or about 19-47% of the disposable fishing income. The maximum average ancillary income was generated by crew members engaged in bottom trammel net fishing because one crew member engaged in distilling of illicit liquor and his income was much higher than the fishing income. The minimum was reported by crew members of handline fishing with IBM boats.

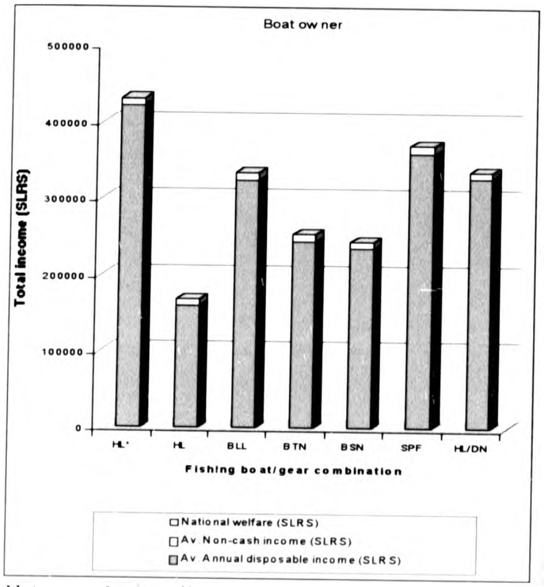
The fishermens' wives who work as hired labour in factories or as housemaids in the Middle East draw Rs. 2,500 – Rs. 7,000 as a monthly salary while the self employed women earned between Rs. 1,200 – Rs. 3,500 per month. The annual average disposable income generated by spouses of boat owners varied from Rs. 27,000 to Rs. 43,000. This improved the boat owners household income by about 12-25% than the fishing income. The maximum average disposable income was reported from households engaged in handline fishing with OBM and the lowest from bottom trammel net fishing. The contribution of spouses to the total disposable income of crew members households were considerable. It varied from Rs 29,000 to Rs 44,000 per annum and was about 27% to 40% of the income generated by fishing. The maximum contribution was reported by the households engaged in bottom trammel nets and handline fishing with OBM boats and the minimum was reported from households engaged in handline combined with drift gillnet fishing.

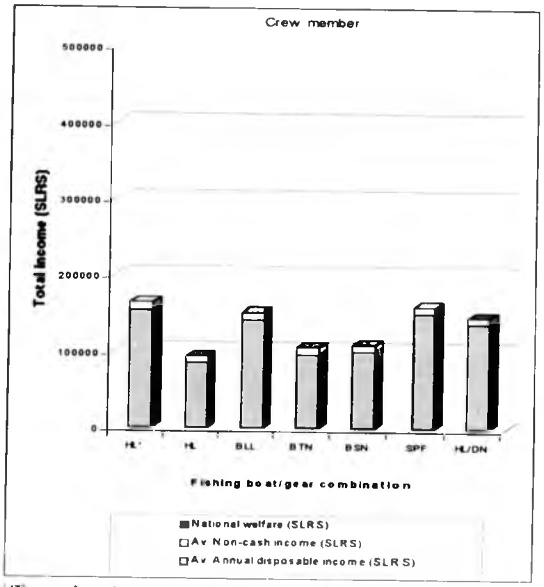
The contribution to the households annual disposable income of boat owners by other members varied between Rs. 46,000 to Rs. 66,000 and it was about 20% to 49% of the fishing income of the households. The maximum income was reported by the members of the households engaged in handline fishing with OBM boats and the minimum was reported from the household of bottom trammel nets and handline combined with drift gillnets. The other members contribution to the total disposable income of crew members households were considerable because most of them were engaged in fishing and made a relatively high contribution. It was also found that some household members are soldiers in the Sri Lanka Army. Their contribution varied from Rs. 54,000 to R. 95,00 or 60-80%

of the fishing income of headman. The maximum annual average income from participation of other members were earned by the households engaged in bottom longline fishing and the minimum by the households engaged in bottom set gillnet fishing. The boat owners household where all three members engaged in income generation received an additional annual income of Rs. 101,000 or 33% higher income than fishing alone. It is very clear that on average more people were engaged in income generating activities in the households engaged in handline fishing with OBM boats to compensate for the lower fishing income.

The total annual household income was the income they get from all sources either in cash or in kind. They get fish for consumption after every fishing trip and some of the households get national welfare food stamps. However, national welfare is only granted for the households who get a monthly income of less than Rs. 3,000 (below poverty level) to uplift the social standards of the poor. The annual average total income of boat owners and crew members engaged in different fisheries are given in Fig. 8. 17.

The maximum average total income was reported from the households engaged seasonally in handline fishing with IBM boats. It is not surprising as these boats engaged in prawn trawling for about 8-9 months and prawns have a more lucrative market than fish. Though more members engaged in income generating activities the minimum total average income was reported from households engaged in handline fishing with OBM boats. None of the boat owners sampled received any national welfare assistance 'Samurdhi' (food stamps). Thus the disposable income is not much different from total income. On average boat owners' households received annual total income and disposable income of Rs. 277,012 and Rs. 267,991 respectively. In the crew members' households the average total annual income varied between Rs. 94,000 to Rs. 164,000. As for the boat owners' household income the maximum total annual income was reported from those engaged in seasonal handline fishing with IBM boats and the minimum for traditional handline fishermen operating with OBM boats.





Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1

Fig. 8.17. Average annual total income of boat owners and crew members engaged in demersal fishing with different boat/gear combination in Negombo in 1999.

8. 3. 13 Expenditure

The average annual boat owners' household expenditure varied from Rs 113,000 to Rs 251,000 that is about 58% to 71% of the total annual household disposable income (Fig. 8.18). The maximum level of expenditure (Rs. 251,000) was reported of the boat owners' households engaged in seasonal handline fishing with IBM boats and the lowest (Rs. 113,000) was for handline fishing with OBM boats. But the highest proportion of income to expenditure was reported from the boat owners' households engaged in handline fishing with OBM boats followed by bottom set gillnetting and bottom trammel net fishing and the lowest was reported by households engaged in spear fishing and bottom longline fishing. On average boat owners' households spend about 66% of their disposable income.

The crew members average annual household expenditure varied from Rs 80,000 to Rs 126,000 (Fig. 8.18). As for the boat owners' households the highest household expenditure of the crew members (Rs. 126,000) was reported from fishermen engaged in seasonal handline fishing with IBM boats while the lowest (Rs. 81,000) was reported by crewmen who operated handline fishing with OBM boats. However, the highest proportion of disposable income to expenditure was reported from boat owners' households engaged in handline fishing with OBM boats (95%) and bottom set gillnet fishing (94%) and the lowest (72%) was reported from crew members engaged in spear fishing. On average crew members' households spent 86% of the disposable household income from all sources.

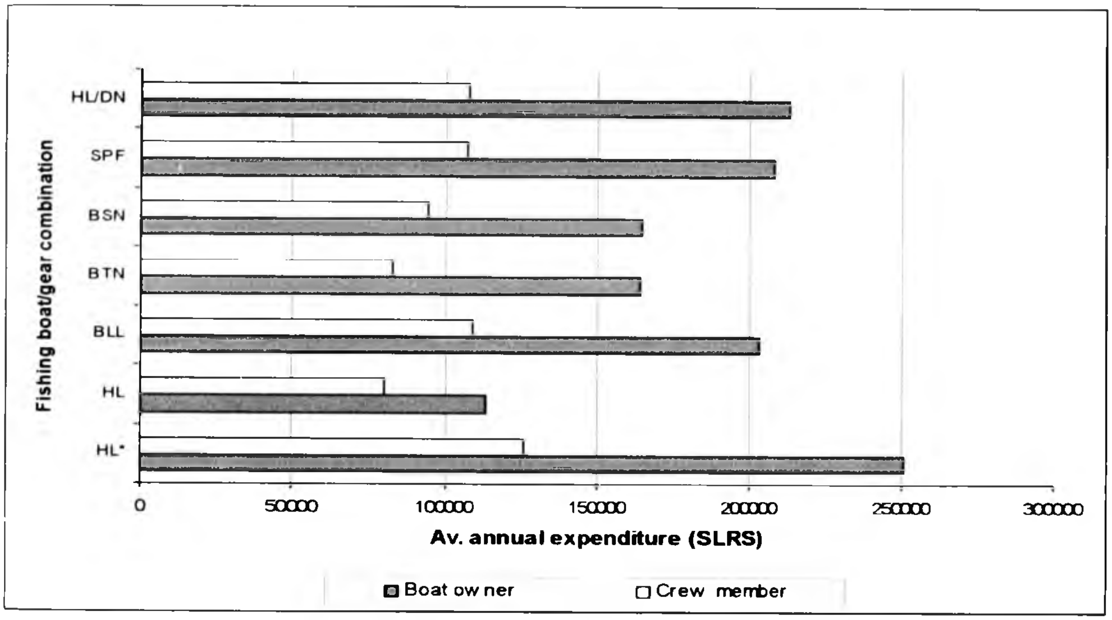
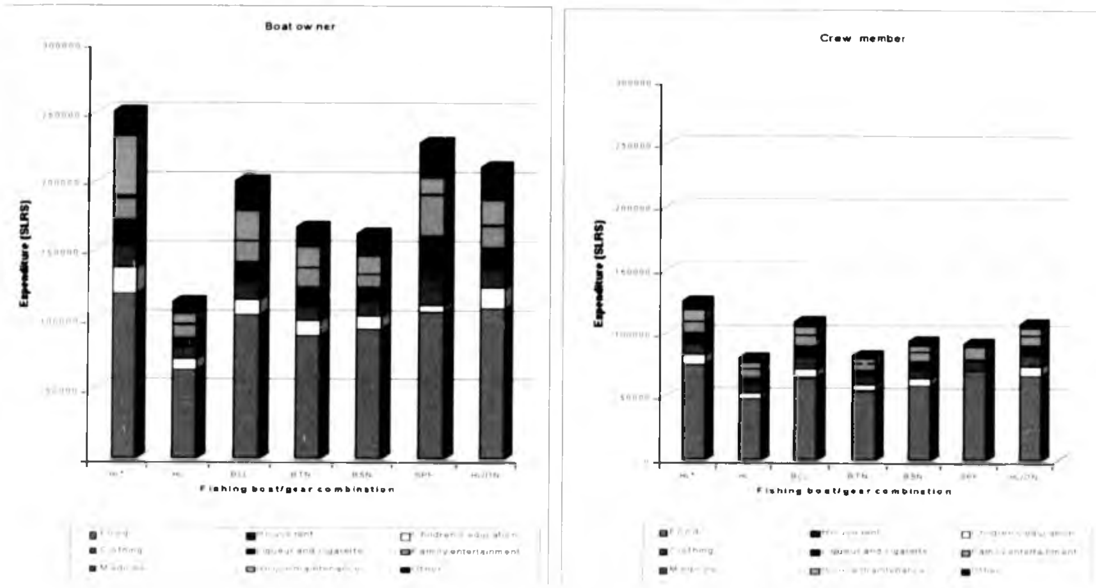


Table 8. 18. Annual average expenditure of boat owners' and crew members' households engaged in demersal fisheries by different boat/gear combination in Negombo during 1999

HL* Handline fishing with inboard engine (IBM) boats. HL Handline fishing with outboard engine (OBM) boats. BLL Bottom longline fishing with OBM. BTN Bottom trammel net fishing with OBM boats. BSN Bottom set gill net fishing with OBM boats. SPF Spear fishing with OBM boats. HL/DN handline fishing combined with drift gill net fishing with OBM boats.

The annual expenditure spent on different items by the boat owners and crew members are given in Fig. 8. 19.



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig.8.19. Average annual expenditure by different items of boat owners and crew members households engaged in demersal fishing by different boat/gear combinations in Negombo in 1999.

Food expenditure was the highest single item in all households sampled (Fig. 8. 19) but the structure of expenditure shows a relatively high share of other consumer non-durable items. Most of these are personal expenditures, most noticeably on clothing, liquor, cigarettes and family entertainment. This is common to both boat owners and crew members households. The proportion of expenditure devoted for children's education was highest among boat owners engaged in seasonal handline fishing with IBM boats and handline fishing combined with drift gillnets and lowest among the boat owners of bottom longline fishing and bottom set gillnets. On average 22% of the annual expenditure of boat owners' households was for purchasing clothing, liquor, cigarettes and family entertainment. No boat owner interviewed paid house rent. They either have their own house or live with relatives.

In crew members' households the highest proportion of income was spent on childrens' education by fishermen engaged in handline fishing combined with drift gillnets, handline fishing with IBM boats and bottom set gillnets and the lowest proportion was reported from bottom trammel net fishing crew members households. On average crew members' household spend 5.7% of their expenditure on children's education and 23% on clothing, liqueur and cigarette and family entertainment. Of the 127 crew members' households interviewed 8 were found in rented houses. Others live in their own house or with their relatives. The expenditure spent on medicine was minimal in both boat owners and crew members households because heath care in Sri Lanka is free for the public. It is unfortunate that there is no information available on average annual expenditure in the comparable period for other sectors or the national average to compare with this data.

8. 3. 14 Food Expenditure and Engel's Coefficient

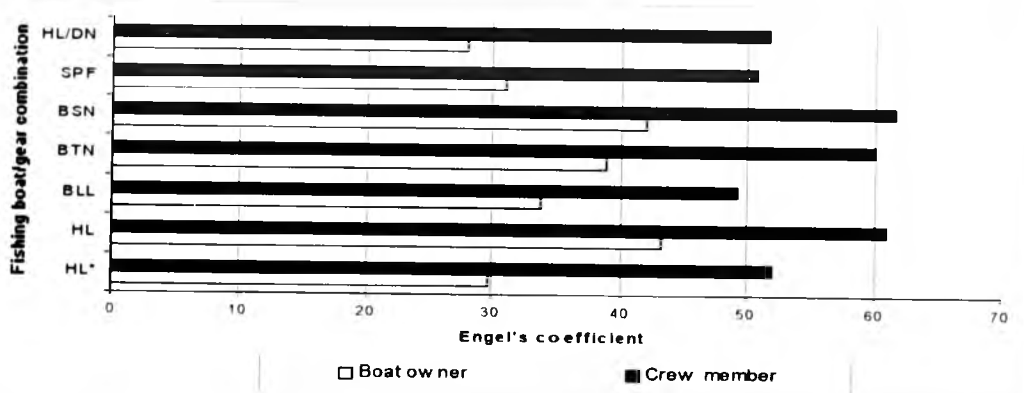


Fig 8. 20. Engel's coefficient of boat owners and crew members household engaged in demersal fishing in Negombo.

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats.

Food accounted for over half of the total expenditures of most crew members households. The Engel's coefficient of boat owners' households of all boat/gear combination were lower than the crew members' households. Among boat owners' and crew members households the highest average Engel's coefficient was reported from households engaged in handline fishing with OBM, bottom set gillnets and bottom trammel net fishing (Fig. 8. 20).

8. 3. 15 Household savings

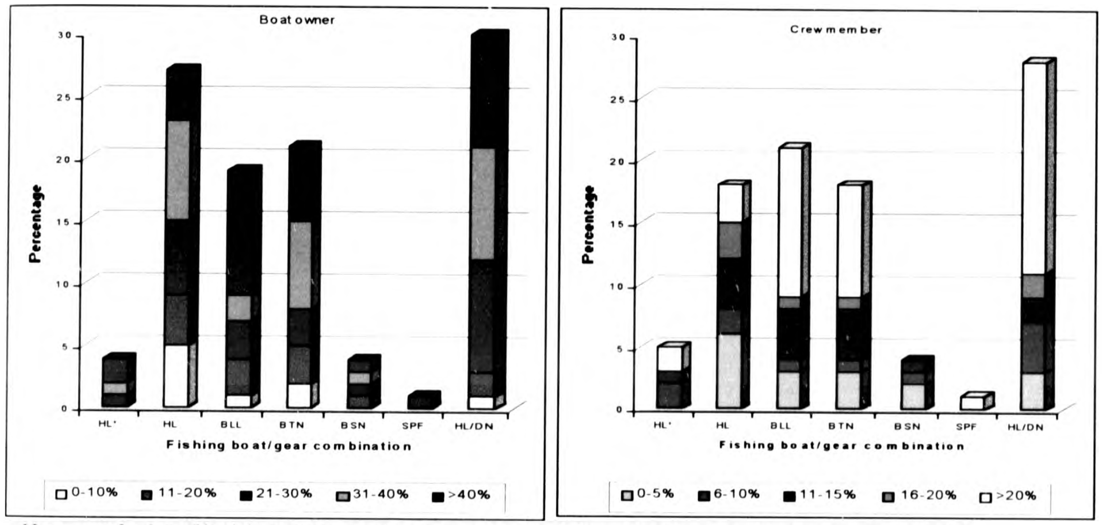
Household savings are part of spending or disposable income which is not consumed. In the present study all expenditure made for purchases of consumer durables, property and jewelry were treated as part of the savings. All boat owners interviewed regularly save part of their earnings, but 25% of the crew members households interviewed were in debt. Except for handline fishing with IBM boats and spear fishing, crew members' households in all other fisheries reported that they were in debt. The highest percentage of debt was reported from the crew members' households engaged in traditional handline fishing with OBM boats (Table 8. 6).

Table 8. 6. Number of households engaged in demersal fisheries with savings and debts during 1999.

No. of households	Craft gear combination						
	HL*	HL	BLL	BTN	BSN	SPF	HL/DN
Boat owner							
With savings	4	27	19	21	4	1	30
Debt	-	-	-	-	-	-	-
Sample number	4	27	19	21	4	1	30
Crew member							
With savings	5	18	21	18	4	1	28
Debt	-	13	3	8	1	-	7
Sample number	5	31	24	26	5	1	35

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats

The distribution pattern of savings of fishermen households revealed that about 79% of the boat owners' and 35% of crew members' households interviewed regularly save more than 20% of their disposable income (Fig 8. 21). The lowest proportion of households which saved >20% of their disposable income was reported from households engaged in handline fishing with OBM boats while the highest propotion was reported from households engaged in spear fishing and handline fishing with IBM boats. In the crew members households the lowest proportion of households which saved >20% of their annual disposable income was reported from households engaged in bottom set gill net and handline fishing with OBM boats while the maximum was reported from households engaged in handline combined with drift gillnets, bottom longline and bottom trammel net fishing. On average about 8% of boat owners households saved <10% and 13% of crew members households saved <5%.



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

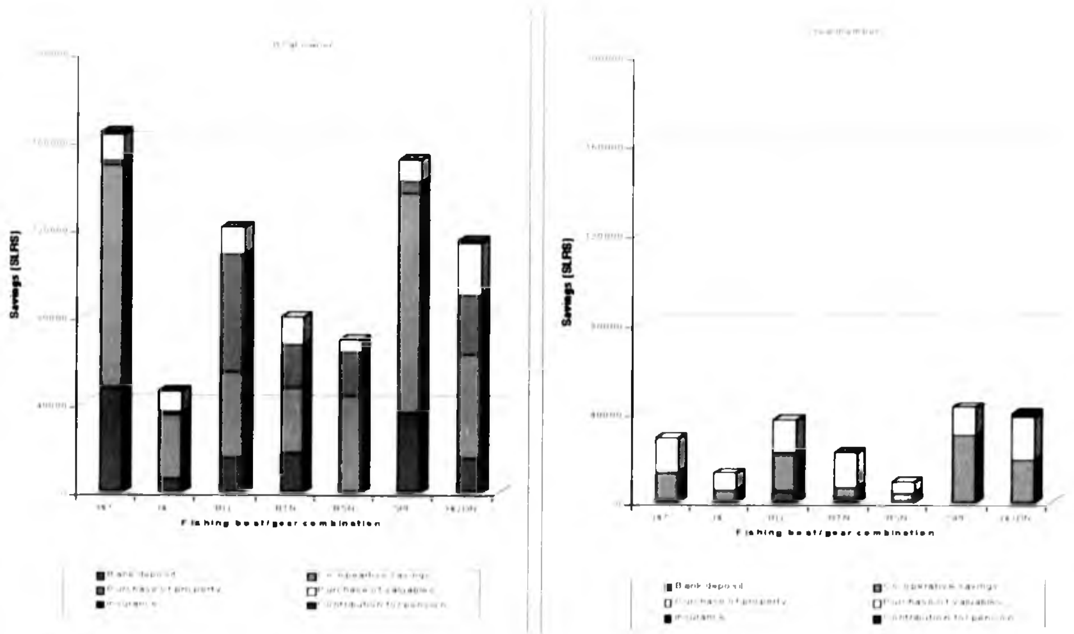
Fig.8. 21. Distribution of percentage annual savings of boat owners and crew members households engaged in demersal fishing with different craft gear combination in Negombo during 1999.

HL* Handline fishing with inboard engine (IBM) boats, HL Handline fishing with outboard engine (OBM) boats, BLL Bottom longline fishing with OBM, BTN Bottom trammel net fishing with OBM boats, BSN Bottom set gill net fishing with OBM boats, SPF Spear fishing with OBM boats, HL/DN handline fishing combined with drift gill net fishing with OBM boats.

When considering the boat owners household savings, the highest average savings was reported from households engaged in seasonal handline fishing with IBM boats followed by spear fishing and bottom longline fishing (Fig. 8.22). They saved about 40%, 42% and 37% of their disposable income respectively. The lowest saving of 29% and 30% was reported from boat owners households engaged in handline fishing with OBM boats and bottom set gillnet fishing respectively.

In the crew members households the highest amount of annual savings were reported from households engaged in spear fishing, handline fishing combined with drift gillnets and bottom longline. They saved about 28%, 29% and 27% of their disposable income respectively. The minimum amount was reported from households engaged in bottom set gillnet fishing and handline fishing with OBM boats. They saved 9% and 15% of their disposable in come respectively.

The household savings are allocated among different assets for future return or benefit. They invest the savings in three main ways, 1) financial investment 2) physical investment, 3) savings. Financial investment include savings in Banks. Physical investment includes purchasing land, residential buildings, vehicles, jewelry or other durables of a physical nature. Savings include life insurance premiums, pension fund contributions, co-operative savings or belonging to a local savings club (cheetus). The amount of money invested in each category varies among households engaged in fishing with different boat/ gear combination (Fig. 8.22).



Note: sample size of both boat owners and crew members by different boat/gear combination are as Table 6.1.

Fig.8. 22. Average annual savings of boat owners and crew members households engaged in demersal fishing with different craft gear combination in Negombo during 1999

Generally financial investment was more common among boat owners, especially boat owners engaged in seasonal handline fishing with IBM boats and spear fishing. The financial investment accounted for 15.6% of the total investment of boat owners' households and 4.2% in crew members' households. Only crew members households engaged in bottom longline, bottom trammel net fishing and seasonal handline fishing with IBM boats saved money in bank deposits.

Physical investment on average accounted for about 40% and 45% of the total investment of boat owners and crew members households respectively (Fig. 8. 22). The maximum physical investment was made by the boat owners households engaged in bottom longline fishing and handline fishing combined with drift gillnets. They invested about 55% (Rs. 66,345) and 44% (Rs. 50,877) of their annual savings respectively. The minimum was reported by the boat owners engaged in bottom set gillnet and spear fishing. They only invested about 8% (Rs. 25,615) and 10% (Rs. 15,500) of their annual savings as physical investments. In the crew members households the maximum physical investment were reported from households engaged in bottom trammel net fishing, handline fishing with OBM boats and bottom set gillnet fishing. They invested 71% (Rs. 15,817), 57% (Rs. 7,256) and 57% (Rs. 5,025) of their total savings. Purchase of gold jewelry is the most attractive physical investment among fishermen in Negombo area.

Three categories of savings were identified in this study. They are life insurance premiums, pension fund contributions and co-operative saving or belonging to a local saving club (cheetus). Co-operative savings are the most popular mode of investment in both boat owners' and crew members' households. On average it was 43% of the total investment of both boat owners' and crew members' households. The boat owners' households with maximum amount of co-operative savings were reported from households engaged in seasonal handline fishing with IBM boats (Rs. 101,250) and spear fishing (Rs. 100,000) and in crew members' households engaged in spear fishing (Rs. 30,000). Out of 106 boat owners interviewed only 32% of boat owners and 1% of crew members contributed to a pension scheme. Life insurance has not been attractive. Among the 233 households sample only one boat owner had a life insurance and another had contributed to a minor insurance scheme for his children.

8. 3. 16 Ownership of property and Assets

The ownership of property and assets did not show much variation between the boat owners engaged demersal fishing with different boat/gear combinations, but considerable differences were observed between boat owners and crew members.

Table 8. 7. Ownership of property and assets

Items	Boat owner		Crew member	
	No.	%	No	%
Own permanent house	87	63 2	21	16 5
Own temporary house	3	2 8	69	54 3
Motor bicycle	4	3 8		
Push bicycle	11	10 4	7	5.5
Refrigerator	71	67.0	5	3 9
Washing machine	8	7.5		
Sewing machine	37	34 9	13	10.2
TV colour/ black and white	79	74 5	41	32.3
Cassette recorder	86	81 1	67	52 8
Video player	11	10 4	3	2 4
Radio	106	100.0	115	90 6
Telephone	4	3 8		
Gas cooker	58	54 7	18	14 2
Sample No	106		127	

The ownership of properties and assets was clearly higher among boat owners (Table 8 7). In most instances crew members have temporary houses built on crown land or land belonging to the church. Sophisticated household apparatus was more familiar among boat owners' households

8. 3. 17 Debts and Liabilities

According to the information collected during the survey the fishing households mainly get short term loans either in cash or in commodities when they were short of cash for emergency use or consumption. Commodity loans were more common among crew members who take their daily rations from nearby grocery shops. Though these consumption loans were interest free, various hidden costs were generally involved in these transactions, as the selling price of the consumption goods is generally higher than the normal price. The sources of cash loans taken by the fishermen can be broadly classified as institutional and non-institutional. Institutional sources comprised banks and cooperatives mainly thrift societies and non-governmental organizations. Non-institutional sources are moneylenders, friends and relatives. This was the main source of lending for both boat owners and crew members. Friends and relatives generally provide non-interest loans. Crew members also obtained loans from boat owners to be repaid from their forthcoming earnings. The most prominent source of obtaining short-term loans were from moneylenders. Their interest rate is higher than the interest rate of banks and security is in the form of jewelry or other durable goods. When the fishermen wanted to have larger sums of money to purchase a boat or land, they depended on long term institutional loans. These loans are secured by immovable property and more popular with boat owners.

8. 4 DISCUSSION

Of a population of around 250,664 in the Negombo DFEO area, about 52,535 people depend exclusively on the fishing industry, of which about 13,348 are active fishermen (Appendix Table 8. 1). The area is multiracial and multireligion. The population of the fishing villages represented 69% Christian, 24% Buddhists, 3 % Muslim and 4% Hindu, but about 99% of the fishermen engaged in demersal fishing are Christian. Fishing in the area is thus carried out by a Christian dominated society. The population of the fishing villagers is dominated by Sinhalese 83.2%, with Tamil 12.4%, Muslim 3.8% and others 0.6%. In the multiracial and multireligious society of the Negombo, religion appear to influence the choice of fishing as a vocation. The Buddhists percept against the taking of life may have acted as a barrier to the Buddhists entering the fishing industry.

Each race generally has a discrete mother tongue. Sinhala is the mother tongue of Sinhalese, and Tamils and Muslims primarily speak the Tamil language. Though the majority of fishermen in the Negombo area are Sinhalese their mother tongue is Tamil.

The language barrier and the religion make for limited coordination and contact of the fishing society with Sinhala speaking Buddhist dominated fishing societies in other parts of the country. It seems that the fishermen in the Negombo area appear to have developed a culture of their own which has made it a closed fishing community, with all boat owners and the majority of crew members being within the society. This socio-cultural barrier creates some kind of propriety right over their fishing grounds. Similar kinds of socio-cultural barriers to mixing people belonging to different groups which prevents open access to the fishing grounds has been reported in some other parts of the Island (Fernado, 1985a; Atapattu, 1994). Though there is a socio-cultural barrier existing for outsiders, the fishing grounds are still open access within the community.

The labour available in many fishing households in developing countries is high because of the high birth rates (Bailey, 1982; Bailey *et al.*, 1987). A similar situation is observed in the demersal fishing households in the Negombo area. The average size of a boat owner's family was 5.3 members and a crew member's was 5.6 members. This was higher than the national average (4.6 members) recorded in 1996/1997 (Anon, 1999c) but lower than the average family size (6.8) of fishermen in the marine sector reported in 1985 (Munasinghe, 1985). It is similar to the situation in the urban sector in Sri Lanka where larger families (4.9 members) are found among urban dwellers who are in the higher income group (Anon, 1999c). Fernando (1985a) observed a positive correlation between family size and higher income group in the fisheries sector in Sri Lanka. The larger the family size the more members are engaged in income generating activities. It was observed in the present study that in both boat owners' and crew members' households about 1.3 members were involved in income generating activities.

The labour available to the fishery ranges from about 15 years old onwards and they engage in fishing up to about 60 years old. Generally fishermen take up fishing at an early age and select fishing as their main source of income and employment. The concentration of crew members in the 25-30 years age group implies a high entry rate of youth into fishing. Fishing is viewed as a profitable economic activity by younger members of the community compared to the other economic activities available in the area. This is an important implication for the future supply of fishermen and at the same time it shows that continuous entry to the fishery is unabated. The importance of fishing reflects the high profitability of fishing compared to other sources of employment available in the area (Chapter 6). Most of the boat owners started their career as a crew member and worked for sometime before becoming a boat owner. During that period they developed managerial ability, skills and adequate capital to purchase craft and gear. This indicated that the income generated by working as a crew member can allow advancement to become a boat owner. It is noted that young members mostly joined the demersal fisheries as crew members in handline fishing combined with drift gillnet, bottom trammel net, bottom longline and handline fishing with OBM boats.

The average age of crew members was 33 years whereas the majority of boat owners were about 40 years. The majority of both boat owners and crew members are in their middle age and the majority were married. Thus they have more responsibility and are more cautious and conservative than single persons who may tend to take more risk. Over 70% of the boat owners and over 50% of crew members have more than 10 years of fishing experience.

The literacy rate of both boat owners and crew members is at a high level. This is an added advantage in economic fishing, but relatively low educational attainment and a lack of formal training in fisheries or in other specific fields hampers fishermen's mobility, abilities and lowers their opportunity costs. It is sad that though there has been a Fisheries Training Institute at Negombo functioning for about 38 years (since 1962), only one boat owner engaged in demersal fishing has been trained there.

Fish catching in Sri Lanka is a male dominated occupation. No female is engaged in demersal fisheries in the study area. However, females are engaged in fishery related activities formally or informally. In most instances, marketing and processing is done by females as unpaid family labour. Especially in Palagathurai, Kammalthota areas where bottom trammel net fishing are concentrated, females are involved in supervising and marketing their catches (Fig. 7. 1). On average about 13% of the crew members' wives are engaged in income generating activities but a relatively higher percentage (18%) of boats owners' wives are working. Most of them are working as hired labour in the factories in nearby areas. They feel comfortable and more secure working in factories than working in fishery related activities or as self employed. This reduces the fishing household's vulnerability to loss associated with any one activity and also influences children to undertake more diverse economic activities. However, the majority of housewives expressed unwillingness to find employment outside the home because they are more concerned about their children's' security and education. This shows that the desire is to educate their children and find employment outside fishing. It was noted that working wives have fewer children than housewives. Large families kept the mother busy and thus did not permit them to do much else outside the house. Small family size implies less future demand on fisheries. This is a development area, which has not been adequately looked into, and careful planning could provide gainful employment to the womenfolk in fishing communities. Working women may yet be the answer to the problem that accompanies over population.

The majority of household heads are engaged in full time fishing. The success of recent development activities and innovations of fishing gears in the area has reduced the seasonal limitations of fishing and encouraged fishermen to engage in year round fishing. At present they work 6 days per week and spend their free time on repairing gear. They have limited time to be with their family members or engaged in other activities. Therefore the income generated by other activities by the household head compared to fishing was low. The employment characteristics of fishing households implies a high degree of dependence on the household head. Over 57% of boat owners and 63% of crew members derived their entire household income from fishing. Many of the boat owners and crew members appeared to be peripherally involved in other part-time occupations. Womens' participation in income generating activities in the area is still at a low level with only 16% reported during this study. On average the contribution of income by other members of boat owners' and crew members' households was about 27% and 71% respectively, but most of them were engaged in fishing. The analysis of household income revealed the importance of income generated by the household head by fishing as opposed to the wife's. or other member's income. Diversity of economic activities has only developed among women. Creating a diversity of economic pursuits may be important to the long-term economic survival of fishing households. If the open access to fishery prevails and the use of efficient technology increases, sooner or later fishing income will decrease due to the finite nature of the resources. Thus the involvement of household members in diverse economic activities serves to make the household more secure and also the households are better situated to adapt to changing circumstances.

The average annual disposable income of boat owner (Rs. 267,991) was higher than the crew member, but the average income of crew member (Rs. 112,417) engaged in demersal fishing is clearly far above other members of the rural community or estate workers, which is about Rs 64,872 and Rs 30,948 respectively (Anon, 1999c). The majority of the fishermen engaged in demersal fishing with modern and efficient gears such as bottom longline, handline combined with drift gillnets, spear fishing and bottom trammel net expressed satisfaction with their fishing income. However, after four or five decades of development the traditional handline fishermen remained in a low income group and thereby had lower social standards. Modern fishing technology has accelerated the growth of the demersal fishing industry in terms of production (Chapter 5) and income (Chapter 6) and thereby generated higher social standards.

Traditional handline fishermen generally depended on their traditional experience gained from their forefathers without changing the situation. Generally the condition of crew members was much lower than boat owners. Their social standard are clearly different from boat owners. They have not fully adapted to the technological improvements in the demersal fisheries, so that the fisheries sector today in Negombo presents a dual and heterogeneous structure which reflects in the appropriation of benefits and thereby social well being. One would that expect those from low income fisheries would shift to fisheries from which can derive a better income. This reaction has however not been evident in traditional handline fishermen. They remained unchanged in their fishing practice. The occupational specialization, family employment and associated risk ensured fishermen continued with handline fishery. It is thus important to encourage traditional fishermen to adapt to variable resource availability. There is, however, reason to doubt whether all traditional fishermen are reluctant to change traditional practices and technologies. It is clear for example that some fishermen did adapt to bottom longline fishery due to the clear advantage of fishing this gear during the lean season. The rapid increase in the use of bottom trammel net also supports the innovative behavior of some fishermen in the Negombo area.

The expenditure pattern of fishing households in the area shows a high percentage of spending on consumption, consumable and personal amusements. Fishing communities in Negombo have greater cultural needs than other communities. The fishermen in the area spend large amounts on celebrations. They celebrate all the Christian festivals and rituals, due to cultural practices among fishermen in the area. They also spend extravagantly on clothes, recreation and on alcohol and cigarettes. Having spent most of their income on consumption, clothes, entertainment and alcohol, crew members often have to rely on credit or consumption loans. Thus they often are in debt to groceries or moneylenders but boat owners households are much efficiently managed. Both boat owners and crew members however spend a considerable amount of their income on purchasing semi-luxury goods and gold jewelry. This sometimes has an advantage because they can use these as a security to obtain loans or can pawn them to get cash if necessary. Despite all these extra expenses it is clear that parents in fishing communities regard education as an important means of bettering their children's lives and broadening their employment prospects. Many boat owners and crew members tend to spend a sizable portion of their earnings for their children education despite education being free. It is important, therefore, to note that it is the fisherman's behaviour and not his income that is responsible for crew members debts. This has an important implication for the government's credit policy. At present no one engaged in demersal fisheries receives government assistance. Instead of giving direct assistance or by introduction of technological innovations to improve the standards of fishermen through improved production, indirect assistance to improve the socio-economic conditions of their community has received encouragement from the Government (Anon, 1999b).

Boat owners save a considerably higher proportion of their income than crew members but few have invested in other economic activities instead of fishing. All boat owners sampled had one boat or a single fishing unit. Most of the boat owners bought their fishing assets, land, buildings and other related properties with their savings, showing that the boat owners systematically plan for their future more than crew members. The pension scheme introduced by the Ministry of Fisheries and Aquatic Resources Development or life insurance has not gained popularity among small scale fishermen. It seems that they have not planned for their old age and thus depend on their children.

Sustainable fisheries development cannot be separated from policies of resource management and equitable allocation and thereby socio-economic uplift fishing community. It should balance between development and management when allocating access to resources among competing users (Chapter 9). The fishermen engaged in demersal fisheries are economically at a better level than most other economic activities. This would tend to attract newcomers. Management interventions should therefore place more emphasis on preserving the fish resources in the area, because the resources in the shallow areas are currently over exploited, and thereby optimize the benefits and socioeconomic condition of people harvesting the resources. Fisheries management should focus not only on limiting new entry from outside but also to encourage existing fishermen, especially those with fishing gears with a high effort level at present, which affect the sustainability of resources in the shallow waters, to diversify their economic activities. In that sense it is important to encourage family members, especially the children, to diversify their economic activities because where stocks are heavily exploited, fishing provides a particularly precarious livelihood. There is also a need to improve the economics of exploitation by adding value to the existing catch as discussed in Chapter 7.

Most of the demersal fishermen no longer migrate to the north or east coast during the poor fishing season (monsoon season) as they did before (De Alwis, 1985). The population pressure and profitability is likely to increase the number of fishermen in the demersal fishery where minimal requirement of capital is required. Therefore to prevent new crises within the community and divert them in different vocations, it is important to identify the opportunities that are available and familiar to fishing societies. In most households the entire income is derived from fishing. Fishermen like being more independent and in self-employment, and diverting fishermen to a completely different vocation would be difficult.

Negombo is a highly urbanized area. Colombo International Airport, industrial zones (Katunayaka and Ekala) and several Government Institutes, boatyards etc. are found close proximity. Negombo is also a major tourist area, with tourist hotels and resorts found along the beach. The most important natural resources in the area are the sea, the lagoon and fish. Tourist and fishing industries are limited to the coastal belt, and agricultural lands are scarce. There is scope for industrial and tourism related employment, natural resource extraction activities, or casual employment but switching to such occupations is difficult for most members of the fishing community who have limited skills, training and educational qualifications

Appendix Table 8.1. Religion and ethnic group wise distribution of population in the fishing villages.

Divisional Secretariat	Fishing village	Population	Ethnic group				Religion group				
			Singhala	Tamil	Muslim	Other	Buddhist	Christian	Muslim	Hindu	Other
Wattala	Pamunugama	3462	3458	3458	4		15	3446		1	
	Uswettakkeiyawa	4564	3900	84	500		54	4400			
	Palliyawatta (South)	3313	2936	289	20	68	158	2947	20	120	
	Palliyawatta (North)	3856	2000	1700	156		1700	2100	56		
	Dickowita	2150	1815	220	30	45	578	1346	30	168	28
	Hekiththa	6253	3776	2399	36	42	1034	3697	36	1444	42
	Kuruduhena	6890	4860	1800	80	150	1800	4000	80	800	210
	Elakanda	2634	1490	952	40	152	480	1488	46	482	144
	Matagoda	7069	5200	1805	40	24	3900	2710	40	245	174
	Balegala	6281	5953	220	85	23	1977	4195	85	24	
	Hedale (South)	3620	2840	695	75	10	2236	884	75	425	
	Hedala (North)	4760	3760	796	185		1942	1920	16		72
	Total	54852	41988	14418	1250	514	15874	33133	484	3709	670
	Total population in the DS	167605									
Divisional Secretariat	Fishing village	Population	Ethnic group				Religion group				
			Singhala	Tamil	Muslim	Other	Buddhist	Christian	Muslim	Hindu	Other
Ja-Ela	Relawulla	3868	3040	133	20	25	105	3728	20	15	
	Thala Eliya	2485	2447	38			85	2400			
	Wewala	3104	3049	40	19	6	91	2994	19		
	Weligampitiya (South)	3389	3241	98		50	62	3277			50
	Weligampitiya (North)	3919	3457	349	63	50	35	3764	63	31	26
	Edivitiya	3022	2910	63	14	35	26	2947	14		35
	Kanuwaha	2976	2781	170	4	21	41	2910	4		21
	Ja-Ela	2222	1949	186	22	85	18	2061	22	36	85
	Thudella (West)	2945	2793	86	42	24	11	2892	42		
	Thudella (South)	1860	1842	14		4		1860			
	Dadugama	2356	2310	10	8	28	21	2312	8		15
	Dehiyagana (South)	1613	1595	10		8		1588		25	
	Dehiyagana (North)	2735	2712	16	2	5	72	2661	2		
	Kudahapola (South)	1700	1663	15		22	166	1512			22
	Kudahapola (North)	2145	2141	4			426	1719			
	Ekala	2292	2249	7	27	9	312	1953	27		
	Batagama (North)	3370	3243	51	14	62	174	3106	14	51	25
	Total	46001	43422	1290	235	434	1645	43684	235	158	279
	Total population in the DS	182055									

Continuation

Divisional Secretariat	Fishing village	Population	Ethnic group				Religion group				
			Singhala	Tamil	Muslim	Other	Buddhist	Christian	Muslim	Hindu	Other
Negombo	Kudapaduwa	3253	1891	302	1056	4	121	1908	1056	168	
	Kudapaduwa (North)	5286	5286	758	248	48	20	4760	248	258	
	Kudapaduwa (South)	6740	6267	351	100	22	72	6105	100	351	22
	Palagathurai	2376	4779	125	416		150	4139	416	15	
	Kammalthota	3228	1356	57	1815		10	1346	1815	57	
	Munnakkarai	6360	5892	375	93		33	5906	93	328	
	Munnakkarai (North)	3167	2691	126	316	34	133	2558	316	126	34
	Munnakkarai (East)	3175	2932	161	32		60	3000	82	33	
	Siriwardena place	5435	4709	675	51		237	4535	51	12	
	Wellaweediya	5330	3470	1675	175	10		4000	185	1145	
	Wellaweediya (South)	5719	1591	2929	1299		424	1676	1299	2320	
	Wellaweediya (East)	4125	3560	526	45		325	3220	45	410	125
	Udayarithoppuwa	6573	5962	255	289	58	2127	3843	298	220	83
	Thaladuwa	6771	5550	951	210	60	186	6325	170	90	
	Pitipana	2895	2860	30		50	20	2816		14	35
	Duwa	3699	3672	25		2		3682		7	
	Pitipana (South)	2792	2776	16			86	2582			130
	Pitipana (East)	4132	4122	7		5	26	4049			59
	Pitipana (Central)	1774	1770	4			3	1734			37
	Kalahena	4770	4729	15	15	11	62	4621	15	6	66
	Keppungoda	1771	1758	13			361	1731			4
	Dungalpitiya	2250	2221	14	3	12	43	2194	1		12
	Seththappaduwa	2441	2441					2441			
	Total	94062	82285	9290	6163	271	4499	79171	6190	5560	607
	Total population in the DS	171004									

Chapter 9

General Discussion, Conclusions, Alternative Management Options, Limitations of the Study and Future Research

9.1 GENERAL DISCUSSION

The present multidisciplinary study has focused on the multispecies multigear demersal fishery in the Negombo area with the aim of planning an appropriate management strategy to optimize the bio-socio-economic benefit of the fishery. The multispecies and multigear nature of the demersal fishery does present, special problems in the management of resources, poseing difficult question on how to approach the biological research in the right way because of complex and as yet unknown intra- and inter species relationships. More than 139 economically valuable species belonging to 68 families of fish have been recorded in this study (Table 2. 4). It offers a clear picture of the multispecies nature of the resources, which includes demersal, semi-demersal and pelagic varieties. This indicates that they may be living together as a community and that the inter- and intra-species relationships are indeed complex. The boundaries between pelagic and demersal fishermen are not clear in the shallow near shore areas where substantial quantities of pelagic fishes are caught in the multigear demersal fishery which exploit all vulnerable species. In order to plan for proper management and effective control of the multispecies, multigear demersal fishery in the area, it is necessary to determine the status of the fishery, resources and their exploitation.

The demersal fishery has undergone rapid development through innovation of efficient fishing methods and increased use of small multipurpose 17-22 ft OBM boats in relatively recent times. Thereby the fishery has become highly diversified and many types of boat/gear combinations have come into operation. The fishing gears most commonly used are bottom longline, handline either bait cage handline or drop handline, bottom trammel net and to a lesser amount with bottom set gillnets and spear fishing. There are differences in fishing operations and target species among the demersal fishing gears but most common gears have been identified as interactive because their catches consisted of considerable amount of common species. Fishing activities of all gears predominantly are engaged in shallow waters less than 40 m depth. Only bottom longline and bait cage handline fishing operate beyond > 80 m but the effort is less than 2% of the total effort deployed by all gears. Except for the main gears other fishing gears operate seasonally, but access to and use of demersal resources have noticeably increased in all gears during the season because the fishermen engaged in other fisheries such as small pelagic and prawn trawl fisheries shift their operation to demersal fisheries to maximize their income. This seasonal change of fishing gear used has constrained the management of demersal fisheries in the area.

With the increase of fishing effort the harvest of demersal resources has shown a steady increase from 853 t in 1982 to 2,194 t in 1992 and maximized to 2,481 t in 1997 and then a slight decline to 2,042 t in 1999. Though the fish production has increased, the fishery has shown some sings of overfishing. The CPUE of the major fishing gears, bottom longline, bottom trammel net and bait cage traditional handline fishing with OBM has notably declined over the years. Fluctuation in the volume of the catch of major demersal fish categories showed a clear increasing and then decreasing trend. The contribution of squid and cuttlefish has increased while sharks and skate has decreased. The number of major fish families which contributed in early 1990s has declined in the late 1990s. Carangids, as dominant fish, were replaced by Lethrinids, which now seem to be over fished. This indicates some signs of ecological overfishing, which has been noted in other countries (Ritragsa, 1976; Pauly, 1979; Wright and Richards, 1985).

The exploitation rate of economically important major Lethrinds, such as *L. nebulosus* and *L. lentjan* have both exceeded the recommended level of 0.5 by most gears. It was noted that there were few year classes of *L. lentjan* in the demersal fish catches and the catch consisted of over 80% juvenile fish. They are suffering from growth overfishing. Catching large number of juvenile fish would reduce the maximum sustainable yield and further reduce the potential spawners and thereby future recruitment. In contrast over 65% of the *L. nebulosus* catch consists of adult spawners. High exploitation of spawning stock would adversely affect the future recruitment due to recruitment overfishing. The large number of adult fish susceptible to capture with bottom longline fishery seems to relate to the seasonal increase of bottom longline fishing effort and the spawning migration of *L. nebulosus* into deep waters.

The concept of maximum sustainable yield (MSY) has been considered as the key reference point for biological fisheries management. In view of the lack of information of biological parameters of most species, of species interactions etc., the assessment of yield of demersal fishery in the Negombo area has been based on the total biomass production model. This approach was useful for determining the theoretical total effort level, which produces MSY for the fishery as a whole. It was estimated that the demersal fishery in the Negombo area can produce an annual MSY of 2236 t with the optimum fishing effort (f_{MSY}) of 103421 standard fishing days. The demersal fish production in the Negombo area exceeded the MSY during 1996 and 1997 and the recommended optimum effort level in 1997. Though fishing effort has substantially declined in 1998 and 1999 below the optimum effort level, yield has not yet recovered to a sustainable level. The effect of overfishing in 1997 clearly demonstrated the long time lag for recovery of the total biomass of the demersal resources in the area. This emphasizes the importance of effort rationalization for the sustainability of the resources. Although the estimate of MSY may be used as a broad indication of the status of the multispecies demersal fishery in the Negombo area, the use of the total biomass surplus production model involved a number of assumptions (Larkin, 1977; Gulland, 1977; 1978, Hilborn and Walters, 1992). The problem is that a fishery managed at MSY will tend to be less profitable, species of low productivity could be overexploited and stocks will be vulnerable to collapse when environmental fluctuations affect the managed stocks (Beddington and May, 1977). Therefore MSY estimated for the multispecies condition has been considered as an upper limit reference point rather than a suitable management target for the exploitation of demersal fish resources in the Negombo area.

The single species stock assessment was performed with two indicator species *L. nebulosus* and *L. lentjan* as a precautionary fishery management, as recommended in the FAO Code of Conduct for Responsible Fisheries (FAO, 1995). It was found that these indicator species are threatened with depletion with most gears. This problem has become particularly acute for *L. lentjan*. These species are considered as an indicative species in deep and shallow waters and it assumed that the fishing pressure on the economically important species in this area is similar. This shows that the shallow water fish resources are more over exploited than deep waters. The operation of destructive and non-selective gears like trammel nets in the coastal waters and high fishing pressure by all gears affect the sustainability of resources in the shallow waters. When considering some of the likely consequences, in the context of future management the importance of effort reduction of bottom trammel net or traditional bait cage handline fishery by 50% to improve the total yield of these two indicator species has hilighted.

Further it is important to control the effort of bottom longline at the optimum level to ensure continuous recruitment of these species because the fishing effort of bottom longline in 1999 has exceeded the optimum effort which produce MSY.

Biological overfishing is always accompanied with economic overfishing. In the context of maximum economical yield (MEY) in the multispecies situation, demersal fisheries in the Negombo area have been overexploited over the years. The increase of fishing units and the increase use of more efficient but expensive fishing gears lower the economic returns of demersal fisheries. According to the present study the fishing effort to produce maximum economic yield (f_{MEY}) for the multispecies fishery is reached at 53149 standard fishing days which is a considerably lower effort level than f_{MSY}. MEY is a more conservative management reference point than MSY. The present demersal fishing effort of 86915 standard fishing days produced a total revenue of Rs. million 160 and at f_{MSY} and f_{MEY} levels they produced Rs. million 165 and Rs. million 123 respectively. The open-access equilibrium comes at 106297 standard fishing days. The bio-economic multispecies model shows that the reduction of fishing effort always reduces the total revenue of the fishery as well as total catch, but increases the profit.

The economics of exploitation of *L. nebulosus* and *L. lentjan* by all gears showed that the effort in 1999 has exceeded the optimum effort which produces MEY for both species. The projected performance under different fishing strategies showed that an increase of effort of any fishery would never improve the value of the catch of both species and an increase of value can only be achieved by a reduction of fishing effort of bottom trammel net or handline fisheries. This means that if the fishery is to be economically rewarding and a viable occupation, access to the fisheries must be limited to a specific number of people using such gears. The most important observation was that the long-term bio-economic forecast analysis of the single species suggests that the reduction of fishing effort of bottom trammel net or handline by about 50% would improve the fishery performance biologically and economically. The adverse effect of such measures on the fishing community will also however have to be looked into.

Although present fishing of demersal fisheries in the Negombo area has exceeded MEY by about 63%, all fisheries are still operated at a positive net profit. The relatively low fixed cost, mainly due to the long life of fishing vessels and the low capital cost of fishing gears besides a competitive market, high demand and low indebitness to middlemen results in a high net profit from demersal fishery. All fishing households, both boat owners and crew members, are above the poverty line but the crew members income was much lower than the boat owners because the additional shares the owner receives for his investment. However, the economic performance between technologies is highly varied. The introduced fisheries such as bottom longline, bottom trammel net, spear fishing, bottom set gillnet and drop handline combined with drift gillnet have been of great importance to the fishermen in terms of income, compared to traditional handline fishery operated with OBM boats. In most instances traditional bait cage handline fishing with OBM boats is less profitable and made low returns to labour and capital investment. The present study also investigated the reasons which led to dualism of income between traditional handline fishing with OBM boats and other boat/gear combinations. The observation revealed that relatively low CPUE and high operational cost meant that the traditional bait cage handline fishing operations were a marginal venture. Among the operational cost items 43% and 36% was incurred for purchasing live bait and fuel respectively. The CUPE of traditional handline fishing can be improved by extending fishing effort to the more offshore areas where a high CPUE was reported but the craft and gear in use at present could not undertake a year round fishery. There would need to be more technological improvements to the fishery, which would increase both fixed and variable costs as well as the effective fishing effort. The economical feasibility and distribution of stocks should be evaluated before starting such a development.

It was realized that fishermen engaged in seasonal fishing get an income far above those of full time fishermen but they have extra gear and need to invest some capital. The fishermen switch gears on a seasonal basis, harvesting various resources depending on their availability. The change of fishing gear is the key factor that small scale fishermen have adopted to maintain a high income. Most small scale fishermen are well adapted to the spatial and temporally available resource base. They have understood not to depend on a single resource but on a whole ecosystem. The boats with single gear are able to get a high catch only in part of the year and they cannot get the advantage of seasonal abundances of species.

The developments that have taken place in the demersal fishing over the past two decades have brought problems rather than benefits to the resource base as well as to the traditional fisheries. This shows the need to provide effective management programmes to regulate fisheries to cater for the well being and equity of all participant fishermen.

Generally fisheries governed by customary proprietary rights guarantee a higher income (Fernando, 1985a; Atapattu, 1994). According to statutory law, coastal fisheries in Sri Lanka are under open access except for a few fisheries, beach seines (madel), stake net (kattudela), fish weir (Jakotu) fisheries (Atapattu, 1994). However, in most fishing communities customary fishing rights are vested in a different form which create barriers to outsiders to enter their fishing grounds. In the Negombo area the technological and socio-cultural factors, particularly language and religion, limits entry to the demersal fishery. The seasonal nature of some fisheries further self regulates the fishing action. However, demersal fishery in the Negombo area is still a common property at least to anyone belonging to the appropriate social category who is able to participate in the fishery. The present access controls are applied to outsiders and people from other social groups. With the population increase and decline of alternative income activities in the area, this would result in an increase in fishing effort in the future.

The majority of owners' and crew members' household engaged in demersal fisheries depend entirely on fishing for their income. They have limited education and their skills are more on fishery related. The participation of housewives in the income generating activities were relatively low. The majority of their children are also engaged in fishing activities. Their mother tongue is an advantage to the Negombo fishing community by acting as a barrier to entry to the fishery but it is a disadvantage to them when seeking employment outside fishing. Without fishing assets they have no investments in other economic activities, and other than fishing they cannot do anything with fishing assets. They have not planned for their old age. The fishing community in the Negombo area has great cultural needs, spending large amount on religious celebrations and festivals. Thus they need a large amount of money to keep the socio-cultural habits of their society and maintain their independence. Therefore not only bio-economics social consequences should also be considered in the management of this fishery.

The objectives of management of coastal fisheries in Sri Lanka are many. The Government seeks solutions to increase nutritional status and food security of the people through increased fish production, increased employment opportunities in the fisheries sector, increased foreign exchange earnings and to uplift the socioeconomic status of the fisherfolk through fishery management (Anon 1999b). Under the condition where stocks are fully exploited, these objectives may be contradictory. If the objective is long term increase of the fish production to increase the nutritional status of the population and increase foreign exchange earnings, there must be effort rationalization to obtain maximum sustainable yield from the fishery. If the objective is to uplift the socioeconomic status of the fisherfolk, then the emphasis should be more on effort rationalization because MEY is more conservative than a fishery based on MSY as the economically optimal effort is less than the effort needed to maximize the sustainable yield. Therefore the focus should be broadened to include income generation rather than fishing. The objective of increased employment opportunities in the fishery would be limited by the rationalization of effort. Thus there should need to be recognize the opportunities of exploiting non-conventional resources in the area or of employment outside fishing.

It appears that the conservation of fish resources or to measures maximize the economic yield through rationalization is not the only necessary condition to make a fishery system sustainable. The best management strategy would be a compromise of all incompatible objectives. The management effort must ensure the sustainability of fish resources, fishermens' livelihood and the fishing community and their culture. Thus practical fisheries management has to deal with biological, economic and social goals. To achieve all these goals of fisheries management, the assurance of long term sustainability of resources is of prime importance. The main purpose of subjecting demersal fisheries in the Negombo area to management measures is to achieve a long term sustainable use of the resource and thereby improve the economic and social standard of fishing communities and employment opportunities.

The twin problem of over fishing and the inequitable distribution of benefits can only be overcome if steps are taken to limit effective fishing effort by managing the fishery. The removal of the open access situation in the long term and a reduction of excess fishing effect employed is seen as the principal measures required to address effectively the present condition of the demersal fishery in the Negombo area. The reduction of excess fishing effort currently employed by the bottom trammel net or traditional handline fisheries has been identified as the priority for the sustainable development of economically important resources. The main difference between the two gears is the way in which fish are caught unless both are common user groups in the shallow waters. The indiscriminate fishing and destruction made to the habitats by trammel nets has led to several conflicts between these two fisheries. Increase of population and steady mounting demand of fresh fish for domestic consumption in the area directly influences the investment in bottom trammel nets because of their high profitability. The high operational cost of handline fishing would depress the fishing over demand in future. Fishermen generally acquire more efficient fishing methods, which are often accompanied with a shift towards being less selective. Bottom trammel nets not only indiscriminately exploit resources, but they also cause severe damage to the seabed. Studies conducted in other parts of the country have repeatedly shown environmental impacts (Rajasuriya *et al.*, 1995; Jayawardena and Dayaratne, 1995) and effects on bio-diversity (Rajasuriya *et al.*, 1995) by operating bottom trammel nets and bottom set gillnets on reef areas for demersal resources. As a result regulations are formulated to prohibit the operations of bottom trammel nets on coral reefs. White (1984) identified the control of destructive gears as the key to improved management in many Philippine fisheries.

9. 2 MANAGEMENT OPTIONS

Successful management systems have to consider habitat protection, recovery of damaged reef, conservation of vulnerable exploited species, protection of livelihoods of the fishermen and to increase their income through enhancing resources base (Medley *et al.*, 1993). Therefore considering ecological, economical and sociological advantages to maximize the yield and value and to minimize the risk of over fishing, and reduce the environmental impact and conflicts between handline and bottom trammel net fisheries operating in the shallow waters, it is proposed to rationalize the current fishing effort of bottom trammel nets by 50% as a key management intervention in the area. With this issue about 72 fishermen (36 boat owners and 36 crew members) will have to change to different economic activities. Further, to achieve MSY of *L. nebulosus* the current effort of bottom longline should be also reduced by 10% in addition to the removal of the open access situation in the area. This will ensure a sufficient residual biomass, thereby avoiding recruitment over fishing of this species but to achieve MSY of *L. lentjan* it would need to reduce by 60%.

It was noted that when the bottom longline trails in the Negombo area were conducted with large hooks, No. 5 and 6 and with squid bait, the catch mainly consisted of large species belonging to the family Lethrinids, Lutlanids and Serranids. Among Lethrinids *L. nebulosus* dominated the catch followed by *L. miniatus* and *L. caereleus*. Lutjanids were dominated by *Lutjanus bohar*, *L. rivulatus*, *L. argentimaculatus* (Weerasooriya *et al.*, 1985). At present bottom longlines operate with a wide size range of hooks, No. 5-10 which enable them to use cheaper varieties of bait, mainly cut pieces of small pelagic fish and thereby reduce the operational cost. These small hook bottom longlines generally operate in more shallow waters and thus operate year round. Banning longlines operated with small hooks could reduce the effect of bottom longline fishing in the shallow waters and thereby reduce the risk of overfishing of the spawning biomass of *L. lentjan*. Further it is important to consider the spawning season when rationalizing the effort of bottom longline fishery to minimize the effect of fishing on spawning activities. Therefore rationalization could be done by implementing seasonal closure of bottom longline fishery during the spawning season. However, the social hardship of such a decision would be considerable and as part of the limitation programme, the need to minimize the adverse impact of fishermen, their families and the people involved in fishery related activities should also be addressed. The sensitive nature of these issues and the range of management options would have to be evaluated with the consultation of all user groups.

9. 3 ALTERNATIVE MANAGEMENT OPTIONS

As well as reducing fishing effort in the shallow areas there are opportunities to rebuild demersal fish resource biomass and thereby increase yield through enhancing productivity of stocks. The most widely use method is providing new shelter/habitat for the reef fisheries. The idea is that by creating additional shelter with the use of various types of artificial reefs, it is possible to raise the biomass. However, there is controversy over the extent to which artificial reefs increase biomass (Doherty and Williams, 1988).

Work on this concept has already been started in Sri Lanka providing shelters 'casitas' for lobsters. There are large number of abandoned cars and bus bodies. It may well be that by the use of artificial reefs making buffer zone around the coral reefs in the area. These areas could be conserved as marine reserves. Development of marine reserves has been successfully implemented in Philippines to rebuild the stocks and improve the catches outside these reserves (Russ and Alcala, 1989) and similar results have been reported from other countries (Clark *et al.*, 1989). Development of marine reserves and artificial reefs are also important in a tourist area like Negombo because they could advantageous in developing echo-tourism in that area through integrated management in the future. A programme for the re-plantation of mangroves and conservation of seagrass beds along the lagoon, as well as banning of destructive fishing methods operating in the lagoon, shallow coastal area and coral reefs is also important to preserve the nursery areas of the demersal resources.

In the need to recognize and take advantage of the multispecies resource in the area it is important to identify alternative fisheries. Some of the excess fishing units operating in the shallow areas can be switched to alternative fisheries after surveys of stock densities, their distribution patterns and economic viability. There is a need to adequately train the fishermen on operating gears in the area and to improve the units with high efficiency technology. Nevertheless, careful research must precede the implementation of any such project. The present study found that the demersal resources outside 40 m are still largely untouched, offering considerable potential for artisanal fisheries development. At present traditional bait cage handline and bottom longline fisheries are seasonally engaged in fishing activities in this zone. Handline fishing mainly target red snappers in deep waters while bottom longline target on lethrinids such as *L. elongatus*, *L. nebulosus*, groupers and carangids. The fishing gear currently operates only in the non-monsoon period but a year round fishery could be established with a limited number of boats equipped with appropriate gears. Mechanical handline and vertical longline can be successfully used in deep waters. In Jamaica and Gulf of Mexico mechanical handlines are used year round for red snappers (Munro and Thompson, 1983; Goodyear and Phares, 1990). At present no fishery in Sri Lanka targets large semi-demersal fish on the shelf-slopes. Thus the introduction of vertical longlines will be economically rewarding. Further development of deep-water longline for dogfish and squid jigging can also be introduced to fishermen. Dogfish can be use to extract high quality shark oil which has high demand in pharmaceutical industry. Squid and cuttlefish used to be a favorite food and are now in great demand by restaurants and hotels catering to the tourist industry. Economically this is an added advantage to the fishermen exploiting fish in Negombo area. The Government should initiate new fisheries developments and promote the fishermen by providing credit facilities and marketing. However, the linkage between inshore and offshore stock is still a question. Therefore distribution and migration patterns of offshore stocks should be studied.

Promoting occupational multiplicity and expanding the diversity of income sources helps make coastal communities relatively stable. Past development activities promoting adoption of more effective fishing technologies run counter to the natural diversity that characterizes relative stable fishing community. In Negombo, employment opportunities are not limited because there are many factories and industries around this area but switching to such occupations is inhibited because they have limited skills and education qualifications as well as being socio-culturally different from other communities. Fishermen like to be more independent than salaried labour. Therefore a workable solution will have to be found which is fair for all the phased out fishermen.

Small scale animal husbandry like pig raising and maintaining poultry, are already practiced in some households and can be a promising alternative to attract some of the fishermen affected by reducing fishing effort. The coastal zone of Negombo not only provides fish, but the coastal environment itself provides marketable goods and services to the community. The integral parts of the coastal zone such as lagoon, estuary, coral reef, exotic marine life and tropical beaches can be developed to generate a large amount of employment. Negombo is one of the most popular coastal resort areas in Sri Lanka but the tourist industry in the area has not been properly planned to generate employment by integrating the tourist industry with the environment. Such integrated coastal zone management would generate a large amount of employment to divert the excess fishermen to different activities. Activities like ferrying tourists, snorkeling, scuba diving, viewing coral through glass bottom boats, and aqua-safari could be systematically developed and even at present some of the fishermen are engaged in such activities. In addition women should be promoted in self employment activities like lace and handicraft making, batik industry and dress making etc. Most of these are however ancillary activities than alternative employments. Aquaculture offers no opportunities because fishermen do not have land or farming skills. Opportunities in offshore fisheries is also limited because the present level of offshore fish production has exceeded the estimated MSY of area and also fishermen have no fisheries training in engaging in offshore fisheries. Value addition to the present fish catch would improve the economic condition of fishermen as well as fish traders but it is a dilemma that it would encourage the exploitation.

9. 4 MANAGEMENT BODIES AND INTERVENTIONS

The Government of Sri Lanka has experience in terminating fisheries for proper management. Such decisions are based not only on resource potential but on a wider range of social and economic concerns (De Alwise, 1996, Fernando, 1996). The prawn trawl fishing with 3.5 t IBM boats in the Chilaw area was terminated in 1993 considering the benefit to a large number of small scale trammel net fishermen (De Alwise, 1996). The purse seine operation for small pelagic species in the island was banned in 1994 in favour of a large number of small mesh gillnet operators with different craft types after a detailed study on bio-socio-economic of fishermen engaged in these fisheries (Dayaratne and Sivakumaran, 1994). Not only Sri Lanka but many other developing countries have banned some of the more efficient fisheries in favour of a large number of small scale coastal fisheries sacrificing short term production gains and even economic efficiency. The Government of Indonesia has totally eliminated the trawler fleet from coastal waters since 1983 (Bailey *et al.*, 1987). In the San Miguel Bay in Philippines all commercial trawl fishing was banned from waters within 7 km of the shore since 1982 (Smith *et al.*, 1983).

The steps undertaken as management measures are the promulgation of fisheries laws. Fisheries administration and management in Sri Lanka primarily remain under control of the Ministry of Fisheries and Aquatic Resources Development, headed by a cabinet minister. The Department of Fisheries and Aquatic Resources Development is the key organization responsible for the development and management of fisheries. The scientific information on resource bases and socio-economic of fisheries is provided by the National Aquatic Resources Research and Development Agency (NARA), which is the research arm of the ministry. Legislation has been prepared to this end through the New Fisheries Act 2.

But in Sri Lanka most of the regulations that have been formulated for fisheries management remain unenforced. The fact that the bottom trammel net fishery affects the coral reef fishes is largely because of a lack of enforcement of laws. Except for the regulation for bottom trammel net operation in coral reef areas, most of the management intervention mechanisms are not applicable to the demersal fisheries in the Negombo area. Recently the Department of Fisheries and Aquatic Resources Development has established a new licensing scheme, which aims to freeze the number of units at the current level and to reduce it thereafter. These measures may prevent the new entry and may reduce the fishing effort by normal attrition. But it will take a long time and the results may not be promising because the systematic approach to management of fisheries resources does not yet exist. Frequent changes in fishing methods and fishing vessels that acquire more than one type of fishing gears but hold only one type of fishing license also make assessment as well as the management difficult. The effective introduction of effort limitation programme necessitates a tight licensing control of fishing craft and gear. Theoretically a higher license fee is an effective way to limit entrants and has had success in other countries (Meany, 1979). The present annual license fee in Sri Lanka is very small, only Rs. 50, for all small scale fishing gears and all types of handline are exempted from licensing. It should vary according to the fishing power of the gear *i.e.* a higher fee for more efficient gears and also for the second gear, which is possessed. However, license fees would not control all elements of effective effort as fishermen would continue to upgrade their fishing units.

Introduction of a territorial limit for bottom trammel net operation is vital because it could prevent them fishing in reef areas and could also restrict their numbers. At present the majority of them operate in the Palagathurai and Kammalthota areas where the sea bed is predominately sand or muddy- sand and prawn trawling is regularly taking place. Hook size restriction and seasonal closure of bottom longline fishing in the peak spawning season of economically important species is important. When considering the spawning season of *L. nebulosus*, it should be from July to November and in February but it is not practical to restrict fishing for such a long period because bottom longline is fishing on a multispecies resource. Therefore it is proposed to close the fishing season for about 3 months from July to September as a precautionary management measure to protect spawners of these species.

9. 5 MANAGEMENT STRATEGY AND IMPLEMENTATION

Although the Government has introduced a licensing programme to control open access to fishery, it seems that implementation is difficult and has limited success in totally restricting new entrants. In the development of strategy for fisheries management, the participation of the fisherfolk community is essential. In this context, traditional and customary initiatives by fishermen in fisheries management should be recognized and very often these management measures are very effective in the context of small scale fisheries management in Sri Lanka. The enforcement of fisheries regulation is more effective through 'bottom up' rather than 'top down' planning (Ruddel, 1987, Kalland, 1996). Therefore community-based approaches based on a fishing rights system to the management process have been emphasized because it is more efficient in preventing overfishing of coastal resources. Fishermen and the fishing community should be properly educated regarding the importance of management. The fisheries cooperative of the fishermen's group should be designated to manage and administer the fisheries resources in the given area. This type of management system has been efficiently applied for coastal fisheries management in other countries (Ruddle, 1985). However, the status quo of existing fisheries authorities as the overall guardian of fisheries and enforces of fisheries laws and regulations must be maintained and licensing for fishing rights should be continued. Through this approach however all problems associated with open access fishery cannot be answered but they will at least be reduced.

The absence of effective fisheries management leads to a waste of resources and environmental degradation. Socio-economically, it leads to severe conflicts between groups of fishermen, which are detrimental to the community as a whole. The early introduction of management measures for the demersal fisheries in the Negombo area would help to alleviate harmful effects on the resource and would improve the socio-economic conditions of fisherfolk communities.

9. 6 CONCLUSION

The present status of demersal fish resources in the Negombo area appears to be overexploited in the shallow water economically important species more than in deep waters. These species are under a high risk of recruitment overfishing. Growth overfishing and ecosystem overfishing are also indicated. High fishing pressure in the shallow waters has led to a degradation of the resource sustainability in the area. Sustainability of resources could be possible through restrictions on gears which are relatively less efficient in terms of resource conservation such as bottom trammel net. An increase of fish production in the shallow waters cannot be achieved by technological improvements but may be improved by an expansion of effort toward offshore waters. Exploitation of multispecies resource by all gears shows changes around the MSY over the past few years but the exploitation of economically important species has exceeded the MSY of most fisheries. The economic of exploitation of multispecies resources has long exceeded the MEY and the exploitation of economically important species have exceeded the optimum in terms of catch value by all major gears. However, socio-cultural and technological barriers in the area enable them to maintain 'quasi' rent for all fisheries. All boat/gear combinations engaged in demersal fishing in the area appear to be satisfactory and able to sustain the livelihood of the local fisherfolk. The rapid development of modern fisheries has brought a disparity in income distribution between traditional handline fishery and other fisheries. Improvements to handline fishing income may be possible through expansion of their fishing range toward offshore, or by targeting less exploited species, or by rationalizing competitive gears operating in shallow waters. Better management of the resources through the restriction of the more damaging gears, either to environment or to resource, and by limiting further entry into fishery should ensure the sustainability of resources, fishery and fisherfolk.

9. 7 LIMITATION OF THE STUDY

The catch and effort data are the most comprehensive so far reported for demersal fisheries in Negombo area. They are nevertheless not without error. The catch weights are not from actual weights, but are estimates from visual examination by the enumerators at the landing sites. The information on fishing effort was arrived at by interviewing the fishermen at the time of landings, and hence their acceptability relies on the integrity of the interviewer. The short time during which the catches are available for examination is also a factor, which may increase the incidence of error. The result is that a fully comprehensive identification of all the species is not always practical to achieve. In certain months, the frequently used gears were poorly represented amongst the sampled landings. Notwithstanding, it can be reported that the fishermen appeared always fully cooperative, and the enumerators were well trained and professional.

Sensitivity analysis or risk analysis was not performed to mitigate the uncertainty associated with bio-economic estimates obtained in the present study. Uncertainty could enter into the assessment models in various ways. There may be uncertainties in the values of input parameters and other errors associated with input data. The formulation of the assessment models may also be subject to uncertainty. The estimation of investment cost (capital), repair and maintenance cost are based on estimated mean life and cost of repair and maintenance was estimated respectively for the fleet operated in 1999. The investment cost should be based on the cost of acquisition and fishing unit within the sample during 1999 and cost and earnings data were not adjusted for depreciation.

The present study is limited to a specific area (Negombo), and is concerned only with the demersal fisheries in isolation. The Negombo area is a heavily populated region with overwhelming pressures on all coastal resources for intensive exploitation. There are three major small-scale marine capture fisheries in the area, 1) small pelagic, 2) demersal and 3) shellfish. Competition and interaction are characteristics of these fisheries. Fishermen shift the target opportunistically to maximize their profits. The fishermen engaged in traditional handline fishing with small boats are the persons who mainly change their fishing strategy. As such the management of fishery in isolation is not effective and an integrated fisheries management plan, which addresses the relevant issues, becomes essential.

The increase in human settlement, industrial development, the use of destructive fishing gears such as trammel nets and bottom set gillnets on the reefs, and sea erosion have increased the pressure on the coastal environment off Negombo leading to a degradation of natural habits and resources. The discharge of industrial effluents into coastal areas and the use of agro-chemicals in upstream areas are also becoming a threat to the quality of water in coastal areas. Destruction of natural mangrove and seagrass vegetation leads to ecological imbalance and affects the sustainability of many marine populations. Information on human activities and coastal habitats and monitoring of water quality and other oceanographic parameters in the coastal systems should therefore be incorporated into the development of a bio-economic model of fisheries in the area.

9. 8 FUTURE RESEARCH NEEDS

The findings of the present multidisciplinary study provide information for management of demersal fisheries in the Negombo area but there is a need for additional studies both to confirm and improve the present findings

- Biological studies have been limited to the economically important two indicator species but in a multispecies condition there are many other important species and future biological studies should be extended to cover more species and many biological aspects in addition to growth and reproduction such as food and feeding habits. This would facilitate the application of analytical multispecies stock assessment in future.
- Growth estimation of the fish in the present study was made with length frequency data. Gear selectivity and spawning periodicity would affect the growth estimation of length frequency analysis. Accurate estimates are of vital importance to the accuracy of the analytical stock assessment. This information could be obtained through counting of daily rings in otoliths.
- As there was no information on the distribution and migration of demersal fish species stock assessment studies were performed by assuming the demersal fish assemblage off Negombo area form a unit stock. It is vital to obtain a better understanding of the distribution and migration of the major species. This knowledge could be achieved through genetic studies or a tagging exercise. This in turn would need to be associated with substantial publicity and a system of rewards to encourage the returns.

- This study highlighted the need to correlate biological and fisheries data with oceanographic data. This would facilitate the assessment of the effect of environmental factors on fisheries through ecosystem modeling.
- More extended study on fish marketing should be performed to obtain information on direct and indirect effect of marketing channels on fishermen income and resource exploitation.
- Research to monitor the fishery and its economic performance clearly must continue. This facilitates monitoring the impact of management measures on the fishery and also helps to modify some of these measures.
- Demersal fishery can not be managed in isolation. Fishermen in the Negombo area seasonally change to exploit different resources. Multidisciplinary studies should be extended to all major fisheries for the development of a common management strategy in future.

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