REGIONAL FISHERIES LIVELIHOODS PROGRAMME
FOR SOUTH AND SOUTHEAST ASIA (RFLP)

Fisheries and environmental profile of Negombo lagoon: a literature review

(Activity 1.2.1 Prepare fisheries and environmental profile of Negombo lagoon using secondary data and survey reports)

For the Regional Fisheries Livelihoods Programme for South and Southeast Asia

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ABBREVIATIONS AND ACRONYMS

BOD	- Biological Oxygen Demand
CBO	- Community Based Organization
CCC	- Community Coordinating Committee
CCD	- Coast Conservation Department
COD	- Chemical Oxygen Demand
CEA	- Central Environmental Authority
CPUE	- Catch per Unit Effort
DFAR	- Department of Fisheries and Aquatic Resources
DO	- Dissolved Oxygen
DS	- Divisional Secretary
FAO	- Food and Agriculture Organization
FC	- Fisheries Committee
FI	- Fisheries Inspector
FMA	- Fisheries Management Authority
GCEC	- Greater Colombo Economic Commission
IRMP	- Integrated Resources Management Project
NARA	- National aquatic Resources Research and Development Agency
SAM	- Special Area Management
SDC	- Sustainable Development Consultants
TURF	- Territorial User Rights in Fisheries
UNDP	-United Nations Development Programme

1. Introduction

The term 'lagoon' is loosely used in Sri Lanka to describe many brackish water bodies that should correctly be designated as basin estuaries.

The Negombo lagoon is a shallow basin estuary of approximately 3,164 ha in extent, situated about 20 km north of Colombo ($7^0$4'-$7^0$12' N / $79^0$47' – $79^0$51' E), and is connected to the sea by a single narrow opening, the Negombo channel segment at its northern end, open year round. The estuary and the entire wetland are separated from the sea by a narrow stretch of land consisting of a very fragile coastal dune system situated on beach rock formed during sea level changes over geological periods of time. The marsh-estuary complex in its present form is estimated to have originated about 5,000 years BP (CEA, 1994). One of the unique features of the estuary is that its transition to the sea consists of several narrow channels. The channels of the outlet of the Negombo estuary have been formed because of the natural process of delta formation. The total cross-sectional area of the inlet channels is estimated to be 250m^2 with a length of 2.5 km. Only 11 islands existed in 1956. At present, a total of thirteen islands of different sizes, mostly covered with mangrove vegetation are situated in the estuary outlet to the sea. The size of these islands and the several sand shoals vary from about 2 ha to slightly more than 30 ha (CCD, 2005).

The Negombo estuary extends 12.5 km in length, 0.6 – 3.6 km in width, has a shoreline of 24 km (Anon, 2002) and a mean depth of 0.65 m. It has a surface area of 35 km^2 and holds 22.5 million m^3 of water (Hettiarachchi and Samarawickrama, 2003). It is part of a much larger Muthurajawela marsh - Negombo estuary coastal wetland of total area of 6,232 ha (**Fig. 1**). The Muthurajawela marsh is 31,068 ha in extent and extends southwards from the 3,164 ha lagoon. The Muthurajawela marsh - Negombo estuary coastal wetland has been named as a protected area for biodiversity conservation by the Wildlife Act, 1989 (Devendra, 2003).

The Muthurajawela marsh - Negombo estuary wetland system has served multiple uses including fishery, agriculture, trade and shipping, and habitation from times preceding the colonization of the maritime province in 1,505. These uses have expanded during the post-independence period with increasing urbanization and industrialization of the area to the east of the marsh and to Negombo in the north. During the recent past, there has been visible degradation of the ecological complex, stemming from inadequately planned settlement, industrial and municipal pollution, increasing fishing pressure and general habitat destruction.

2. SOCIO-ECONOMIC PROFILE

The environmental profile prepared under the Greater Colombo Economic Commission (GCEC, 1991) considered the Muthurajawela marsh-Negombo estuary complex as an interdependent ecological system. The total population in this area was 169,669 in 1981 and it had increased to 208,615 in 1990 at the rate of 2.3% annum, higher than the national average of 1.6% per annum.

Only two islands in the channel segment of the estuary – Munnakkare and Siriwardena Pedesa were inhabited in 1955. The encroachment of islands began almost 300 years ago in

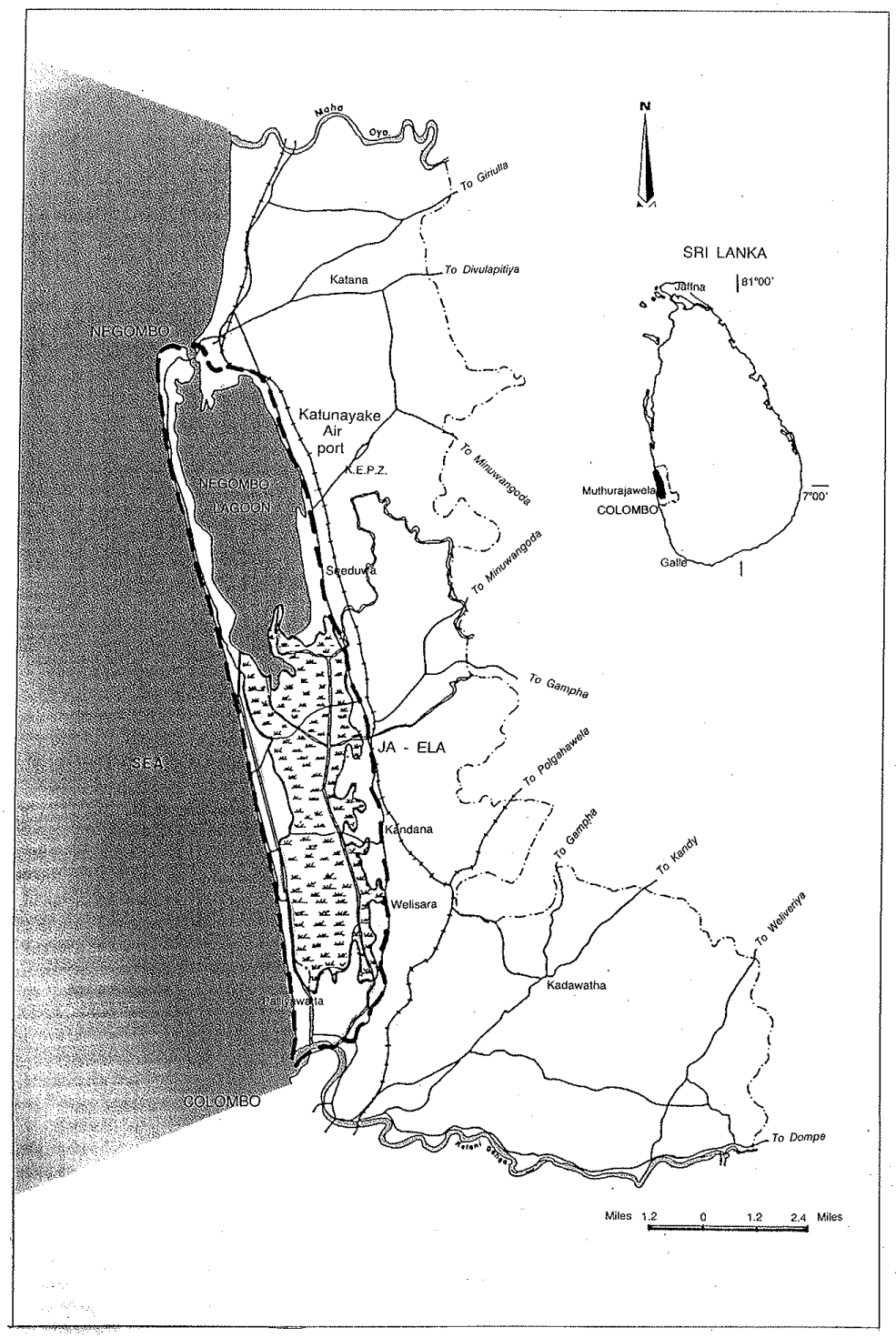

Fig. 1: Location of Muthurajawela marsh – Negombo estuary wetland (Source: GCEC, 1991)

Munnakkare, followed by Siriwardene *Pedesa* in 1955, Pitipana Islands 1 and 2 since 1975 and Regina Road settlement since 1970. The extent of land utilized for housing has increased from 16.9 ha in 1956 to 20.6 ha in 1993 (CCD, 2005). The total number of houses has increased from 380 in 1955 to 1,788 in 1993 and the population in the channel segment has increased from 2,160 in 1955 to 10,090 in 1993.

The Negombo estuary itself is bordered by four administrative divisions referred to as Divisional Secretary Divisions; the Negombo DS division on the northern and the western sides, Katana DS division on the eastern side, Ja-Ela DS division on the southern side and Wattala DS division on the south. While the largest area of the lagoon is bordered by Negombo DS division, only a small part of the lagoon is bordered by Ja-Ela and Wattala DS divisions (**Fig. 2**). The main towns and villages bordering Negombo estuary are shown in **Fig. 3**.

The total population in the four DS divisions was 766,045 in 2008 (**Table 1**). The population density ranges from a high 5,112 /km^2 in Negombo DS division (which has the smallest land area) to a low 1,938/km^2 in Katana DS division (which has the largest land area), with a mean of 3,146/km^2 for all four DS divisions.

Table 1: Population distribution in DS divisions bordering Negombo estuary

DS Division	Total population	No. of households	Land area (km^2)	Population density (no. / km^2)
Negombo	157,456	34,625	30.8	5,112
Katana	208,519	45,275	107.6	1,938
Ja-Ela	226,988	53,547	58.9	3,854
Wattala	173,082	39,775	46.2	3,746
Total	**766,045**	**173,222**	**243.5**	**3,146**

(Source: Anon, 2008a, Anon, 2008b, Anon, 2010 and Anon, 2009)

The employment pattern of the population in the Muthurajawela marsh-Negombo lagoon complex and the marsh proper in 1990 is given in **Fig. 4** (GCEC, 1991).

Employment pattern of the population in the four DS divisions bordering Negombo estuary in recent years is given in Table 2. Complete data regarding employment pattern in the Negombo DS division is not available to make a proper evaluation of the employment pattern in the four DS divisions.

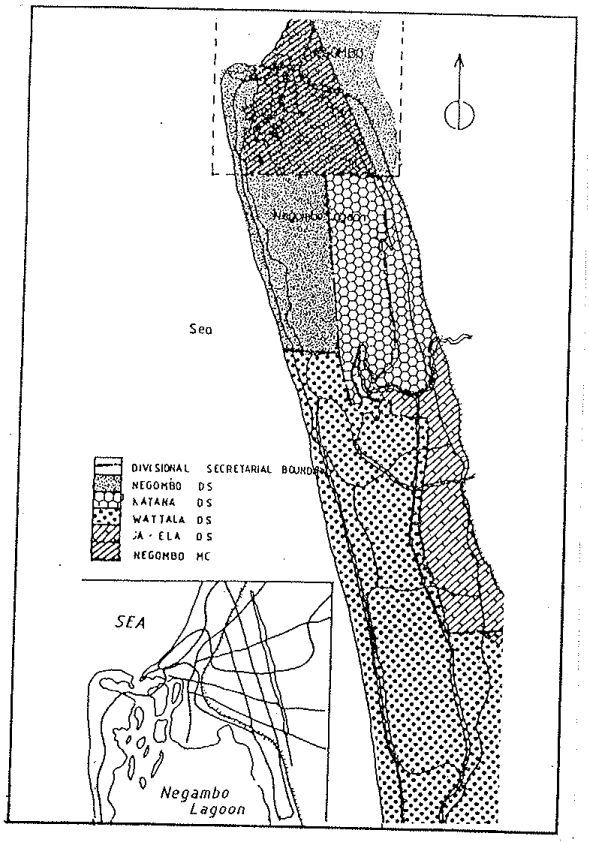

Fig. 2:
Boundary of Negombo, Katana, Ja-Ela and Wattala Divisional Secretary's Divisions (Source: CEA, 1994)

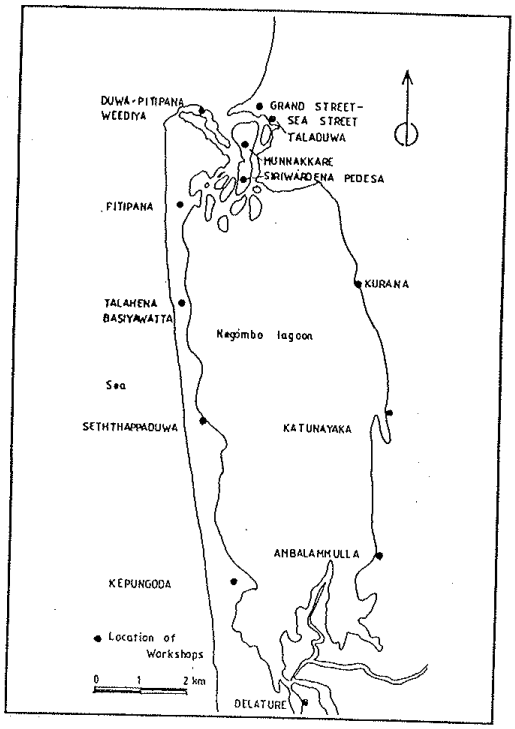

Fig. 3:
Main towns and villages around Negombo estuary (Source: CEA, 1994)

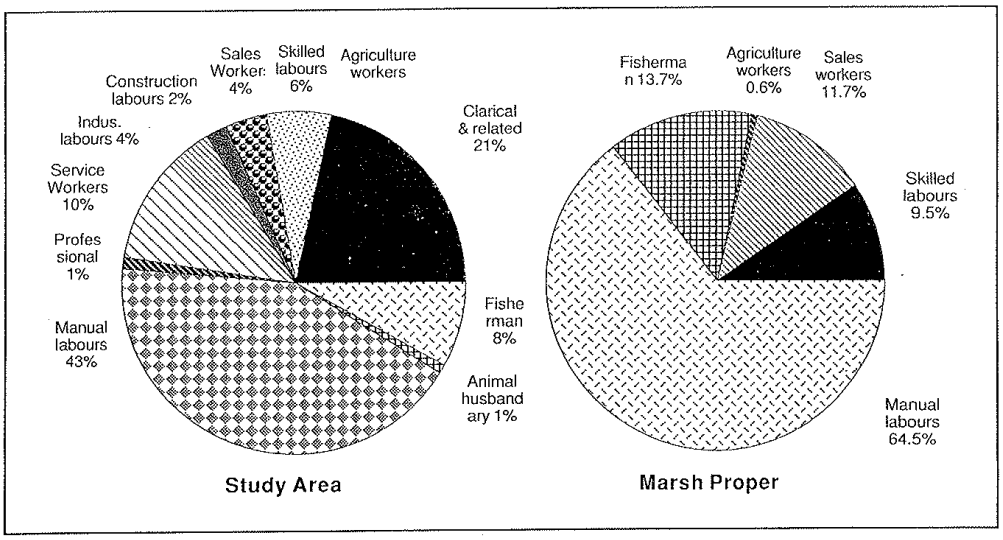

Fig. 4: Employment pattern of the population in the study area and in the marsh proper (Source: GCEC, 1991)

Table 2: Employment characteristics in DS divisions bordering Negombo estuary

Nature of employment	DS division				Total
	Negombo	Katana	Ja-Ela	Wattala	
State sector	3,994	4,052	11,065	6,860	25,971
Semi-government			9,171	6,981	
Private sector	26,284	25,072	39,155	43,775	134,286
Self employment		10,303	10,388	12,468	
Foreign employment		2,748	7,375	3,638	
Agriculture	249	1,186			
Animal husbandry		1,011			
Fisheries		320			
Business		4,101			
Labour / menial work		14,920			
Others		3,604			
Total		67,317	77,154	73,732	

(Source: Anon, 2008a, Anon, 2008b, Anon, 2010 and Anon, 2009)

For purposes of fisheries administration, the coastal area of Gampaha district is divided into a number of Fisheries Inspector divisions, each under the care of a Fisheries Inspector (FI). Negombo estuary is bordered by 09 FI divisions. Full time and part-time fishers operating in Negombo estuary by DS and FI division during 2010 are given in **Table 3**. Of the total of 3,310 fishers, 2,586 or 78% fish fulltime in the estuary while 724 or 22% are part time fishers who move into the estuary only during the southwest monsoon periods when sea fishing is difficult.

Table 3: Fishers involved in Negombo estuarine fisheries

DS division	FI division	No. of fishers		
		Full time	Part time	Total
Negombo	Duwa	88	-	88
Negombo	Negombo Town I	39	-	39
Negombo	Negombo Town II	120	60	180
Negombo	Negombo Town III	1,044	320	1,364
Negombo	Pitipana	110	20	130
Negombo	Alutkuruwa	255	65	320
Negombo	Kepungoda	600	108	708
Wattala	Uswetakeyiyawa	140	26	166
Katana	Ja-Ela	127	50	177
Ja-Ela	Ja-Ela	63	75	138
Total		**2,586**	**724**	**3,310**

(Source: Anon, 2011)

It is also seen that over 85% of the estuarine fishers come from the Negombo DS division and that the number of fishers are low in FI divisions covering the extreme south and northern end of the estuary. All fishers from Duwa and Negombo Town I FI divisions are engaged in stake net fishery in the channel segment of the estuary. NARA (1991) has earlier estimated that about 3,000 fishers obtain their sole income from fishing in the estuary.

3. LAND AND RESOURCE UTILIZATION

The area under the Negombo 'lagoon' Special Area Management (SAM) plan consists of 10,694 ha which includes 3,068 of marsh proper, 3, 164 ha of the Negombo estuary and 4,462 ha of high ground. The southern part of the lagoon is covered with mixed vegetation such as sedges, reeds and ferns associated with typical mangrove species. Mangroves extend over a very narrow inter-tidal area around the lagoon, covering approximately 350 ha. Sea grass beds (704 ha) cover 22% of the lagoon area (CCD, 2005).

The high ground area can be divided into two segments – the agriculture area and the built up area. The agriculture area contains homestead gardens, coconut, paddy, horticulture and pasture. Most of the built up area includes residential, industrial and infrastructural constructions (**Table 4**). Service infrastructure including roads, power, water supply and telecommunication facilities cover nearly 500 ha (CCD, 2005).

Table 4: Land use in Negombo SAM area

Land cover type	Area (ha)	%
Marsh proper	2,688	25.1
Negombo lagoon	3,164	29.6
Mangrove – 350 ha		
Sea grass beds – 704 ha		
Agriculture	1,039	9.7
-Homestead garden 543 ha		

- Coconut	430 ha		
- Paddy	30 ha		
- Horticulture	30 ha		
- Pasture	06 ha		
Built up areas		3,803	35.6
	Total	**10,694**	**100**

(Source: CCD, 2005)

The land use pattern in the Muthurajawela marsh – Negombo estuary wetland during early 1990's is shown in **Fig. 5** (GCEC, 1991).

In more recent times, land use in the four DS divisions bordering Negombo estuary is dominated by homesteads (35.7%), coconut plantations (18.4%), urban construction (11.3%) and paddy cultivation (7.7%). The Negombo estuary-Muthurajawela marsh complex accounts for 22% of the land cover (**Table 5**). While Katana and Ja-Ela are the most populous DS divisions, land use

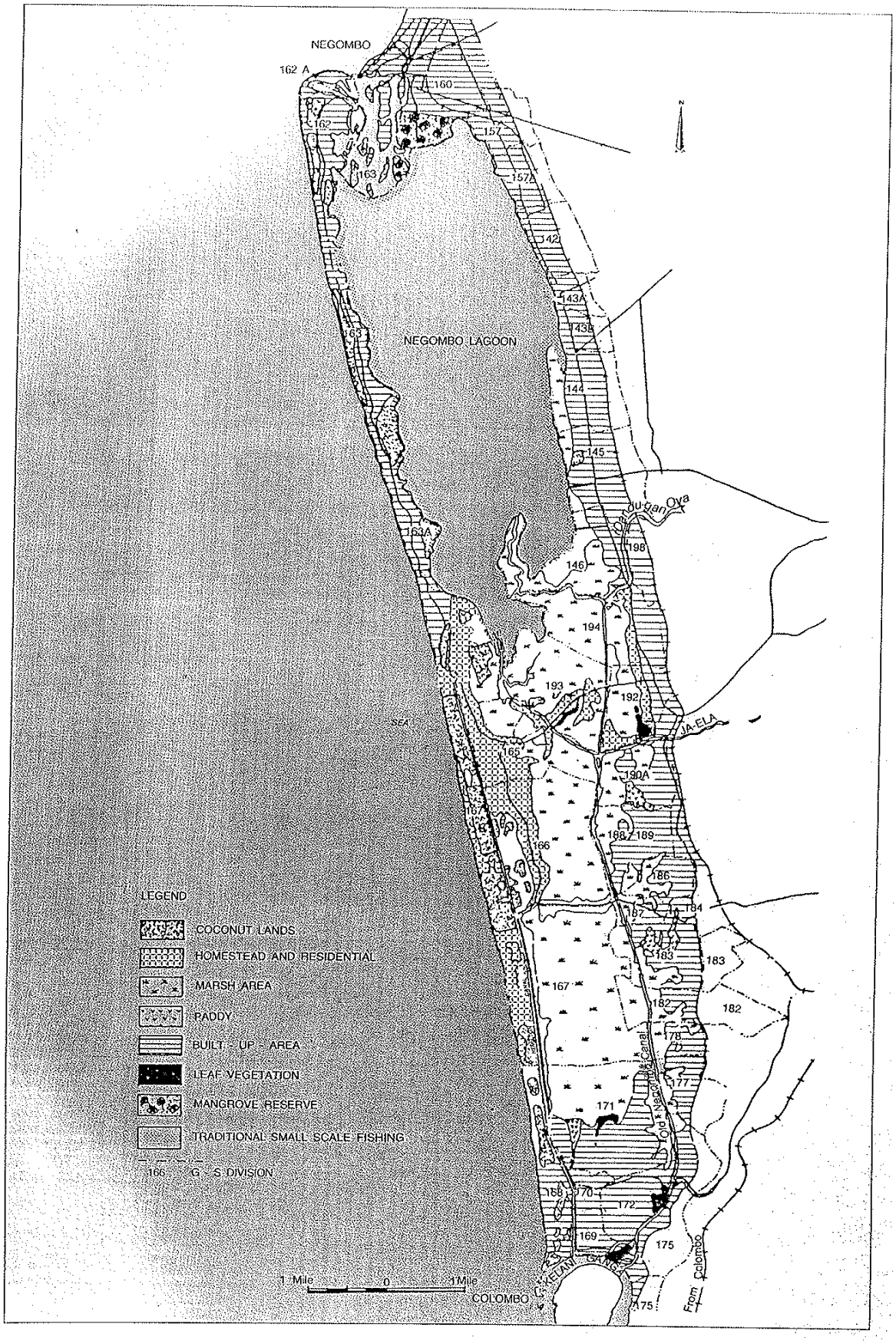

Fig. 5: Existing land use in the study area (Source: GCEC, 1991)

for urban construction is highest in Negombo DS division. Over 90% of the coconut cultivation and 57% of the paddy cultivation is found in Katana DS division.

Table 5: Land use in DS divisions bordering Negombo estuary (in ha)

Land use	DS division				Total
	Negombo	Katana	Ja-Ela	Wattala	
Urban construction	1,416.8	769.1	655.9	180.0	3,021.8
Paddy cultivation	17.7	1,168.8	697.5	160.0	2,044.0
Homestead	651.1	3,499.1	3,536.8	1,810	9,497.0
Coconut	273.0	4,480.8	127.4	16.0	4,897.2
Rubber		18.4	49.1		67.5
Cinnamon			38.6		38.6
Other perennial crops				280.0	280.0
Minor crops	31.0		13.7	10.0	54.7
Forest		74.5			74.5
Shrub jungle		7.0	104.9	20.0	131.9
Marshy land	0.8	218.0	613.4	1,700	2,532.2
Mangrove	57.7	36.1		210.0	303.8
Water areas	1.1	9.7	51.1	180.0	241.9
Sand	74.2				74.2
Lagoon area	1,851.4	1,472			3,323.4
Others (play grounds, cemetery, etc.)	17.6	5.9			23.5
Total	**4,392.4**	**11,759.4**	**5,888.4**	**4,566.0**	**26,606.2**

(Source: Anon, 2008a, Anon, 2008b, Anon, 2010 and Anon, 2009)

4. FISHERIES IN NEGOMBO ESTUARY

The Negombo estuary associated wetland ecosystem supports a wide range of economic activities, most of which depends on the structure and functioning of the ecosystem. Fishing is one of the most important economic activities, with an estimated annual value of Rs. 150 million (SDC, 1998).

The Negombo estuary is a very important fishery centre in the country. The estuary itself was estimated to support a fishery with an annual value exceeding Rs. 100 million (CEA, 2004). The estuary also serves as a shrimp nursery and a nutrient source for the coastal sea. The coastal shrimp fishery for which the estuary serves as a nursery, and the small pelagic fishery entrained by nutrients released from the estuary have an estimated annual value of about Rs. 100 million. Together, about 6,000 small-scale fishers obtain their primary income from the estuary and the linked coastal fishery.

Because of the traditional and small–scale nature, Negombo estuarine fisheries provide livelihoods and income to a substantial segment of the population around it. Fishing in the estuary has been the sole income of an estimated 3, 000 fishers in 1990 (NARA, 1991). CEA (1994) has also reported that the Negombo estuarine fisheries provide primary income to at

least 3,000 fisher families from the 26 villages bordering the estuary. CCD (2005) has estimated a total of nearly 5,000 engaged in Negombo estuarine fisheries, a majority of them in trammel net (1,300) and push net (1,200) fishing. According to Anon (2002), a study in 1998-99 has estimated a total of 20,000 being directly or indirectly dependent on the lagoon for their sustenance.

The study by Sanders et al (2000) has brought out many characteristics of the Negombo lagoon fisheries. The fisheries are characterized by low costs (important in preserving remuneration levels) and high integration. A multitude of gears target different species and sizes of shrimp. All available niches for exploiting shrimp stocks have been identified and are being successfully utilized. Another feature is the ability of fishermen to shift operations, from one fishery to another (except stake net fishery). This is reflected by the more or less same remuneration levels across fisheries, conferring additional stability to the performance of the fisheries (collectively).

4.1 FISH RESOURCES AND PRODUCTIVITY

In general, bulk of the brackish water fish population is maintained by continuous migration from the sea and fresh waters. In the brackish waters of Sri Lanka, Pillai (1965) has recorded a total of 142 species of which112 were considered edible (100 species of finfish, 07 species of shrimp, 04 species of Molluscs and 01 species of crab. Among the edible varieties were 65 percent migrants from the sea, 30 percent strictly brackish water species and 5 percent migrant from fresh waters.

In Negombo estuary, De Silva and Silva (1979a) have identified a total of 62 fish species belonging to 36 families in the brush pile fishery. While 32 species identified were of marine origin, only three species have been typically fresh water. The number of species occurring in the estuary has shown two peaks – a higher one in February and a lower one in August. Over 40% of the species were observed to be occurring in the lagoon for ten or more months of the year. Only two species were found to occur for less than three months. De Silva and Silva (1979) contended that the seasonal increase in the fish fauna of the estuary is primarily brought about by an increase in the number of marine species migrating into the estuary, coinciding with increasing salinities in the estuary.

At least 133 different species were reported to inhabit Negombo estuary (GCEC, 1991), more than half marine species moving into the estuary from the sea. Wijeyaratne and Perera (1992) have recorded 82 fish species of which 98% were edible. Dominant finfish varieties include the milkfish (*Chanos chanos*), catfish, half beaks (Hemirhamphidae), grey mullet (*Mugil cephalus*), Giant Perch, surgeon fish, banded Etroplus, silver whiting and pony fish.

Ten species of shrimp have been identified during a three year study on shrimp catches from the stake net fishery in Negombo estuary (De Bruin, 1970). *Metapenaeus dobsoni* was the most dominant (71%), followed by *Peneaus indicus* (15%), *P. semisulcatus* (6.7%) and *M. elegans* (5.8). Although very high in abundance, *M. dobsoni* is not as commercially important as the other abundant species such as *Peneaus indicus, P. semisulcatus* and *M. elegans* as it is one of the smallest shrimp in size. Other species found in very small quantities included *P. monodon, P. latisulactus*, *M. burkenroadi*, M. *affinis, M. monoceros* and *Parapeneopsis*

cornuta. These species were caught in negligible quantities and were present in the estuary only during few months of the year.

From the monthly variation in abundance, De Bruin (1971) concluded that *Metapenaeus dobsoni*, *Peneaus indicus* and *P. semisulcatus* are migratory as there was an enormous fluctuation in their relative abundance for different months of the year. High catches of *M. dobsoni* in May, after a significant decrease in abundance in April was indicative of fresh recruits entering the estuary in this month. The relative abundance of *Peneaus indicus* has increased sharply in November while the relative abundance of *P. semisulcatus* has increased significantly during March and September. *M. elegans* was considered to be a non-migratory species as it showed the least monthly fluctuations in abundance.

Schuster (1951) has estimated the average annual production of Sri Lanka's brackish waters to be less than 22 kg per ha per annum. However, Pillai (1965) has estimated the productivity of Negombo estuary in 1960 to be 72.9/ha/annum. Wijeyaratne (1984) has obtained a value of 15 kg/ha for Negombo estuary finfish, excluding shrimp and crab.

Annual yields of fish and crustaceans from different parts of the Negombo estuary have been estimated and reported in GCEC (1991). **Table 6**, extracted from GCEC (1991) shows an annual yield of 293,500 kg/year. The important species captured, their annual production and the estimated values are also given in **Table 6**. The estimated annual yield and value of ornamental fish and seed selected for aquaculture are also given separately.

Quoting that highly productive estuarine and lagoon systems have a productivity of 100 kg/ha/year, Jayakody (1996) too contends that fish productivity of Negombo lagoon wetland is outstanding by international standards as its annual yield exceeds 150 kg/ha (excluding ornamental fish).

Table 6: Estimated annual yields of fish and crustaceans from Negombo estuary-Muthurajawela marsh wetland.

Segment/Zone	Main species	Estimated annual yield (kg/yr)	Annual yield (kg)/ha/yr	Estimated value (Rs.)	Source
Channel segment					
Stake net (Kattu del)	*Peneaus indicus* *Metapeneaus dobsoni*	60,000	20	3,000,000	Jayakody (1990)
Basin segment					
Brush piles	*Peneaus indicus* *Mugil* spp. *Etroplus suratensis* *Siganus* spp. *Lates calcarifer*	48,000		960,000 (Rs. 20/kg)	Jayakody (1990)
Encircling nets & other nets	*Mugil* spp. *Liza spp.*	40,000	13	1,200,000 (Rs. 30/kg)	Wijeyratne, (1984)
Crab traps	*Scylla serrata*	40,000	13	8,000,000 (Rs. 200/kg)	Jayamanne, 1990)

Trammel nets	*Peneaus indicus*	60,000	20	9,000,000 (Rs. 150/kg)	Kuruta and Nishida (1988)
Transition zone					
Encircling nets & other gillnets	*Lates calcarifer*	18,000	6		Wijeyratne (1990)
Trammel nets	*Peneaus indicus*	26,000	9.6		
Crab traps	*Scylla serrata*	1,500	0.5		
Total		**293,500**	**97.5**		
Ornamental fish & seed for aquaculture	*Monodactylus argenteus* *Scatophagus argus* *Lates calcarifer* *Epinephalus spp.* (Av. Wt. 2.0 g)	30,000	10	50,000,000	Jayakody (1990)

(Source: GCEC, 1991)

Ornamental fish and collection of commercially important juveniles of finfish from Negombo estuary has expanded rapidly in mid-1980s. Juveniles of Epinephelus and Cephapolis have been collected in large numbers, 5,000 – 10,000 individuals per day during May – August period (NARA, 1988). These fish are usually collected from brush piles, scoop nets and push nets. Juveniles of groupers (Epinephelus) have been reported to increase dramatically soon after periods of heavy rains and some 12-15 million grouper fingerlings have been exported during certain seasons, valued at Rs. 35,000 million.

Based on studies on the feeding behavior of four commercially important species of fish in Negombo lagoon, Parakrama et al (2003) reported that *Arius caelatus* and *Triacanthus biaculeatus* are predominantly carnivores, feeding mainly on fish and crustaceans during two feeding peaks. *Liza macrolepis* was found to be a benthic feeder, with diatoms been the main food item.

The grey mullet, *Mugil cephalus* is an important constituent in the Negombo estuary fish catch. Detailed investigations into the biology, ecology and fishery of grey mullet in Negombo estuary have been conducted by De Silva and Silva (1979b), De Silva and Perera (1976), De Silva and Wijayaratne (1977), Perera and De Silva (1978b) and, Wijayaratne and Costa (1987).

Wijeyaratne, et al (1995) studied the population dynamics of the vermiculated rabbit fish, Siganus *vermiculatus*, which makes an important contribution to the catches made by the brush piles, gillnets and seines in Negombo lagoon and found that the stock was not over-fished. It was recommended that the mean size at first capture should be increased from 19.3 cm to 23.3 cm to obtain maximum sustainable yield.

Polychaetes are an important constituent of the estuarine benthic macro-faunal community, exhibiting a wide range of sediment choice. Dahanayake, et al (2007) identified 36 species of polychaetes belonging to 16 families from Negombo lagoon. Low or zero diversity has been recorded from the lagoon mouth area and from deeper areas of the middle region of the lagoon. High abundance and diversity were observed at lagoon margins and inner regions. Polychaete abundance has decreased with increasing depth and their diversity has also changes with salinity. A combination of salinity, depth and nutrient contents of water were thought to affect the abundance and diversity of polychaetes in the lagoon.

4.2 FISHING FLEET

SDC (1998) has traced the fishing fleet development in Negombo estuary, from 369 in 1981 to 1,181 in 1997 (**Table 7**).

Table 7: Fishing fleet development in Negombo lagoon

	1981	**1984**	**1989**	**1997**	**2010**
- Outrigger canoe (*Oru*)	300	836	577	697	866
- Log Raft (*Teppam*)	69	183		413	492
Total	**369**	**1019**	**577**	**1,110**	**1,358**

(Sources: SDC, 1998 / Anon. 2011)

Anon (2002) refers to a study conducted in 1998-99 that has placed the fishing fleet in Negombo estuary at 1,500 made up of 1,160 dug out outrigger canoes and 340 log raft. More recent data available at the district fisheries office, Negombo (Anon, 2011) points to a fishing fleet of 1,358 made up of 866 (64%) outrigger canoes and 492 (36%) log rafts (**Table 8**).

Table 8: Fishing fleet distribution in Negombo estuary by FI division, 2010

FI division	**Outrigger canoe (*Oru*)**	**Log Raft (*Teppam*)**	**Total**
Duwa	44		44
Town I	39	-	39
Town II	85	08	93
Town III	275	-	275
Pitipana	92	16	108
Kapungoda	60	338	398
Aluthkuruwa	176	20	196
Uswetakeyiyawa	15	45	60
Ja-Ela	80	65	145
Total	866	492	1,358

(Source: Anon. 2011)

The traditional fishing craft used in the Muthurajawela – Negombo estuary wetland are shown in **Fig. 6** (GCEC, 1991). There are about 40 traditional landing sites located around the estuary (CCD, 2005).

4.3 FISHING GEAR AND METHODS

Many authors refer to a variety of fishing gear and methods used in Negombo estuary. Jayakody (1996) has recorded 22 fishing methods used in Negombo estuary, of which 13 were considered traditional fishing methods. These were the cast net, stake net, Katta, brush pile, Kadippu dela, angling, crab pots, scoop net, Karak gediya, Iratta, fish krall, Kemana and dip net. Other more modern methods include the Gokran dela, hand trawl, gillnet, drift gillnet, polychaete worm digging, drift net, trammel net and Gawana dela.

SDC (1998) provides information on major fisheries conducted in Negombo estuary during late 1990s, in terms of different craft/gear combinations during the southwest (May to October) and northeast (November to April) monsoon seasons (**Table 9**), based on percentage distribution of fishing effort.

Table 9: Major fisheries conducted in Negombo lagoon in different seasons (percentage distribution of fishing effort)

Fishery	May-Oct.	Nov.-April	All year
Non-motorized outrigger canoe (*Oru*)			
Trammel net fishery	42.0	35.5	38.5
Cast net fishery	39.8	25.5	32.2
Gillnet fishery (*Sala dela*)	1.0	16.4	9.3
Trap net fishery (*kudu dela*)	6.3	4.0	5.1
Crab pot fishery (*kakulu thatiya)*	6.2	8.0	7.2
Lagoon seine (*gawana dela*)	2.8	1.6	2.2
Trawl fishery	1.0	6.6	4.0
Stake net fishery (*kattu del*)	0.5	0.6	0.6
Gokran dela	0.2	1.5	0.9
Non-motorized log raft (*Teppam*)			
Trammel net fishery	32.9	41.1	36.0
Cast net fishery	17.1	26.0	20.5
Gillnet fishery (*Sala dela*)	14.7	27.4	19.8
Lagoon seine (*gawana dela*)	15.8	5.4	11.7
Gokran dela	3.7	-	2.2
Longline	15.8	-	9.4

(Source: SDC, 1998)

CCD (2005) has reported 19 fishing methods practiced around the estuary with 08 main types, all targeting shrimp except for gillnets and the hand lines. The trammel net was considered the most common, used throughout the northern end of the estuary along with the cast nets. The traditional fishing methods in Negombo lagoon and the number of fishers involved are given in **Table 10** (CCD, 2005).

Table 10: Traditional fishing methods and numbers of fishers involved

Traditional fishing method	No. of fishers
Stake net fishery (*kattu del*)	350
Cast net fishery	1000
Brush pile fishery (mas athu)	450
Crab pot fishery (*kakulu thatiya)*	300
Angling	200
Stake trap (*Ja kottu*)	10
Shrimp eye noose (Iratta)	60
Cover pot (*Karakgediya)*	100
Gill net (*Elana del*)	1370

Traditional fishing method	No. of fishers
Drive-in-net (*Gokran dela*)	60
Atu gema	70

(Source: CCD 2005)

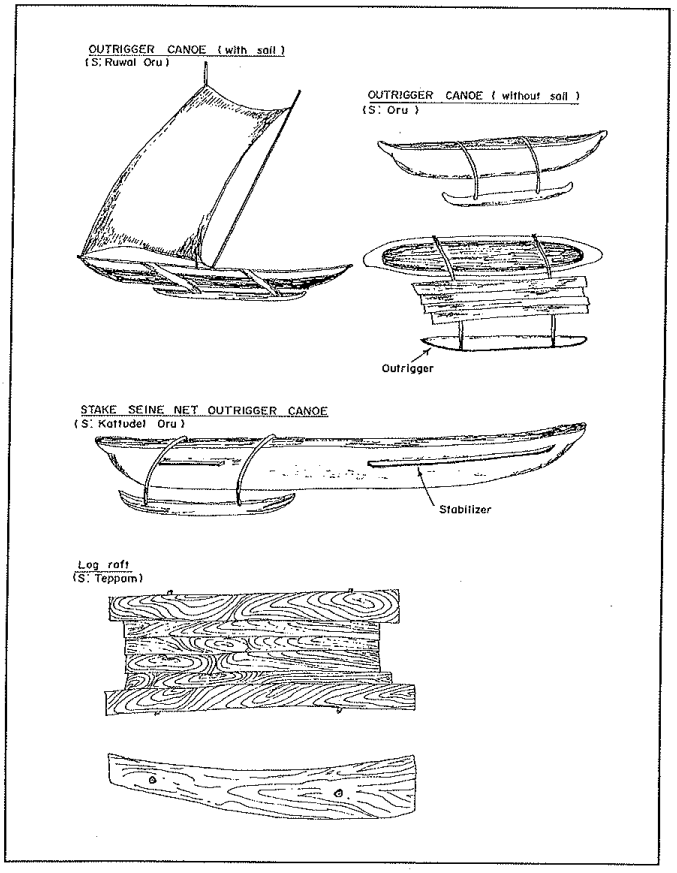

Fig.6: Traditional fishing crafts used in the Muthurajawela marsh - Negombo estuary wetland (Source: GCEC, 1991)

Some important fishing gear and methods used in the Muthurajawela marsh – Negombo estuary wetland is shown in **Fig.7.** The three most prominent recent additions to the range of fishing gear in use are the trammel net (disco net), push net and the trawl.

Trammel net fishing for fish and shrimp is the dominant fishery operated from all types of crafts. Cast net fishing, also for small varieties of finfish and shrimp, is the second major type of fishing of those using *orus* and *teppams*. Both fisheries are conducted year round. Mesh size and the number of panels in the small mesh gillnets used in Negombo estuary vary according to the target species and the depths at which the nets are operated. The "*gawana dela*" or the lagoon seine is operated in the shallow areas of the estuary, targeting the green Tiger shrimp and the flower shrimp. Small- mesh gillnets fisheries become more important during the northeast monsoon months of November to March. The trap net or the "*kudu dela*" fishery is a traditional fishery handed down from generation to generation; now carried out by only a limited number of fishermen due to non-availability of suitable fishing areas.

Anon (2002) has recorded that trammel nets, brush piles, cast nets and drag nets to be the four main types of fishing gear used by log rafts and dugout canoes.

Cast netting is one of the oldest fishing methods conducted during day time in areas with smooth bottom. Shrimp cast nets are of two types – one is operated from a canoe and the other is operated by wading across the water. The cast net used for fish is larger in size with bigger mesh. Approximately 350-550 cast net fishers operate on a single day in Negombo estuary, with an estimated catch per fisher ranging from 0.5 – 3.5 kg per day (Jayakody, 1996).

Sri Lanka has a fairly long history of traditional community based fisheries management. Under these management regimes, local fishermen have developed management strategies in the conduct of fisheries within waters, which they consider as 'theirs'. Most of these traditional management systems have collapsed in recent times due to introduction of new technologies. However, there are still some small, localized fisheries, which are still being managed through traditional methods. The stake net fishery in Negombo estuary is an example of fisheries where territorial user rights in fisheries (TURFs) are still in force. This fishery is well managed with a system of limited entry, which is based on criteria such as area of residence, inheritance, etc (Joseph, 2010).

According to Jayakody (1996), the stake net (*Katttu del*) fishery in Negombo estuary dates back to 1721. The Church guides the kattudel fishermen's association. One tenth of the income obtained from the fishery is donated to the church. About 8% of the estuarine fishermen are in control of the fishery and the strictly enforced user rights management system prevents others from entering this fishery. Fishing is conducted from 06.00 pm to 06.00 am the following day, throughout the year. The stake net is a passive gear, with two wings and a cod end. It is operated in the channel segment of the estuary, close to the mouth of the estuary. The net is fixed to the estuarine bottom using sticks, to catch shrimp and fish as the tidal currents move out to sea. Many katttudel fishermen are therefore free during other times and are engaged in activities such as carpentry, teaching and other jobs.

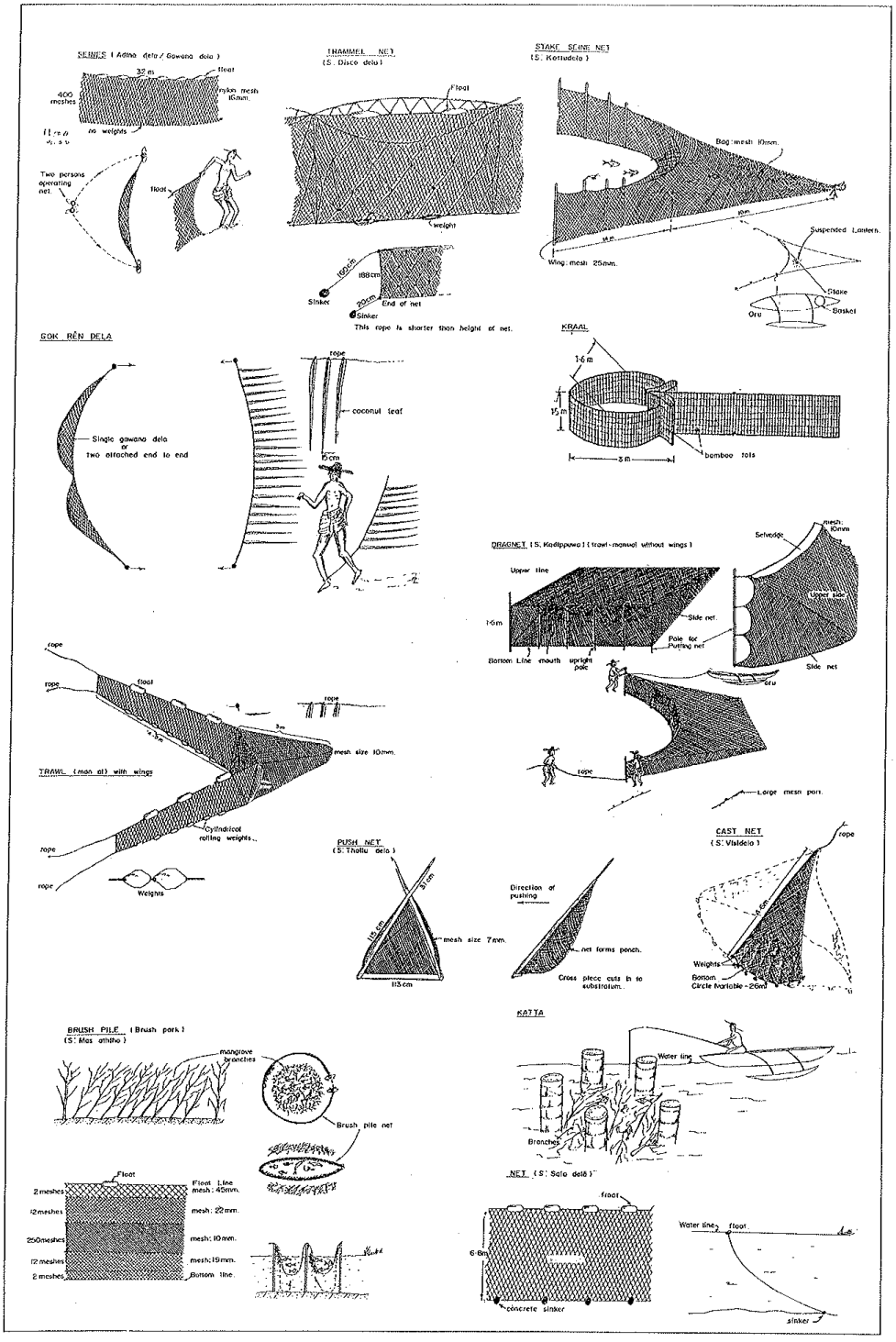

Fig. 7: Some important fishing gear and methods used in the Muthurajawela marsh - Negombo estuary wetland (Source: GCEC, 1991)

A substantial number of fishers in Negombo estuary are also engaged in fishing activities that do not require the use of a fishing craft. Nearly 100 families (about 42% of those fishing without crafts) are engaged in brush pile fishery. A brush pile is made up of a pile of mangrove brushwood place in shallow water and pegged down with sticks. Rotting and decaying mangrove twigs in a brush pile are replaced regularly so that a single brush pile will remain in its place for a long time. Brush pile fishing has a long history, with the first reference to it dating back to 1910 (Jayakody, 1996). The brush piles (*mas athu*) are visited every 3-4 days when targeting for shrimp and at 20-30 days intervals when targeting finfish. Fish or shrimp are collected by encircling the brush pile with a net fixed to a number of sticks. The twigs of the brush pile are removed manually and the trapped fish or shrimp harvested. Brush pile catches consist mainly of Siganus sp., Mugil sp., Lutjanus sp., Lates calcarifer, Monodactylus argenteus, Scatophagus argus, Ambassis sp. and Hemirhamphus sp. An individual or a family unit may own and operate 20-30 brush piles. While SDC (1998) has reported of 1000 brush piles from Negombo estuary, Jayakody has estimated it to be 1,800 to 2,000, presumably for the same period of mid and late 1990s. The brush pile fishery was also claimed to contribute 36% to the total estuarine fish production (Jayakody, 1996). Brush piles have also contributed to increased catches of ornamental fish from the lagoon.

The *katta* is a fish aggregation device in which a large number of coconut tree trunks are fixed to the estuary bottom, close to each other at a depth of about 1.5 m and mangrove twigs are also fixed among the coconut tree trunks to provide a protected area for fish which are caught using rod and line. The daily catch of a fisherman from this device has been estimated at 1.0 to 3.5 kg (Jayakody, 1996).

The *Kadippu dela* is a tradition type of drag net with poles and a bag type cod end. The poles keep the net mouth open while the fish and crustaceans get collected at the cod end when the net is dragged along the bottom of the estuary by two men at a speed that will prevent the fish already collected at the cod end from escaping. This gear is operated in both day and night, targeting cichlids, shrimp and grouper, and the best season is from September to March the following year. *Kadippu dela* is known to damage sea grass beds. However, Jayakody (1996) has observed a decline in its use, from 20-30 nets in 1985-88 periods to only 3-4 during late 1990s.

The lift net for crabs (crab pot) is a simple but ancient gear dating back to the last century, and used throughout the year in both day and night. The gear consists of a bamboo or a metal circular ring of 40-50 cm diameter with a cone shaped netting attached to it. Pieces of trash fish and fish offal are placed inside the pot to attract the crabs that gets entangled in the netting. About 40-60 such crab pots are attached to a 3-4 mm rope and taken to the fishing grounds**.**

The cover pot or *karakgediya* is an old traditional gear operated year round in shallow waters up to 0.5 m depth. It is operated at night with a light to locate fish or shrimp on the estuarine bottom, which are then quickly covered with the cone shaped device and taken out through the opening at the top by hand. With the introduction of more efficient gear such as trammel nets, its use is now very much limited.

The Push net is a very primitive type of gear which has become popular since early 1990s for catching green tiger shrimp, juveniles of grouper fish (*Epinephalus* sp.) and other aquarium fish. Push net fishing is conducted by nearly 1,000 fishers (about 50% of those fishing without craft) in Negombo estuary. It is operated mainly during the months of November to February when there is more fresh water in the lagoon.

In an assessment of the shrimp fishery in Negombo estuary, Sanders, et al (2000) reported that shrimps are caught using six types of gear – the trammel nets and the cast nets operated across the central portion of the estuary, the stake nets operated immediately inside the entrance to the estuary, lagoon seines (drag nets) and brush piles along the perimeter of the estuary and the Fyke nets used at the southern end of the estuary. Outside the estuary, non-motorized shrimp trawlers (outrigger canoes) operate north of the entrance while motorized trawlers operate 5-10 km to the south.

Fishing gear and methods used in different zones in the Muthurajawela – Negombo estuary wetland is shown in **Fig. 8** (GCEC, 1991). It is seen that most of the fishing methods are used in the basin segment of the estuary.

4.4 FISH PRODUCTION FROM NEGOMBO ESTUARY

In Sri Lanka, statistics on fish production from estuaries and lagoons are incorporated into those for coastal marine fisheries. For this reason, no separate data and information is available on Negombo estuary fish production, fishing effort or catch composition. However, limited data/information is available from specific studies conducted over limited time periods at different times.

Shrimp catch in the estuary during 1997 was estimated at 613 t while the estimated catch of others (mostly fish) was 1,044 t (Sanders et al, 2000). The production from trawlers operating outside the estuary was 270 t shrimp and 239 t of others. Of the 14 species of shrimp identified, 06 were dominant in the catches. These included *Penaeus indicus* (trammel nets, cast nets and brush piles), *P. semisulcatus* (trammel nets and cast nets), *Metapenaeus moyebi* (stake nets, lagoon seine), *M. dobsoni* (stake nets) and *M. elegans*. Trawl catches outside were dominated by *M. dobsoni* and *Parapenaeopsis coromandelica*.

Anon (2002) refers to a total production of 1,000 t from the Negombo estuary, with shrimp accounting for 66% of the catch. The estimated total catch from Negombo estuary in 2010 by FI division is given in **Table 11** (Anon, 2011). This catch of 1,385.6 t is less than the total catch of 1,657 t reported by Sanders et al (2000).

Table 11: Fish catch from Negombo estuary by FI division, 2010

FI division	Estimated production (kg)
Duwa	95,650
Town I	23,400
Town II	60,000
Town III	720,000
Pitipana	77,760
Aluthkuruwa	9,750
Kapungoda	240,000
Uswetakeyiyawa	78,000
Ja-Ela	81,000
Total	1,385,560

(Source: Anon, 2011)

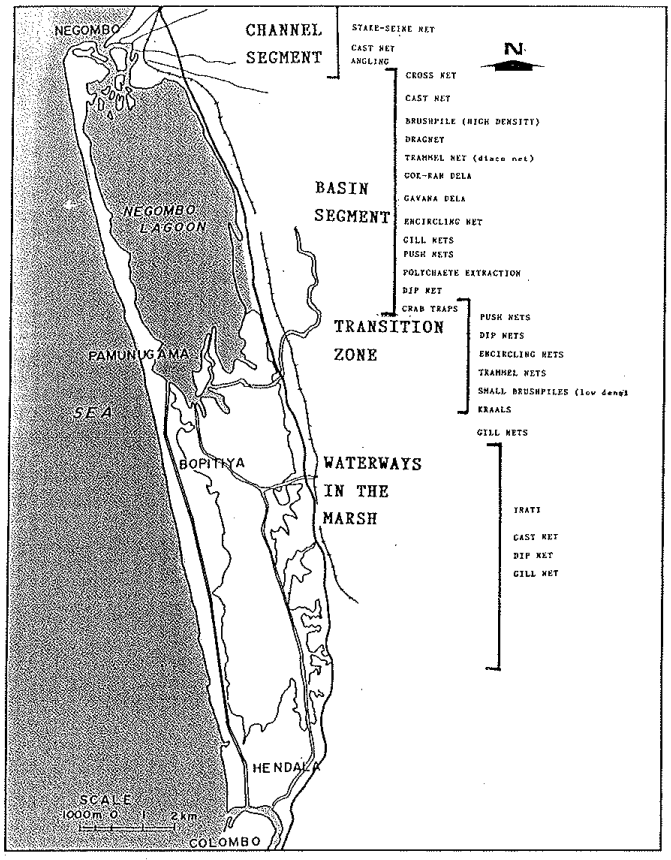

Fig. 8: Generalized zones of operation of different fishing gear and methods in the Muthurajawela marsh - Negombo estuary wetland (Source: GCEC, 1991)

Studies related to fish catch and effort trends in Negombo estuarine fisheries are very limited. Over a period of two decades, Samarakoon (1990) has surmised that the fish and crustacean resources in the estuary have been distinctly overfished; as reflected by an increase in the number of fishers, decrease in the size of fish caught in different gears, increase in the value of ornamental fish and an increase in their exploitation, progressive decrease in mesh sizes of nets used and multiplication of gear types used including those that are destructive to early stages of fish and shrimp.

In the brush pile fishery, there has been a clear decrease in the size of the fish captured during 1988 when compared to the size of same fish species caught during 1976/77 (**Fig. 9)** (GCEC, 1991). The decrease in the size of fish has also been accompanied by a decrease in the yield per unit effort (**Fig. 10**) (GCEC, 1991).

Edirisinghe and Wijeyaratne (1986) studied the food resource partitioning among the fishes co-existing in brush piles. Brush piles are occupied by fish species exhibiting a wide range of morphological features and dietary habits. Perera and Amarsinghe (2007) found high dietary overlaps occurring in only 7% of the fish species in brush piles of Negombo estuary, and concluded that attraction of fish species to brush piles is governed more by their food

resource partitioning and ruled out inter-specific competition among fish species co-occurring in brush piles.

Sanders et al (2000) used a length-based "Thompson and Bell" type model to determine the impact of increasing fishing effort on the annual catch, income and CPUE in shrimp fisheries. The results showed that a doubling of stake net fishing effort would yield a proportionate increase the catch from stake nets (294 to 486 MT), accompanied by slightly reduced catches for the non-motorized trawl fishery (305 to 272 MT) and the motorized trawl fishery (194 to 176 MT). The CPUE decreases are modest for all gears. In reality, there is little scope for increasing fishing effort from the stake net fishery as the suitable sites are already utilized. There was no justification for reducing stake net fishing effort as it would provide only marginal increases in the catches of trawl fisheries.

A doubling of trammel net fishing effort yielded an increase in catches from 1050mt to 1448 MT with a substantial decline of CPUE from an already low 4.6 kg/landing to 3.2 kg/landing. Estimated decrease in catches from other gears is 294 to 288 MT for the stake net fishery, 89 to 61 MT for the cast net fishery and almost no change in the catches from trawl fisheries.

Doubling of fishing effort in motorized shrimp trawl fishery yielded only a marginal increase – from 194 to 204 MT, with a decline in CPUE from 26.0/ landing kg to 13.7 kg/landing. On the other hand, a doubling of fishing effort in non-motorized trawl fishery yielded better returns – an increase from 305 to 400 MT with a decline in CPUE from 17.7 kg/landing to 11.6 kg/landing.

The above findings led Sanders et al (2000) to imply that the fisheries were collectively performing satisfactorily, with little opportunity to increase either catches or employment. The model has not included a stock-recruitment relationship, and hence makes no allowance for the possibility of reduced annual recruitments of shrimp when parent stocks are depleted (as from high fishing effort). While reduced fishing effort (units) may result in improved CPUEs for those remaining in the fishery, there would be negative impacts from low catches and the loss of employment for those displaced.

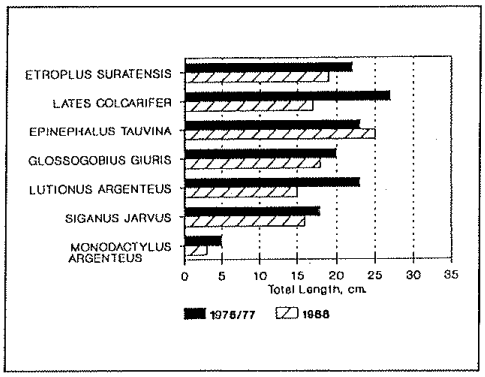

Fig. 9: Decrease in the size of fish captured in the brush pile fishery since 1976/77 (Source: GCEC, 1991)

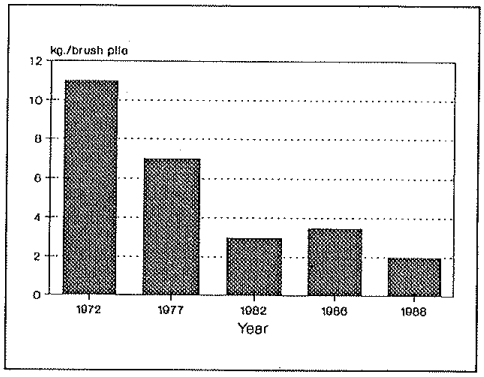

Fig. 10: Decrease in fish yield from brush pile fishery in Thalahena, 1972 to 1988 (GCEC, 1991)

4.5 STAKE NET FISHERY

A study of the social and economic aspects of the stake net (*kattu del*) fishery in Negombo estuary (Wimalasena, 2005) has revealed that there were 22 specific locations called "*kattudel padus*" in the channel segments of the estuary where user rights are in force and 57-60 nets can be operated on any given day. The total of 284 stake net fishers is organized under four stake net fishermen's associations. While each member gets a property right quota, 62 additional quotas have been allocated to the church and the four associations, bringing the total number of quotas to 346. Each stake net fishery association gets a fixed number of days in a month for its members to operate stake nets and each association in turn allocate these fishing days for its members using a complex lottery system.

The mean total investment in stake net fishing was estimated at Rs. 29,176 (canoe, fishing gear and accessories) while the annual financial cost of a fishing unit was estimated at Rs. 58,614. The operating profit (gross revenue minus operating costs) is shared according to a traditional norm practiced among the stakeholders. The boat owner/fisher and the crew member (helper) get 90%. The share of the crew member is about 10-20% of this total, depending on the level of involvement. An owner who cannot be involved in activities such as net mending and craft maintenance pays a higher share to the helper. The balance operational profit is shared between the Church (4%), Auctioneer (3%) and the Stake net Fishermen's Association (3%).

Net return for a craft owner was estimated at Rs. 98,000 /annum, which is 38% of the total family income of Rs. 259,760 per year. The stake net fishing operations begin at dusk or later in the evening and ends early in the morning. Hence, stake net fishers are able to engage in other income generating activities during the day time. Fish vending, marine fishing, private and public sector employment provide additional income sources.

4.6 FISHERIES MANAGEMENT IN NEGOMBO ESTUARY

Sri Lanka also has a fairly long history of traditional community based fisheries management. Under these management regimes, local fishermen have developed management strategies in the conduct of fisheries within waters, which they consider as 'theirs'. Most of these traditional management systems have collapsed due to introduction of new technologies. However, there are still some small, localized fisheries, which are still being managed through traditional methods. The stake net fishery in Negombo and Chilaw lagoons are examples of fisheries where territorial user rights in fisheries (TURFs) are still in force. These fisheries are comparatively well managed with a system of limited entry, which is based on criteria such as area of residence, inheritance, etc.

According to Jayakody (1996), the k*atttu del* (stake net) fishery in Negombo lagoon dates back to 1721. The Church guides the *kattu del* fishermen's association. One tenth of the income obtained from the fishery is donated to the church. About 8% of the total lagoon fishermen who are in control prevent others from entering this fishery. Fishing is conducted from 06.00 pm to 06.00 am the following day, throughout the year. Many *katttu del* fishermen are therefore free during other times and are engaged in activities such as carpentry, teaching and other jobs

The first attempt to promote fisheries co-management under the provisions of the Fisheries and Aquatic Resources Act No. 2 of 1996 was through a FAO/UNDP project, the "Marine Fisheries Management Project" implemented by DFAR during 1994-1996 in Negombo estuary. A total of 10 Fisheries Committees (FCs) have been established to cater to over 3,500 fishermen scattered over 26 villages around the estuary. A set of management regulations prohibiting the use of some harmful fishing gear and methods, fixing fishing times, areas and quantities to be used for specific gear types have been published in the Government Gazette in July 1998. The Fisheries Management Authority (FMA), composed of representatives from the 10 Fisheries Committees was established under a Government Gazette notification in November 1999. Although the experiences in co-management from Negombo estuary have not been well documented, it is reported that many issues have hampered the implementation of the management regulations. Conflicts have arisen between FCs and the FMA. Many FCs have been reluctant to enforce management regulations for fear of antagonizing the fishermen. These FCs and the FMA also had to contend with other bigger issues in the estuary such as pollution, land reclamation, destruction of mangroves, etc. and were frustrated by their inability to address such issues. In addition, the FMA has been in constant conflict with DFAR, seeking more powers for the FMA to deal with a host of non-fishery issues (disposal of sewage, industrial effluents and domestic solid waste, illegal land filling, etc.) coming under the mandate of other ministries, departments and agencies.

It is reported that a draft fishery management plan developed using expatriate technical assistance under the FAO/UNDP project has not found favor with the fisher community (CEA 2004). Another draft fisheries management plan was developed for the Negombo estuary under the project "Integrated Resources Management Programme in Wetlands (CEA-IRMP; 1998-2004)", implemented by the Central Environmental Authority and supported by the Netherlands Government. The plan has been developed jointly with DFAR, adopting a participatory approach, in consultation with the fisherfolk. A steering committee comprised of representatives of key stakeholders including CBOs, the Catholic Church, DFAR, CCD, Dept. of Wildlife Conservation and local civil administration have been involved in drafting the management plan. This plan too has not seeing the light of the day due to the long delay in organizing the FCs, inadequate leadership from DFAR combined with the transfer of field officers of DFAR who were involved in drafting the plan and the political changes that occurred following the General elections held in the year 2000.

The situation in Negombo estuary seemed to have worsened over the years. The increased intensity and diversity of activities taking place in and around the Negombo estuary, which have the effect of depleting fish and other aquatic resources and affecting water quality in the estuary include disposal of sewage, industrial effluents and domestic solid waste in the estuary, dredging and the construction of inlets into the estuary and other development activities in the area (Anon, 2010b). These and the illegal land filling that has been going on for some time have reduced the estuary area, impacting livelihoods of the communities. Fisheries committees and the management authority are considered weak with no power to enforce compliance with the regulations applicable to the management area.

5. BRACKISH WATER AQUACULTURE ASSOCIATED WITH NEGOMBO ESTUARY

Brackish water fish culture in Sri Lanka began with the active promotion of milkfish (*Chanos chanos*) culture by the Government during 1970s. The Ministry of Fisheries had two brackish water stations in Pitipana (Negombo) and Pambala (Chilaw). Fry collected from the Northern Province were reared up to fingerling stage for distribution to fish pond operators. Joseph (1993) has reported that there were 58 establishments engaged in extensive culture of milkfish in 1987, in a total water area of 3.7 ha. The production of 6.6 t of milkfish in 1987 has been valued at Rs. 92,000.

The Ministry of Fisheries promoted milkfish culture through a subsidy scheme. Referring to a survey conducted by NARA in 1987, GCEC (1991) has reported that 82% of the pond aquaculture projects for the culture of milk fish, started under the subsidy scheme of the Ministry of Fisheries in Muthurajawela marsh –Negombo estuary wetland area have been abandoned due to low yields and high mortalities. In Negombo estuary area, 15 persons have been engaged in pond brackish water aquaculture (**Fig.11**). Interest in milkfish culture waned due to high production costs and the onset of civil disturbances in early 1908s which prevented access to the rich fry supply areas of Mannar (Joseph, 1993).

Amandakoon et al (1983) have reported o the culture of milkfish in fish ponds in Pitipana. Ramanathan (1969) has reported on the Milkfish, *Chanos chanos* fry surveys conducted in Negombo lagoon in late 1960s when Milkfish fry was in much demand for fish culture. The most suitable places for fry collection were found to be the gently sloping areas with sandy bottom near the sea mouth region. April – May period was considered the best for fry collection when all the mud pools in Taladuwa area get filled up during the high tide and water was retained even during low tides.

Interest in shrimp farming developed in late 1970s, with a small farm in Batticaloa commencing operations in 1977. With the Government offering various incentives, a number of small-scale entrepreneurs and a few large multinational companies ventured into shrimp farming since 1982. While shrimp culture operations on the east coast ceased after 1983 due to civil unrest, it developed rapidly on the west and northwest coasts. Most of the development was in the northwest compared to the west. In 1988, only two farms have been operating around Negombo estuary – a total of 1.2 ha of water area under culture producing 2.4 t of shrimp, *Penaeus monodon* (Joseph, 1993). GCEC (1991) has reported that shrimp production from the area is a low 200 kg/ha/yr while at other locations shrimp harvest has exceeded 1,600 kg /ha / yr. The acid sulphate nature of the soil has prevented growth of shrimp aquaculture in the area.

In a study to determine the presence of pharmacologically active fatty acids in selected edible bivalve species from coastal lagoons of Sri Lanka, which included the Blood cockle, *Anadara antiquate* from Negombo lagoon, Senadheera and Chandrika (2005) concluded that the edible bivalve species studied could be considered as a potential source of important omega-3 fatty acids which play a significant role in human health, preventing coronary heart diseases.

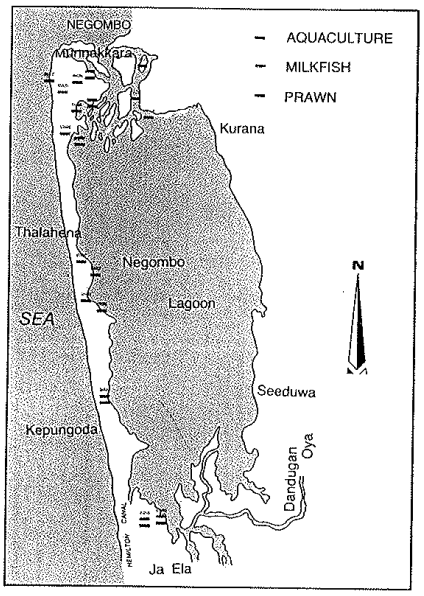

Fig. 11: Pond aquaculture sites in the vicinity of Negombo estuary (Source: GCEC, 1991)

6. ENVIRONMENTAL PROFILE OF NEGOMBO ESTUARY

6.1 GEOLOGY AND GEOMORPHOLOGY

A detailed description of the geological history of Muthurajawela marsh - Negombo estuary complex is found in GCEC (1991). The Muthurajawela marsh - Negombo estuary complex has developed during the Holocene period on the Pleistocene landscape that existed after the last glacial period. After a glacial low of about 100m, the water has risen to its present level during the past 12,000 years. According to GCEC (1991), the sea level rise and fluctuations over the years has caused changes in the coastal landscape from Colombo (Mutwal) to Negombo and has ultimately resulted in the "*formation of a large lagoon (the Negombo estuary) with its only connection to the sea in the north and with the Dandugam Oya supplying fresh water*".

To quote GCEC (1991) further, "*Peat started forming in the southern part of the lagoon during a period of low sea level, probably around 6000 years B.P. and eventually filled up the entire southern part at the beginning of the historical times. A lagoon was left in the northern part of the area, the tidal delta of the Dandugam Oya and Ja-Ela separating the two*".

Three strata of peat has been identified, from top to bottom: light and spongy reed and sedge type peat consisting mainly of grass and sedge debris; compact, hard textured shrub and tree type peat composed mainly of remains of trees and shrubs and humus-type peat consisting of fully decomposed plant material.

GCEC (1991) further contends that "*The inclusion of marine elements in the older sediment layer, the presence of pyrite in the deeper clayey deposits, the high sulphur content of most of*

the peat and the occurrence of shells and other remains of sea organisms in the peat confirm that an abrupt and fast transition from forests to the present day marshy vegetation had taken place".

The low pH of the peat bog has aided in the conversion of the metals in the Muthurajawela peat to free ions which are absorbed onto the clay complex. The bottom horizon with high clay content therefore contains the highest amount s of these metal ions. This governs the nutrient availability of the Negombo estuary and hence its productivity. The nature of the geo-chemical cycling of the nutrients between the Negombo estuary and the Muthurajawela marsh is therefore of prime importance and any disturbance of this balance was considered to have adverse effects on the productivity of the estuary (GCEC, 1991).

6.2 SOILS

Three basic types of soil have been described for the Negombo estuary – Muthurajawela marsh complex (GCEC, 1991), all of which are acid sulphate or potentially acid sulphate. The predominant soil of Muthurajawela marsh consists of poorly drained, organic soil (bog soil), dark brown to black in colour and overlying waterlogged mineral subsoil. All these soils contain pyrites (compounds of iron and sulphur) to the extent that they are potential acid sulphate soils. The bog soils bordering the Negombo estuary and those on the western segment of the main marsh become saline due to tidal influence.

The second major soil type are the mineral soils with larger amounts of organic matter but in quantities insufficient to be classified as bog soils. These soils have properties intermediate between bog and mineral soils with low levels of organic matter. These soils also contain sufficient pyrites to be classified as potential acid sulphate soils.

The third soil type consists of soils formed of inorganic material (minerals) with a thin layer of organic material (humus) at the surface. These soils, deposited mainly by river flow and floods are therefore termed alluvial. These soils are waterlogged and poorly drained, and are also potential acid sulphate soils because of high levels of pyrites.

6.3 CLIMATE (RAINFALL AND TEMPERATURE)

Negombo estuary lies in a part of the wet zone of Sri Lanka which receives 2,000 – 2,500 mm rainfall per year (**Fig. 12**) (GCEC, 1991). Rainfall in the area is influenced by both the southwest monsoon and the northeast monsoon. CEA (1994) has reported that the Negombo estuary-Muthurajawela marsh complex is affected by two periods of heavy rain occurring in April/May and in October/November, immediately preceding and following the southwest monsoon which lasts from mid-May to September. Daily maximum rainfall was reported to be as high as 340 mm.

Evaporation exceeds rainfall in January, February and March while there is an excess of rainfall in all other months. The highest excess of rainfall over evaporation occurs in May and October while the lowest is in August (**Fig. 13**) (GCEC, 1991).

According to GCEC (1991), data from the Colombo Observatory has shown that during the period 1961 – 1980, the highest mean daily maximum temperature of 31.5^0C occurs in April and the lowest mean daily minimum temperature of 22.3^0C occurs in January. The highest maximum temperature and the lowest minimum temperature recorded at the Colombo Observatory between 1910 and 1989 were 36.2^0C on 23rd February 1915 and 15.2^0C on 04th January 1950n respectively. The highest day temperature occurs between 12.00 and 15.00 hours and the lowest between 05.00 and 06.00 hours.

6.4 HYDROLOGY AND WATER QUALITY

The Negombo estuary between the swampy delta in the south, the high ground in the east, the dune ridge in the west and the flood delta of its inlet in the north, is fringed by a narrow strip of low land. The tides and saline waters enter the estuary through its inlet, the salinity being balanced by the inflow of fresh water from the Dandugam Oya, the marsh and precipitation/evaporation.

The estuary receives fresh water from the Attanagalu Oya which empties as Ja-Ela and Dandugam oya at its southern end. In addition, the Hamiltan canal is the connecting water course of the Kelaniya estuary and the Negombo estuary, running parallel to the west coast from the north to the south along the Muthurajawela marsh. The Dandugam oya is the main river falling into the estuary. The drainage basin of Dandugam Oya (Attanagalu Oya) receives run off from a catchment of 720 km^2 and discharges at the junction of the estuary and the marsh.

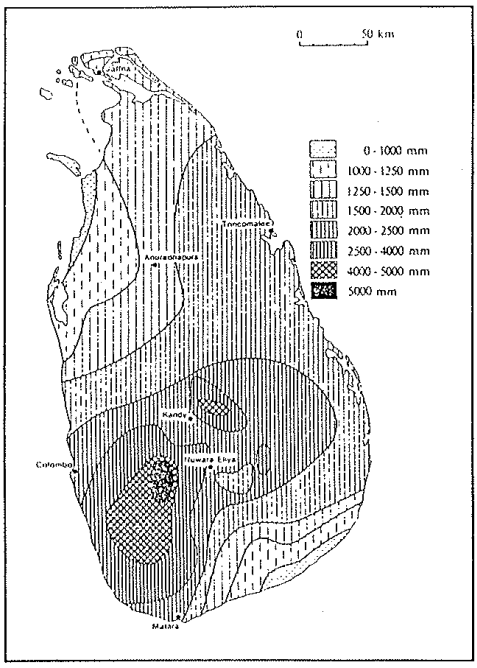

Fig. 12: Average annual rainfall in Sri Lanka (Source: GCEC, 1991)

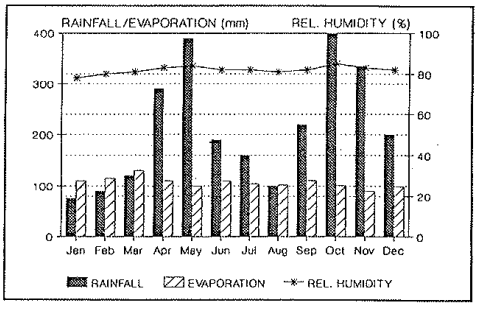

Fig. 13: Monthly rainfall, evaporation (mm) and relative humidity (%) at Colombo Observatory, 1964 – 1989 (Source: GCEC, 1991)

The men annual run off from this catchment is 1,326 million m^3 and the major portion of this run off flows into the Negombo estuary. Considerable draw off of water occurs from Dandugam Oya for irrigated agriculture (CEA, 1994).

According to Wickremaratne et al (1991), fresh water enters the estuary from the Attanagalu Oya (Dandugam Oya and Ja-Ela) 1.5 km^3/y and from precipitation (0.2 km^3/y). Occasional inflows can occur from the Kalu Oya and the Kelani Ganga during exceptional floods. Evaporation and evapo-transpiration was estimated to remove about 0.15 km^3 annually. The balance flows into the sea; mainly via the inlets of the estuary and a lesser part through the Hamilton Canal into the mouth of the Kelani Ganga. The inflow of saline water from the sea through the inlet of the estuary was estimated at 1.1 km^3 per year and a considerably lower quantity through the Hamilton Canal.

The balance shows that the main flow is from the river to the estuary and, after mixing with the saline water, towards the sea via the inlet of Negombo estuary. It appears that the estuary generally has a positive balance of water but a shortfall in inputs occurs because of evaporation in the marsh during January – March. Spring tides are also relatively high during that period, resulting in an enhanced flow of sea water into the estuary.

The supply of fresh water varies from virtually zero during the dry season to more than 100 m^3/s during the rainy seasons. The salinity of the estuary varies from 5 to 30 ppt for a river input of 15 -225 m^3s^{-1} of which 72% is from Dandugam Oya and 28% from Ja-Ela (Rajapaksha, 1997). While the estimated river input to the estuary varies from 15 to 225 m^3s^{-1}, the oceanic water inflow varies from 17 to 49 m^3s^{-1} and the estuary water outflow varies from 39 to 213 m^3s^{-1}. The resident time for the estuarine waters varies from 2 to 11 days, being influenced by fresh water input and tides. Resident time is short when fresh water discharge into the estuary is high and the water exchange is dominated by estuarine circulation. When the fresh water discharge is low, resident time is high and the water exchange is dominated by the tide (Rajapaksha, 1997).

The exchange of water in the estuary is influenced by the tides from the ocean and fresh water supply from the inland. The tide is semi-diurnal and the tidal range in the estuary varies in the order of 0.07m at neap tides to 0.2m at spring tides, these values being about one third of tide at sea (Hettiarachchi and Samarawickrama, 2003). The men tidal range is 0.6m. The volume of water stored and released is estimated to vary between 2.5 million m^3 and 7.0 million m^3 per tide.

The Negombo lagoon has an estimated water volume of 20 million m^3. The exchange of water in the lagoon is influenced by the tides from the ocean and fresh water supply from the inland. The lagoon receives fresh water from the Attanagalu Oya which empties as Ja-Ela and Dandugam oya at its southern end. In addition, the Hamiltan canal is the connecting water course of the Kelaniya estuary and the Negombo lagoon, running parallel to the west coast from the north to the south along the Muthurajawela Marsh. The Dandugam oya is the main river falling into the lagoon. It drains a catchment of 727km^2 and discharges at the junction of the lagoon and the marsh. The supply of fresh water varies from virtually zero during the dry season to more than 100 m^3 during the rainy season.

Simulation of storage and drainage relationships for Negombo estuary has indicated that water level in the estuary could rise as much as 1 m and remain at that level for a day during rainfall that causes flooding (Wickremasooriya, 1986). A rise of 0.1 m of the mean level of

the estuary correspond to a storage of 3.5 million m^3 of water and leads to an estimated seaward flow of about 80 m^3/s. The retention time appears to be about 12 hours or one tidal cycle (Wickremaratne, et al, 1991).

The salinity of the Negombo estuary varies from 5 to 30 ppt for a river input of 15 -225 m^3s^{-1} of which 72% is from Dandugam Oya and 28% from Ja-Ela (Rajapaksha, 1997). While the estimated river input to the lagoon varies from 15 to 225 m^3s^{-1}, the oceanic water inflow varies from 17 to 49 m^3s^{-1} and the lagoon water outflow varies from 39 to 213 m^3s^{-1}. The resident time for the lagoon waters varies from 2 to 11 days, being influenced by fresh water input and tides. Resident time is short when fresh water discharge into the lagoon is high and the water exchange is dominated by estuarine circulation. When the fresh water discharge is low, resident time is high and the water exchange is dominated by the tide (Rajapaksha, 1997).

Wickremaratne, et al (1991) has also reported that salinity is quite low in the estuary during the wet season. It varied between 2 kg/m^3 (ppt) during the wet season and 31 kg/m^3 (ppt) at the end of the main dry season. The mean salinity outside the mouth of the estuary was 34.2 kg/m^3 (ppt) in the open sea (GCEC, 1991).

The lagoon shows temporal and spatial variation in salinity. Maximum salinities are recorded during the inter-monsoonal periods of March-April and October- November. Minimum salinities are recorded during the southwest monsoon (June –July) and November-December. During the intermediate rainy season (i.e. January and July), a pronounced salinity gradient develop in the lagoon, varying from 20-30ppt at the mouth to <5-10ppt at the head of the estuary (Devendra 2003).

GCEC (1991) provides water quality parameters for the surface water at nine locations in the lagoon, sans any information on the period of study, analytical methods used and frequency of sampling. Silva (1996) has reviewed available information on water quality of several water bodies, including Negombo lagoon. NARA (1992) has determined basic physico-chemical parameters at 20 locations in the lagoon, some of which were the very close to the locations covered during previous studies, enabling direct comparison between different water quality studies.

Devendra (2003), in a review of the results of various water quality studies conducted in Negombo lagoon, observed a uniform pattern in the seasonal variation of several basic physic-chemical characteristics of the lagoon. Due to its shallow depth (mean of 0.65m), the lagoon is influenced by air temperature and thermal conditions. It was difficult to derive a spatial and/or temporal pattern in the distribution of dissolved oxygen in the lagoon as DO values are dependent on sampling time, photosynthetic activity, temperature and mixing of sea water and fresh water.

Turbidity, a function of suspended matter, represents both the sediment loading and turbulent mixing in the lagoon. Generally, seasonal and spatial distribution of turbidity and suspended solids are directly associated with fresh water inflow and the annual rainfall. However, the low correlation coefficients obtained between turbidity and net fresh water flow (0.54) and between suspended solids and net fresh water influx (0.59) may be attributed to non-continuous measurement of fluxes and non-corrected data for the area of drainage basin (Rajapaksha, 1997).

Some hydrographical parameters have shown marked site specific diurnal variations. Silva (1996) has reported on diurnal variations in temperature, salinity, DO and pH between two locations while NARA (1988) has reported on diurnal variations in temperature, salinity, DO, turbidity and nitrate at the lower and upper reaches of the Negombo lagoon. The difference in temperature between the surface and bottom waters is less than $<1^0$C and the lagoon water becomes warmer from February to April. Diurnal changes in salinity, pH and DO may occur with the diurnal tide rhythm. Additionally, diurnal changes in pH and DO may be attributed to temperature, photosynthetic activity and the mixing of fresh and sea water. There was no marked diurnal change in turbidity at both the upper and lower reaches of the lagoon.

There have also been some studies on the water quality of the 14.7 km long, 16 -18m wide and 1.5-1.75m deep Hamilton canal, the connecting water course of the Kelani Ganga and the Negombo lagoon. GCEC (1991) has reported on the general physic-chemical parameters and several pollution-indicative water quality parameters at one location of Hamilton canal. The results from a more systematic survey reported by Dasanayake (1993) showed that the spatial and temporal changes in temperature at the surface indicated that there is no thermal pollution resulting from the discharge of thermal effluent. The salinity level falls well within the acceptable range for coastal water bodies influenced by both sea water and fresh water (Silva, 1996). However, the distribution of salinities is very wide and high salinities have been recorded at both ends of the canal compared to the middle portion.

The distribution pattern of pH along the canal reflects the influence of the tidal floods of the lagoon and the fresh water outflow of the marsh to the Hamilton canal (Silva, 1996). The patterns of distribution of turbidity and suspended solids are more or less similar, but the higher values for each parameter reported at the lagoon end of the canal could be attributed to the enormous amount of sediment loading in to the lagoon through the Dandugam Oya and Ja Ela (Silva, 1996).

Salinity and river discharge data have been used by Rajapaksha and Jayasiri (1994) to determine the axial salinity distribution and the salinity response to river discharge. The finding that the vertical variation in salinity (about 1-2 ppt) is much weaker than the axial one (about 32 ppt) is consistent with the classification of the estuary as weakly stratified. The maximum mean salinity (31.13 ppt*)* was observed in April and the minimum mean salinity (3.14 ppt) was observed in December. The maximum rate of river discharge was about 60 m^3s^{-1} in May and October while the minimum was about 3.5 m^3 s^{-1} in August-September.

6.5 ESTUARINE VEGETATION

Estuarine vegetation, apart from phytoplankton, consists of two main types – the fringing types such as mangroves and reeds and the submerged type which includes sea grasses and filamentous algae. The inter-tidal vegetation and the submerged sea grasses provide critical nursery habitat for fishery resources in the estuary.

Extensive reed beds (*Phragmites karka*) occur along the southern border of Negombo estuary where salinity is generally low. In this area, where mangroves have already been depleted, the reed beds compensate for the loss of the mangrove nursery function. These reeds are also harvested for construction of fish kraals (CEA, 1994).

In Negombo estuary, the filamentous green algae, *Chaetomorpha* sp. form thick mats completely covering sea grass during the period following each rainy season. The shaded sea grass die off from lack of sunlight. When the filamentous green algae begin to die within a period of 1-2 months, the sea grass re-generate from the rhizome root system.

6.5.1 MANGROVES

Mangroves cover the narrow inter-tidal areas on the fringes of the lagoon, at a width not exceeding 100m (**Fig. 14**). Mangroves occur as a narrow belt along some segments of the shoreline of Negombo estuary and the islands in the channel segment. Since the tidal amplitude in Negombo estuary is on the average less than 20 cm, the extent of inter-tidal mangroves that can provide critical fisheries nursery function is confined to a narrow band about 10 m wide (CEA, 1994). Most of the mangroves in Negombo estuary are confined to about 11 islets close to its northern end. These islets trap and retain silt of the in-flowing and out-flowing water, thus enriching the mangroves. Mangrove profiles on the islets in the channel segment of Negombo estuary are shown in **Fig. 15** (GCEC, 1991).

In the early 1990s, the total area of mangroves in the estuary was estimated at 350 ha (GCEC, 1991). Over a period of 10 years (1981 -1992), the extent of mangals or true mangroves in the estuary has decreased by about 30 ha, which is approximately 10% of the total area (Pahalawattaarachchi, 1995). Sewalanka (2011) claims that of the 700 ha of mangrove forest that existed around Negombo estuary three decades back, nearly 400 ha have been destroyed primarily due to human activities. The floristic composition of the true mangrove communities in the estuary includes eleven common species (**Table 12**).

Table 12: Common mangrove species in Negombo estuary

Species	Family	Sinhala name	Tamil name
Rhizophora mucronata	*Rhizophora*	Kadol	Kandal
Rhizophora apiculata	*Rhizophora*	Kadol	Kandal
Bruguiera gymnorbiza	*Rhizophoraceae*	Malkadol / Sirikanda	
Bruguiera sexangula	*Rhizophoraceae*	Malkadol / Sirikanda	
Bruguiera cylindrica	*Rhizophoraceae*	Malkadol / Sirikanda	
Avicennia marina	*Avicennioaceae*	Manda / Mada gas	Kanna
Ceriops tagal	*Rhizophoraceae*	Punkanda / Rahugas	Chirukandal
Lumnitzera racemosa	*Combretaceae*	Bariya	Tipparethai
Excoecaria aggalocha	*Euphorbiaceae*	Thelakiriya / Thela	Thilla
Sonneratia caseolaris	*Sonneratiaceae*	Kirilla	Kinna
Sonneratia alba	*Sonneratiaceae*	Kirilla	Kinna
Aegiceras comiculatum	*Myrsinaceae*	Heen kadol	Vethilikanna
Acantbus ilicifolius	*Acanthaceae*	Ikili / Katu ikili / Mulli	Mulli
Xylocarpus granatum	*Meliaceae*	Mutti kadol	Somuntheri

(Source: CCD, 2005)

In addition to the extractive uses, people living in and around the estuary depend on the products from and the environment created by the mangroves. A socio-economic survey has revealed that 30% of the households around Negombo estuary are dependent on the mangroves (Amerasinghe and Liyanage, 1996).

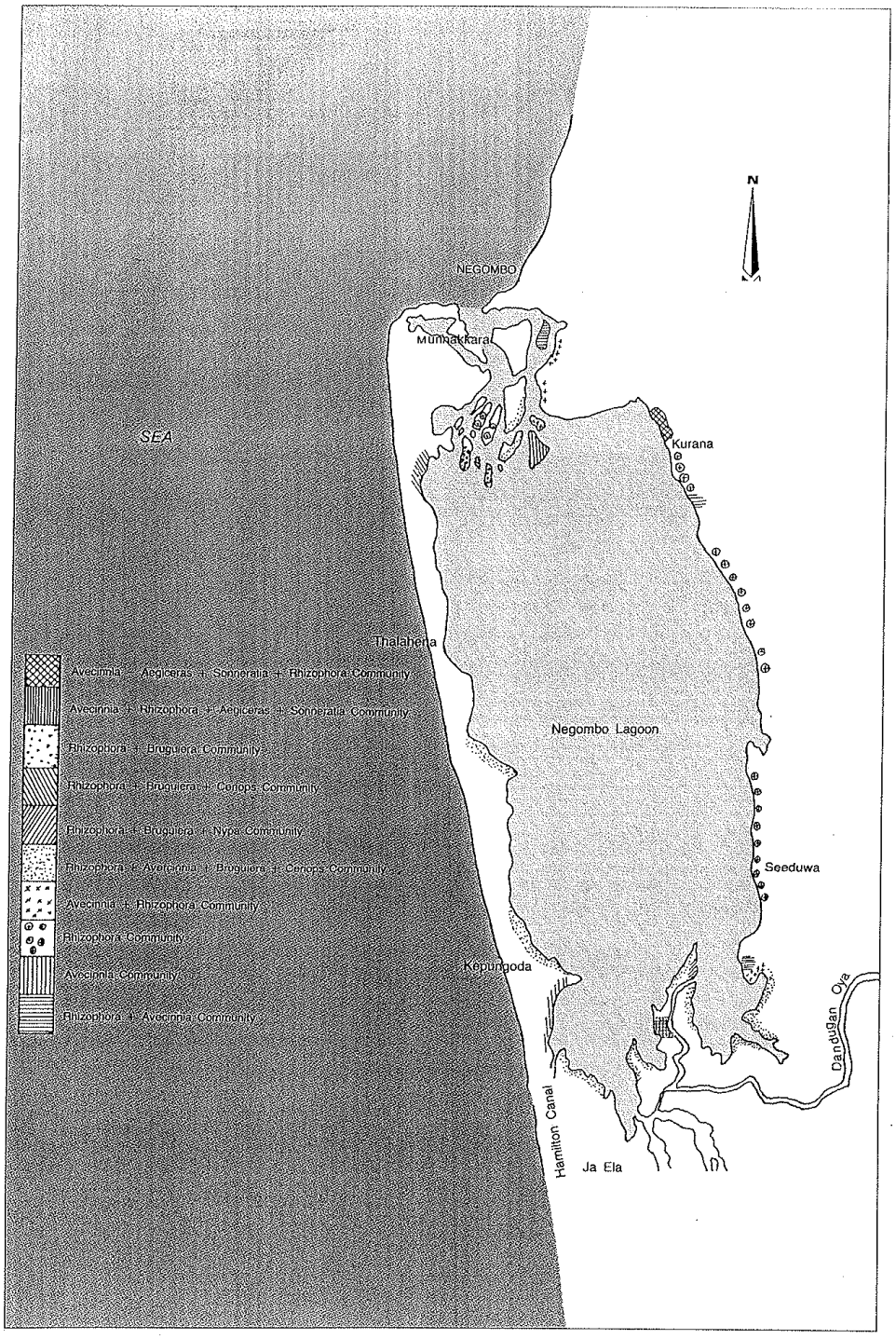

Fig. 14: Distribution and community structure of mangroves at Negombo estuary (Source: GCEC, 1991)

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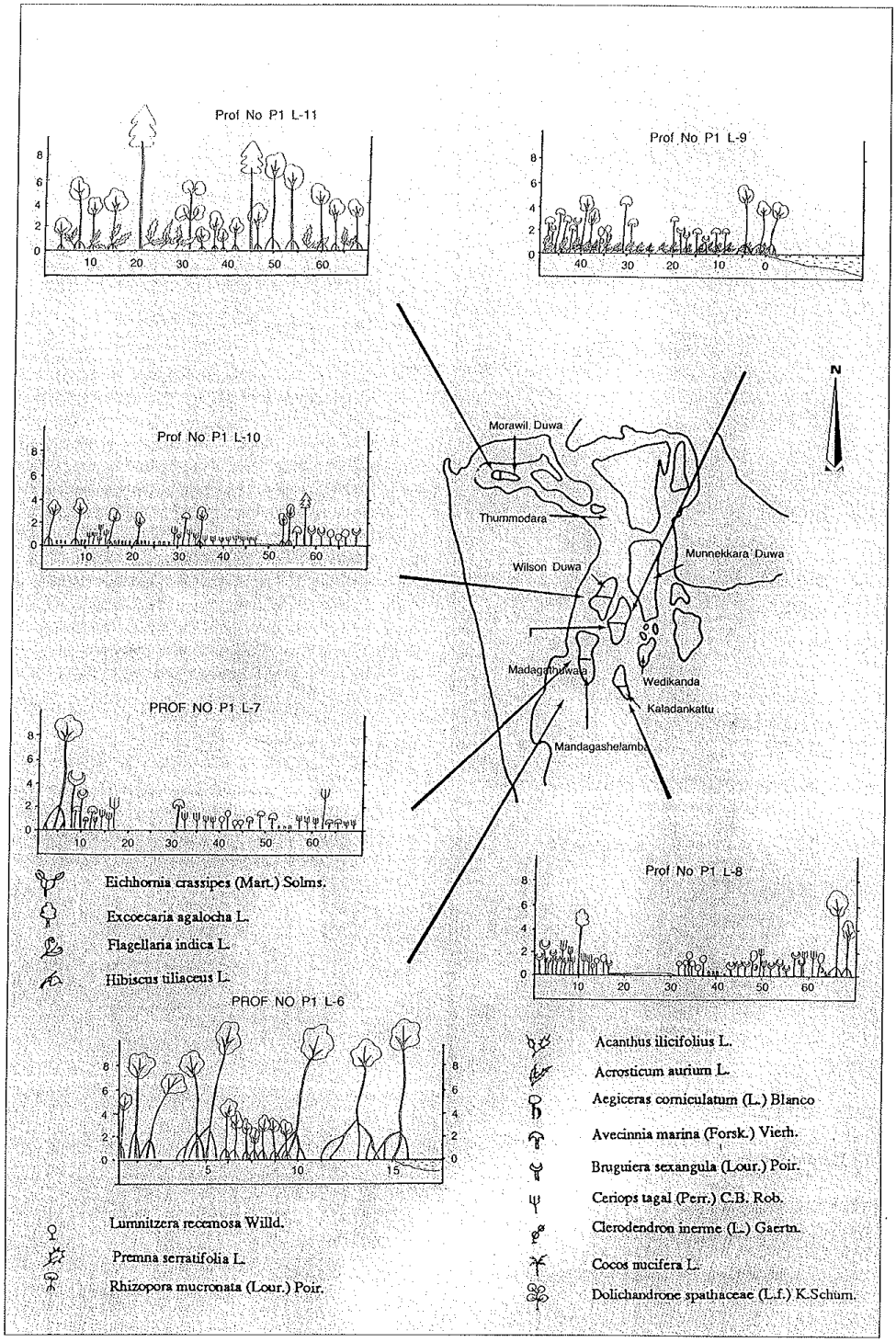

Fig. 15: Mangrove profiles on islands in the channel segment of Negombo estuary (Source: GCEC, 1991)

About 300 brush piles made of twigs and branches of mangroves are reported from the estuary, about 250 of these are operated in the northern part of the estuary (CCD, 2005). Indiscriminate land reclamation for housing and industrial development has led to the reduction of the mangrove forest area.

In a situation where the hydrology of Negombo estuary is impeded by shoal formation, mangroves contribute to stabilization and building up of temporary tidal flats as islands, further aggravating poor water exchange.

Indiscriminate land reclamation for housing and industrial development has led to the reduction of mangrove cover. Mangroves along the sea side (western) boundary of the lagoon have been most vulnerable, as the uncertainty of the lagoon boundaries has allowed land owners to claim mangrove forest as their own, for clearing to initiate other development activities (CCD, 2005).

In 2002, five mangrove islands (approximately 50 ha) in the northern part of the lagoon (Munnakkare) have been declared as conservation forests under the Forest Ordinance (Seawalanka, 2011).

6.5.2 SEA GRASS BEDS

The marine angiosperms in general are termed sea grasses due to their grass-like structure and habit and play a significant ecological role in the functioning of near-shore coastal ecosystems, including lagoons, estuaries and shallow continental shelf waters. Sea grass ecosystems that occur in tropical and sub-tropical shallow marine waters are ranked high amongst the Earth's most productive ecosystems and serve as a source of energy for complex food webs in shallow coastal waters. They also contribute to provision of habitats for aquatic organisms, including epiphytes, to consolidate sediments and to produce detritus for the aquatic food webs in these waters. They also serve a nursery function for a large number of commercially important fish and crustaceans that take these ecosystems as refuge, particularly during the early stages of their life cycles that are vulnerable to environmental changes and predation.

The bio-diversity of Negombo lagoon is further enriched by sea grass beds spread over about one fifth of the lagoon bed. Jayakody (1996) has reported that sea grass cover approximately 684 ha or 22% of the estuary area. The width of the sea grass beds is reported to vary from about 200m to 2,000m (CEA, 1994). A total of 15 species belonging to 09 genera have hitherto being recorded from Sri Lanka (Dayaratne, et al, 1997, Amerasinghe, et al, 2003). Of these, four major genera and seven species, out of which four are true grasses, are reported to occur in Negombo lagoon – *Halophila beccari*, *H. minor*, *H. ovalis*, *Thalassia hemprichii*, *Potemogeton pectinalis*, *Halodule pinifolia* and *Ruppia maritime* (Jayasuriya, 1990, Jayakody, 1996 and Amerasinghe, et al, 2003).

De Silva and Amarasinghe (2007) found only two species - *Halodule pinifolia* and *Halophila ovalis* in the north eastern part of the Negombo lagoon near Kadolkele. *Halodule pinifolia* was the most abundant, extending up to 30 m from the shoreline and the area beyond.

Four major sea grass beds have been located during studies by Jayasuriya (1990). These were:

a) A large mixed bed of *H. ovalis*, Halophia sp. and Halodule found to the northeast, extending from Kadolkele, Kurana down to Katunayake in the south
b) A narrow strip of mixed sea grass running almost the entire length of the western bank
c) A fairly large bed of *H. ovalis* found to the west of the centre of the lagoon
d) A mixed bed of *H. ovalis*, Halophia sp. and Halodule extending north from Katunayake

The northern islands within the estuary have a fringe of sea grass around them. The distribution of sea grass in Negombo estuary is shown in **Fig. 16** (GCEC, 1991).

Potemogeton pectinalis and *Ruppia maritime* were found to reach their maximum height during the rainy season when the salinity of the estuarine water is lowest. These beds have declined considerably in extent due to the effect of increased silt loads from river waters entering the estuary.

Approximately 20% of the sea grass cover in Negombo lagoon has been lost due to pollution and conversion of wetlands for other development. Macro-algal proliferation on sea grass beds as a result of nutrient loading of the water column, causing a reduction in light availability, adversely impact on the growth of sea grass.

7. THREATS AND CONSERVATION

The high population density in Negombo, the fairly high concentration of industries around Negombo and fishing and fishery related activities have combined to make heavy demands on Negombo estuary. The Negombo estuarine water is polluted by faecal pollution, visual pollution, nutrient enrichment (eutrophication), organic and heavy metal pollution and oil pollution.

Land filling for encroachment, building of new piers, jetties and bridges that restrict water flow and promote siltation and, deposition of garbage has resulted in the reduction of the effective water area of Negombo lagoon by 791 ha between 1956 and 1981 (MOFE, 1998).

The value of Negombo estuary as a sink is estimated in excess of Rs. 300 million (CEA, 1994). The estuary has continued to provide a service as a sink for industrial effluents for over three decades, only because flushing has been adequate since the hydrological linkages are functional.

Untreated effluents from the Ekala Industrial Estate (45 industries) and the Ekala area (60 industries), State Distilleries Corporation, and partially treated effluents from the Katunayake Export Promotion Zone are discharged into the Negombo lagoon (**Fig. 17**) (GCEC, 1991). In addition to the large industrial establishments, numerous small-scale industrial operations discharge their untreated effluents directly and indirectly into the estuary. Periodic occurrences of fish kills reported from the area are mainly attributed to discharge of toxic effluents. Pollution has become chronic, as indicated by the persistence of skin ulcerations among sensitive fish such as rabbi fishes.

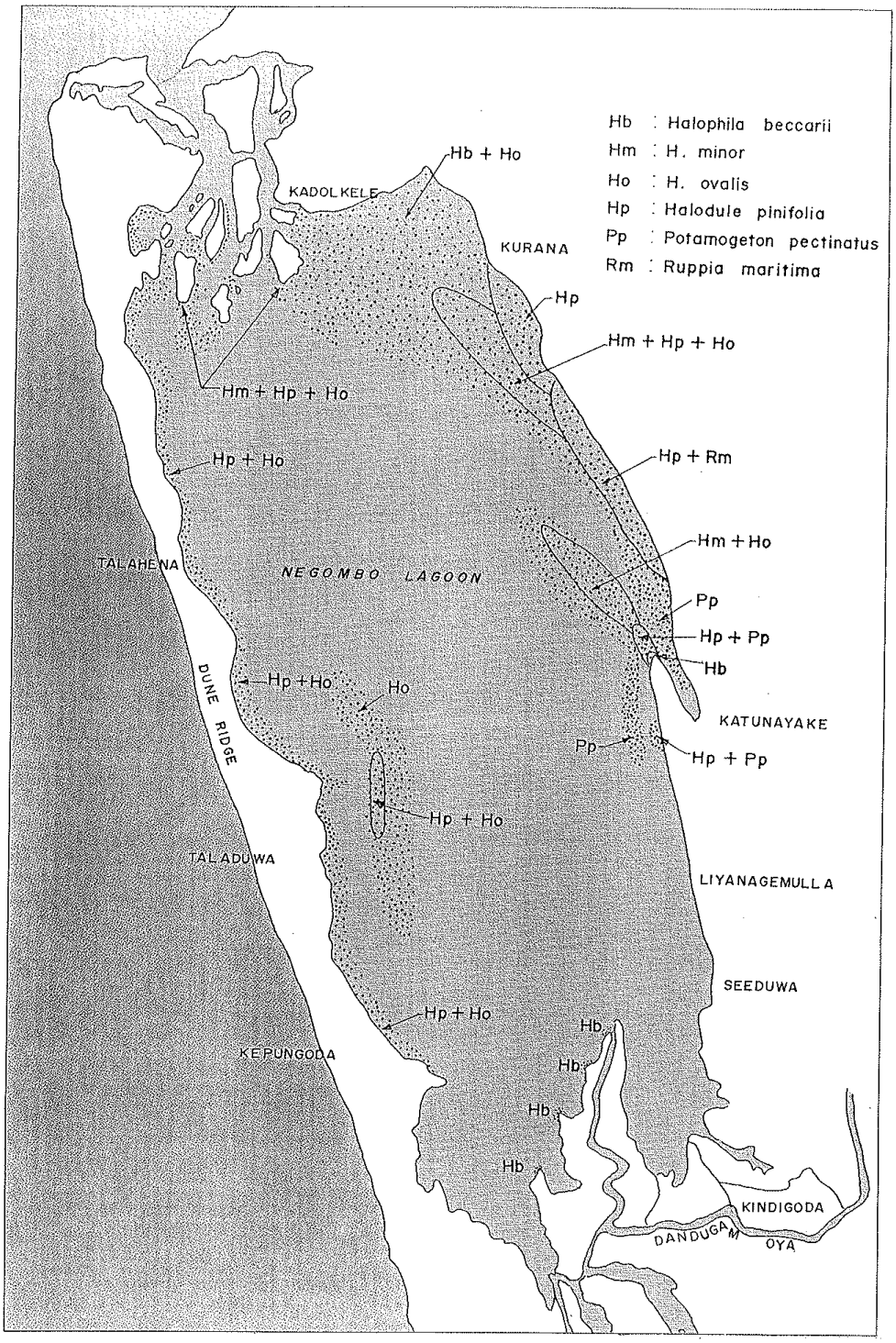

Fig. 16: Sea grass composition and distribution in Negombo estuary (Source: GCEC, 1991)

However, data are scarce on the quantities of water outputs and inputs as well as water quality of industrial effluents and the quality of water in and around the wetland ecosystem. The total discharge of industrial effluents in late 1990's was approximately 1103.46m^3 per day (0.13m^3/s), considered negligible compared to other fluxes, although the micro element concentrations in the industrial discharge may have significant impact on lagoon water quality (Devendra, 2003).

7.1 FAECAL POLLUTION

Fecal pollution is a major problem in coastal waters due to the direct discharge of untreated municipal sewage into land and waterways. The growing urban population in coastal areas, with inadequate housing and sewage disposal facilities compounds fecal contamination of surface and ground waters.

Faecal pollution is more pronounced in recent times due to low-income settlements in the proximity to the mouth of the estuary, industrial development in the catchment area, aquaculture practices and tourist sector development, particularly in the shoreline and municipal sewage brought in by riverine flow from Dandugam Oya and Ja-Ela. In early 1990s, CEA (1994) has estimated that a population in excess of 1,000 discharged, directly or indirectly into the estuary, a minimum of 90 metric tons of raw faeces annually.

Toilets are the major problem for the residents in the Negombo SAM area (eatuary and marsh area) and nearly 8% of the houses had no proper toilet facilities (CCD, 2005) and used common areas for sanitary purposes. More than 2,000 houses in the islands and on the west bank of the lagoon were reported to discharge septic waste into the lagoon through P.V.C. pipes. One reason for the large number of houses without sanitary facilities is the high number of encroachments. CCD (2005) reports that a total of 943 houses have been built encroaching the estuarine water area and most of these were in the channel segment of the islands.

It is estimated that about 250 kg/day of raw faeces are discharged from the channel segment into Negombo lagoon, resulting in an annual total load exceeding 90 t. The very high levels of faecal coliforms indicate that raw sewage is in contact with estuarine waters, with potential hazards to flora and fauna including humans. The total and faecal coliforms in the estuary and its connecting watercourses are given in **Table 13**.

Table13: Total and faecal coliforms in Negombo estuary

Location	Parameters			
	Total coliforms per 100 ml		Faecal coliforms per 100 ml	
	1991	2003	1991	2003
Dndugam Oya	-	2,200	-	140 -170
Ja-Ela	-	5,000-16,000	-	140 -220
Hamilton canal	23,000	340 -500	70 -3,000	70 -79
Middle of estuary (close to Pitipana)	3,200	17	750 – 1,200	2 -4
Mouth of estuary (in the main channel)	8,010	270 – 9,000	50 – 3,500	70 -110
Mouth of estuary (towards Duwa)	5,200	300 -500	73 -150	70 -80
Mouth of estuary (towards Kadolkelle)	11,200	500 – 16,000	Nil – 2,500	140 -170

(Source: CCD, 2005)

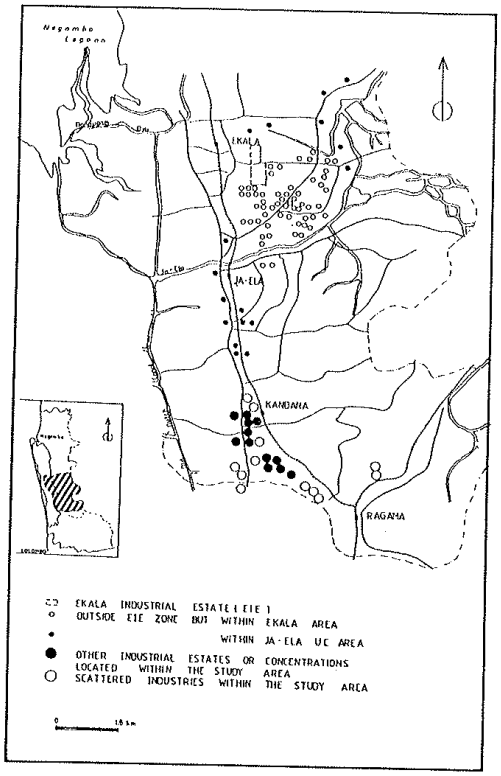

Fig. 17: Sources of untreated industrial effluents into Negombo estuary (Source: CEA, 1994)

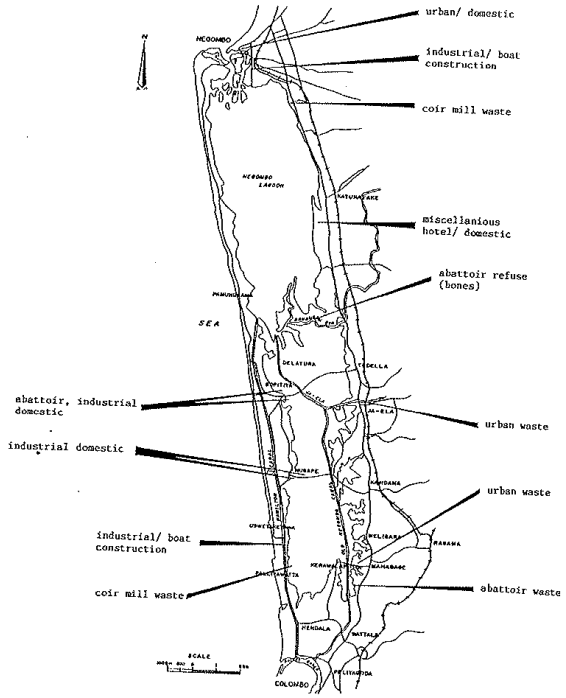

Fig. 18: Solid waste dumping sites in the study area (Source: GCEC, 1991)

The microbial quality seems to have improved in 2003 compared to 1991. The high total coliform levels in Dandugam Oya and Ja-Ela indicates that the riverine flow brings in municipal sewage into the estuary. High dilution occurs when the faecal-matter rich waters meet the estuarine water. The total coliform levels are once again high at the mouth of the estuary due to sewage from the low income settlements and fisher community. Therefore, both confluences where fresh water meets the estuary and where sea water meets the estuary are polluted by faecal matter to an extent that no beneficial use could be practiced without significant health hazards. Nevertheless, in all parts of the estuary, faecal coliform levels are within permissible levels for all classes of use, and the degree of intensity of faecal pollution could be significantly reduced with the enhancement of tidal flow within the estuary (CCD, 2005).

7.2 VISUAL POLLUTION

Visual pollution is mainly due to solid waste thrown into the estuary. Indiscriminate dumping of solid waste is a major environmental concern in Negombo estuary. It serves as a sink for both municipal and domestic waste for the urban areas lying contiguous with it, principally the Negombo Town. When water level rises during high tide, the solid waste dumped in the backyards of houses is carried away with the tidal flow and deposited particularly in the mangrove islands located close to the estuary mouth.

Several locations of the estuary are used by the local authorities to dump solid waste. In addition to solid waste, municipal waste and surface water discharging drains are also diverted to the estuary. Some of the notable soild waste dumping sites in the Muthurajawela marsh – Negombo estuary wetland are shown in **Fig. 18** (GCEC, 1991).

7.3 NUTRIENT ENRICHMENT (EUTROPHICATION)

Municipal sewage, fertilizer runoff and industrial wastewaters carried in by riverine flow usually contain high levels of nitrogen and phosphorus that can stimulate eutrophication. Tourist sector development activities and squatter settlements in the shoreline too contribute significantly to the nutrient budget (CCD, 2005). Eutrophication has adversely affected the health of the estuarine ecosystem, stimulating algal growth, declining biodiversity and changes in water quality. Average nutrient levels in different reaches of the estuary in 1988, 1991 and 2003 are given in **Table 14**.

Table 14: Average nutrient levels in different reaches of Negombo estuary

Parameters	**Year and location**								
	1988			**1991**			**2003**		
	Upper reach	Middle reach	Lower reach	Upper reach	Middle reach	Lower reach	Upper reach	Middle reach	Lower reach
Nitrates (mg/l)	0.10	-	0.18	-	0.10	0.11	0.35	0.18	0.18
Nitrites (mg/l)	0.002	-	0.003	-	0.002	0.003	-	-	-
Ammonia (mg/r)	-	-	-	-	<1.0	<1.0	0.00	0.00	0.31

Total nitrogen (mg/l)	-	-	-	-	-	-	1.14	0.24	0.35
Phosphates (mg/l)	0.04	-	0.05	-	0.25	0.25	0.12	0.18	0.18
Total Phosphates (mg/l)	-	-	-	-	-	-	0.15	0.28	0.15

(Source: CCD, 2005)

The nitrate levels in the upper reaches have gone up, indicating a considerable input from streams in the form of nitrate nitrogen, mainly from Municipal sewage and fertilizer runoff through Dandugam Oya. Ammonia levels were comparatively low. However, the total nitrogen in the upper reaches was extremely high, due to no or very mild flushing taking place in the upper reaches and storage of nitrogen in the form of particulate matter (CCD, 2005). The phosphate levels too have gone up in all reaches of the estuary, indicating that the overall input into the estuary is on the rise. The source of high levels of Phosphates is attributed to activities associated with the lower reaches of the estuary.

An analysis on the nutrient loads from the agriculture sector has been based on the annual use of nitrogen and phosphate fertilizer in the Attanagalu Oya basin (**Table 15**).

Table 15: Annual use of nitrogen and phosphate fertilizer in the Attanagalu Oya basin

Crop/Land use	Ares (ha)	N applied (kg/ha)	PO_4 applied (Kg/ha)	Total N (MT)	Total PO_4 (MT)
Paddy	10,740	98	18	1,053	193
Coconut	12,195	8	6	98	73
Rubber	5,115	10	12	51	61
Homesteads	43,280	-	-	-	-
Sparsely used cropland	2,100	-	-	-	-
Total	**73,430**			**1,201**	**328**

(Source: CCD, 2005)

Paddy accounts for about 85% of the nitrogen and two thirds of the phosphate fertilizer used for the main crops.

It has been estimated that the total nitrogen and phosphate loads into the estuary are approximately 6,000 MT/year and 100 MT/year respectively. Out of these, the total industrial loads were estimated to be 27 MT/year of nitrogen and 50 MT/year of phosphate. The nutrient loads are therefore predominantly from fertilizer run off carried into the estuary by the Dandugam Oya (CCD, 2005).

7.4 Organic and heavy metal pollution

Organic pollution is generally due to municipal waste, industrial and domestic wastewaters. Toxic components are mainly from industrial and fertilizer run off. The BOD and COD levels of the Negombo estuarine water at different reaches during 1991 and 2003 are given in **Table 16**.

Table 16: Organic pollution in different parts of the Negombo estuary

Location	Year and Parameters			
	1991		2003	
	BOD	COD	BOD	COD
Lower reach	21	-	28	31
Middle reach	20	-	12	31
Upper reach	-	-	19	23
Dandugam Oya	16	-	17	25
Ja-Ela	25	-	12	21
Hamilton Canal	19	-	11	19

(Source: CCD, 2005)

Over the years, there have been no drastic changes in BOD levels, with a trend of high BOD at the lower reaches than the upper reaches of the estuary. The BOD values of different areas suggest organic pollution, with the water unsuitable for all beneficial uses. The high BOD levels are attributed mostly to low flushing rates in the estuary (CCD, 2005).

During low flows (non- monsoonal periods), the COD load is estimated at 850kg/day while the BOD load was 280 kg/day. The COD to BOD ratio suggest that the major portion of the organic matter is biodegradable and hence lesser in toxicity. These loads seem to be made up of urban and/or industrial run off. Organic loading for the entire year was estimated at 2,500 MT/yr of BOD and 5,500 MT/yr of COD respectively. Of these, about 500 MT/yr of BOD and 2,000 MT/yr of COD were estimated to be from industrial flows. During the dry season, more than 50% of the load is from industrial flows (CCD, 2005).

GCEC (1991) has reported cadmium and mercury levels in the estuarine waters, much less than the proposed ambient standard levels for all classes. Despite the low levels in the water column, it is anticipated that higher heavy metal loads are absorbed into the organic layer present at the bottom, particularly at the upper reaches of the estuary. The analysis of industrial effluents has indicated that the heavy metal loading into the estuary was approximately at 20 kg/yr for mercury and chromium and 10 kg/yr for lead, copper and cobalt (CCD, 2005).

Selladurai, M. and S. A. M. Azmy (1994) studied the bio-accumulation of trace metals in water, sediments and soft tissues of commercial fish in Negombo estuary. Bio-accumulation of Iron was high in various species of fish, with a range of 40 to 83.4 µg/g dry weight. The maximum Iron concentration of 143.1µg/g was observed in crabs. While the level of Zinc was in the range of 11.8 – 70 6 g/g, the average levels of Manganese, Copper and Lead was found to be within 1.95 – 10.9 µg/g. Of all the metals analyzed, Iron was found to be in highest concentration in the sediments (14 -36 mg/g). The concentration levels of the five elements in the biotic and a-biotic media were found to be below that is known to affect adversely the life and quality of estuarine communities.

7.5 OIL POLLUTION

Oil pollution in Negombo estuary is primarily due to the anchorage of fishing boats in and around the estuary mouth, described in detail under section 7.6.

7.6 SEDIMENTATION

During the last 50 years nearly 800 ha of the estuarine water area have been reclaimed by various people for many activities. This land filling has increased the rate of sedimentation in the estuary. Sedimentation is a severe problem in Negombo estuary. The delta at the junction of Dandugam Oya and Negombo estuary has increased from 44.1 ha in 1956 to 92.25 ha in 1981 (CEA, 1994). The sediment transport relationships suggest entrapment of 50,000m^3 of sediment within the lagoon every year (CEA, 1994), resulting in a decrease in lagoon depth of about 1.5mm.

A study by Hettiarchchi and Wijayananda (1994) concluded that both inland drainage and tidal flow had a pronounced influence on the sedimentation in the main body (basin) of the estuary and its outlet. The hydrology of the estuary encourages a large proportion of the sediment load to settle within the main body and the outlet. The main sediment deposition area within the basin occur some distance from the discharge point of the river and where the basin flows into the channel segment. A portion of sand carried into the estuary by tidal flow becomes deposited in the outlet. Hettiarchchi and Wijayananda (1994) have warned that existing sedimentation process will progressively fill segments of the estuary which will become unavailable for fishing and navigation.

Holms and Samarawickrama (1997) discuss the sedimentation process in the Negombo lagoon, particularly at the inlet/exit and the results of the modeling studies done to predict the sedimentation process of the lagoon and the future behavior of the lagoon inlet. Although tidal velocities in the lagoon are not high enough to generate a significant amount of sediment movement, Holms and Samarawickrama (1997) contended that there can be significant sediment transportation due to wave action. The results of sediment transportation studies indicated a continuing reduction in water depths in the narrow inlet/exit channel, caused by unauthorized landfill and unplanned development along the water front during the last three decades. The reduction in the inlet/exit channel directly reduces the tidal exchange and flushing.

Even engineering interventions were contemplated to improve water circulation in Negombo lagoon in order to minimize further siltation and contribute to sustenance of its rich biodiversity. Under the ADB financed Coastal Resources Management Project implemented by the Ministry of Fisheries and Aquatic Resources, the University of Moratuwa and the Lanka Hydraulics Institute jointly carried out a study on the "Feasibility of Dredging the Negombo Lagoon". Hettiarachchi and Samarawickrema (2003) have reported that a number of dredging options were proposed, based on extensive field investigations (topographic survey, bathymetric survey, sediment sampling, salinity, current, tide, river discharge and wind measurements) combined with numerical modeling. Dredging of both eastern and western channels up to a depth of 2.5 m, involving a total dredging volume of 900,000 m^3 was considered the best option, resulting in a 34% increased discharge through the entrance channel system. However, there has not been any follow up on this work.

According to Devedra (2003), there are six major variables that need to be monitored for effective management and impact assessment of wetlands. These include the water balance, water level regime, water level-area-volume relationship, water quality, turnover rate, extreme hydrological events and sediment transportation and erosion.

7.7 FISHERY AND AQUACULTURE RELATED ENVIRONMENTAL IMPACTS

Negombo estuary is cluttered with hundreds of motorized fishing boats, polluting it and endangering the once rich estuarine fishery. Negombo does not have a fisheries harbor, nor is there a fully fledged anchorage for marine fishing vessels, particularly the so called offshore 'multi-day' boats of 10-15m LOA. In early 2000, around 100 offshore boats were estimated to have been anchored within the estuary at any one time (Anon, 2002). Many of these boats have got firmly entrenched between the main estuary mouth at Duwa and the Pitipana *Lellama* near the bridge and inside the estuary opposite Kuttiduwa. These sections of the estuary banks are also cluttered with a number of temporary wooden jetties used for unloading fish (**Fig. 19**) (GCEC, 1991). CCD (2005) has reported that more than 60 such jetties have been constructed, most without any approval. Nearly 3,000 Fibre Reinforced Plastic (FRP) boats powered by outboard motor engines are also anchored along the estuary banks.

The drainage of bilge water and waste oil from the FRP boats as well as multi-day boats cause pollution of the estuary. It has been estimated 40,000 litres of waste oil from motorized boats and 13,000 litres of oil from service stations are discharged into the estuary annually (Anon, 2002). Fish caught in some areas of the estuary are reported to be tainted with kerosene and unfit for human consumption.

In addition, there is a string of physical infrastructure (boat building and repair yards, slipways, fuel stations, ice plant) along the basin shoreline.

There are several places around the estuary (particularly Pitipana and Duwa area) used for processing fish for 'dry' fish production and waste from this is dumped into the estuary, polluting it.

Pahalawattaarachchi and Siriwardene (2003) investigated the effect of waste water discharge from small-scale shrimp farms on algal proliferation and subsequently on sea grass beds. While *Hypnea* was found to be the most common macro-algae proliferate due to nutrient enrichment, the scattering of algae which affected sea grass growth extended a distance of 100m from the outlet of effluents of the respective farms. Sea grass distribution was found to be severely affected due to algal proliferation within a radius of 0-50m from the shore loadings.

Pathmi et al (2003) have investigated the impact of crab fattening on the estuarine environment and the livelihood of fishers in Negombo estuary. Crab fattening involve keeping water crabs in captivity near lagoon/estuarine mouths and providing them with supplementary feed such as trash fish and fish offal until they reach a marketable size. This economic activity has begun in Negombo estuary in 1999 and there have been 22 farms maintaining 159 cages by 2003. Investigations have revealed a significant increase of un-ionized ammonia, sulfide and moisture content of soil in crab fattening areas, indicating deterioration of water quality. Although the activity earned a profit of 80-90% per cycle on

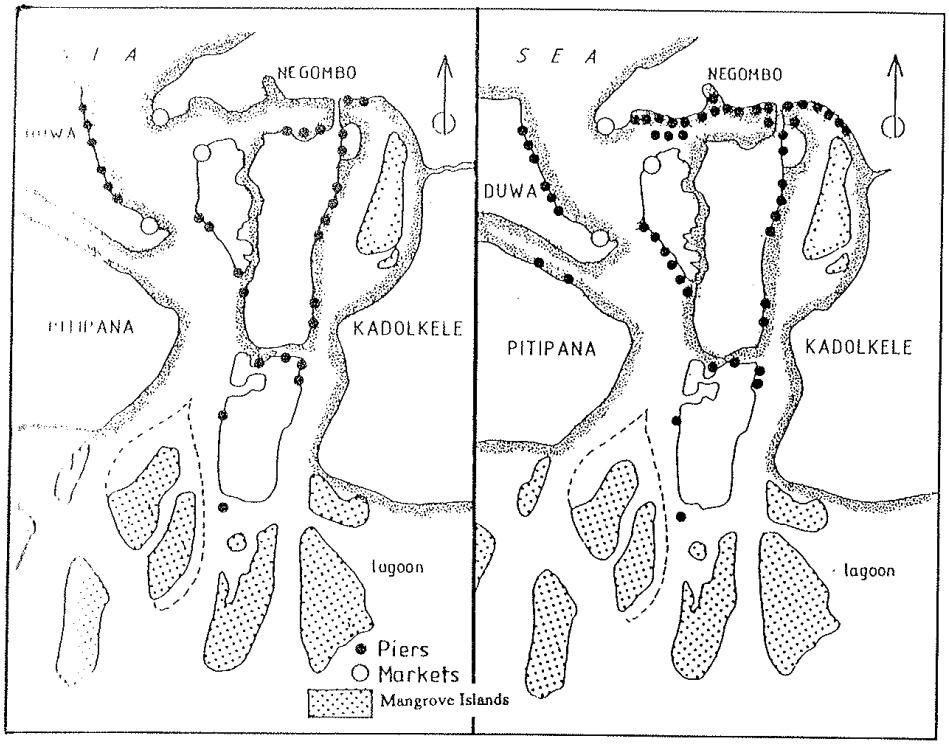

Fig. 19: Proliferation of piers and anchorages in Negombo estuary from 1980s to 1990s (Source: CEA, 1994)

investment, further studies were deemed necessary to estimate the carrying capacity of the estuary for crab fattening to continue as a livelihood activity of the estuarine fisher community.

The use of some fishing gear such as the drag net, push net and trawl on sea grass beds cause much harm to the sea grass beds. Very serious destruction of sea grass beds results from digging polychaete worms which are commonly used as feed in shrimp hatcheries located near the estuary. The operational areas of push nets, trawls and polychate extraction on sea grass beds in Negombo estuary are shown in **Fig. 20** (GCEC, 1991). The immediate consequence of the use of these gear types that rake the sea grass bed and disturb the bottom has been the near extinction of the indigenous cichlid fish, the orange chromide (*Etroplus maculatus*) from the Negombo estuary (Jayakody, 1990). This species use the sea grass beds for nest building, breeding and as a nursery. As the parents tend to remain close to their offspring, even when disturbed by fishing gear, they are easily caught by fishing gear moving along the bottom. This species which was common in Negombo estuary in late 1970s is now considered to be rare.

Samarakoon and van Zon (1991) have estimated a dry weight of 16.8 t sea grass destroyed due to destructive fishing practices (Push net 7.04 t, Trawl 7.78 t and Polychaete extraction 2.02 t).

An analysis by CEA (1994) of the problems, resource use conflicts and issues for the Negombo estuary is presented in **Table 17**.

Table 17: Problems, resource use conflicts and management issues for the Negombo estuary

Problem	Conflict	Issue
Maintenance of adequate tidal exchange, flushing, linkages, dynamic stability and resilience	Maintaining channel width and depth Vs loss of opportunity for unauthorized housing construction in the channel segment, landfill by industrialists	Boundary demarcation, removal of obstructions to water flow, dredging
Habitat degradation stemming from destructive over-fishing, absence of alternative occupations, traditional behavioral patterns (school dropout / early marriages)	Optimization of ecosystem bio-diversity, optimizing fishery income and limiting access to the fishery Vs loss of income and occupation in the absence of alternatives.	Preparation of a fishery management plan based on ecosystem considerations with community participation and the empowerment of women.
Sedimentation and loss of fishing area, enhancement of nutrient load, eutrophication, loss of bio-diversity	Uncontrolled use of watershed resulting in externalities Vs loss of ecosystem bio-diversity	*Long term* : watershed management *Short term*: strategic dredging
Eutrophication (filamentous algal blooms)	Loss of convenient, 'no cost' discharge of sewage Vs prevention of eutrophication and enhancement of ecosystem bio-diversity	Control of convenient discharge of sewage, an urban sewage management scheme based upon cost recovery
Controlling discharge of untreated industrial effluents resulting in pollution of the estuary	Loss of 'no cost' discharge of untreated industrial effluents from EPZs, installation of treatment, charging tariffs Vs loss of ecosystem biodiversity	Cost recovery waste treatment for EPZs, discharge of waste by way of a sea outfall
Oil pollution	Uncontrolled and 'no cost' expansion of anchorage facilities Vs loss of fishery income (tainting of fish)	Limiting and management of anchorages based upon carrying capacity

(Source: CEA, 1994)

7.8 CONSERVATION MEASURES

The Greater Colombo Economic Commission (GCEC) facilitated the preparation of a Master Plan for the Muthurajawela marsh –Negombo estuary complex. An ecological survey and a socio-economic survey were carried out, and an environmental profile prepared during the process of preparation of the Master Plan in 1991.

During 1999-2003, the Central Environmental Authority (CEA) developed an Integrated Wetland Resources Management Plan for the Negombo estuary and the Muthurajawela marsh, with the objective of promoting optimally sustainable exploitation of natural resources.

The Coast Conservation Department (CCD) introduced the Special Area Management concept (SAM) in 1997, with ecosystem management, fishery management, pollution control and waste management, community development and institutional strengthening as key focus areas. A Community Coordinating Committee (CCC) was established to coordinate the implementation of the Special Area Management Plan for Negombo estuary. The SAM plan sought an integrated management of the ecosystem, including fishery management, pollution control and waste management, community development and up-liftmen of the socio-economic condition and strengthening of institutional capabilities and mechanisms. In a review of the SAM process in Negombo estuary, Premaratne (2010) has observed that the process has taken too long (over two decades during which several policy changes have occurred), programmes have been more project and development oriented than participatory co-management, the CCC more state dominant, lead agency participation inadequate, very high political involvement and that the major issues of the SAM area have been neglected.

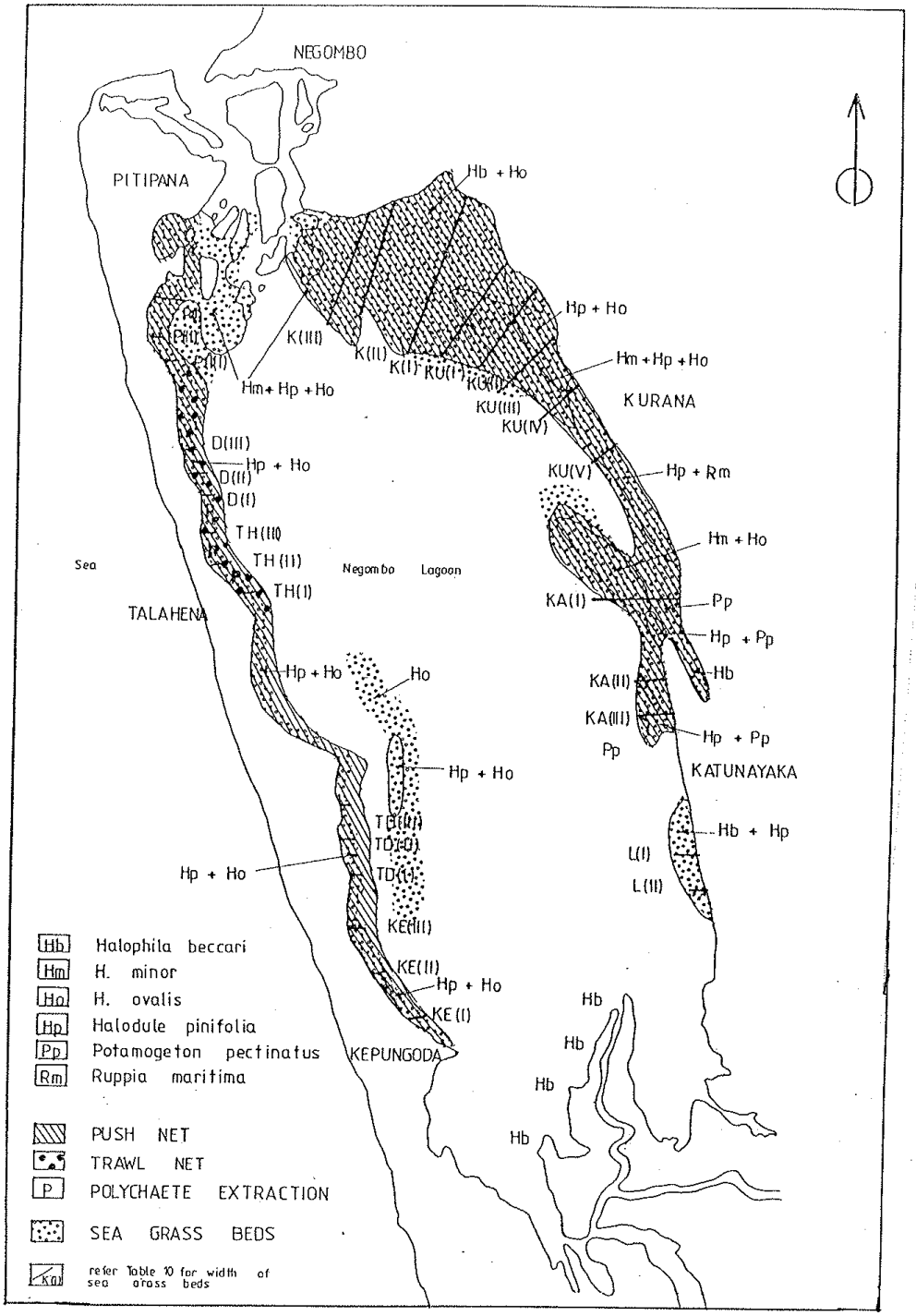

Fig. 20: Operational areas of push nets, trawls and polychaete extraction on sea grass beds (Source: CEA, 1994)

Five mangrove islands have been gazetted as forest reserves by the Forest Department. IUCN (1996) has prepared a mangrove zoning plan which has been adopted by the Forest Department for implementation in the Negombo SAM area (CCD, 2002). The plan recognizes zoning areas where different activities are allowed:

- **Preservation zone:** Education / research

- **Conservation zone:** Collection of branches for firewood/ twigs and sticks for brush piles/ bark for tannin / fruits and tourism

- **Utility zone:** Timber production/fire wood production (charcoal)/ collection of branches for firewood/ twigs and sticks for brush piles/ bark for tannin and fruits

- **Non-mangrove zone:** Traditional fishing, tourism and sand mining

Nearly 10 ha of mangrove area are being used for educational and research purposes in the Kadolkele by NARA.

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