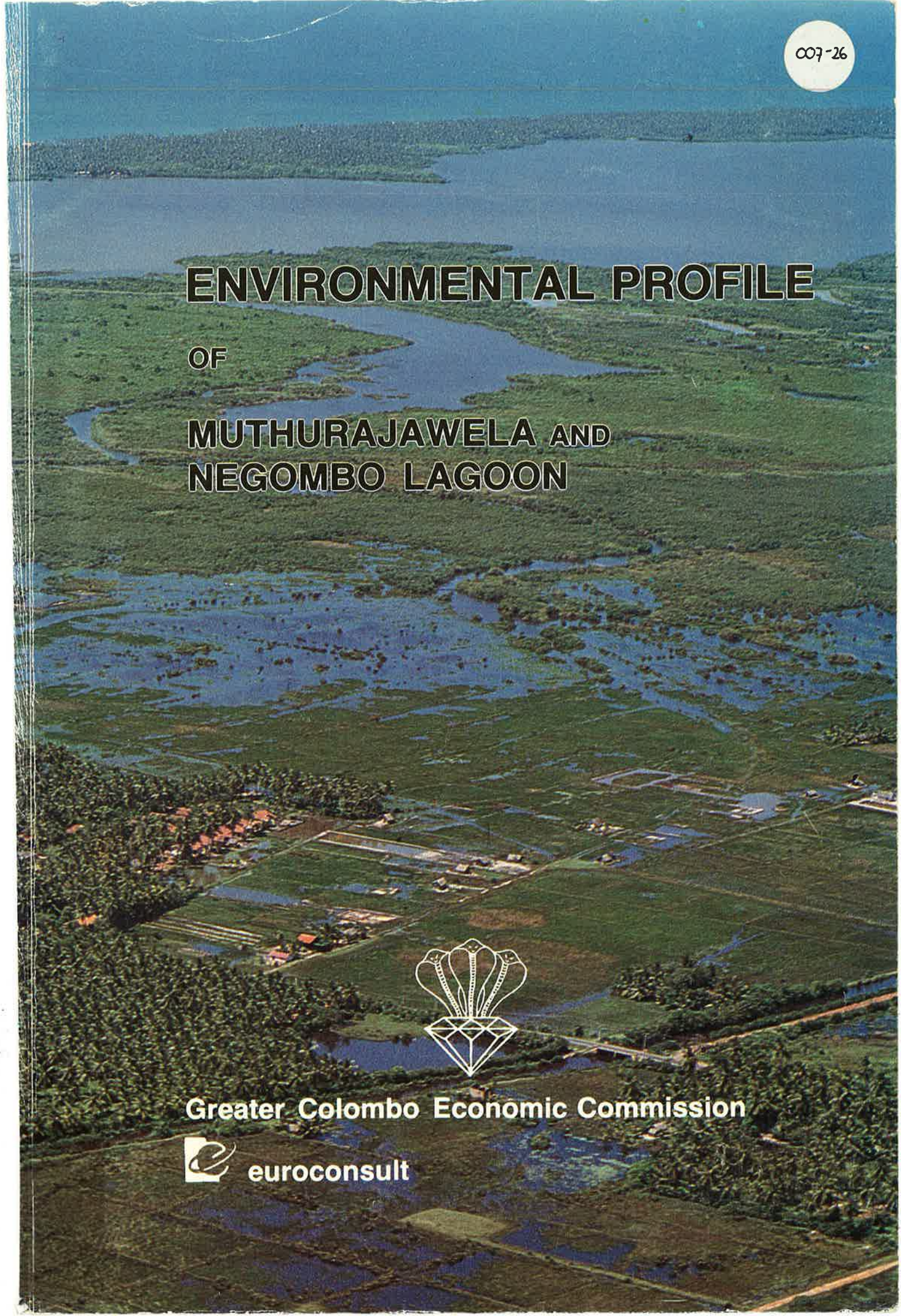

ENVIRONMENTAL PROFILE

OF

MUTHURAJAWELA AND NEGOMBO LAGOON

Greater Colombo Economic Commission

euroconsult

ENVIRONMENTAL PROFILE OF MUTHURAJAWELA AND NEGOMBO LAGOON

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March, 1991

GREATER COLOMBO ECONOMIC COMMISSION
EUROCONSULT, THE NETHERLANDS

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FOREWORD

Wetlands have generally been regarded as unproductive and even unhealthy and are commonly associated with disease-carrying insects, crocodiles, etc. That the saga of Muthurajawela has been shaped by a similar perception is evident from the irrigation and drainage works constructed in the past, now lying in a state of disrepair. The raised bunds of paddy fields, still intact, bear ample testimony to failed agriculture, because it was unsustainable for a variety of reasons, including the inherent character of a coastal, marshy wetland. Nevertheless, a fresh call for development of this wetland was inevitable since it lies continuous with the city of Colombo with its agglomeration of urban and commercial infrastructure, and other urban centers such as Hendala, Wattala, Kandana, Ja-Ela abutting on it which have a pressing demand for land for residential and industrial uses.

However, the rising environmental consciousness in general, and with respect to wetlands in particular, required that development of Muthurajawela could no longer be undertaken in a piecemeal manner. Consequently when a Cabinet decision was taken to prepare a Master Plan for development of Muthurajawela, the directive from the Presidential Secretariat stated that an ecological survey had to be carried out prior to plan preparation. The GCEC though not geared to such activity embarked on this exercise with the available resources. However, the given time frame of one year was daunting. The challenge was taken, organizational arrangements made; an ecological survey was carried out, and the "Environmental Profile" prepared, all within the allotted time frame in keeping with the highest spirit of good planning. The complexity, yet the simplicity of this planning document, has set the ecological conditions for the Master Plan in a manner that the planning team has grasped.

I am grateful to the Netherlands Government for providing the necessary funds effectively mediated by Mr. Jan Suurland who served as the Policy Advisor to CEA at the time. It is with great pleasure that I thank Euroconsult for assigning the best expertise for project advice, and the specialists themselves: Dr. Hans van Zon (Team Leader), Mrs. Caroline Hoisington, Mr. Bart van Lavieren Mr. Franz Ziegler and Mr. E. Allersma. A special thank to you Mr. Derk Oldenburg of Netherlands Embassy in Sri Lanka for the personal interest taken in the project.

I thank the Vice-Chancellor, University of Kelaniya, for granting leave to Dr. Jayampathy Samarakoon, who served as the project manager. He worked tirelessly, ably assisted by Mr. P.K.S. Mahanama, Regional Planning Assistant to ensure that the time target was met.

Mr. L.D. Dickman, Senior Manager, Area Administration Department, supported the project in a dual role, providing material and services of his officers, and as Secretary of the Working Group.

Members of the Working Group, comprising representatives of UDA, NARA, CEA, SLLRDC, CCD and ID even after a hard day's work in their own offices, took time to participate in the regular meetings to ensure that the project moved on course. It was indeed a pleasure to work with them.

The ecological survey would not have been possible if not for the individual specialists who carried out the studies. Despite their other responsibilities, they engaged in the necessary field work, prepared and submitted the relevant reports on time. I thank them warmly for there dedication and assistance.

I trust that this project will serve as a model for future efforts in wetland development and management planning.

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Forest Department
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Irrigation Department
Land Commission's Department
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Ministry of Fisheries
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Natural Resources, Energy and Science Authority
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ECOLOGICAL SURVEY STUDIES

THE ENVIRONMENTAL PROFILE IS BASED UPON THE FOLLOWING STUDIES

Government Agencies

AD	:	Ranasinghe, T. Agriculture in Muthurajawela marsh.
CCD	:	Perera, H.N.R. 1991. Erosion study.
CDA	:	Ranbanda, L.B. Jayasuriya and S. Jayasekera. Feasibility of Coconut cultivation at Muthurajawela.
CTB	:	Tourism development
DFAR	:	Fisheries sector study for Negombo Lagoon.
DSI	:	De Silva, B.C. Development Perceptions for Industry.
FD	:	Bandaratillake, H.M. and A.N.S. Baminiwatte. The Forestry Component.
GCEC	:	Environment Department. Baseline study of water quality
		Mahanama, P.K.S. Socio-economics of the study area. Area Administration Department.
ID	:	Dharmasena, G.T. Estimation of flood buffer capacity. Hydrology Div.
	:	Dimantha, S. Soils of Muthurajawela, Landuse Division.
	:	Dimantha, S. Changes and Impacts in the catchment. Landuse Division
MRI	:	Public Health Aspects.
	:	Jayasekera, N. Entomological survey
	:	Seneviratne, U. Preliminary parasitological study.
	:	Nutrition Dept. Nutrition aspects for Muthurajawela.
MD	:	Fernando, T.K. Climate study.
NARA	:	Amarasinghe, M.D. Mangrove vegetation of Negombo Lagoon.
	:	Jayamanne, S.C. Mud crabs of Negombo Lagoon.
	:	Jayamanne, S.C. Aquaculture at Negombo Lagoon.
	:	Jayasuriya, a. Status of seagrass beds in Negombo Lagoon
	:	Wickremaratne, W.S., J.M. Niwas; E.M.S. Wijeratne and K.S. Guruge. Hydrological and pollution aspects.
NHDA	:	Dassanayake, A. Housing at Muthurajawela.
UDA	:	Urbanization and Industrialization.

Non-Governmental Organizations

WL & NPS	:	Avifaunal study for Muthurajawela.

Specialists

De Silva, Rex I.	:	Avifauna of Muthurajawela and Negombo Lagoon.
Dissanayake, C.B.	:	Geology and evolution of Muthurajawela marsh and peat utilization. University of Peradeniya.
Herat, T.	:	Vegetation of Muthurajawela and mangroves of Negombo Lagoon. Open University.
Jayasinghe, J.M.P.K.	:	Aquaculture at Muthurajawela. University of Stirling, U.K.
Karunaratne, G.P.B.	:	Mammals, reptiles, amphibians, butterflies and dragonflies of Muthurajawela.
Pinto, L.	:	Fish and aquatic fauna of Muthurajawela. Open University.
Wijeyaratne, M.J.S.	:	Fisheries of Muthurajawela. University of Kelaniya.

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LIST OF ABREVIATIONS

AD	Agriculture Department
BEPZ	Biyagama Export Processing Zone
CCD	Coast Conservation Department
CDA	Coconut Development Authority
CEA	Central Environmental Authority
CTB	Ceylon Tourist Board
DSI	Department of Small Industries
DFAR	Department of Fisheries and Aquatic Resources
EIA	Environmental Impact Assessment
ESCAP	Economic and Social Commission for Asia and the Pacific.
FD	Forest Department
GCEC	Greater Colombo Economic Commission
ID	Irrigation Department
IUCN	International Union for the Conservation of Nature and Natural Resources
JE	Japanese Encephalitis
JICA	Japanese International Cooperation Agency
KEPZ	Katunayake Export Processing Zone
M.S.L.	Mean sea level
MRI	Medical Research Institute
NARA	National Aquatic Resources Agency
NARESA	Natural Resources Energy and Science Authority
NEA	National Environment Act
NGO	Non-governmental Organization
NHDA	National Housing Development Authority
NRC	National Research Council
NWS&DB	National Water Supply and Drainage Board
SLLRDC	Sri Lanka Land Reclamation and Development Corporation
UDA	Urban Development Authority
UNEP	United Nations Environmental Program
WCED	World Commission for Environment and Development
WD	WildLife Conservation Department
WL	Waterloopkundig Laboratorium
WL&NPS	WildLife and Nature Protection Society

SUMMARY AND CONCLUSION

1. The Environmental Profile of Muthurajawela and Negombo Lagoon consists of an abstraction of information based upon 33 separate studies constituting an ecological survey including a socio-economic survey focussing on the relations between people of the study area and renewable resources. Muthurajawela marsh and Negombo Lagoon constitute a conjoined, tidally influenced, coastal wetland.

2. Muthurajawela marsh, the actual planning area is inextricably linked ecologically to the dune system to the west, Negombo Lagoon to the north and activities in the already developed areas surrounding it. Therefore the study area consisted of the marsh (planning area and the linked dune, lagoon and contiguous built up area.

PART A: DESCRIPTIVE PROFILE OF THE STUDY AREA.

3. Location: Muthurajawela marsh-Negombo Lagoon coastal wetland is situated in the Gampaha District, on the western coast about 10 km north of Colombo and extending northward about 30 km to Negombo town.

   3.1 The wetland opens to the sea by way of a single opening at the northern end. Dandugam Oya draining a catchment of 182,000 acres is the main source of freshwater.

4. **History:** Muthurajawela is reported to have been a part of an extensive paddy tract during the period of the Kotte Kingdom. Because of engineering works that facilitated salt intrusion, paddy cultivation declined. All subsequent efforts have failed to rehabilitate paddy cultivation by way of various engineering works:

   4.1 Today, Muthurajawela marsh consists of a network of canals and water control structures in a state of disrepair, patches of marsh with mixed vegetation serving as wildlife habitat and ten squatter settlements.

   4.2 Negombo Lagoon was a thriving sea port during the period of the Kotte Kingdom, and under the Portuguese. Its importance as a port declined under the Dutch simultaneously with development of Colombo as the capital city and main sea port.

   4.3 Negombo Lagoon today is a marine fishing center of national importance. However, the Lagoon fishery, of high socio-economic importance, is overexploited and has suffered from absence of management.

5 **Regional context** The wetland is situated in the Western Province, whose potentials and problems have greatly influenced national development policy. The development pattern in the Western Province is influenced by the political imperatives relevant to Colombo. Owing to a pressing demand for residential land, Muthurajawela marsh has persistently been a target for landfill in development plans.

   5.1 Urban centers lying contiguous with the wetland impose their own demands for land for residential and industrial purposes, discharge of industrial effluents and as a flood buffer.

   5.2 The Gampaha District population of 1.3 million in 1981 is expected to double by the year 2001. Therefore, the demands will increase for development as well as for the 'free' services provided by the wetland in its natural state.

   5.3 The wetland comes under the planning authority of GCEC. In its landuse plan, the marsh was to be kept in deferment while the amenity values of Negombo Lagoon were to be improved.

6. **Climate:** The study area is influenced by two periods of heavy rainfall at the beginning and at the end of the South West Monsoons. At other times, evaporation, exceeds rainfall only during January, February and March. Temperature varies between 210 and 32 C0 Wind speed varies between 5 km/h and 15 km/h, direction being mainly SW. Along the south west coast cyclonic winds are rare.

7. **Geology and Soils:** Geomorphologically the wetland system is less than 6000 yrs old having

originated during the Holocene transgression. Muthurajawela marsh consists mainly of immature peat of reed-sedge-tree-humus composition. It is linked hydrologically to Negombo Lagoon which is a bar-built estuary. The continued existence of this wetland system is dependent upon persistence of the coastal barrier dune to the west.

7.1 The soils of Muthurajawela classify as bog soils which are uniformly, potentially acid sulphate. The soil limitations make commercial agriculture difficult or impossible.

8. **Hydrology:** Initially the marsh received water from rainfall, and mainly from Dandugam Oya in flood. Poor drainage enabled marsh development. Since the 15th Century various forms of engineering works, navigation canals, irrigations and drainage systems changed the water retention pattern of the marsh, reducing it to about 7 days from a previous retention time of about 35 days. Enhanced drainage has resulted in subsidence of the marsh surface. Of the total fresh water received by the wetland (1.7 cu km/y the main outflow is via the lagoon mouth. The system receives about 0.6 cu km/yr more freshwater than tidal seawater. During the dry months the marsh supplies freshwater to the lagoon to maintain brackish water conditions.

8.1 Roads have separated the marsh into three segments of about equal dimensions. Existing drainage, salt intrusion and flood protection bunds maintain an east-west flow in the southern two segments during the dry months. Only the northern segment is hydrologically connected with Negombo Lagoon.

8.2 The water in the marsh is acidic while in the lagoon it is alkaline. At present water quality in the lagoon and northern marsh is adequate for high fishery productivity. At location where encroachment inhabitation occurs, fecal contamination is high.

8.3 At present sedimentation rate in the lagoon is about 50,000 t/y resulting in a decrease in depth of about 1.5 mm/y. At the present rate of sedimentation filling in time for Negombo Lagoon exceeds 400 years. The present rate of sea level rise compensates for sedimentation while the anticipated sea level rise will ensure its existence for the next 1000 years.

9. **Vegetation:** In the marsh the main types of vegetation are grasses, reeds, sedges and cattails, with aquatic vegetation such as water lilies in the canals and water bodies.Shrubs and trees occur on well drained areas such as embankments of canals. The dominant tree species in the marsh is the introduced Anona glabra. The marsh does not constitute an important location for any rare endemic or threatened species. The plant community structure provides divers habitat for animals. In the lagoon the important vegetation types are submerged seagrasses, fringing mangroves and reeds. These plant communities provide critical nursery areas for commercially important fishery organisms. There were no endemic or threatened plant species confined to this wetland as their only habitat.

10. **Fauna:** The most spectacular faunal assemblages consist of birds, fish and crustaceans 40% of Sri Lankan mammal species are recorded for Muthurajawela. Excepting rats and mice, other mammal populations are sparse. 7 species are endemic/threatened. 39% of Sri Lanka bird species occur at the wetland. 40% of migrants to Sri Lanka were recorded for this wetland. The wetland constitutes the most important bird habitat in the wet zone of Sri Lanka. 23% of reptile species in Sri Lanka were recorded for the wetland including the threatened estuarine crocodile; Crocodilus porosus. 39% of Sri lankan amphibians were recorded for the marsh with its diverse aquatic habitats. They occurred mainly in the southern segments. About 140 species of fish have been recorded for the wetland, the majority being species that migrate from the sea. Many of these are commercially important and exist as substantial populations that support a fishery. Six species of penaeid shrimps with an obligatory estuarine phase in their life cycle occur as substantial stocks in the wetland and support a major export-oriented fishery. 27% of Sri Lankan butterfly species were recorded for the marsh, while dragonflies recorded constituted 40%. The faunal assemblage occurring in the wetland is high in species richness and diversity. There are no endemic or threatened species confined to this wetland as their only habitat.

10.1 Numerous species of disease vectors and pathogens are associated with the habitats created mainly by encroacher settlements in the marsh. The most important pathogen is the bacterium causing potentially fatal leptospirosis, and transmitted by way of rat urine. Numerous, favourable habitat have also been created for disease transmitting mosquito species belonging in the genera, Aedes, Culex and Anopheles. Pathogens

causing bowel diseases are transmitted with ease since the wetland (marsh) provides ideal conditions for faecal contamination of water which is used for washing and bathing.

11. **Ecosystem:** The marsh-lagoon wetland constitutes an ecosystem that is tidally linked to the marine coastal waters and which receives essential terrestrial material by way of Dandugam Oya. The main energy sources are the sun, currents, nutrients (from outside the system as well as from decaying vegetation within the system). These energy sources together with complex vegetation combine to support a diversity of animals that impart a uniqueness to the ecosystem as a whole. The seagrass bed in Negombo Lagoon constitutes the single most important habitat type that supports the exceptional fishery productivity of the wetland.

12. **Socio-economics:** The encroacher population in the marsh has increased rapidly since 1970 to reach the present level of 3366 distributed among 10 settlements. The majority of the population belong to the age groups below 30 yrs. They are mainly Sinhala, Catholics who immigrated from densely populated urban areas within 3 km of their present residences. The major 'pull factor' was availability of 'free' state-owned land for house construction . The majority have education to secondary level. The majority of families are below the poverty line and receive food stamps. However, the level of poverty as indicated by receipt of food stamps varies by settlement. One hundred percent families living in the northern most encroacher settlement receive food stamps. However, their major source of income is the lagoon fishery.

    12.1 The labour force in the marsh constitutes 50% of the total population. The majority engage in daily wage labour in nearby urban centers. The second most important occupation is fishing in Negombo Lagoon. About 30% of the labour force is unemployed. The national average for unemployment is about 20%.

    12.2 Housing is mainly of a temporary type without proper amenities. Water for drinking and cooking is obtained from nearest pipe stand or wells. Defecation is in pit latrines that flood during the rains, or in unoccupied areas. Kerosene is used for lighting and fuelwood for cooking. The health conditions of the encroachers in the marsh reflect a status below national averages.

13. **Urbanization and Industrialization:** Until about mid 1980's populations in urban centers contiguous with the study area grew because of immigration rather than natural increase and thereby reflected a period of rapid urbanization. At the present time immigration to these centers has declined while immigration to more hinterland areas has increased. The most important urbanization need served by the wetland is supply of fish protein. It does not serve in urban waste disposal at an organized level. However, there is haphazard solid waste disposal.

    13.1 Two of the major industrial areas are situated near the study area: Ekala Industrial Estate and Katunayake Export Processing Zone. The wetland serves the major function of absorbing untreated and treated industrial effluents from these industrial zones.

    13.2 It provides raw materials for two major export industries: crustaceans (shrimps, crabs) and ornamental fish.

14. **Land Use:** The areal extents composing the study area: marsh proper: 3068 ha; Negombo Lagoon: 3164 ha: high ground 4462 ha.

    14.1 The major economic activity supported by the wetland is fisheries with an annual productivity exceeding 100 kg/ha/y which ranks above global averages for highly productive estuaries. The value of this production is estimated to be about Rs. 100 million/y. About 3000 fisherfolk are engaged in fishing in the wetland.

    14.2 Residential units and homestead gardens constitutes the most prominent land use in the high ground area.

    14.3 The most important agricultural crop in the study area is coconut. Paddy cultivation is now marginal. Coconut cultivation in the marsh again is a marginal activity constituting about 60 ha reclaimed and planted during a period of about 30 years.

    14.4 Aquaculture which had previously seemed intuitively practical is not viable since soils are unsuitable.

    14.5 A substantial area of the marsh segment has already been transformed by infrastructure: roads, irrigation and drainage systems. Low voltage power supply exists along main roads. Pipe borne water supply exists only to the southern margin of the marsh.

15. **Other economic activities:** Small scale economic activities in the marsh area consists of illicit liquor brewing, buffalo rearing, hunting of crocodiles and tortoises, timber extraction, reed extraction and animal husbandry.

PART B: CHANGES IN THE NATURAL ENVIRONMENT AND THEIR IMPACTS

16 **Natural Changes :** Causes and Interrelationships

16.1 Geomorphology and Hydrology The present trends in the geo-morphological development of the area appear to be:

16.1.1 An expected considerable rise of mean sea level in the future,

16.1.2 A recession of the coast mainly caused by the rise of sea level that has already occurred and the mining of sand from the Kelani Ganga estuary, possibly leading to breaches of the coastal barrier,

16.1.3 A considerable reduction or even cessation of the accumulation of peat in the Muthurajawela marsh leading to its vertical growth to lag behind the rise of sea level,

16.1.4 A growth of the tidal delta of the Dandugam Oya and the Ja-ela into Negombo Lagoon which is expected to be retarded by future sea level rise,

16.1.5 A net sedimentation in Negombo Lagoon which, however, is expected to be less than the increase of volume caused by sea level rise, and

16.1.6 A rather stable situation in the inlet of the lagoon under tidal and fluvial flows with, however, a tendency of narrowing caused by socio-economic development on channel banks.

16.2 The coast is expected to require considerable sea defence works to protect the inhabited area along the landward side of the dunes as well as (in the long run) the low lying marsh and the lagoon against the attack of the ocean.

16.3 With respect to the marsh, a **policy** decision has to be made as to **whether the marsh should be maintained** and provide the conditions for the formation of peat, or to let it further deteriorate into a shallow body of brackish water.

16.4 The **interrelated system of the tidal river delta and the Negombo Lagoon** needs attention to keep conditions conductive to a further harmonious development serving this intricate ecological system.

16.5 The **inlet channel to the lagoon may require protection** against further encroachment along its banks in order to maintain the exchange of water between the lagoon and the sea at a proper leve

1.6.6 **General trends:** The **main trend** that can be observed in the hydrological system of the Muthurajawela area is the **deterioration of the drainage works leading to even more water logging in certain areas and increased intrusion of salt;** both exacerbated by an increasing rate of sea level rise in the future. There are no definite plans to halt or reverse this development. Others include:

16.7 Breaching of the coastal barrier at one or more places may worsen the situation on the long term.

16.8 Pollution is on the increase because of economic development around the area and in the catchment of the Dandugam Oya (Attanagalu Oya).

16.9 Preservation of the marsh will require almost **complete impoundment** to prevent unwanted drainage and salt penetration, and to maintain a proper water balance for peat growth.

16.10 The salt and nutrient balance in the lagoon and the adjacent delta of the two rivers should be maintained for a proper functioning of the complex ecological system. However, there appears to be a trend toward declining salinity. The latter requires fresh deposits of soil and, therefore, sedimentation in the delta as a source of nutrients.

16.11 **Population Growth** Encroachment into the **Muthurajawela** marsh and inter-tidal areas of Negombo Lagoon is a clear impact of population growth. These areas are prone to flooding and are generally unsafe. However, land scarcity impels settlement on these areas.

17 DEVELOPMENT OF RESOURCE EXPLOITATION

17.1 General trend in agriculture in the marsh is abandonment of paddy cultivation. Small scale cultivation of vegetables and coconuts persists. The longterm objective of coconut cultivation is landfill for housing etc.

17.2 The trend in fisheries is overexploitation combined with habitat destruction.

17.3 Pond aquaculture in the marsh cannot be profitable because of soil limitations. The majority who attempted it have abandoned their ponds.Based upon the above trends:

17.4 Efforts to restart rice production should not be made.

17.5 It is suggested that the current smallscale land reclamation cum homesteading is not a high-value use of the land. It is not recommended as a dominant activity for using the marsh. The system may have its place in an overall mixed land use strategy. If the strategy is to develop certain areas for housing via land-fill, making these areas no longer marsh, and to keep other areas for conservation as a marsh, it will be necessary to create a buffer zone between the two, and there may be a place for low-intensity land use via mixed farming as a part of the buffer zone as long as the location of this kind of activity is controlled.

17.6 In those areas of the marsh that are considered environmentally critical, new squatting should not be allowed. Current residents should be offered alternative low-income housing.

17.7 In order to preserve the productivity of the lagoon, a lagoon management plan is needed. It is also necessary that part of the management plan would be a set of initial measures designed to bring about a better ecological balance than now prevails in the lagoon. These measures could include:

17.8 dredging and clearing the mouth of the lagoon to allow a better exchange of water and clear the "choking" effect,

17.9 relocation of squatters who are contributing to its "choking" away from the channel segment of the lagoon.

17.10 prohibiting the use of the lagoon for dumping of any kind of industrial wastes

17.11 integrated management of the fishery in the Negombo Lagoon in order to ensure that the coastal stocks, including shrimps and several important fish species do not collapse.

17.12 provide alternative lowincome housing for the relocation of those squatters currently blocking the mouth of the Negombo Lagoon with their land reclamation activities.

17.13 in the event that the Lagoon and coastal fisherman lose their occupations and income because of nonmanagement, alternative jobs would have to be created. In 1988, the estimated cost of creation of a job in this sector was Rs. 10,000 (Sessional paper 12, 1988).

17.14 exploitation of the reeds and grasses in the marsh does not present a problem. The demand for mats etc. is not high enough to cause over-exploitation, and the reeds and grasses regenerate easily and quickly. This smallscale activity can continue unregulated

17.15 mangrove exploitation and tree-cutting in general has reached a point where there are no important tree resources left. There is no real possibility of replanting mangroves since the limited extent of land available for such planting would make it uneconomical. However, certain critical areas at the north and south of the Negombo Lagoon must be protected from wood extraction. While prohibiting mangrove cutting, it will be necessary to develop alternative sources of fuelwood for the households.

17.16 pond aquaculture, under prevailing soil conditions, cannot be undertaken profitably and should not be promoted.

17.17 small scale pen culture deserves development on a well organized basis, taking measures to ensure that it does not depress the incomes of fisherfolk through oversupply.

18 Urbanization and Industrialization

18.1 The existing trend in urbanization is toward the hinterland and away from the Muthurajawela marsh. This parallels the pattern of infrastructure development.

18.2 The demand for land for industrial activities is higher in areas in the hinterland and least in the marsh.

18.3 An urgent need does not appear to exist for development of Muthurajawela as a response to current trends in urbanization and industrialization. However, if the marsh is developed as a matter of policy, urbanization of the area may be stimulated mainly because of proximity to Colombo city where agglomeration of commercial and administrative establishments has already occurred.

19 **SocioEconomic Impacts**

19.1 The existing trend is toward intensification of exploitation of all economically important renewable natural resources. As a result, the present level of income will decline. Alternative income generating activities need to be promoted.

19.2 Immigration will resume if not controlled, since in the absence of alternatives the marsh will be seen as an area of opportunity.

19.3 Although encroachment into the marsh gives immediate relief by providing 'free' land for housing, the environmental changes created and the health problems entrained diminish the quality of life in the longer term (increased incidence of disease).

19.4 Encroachment into the intertidal shoal of the Negombo Lagoon provides both free land for housing and entrains dependance on the fishery resource. It appears that most encroachers immediately begin to use destructive fishing methods (push nets, dragnets, excavation for polychaete worms), since using them requiresminimal experience, and they are relatively cheap to construct.

19.5 In view of the expected sea level rise, the state will in any event, have to relocate people from the marsh as well as intertidal shoals.

20 **Public Health**

20.1 The preliminary list of debilitating, and, in combination with sub-optimal nutritional conditions, often fatal diseases, more than justify extremeprecaution in development planning and the need for public health programmes.

20.2 The general conclusion of the survey is that the nutritional status of the population studied is unsatisfactory relative to national averages, and that a general improvement of living conditions is necessary, including a safe drinking water supply, sanitation and dietary improvements. However, it was felt that more detailed studies based on larger, more representative samples would be required to get a reliable picture on nutritional deficiencies, its causal factors and remedial measures.

20.3 The existing conditions are favourable to an aggravation of the disease status: threat of an outbreak of JE, introduction of malaria, therefore due consideration would be necessary with respect to the above, in case expansion of settlements is planned in the marsh area.

PART C: INTEGRATED DEVELOPMENT: SUSTAINABLE USE OF NATURAL RESOURCES

21 **General Objectives :** Implementation of development options will have various effects on the ecosystem functions. Some will be positive, others will be minor, temporary and manageable, but many will be negative, permanent and irreversible. Levels of impact depend upon the scale, location and technical implementation of development options. Practically all options will conflict with one or more of the ecological functions. Therefore utmost care is required in planning development. Implementation of selected development options should take place in a phased manner with constant monitoring of pre-selected environmental and socio-economic indicators.

22 **Development Options**: The development options to be considered in the Master Plan include, conservation, housing and industry, tourism/recreation, infrastructure, agriculture, fisheries, aquaculture, forestry, peat extraction, water resources, education/research.

22.1 These development options are analysed with respect to their impact on:

Sustainability of yield: the planning area and study area at the present time provide a wide range of products (goods) and services to which a financial interpretation could be given. The supply of these products must be maintained or enhanced, but not allowed to be depleted.

Sustainability of function: the planning and study areas constitute parts of ecological systems whose linkages and processes cannot be financially interpreted, but the continuity of which is essential for present and future yields. e.g. seawater-freshwater mixing, poor drainage, genetic resources, dune stability etc. and

Sustainability of investment: any development option selected for implementation by the decision makers should necessarily mean that finances allocated to it will result in the **anticipatedbenefits** envisaged without merely transforming existing conditions irreversibly in a manner that could lead to abandonment of projects. The development options considered from an environmental viewpoint are:

22.2 **Conservation** The results of environmental investigations indicate the following are the most important areas of the marsh and associated functions (Fig. 85)

22.2.1 The area of transition between the lagoon and the marsh, that is the northernmost portion of the marsh, from the southern edge of the lagoon, south to the edge of the densely populated area on the TudellaPamunagama road, is the most critical ecologically. It is also one of the least-developed areas. The squatters who now live there are few in number and largely dependent upon fishing. They do relatively little environmental damage, but some of their activities should be curtailed, specifically path construction on any scale and tortoisehunting.

22.2.2 A central area of the marsh should remain open: as a corridor for the movement of fauna between the marsh and the lagoon areas. This area should include some water bodies and it should also retain the natural flora of reeds, sedges, etc and remain a habitat for marsh species. This central open area should be linked to conservation at the northern edge of the marsh.

22.2.3 From an economic point of view, these areas are the **least interesting** to develop for the high intensity uses of landfill and housing and/or industry.

22.2.4 The sizes of these areas will be determined during the Master Plan preparation.

22.3 **Housing and Industry** The overall picture of the economics of developing land for housing and for industry that emerges is the following.22.3.1Cost of landfill and of providing services for housing and/or industrial development to the areas within the marsh proper are considerably high. Due to the depth and quality of the peat soils found within the marsh and the high water table, these soils require relatively large amounts of fill, prolonged settling times, substantial drainage measures, protection against sideways loss of soils and subsequent subsoil collapse.

22.3.2 The relatively high-cost of land can be offset somewhat by the high demand for land particularly in the regions closest to Colombo and for relatively high-value uses. The existence of privately financed, high-value housing developments where developers are paying full costs of land fill and development, and building and selling lots with houses suggests that certain combinations of costs and value-added can be profitable.

22.3.3 Social considerations will presumably require that a proportion of the land developed for housing be available for low-cost housing, to allow for the relocation of some of the marginal squatters in the marsh and at the mouth of the Negombo Lagoon andpossibly to accommodate some of the lowincome, landless and houseless people of Colombo. The costs of landfill and development will be too high to be borne by the inhabitants of lowincome housing. These costs will be further increased by measures required for protecting the rest of the area from the negative effects of housing development (flooding, sanitation, increased pressure on natural resources). The costs will therefore need to be either borne completely by the government or (partially) recovered in the form of higher prices, or an outright tax, levied on the purchasers of the higher cost land.

22.3.4 From a budgetary and costrecovery point of view, landfill for low income housing in the Muthurajawela marsh is an

expensive proposition. One solution may be to provide relatively high-density low-income housing in the most southerly area of the marsh, close to the Colombo-Negombo road with relatively good access to public transportation. As a number of the most marginal squatters in the marsh leave during the day to find work, often paid day-labor, completely outside the marsh, this location would be suitable.

22.3.5 Another solution to meet (some of) the need for low-income housing may be to allow the continued homesteading of small plots of land with the coconut planting/land reclamation technique that now takes place around the edges of the marsh to continue in other specified areas too. Here too proper sanitation would have to be provided to ensure an acceptable quality of life, in this event to the legal dwellers. These areas would act as a transition zone between the more intensely developed, land-fill areas and the lowimpact uses of tourism and recreation.

22.3.6 Land servicing costs will generally be lower where hook-up distances to major water, electric and sewage lines are shortest, in other words, nearest to the ColomboNegombo road. Access to major transportation arteries to bring in materials and to ship out goods to markets is crucial for industries as increasing shipping distances increases operating costs. This is one (strong) argument for the location of any new industrial areas in close proximity to Colombo and to major transport lines as possible.

22.3.7 There appears to be room within existing industrial areas, within and outside of the EPZs for expansion and new housing (see Figure 7). What may be in short supply, however, is land for space-consuming industries such as warehouses and container storage sites. It may be that some of these industries could afford to pay for the land fill necessary to make the sites possible.

The ideal sort of industry for the Muthurajawela marsh area would be:

- labour intensive, demanding local unemployed workers,
- high value, and
- low impact on the environment.

22.3.8 The areas of interest for housing and industry development are shown in Fig. 86.

22.4 **Tourism and Recreation:** The advantages of Muthurajawela marsh-Negombo Lagoon wetland as a tourist area are limited, but there are certain possibilities. Two broad categories of tourists might be attracted to the area are nature buffs and sports fans

22.2.4.1 Actual development investments in this line would not be high, but marketing would require a careful campaign. This type of tourist is currently a relatively small part of the market, but may grow as ecological consciousness is generally increasing worldwide

.22.4.2 From an environmental point of view, a golf course and tennis courts, and perhaps additional parks or nature trails are an ideal sort of environmentally friendly activity for a "buffer zone" between a nature reserve area and area with greater human inhabitation (provided herbicides for golf course maintenance are kept under control).

22.4.3 Facilities to attract high-paying tourists would have to be balanced by facilities for use by local people, preferably free or for low fees.

22.4.4 Areas of interest for touristic development are shown in Fig. 87.

22.5 **Infrastructure**: Ongoing infrastructure development would likely shift industrial development generally to the east and leave the area immediately bordering the Colombo-Negombo road to the small scale entrepreneurs and traders and the area to the west of the road more sustainable for housing development than for industry. If development is undertaken in the marsh area, adequate infrastructure will have to be provided, including water supply, drainage and sanitation.

22.6 **Agriculture:** Because of major soil constraints, agricultural development cannot be undertaken except at the homestead level. This type of small scale agriculture will be suitable for a buffer zone.

22.7 **Fisheries:** The existing fishery is overexploiting as well as destroying the critical habitats (nursery areas). The major issue is adequate fishery management.

22.7.1 The elements of a fishery management model would have to include relevant ecosystem characteristics, features of fishery stocks, public education, protected areas and gear regulation (also see 17.11).

22.7.2 Implementation of a successful fishery management plan will depend entirely on adequate participation by the resource users.

22.8 **Aquaculture** Pond aquaculture in the marsh is not an option for serious consideration.

22.8.1 Small scale shrimp/ornamental fish culture in brush pile-mini pens in the lagoon appears to hold promise if developed in an organized and controlled manner.

22.9 **Forestry:** Forestry development is an important option since it would supply fuelwood, and perhaps stem the present tendency to destroy the remaining mangroves. Social forestry programmes may be viable with appropriate support. However, land extents available for replanting would not make mangrove replanting viable.

22.9.1 Vegetational dune protection will become important in the face of the rising sea level.

22.10 **Peat Extraction:** The high sulphur content, high ash content, and the limited quantity of peat available does not allow serious consideration of Muthurajawela peat as an energy source for industry or for domestic use.

22.10.1 Use of peat in potting mixtures for small scale horticulture is acceptable.

22.10.2 Aquaculture in pits remaining after peat excavation will not be profitable.

22.11 **Education/Research:**

22.11.1 A part of planned landfill would be required for expansion of educational facilities; schools, playing fields.

22.11.2 Proximity of the wetland to 4 universities means that, their support could be obtained in training and research in natural resources management within the framework of a management plan.

23 Intergrated Water Management

23.1 Hydrological Resources

23.1.1 The main body of open water in the area is the Negombo Lagoon with an estimated volume of 20 million cu m. Its salinity varies with the seasons. A thin but variable sheet of water covers the greater part of the marsh. The volume is estimated to vary between two and ten million cubic meters; the latter only during heavy rain. Some salt penetrates into this area during the dry seasons.

23.1.2 Salinity is a positive qualitative factor in the lagoon, but is generally regarded as detrimental in other part of the area, e.g the marsh in agriculture.

23.1.3 Domestic sewage and effluents from industry and touristic facilities cause localized, and temporarily excessive pollution.

23.1.4 The general state of pollution in the wetland seems still to be within acceptable levels.

23.2 Ecological Demands

23.2.1 The lagoon and the delta form an interrelated system exchanging water, dissolved matter, sediments and biomass. A considerable, although seasonally variable, salinity is imperative for aquatic life. Sedimentation and erosion play a vital role in the development of vegetation (i.e seagrasses) in the lagoon and mangroves of the swampy delta. The inflow of large amounts of fresh water maintains the variable salinity in the lagoon and prevents the delta from becoming too saline. The rivers supply fresh sediments.

23.2.2 The connection with the sea, via the tidal inlet near Negombo, is **vital** to the ecological system of the Lagoon and the delta.

23.3 **Socio-economic demands:** Housing, industry, tourism, infrastructure and educational activities use relatively little water, but generally of good quality, an exception being water for cooling. That, however, is not consumed but its quality (temperature) is changed. Housing, industry and tourism have a tendency to pollute the water. The reclamation of land and construction of roads may change the drainage system, storage area, and the drainage capacity.

23.4 **Demands of sustainability** Sustainability in the hydrological sense means that the demands on the system should not, at any time and location, exceed the capacity of the resources. This should include quantity as well as quality, taking into consideration the relationship between these two factors. This will require the proper balancing of the water budget with proper compensating measures in the case of certain demands exceeding the specific resource.

It is important to avoid chronic shortages of water with the required quality as well as the initiation of progressive deterioration.

23.5 **Boundary conditions**

23.5.1 Not only the phenomena within the area but also external developments do and will continue to influence the resources. The most important factors are: the sea with its mean level and salt water,the closed dune ridge along the coast,

- the inflow of water from the rivers, and
- climatological factors via the atmosphere.

23.5.1 Of these, the salinity of the water and probably the climate can be regarded as invariable.

23.5.2 The management of the combined basins of rivers should be coordinated with water management in the Muthurajawela and Negombo Lagoon area.

23.5.3 The sea level is expected to rise slowly but at an increasing rate during the next century, **nothing can be done to stop or reverse this tendency.** Ongoing erosion may lead to breaches in the dune ridge if the necessary (technically feasible) defence measures are not taken. Perforation of the coast would induce an increase of the penetration of salt into the area. No fresh water is available to counter this threat.

23.6 **An integrated approach**

The hydrological system of the Muthurajawela marsh and the Negombo Lagoon must be considered as one system. **An intervention in any one part of this system will cause effects in the whole system,** the larger the intervention, the more serious the effect. The total amount of water, although variable in time, is limited and quality disturbances can spread rapidly with the moving water.

23.7 **Constraints:** The main constraints on further development of water resources are:

- the limited amount of water available,
- the large quantity already required for maintaining the proper salt balance in the lagoon and in the southern end ofthe Hamilton Canal,
- the limited buffer capacity of the marsh for water as well as for dissolved matter,
- the low level of the land precluding proper gravity drainage and probably justifiably, aversion against pumped drainage,
- the expected accelerated rise of sea level which penetrates into the area, and
- the norms, existing or to be set, with respect to the pollution of the water.

The objective of **sustainability imposes a general constraint.**

23.8 **Basic information:** An analysis of the affects of socio-economic development can only be made on the basis of adequate information about the state and the processes of the hydrological system. The best way to make such information operational is an integrated model which can simulate the processes in the area and parts of it. The available information is variable in quality.

23.8.1 An effort should be made to acquire information in the long term based on an appropriate model.

23.9 **Effects of reclamation**

23.9.1 Reclamation of land by raising its surface by the dumping of a layer of sand on the existing surface prevents inundation during floods, and decreases retention capacity. Water (possibly saline) will be used to transport the sand to its place of deposition (sand pumping from the sea). The heavy layer of sand will compress the underlying peat and squeeze the ground water out.

23.9.2 The Irrigation Department (Dharmasena, 1991) used a model to simulate the effects of reclamation of 1.4, 3 and 5.3 sq km in the Muthurajawela area of 23 sq km as described in A-6. The main results are given in Table 28, all based on an initial level of mean sea level at the onset of the period of heavy rainfall. The reduction of the storage areas and the reduction of drainage capacity appears to lead to higher water levels, less retention and lower rates of outflow. Starting from a higher level at@+the beginning of the period leads to higher maximum levels, less retention and higher rates of outflow.

23.9.3 The conclusion is that filling of an area should be carried out with a network of drainage channels within the area in order to maintain the natural drainage without changing the water levels.

23.9.4 Deposition of 3 m of sand on a peat layer of 2.5 m thickness will cause a compaction of the peat to about 1.25 m and a land surface 1.8 m above mean sea level. Three million cu.m of sand are required for each sq km of land to be raised in this way. Its transportation will require about 6 million cu m of sea water and about 1.25 million cu m of water will be squeezed out of the peat, also per sq.km of land. Although **such quantities are small** compared with the general water balance of the area, the local effects of the salt and other dissolved matter in the water can be considerable. Therefore, a proper way of **discharging the water from transport and compaction** must be included in the project.

23.10 **Gravity drainage and pumping**

23.10.1 Gravity drainage of the marsh will become increasingly difficult in view of the sea level rise.

23.10.2 **Drainage by pumping** can maintain any level. The cost is roughly proportional with the level and the quantity to be removed. In the case of Muthurajawela marsh, the head is small but the climate demands a high capacity. To remove the 200 mm of water from rain of one day (not unusual in Colombo) from an area of 1 sq km (100 ha) in 2 1/2 days, a capacity of 1 cu m/s is required.

23.10.3 The operation of a pumped drainage system requires alertness in the case of sudden rain and reliability. The former means attendance or automatic control, and the latter requires proper maintenance and reliable power supply. Non-compliance with the latter requirements seems to have led to the bad experiences of the past.

23.10.4 Higher demands on the water management and sea level rise may, however, lead to more and more pumping, possibly in combination with gravity drainage.

24 **Environmental impacts:** Impacts relevant to each development option are listed together with appropriate mitigatory measures.

24.1 Impacts on public health stemming from development are identified. Appropriate safeguards have been listed.

25 **Development conditions:** The following areas need to be protected and adequately managed:

- the coastal dune
- the area of transition between the marsh and the lagoon
- a central area of the marsh with a corridor consisting of vegetation and water bodies linking with the transition zone.
- the inlet area of Negombo Lagoon.

25.1 In order to ensure that development does not cause excessive damage to the ecosystem, an EIA should be mandatory for each project.

25.2 Close adherence to standards and guidelines of CEA will be essential.

26 Implementation arrangements.

26.1 Institutional aspects

The three levels of authority dealing with development planning, and implementation at the community level are:

- Central governmental agencies including GCEC
- District and local government agencies
- NGO's

26.1.1. Separate government agencies have authority over segments of the wetland ecosystem

26.1.2 In order to ensure that development/management of the wetland is in keeping with the interests of the entire ecosystem, the CEA should take a major coordinating role.

26.2 **Legal aspects:** A wide range of existing legislation is relevant to development planning and implementation in the study area. Therefore, it is necessary to formulate an appropriate legal framework that would facilitate removal of obstacles to implementation.

26.3 **Future studies:** All future studies should be problem oriented and relate to the requirements of ecosystem management. The four critical areas for future studies are: coastal stability, hydrology, fishery productivity and socio-economics.

26.4 **Monitoring:** The environmental indicators for monitoring are:

coastal recession, suspended load, water level and flows, salinity, acidity, water quality in relation to CEA standards, disease vectors, incidence of disease, fauna and flora, fishery yield.

26.4.1 In order to ensure success of the monitoring program, it would be essential to ensure that, fundamentally, there is no clash between objectives of the wetland manager and the specialists/agencies responsible for the relevant field work.

INTRODUCTION

1. BACKGROUND

H.E. President of Sri Lanka directed in 1989 that an environmentally sound master plan for sustainable development of Muthurajawela Marshes be prepared by the Greater Colombo Economic Commission (GCEC). While conveying this directive, it was acknowledged that numerous ecological values could be ascribed to the Muthurajawela Marsh area, that it serves as an important retention area for surface storm water runoff, and that it supports economic activities of a large population. Furthermore, the need for due consideration of ecological linkage of Muthurajawela marshes to contiguous areas such as Negombo Lagoon was implied (Fig.1). Consequently, an ecological survey was recognized as a necessary first step to facilitate identification of those locations in the marsh which should be conserved and those that would be suited to landfill for housing or other development projects and strategies.

2. PLANNING PROCESS

The GCEC organized the Master Planning process. The Master Plan was to be based on three sets of basic information:

- A consolidated review of existing and potential development options (including those for conservation), with assessments of their impact on the environment, the socio-economic and health status of the inhabitants;

- A socio-economic survey, showing present and future status and requirements of the population in and around the area;

- An ecological survey showing the status and significance of the natural and physical resources, as well as ongoing trends in their development.

The first, a review, was to summarise the requirements for development, while the two surveys were expected to set conditions for development. Requirements and conditions were to be integrated within the Master Plan (Fig.2).

The GCEC was provided financial assistance by the Dutch Ministry of Foreign Affairs, Director General of Development Cooperation for procurement of essential equipment and for, contracting national experts and international specialists (from Euroconsult, Arnhem, the Netherlands).

In order to ensure that the existing integrity of the Muthurajawela Marshes would be preserved until the Master Plan was completed, the Cabinet of Ministers decided to **"Freeze all development proposals of both the public and private sectors, until such time an environmentally sound and sustainable master plan is evolved for the development of the Muthurajawela marshes".** This became necessary since, in the absence of such control, unwarranted and environmentally unacceptable developments may have occurred, thereby violating the basic objectives of the planning process.

3. PLANNING AND STUDY AREA (Fig. 1)

The GCEC mandate was for plan preparation for the marsh proper of Muthurajawela which constituted the **planning area**. The metes and bounds of this area were demarcated with the assistance of the Survey Department. The marsh is a tidally influenced, lowlying, coastal wetland. Basically, the continued existence of the marsh depends upon the stability of the sand dune extending from the mouth of the Kelani Ganga to the mouth of the Negombo Lagoon. The main tidal influence on the marsh is by way of the Negombo Lagoon and to a lesser extent by way of the Hamilton Canal which connects the Kelani Ganga to the southern end of the Negombo Lagoon. The proper ecological functioning of both the marsh and the lagoon is strongly influenced by this hydrological linkage; for instance the northern segment of the marsh provides a nursery habitat for the young fish and shrimps that are predestined to form commercially exploitable stocks in the lagoon later on, and vice versa; the lagoon provides the feeding grounds for numerous birds that inhabit the marsh permanently or temporarily.The hydrological linkage also includes: surface and groundwater flows, and their qualities and effects (erosion, flooding, shoreline stabilization, sedimentation, salination, etc.). Such interlinked systems are ecologically considered to be one single unit.

By reason of this unity, all developments in the marsh will affect the coastal dune, and functioning of the lagoon. Since such impacts will have to be foreseen and their prevention or management will have to be an intrinsic part of development planning, **the study area**

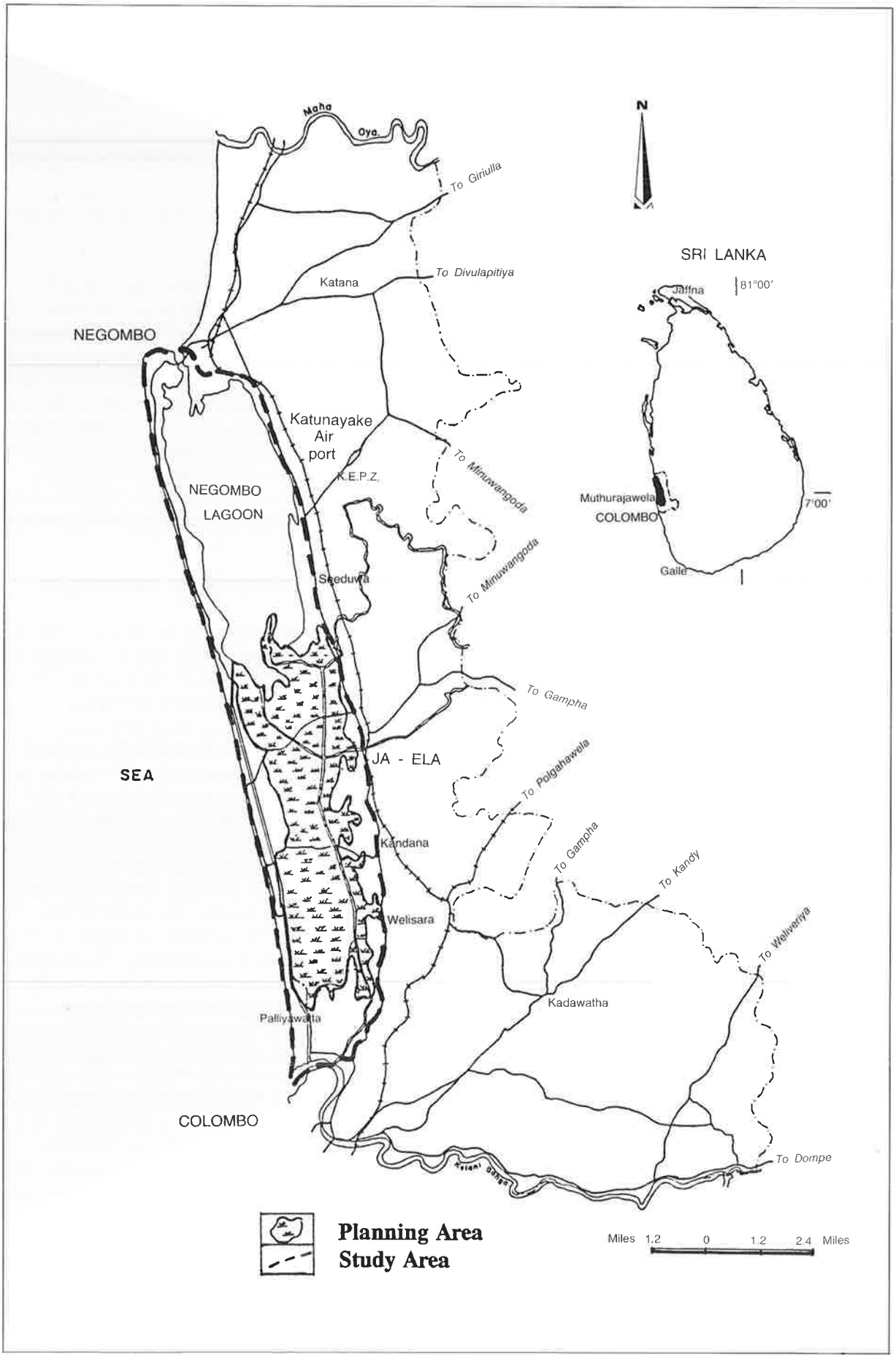


Fig 1 Location of Muthurajawela marsh - Negombo Lagoon wetland

was expanded beyond the actual planning area to include the coastal dune and the lagoon.

In addition, since the **ecologically linked marsh lagoon system** is surrounded by already developed areas with dense settlements, its functioning is also affected by further development and activities in the immediate surroundings. Therefore the study area also included the tract of land north of Kelani Ganga, west of Colombo-Negombo main highway and south of the road alongside the northern border of Negombo Lagoon (Fig. 3).

4. INTENTION AND STRUCTURE OF THE REPORT

The objective of the present report is to provide relevant environmental and ecological background information for the Master Planning process. This will ensure that the dynamics of the study area are properly understood, and that the marsh and the lagoon will be seen as one ecosystems linked together by its hydrology. Moreover, the report will provide an analysis of environmental impacts of proposed developments that have to be taken into account in planning for sustainable exploitation of resources.

The report consists of an introduction followed by three main parts:

> "wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tides does not exceed six meters" *(International Convention on the Conservation of Wetlands of International Importance)*

Part A: Describes the present situation of the natural and physical resources in the area;

Part B: Describes the ongoing changes in the area, both natural and man induced, their trends and future projections where trends continue unaltered;

Part C: Describes the available development options for the area, as well as condition and fate of the resources of the area. This third part presents the basic considerations to be included in the Master Plan, with emphasis on sustainability of proposed developments with respect to;

- **ecosystem function**
- **ecosystem yield, and**
- **investment in development.**

The text is supported by relevant maps, graphs, tables and plates. Five maps, 1:20,000 scale acompany the text and are given in a pocket in the back cover of the report. These maps the planning area shows:

- Contours
- Soil profiles
- Vegetation
- Land use
- Existing engineering works

The above six maps are available in the Area Administration Department, Greater Colombo Economic Commission.

The text is based upon 25 technical reports prepared by government agencies and specialists in different subject areas (page). These reports are also available for reference in the Area Administration Department.

5. ORGANIZATION OF THE SURVEY

The ecological survey, coordinated by the Project Manager, was carried out between July 1990 and February 1991. The sources of information included:

- existing publications on the area and its resources;
- unpublished information available with various agencies, NGO's and individuals;
- new or additional information collected in the field by specialists.

Data requirements were identified at the start of the survey period and laid down in a detailed Working Plan. On the basis of this, collection and initial analysis of data were contracted to a large number of agencies and specialists, and deadlines for drafts and final contributions were fixed. Draft contributions were screened at biweekly meetings by a multidisciplinary Working Group, set up by the Project Steering Committee (page ii). The high-powered Steering Committee guided the overall process and intervened whenever deadlines were not met. Analysis of the collected material and preparation of the present concise document was carried out by the Project Manager, with the assistance of the Dutch specialists. Although in general the information could be acquired reasonably timely, a number of contributions could not be collected in the requested optimal form for a variety of reasons, of which the most important were time-consuming contracting procedures, other commitments of the agencies concerned, or constraints in time, budgets or equipment. In those cases, after intensive discussions in the Working Group, the Editors made the best possible

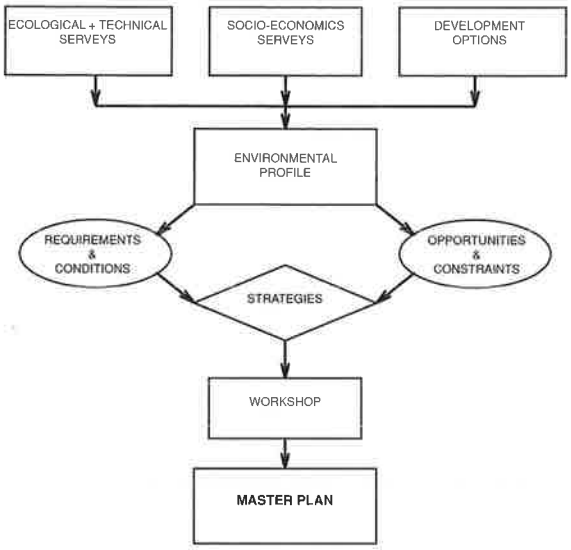


Fig.2 The Master Planning Process

professional assumptions based on the available references and data.

Information indispensable for this report was abstracted from the number of contributions too elaborate and specialized for inclusion in toto in this report. These are given in the List of References (page iii), and are available for ready reference at the GCEC office.

6. METHODS AND AIMS OF ECOLOGICAL SURVEY

The essence of survey is abstraction and summarization of information; consequently an ecological survey is based on the simplification of the variety in nature (Parry, Johnson and Bell, 1984). Generally in development planning of terrestrial ecosystems, vegetation types are used as management units. In the case of a coastal wetland ecosystem which combines elements of both terrestrial ecosystems (significant vegetation: mangroves, seagrass, reeds, sedges) and oceanic ecosystems (here, vegetation of significance being the microscopic floating plants, phytoplankton) the task of representation of the system is enormously more complicated. Since ecological process in a wetland are largely based on dynamic hydrological features, a description of the relevant ecosystems will have to include interpretation of such dynamics. This means that simple classification from aerial photos and literature has to be supplemented by original, objective studies.

Four systems of ecological survey have been identified (Holdgate, 1976):

- Within site studies designed to describe variation within ecological systems within defined areas (e.g. southern and northern segments of the marsh)
- Between site surveys designed to describe variation between comparable ecological systems from site to site (e.g. Muthurajawela wetland and Bolgoda wetland)
- Species surveys intended to quantify variation within a species range (e.g. an endemic fish such as Channa orientalis in all wetlands in Sri Lanka)
- Surveillance studies to describe variation with time, commonly with respect to land use and pollution.

An environmental baseline study as required here involves at least two of the above four systems. In the ecological survey of Muthurajawela marsh-Negombo Lagoon wetland, systems (a) and (d) have been used to the extent that the brief study period of 8 months (July 1990 - February 1991) allowed.

The information in the ecological survey part of this report, Part A, sections 1 to 12, is meant mainly for planning. More detailed information is available in the basic technical reports; the presented information is supplemented with an analysis of environmental costs of development and measures to be taken to secure sustainability of ecological functions and yields. Also this additional information serves mainly the purpose of (ecologically justified) development planning.

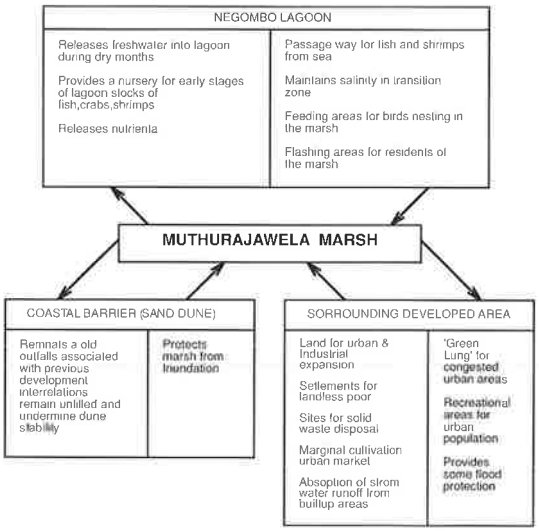


Fig.3 Some basic structural and functional linkages between the planning area, Negombo Lagoon, coastal dune and developed areas.

PART A : DESCRIPTIVE PROFILE OF STUDY AREA

1. MUTHURAJAWELA

The Muthurajawela marsh and Negombo Lagoon are interdependent ecological systems, that will be regarded as one wetland within the framework of this document. The wetland is located at mainly sea level in the Gampaha District, Western Province, some 10-30 km north of Colombo. The marshes cover an area of approximately 3,100 ha. (Plate 1).

The wetland represents a large area of brackish marshes, merging into an estuarine lagoon about 3200 ha. to the northwest. The lagoon opens to the sea at its northern end (Plate 2).

Negombo town with a population of 79,000 in 1981 (Dept. of Census and Statistics, 1988) is situated to the north contiguous with the northern border of the Negombo Lagoon. The municipality of Negombo extends into the northern segment of the lagoon and includes dense settlements on the islands there.

The transition zone between the Muthurajawela peat marsh and Negombo Lagoon is traversed by the Dandugam Oya. The Dandugam Oya is the lower segment of the Attanagalu Oya which has a catchment area of 182,000 acres. This catchment which yields 685,000 acre feet of water annually (Samarasekera, 1982) has little forest cover left and erodes with ease. The eroded sediment is eventually discharged into the transition zone and thence into the Negombo Lagoon (Plate 3).

The Muthurajawela marshes consists of a complex mixture of squatter settlements, almost freshwater ponds, canals, areas planted with coconut, embankments with tree and shrub vegetation, vast expanses of grasses and sedges which overlie soft peat reaching down to a depth of more than 3 meters at some locations (Plate 4).

Some areas of Muthurajawela still show evidence of the paddy fields that existed from about 1935 until the early sixties. These paddy fields were constructed after the Irrigation Department made a major effort to bring substantial extents of the marsh under paddy cultivation. These abandoned paddy fields now provide a habitat for wildlife (Plate 5).

The present state of Muthurajawela is the result of natural phenomena, in combination with unplanned, inadequately planned and illicit human intervention. The existing resources in Muthurajawela marsh-Negombo Lagoon wetland are given in Fig. 4.

2 HISTORY

Muthurajawela area and Negombo Lagoon acquired significance in the rise and fall of regimes in years past, while to-day a planning process is underway to conserve and develop parts of this same wetland system for multiple uses. The historical events that influenced the decline of these wetlands are important reminders of the manner in which human intervention could accelerate degrational changes in natural resource systems.

It is on record that in the years preceding the rule of Vira Parakrama Bahu VIII (15th Century) Muthurajawela was a vast extent of fertile paddy land that was cultivated under the supervision of a princeling resident at Balagalakanda, a southern location (Abeysekera, 1954). The Muthurajawela of today that is the subject of the present planning exercise is a mere part of that ancient Muthurajawela.

In the succeeding period, under Vira Parakrama Bahu VIII, the Negombo Lagoon served as the chief seaport for trading in cinnamon and other commodities. In keeping with superior economic considerations, to facilitate access and transport the king began constructing a canal (presently called the "Dutch Canal") linking Negombo Lagoon to the Kelani Ganga (Plate 6). The results were disastrous to paddy cultivation, owing to salt intrusion from the Negombo Lagoon. It is said that the adverse impact of the canal sparked off a rebellion against the king which he was barely able to quell.

During the following Portuguese period the Negombo Lagoon continued to serve as the foremost seaport for maritime trading. It seems that during this period paddy cultivation at Muthurajawela was neglected by the rulers. Consequently, the changes initiated by the canal linkage of the lagoon to Muthurajawela probably became more widespread.

The Dutch colonial government, which succeeded the Portuguese, became keenly interested in simultaneously rehabilitating paddy cultivation in Muthurajawela, and

Plate 1

The Muthurajawela marshes; peat bog covered by a thin crust of grasses and sedges (bottom) merges into Negombo Lagoon top. Note: white spots are squatters' houses.

Plate 2

A view southward into Negombo Lagoon through its connection with the sea. Note sand barrier separating the lagoon from the sea on the right.

Plate 3

Meandering Dandugam Oya (top left) discharges into Negombo Lagoon through the birds foot delta (middle right) into the transition zone. Note the Hamilton Canal opening into the lagoon (bottom right).

Plate 4

Ponds, canals, grass covered marsh, clusters of trees constitute the varied habitats at Muthurajawela.

Plate 5

Abandoned paddy field in the Southern segment of the Muthurajawela marsh.

Plate 6

The "Dutch Canal" flows through the eastern fringe of Muthurajawela marsh.

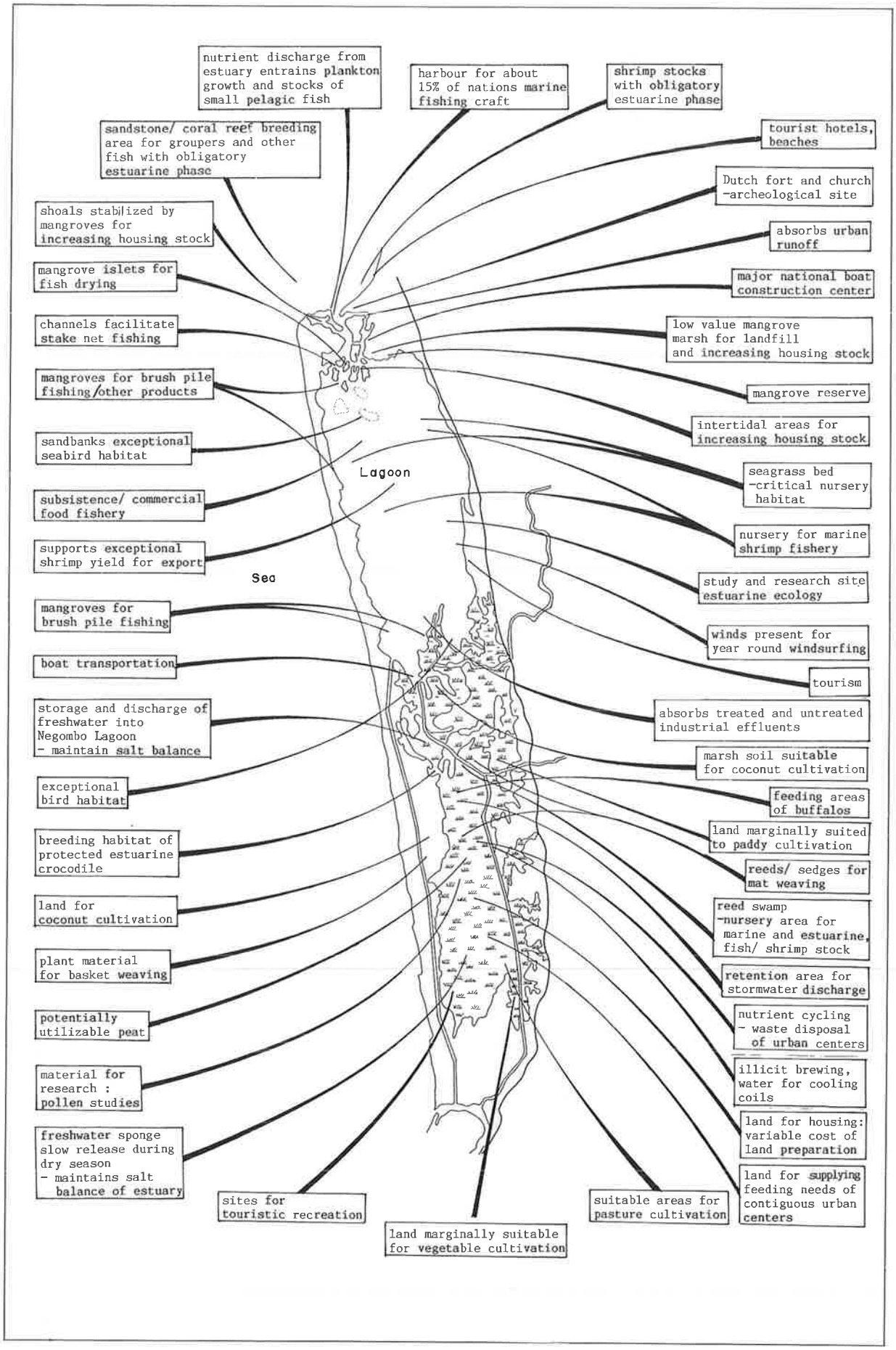


Fig. 4 Resources of the Muthurajawela marsh - Negombo Lagoon wetland

developing Colombo as a seaport and commercial center. The Colombo port soon superseded Negombo Lagoon in importance. With a view to supplying the growing population of Colombo with rice, it was attempted to bring 6,000 acres of Muthurajawela under paddy cultivation. Two types of supporting hydraulic engineering works were carried out: dams and gates were installed to prevent salt intrusion, and the Ja-ela canal was constructed to deliver freshwater from Attanagalu Oya to the traditional paddy lands and flush out the salt from the soil (Plate 7).

In spite of massive investment, to such a magnitude that it is stated to have contributed to the bankruptcy and eventual downfall of the Dutch regime, paddy cultivation at Muthurajawela failed (Abeysekara, 1954). Another instance which reveals that, the costs of restoration of damaged ecosystems, far surpasses the short-term benefits from hastily implemented artificial changes.

The British took a keen interest in paddy cultivation at Muthurajawela: for conservation of foreign exchange through rice import substitution. Their program for rehabilitation of the tract that corresponds fairly closely with the present planning area, was targeted to achieve the desired objective. It included construction of the Hamilton Canal. However, "The best laid plans of mice and men gang aft agley" (Burns): the war with the Kandyan Kingdom compelled the abandonment of the entire program of engineering works. Muthurajawela once again went through a period of neglect as the British pushed the development of coffee and subsequently tea in the hinterland, as a major foreign exchange earner.

A program of Engineering interventions was initiated in the early part of this century, until the sixties, in an attempt to rehabilitate paddy cultivation at Muthurajawela. The breakdown of rice supplies from Burma during World War II proved a major stimulus to this project. This scheme was not fully implemented as studies by the Irrigation Department recognized that paddy cultivation in this area was even by that time non-viable.

Successive post independence governments have planned to develop Muthurajawela, with the aim of transforming this "waste land" (Jayawardene, 1966) into an agriculturally more productive area, or to utilize it for expansion of Colombo and its suburbs. To most people, worldwide, a marsh became good only after being drained or filled up (Larson, 1982). However, this view of marsh or swamp wetland has now changed.

In contrast to the interest in development of Muthurajawela, the historical narrative of the Negombo Lagoon is baleful. Since its decline as a major sea port (Plate. 8) and commercial center, its economic importance has rested entirely on its role in subsistence fisheries and supporting marine fisheries. The various developments that have been carried out in the Negombo Lagoon, have been fragmented responses to the needs of the marine fishery industry. Little consideration, however, has been given to the ecological role of the lagoon in sustaining marine fishery productivity. That, many efforts have been made since 1920 to rationalize fishing in Negombo Lagoon, is a heartening feature.

Recently, the pressure for development of the Muthurajawela area has increased again, especially because of its proximity to the country's main urban and industrial centers and the international sea port and airport. It is stated by various authorities that reclamation of (parts of) Muthurajawela could help solve the increasing demand for housing and industry space, and for organized recreation. Further infrastructural developments have also been indicated for the area, the main being construction of a highway linking Colombo to the Katunayake Airport and construction of freshwater storage basins (Sessional Paper, 1966, SLLRDC, 1985, JICA, 1984).

None of the integrated or specific development plans for the area have so far been implemented, initially because of the high capital investment required, and more recently because of the increasing concern expressed by environmentalists for the potential negative ecological effects on the wetland ecosystem. But this does not mean that the area remained undisturbed: numerous activities, both overt and covert, varying from small-scale exploitation of reeds to large-scale encroachments, fuel wood extraction and fisheries are continuing (See A-10).

These unplanned (and to some extent illicit) activities not only threaten the natural values of the area as such, but also the possibility of planned, sustainable development later on. Recognition of this by the Sri Lankan authorities led to the decision in 1989 to prepare a Master Plan for the development of the Muthurajawela marshes in keeping with the objectives and decisions of the National Conservation Strategy (CEA, 1989) and the Coastal Zone Management Plan for Sri Lanka (CCD, 1990).

Plate 7 *The Ja-ela flows through the northern segment of the Muthurajawela marsh and discharges into Negombo Lagoon(top right).*

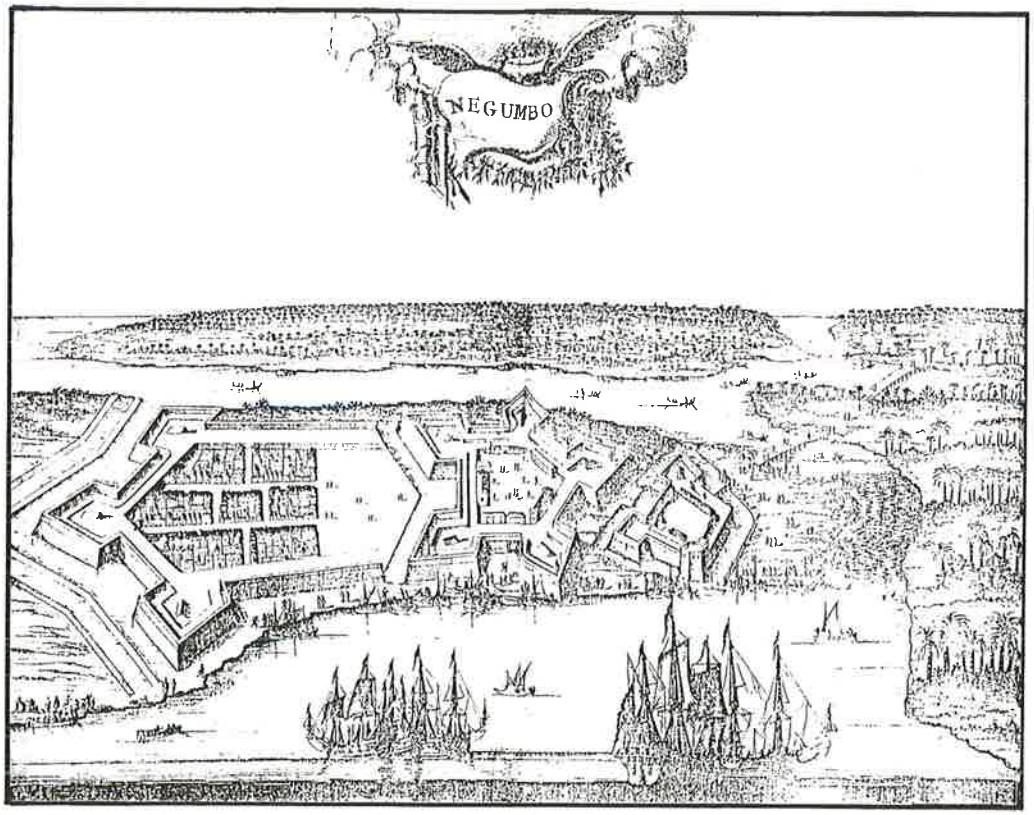


Plate 8 *The inlet section of Negombo Lagoon and the Dutch Fort. Negombo was a thriving sea port until the Dutch period.*

3 REGIONAL DEVELOPMENT

An area cannot be isolated from the region it is part of; developments in and development plans for that area, therefore, have to be considered in a regional context.

The Muthurajawela marsh-Negombo Lagoon wetland system is situated in the Western Province, which in the national context is the political, administrative and commercial nucleus of Sri Lanka. Since the establishment of Provincial Councils for devolution of legislative, administrative and development functions, the Muthurajawela-Negombo Lagoon wetland is subsumed within a hierarchy of political and governance systems. Consequently, a system of planning authorities is found, with interlocking powers and functions relevant to the planning and development of the study area (Fig.5).

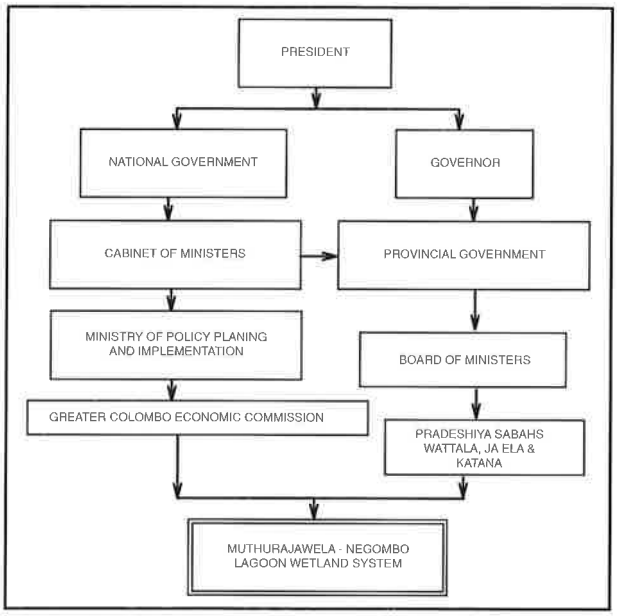


Fig. 5 Governance systems influencing the project area

Potentials and problems of the Western Province (Fig.6) to a great extent determine trends in the national economy (UDA, 1990). Some pertinent characteristics of this Province are:

- it occupies 5.7% of the national territory;
- it contains 25% of the national population;
- it contains 28% of the voting population;
- it controls 25.8% of the parliamentary seats;
- population density is 4x the national average;
- 14% of the population is engaged in agriculture;
- it contains 35% of national industrial establishments;
- it has an unemployment rate exceeding the national average.

The political and economic supremacy of the Western Province has set the tone for the development policy environment which is reflected by the entrainment of development projects. During the past decade the Province has had three lead projects: GCEC's Export Processing Zone, the New Capital City Project, and the City of Colombo Urbanization scheme. Similarly, some of the major capital investment projects have also been concentrated in the Western Province: Katunayake International Airport, Colombo Port Containerization, Colombo City Road/Surface Drainage, and Telecommunication improvement. The ongoing lead development project, the Janasaviya, is also accentuated in Western Province, where only 18.7 % of Sri Lanka's Janasaviya recipients (mainly slum and shanty dwellers) are concentrated (UDA, 1990).

The development patterns of Western Province are greatly influenced by Colombo. The political imperatives relevant to Colombo include two major push-pull factors:

- a tendency towards urban immigration, and
- an increasing emigration from Colombo towards outlying employment centers.

The overall result is an out migration which imposes a heavy demand upon residential land. The Western Province as a whole, and the Greater Colombo area in particular, are recognized as the most rapidly urbanizing areas in Sri Lanka. In consequence, the demand for residential land use predominates, and paddy fields and marsh lands are seen as formidable constraints to urban development. The Muthurajawela marshes, therefore, played a major contributory role in all urbanization plans in the Western Province. For the Negombo Lagoon another function is recognized in relation to urbanization of the Western Province: the role of fish supplier to this urban population. Already about 15 % of the national fish supply is landed at Negombo Lagoon; the major portion being transported directly to the central fish market in Colombo.

The most immediate development relevance of the Muthurajawela-Negombo Lagoon wetland is connected with the Gampaha District. This District had a total population of 1,390,862 in 1981 (Dept. of Census and Statistics,1988), with a slightly higher than national growth rate of 1.8%. With the ongoing and planned developments, it is presently assumed that the District's population will increase at an annual rate exceeding 2.5%, leading towards a size of around 2,700,000 in 2001 (UDA, 1990). Within this broad perspective, it is anticipated that in proposed development centers population increase will be close to 5% per annum, with a pronounced need for residential land. These centers include the areas of Wattala-Mabole, Kandana and Ja-ela, contiguous with the Muthurajawela marshes.

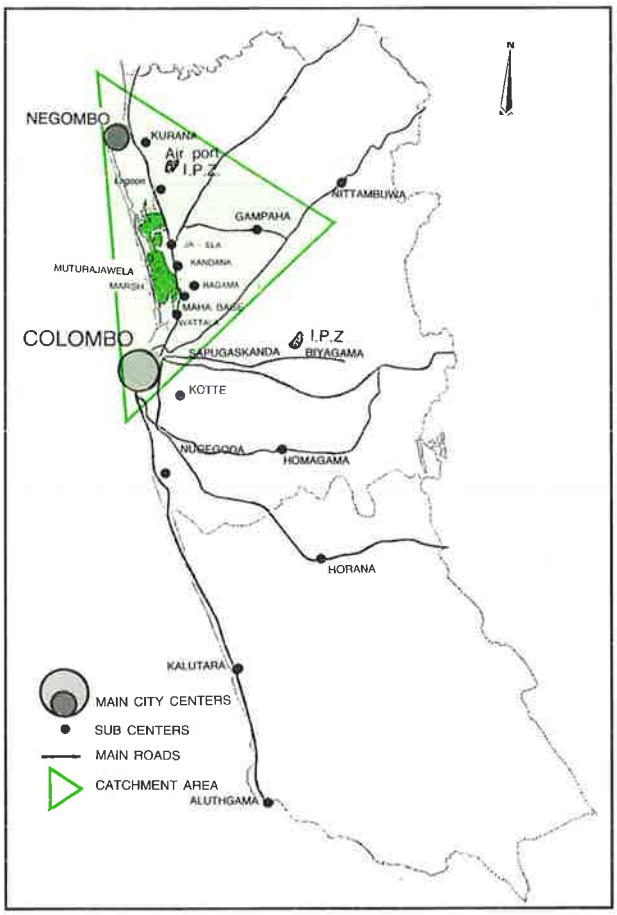


Fig. 6 *The Muthurajawela marsh - Negombo Lagoon wetland as a part of the Western Province*

The proximity of Muthurajawela to the city of Colombo and to Katunayake and Biyagama Export Processing Zones imposes on the national planning framework the potential for creating new linkages for promotion of commodity and communication flows.

Owing to the recognized sensitive ecological conditions in the area, the types of development proposed for the marshes consist of an appropriate combination of the following activities: residential housing, commercial and industrial development, warehousing, education and training, and recreation and tourism.

Telescoped within the Gampaha District stands the area of authority of the GCEC, for which already a land-use plan has been prepared (1984 Fig. 7). Development of the Muthurajawela marshes and the Negombo Lagoon are accorded a marginal role in this plan. However, it was acknowledged that this marsh area would be kept in deferment in association with GCEC's investment promotion activities, while appropriate steps would be taken to improve the amenity and recreation values of Negombo Lagoon (GCEC, 1882).

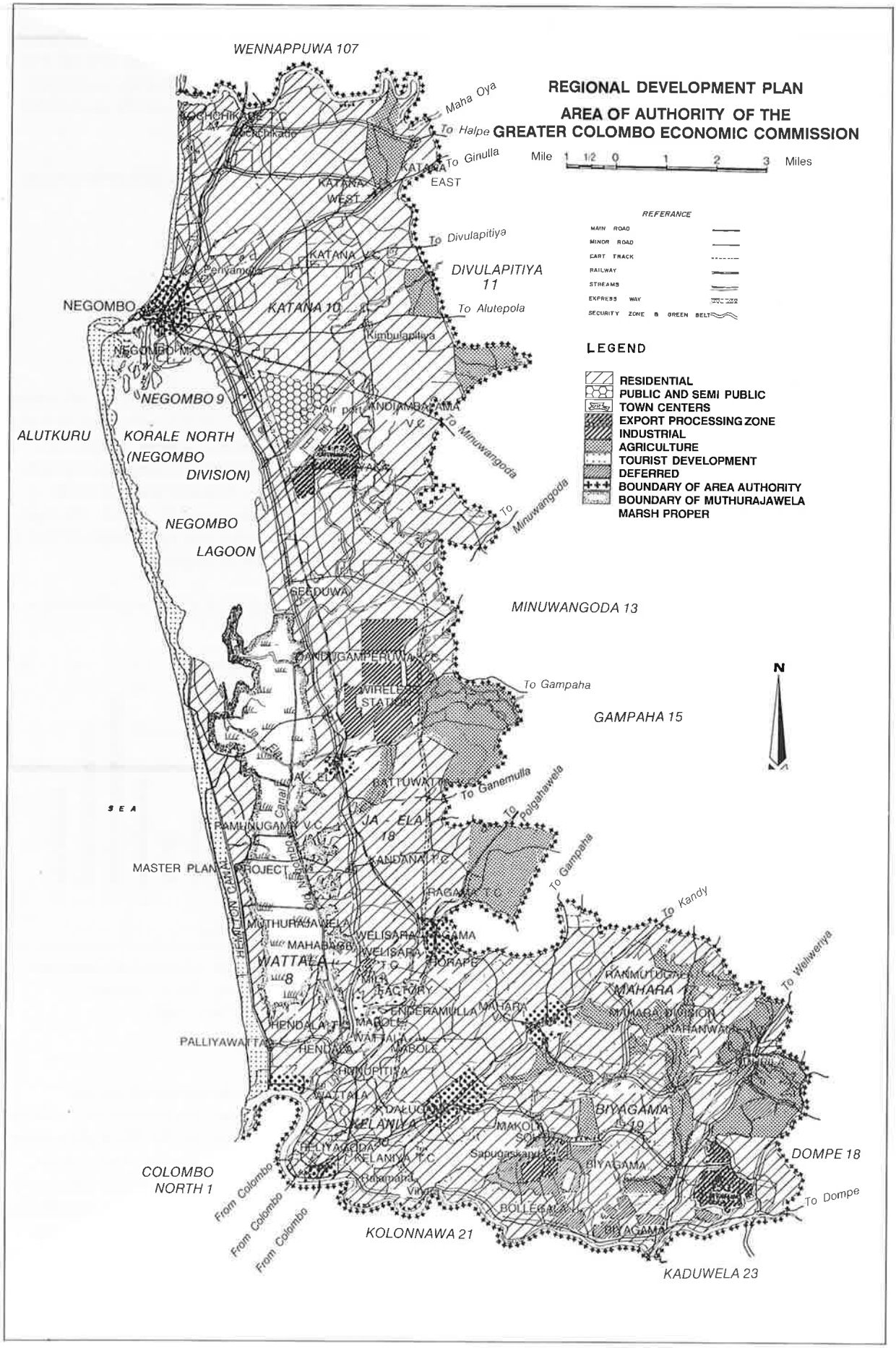


Fig. 7 Land use map for the GCEC area of authority (source: Area Administration Dept. GCEC).

4 CLIMATE

The climatological analysis is based upon the report of Fernando (1990). The climate of Sri Lanka is determined by three factors that influence each other mutually:

- the country is situated in the area of South-Asian monsoons,
- the landmass consists of a mountainous area in the south-central parts, and
- it is an island where no point is further than 180 km from the sea.

4.1 Rainfall

The character of the study area is influenced by the South West Monsoons. It lies in a part of the wet zone of Sri Lanka which receives 2000-2500 mm rainfall per year (Fig. 8). The South West Monsoons in Sri Lanka are characterized by two periods of heavy rainfall immediately preceding and following the monsoons period which lasts from mid-May to September.

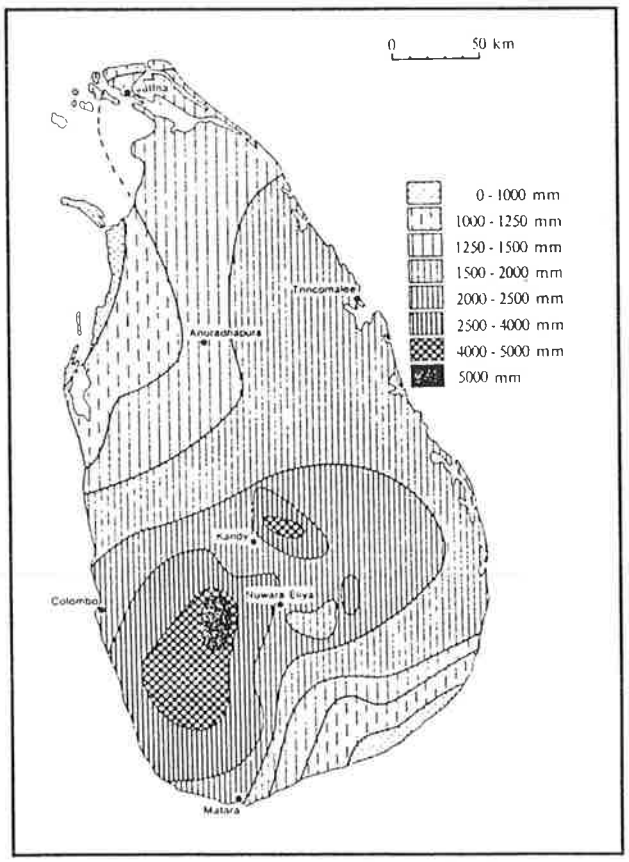


Fig. 8 Average annual rainfall in Sri Lanka

For analysis of rainfall, data of the Colombo Observatory have been used, since this station is the closest to the Muthurajawela area with uninterrupted data over a longer period. Daily maximum rainfall can be as high as 340 mm, maximum rainfall in two consecutive days 470 mm, in three consecutive days 526 mm, and in 4 consecutive days 588 mm, all with return periods of 200 years. Trend analysis shows a slight declining trend in rainfall over the years 1962-1984.

Annual mean rainfall at Colombo during the present century amounted to:

. 1901-1930: 2,240 ± 458 mm;
. 1931-1960: 2,374 ± 318 mm;
. 1961-1989: 2,383 ± 547 mm.

4.2 Evaporation and humidity

The monthly average rainfall, evaporation and relative humidity recorded at the Colombo Observatory during the period 1964-1989 were compared. Results are shown in Fig. 9. It is seen, that evaporation exceeds rainfall only in January, February and March. In all other months there is an excess of rainfall. The highest excesses of rainfall occurs over evaporation in May and October, and the lowest in August.

Monthly average humidity for Colombo Observatory is also shown in Fig. 9.

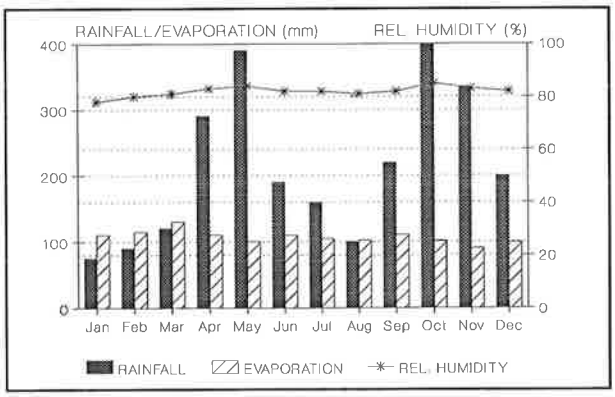


Fig. 9 Monthly rainfall, evaporation (mm) and relative humidity (%) at Colombo Observatory(1964-1989)

4.3 Temperature

Mean daily maximum, minimum and average temperatures, recorded over the period 1961-1980 in Colombo, are presented in Fig. 10. The highest mean daily maximum of 31.5°C occurs in April and the lowest mean daily minimum of 22.3°C in January. The highest maximum temperature and the lowest minimum temperature recorded at the Colombo Observatory between 1910 and 1989 were 36.2°C on 23 February 1915 and 15.2°C on 4 January 1950 respectively. The highest day temperatures generally occur between 12.00 and 15.00 hours and the lowest between 05.00 and 06.00 hours.

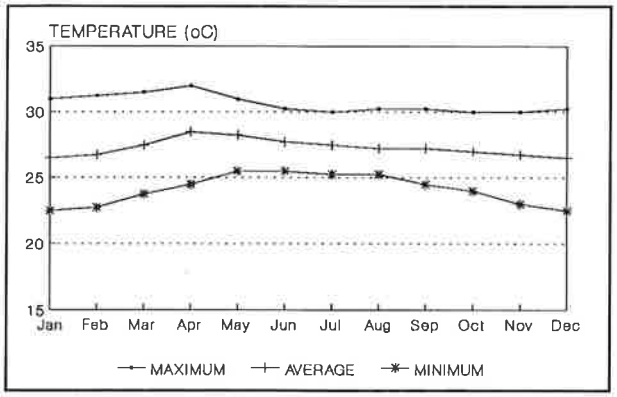


Fig. 10 Mean monthly maximum, minimum and average temperature at Colombo Observatory (1961-1980)

4.4 Wind

Wind data of the Colombo Observatory for two daily times (08.30 and 17.30 hours) over 25 years were analyzed; results are presented in Fig. 11. The maximum wind speed recorded at 08.30 hours local time was 15.3 km/h in March, and the minimum was 5.3 km/h in April. Corresponding figures for 17.30 hours are 11.9 km/h in January and 8.0 km/h in November (all data recorded at the hour).

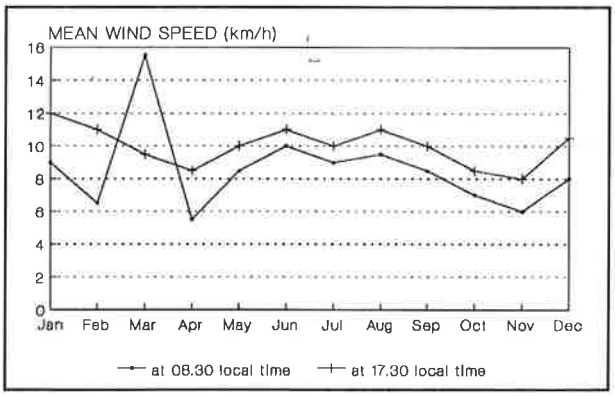


Fig. 11 Mean monthly wind speed (km/h) at Colombo Observatory

The main wind directions are at 8.30 hours N to NW from November through February, and mainly SW in the rest of the year. At 17.30 hours the winds are NE from November through February, E in April and March, and mainly SW in the rest of the year.

An analysis of the number of cyclonic storms reaching the east coast of Sri Lanka between 1881-1989, revealed that the majority of storms (83%) occurred in November to December. Four of these storms were severe: 9 March 1907, 22 November 1922, 22 December 1964 and 23 November 1978. The last one was the most devastating, taking a toll of 915 lives. The average life time of cyclonic storms in Sri Lanka is 4-5 days.

Cyclonic storms have devastated the East Coast of the island, but along the west coast cyclonic storms are rare. However, two important ones were registered during the 1881-1989 period: December 1912 and the cyclone in Chilaw in October 1967.

Although no trend or periodicity of occurrence of cyclones is apparent over the mentioned period, the frequency of cyclonic storms can be set at one in eight years, with one of greater intensity, once in 25 years.

5 GEOLOGY AND SOILS

5.1 Geological history

The geological history of the area has been studied and documented by Cooray (1984). Other sources of information are Katupotha (1988), Swan (1983), Fairbridge (1961) and Dissanayake (1990). The following description of the geological processes is based upon these publications and field observation of the present state of the area.

The Muthurajawela marsh and the Negombo Lagoon have developed during the Holocene period on the Pleistocene landscape that existed after the last glacial period. Fig. 12 shows a schematic cross-section of the coastal area including the continental shelf and a 25 km section of the present dry land. After a glacial low of about 100 m the water rose to its present level during the past 12,000 years; Fig. 13 shows how it reached its present level about 6000 years ago and then remained the same with decreasing oscillations. The sea level rose at a rate of 1.2 mm/year during the past century as can also be seen from a comparison of predicted water levels at Colombo (Based on an analysis of 1884-1895) and recent observations (Perera, 1990).

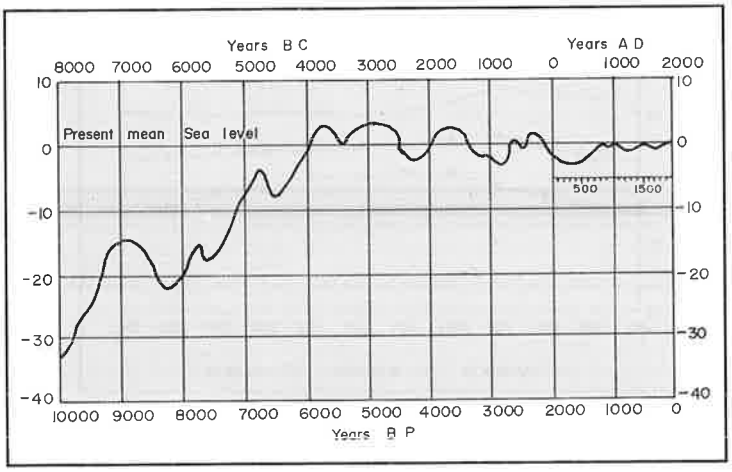


Fig. 13 Variation of mean sea level during the last 10,000 years

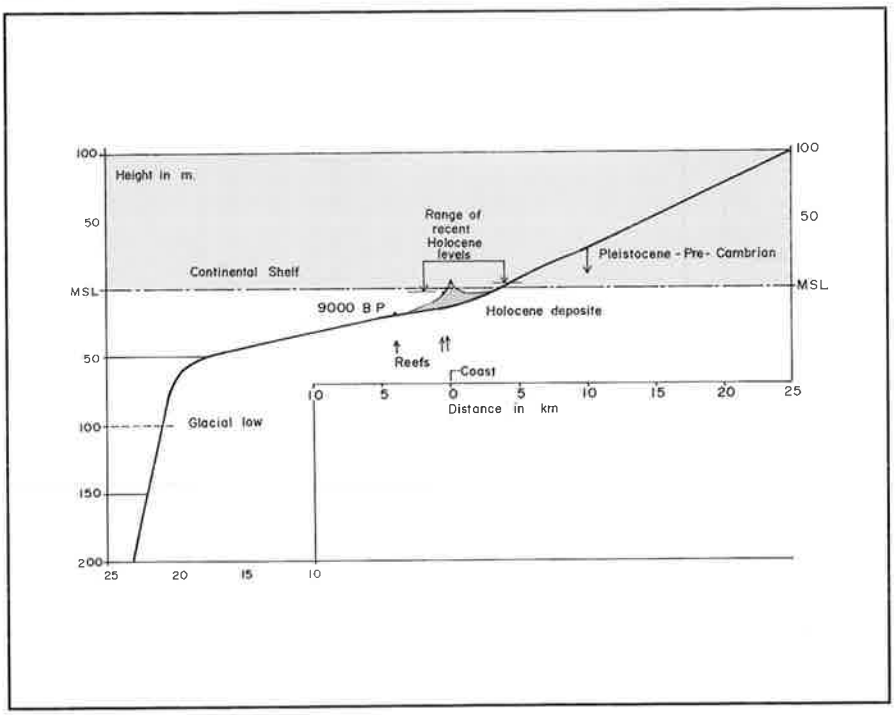


Fig. 12 Schematic cross section of the coastal area in the vicinity of Muthurajawela

At the onset of the Flandrian Transgression, the landscape in the area under consideration probably resembled the present landscape to the east of it. Hills of Pre-Cambrian gneiss occurred in the southern part; Pleistocene deposits formed some of the northern half.(Cooray, 1984; Katupotha, 1988). Relatively high hills existed at Colombo and Negombo and probably in the Bopitiya area.

The rise of the sea level caused the coast to transgress over the continental shelf; leaving reefs at depths of 25, 17-18 and 10 m where coasts formed during temporary stand-stills in the process. Higher reefs extending northward from Colombo and Mutwal are witnesses of other former coasts in front of the present coast from Hendala to Pitipana and extending further northward as a reef. These reefs consist of beach rock which has been formed in the intertidal range within a beach ridge.

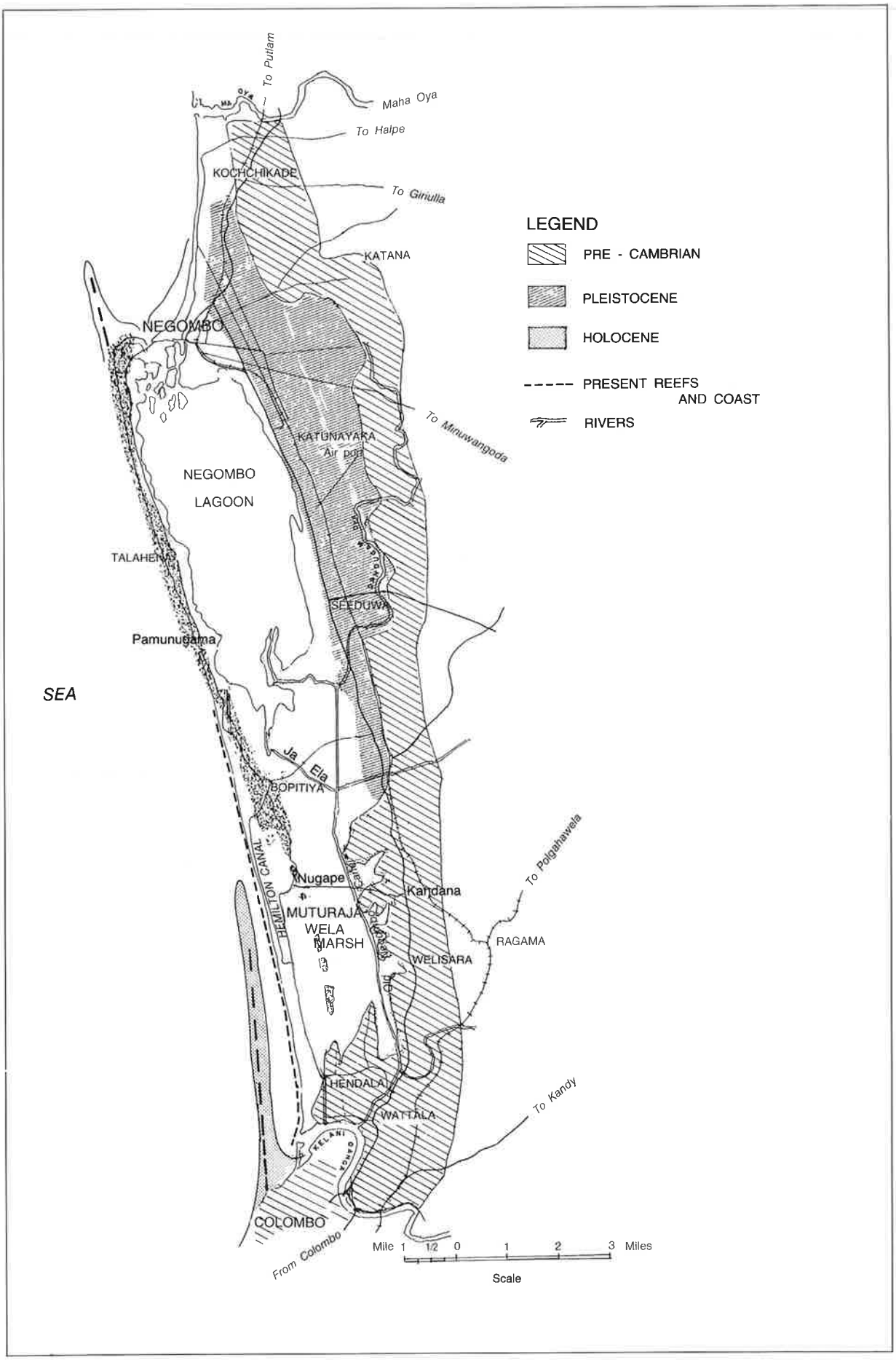


Fig. 14 Stages in the geological history of the Muthurajawela marsh - Negombo Lagoon area

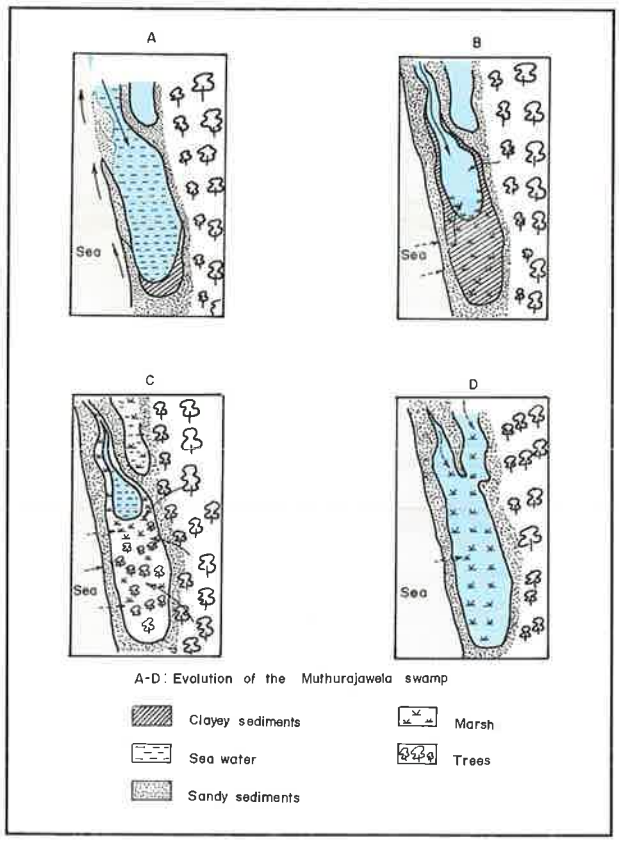


Fig. 15 Evolution of the Muthurajawela marsh (Dissanayake, 1990)

Probably, an early coast formed from Mutwal northward while another ran from an island or shoal near Bopitiya past an island or headland off Negombo. Because there is no gap in the reef off the mouth of the Kelani Ganga, this river must have flowed to the North; possibly with its mouth near Bopitiya. Fig. 14 gives a sketch of this situation. A lagoon existed between these coastal barriers and the mainland. The Kelani Ganga could bring its sediments into that area thus forming lagoonal deposits of fine sands and clays.

At a later stage,probably during a period with a higher sea level, the barrier extending from Mutwal was destroyed. The Kelani Ganga could flow over the remaining reef which is presently at about 3 m below sea level. A new convex coast formed between the Hendala headland and the coast near Bopitiya. The northern part of the coast remained. A sharp bend still marks the location where these two coasts met.

These processes led to the formation of a large lagoon with its only connection to the sea in the north and with the Dadugam Oya (and possibly the Kelani Ganga during floods) supplying fresh water.

Peat started forming in the southern part of the lagoon during a period of low sea level, probably around 6000 years B.P. (also see Dissanayake, 1990). Its development was hindered by transgressions but eventually it filled the entire southern part of the area at the beginning of historical times. Fig. 15 pictures this process.

A lagoon was left in the northern half of the area. The tidal delta of the Dandugam Oya and Ja-ela separates the two; together with some higher remnants of the former coast near Bopitiya.

The total volume of the Holocene complex is about 1000 million cu m (1 cu km) of which 25 million cu m is water, about 100 million cu m is peat and an estimated 100 million cu m is beach sand the rest are sands and clays deposited in the lagoonal area at an average rate of roughly 150,000 cu m/yr (200,000 tons/yr).

Three strata of peat can be identified, from top to bottom:

- reed and sedge-type peat: consisting mainly of grass and sedge debris, together with debris from other marsh vegetation. This type of peat is light and spongy and has a fibrous and matted appearance;
- shrub and tree-type peat: composed mainly of clearly recognizable remains of trees and shrubs, and being of a compact, hard texture;
- humus-type peat: very different from the other (younger) peat types. It consists of fully decomposed, no longer recognizable plant material.

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, particularly in the middle peat layer, 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 marsh vegetation had taken place. (Dissanayake et al, 1982). The location of peat deposits and bore hole profiles are given in Fig. 16.

However, during the last thousand years, the southern marsh area had been free of salt water influences that is to say until the intervention of human agencies in the construction of irrigation canals, and drainage channels which caused seepage, infiltration and in-flow of salt water (see B-1).

The abundance of metals in the Muthurajawela peat has been studied by Dissanayake (1984). Their presence appears to be closely associated with the clay particles. The low pH of the peat bog has aided in the conversion of the metals to free ions which are adsorbed onto the clay complex. The bottom horizon with high clay

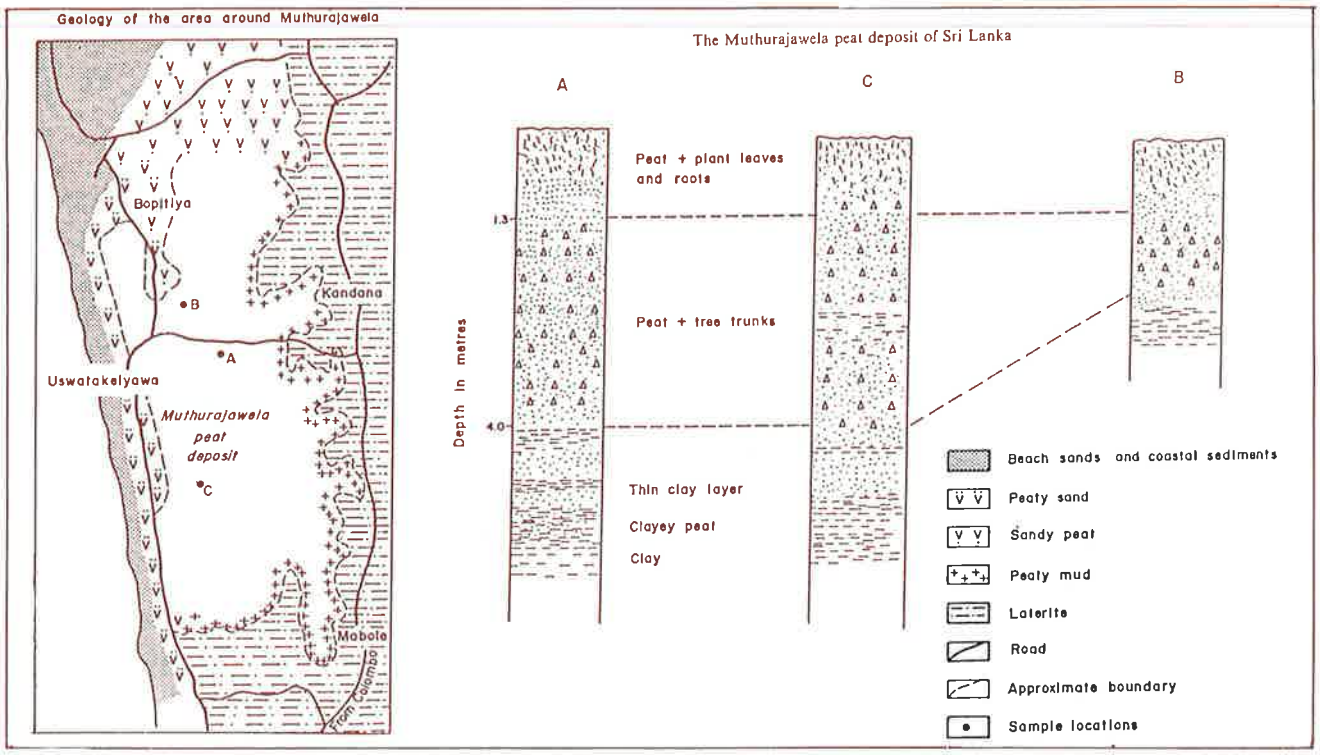


Fig. 16 The geology of the Muthurajawela marsh and its peat deposits: A, B and C denote the locations of bore holes for depth profiles.

content therefore contains the highest amounts of these metal ions. This governs the nutrient availability of the Negombo Lagoon and hence its productivity. The nature of the geo-chemical cycling of the nutrients between the Negombo Lagoon and the Muthurajawela marsh is therefore of prime importance. Any disturbance of this balance will undoubtedly have adverse effects on the productivity of the lagoon. These findings indicate that, in planning development projects in the area, **it is essential to maintain and preserve a linkage-corridor in a south-north direction between the marsh, transition zone (Fig. 85) and the lagoon.**

5.2 Soils

The soils were studied from an agronomic viewpoint by Dimantha (1991). Several soil types occur in the Muthurajawela marsh ranging from very poorly drained organic soils to poorly drained mineral alluvial soils. Most of the soils contain sulphur at levels that could become toxic to most agricultural crops. A large portion of the marsh is subject to tidal influence which raises the soluble salt content to levels that adversely affect crops (Table 1).

Soil classification in Sri Lanka is based on the soil taxonomy of the United states in which the provisions for classification of soils with high sulphide content, as those occurring at Muthurajawela, is still being refined. The present classification therefore draws upon other sources which deal more directly with acid sulphate and potential acid sulphate soils. Nevertheless, the classification given for soils of Muthurajawela in this report would require finalization based upon further investigations (Dimantha, 1991).

The soil types present at Muthurajawela were classified into 3 basic types, all of which are acid sulphate or potentially acid sulphate.

The predominant soil of Muthurajawela consists of poorly drained, organic soil (bog soils), dark brown to black in colour and overlying waterlogged mineral subsoils. All these soils contain pyrites (compounds of iron and sulphur) to the extent that they classify as potential acid sulphate soils. The bog soils bordering the Negombo Lagoon and those situated on the western segment of the main marsh become saline because of tidal influence.

The second major constituent of Muthurajawela are the mineral soils with large amounts of organic matter, but in quantities insufficient to classify as bog soils. These are the half bog soils. They have properties intermediate between bog and mineral soils with low levels of organic matter. These half bog soils also contain sufficient pyrites to classify as potential acid sulphate soil.

The third major group consists of soils formed of inorganic material (mineral), with a thin layer of organic material (humus) at the surface. These soils have been deposited mainly by river flow, and floods and are therefore termed alluvial. These soils classify as humic alluvial gley soils since they are waterlogged and poorly drained. These too are potentially acid sulphate soils because of a high level of pyrites.

TABLE 1 THE PROPERTIES OF BOG SOIL (ORGANIC SOIL) OF MUTHURAJAWELA

Organic carbon content	18-54% generally the surface layers consist of highly decomposed or partially decomposed plant material mixed with peat, medium to strongly acidic (pH 4.5-6.0) when most in the field state. On drying extremely acid condition develop because of oxidation of sulphate forming sulphuric acid and subsequent formation of jarosite crystals which gives a yellow mottled appearance to the soil
Soluble salt content	High where brackish water influence occurs. Salt content is high bordering Negombo Lagoon and Hamilton Canal, and bordering the Dutch Canal.
Cation exchange capacity (CEC)	Very high on a soil weight basis, however, because of the low bulk density of the soil it decreases on a volume basis. Base saturation is 40-60% with the dominant cation being calcium. The exchange sodium percentage is low indicating that the soil has not become sodic although exposed to sodium.
Nitrogen	Varies between 0.2-1.5% with a carbon/Nitrogen ratio of 20:80. This ratio being wide, the nitrogen is not available.
Phosphorous	Very low, traces to 100 parts per 1000 ml.
Potasium	Exchangeable content very low, 0.06 - 1 milli equivalent per 100 g soil.
Iron	High 1-7% with most of the iron being bound with sulpher as pyrites. However, soluble iron also is high and at a level that is toxic to rice and causes "bronzing".
Sulphur	High 2-6%, with most occurring as pyrite.
Specific Density	Varies between 1.4 and 1.9. Bulk density varies with state of shrink/swelling. At high field moisture content, reaching 1000% on a weight basis, bulk density is about 0.19/ml i.e. the soil swells on saturation. At lower moisture level, about 200% bulk density is about 0.4 g/ml demonstrating shrinkage to quarter volume.
Erodability	Very high because of low specific density. During floods the low density material detaches form subsoil and floats away.
Bearing capacity	Very low at high moisture content thereby making it impossible to work the soil with animals or machinery for agriculture purpose . (also see A-4)
Agriculture potential	low to extremely low

5.3 Land suitability classification

The Muthurajawela soil has been grouped according to the FAO framework for Land Evaluation based upon 5 land-use types (Table 1; Fig 17).

It is evident from the land suitability classification for selected agricultural land use types that the soils of Muthurajawela are not suitable or for the most part only marginally suitable for most conventional uses such as rice and leafy vegetables. This is mainly attributable to multiple problems of among others, salinity, flooding and potential acidity. Some non-conventional uses such as cultivation of sedges and medicinal plants holds out more promise. However, the impact of these uses also needs to be evaluated in terms of sustainability of production. The response of coconut to acid sulphate soil at Muthurajawela is not clear. In certain locations coconut seems to survive on drained soils with jarosite mottles. There are some indications that coconut seedlings had been replanted several times before establishment. It is probable that initial extreme acidity had been leached out by rainfall prior to seedling establishment. The leached out acidic water would necessarily increase the acidity of adjacent water bodies. Any form of agricultural development which seeks to reclaim large extents therefore appears to be unsustainable (Dimantha, 1991).

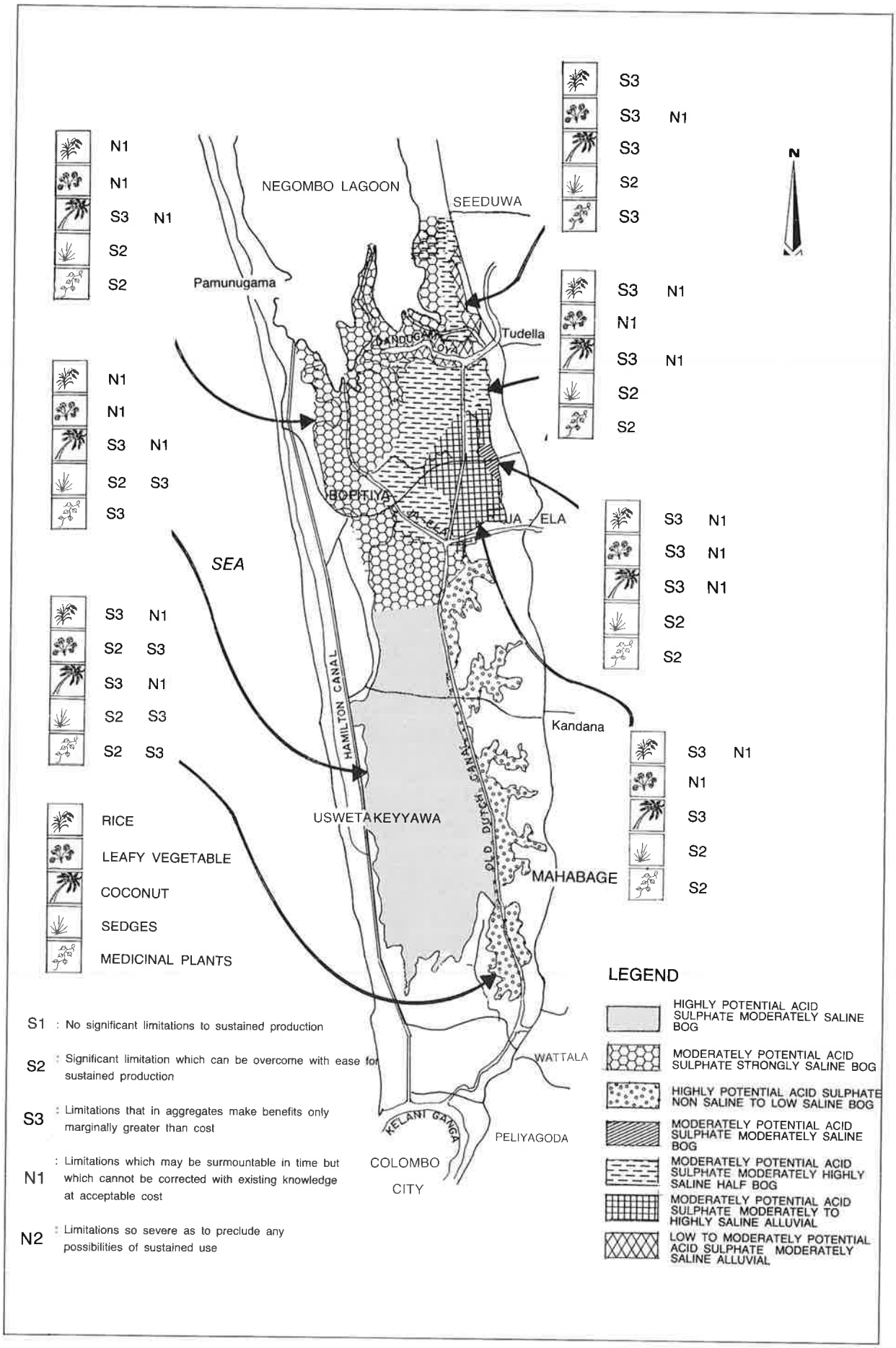


Fig. 17 Land suitability classification of soil in the Muthurajawela marsh

6. HYDROLOGY.

6.1 Hydrological History

The geological development of the area upto about 1,200 AD, produced a large tract of marshy land bordered by the old high grounds in the east, and on the south, by a narrow dune ridge along the area in the west and Negombo Lagoon in the north. The northern part of Muthurajawela was, in fact the swampy, brackish water tidal delta of the Dandugam Oya. The marsh penetrated in some drowned valleys in the old land and a narrow connection existed with the Kalu Oya and Kelani Ganga.

The marsh received water from rainfall, from the Dandugam Oya, from surrounding higher grounds, and probably occasionally in the floods from the Kalu Oya, and Kelani Ganga. Some of the water must have been removed from the area by evaporation of open water and evapo-transpiration of the vegetation. The drainage was very poor, as in similar marshes (Holland, Guyana) without any distinct channels. With rain and inflow exceeding losses to the atmosphere in the wet season, and vice versa in the dry seasons, there was a net outflow from the area. The marsh acted as a source of fresh water to its surroundings; especially to the tidal delta and the lagoon.

The water level in the marsh, and probably also the marsh itself was slightly higher in the middle than along its fringes. The level varied with the seasons but the retention time was long enough to leave the area inundated, or at least very wet, during the entire year. The area was above sea level; tides and saline waters only penetrated in the swampy delta. The vegetation caused a vertical and horizontal growth of the marsh; the Dandugam Oya added sediments to its delta and some sediments entered from the surrounding high grounds.

The Lagoon 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, was fringed by a narrow strip of low land. The tides and saline waters entered the lagoon through its inlet, the salinity being in balance by the inflow of fresh water from the Dandugam Oya, the marsh and precipitation /evaporation.

Adequate soils and ample supply of water by the Dandugam Oya and the marsh must have been excellent conditions for agriculture (rice) especially in the north-eastern part of the area.The kings of Kotte (Arumugam, 1969) constructed the Old Dutch canal in the 15th century to improve communication. It linked the Kelani Ganga, and the Dandugam Oya. Unfortunately, its effects were partly adverse, the reasons probably being:-

- a lowering of the water level, and the level of the peat surface along the canal,
- better drainage, a shorter retention time and greater variation of water level in the marsh,
- possibly periods of a water shortage in the dry season(s),
- partly because of this, intrusion of saline water into the area from both ends of the canal, and
- more effects of floods in the Kelani Ganga and the Dandugam Oya in the marsh.

A slight rise of the mean sea level around this time may have worsened the situation.

The previously cultivated fields were found abandoned by the Dutch in the middle of the 18th century, however, the lands were partly reclaimed by Dissave de Costa (Abeyasekera, 1954). The main features of his scheme were:

- A bund in the north now known as the Tudella-Pamunugama road;
- The construction of the Ja-ela which led fresh water, from a tank at Man-eliya, in a area about 3 km to the south from the mouth of the Dandugam Oya and,
- a sluice at Mabole controlling the canal in the south.

These however, went into decay and the area relapsed once more to a state of disuse.

The Hamilton canal was constructed along the western side of the area under British rule in the beginning of the 19th Century. It connected the mouth of the Kelani Ganga and Negombo Lagoon. Its effects were similar to those of the Old Dutch canal, but now along the other fringe of the marsh. To prevent the intrusion of the salt water and to protect the area against flooding (probably partly caused by another rise of sea level) a comprehensive scheme of works was executed in 1929-1935; including;

- the Kelani north bund with sluices at Peliyagoda and Talwatta;
- the Wattala bund with a sluice;
- the Ja-ela bund with sluices;
- the Pamunugama road bund with no sluices;
- the Pamunugama diversion bund;
- the Bopitiya road gap with culvert and flap gates;
- the Telengapata sluice in the Colombo-Negombo road;

- the Peliyagoda main drain, and
- some controlled pipes.

These works excluded salt water from the Kalu Oya basin and the Muthurajawela area. They guided the floods of the Kelani Ganga, the Kalu Oya and the Ja-ela.

Additional works were undertaken to improve the drainage of the area;

- 28 canals between the Old Dutch canal and a canal parallel with the Hamilton Canal, 32 km in total;
- Seven salt water exclusion structures, and
- 6.5 km of marginal bunds along the Old Dutch Canal.

The drainage canals were connected to the Old Dutch Canal in the east and, via the salt exclusion structures to the Hamilton Canal. Salt water was excluded from the Old Dutch Canal by sluices at Ja-ela and Wattala.

These works facilitated the development of agriculture in large parts of the area; especially during the 2nd world war. Abandonment started again around 1955. Pumping stations were advised to improve conditions around 1960; some were actually built between Bopitiya and Ja-ela. The Jayasuriya road was constructed across the marsh with a bridge over the Old Dutch Canal.
To improve the situation in the south-eastern part of the area some specific works were executed in 1956;

- a bund at Mabole isolating the Kalu Oya catchment (61 sq km) from the basin (2.2 sq km), the water from the Kalu Oya flows to the Kelani Ganga via a new Wattala sluice;

- Widening of the southern part of the Old Dutch Canal; in the case that a flood in the Kelani Ganga obstructs the release of the water from the Kalu Oya, it can be routed via the drainage canals to the Hamilton Canal.

A general cleaning of the Old Dutch Canal was performed in 1968. Experiments with a fish farm and the export of peat are reported from this period.

The change of government policy in 1977 and a reorganization of the Irrigation Department (1978) led to a further deterioration of the water management infra-structure in the area. The engineering works in the Muthurajawela marsh are shown in Existing Engineering works Map (see Palet in the back cover)

The effect of the drainage works has been to further lower the water level in the area causing compaction of the peat and lowering of the land surface. The retention time has been reduced; making the area even more vulnerable to the seasons. Moreover, drainage by gravity is becoming more and more hampered by the lower ground level and rising sea level.

As a consequence, and also for economic reasons, agriculture has withered, the canals are not maintained and the salt exclusion gates are in bad repair (Plate 9).

Compared with the marsh, relatively little changed in the Negombo Lagoon area. Deposition of sediments from the river and the sea induced shoaling in the entire lagoon, and the growth of the river delta as well as the inner tidal delta continued naturally. Land above the water level was secured by vegetation and human settlement.

6.2 Present Drainage Pattern

Data for most hydrological interpretation were provided by the National Aquatic Resources Agency (Wickremeratne et al, 1990).

In its present state, the hydrologically significant area measures about 100 km^2 in which the Lagoon (35 km^2) and the marsh (35 km^2) are the main elements with an altitude around mean sea level. The remainder of the area are a dune belt along the coast, the fringes of the lagoon and some higher ground along the eastern and southern boundaries.

Fresh water enters the area from the Attanagalu Oya (Dandugam Oya and Ja-ela) 1.5 km3/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 remove about 0.15 km^3 annually. The balance flows to the sea; mainly via the inlet of the Lagoon and for a lesser part through the Hamilton Canal into the mouth of the Kelani Ganga.The inflow of saline water from the sea is estimated at 1.1 km^3 per year through the inlet of the lagoon and a considerably lower quantity through the Hamilton Canal.

The balance shows that the main flow is from the river to the lagoon and, after mixing with the saline water, towards the sea via the inlet of Negombo Lagoon. On the way it passes through the marsh and the swampy tidal delta to the north from the southern bund along Ja-ela and the bund road to Bopitiya. These structures form a barrier between this northern system and the marsh to the south of it except a regulator and some pumps connecting the Old Dutch Canal to Ja-ela. There, water from the Ja-ela can be supplied to the marsh and the marsh can drain to the Ja-ela. The Jayasuriya road cuts the main marsh into two parts except the bridge across the Old Dutch Canal. Both parts receive water from higher grounds to the east and south and from the higher area around Bopitiya village.

Agriculture along this eastern fringe may receive water from the marsh during dry periods.

The western boundary of the marsh is formed by the bund road along the Hamilton Canal between Hendala and Bopitiya; about 10 km long and 0.4-1.0 m above M.S.L. Seven sluices (with bad gates) cross this bund as well as numerous small culverts. These form the main drainage of the marsh between Ja-ela and Hendala towards the Hamilton Canal. They are connected to the 28 east-west running canals which are all in open connection with the Old Dutch Canal which in turn, has a possibility to drain towards the Kelani Ganga at its southern end.

This describes the general pattern of flow at least during normal water levels. The detailed drainage is guided by numerous, more or less deteriorated, canals and low bunds with roads and paths. Most of these structures, however, including low parts of the Hamilton Canal bund, are drowned during floods. Then, a more or less continuous sheet of water flows towards the Hamilton Canal (Fig. 18).

This, 14.5 km long, canal further carries the water towards the Kelani Ganga mouth and Negombo Lagoon. It also receives some water from the 0.5 km wide, area to the west of it. Its capacity is limited and it varies with the mean sea level and the tide at both ends.

Salinity is quite low in the Lagoon and estuary of the Kelani Ganga during the wet seasons. Moreover, at such times there is a surplus of water in the marsh. No salt can penetrate. A deficit of water may however occur during the dry seasons leading to an inward flow of saline water which is not any more prevented by the dilapidated sluices along the Hamilton Canal.

Table 2 Hydrological units (sq. km) consisting the Muthurajawela marsh-Negombo Lagoon wetland

	UNITS	HIGH GROUND	LOW LAGOON /MARSH	TOTAL
1	Lagoon	7	35	42
2	Delta,swamp N. of Ja Ela	2	12	14
3	Marsh N: Ja Ela to Jayasooriya road	6	8	14
4	Marsh 5: Jayasooriya road - Hendala	10	11	21
5	West from Hamilton Canal	5	4	9
	TOTAL	30	70	100

Little is known about the quality of the ground water in and under the marsh and the lagoon. Probably it is saline in the sand and clay. Lenses of fresh water, fed by rain, are supposed to exist in the dunes and in the sandy area around Bopitiya.

Summarizing, the area of 100 sq km roughly between the Colombo-Negombo road and the sea, contains the following hydrological units, in sq km (Table 2).

6.3 The Hydrological Systems

6.3.1 General Information

Sea Level: The datum of the National Topographic Survey is mean sea level as derived from tidal observations at Galle, Colombo and Trincomalee between 1884 and 1985. Recent observations at Colombo indicate a 0.12 m higher mean sea level in accordance with the rate of eustatic sea level rise of 1.2 mm/y.

The analysis of the tide, performed over the same period, yielded the following main tidal constants and characteristics:

Constants			Characteristics	
Sa	H=9.5cm;	k=308°	Highest artr. tide	0.5 m
Ssa	4.1cm	111	MHWS	0.3 m
M2	17.6cm	50	MHWN	0.1 m
S2	11.9cm	95	MSL	0 m
K1	7.3cm	33	MLWS	-0.1 m
0I	2.9cm	62	MLWS	-0.3 m
			Lowest astr. tide	-0.5 m

The seasonal variation of mean sea level and the highest spring high waters per month are given in Table 3 with respect to present mean sea level.

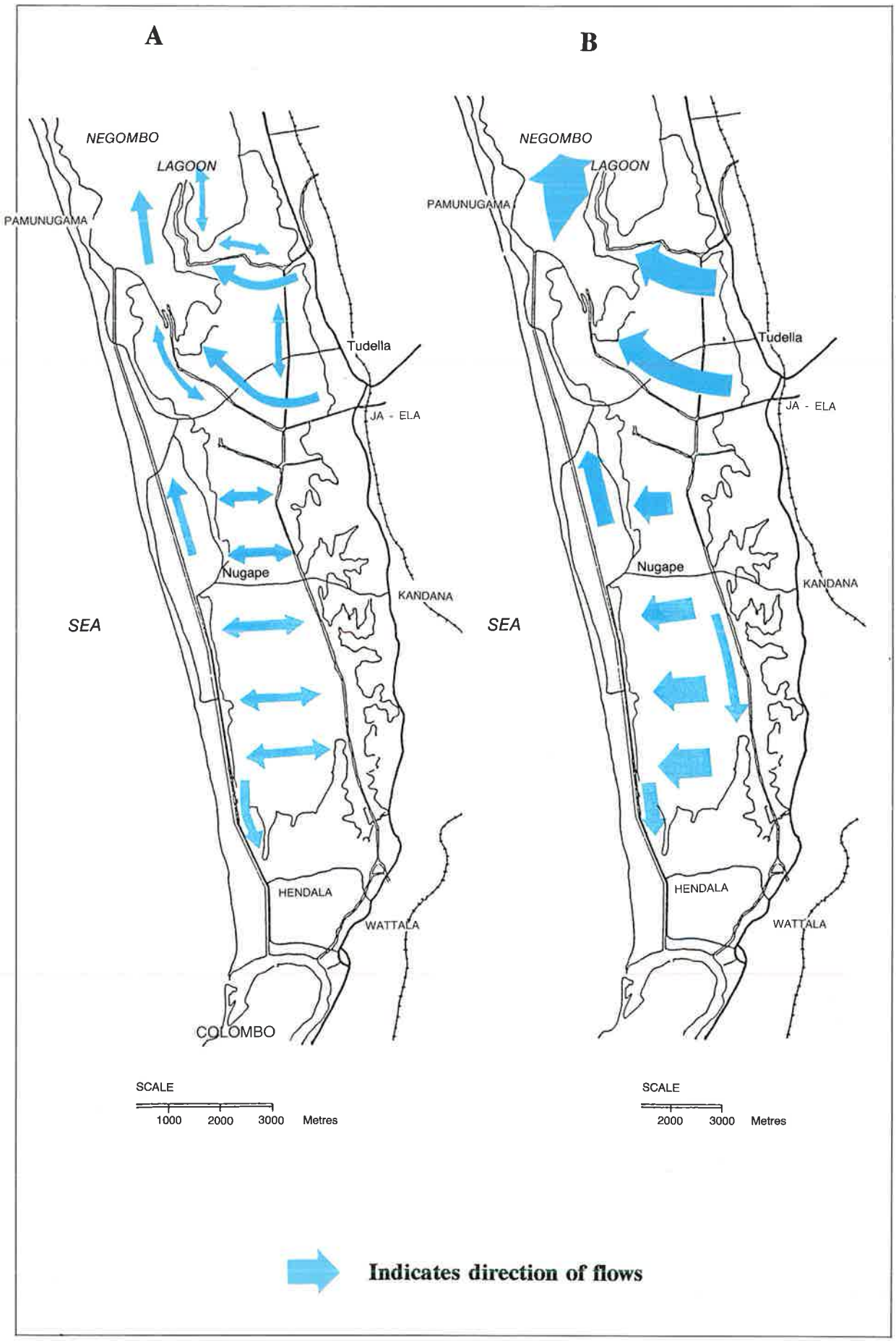


Fig. 18 Water flow pattern in Muthurajawela during the dry and wet seasons

TABLE 3 MAIN CLIMATOLOGICAL AND HYDROLOGICAL CHARACTERISTICS

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.	Unit
Climate														
- Temperature														
Daily maxi.	30	31	31	31	31	30	30	29	29	29	30	30	30	0C
Daily mini.	22	22	23	24	26	25	25	25	25	24	23	24	24	
- Rain	75	75	110	225	360	200	125	110	190	365	350	180	2360	mm
- Evaporation (E)	110	115	130	110	100	110	105	100	110	100	90	100	1280	mm
- R - E	-35	-40	-20	145	260	90	20	10	80	265	225	80	1080	mm
- Wind														m/s
Direction SW	6	8	19	36	58	62	59	62	60	40	15	6	36	
W	8	20	25	22	19	24	30	26	25	25	20	9	21	
NW	21	25	16	19	4	4	5	5	6	12	19	20	12	
N	19	8	5	2	2	0	0	0	0	3	12	20	6	
NE	35	25	14	6	2	0	0	0	0	4	17	34	12	
Others,calm	11	14	21	15	15	10	6	7	9	16	17	11	13	
.Av. meanspeed	2	1.5	2	2.5	2.5	2.5	2	1.5	1.5	2	2	2		m/s
Waves :														
. Direction SW	1			7			35			14		18		m/s
W	4			16			29			24		19		
NW	10			18			9			15		12		
.Height HI	4.1			3.4			6.3			4.0		5.8		m
H10	2.8			1.3			4.2			2.7		3.5		m
H50	1.6			1.3			2.5			1.5		1.8		m
Tides :														
. Max.M.W.S	0.53	0.58	0.64	0.64	0.60	0.50	0.47	0.44	0.42	0.42	0.45	0.49	0.52	m
. Mean S.L	-0.03	-0.03	-.0.01	0.05	0.08	0.13	0.08	0	-0.08	-0.10	-0.08	-0.05	0	m
Vegetation :														
- Evapo (T) Transp.	145	150	175	160	165	140	150	140	140	135	135	140	1775	mm
- R-T	-70	-75	-65	95	195	60	-25	-30	50	230	180	40	585	mm
- Rice (2 crops)	300	225	150	225	525	450	375	225	-	150	225	150	3000	mm
Lagoon :														
- Attanagalu	40	25	50	130	175	185	115	60	100	100	215	130	1325	10^6m^3
- Rain	3	3	5	9	15	8	5	5	8	15	13	8	97	10^6m^3
- Evaporation	-4	-4	-5	-4	-3	-4	-3	-3	-4	-3	-3	-3	-44	10^6m^3
- Balance	39	24	50	135	187	188	117	62	104	112	225	135	1378	10^6m^3
- Salinity	22	30	27	20	10	7	13	21	20	18	2	20	18	kg/m^3
- Inflow sea	160	170	150	90	45	50	100	140	115	104	110	90	1225	10^6m^3
Marsh (N+S) :														
- Rain	2.4	2.4	3.5	8.2	11.5	6.4	4.0	3.5	6.1	11.7	10.1	5.8	75.6	10^6m^3
- Evapo-tr	-2.7	-2.8	-3.1	-2.7	-2.4	-2.7	-2.5	-2.4	-2.7	-2.4	-2.1	-2.4	-30.9	106m3
- Balance	-0.3	-0.4	0.4	5.5	9.1	3.7	1.5	1.1	3.4	9.3	8.0	3.4	44.7	10^6m^3
Kelani Ganga	200	150	200	340	560	830	650	410	460	690	880	375	5745	10^6m^3

The tidal range (0.2 m at neaps to 0.6 m at springs) is rather small. As a consequence, the seasonal variations, the sea level rise, river floods, set-up by wind and atmospheric air pressure play a considerable role. Uncertainty about the mean sea level used as a reference (geodetic or present) can be confusing. Information about waves is given in Table 3 in relationship with the wind.

Rainfall, evaporation and run-off : Monthly and annual levels of precipitation (1937-1989), evaporation, and evapo-transpiration (Penman) at Colombo are given in Table 3. It appears that there is a deficit in January, February and March and that the effective rain is small in July and August. Evapo-transpiration of a vegetational cover takes more water and also leads to a deficit in July and August. The cultivation of rice takes even more water; the figures, for two crops, in Table 3 include percolation of about 600 mm per crop.

The mean monthly run-off of the Attanagalu Oya and the Kelani Ganga have been derived from observation during 6 years (1956-1961) and 11 years (1975-1985) respectively. The main elements of the water balances of Negombo Lagoon and the Muthurajawela marsh (between Ja Ela and Hendala), as derived from the general data have also been given in Table 3.

It appears that the lagoon 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 seawater into the lagoon.

The meteorological and hydrological phenomena show a considerable variation from year to year, which would make changes in the freshwater balance more pronounced during some years.

Salinity : Information about salinity in Negombo Lagoon is available from fortnightly observations during one hydrological cycle (1989-90) only. The results of an analysis are given in Table 3. The value varies 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 lagoon was 34.2 kg/m^3 (ppt) during the same period; slightly lower than the 35 kg/m^3 (ppt) at open sea.

Storage Capacity : The surface area of Negombo Lagoon is 35/km^3. Its mean depth is estimated to be 0.65 m placing its volume at 22.5 million m^3. The cross-sectional area of the inlet channel is estimated to be 250 sq m with a length of about 2.5 km.

The distribution of the land according to its elevation in the Muthurajawela marsh is:

Below 0	(0-0.1)	6.0 km^2
0-0.3 m	(0.1-0.2)	15.6 km^2
0.3-0.6 m	(0.2-0.5)	1.4 km^2
0.6-0.9 m	(0.5-0.8)	2.0 km^2
0.9-1.2 m	(0.8-1.1)	1.0 km^2
		26.0 km^2

(In brackets with respect to present M.S.L.)

6.3.2 Flood, Retention and Drainage

When flood water or heavy precipitation enters a storage basin, some water will be stored, the water level will rise and this rise will cause the water to flow away. The volume retained is the difference between inflow and outflow. The time it takes to free the area of its excess water greatly depends on the drainage capacity. Characteristic quantities are:

- the area (A) of the basin (as a function of level);
- the rise (h) of the water level;
- the volume retained V=Ah;
- the drainage flow (Q) rising with h, and
- the retention time T=V/Q

A retention time T means that 90 percent of the water has left the basin after about 2.3 T.

The Marsh: The geometry of the area has been given in the previous section. Fig. 19 shows the simulation of a period of high precipitation and its effects on storage and drainage in the marsh. The maximum storage is 11 million cu m with a water level of 0.52 m and maximum discharge is 12.5 m^3/s. The retention time is slightly more than 10 days.

The rainfall/run-off model has also simulated the effects of floods with return periods of 50,100 and 200 years. The results are shown in Fig. 20. The retention times appear to be 8.5 to 7 days. These retention times are too short to bridge the period of negative effective rain in a dry season. A rough calculation leads to the conclusion that retention times must have been at least five to ten times as long before drainage works were constructed in the area. Thus, the marsh remained wet during most of the dry seasons.

The Lagoon: A rise of 0.1 m of the mean level of the lagoon means 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.

The tidal range in the lagoon varies between about 0.07 m at neaps to 0.2 m at springs; about one third of the tide at sea. The volume of water stored and released

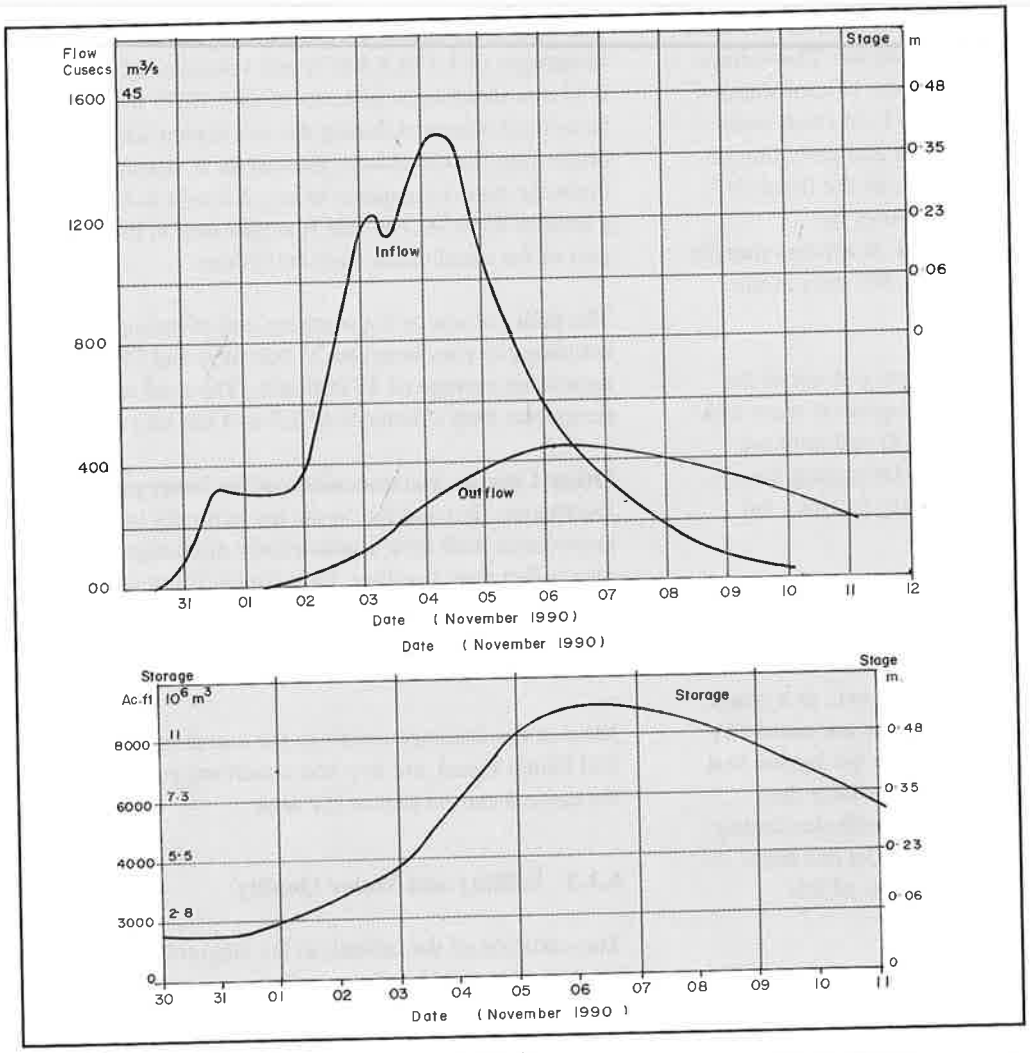


Fig. 19 Simulation of storage and drainage in the Muthurajawela marsh during the flood in November, 1990 (Dharmasena, 1990)

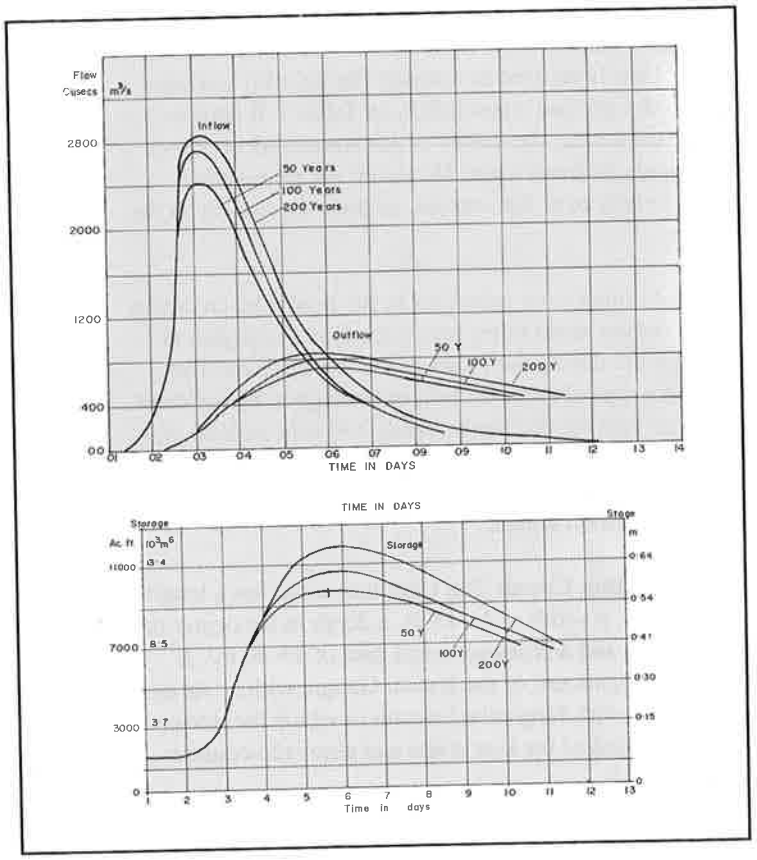


Fig. 20 Simulation of storage and drainage in the Muthurajawela marsh for flood return periods of 50, 100 and 200 years (Dharmasena, 1990)

varies between 2.5 million m^3 and 7 million m^3 per tide; around an average of about 4.5 million m^3. The volume flowing out during ebb (VE) equals the volume entered during flood (VF) plus the inflow (QT) of fresh water during the tidal cycle (T) by the river and precipitation at a rate Q. In general, a rising Q causes the flood (VF) to decrease. Fig. 21 schematically shows the relationship between VE, VF and QT. It appears that the flood ceases to flow once Q exceeds 100 m^3/s in the case of a mean tide.

Another way to estimate the flows into and out of the lagoon uses the salt as a tracer. The lagoon is seem as a vessel receiving fresh water at a rate Q and pure sea water at a rate Qs with salinity S, and releasing the mixture at a rate Qs + Q with a salinity S. Then, the equilibrium in the lagoon leads to

$$Qs\ Ss = (Qs + Q)S$$

Fig. 22 relates the observed (Wickremaratne et al, 1991) values of Q and S, averaged for each month, in a graph. The typical loops around the mean curve are caused by the time required to adapt the salinity in the lagoon to a new rate of inflow. It is related to the flushing time (volume of lagoon/Q) which increases with decreasing inflow. The mean inflow of sea water (Qs) has been derived from the mean curve. The results of this analysis are also given in Fig. 21.

The results of the two approaches agree reasonably well. The "difference" is caused by the fact that the salinities in Qs and (Qs + Q) in the inlet are never exactly equal to the mean densities of the sea and the lagoon, and since they, are affected by density currents. Fig. 22 has been used to estimate the monthly averages of salinity and sea water inflow in Table 3. It appears that, over a year, the inflow of sea water almost equals the supply of fresh water. However, the ratio varies considerably over the seasons, as does the salinity in the lagoon.

The maximum flow velocities in the tidal inlet are about 1 m/s during mean tides; lower at neaps and higher at springs and during the peaks of the wet seasons. The area of a typical cross-section of the lagoon being about 2000 m^2 and the discharges being 100 m^3/s or less, the velocities are very low. Much higher velocities upto 0.5 m/s, are caused by the waves which are generated by strong monsoon winds.

The Hamilton Canal: The Hamilton canal has a length of 14.2 km, a width of 16-18 m, a depth in the center of 1.5-1.75 m and a cross-sectional area of 15-20 m^2. It connects the mouth of the Kelani Ganga, with a tide as at sea, and with Negombo Lagoon in which the tide is only one third of the tide at sea and almost in counter-phase with it.

The tide alone causes oscillating flows in the canal with discharges of 1.5 to 4.5 m^3/s and velocities of 0.1 to 0.25 m/s Discharges of 13 to 15 m^3/s (0.75 to 0.9 m/s) have been observed during the wet season when water drains into the canal from the marsh. A characteristic drainage capacity appears to be 12.5 m^3/s to both ends; a total of 25 m^3/s. The tide is suppressed in the greater part of the canal under such conditions.

The tidal volume at the southern end of the canal is estimated to vary between 25,000 m^3/s and 75,000 m^3/s around an average of 45,000 m^3/s. The tidal water penetrates over a distance of 1.5 to 4 km into the canal.

Other Canals: The dimension of the lower parts of the Dandugam Oya and the Ja-ela are naturally in accordance with their characteristic discharges. This means that they overflow their banks (if not bunded) during high floods; the swamp acting as a flood plain. The Ja-ela releases water into the Heen-ela towards the North.

Most of the drainage canals in the marsh including the Old Dutch Canal, are in a bad condition; especially in the eastern central part of the area.

6.3.3 Salinity and Water Quality

The variation of the salinity in the Negombo Lagoon has been discussed in the previous section in relationship to the flows of water.

Salinity is low in the entire area during the wet seasons. Salt penetrates into the north-eastern part of the area through the Dandugam Oya and the Ja-ela, and in the south-western part through the Hamilton Canal during the dry season. Evaporation seems to lead to high salinities in some places. High salinities of 5 kg/m^3 (ppt) were observed in the south-western half of the Muthurajawela area during the 1989-90 dry season. Salinity exceeded 15 kg/m^3 (ppt) in the north-eastern part.

Dissolved matter enters the lagoon via the two rivers and with the drainage water from the swamp and the marsh. Although the latter is relatively small, it may be of importance. Annex gives baseline water quality values in the study area.

Sewage enters the area from the river, from industrial and touristic facilities along its borders and from the housing around and in the area. Blackening of the lagoon substratum in the vicinity of Airport Garden Hotel during the 2nd week of February, 1991 and the associated odour were suggestive of the release of organic wastes in substantial quantity.

Heavy metals have been found in the river sediments in Negombo Lagoon. They could be released into the water under anaerobic and acid conditions. The latter could be caused by oxidation of the high content of sulphur in the peat of the marsh.

6.3.4 Sediment Transports

The main suppliers of sediments to the area are the Dandugam Oya and the Ja-ela with a catchment of 727 km^2. The only available observation of the sediment yield is 147,000 tons per year; or about 200 tons/km^2 per year. The latter would be relatively low in view of the 600 tons/km^2 per year for the Kelani Ganga.

The Hamilton Canal is reported to supply 62,000 t/y to the Negombo Lagoon; a rather high figure in view of its small catchment and flows, (Wickremaratne et al, 1990).

An estimated annual input of 200,000 tons of sediments to the southern part of Negombo Lagoon seems seasonable.

Roughly 60,000 tons are reported to enter from the sea while about 190,000 tons/y leave the lagoon towards the sea. The balance, 70,000 tons/y, is deposited in the area. Together with some small inputs, the net deposition may be estimated at 50,000 m^3/y; the greater part of it in the lagoon, (Fig. 23).

Thus sedimentation rate in the lagoon appears to be about 1.5 mm/y. The characteristic time scale of the accumulation process leading to filling up is 400 years taking into account the volume of the lagoon. The actual filling will take in the order of 1000 years if the anticipated accelerated sea level rise would occur.

However, sediment buildup in seagrass beds is estimated as 6 mm/y, which means that some areas in the lagoon will fill up more rapidly (Samarakoon et al, 1990)

The present rate of sea level rise (1.2 mm/y) will retard the process of filling in. The predicted future sea level rise of about 5 mm/y would keep the lagoon at least in its present condition.

The sediment balance, as given above, leads only to an estimate of the change of volume of the lagoon. Sediments eroded in the lagoon, probably by wave action, and redeposited in the same body of water do not change its volume but only its shape. Vegetation can greatly enhance local sedimentation; even to the point that its growth can not be sustained and the vegetation disappears or is replaced by other plants, (See B-1). A mean sediment concentration of 50 g/m^3, which usually occurs during a wet season, means that about 200 tons of sediments are suspended in the water of the entire lagoon at one moment. Data about the rates of internal erosion and re-deposition are not available.

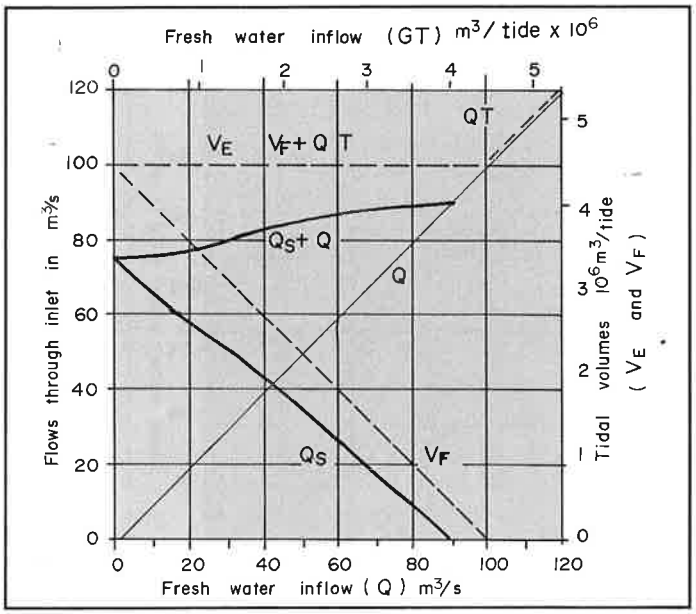


Fig. 21 Schematic relationship among flows: tidal ebb, tidal flood and freshwater inflow atthe Negombo Lagoon inlet.

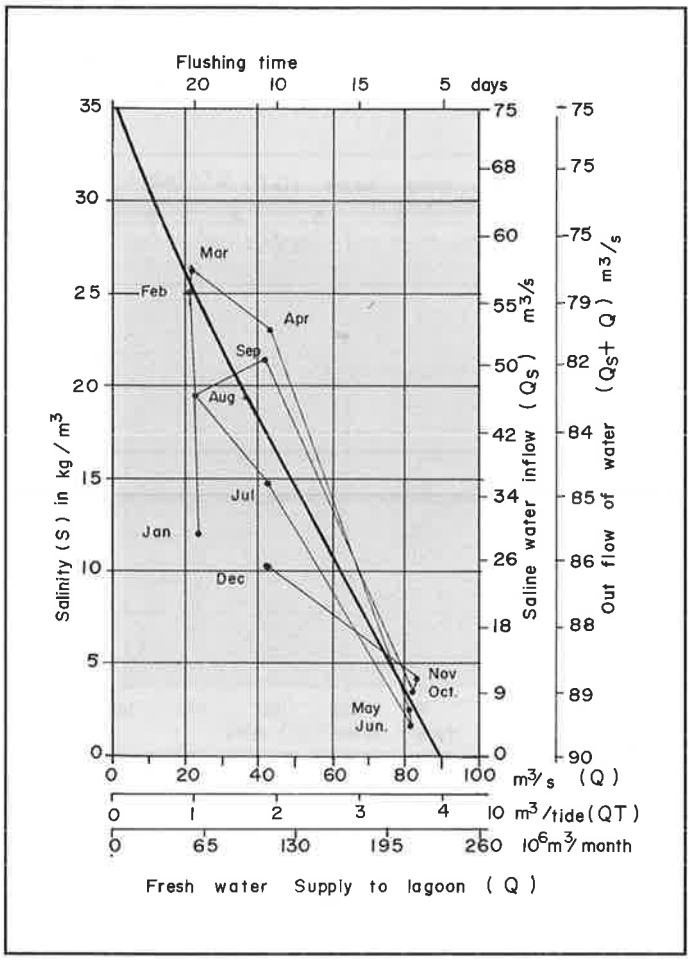


Fig. 22 Schematic changes in salinity in Negombo Lagoon averaged over months

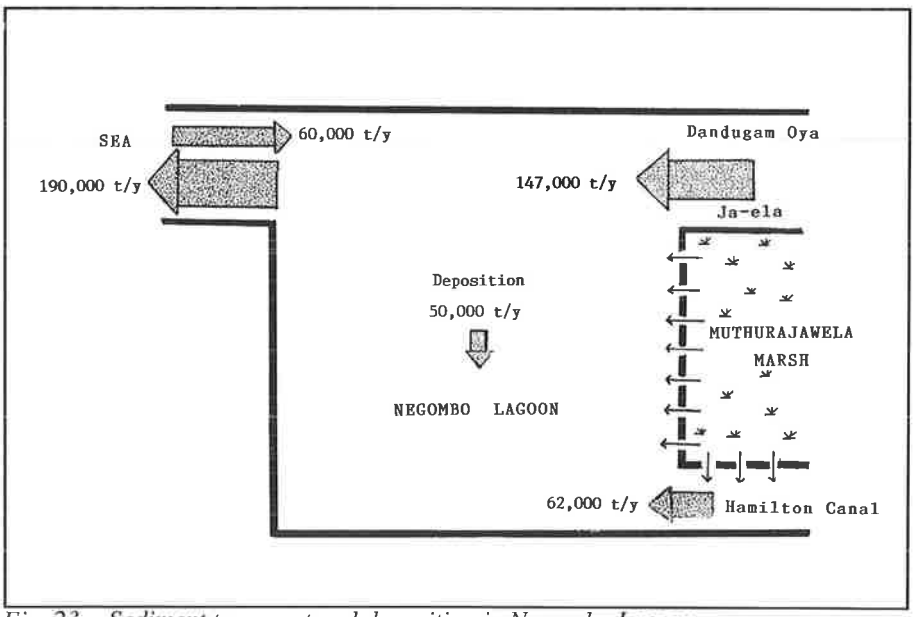


Fig. 23 Sediment transport and deposition in Negombo Lagoon

7. VEGETATION

Vegetation was studied by Herat (1990) and NARA (Amarasinghe, 1990; Jayasuriya, 1990). Three main types of vegetation are described: the vegetation of the marsh proper in the southern half of Muthurajawela, the brackish water swamp-mangrove vegetation in the central part and along the shores of the Negombo Lagoon, and the lagoon vegetation, i.e. its seagrass beds.

7.1 Marsh Proper

The marsh proper lies between the Old Dutch Canal in the East and the Hamilton Canal in the West and extends from Hendela in the South to Ja-ela in the North. It is a typical marsh wetland, poorly drained, temporarily flooded during the monsoon season and with a peaty substrate, saturated for almost all of the year. It is an unstable plant community representing one of the final stages of succession towards a dryland formation. The gradual build-up of the marsh results from accumulation of plant debris. Dominant plant species include grasses and reeds belonging to the family *Poaceae*, sedges belonging to the family *Cyperaceae* and cattails belonging to the family *Typhaceae*.

7.1.1 General

Marshes are among the biologically richest and most productive ecosystems known, providing forage, shelter and breeding sites for a diverse fauna, many species being of economic importance. However, many of these wetlands have been considerably influenced by man. The Muthurajawela marsh now consists of previously cultivated paddy fields, a network of canals, scattered ponds and cultivated fields. Consequently, the natural vegetation in most of the area has been subject to changes but over large areas the vegetation survives in varying stages of naturalness. On the other hand, it is not possible to trace changes that may have taken place during centuries of human activities, in particular regarding the introduction and extermination of certain woody species and aquatic plants.

Two main vegetation types are recognized:

(i) aquatic vegetation
(ii) marsh vegetation

7.1.2 Aquatic Vegetation

A variety of aquatic plants are found in former paddy fields, ponds, canals and channels, their occurrence being related to the level of eutrophication (enrichment of the water by organic and inorganic materials), by the degree of salinity and by water depth. For instance, in the southern part of the Old Dutch Canal which is now very shallow, grasses (*Panicum repens, Ischaemum rugosum*) and sedges (*Carex indica*) form a dense plant cover. At other places, the nutrient-rich water of the canal has been invaded by dense growth of the introduced noxious weed, the fern *Salvinia molesta*. This weed is not found where salinity is high, i.e. it is uncommon to absent in the Hamilton canal. The cover of emergent plants in this canal is generally low (most of the canal banks have been stabilized by masonry). Bottom-rooted floating plants include patches of waterlily while another introduced noxious aquatic weed, the water hyacinth (*Eichhornia crassipes*), occur as floating islands, these may not originate from the canal itself but from the Kelani Ganga.

Shallow pools and canals with more stagnating water, rich in nutrients, are covered with *Salvinia* or with duckweed (*Lemna spp*); in less eutrophic water at deeper sites, water lilies and Nymphoides spp. occur. In the east-west running drainage channels water weeds such as *Hydrilla verticillata, and Aponogeton crispus* (kekatiya) occur Plates 10 and 11.

Where salinity increases (near and in the brackish water marsh further to the North), banks become invaded by tall reeds (*Phragmites karka*) , cattails (*Typha angustifolia*) and ferns (*Acrosticum aurium*).

The open canal waters are usually very rich in phytoplankton and algae, being essential elements in the food chain of many higher organisms.

Vegetation profiles are given in Fig. 24, 25 and 26. Lists of plant species including phytoplankton and algae species are given in the original study reports (see Herat, 1990).

7.1.3 Marsh Vegetation

Large areas of the marsh appear to be uniformly covered with combinations of sedges and grasses. These areas are for at least part of the year waterlogged and the substrate remains moist to saturated throughout the year. Occasionally, patches of *Acrosticum aurium* fern have established and in more open places *Hydrocera triflora* occurs. Dominance and cover of these plants changes gradually from south to north (Fig. 27), probably as a result of changing salinity combined with substrate conditions.

The most aggressive woody pioneer species in the marsh is the recently introduced shrub-like tree *Annona glabra* (wel atha); it establishes everywhere on bank gradients and indicates the first step towards a more dryland plant association on higher, better drained lands. Also common are species like *Cerbera manghas* (gon kaduru), *Osbeckia aspera* (bowitia), and *Syzygium*

Plate 9 *One of many water control structures in Muthurajawelanow in a state of disrepair.*

Plate 10 *East-west running canals transect the Muthurajawela marsh.The bunds support trees while aquatic vegetation is abundant in the canal.*

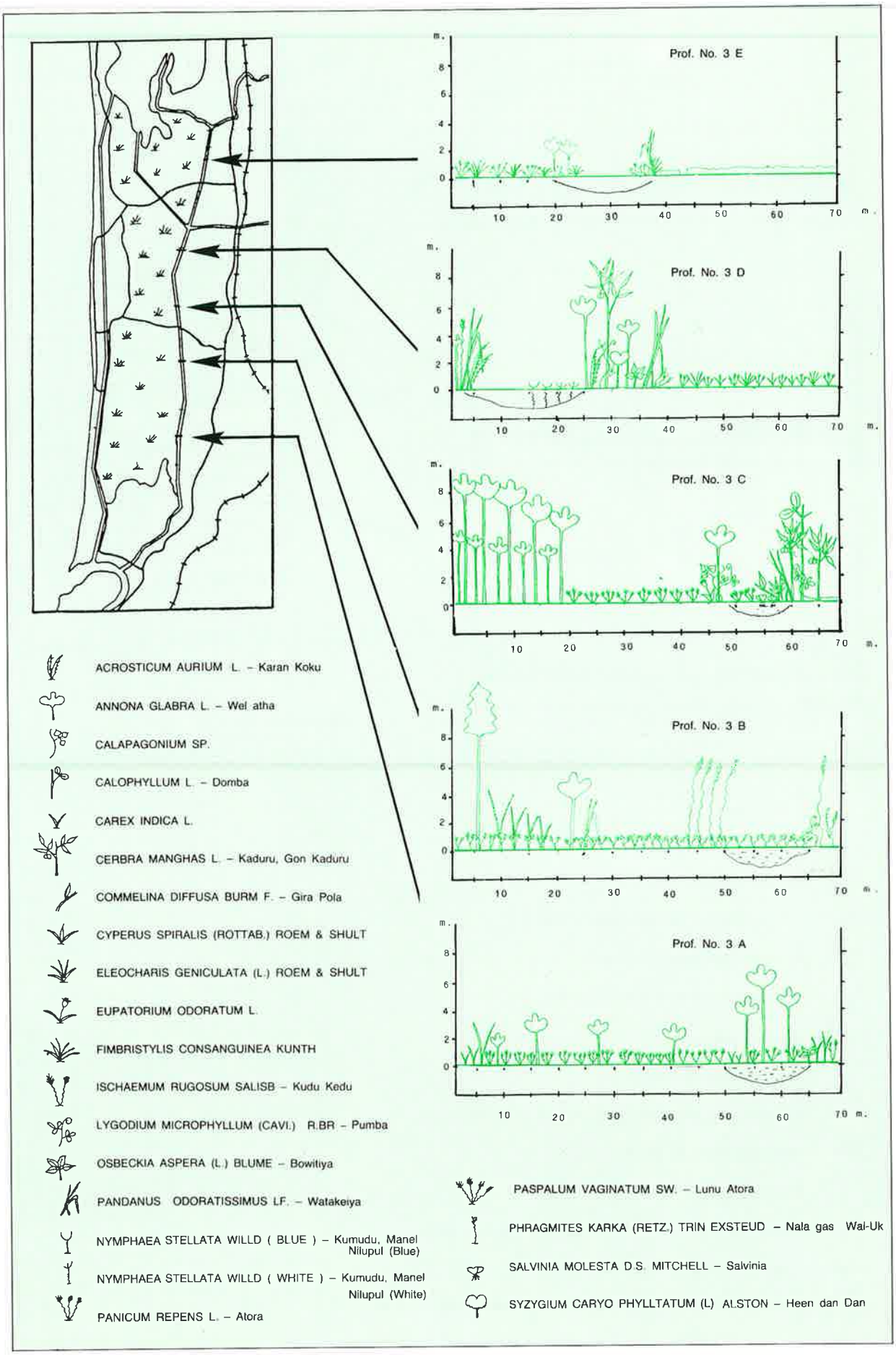


Fig. 24 Profiles of vegetation along the Dutch Canal, Muthurajawela (Herat, 1990)

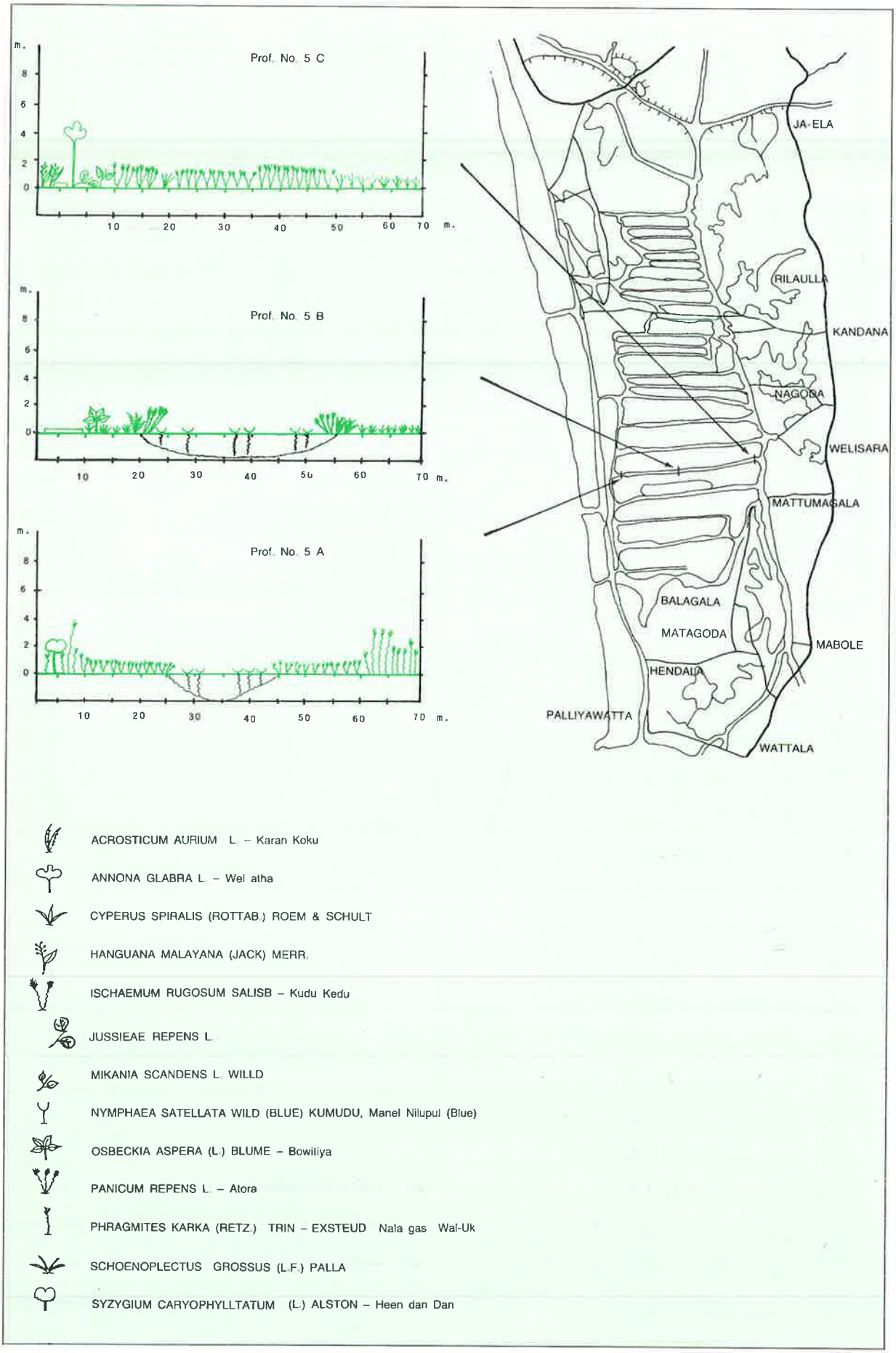


Fig. 25 Profiles of vegetation along drainage channels at Muthurajawela (Herat, 1990)

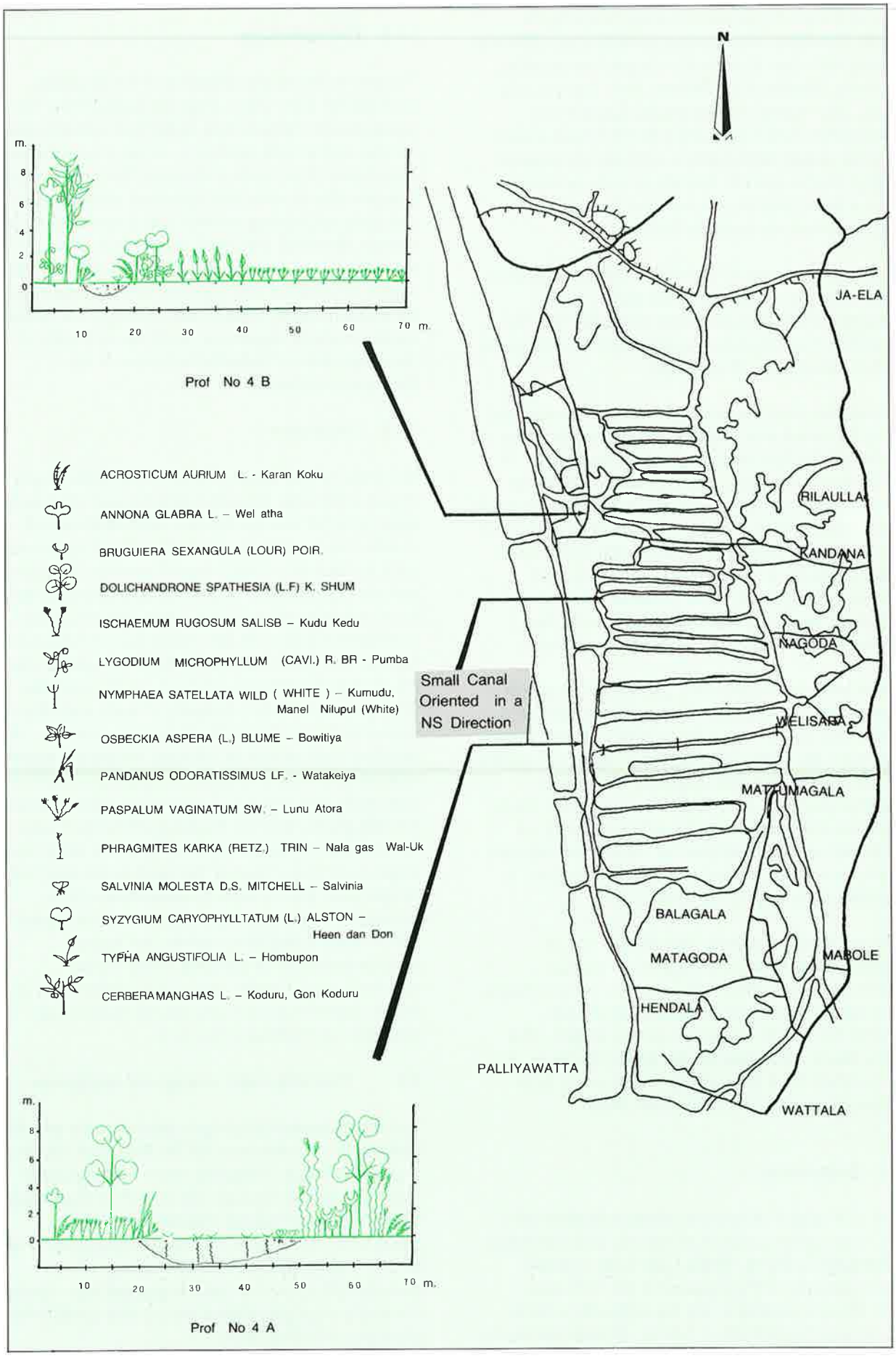


Fig. 26 Profiles of vegetation along irrigation channels at Muthurajawela (Herat, 1990)

caryophyllatum. Remnants of former beach forest include *Pandanus odoratissimus* (wetakeyiya), *Hibiscus tiliaceus* and a few *Calophyllum inophyllum* (domba). Due to the abundance of climbers, and some parasitic species, this vegetation type appears tangled and impenetrable, particularly along the Old Dutch Canal. On-going human disturbance is probably the cause of massive climber growth. Elsewhere in the northern sector, a dense growth of *Acrosticum* fern is found along canal and stream banks Plate 11.

Small islands of more or less similar plant composition are found in the central part of the marsh, mostly spreading from man-made bunds which had become invaded by *Annona glabra*, a phenomenon which seems to have started some 10 years ago.

The endemic palm *Phoenix zeylanica* has become very rare in the marsh area. Also the coastal vegetation on and behind the dune ridge has largely disappeared. A few *Terminalia catappa, Barringtonia sp., Hibiscus tiliaceus and Pandanus sp.* are still to be found but most of this zone has been converted into coconut groves. On the sea side, the dune ridge is still locally protected by trailing plants such as the *grass Spinifex spp.* and *Ipomoea pes-caprae*. It is likely that in time gone by, most of the beach forest fell under the axe for the construction of floats, boats, outriggers and canoes.

Various plant species presently growing in the marsh are of interest to the people. Some of these have been summarized in Table 4. Of the total of 129 plant species collected in the Muthurajawela marsh and the Negombo Lagoon it is reported that 44 species are used for medicinal purposes, 11 species are used as food plants, 13 species provide material for cottage industry, 14 species are used by fishermen for various purposes and 44 species are used for fuelwood, utility wood etc. A complete listing is given by Herat (1990).

Many marsh plants provide food for animals, in particular for aquatic herbivorous birds and for herbivorous fishes. Many species of grasses and sedges, and water lilies, produce an abundance of seeds, favourite food items for certain species of duck. The aquatic fauna maintained by the marsh vegetation, in turn, provides food for a variety of fish-eating birds (herons, egrets etc.) and carnivorous fishes.

7.1.4 Endemisum

Of the 129 species of vascular plants collected in this study none can be qualified as endemic and confined to Muthurajawela (Herat, 1990). Only three endemic species occurred at Muthurajawela: the "wild date palm" *Phoenix zeylanica,* and the sedges *Eleocharis lankana and Fimbristylis zeylanica*. All three are rare in the marsh area but, occur elsewhere, and therefore, cannot be considered "endangered".

7.1.5 Phytoplankton

The area is rich in phytoplankton, a list of species recorded for this study is given by Herat (1990). These organisms are the basic link in the food web of higher animals and as such, determine, in large measure, the importance of wetlands of this type. The present study indicates that the dominant species of phytoplankton and algae are pointing towards high concentrations of nitrates, dissolved salts (high conductivity), low pH and reduced oxygen content. This could indicate a certain degree of pollution. The presence of blue-green algae in the southern marsh support these findings, but further studies would be required to verify the reliability of these organisms as pollution indicators in the Muthurajawela marsh.

7.1.5 Conclusion

For centuries, the marsh vegetation has been subject to human influences. The old ridges (niyara) and trenches (agal) used for rice and coconut cultivation are still visible. The construction of the Old Dutch Canal and later, the Hamilton Canal, caused seawater infiltration and subsequent efforts to develop agricultural cropping have, to a large extent, failed. Other impacts on the vegetation continue till the present day: reclamation of land for new settlements along the fringes of the marsh, the cutting of fuelwood and utility wood, incidental fires, peat exploitation, dumping of waste and effluent (from clandestine liquor distillation) in canals etc., all have had and continue to influence the natural marsh vegetation. In addition, introductions of exotic plants such as the two mentioned noxious aquatic weeds and Annona glabra, have far-reaching effects on natural communities. Thus, the present vegetation in the marsh proper is far from "natural" but its structure and floristic composition still warrants its consideration as an important component of the wetland. In this respect, its role in maintaining the mangrove and lagoon ecosystems further to the north should not be underestimated. For this reason, a substantial part of the marsh should be preserved to ensure its important economic and ecological function.

7.2 Brackish water swamp and mangroves

The central zone of the project area forms the transition between the marsh proper and the Negombo Lagoon. It is characterised by a brackish water flora and some mangrove forests. Ecologically as well as economically this zone is very important maintaining a high productivity, acting as a silt trap, providing spawning, nursing and feeding grounds for a variety of economically important fish, shrimp and other species, constantly supplying coastal waters with nutrients and providing wildlife habitat.

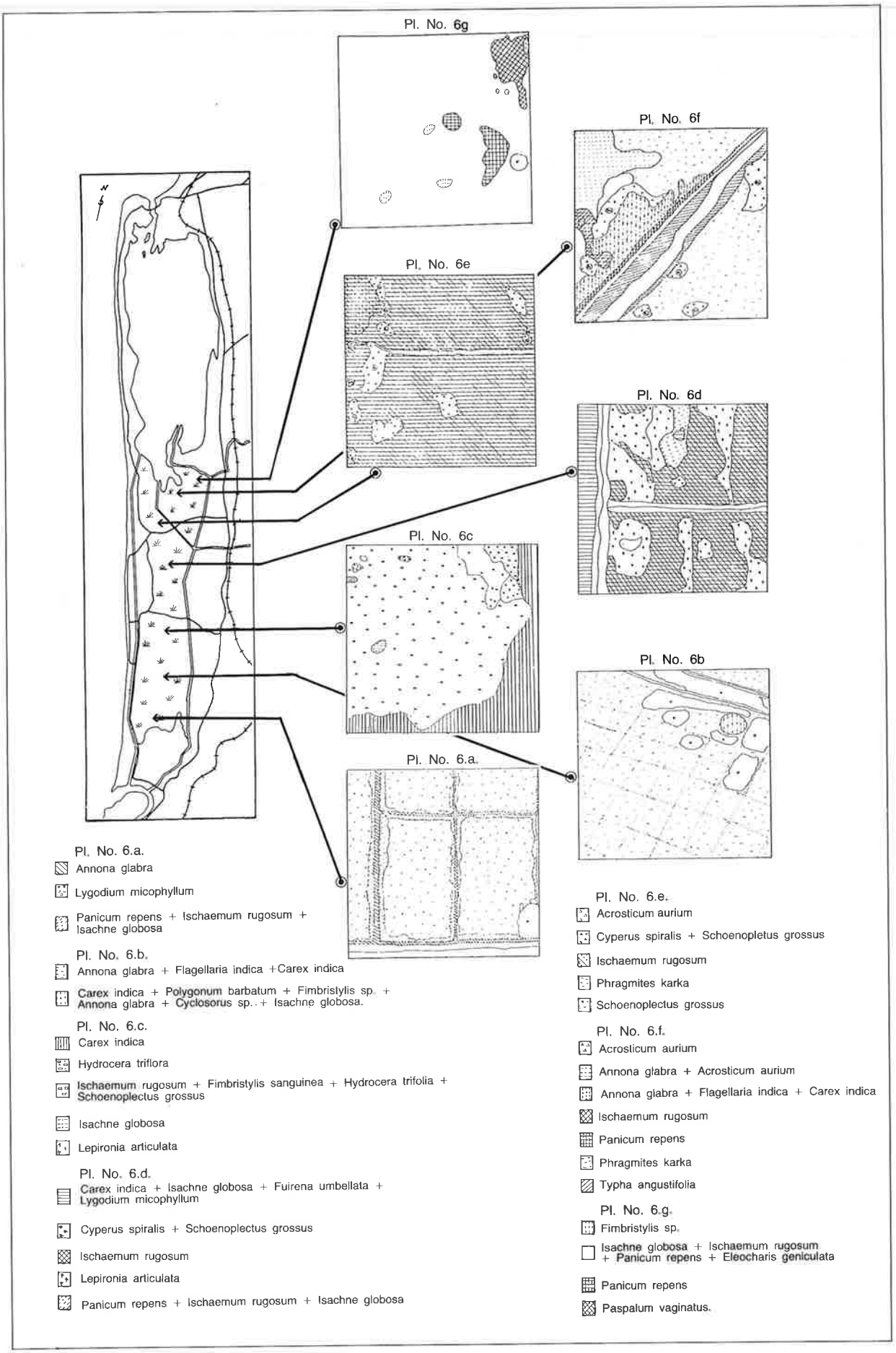


Fig. 27 Vegetation structure at plots (10m x 10m) in the Muthurajawela marsh (Herat, 1990)

Table 4 Human Uses of Some Plant Speices of Muthurajawela Masrh. Source: Herat (1990)

Species	Use
Annona glabra (wel atha)	Fuelwood, poles for fencing
Phragenitis karka (nala-bata)	fishing screens or kraals(maskotu), reed flutes
Typha angustifolia (hambu-pan)	mats
Lepironia articulata (elu-pan)	mats
Cyperus corymbosus (gal-ehi)	mats (also cultivated to some extent)
Carex indica (a sedge)	food container covers (athulpath)
Pheonix zeylainca (indi)	hats
Premna serratifolia (midi)	native medicines; bark decoctions against rheumatism and neuralgia leave decoctions: against flatulence root decoctions: agasinst fever
Asparagus falcata (hathawariya)	native medicine, preparation of porridge
Sonneratia caseolaris (kirella)	fruits; bottle corks (roots)
Ipomoea aquatica (kankun)	vegetable (kankun)
Centella asiatica (gotu-kola)	vegetable

7.2.1 Brackish water swamp

The mixed vegetation of the brackish water swamp just south of the Negombo Lagoon contains sedges, reeds and ferns associated with typical mangrove species. Common sedges include *Cyperus exaltatus* and *Fimbristylis polytricha*. The introduced woody species *Annona glabra*, together with the indigenous *Cerbera manghas*, also found in the marsh proper, are found on raised banks and levees. Vast areas of this swamp are covered by the fern *Acrosticum aureum* .Other associated species include *Clerodendron inerme* (wal gurundha), *Derris uliginosa* (kala-wal) and *Dolichandrone spathacea* (diyadanga). There is the almost total absence of *Nypa fruticans* palm (ginpol) formations in the swamp, except in the southern part. This is probably due to the limited extent of tidal influence and the absence of sufficiently raised muddy levees (Plate 12).

7.2.2 Mangroves

Mangrove forests extend over a very narrow intertidal area on the edges of the Negombo Lagoon, covering approximately 350 ha (Figs. 28, 29). At present this narrow belt is no longer continuous and its width does not exceed 100 m at any one place. In particular, along the eastern lagoon shore most of the former mangrove forest has disappeared. They still occur on most of the islands in the northern lagoon outlet to the sea. On recently emerged islands, mangrove species are being planted by local people for reclamation purposes, but these will be cut again once the soil has stabilized Plate 13 and 14. Elsewhere, cutting of mangroves for brushwood (fishing) and other purposes continues unabated. Thus, human impact on the mangroves gives reason for concern, the main threat being the cutting of twigs and branches for the construction of brush piles used in traditional fishing which is widely practised in the lagoon and adjacent brackish water swamp. This type of fisheries accounts for more than 80% of the total catch of fish and shellfish from the lagoon. More than 750 brush piles are operated annually and about 250 families derive their income from it (Amarasinghe, 1988). Over-exploitation of the mangroves may therefore not only have adverse effects on the ecology and productivity of the lagoon but also directly affect the generally poor fisher folk.

The floristic composition of the true mangrove and mangrove associates plant community includes 11 common species of plants: *Aegiceras corniculatum , Avicennia marina, Bruguiera gymnorhyza, B.sexangula, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Rhizophora apiculata, R.mucronata, Sonneratia caseolaris* and the spiny-leaved scrub *Acanthus ilicifolius*. None of these species are endemic to the area and none can be listed as endangered. However, the extent of mangrove formations in Sri Lanka is very limited indeed and the preservation of this vegetation type for conservation reasons (in addition to its protective, productive and buffering function) is fully justified. The distribution of mangroves is given in Fig. 28. Structural vegetation profiles at selected sites are given in Fig. 29. The most luxuriant and least disturbed mangals (areas covered with mangroves) occur at the mouth of the Dangugam Oya, where *Sonneratia caseolaris* (kirala) grows up to a height of 15 m.

In Table 5 a summary is given of the various uses of mangrove species in the project area.

7.2.3 Lagoon outlet

More than ten islands of different sizes, mostly covered with mangrove vegetation, are situated in the lagoon outlet to the sea, see Fig. 30. The main mangrove species is *Rhizophora mucronata, mixed with a few scattered R.apiculata, Avicennia spp.*, and *Bruguiera spp.* Vegetation profiles are also given in Fig. 30.

These mangrove islands play an important role in controlling the outflow and inflow of lagoon and sea water, which determines the lagoon ecosystem and its

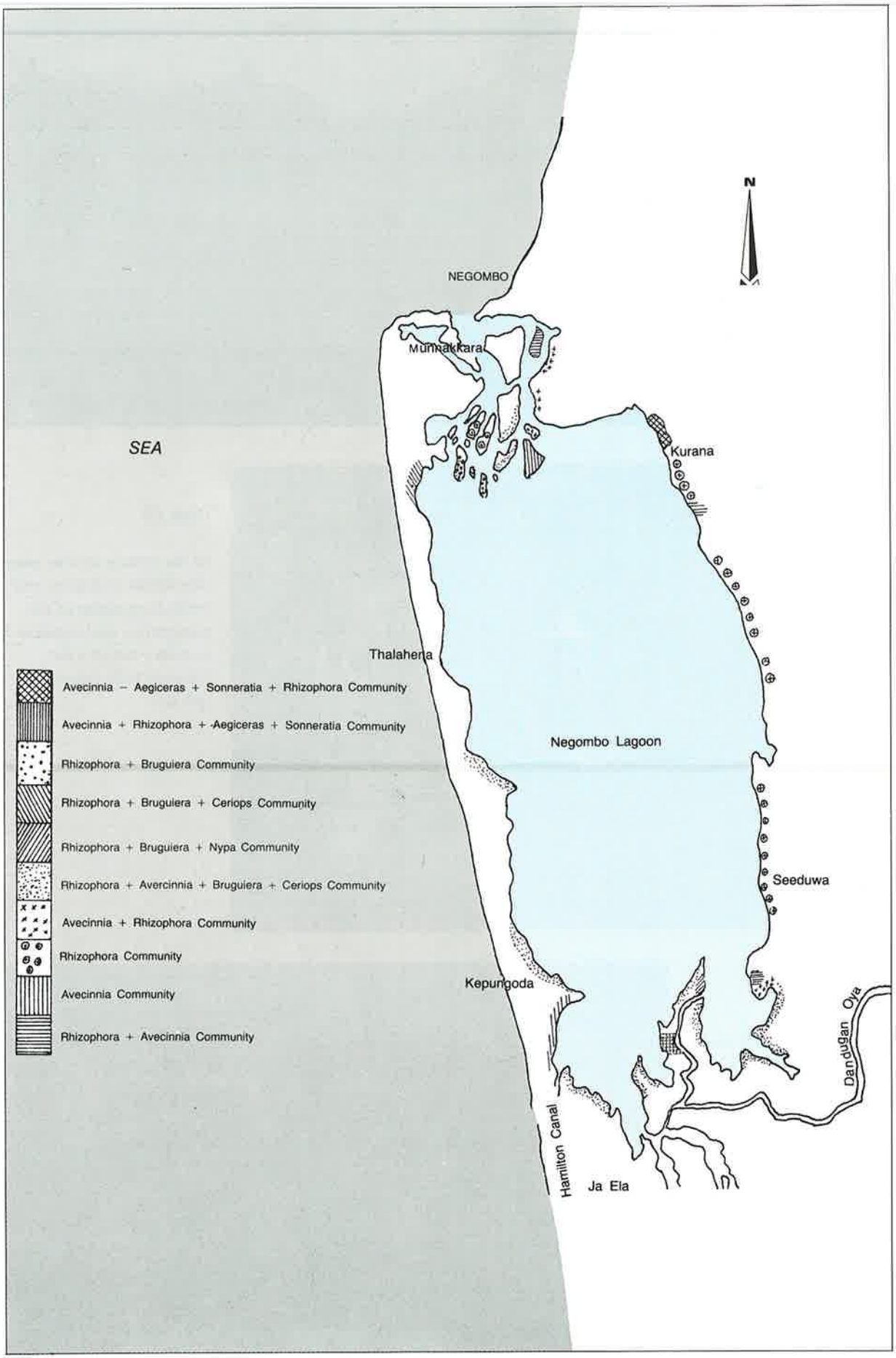


Fig. 28 Distribution and community structure of mangroves at Negombo Lagoon (Herat, 1990)

Plate 11

The dominant vegetation of the marsh consists of grassesand sedges with patches of shrubs and trees. Note: theinvasive, introduced plant, Anona glabra in the foreground.

Plate 12

In the transition zone swamp vegetation of grasses and reeds have replaced cut mangroves, and continue to providea nursery for commercially important species.

Plate 13

Mangroves colonizing sand shoals are protected and nurturedas the first step toward landfill.

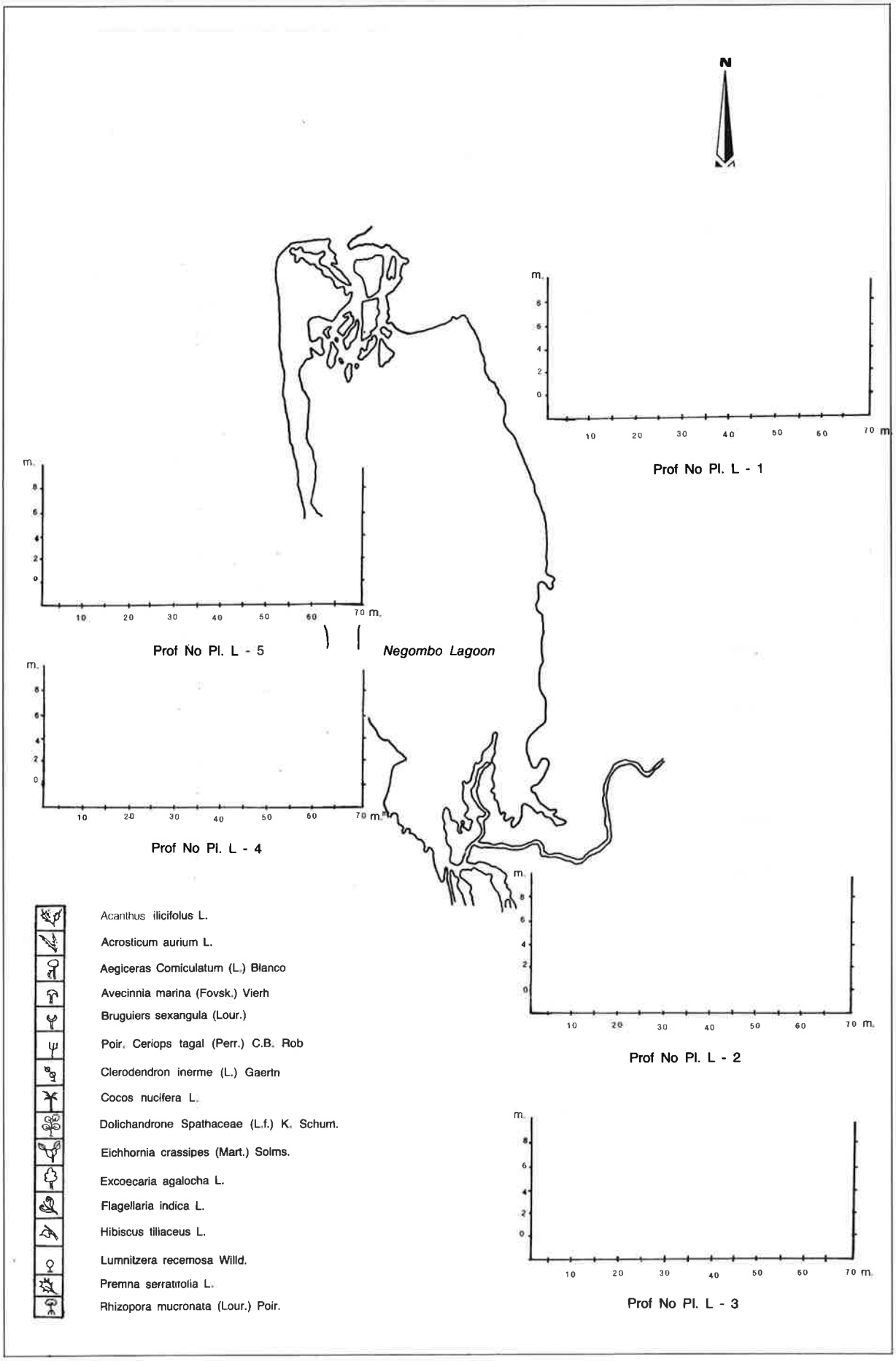


Fig. 29 Mangrove and associated vegetation profiles at Negombo Lagoon (Herat, 1990)

productivity. On the larger islands, mangroves have been cut for settlements and this process is still continuing. However, newly emerging islands are now being planted with mangroves (*mainly Rhizophora spp.* and *Avicennia spp.*, the former being the pioneer invader on such islands). Planted patches are small however and once the new "island" has stabilized, the mangroves are cut for settlement. This process is taking place at an alarming rate (see Plate 13), gradually blocking the in- and outflow of sea- and lagoon water, which eventually could have serious consequences for the fisheries in the lagoon.

7.2.4 Conclusion

The mangrove and brackish water swamp vegetation in the project area are of great importance in maintaining the ecological balance, nutrient flow and productivity of the lagoon and adjacent sea and swamp areas. Apart from its function as a nursery chamber for fish and shellfish species, and its role as wildlife habitat, it supports the important fisheries in the lagoon and adjacent sea, and supplies detritus and nutrients.

Mangroves also have an important buffering function, acting as silt traps, controlling siltation of sensitive sea grass beds (see A-9), filtering pollutants from freshwater runoff and minimizing adverse effects on the important life forms in the lagoon. Mangroves also stabilize the shores of the lagoon against wave action. Finally, their importance for research purposes, in particular in a country where the distribution of this vegetation type is very limited, cannot be denied.

Understandably, the mangroves of the Negombo Lagoon area have been effected, since time immemorial, by a variety of human activities. Recent impacts have resulted from coconut cultivation, tourism development (hotels at lagoon shores), settlements, urban expansion (Negombo township), industrial development (east lagoon shore), and increased levels of traditional uses, in particular brush pile fishing. Consequently, the once continuous mangrove belt along the entire lagoon shores has now been reduced to a few areas in the north and south of the lagoon (Figs. 28, 29 & 30). Further depletion of mangroves would no doubt have adverse effects on the lagoon ecosystem and on its high productivity. Total protection of the remaining mangrove stands appears the only option, as present levels of traditional uses are no longer sustainable. However, total protection would mean that substitute products or commodities will have to be developed on the short run in order to avoid negative effects on the people's livelihood.

7.3 Negombo Lagoon seagrasses

The sea grass beds of the Negombo Lagoon were studied by NARA (Jayasuriya, 1990), the following being a summary of findings.

Twenty-two percent of the Negombo Lagoon 's 3,200 ha is grown over with seagrass. These sea grass beds are very sensitive to turbidity and cannot withstand excessive siltation. These grasses are highly productive (dry weight yields of 2,000 kg/ha are not exceptional) and provide habitat for a variety of aquatic organisms, including many commercially important species.

Four major sea grass genera and seven sea grass species have been recorded in the Negombo Lagoon. Their distribution ranges are given in Fig. 31. Of the recorded species (Fig. 32), two were recorded for the first time in Sri Lanka, i.e. *Halodule pinifolia and Halophila minor. Potamogeton pectinatus* and *Ruppia maritima* appear to undergo major seasonal changes: they can adapt to low salinity levels and in fact reach their maximum height during the rainy season when the salinity of the lagoon water is lowest. Consequently, they occur near places where freshwater from rivers enters the lagoon. It is a common belief among fisherfolk that shrimps will breed only in the dense mats formed by these sea grasses. They also report a considerable decline in area of these beds. As for the distribution of Ruppia, this was confirmed by comparison of present and previous survey records. It could be the effect of increased silt loads of river waters entering the lagoon, see B-1. However, the *Potamogeton beds* seem not to have existed at the time of earlier surveys. This could mean that a general decline of salinity levels in the lagoon is taking place, probably as a result of small-scale reclamation activities at the lagoon outlet gradually inhibiting the entrance of sea water into the lagoon. If these trends of increased siltation and decline in salinity continue, the ultimate effects on fish and prawn productivity in the lagoon would be clearly disastrous.

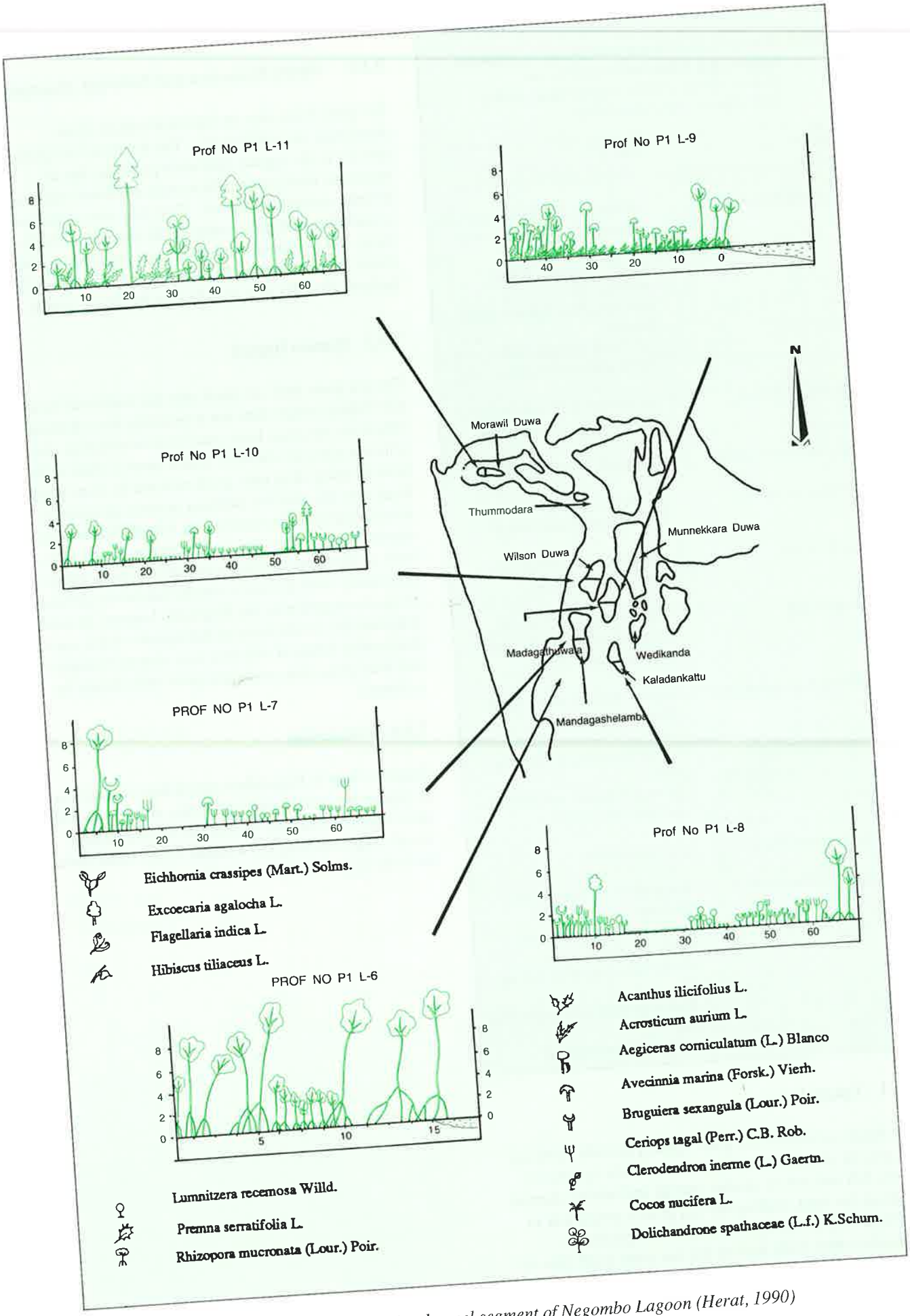


Fig. 30 Mangrove profiles on islands in the channel segment of Negombo Lagoon (Herat, 1990)

Table 5 **Human Uses of Mangrove Species in Negombo Lagoon and Adjacemt Swamp lands. Source: Herat (1990), Amarasinghe (1988), Samarakoon and Pinto (1986).**

Species	Use
Avicennia marina	webbing in fish traps, brush pile fishing, dug-out canoes, boat fittings, masts, bedsteads, drums, mallets, rice mortars, chairs spoons, spade handles, fuelwood, dyeing (bark), small-scale reclamation
Acanthus ilicifolius	lye derived from ash used in soap making, medicinal use
Aegiceras corniculanum	fuelwood, hut construction
Acrosticum aureum	roofing (atap), thatching, fishing screens and fences
Bruguiera ssp.	fuelwood, poles, brush pile fishing medicinal use
Ceriops tagal	webbing for fish traps, fuel, tannin, dye for coloring and preserving nets poles
Dolichandrone spathaces	saddles, wooden shoes, flots, fibre
Excoecaria agallocha	fish poison (latex), carpentry, flots poles, outriggers, sail struts, oars parts of canoes
Lwnnitzera racemosa	fuelwood, poles
Rhizophora mucronata	house posts, frames, screens (fishing), masts, fuelwood, charcoal, bows, tanning for the preservation of fishing nets, leather tanning, hair and pottery dye, small-scale reclamation

7.3.1 Epiphytes

The blades of certain sea grass species provide substrate for growth of other tiny plants and animals (epiphytes). Many fish and prawn species (larvae and adults) depend on these for food, making the sea grass a major link in the food web of the lagoon. Other fish species, i.e. siganids (rabbit fish) feed on the sea grass itself (See A-9, Fig 52).

7.3.2 Shore Protection and Pollutant Absorption

Sea grass beds play an important role in shore protection and stabilization. The dominant sea grass species in the lagoon, *Halodule pinifolia*, has an extensive root system which traps and binds sediment thereby stabilizing the soil. They may also absorb and accumulate pollutants entering the lagoon in which case these will be cycled through the sea grass based food chain. Recent findings from Indonesia (Nienhuis, 1986) indicate that this may also be true for heavy metals.

7.3.3 Human Impact

The sea grass beds are ideal sites for traditional brush pile fishing which does not necessarily have detrimental effects on sea grass beds, provided the numbers and size of brush piles are checked. Much harm is done to these beds by using drag nets, push nets and by trawl fishing. Drag nets are used for catching prawns, grouper fry and ornamental fish, the latter being in high demand for the export market. Very serious destruction of sea grass beds results from digging polychaete worms which are commonly used as feed in shrimp hatcheries presently being developed near the Negombo Lagoon. In order to maintain the productivity of the lagoon waters, such destructive forms of resource uses should be stopped and total protection of the sea grass beds should be enforced.

7.3.4 Conclusion

Seagrass beds in Negombo Lagoon have a critical role in supporting ecosystem functioning and serves as the most important nursery area in the Muthurajawela marsh-Negombo Lagoon wetland. Every effort should be made to protect this vegetation.

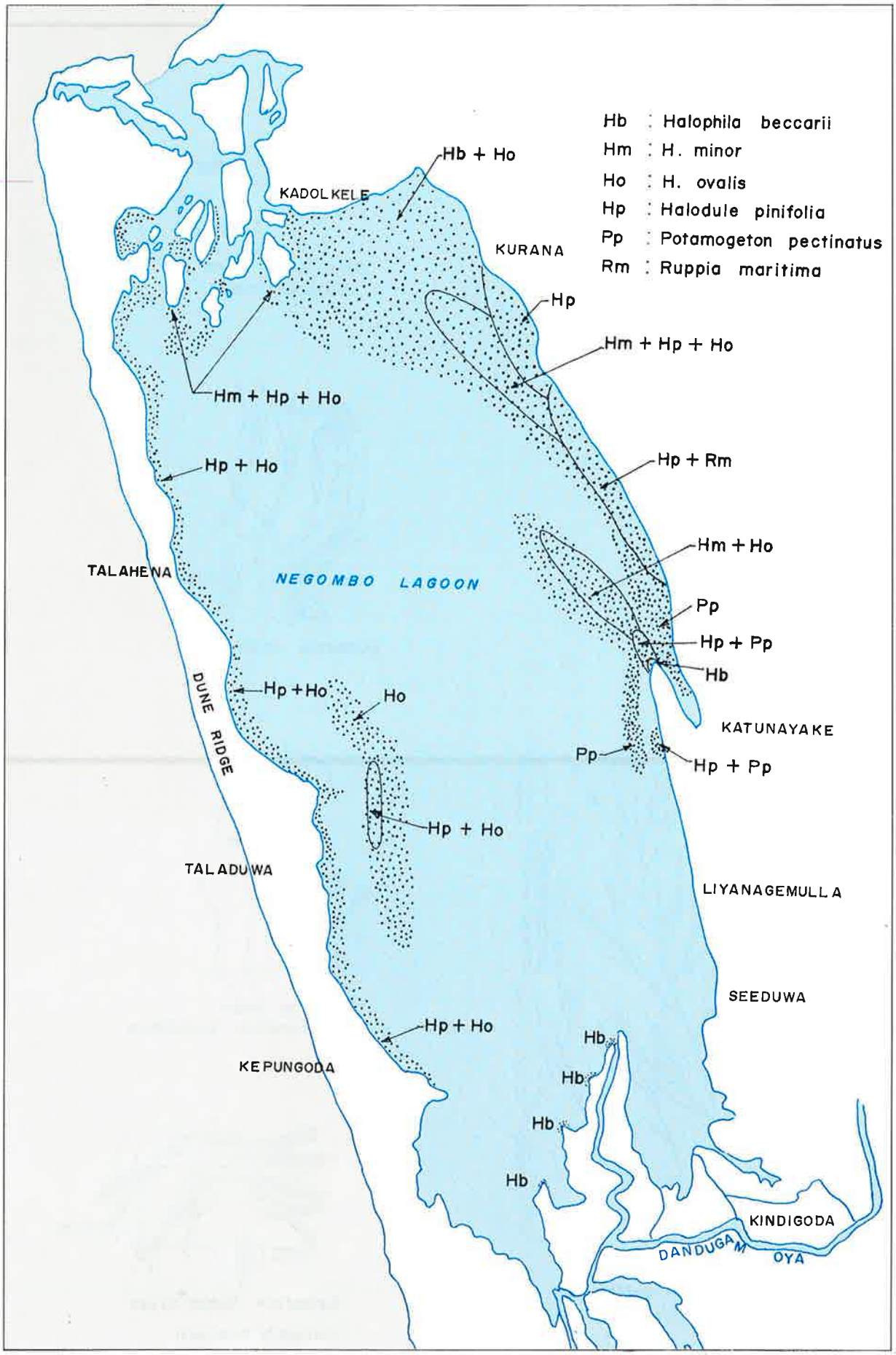


Fig. 31 Seagrass composition and distribution in Negombo Lagoon (Jayasuriya, 1990)

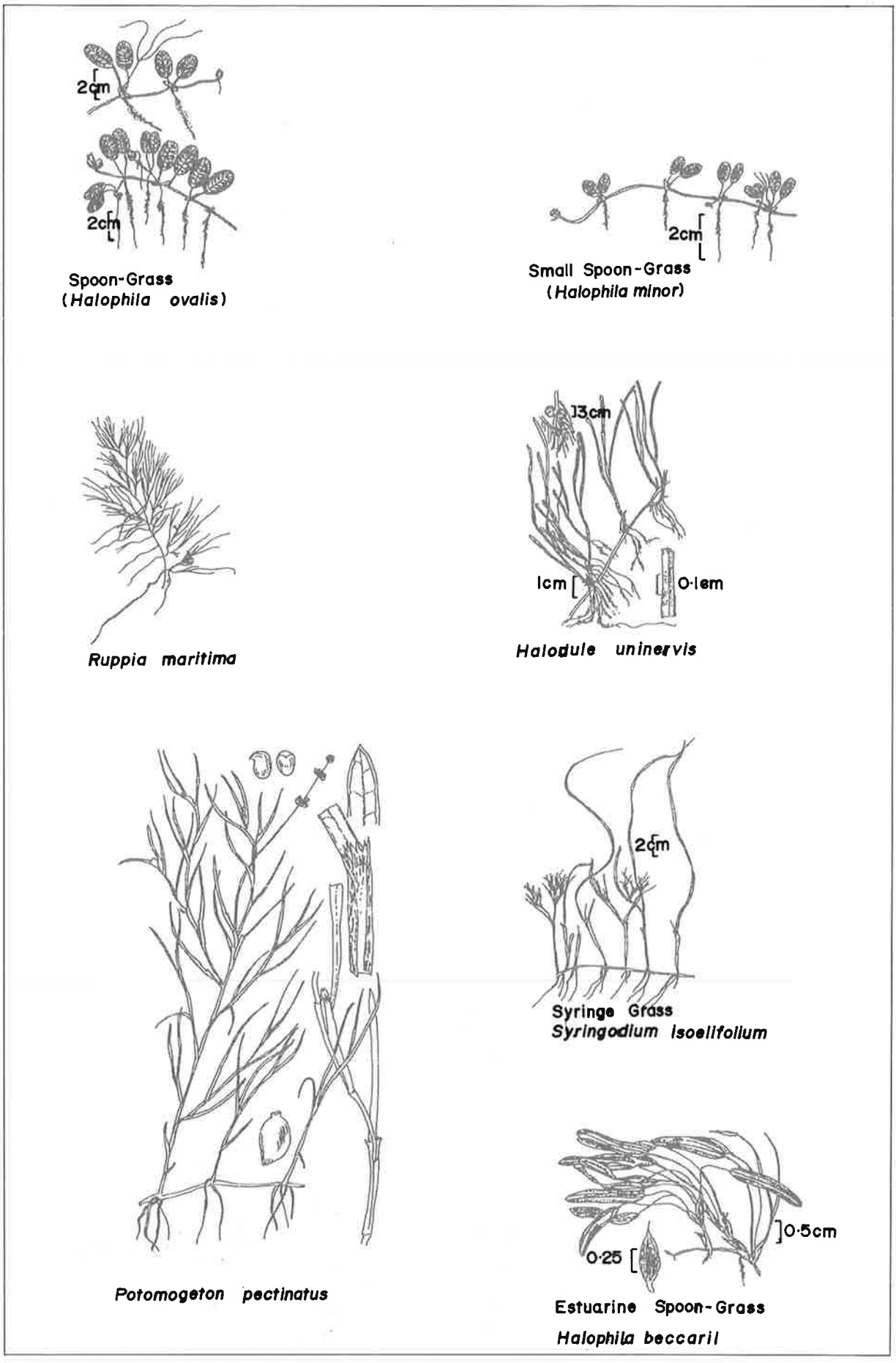


Fig. 32 The common seagrasses of Negombo Lagoon (adopted from Jayasuriya, 1990; Fortes, 1990)

8 FAUNA

The fauna were studied by Karunaratne (1990): mammals, reptiles, amphibians, butterflies and dragonflies; De Silva (1991) birds; Pinto (1991): aquatic organisms including fishes, zooplankton and henthic organisms at Muthurajawela abd by NARA (Jayakody, 1990). The fishes and aquatic organisms of Negombo Lagoon. The information in this section pertains mainly to Muthurajawela marsh.

Sri Lanka's fauna, influenced by the climatic, topographic and zoogeographic history of the country, shows a high degree of diversity. Almost all the general phyla are present. Taxonomical information is fairly comprehensive; ecological information, however, is scanty.

The fauna shows considerable regional variation throughout the country; the majority of endemic species is found in the wet southwestern region. For the ecological survey of Muthurajawela existing information on fauna of the wetland has been collected from literature and through search of museum collections, supplemented by observations, sampling and interviews in the field.

8.1 Mammals

Sri Lanka has a large mammalian fauna, consisting of 86 indigenous and 10 introduced, domesticated species. Of the indigenous species 31 are reported to be threatened (National Status Report on Biological Conservation, 1989). The distribution pattern of the terrestrial mammals follows very closely to that of the natural vegetation types. As with the flora, the highest diversity is found in the low and midcountry wet zone. Especially where the presence of forest cover, as is still the case in parts of Muthurajawela, allows a rich mammalian life.

In the Muthurajawela marsh-Negombo Lagoon wetland 14 families of mammals are recorded, with a total of 34 species (nearly 40% of the species in Sri Lanka). This can be considered very high, given the relatively monotonous character of the landscape, the absence of virtually all larger mammalian species, and the fact that knowledge on the status of the small mammals of the orders Insectiphora, Chiroptera and Rodentia is incomplete. The number of insectivorous bat species can be expected to be substantially higher than the recorded eight, because of the availability of large swarms of food insects in the marshes. From the point of view mammalian species diversity Muthurajawela is a very rich biotope; species are listed in Table 6. Fig. 33 shows the status of these species. Of the 34 species two are endemic to Sri Lanka: the fruit bat *Rousettes seminudes* and the toque macaque *Macaca sinica*. Six mammalian species too that are threatened in Sri Lanka are found: the painted bat *Kerivoula picta,* the slender loris *Loris tardigradus,* the otter Lutra lutra, the wild cat species *Felis viverrina and F. rubiginosa*, and the mouse-deer *Tragulus meminna*. The loris and the two cat species are strictly protected under Schedule III of Sri Lanka's Wildlife Ordinance of 1979. Felis rubiginosa is also included in the IUCN Red List of Treathened Animals, 1988.

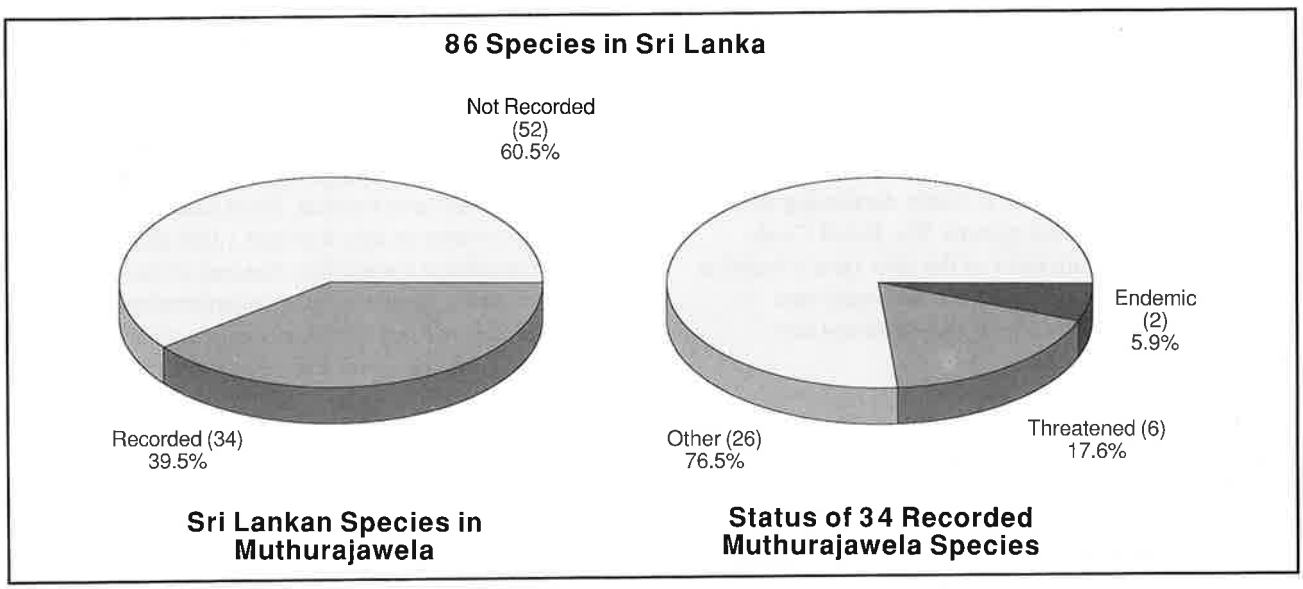


Fig. 33 Status of the mammals of Muthurajawela

TABLE 6 - STATUS OF MAMMALS RECORDED FROM MUTHURAJAWELA

SCIENTIFICNAME	ENGLISH NAME	STATUS*	REMARKS**
Suncus murinus murinus	musk shrew	VC	
S. murinus caerulescens	musk shrew	C	
Pteropus g. giganteus	fruit bat	VC	
Rousettus seminudus	fruit bat	VC	END
Rhinolopus r. rouxi	bat	C	
Hipposideros l. lankadiva	bat	C	
H. galeritus brachyotus	bat	SU	
H. bicolor ater	bat	SU	
Megaderma lyra lyra	bat	C	
Pipistrellus m. mimus	bat	C	
Scotophilus heathi heathi	bat	SU	
Kerivoula picta picta	painted bat	R	THR
Taphozous saccolaimus erassus		C	
Loris tardigradus tardigradus	slender loris	R	THR/PRO
Macaca sinica sinica	toque macaque	VC	END
Lepus nigricollis singhala	black-naped hare	C	
Funambulus palmarum favonicus	Indian palm squirrel	VC	
Hystrix indica	Indian crested porcupine	C	
Bandicota indica indica	larger bandicoot rat	VC	
Mus musculus castaneus	house mouse	C	
M. cervicolor fulvidiventris	fawn coloured mouse	VC	
Rattus rattus rattus	common rat	VC	
R. rattus alexandrinus	brown rat	SU	
R. rattus kandianus	brown rat	C	
R. norvegicus	brown rat	SU	
Lutra lutra nair	Ceylon otter	C	THR
Canis aureus lanka	Asiatic jackal	R	
Viverricula indica mayori	larger Indian civet	R	
Paradoxurus hermaphroditicus	palm civet	C	
Herpestes fuscus rubidior	brown mongoose	C	
H. smithi zeylanicus	ruddy mongoose	C	
Felis (Zibethailurus) viverrina	fishing cat	R	THR/PRO
F. (Prionailurus) rubiginosa	rusty spotted cat	VR	THR/PRO
Tragulus meminna	mouse-deer	R	THR

*E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; PRO = Protected under Wildlife Ordinance

Some of the mammals come under various forms of local threats. The black-naped hare *Lepus nigricollis* and the porcupine *Hystrix indica* are intensively hunted for food. The otter's habitat is vastly decreasing through the filling up of the canal system. The jackal *Canis aureus* and the only member of the deer family found at Muthurajawela *Tragulus meminna* are today rare because of overexploitation of the shrub and tree vegetation.

No reliable data are available concerning the minimum area required by the mammalian species to safeguard their survival in the region. For a number of them survival is secured, since they are common and/or strongly associated with human habitation. For others continuation of their regional existence is related to the size of their specific biotope: the larger, the more solitary, and the higher in the foodchain the species is, the larger its biotope requirements are.

Muthurajawela can play an important role in conservation of the red-listed Felis *rubiginosa* and the threatened *Felis viverina,* provided that enough mangrove/forest area remains. For a healthy population of these predators an area between 1,000 and 2,000 ha can be considered a minimum demand. If this demand is met the Other threatened and endangered species, such as *Rousettus seminudes, Kerivoula picta, Loris tardigradus, Macaca sinica* and *Tragulus meminna* will profit simultaneously.

8.2 Birds

Sri Lanka's rich avifauna comprises 428 species: 221 indigenous birds and 207 migrant species (including "accidentals"). Of the indigenous species 20 species (85 subspecies) are endemic; the majority of these is found in the wet southwestern region of the country. Three of the endemics are confined to the low-country wet-zone: the green-billed coucal, the ashy-headed laughing thrush, and the Legge's flower-pecker. 57 Bird species are considered vulnerable or under severe threat. These include 19 of the endemic species. All these have regularly appeared in various international lists of endangered birds.

In the framework of the present (1990/91) ecological survey, existing data on birds of the Muthurajawela-Negombo Lagoon area were collected, consolidated, and supplemented through an extensive series of field observations: regular observations in sample plots in 29 different areas, and random observations between 21 July and end of February, 1991.

8.2.1 Resident birds

Except for the endemic species and subspecies mentioned above, the indigenous avifauna is common to the Indian mainland and Sri Lanka. The great majority of the Sri Lankan avifauna has its counterparts in the lowland plains of southern India. Interchange, however, is found to be rather low.

Breeding activities of the wet-zone species commence usually in general in early March or April, and are completed before the onset of the South-Western Monsoon rains. Some species breed again when weather conditions improve in the latter part of August through October.

A large number of resident bird species have been recorded from the Muthurajawela-Negombo Lagoon wetlands. The Directory of Asian Wetlands (1989) indicates both the marshes and the lagoon as important areas for a wide variety of waterbirds, including resident and migratory species.

The present survey resulted in a list of 126 resident species: 33% of the national number. None of them is recorded as endemic; four species: the reef heron (*Egretta gularis schistacea*), the grey-headed fishing eagle (*Ichthyophaga ichthyactus plumbeiceps*), the blue-breasted banded quail (*Rallus striatus*) and the black-capped kingfisher (*Halcyon pileata*) are listed as 'threatened' in the National Status Report of 1989.

Table 7 presents the complete list of indigenous species of the area; Fig. 34 shows their status. Table 7 also indicates the 13 species of which breeding was observed continuously; it has to be noted, however, that the main breeding season was not included in the survey period (Fig. 35). In all probability, most of the resident species will breed within the Muthurajawela area.

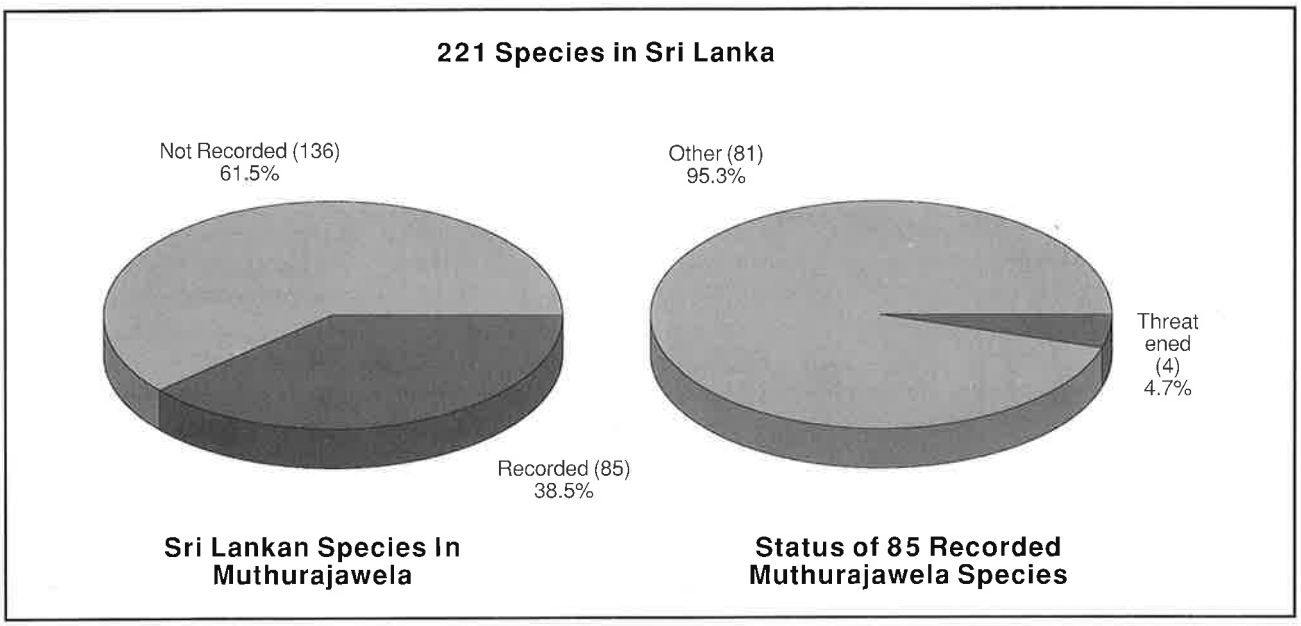


Fig. 34 Status of resident birds of Muthurajawela

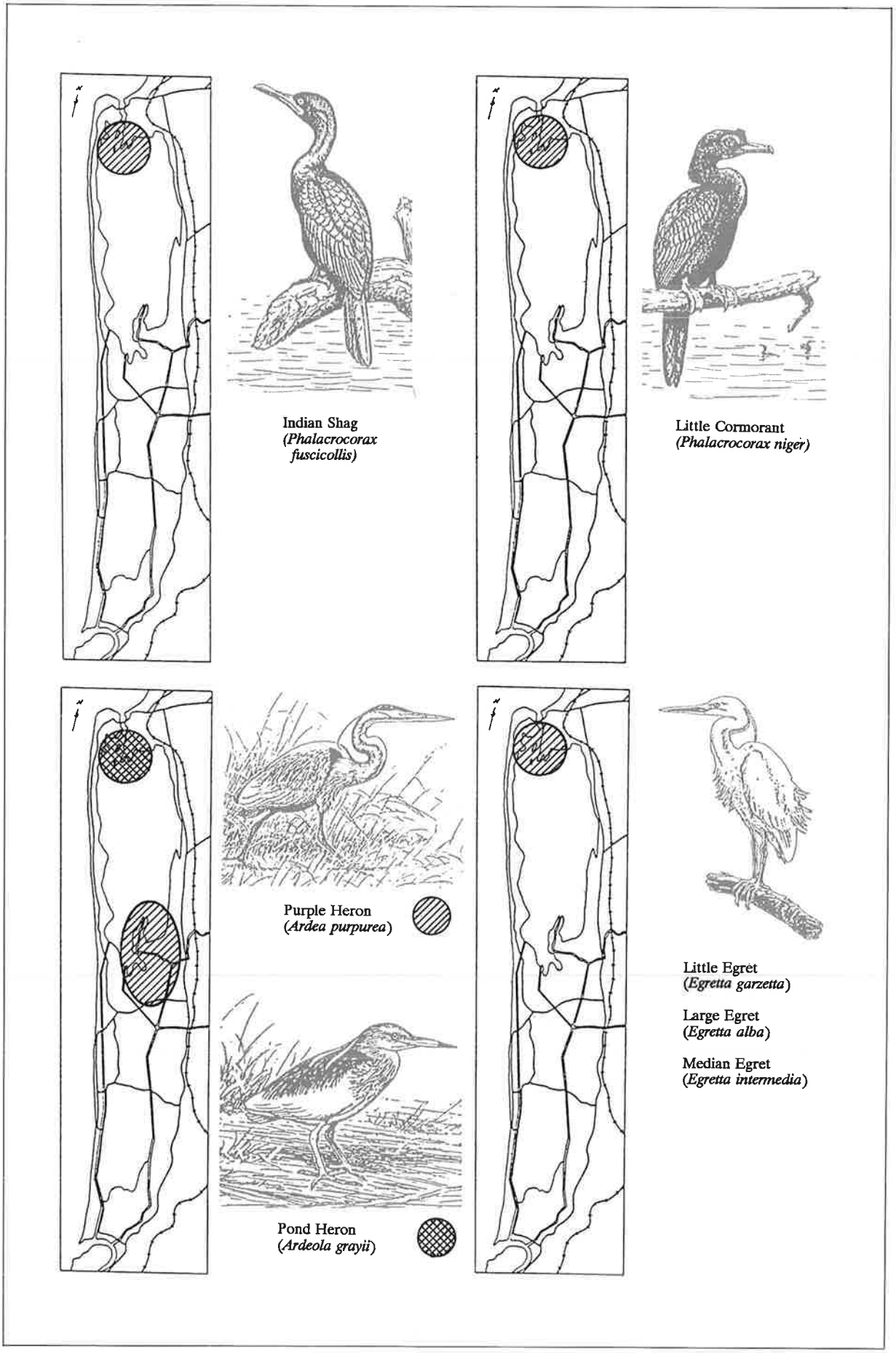
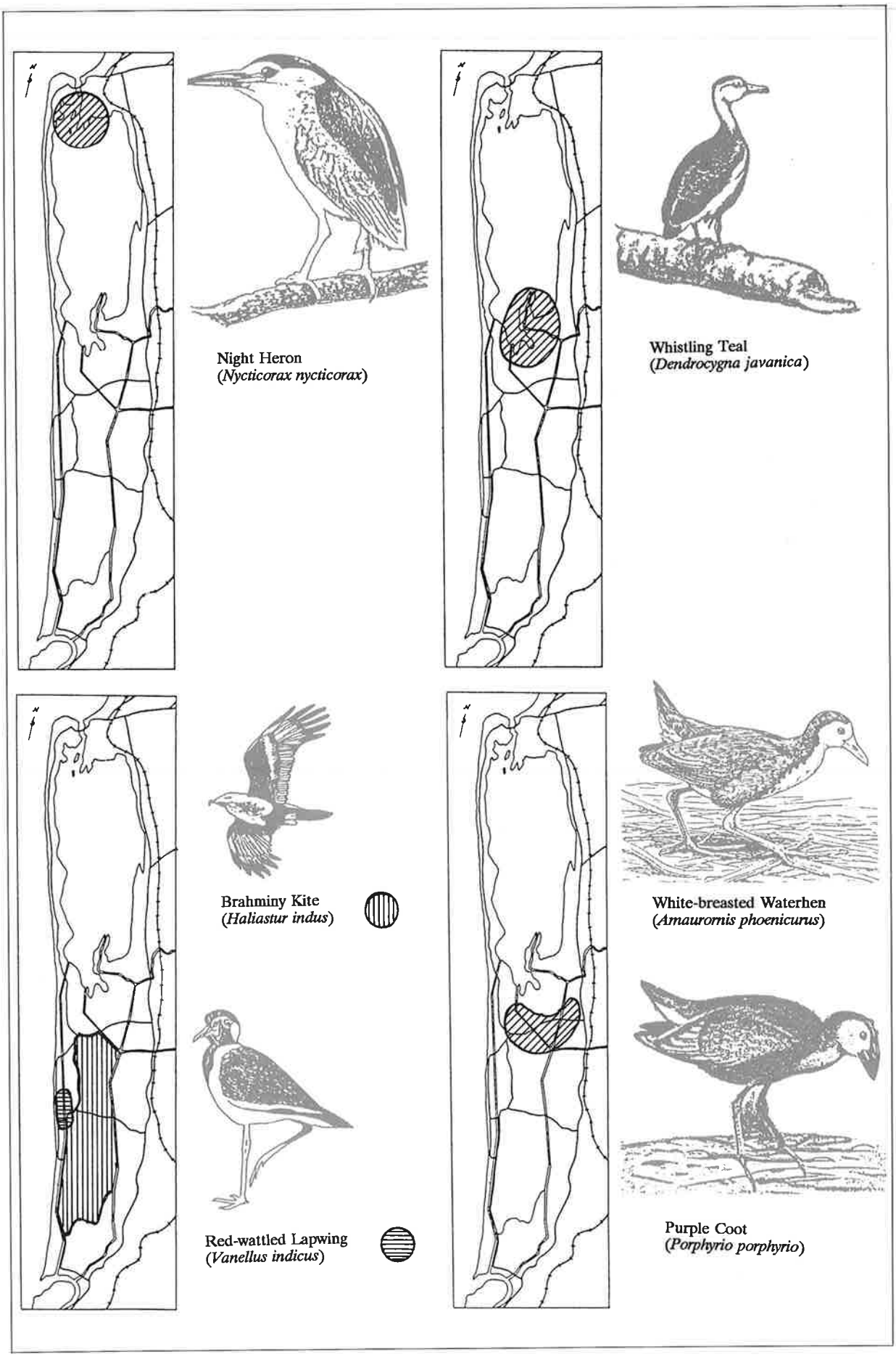


Fig. 35 Breeding locations of resident birds in the Muthurajawela marsh - Negombo Lagoon wetland (De Silva, 1990)



Contd...Fig. 35 Breeding locations of resident birds in the Muthurajawela marsh - Negombo Lagoon wetland (De Silva, 1990)

TABLE 7 - STATUS OF RESIDENT BIRDS RECORDED FROM MUTHURAJAWELA

SCIENTIFIC NAME	ENGLISH NAME	STATUS*	REMARKS**
Podiceps ruficollis capensis	Little Grebe		B
Phalacrocorax fuscicollis	Indian Shag		B
P. niger	Little Cormorant		B
Ardea cinerea rectirostris	Grey Heron		
A. purpurea manilensis	Purple Heron		B
Butorides striatus javanicus	Little Green Heron		B
Ardeola grayii grayii	Pond Heron		B
Bubulous ibis coromandus	Cattle Egret		
Egretta alba modesta	Large Egret		B
E. intermedia intermedia	Median Egret		B
E. garzetta garzetta	Little Egret		B
E. gularis schistacea	Reef Heron		THR
Nycticorax nycticorax nycticorax	Night Heron		B
Ixobrychus cinnamomeus	Chestnut Bittern		
I. sinensis	Yellow Bittern		B
Dupetor flavicollis flavicollis	Black Bittern		
Ibis leucocephalus	Painted Stork		
Anastomus oscitans	Open-bill Stork		
Threshkiornis melanocephala	White Ibis		
Dendrocygna javanica	Whistling Teal		
Haliastur indus indus	Brahaminy Kite		
Accipiter badius badius	Shikra		
Ichthyophaga ichthyaetus plumbeiceps	Grey-headed Fishing Eagle		THR
Coturnix chinensis chinensis	Blue-breated Quail		
Rallus striatus albiventer	Blue-breasted Banded Quail		THR
Amaurornis fuscus zeylonicus	Ruddy Crake		
A. phoenicurus phoenicurus	White-breasted Waterhen		B
Gallicrex cinera cinera	Kora		
Gallinula chloropus indica	Indian Moorhen		B
Porphyrio porphyrio poliocephalus	Purple Coot		B
Hydrophasianus chirurgus	Pheasant-tailed Jacana		
Vanellus indicus lankae	Red-wattled Lapwing		B
Rostratula bengalensis bengalensis	Painted Snipe		
Himantopus himantopus ceylonensis	Black-winged Stilt		
Sterna albifrons	Lesser Tern		
S. bergii velox	Swift Tern		
Streptopelia ceylonensis	Spotted Dove		
Psittacula krameri manillensis	Rose-ringed Parakeet		
Clamator jacobinus jacobinus	Pied Crested Cuckoo		
Eudynamys scolopacea scolopacea	Koel		
Centropus sinensis parroti	Common Coucal		
Otus bakkamoena bakkamoena	Collared Scops Owl		
Bubo zeylonensis zeylonensis	Brown Fish Owl		
Ninox scutulata hirsuta	Brown Hawk Owl		
Apus melba bakeri	White-bellied Swift		
Cypsiurus parvus batasiensis	Palm Swift		
Ceryle rudis leucomelanura	Pied Kingfisher		
Alcedo atthis taprobana	Common Kingfisher		
Pelargopsis capensis capensis	Stork-billed Kingfisher		
Halcyon smyrensis fusca	White-breasted Kingfisher		
H. pileata	Black-capped Kingfisher		THR
Coracias bengalensis indica	Indian Roller		
Megalaima zeylanica zeylanica	Brown-headed Barbet		
M. rubricapilla rubricapilla	Small Barbet		

* E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; B = Breeding in the area confirmed

Contd. Table 7

SCIENTIFIC NAME	ENGLISH NAME	STATUS*	REMARKS**
Dinopium benghalense psarodes	Red-becked Woodpecker		
Hirundo daurica hyperythra	Sri Lanka Swallow		
Oriolus xanthornus ceylonensis	Black-headed Driole		
Dicrurus caerulescens leucopygialis	White-vented Drongo		
Artamus fuscus	Ashy Swallow Shrike		
Acridotheres tristis melanosternus	Common Mynah		
Corvus splendens protegatus	House Crow		
C. macrorhynchos culminatus	Black Crow		
Coracina melanoptera sykesi	Black-headed Cuckoo Shrike		
Pericrocotus c. cinnamomeus	Little Minivet		
Aegithina tiphia multicolor	Common Iora		
Pycnonotus cafer haemorrhousus	Red-vented Bulbul		
P. luteolus insulae	White-browed Bulbul		
Turdoides affinis taprobanus	Common Babbler		
Terpsiphone paradisi ceylonensis	Ceylon Paradise Flycatcher		
Cisticola juncidis omalura	Fantail Warbler		
Prinia subflava insularis	Plain Prinia		
P. sylvatica valida	Large Prinia		
Orthotomus sutorius sutorius	Tailor Bird		
Acrocephalus stentoreus	Great Reed Warbler		
Copsychus saularis ceylonensis	Magpie Robin		
Saxicoloides fulicata leucoptera	Black Robin		
Parus major maharattarum	Grey Tit		
Anthus novaseelandidae malayensis	Indian Pipit		
Dicaeum erythrorhynchos ceylonense	Tickell's Flowerpecker		
Nectarinia zeylonica zeylonica	Purple-rumped Sunbird		
N. lotenia lotenia	Loten's Sunbird		
Passer domesticus indicus	House Sparrow		
Lonchura striata striata	White-backed Munia		
L. punctulata punctulata	Spotted Munia		
L. malacca malacca	Black-headed Munia		

* E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; B = Breeding in the area confirmed

8.2.2 Migrant birds

Most of the migrant species arrive in Sri Lanka towards the end of August and leave the following year during April and May. Waders, ducks and wagtails are the main migrant groups, and they are generally associated with wetland habitats.

The main migratory routes of northern, non-breeding birds, spending the cold weather period in Sri Lanka, are shown in Fig. 36. Sri Lanka is at the extreme south west terminus of the Western and Eastern Trans-Indian Routes, and possibly also of the Andaman Islands Route.

The Western Route has its beginnings in western Siberia and the countries to the west and northwest of the Himalayas (Eastern Europe and Western Asia). This route is taken by many thousands of ducks, waders and passerines; they approach Sri Lanka across the Gulf of Mannar and make a land-fall on the western coasts, mainly north of Mount Lavinia. Eastern Asian species and those that breed beyond the Himalayas (Eastern Siberia, Mongolia) arrive, in even greater numbers, by the Eastern Route, together with species from countries to the east of India. They cross Palk Street into the Jaffna Peninsula of northern Sri Lanka, and spread all over the country.

Some of the far-eastern migrants and vagrants, such as the Philippine shrike (*Lanius cristatus lucionensis*) and the black-capped kingfisher (*Halcyon pileata*) are assumed to travel to Sri Lanka via the Andaman Islands.

A special group of migratory birds are the "Ocean Wanderers": sea-birds that roam the vast expanses of the ocean between the Indian continent and the Antarctics. Many of them visit, from time to time, Sri Lanka's shores and coastal wetland sometimes by accident (albatrosses, shearwaters, storm-petrels, tropic-birds, boobies, gannets, frigate-birds) and sometimes as regular visitors (gulls and terns).

The survey work in the Muthurajawela-Negombo Lagoon resulted in a list of 40 species 38 migrants and

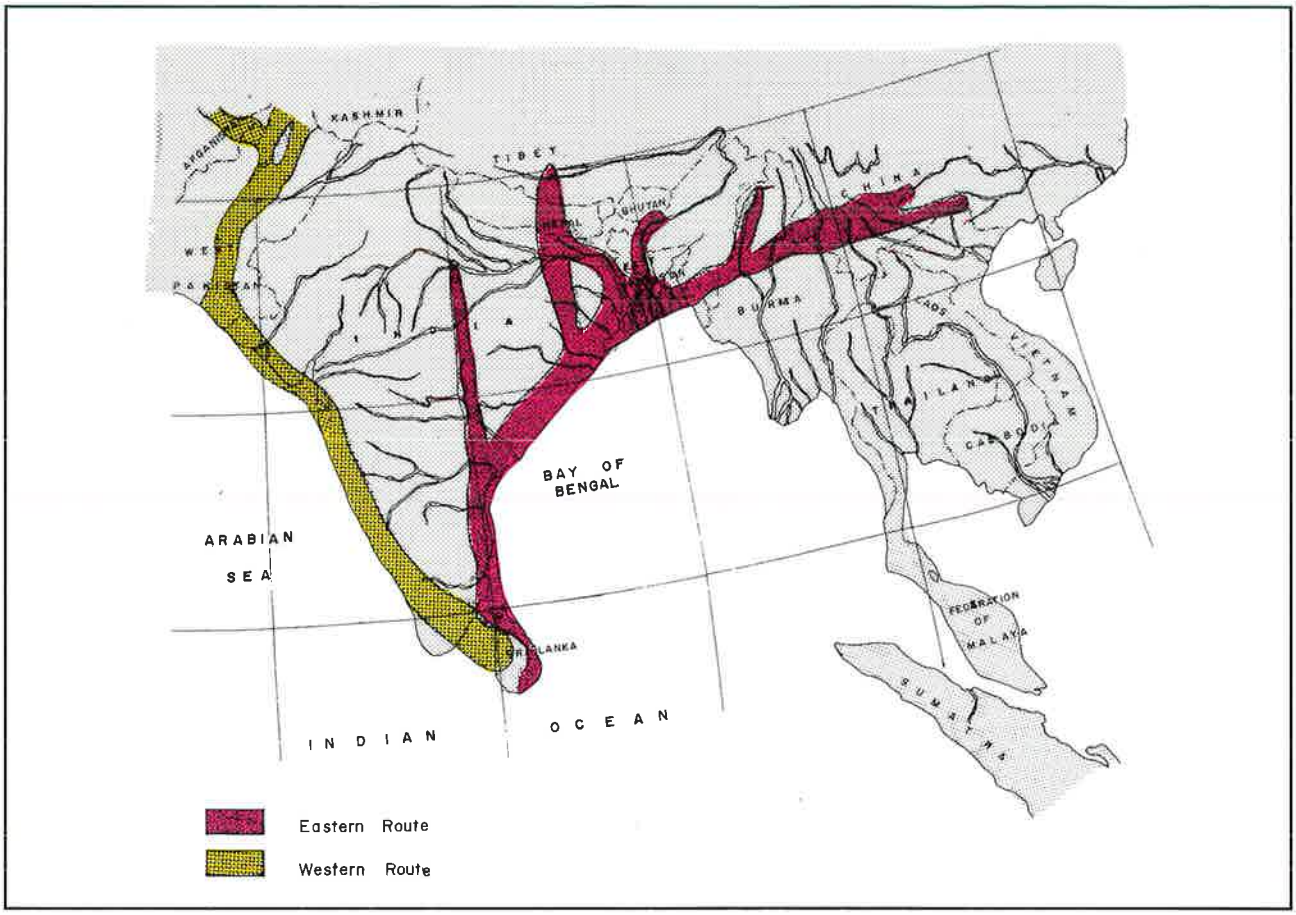


Fig. 36 Routes of migratory birds to Sri Lanka (Phillips, 1980)

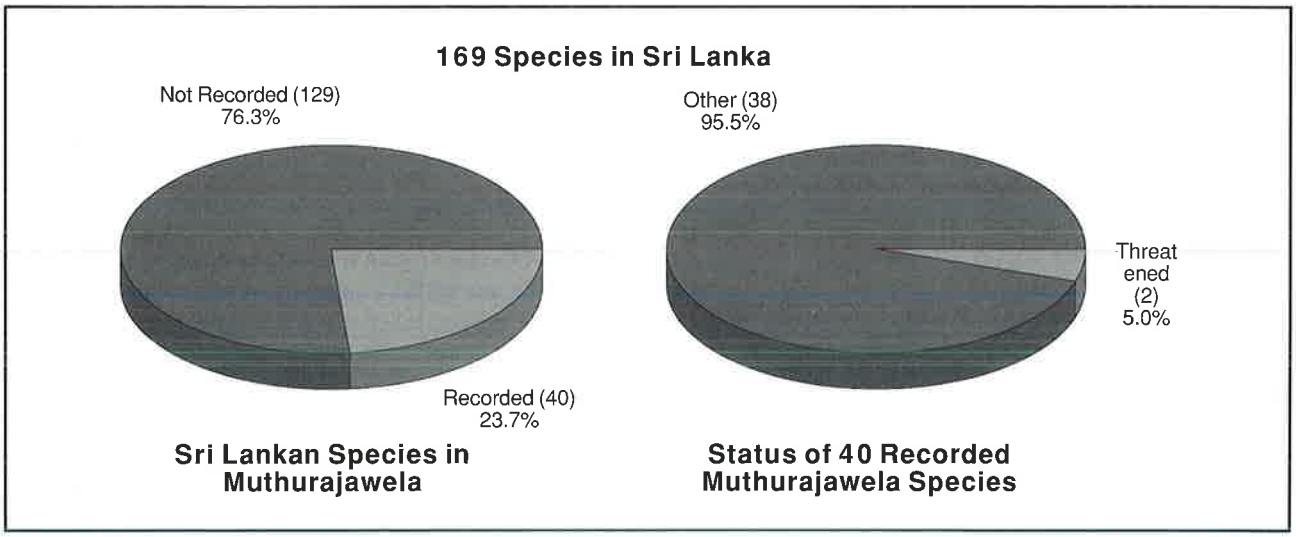


Fig. 37 Status of the migratory birds of Muthurajawela

two accidental stragglers, which amounts to 23% of the national number of species.One species is reported to be threatened: the Common Tern (*Sterna hirundo tibetana*), but according to earlier surveys, quoted in the Directory of Asian Wetlands, the endangered Indian cormorant (*Phalacrocorax carbo sinensis*) is also found in the area, however, it was not recorded during the present survey. Table 8 presents the list of migratory species; Fig. 37 shows their status, while Fig. 38 shows their distribution.

8.2.3 Habitats

The many canals and waterways in the area provide suitable habitat for numerous species of small to medium-sized fish, which are food for a variety of piscivorous bird species. The variety in water depth allows a variety of feeding habits: the plunge-divers such as the kingfishers show preference for deeper waters, the stalkers such as the herons and egrets favour shallow waters, and the shags and cormorants pursue their prey at any depth.

The extensive undisturbed marshes of the area are the habitat of a wide range of insects. They feed a broad spectrum of insectivorous and omnivorous birds. Species found in considerable numbers here include warblers, prinias, swallows and shrikes.

Frugivorous species such as the bulbuls, mynahs and barbets, occur primarily in the more cultivated areas and tend to move around according to the availability of food resources. Nectar feeders, such as the sunbirds, are common throughout the whole of the marsh and mangrove areas.

Marshy areas and especially mudflats are important feeding grounds for waders, both the short and the long-billed varieties: they probe in the ground for burrowing worms and larvae. This group comprises many winter migrants from northern areas (plovers, whimbrels, sandpipers and the like), and also resident stilts.

A number of coots, moorhens and jacanas feed primarily on the aquatic vegetation of the wetlands. An interesting specialistic feeder is the open-bill stork (*Anastomus oscitans*), that is present in reasonably large numbers in the Bopitiya and Uswetikeiyawa marshlands: its bill is specially adapted for feeding on molluscs, including aquatic snails.

On the basis of the observations on species, their numbers and their feeding and breeding biotopes, it is evident that some areas of the Muthurajawela-Negombo Lagoon wetland are of crucial importance to the avifauna particularly the Northern part of the Negombo Lagoon (mangrove islands, open waters and seagrass beds), the lagoon/swamp transition area, and the Muthurajawela central region (Bopitiya and Uswetkeiyawa areas). These areas are dealt with in greater detail below.

The northern lagoon area has been found to be of prime importance to wintering sea-gulls and terns, both migrant and resident. The mudflats and beaches of the mangrove islands in the northern sector of the lagoon are used as roosting and resting sites by two species of gulls and several species of terns. As more than 2,000 individuals winter in this region, it is now evident that this sector is arguably the most important wintering habitat for seabirds in the Wet Zone. Most of these birds capture their small foodfish in the lagoon itself, but many also seek food in the sea nearby.

In addition the lagoon is a habitat of some importance for migratory waders, especially for wintering whimbrels (*Numenius phaeopus*). The trees (mainly coconut) on the waterfront at "Kurusu-Palliya" island and, to a lesser extent, at Munnakara, are used for nesting by several species, notably cormorants and herons.

The lagoon/swamp transition area is of great importance, since it supports a wide variety of avifauna. This area contains large concentrations of whistling teals (*Dendrocygna javanica*) and it has also a plentiful population of pied kingfishers (*Ceryle rudis*) which probably breed in the area, since juveniles were observed regularly. The purple heron (*Ardea purpurea*), observed in some numbers, and the whistling teal have also been reported to breed here. Furthermore, the sub-area supports a fairly large population of the purple coot (*Porphyrio porphyrio*).

The Muthurajawela central region (Bopitiya and Uswetikeiyawa swamps) are largely marshy grasslands with waterways and occasionally loftier vegetation. These areas are the haunts of several insectivorous and omnivorous birds. Among the common species frequenting the area are the fantail warbler (*Cisticola juncidis*), the plain and large prinias (*Prinia subflava and P. sylvatica*), the red-vented and the white-browed bulbuls (*Pycnonotus cafer and P. luteolus*) and many others. Large numbers of the piscivorous large, median and small egrets (*Egretta alba, E. intermedia* and *E. garzetta*), the purple heron (*Ardea purpurea*) and the little cormorant (*Phalacrocorax niger*) are also present, along with the purple coot (*Porphyrio poliocephalus*) and the whistling teal (*Dendrocygna javanica*).

Other interesting species of the central marsh area include the blue-breasted quail (*Coturnix chinensis*), the chestnut bittern (*Ixobrychus cinnamomeus*) and the Indian roller (*Coracias bengalensis*). Furthermore these areas are important habitats for raptors, including the brahminy kite (*Haliaster indus*), the booted eagle (*Heiraaetus pennantus*) and the shikra (*Accipiter badius*).

TABLE 8- MIGRATORY BIRDS RECORDED FROM MUTHURAJAWELA

SCIENTIFICNAME	ENGLISH NAME	STATUS*	REMARKS**
Phalacrocorax carbo sinensis	Ingian Cormorant		THR
Ardea goliath	Goliath Heron		SU
Gorsachius m.melanolophus	Mallay Bittern		
*Anas acuta*Pintail			
A. querquedula	Gargany		
Circus macrourus	Pale Harrier		
C. aeruginosus aeruginosus	Marsh Harrier		
Heiraaetus pennantus	Booted Eagle		
Rallus eurrizonoides amauroptera	Banded Crake		
Pluvialis aquatarola	Grey Plover		
P. Dominica fulva	Eastern Golden Plover		
Charadrius mongolus atrifrons	Lesser Sandplover		
C. leschenaultil	Large Sandplover		
Numenius phaeopus phaeopus	Whimbrel		
Tringa totanus eurithinus	Redshank		
T.nebularia	Greenshank		
T.glareola Wood sandpiper			
T.stagnatilis	Marsh sandpiper		
T.hypoleucos hypoleucos	Common sandpiper		
Capella stenura	Pintail Snipe		
Calidris feruginea	Curiew Sandpiper		
Larus fuscus	Lesser Black-backed Gull		
L.brunnicephalus	Brown-headed Gull		
Chlidonias hybrida indica	Indian Whiskered Tern		
Gelochilidon nilotica nilotica	Gull-billed Tern		
Hydroprogne caspia caspia	Caspian Tern		
Sterna hirundo tibetana	Common Tern		THR
S.bengalensis	Lesser Crested Tern		
S.repressa	White-cheeked Tern		SU
S.sandvicensis	Sandwich Tern		
Merops Philippinus Philippinus	Blue-tailed Bee-eater		
Pitta brachyura brachyura	Indian Pitta		
Hirundo rustica gutturalis	Eastern Swallow		
Lanius cristatus cristatus	Brown Shrike		
Mascicapa latirostris	Brown Flycatcher		
Terpsiphone paradisi paradisi	Paradise Flycatcher		
Acrocephalus dumetorun	Blyth's Reed Warbler		
Anthus novaeseelandidae richardi	Richard's Pipit		
Motacilla flava	Grey-headed Yellow Wagtail		
M. caspica caspica	Grey Wagtail		

*E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; PRO = Protected under Wildlife Ordinance

The marshy grasslands found throughout the Muthurajawela wetland are the hunting/feeding grounds for two species of migrant raptors, the harriers *Circus macrourus* and *C. aeruginosus*. These two species feed mainly on the small rodents (especially burrowing rats) which are plentiful in this habitat. The population density of harriers in these area reaches as high as 35 per sq km-probably the highest population density for these birds in Sri Lanka. The Muthurajawela marsh, therefore, probably is one of the most important habitats for harriers wintering in Sri Lanka.

On the basis of information obtained during the present survey, the areas that are most important as bird habitat are: the northern segment of Negombo Lagoon, the transition zone between the marsh and the lagoon, and the central area of the marsh north of Jayasuriya road.

8.2.4 Arrival and departure

Table 9 gives the probable times of arrival and departure of the migrants. The peak months were September to January, (Table 9).

8.3 Reptiles

The Sri Lankan reptilian fauna comprises two species of crocodiles, 5 turtles, 3 tortoises, 92 snakes (including 13 sea-snakes), 21 geckos, 16 lizards, 2 monitors and 21 skinks. Of these 162 species, 72 (44%) are endemic and 94 (58%) are considered threatened. Most of the endemic species are restricted to special habitats within narrow geographic ranges.

Table 9 Monthly record of arrival and departure of migratory birds

Bird names	Jan	Feb	Mar	Aor	May	June	July	Aug	Sep	Oct	Nov	Dec
Indian Cormorant												
Goliath Heron												--
Malay Bittern												
Pintail											--	
Gargany											--	
Pale Harrier	--											
Montague's Harrier											--	
Marsh Harrier										--		
Booted Eagle												
Banded Crake									--			
Grey Plover									--			
Golden plover									--			
Lesser Sandplover									--			
Greater Sandplover										--		
Whimbrel										--		
redshank										--	--	
Greenshank										--		
Wood Sandpiper												
Marsh Sandpiper												
Pintail Snipe												
Curlew Sandpiper								--				
Lesser Black-backed Gull												--
Brown-headed Gull												--
Whisklered Tern									--			
Gull-billed Tern										--		
Caspian Tern												--
Common Tern	--											
Lesser Crested Tern	--											
White-cheeked Tern	--											
Samdwich Tern									--			
Blue-tailed Bee-eater												--
Indian Pitta											--	
Eastern Swallow											--	
Brown Shrike												--
Brown Flycatcher											--	
Paradise Flycatcher											--	
Blyth's Reed-warbier											--	
Richard's pipit										--		
Grey-headed Yellow Wagtail											--	
Grey Wagtail										--		

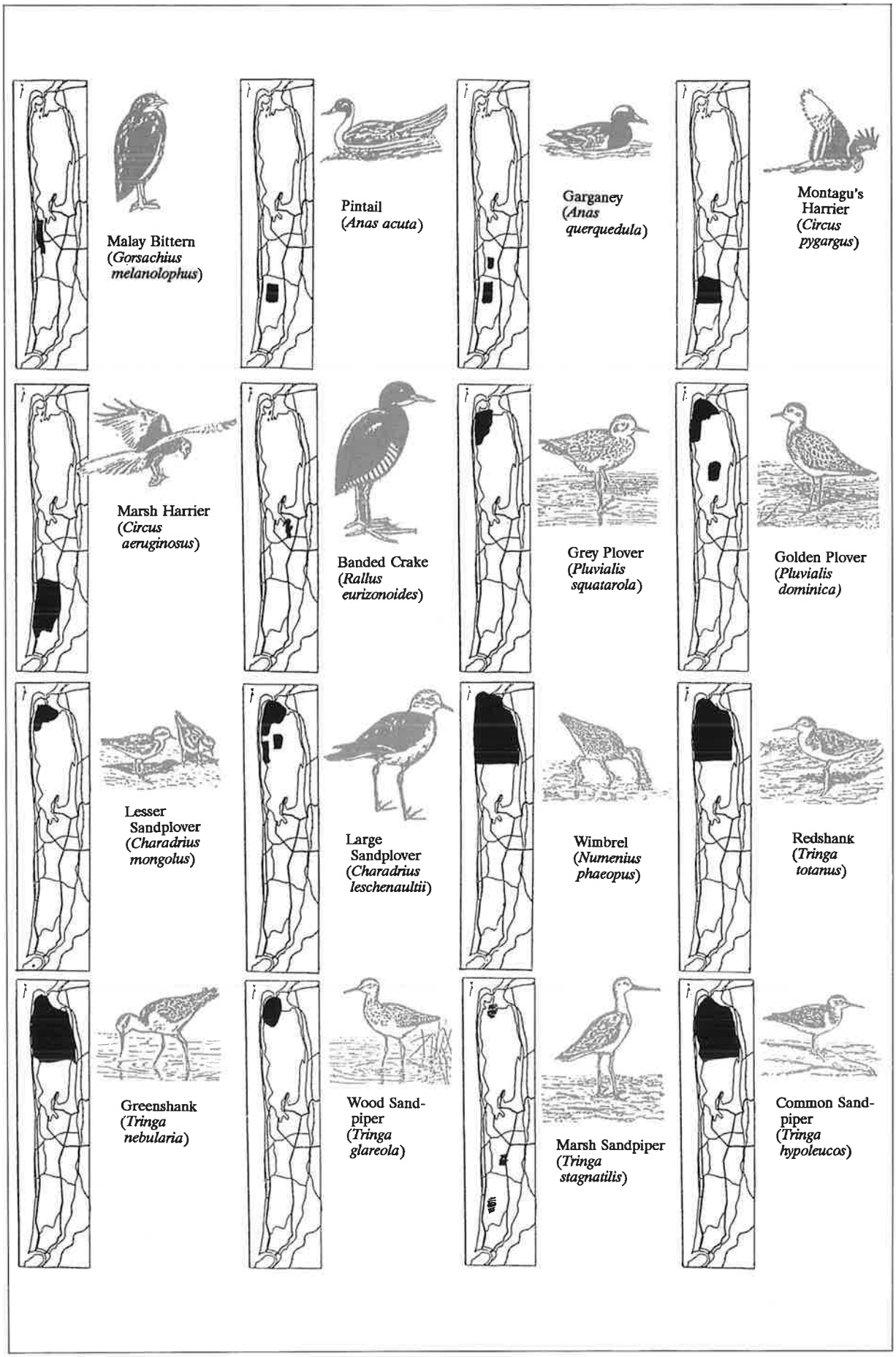
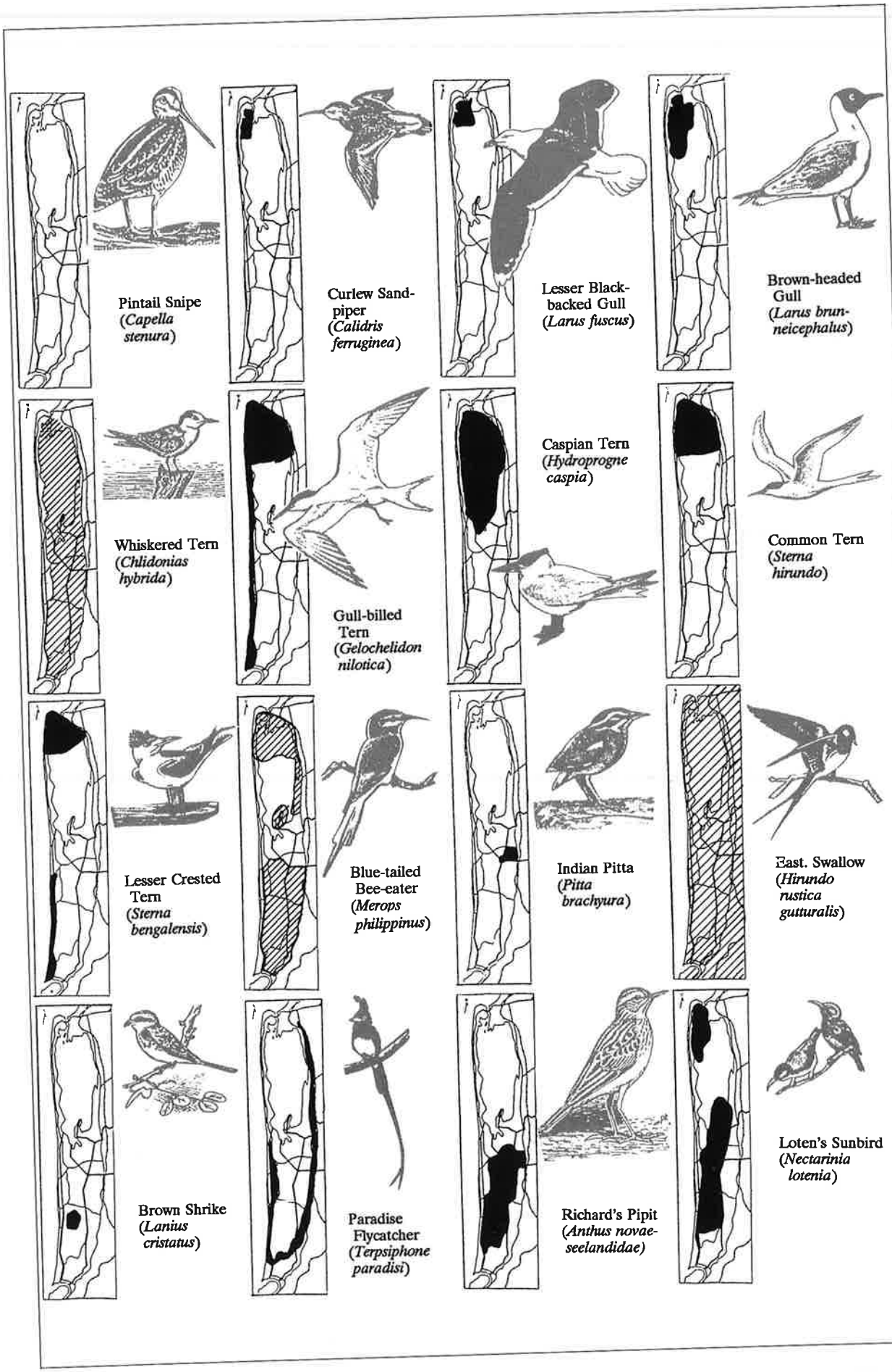


Fig 38 Distribution of migrant birds in the Muthurajawela marsh - Negombo Lagoon wetland (De Silva 1990)



Cntd. Fig 38 Distribution of migrant birds in the Muthurajawela marsh - Negombo Lagoon wetland (De Silva 1990)

TABLE 10- REPTILES RECORDED FROM MUTHURAJAWELA

SCIENTIFIC NAME	ENGLISH NAME	STATUS*	REMARKS**
Cnemaspis k. kandianus	diurnal gecko	R	
Hemadactylus brooki parvimaculatus	jungle gecko	C	
H. frenatus	jungle gecko	C	
Gehyra mutilata	fruit bat	C	
Calotes calotes	green garden lizard	VC	THR
C. versicolor	garden lizard	VC	
Mabuya carinata lankae	skink	VC	
M. macularia	spotted skink	C	END/THR
Sphenomorphus fallax	brown skink	R	END/THR
Riopa punctata	skink	C	
Varanus bengalensis	monitor	C	
V. salvator salvator	monitor	C	PRO
Crocodylus porosus	estuarine crocodile	C	THR/PRO
Melanochelys trijuga thermalis	hard-shelled terrapin	C	THR
Lissemys punctata ceylonensis	sof-shelled terrapin	C	THR
Typhlina bramina		C	THR
Cylindrophis maculatus	Sri Lankan pipe snake	R	END/THR
Python molurus	rock python	R	THR
Acrochordus granulatus		C	
Lycodon striatus	wolf snake	C	
L. aulicus	wolf snake	C	
Oligodon arnensis	kukri snake	R	
Ptyas mucosus		VC	
Boiga ceylonensis	cat snake	C	
Dendrelaphis tristis	bronze back	C	
Ahaetulla nasuta		C	
Aspidura guentheri	Guether's roughside	VR	END/THR
Xenochrophis asperrimus	common pond snake	C	END/THR
Amphiesma stolata		C	
Xenochrophis piscator	pond snake	C	
Atretium schistosum		C	
Cerberus rhynchops	dog-faced water snake	VC	THR
Gerada prevostiana		VR	THR
Naja naja naja	cobra	C	
Bungarus caeruleus	krait	R	
Vipera russelli	Russel's viper	R	
Hypnale hypnale	Merrem's hump-nosed viper	C	THR

* E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; PRO = Protected under Wildlife Ordinance

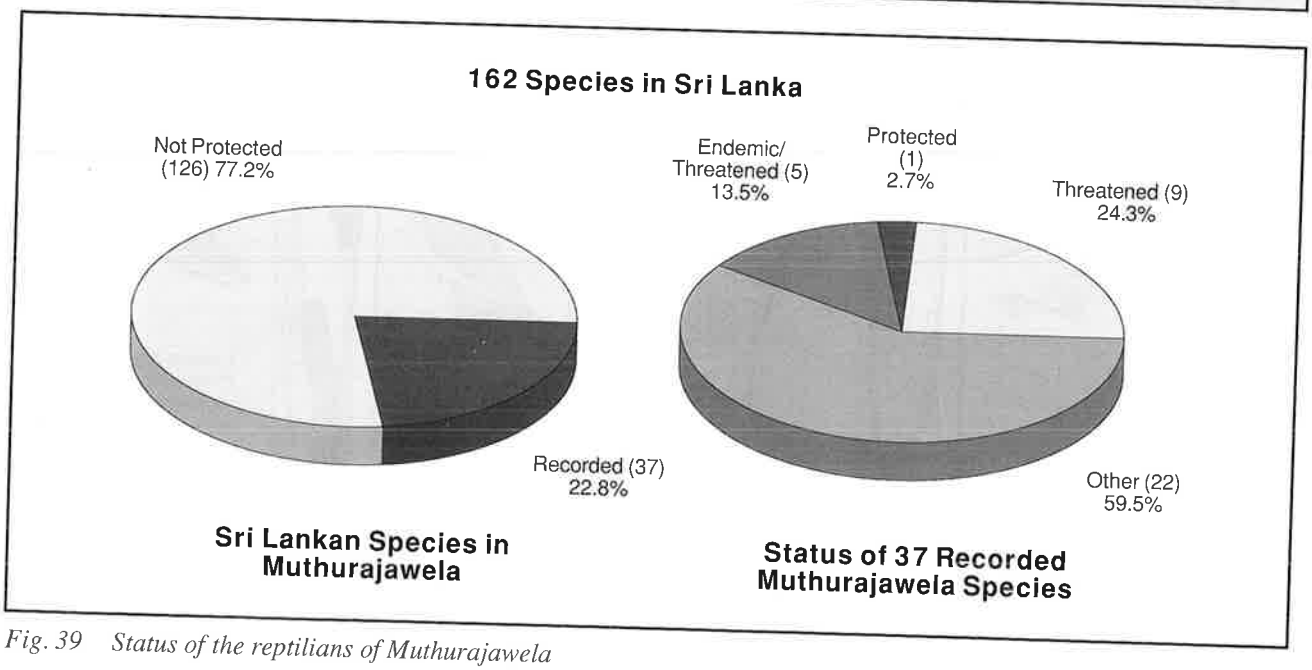


Fig. 39 Status of the reptilians of Muthurajawela

In the Muthurajawela area 37 reptilian species have been recorded: 15 tetrapods and 22 serpentoids. They are presented in Table 10. Fig. 39 shows the status of these species.

Of the 15 tetrapods seven species are threatened in Sri Lanka: two endemic skinks (*Mabuya macularia* and the rare *Sphenomorphus fallax*), two freshwater terrapins (*Melanochelys trijuga and Lissemys punctata*), the estuarine crocodile (*Crocodylus punctata*), the estuarine crocodile (*Crocodylus porosus*), the green garden lizard (*Calotes calotes*), and the lizard *Typhlina bramina*. *Crocodylus porosus* is also listed as an endangered species in the IUCN Red Data Book. Its present breeding grounds in Sri Lanka are greatly reduced. Muthurajawela is one of the few places where it still breeds. The conditions for its continued breeding are reasonable, as long as the area remains marshy. In spite of its official protected status, however, the crocodile population is under increasing threat by hunters: the marsh inhabitants kill crocodiles for flesh and skins (Plate 15).

The monitor lizard (*Varanus bengalensis*) was once very common, but its numbers are greatly reduced due to overexploitation. The other species, *Varanus salvator*, is still common thanks to its protection under the Wildlife Ordinance.

Of the 22 snake species in Muthurajawela, three are endemic and six are listed as threatened in the National Status Report of 1989. Two very rare species in the area are the Guenther's roughside (*Aspidura guentheri:* genus and species endemic) and *Gerada prevostiana*. The latter is so rare that it is not even included in the National Status Report: the species was till recently known from a single specimen collected about 100 years ago from the Kelani River, but recently a second specimen was found in the northern part of Muthurajawela, close to Negombo Lagoon.

The country's largest snake, *Python molurus*, is occasionally found at Muthurajawela. This species is also considered threatened, both nationally and in the IUCN Red Data Book.

A last species worth mentioning is the endemic Sri Lankan pipe snake (*Cylindrophis maculatus*), the only representative of its family in Sri Lanka.

8.4 Amphibians

The amphibian fauna in Sri Lanka is represented by 39 species, of which 19 are endemic. Many of the endemic forms have only a small geographic range. 22 Species are considered to be threatened, including all 19 endemic species.

The total number of amphibian species presently known from Muthurajawela and its environment amounts to 15 (38% of the Sri Lankan species) from five families: *Ranidae* (6), *Bufonidae* (3), *Rhacophoridae* (3) and *Microhylidae* (3). Two of the recorded species are endemic to Sri Lanka: Atukorale's dwarf toad (*Bufo atukoralei*) and the Greater hourglass tree frog (*Rhacophorus (Polypedates)* cruciger). Both are also threatened species. The list of species is shown in Table 11; Fig. 40 shows the status of the species found in Muthurajawela.

The Ranidae generally prefer Muthurajawela's aquatic habitat: the larger frogs (*Rana hexadactyla and Rana tigrina*) dominate in open waters with floating vegetation. *Rana cyanophlyctis* and *Rana limnocharis* occupy the shallow, heavily vegetated pools. And *Rana temporalis* is mainly found in the reed marshes, especially along the canals.

The sixth Rana species (*Rana breviceps*) is a burrowing frog, breeding in rainwater-filled ditches and mud holes along the roads and in the higher grounds in and around Muthurajawela. This biotope is also used by the three Mycrohylid species and by the endemic dwarf toad *Bufo atukoralei*.

The other two toads (*Bufo melanostictus and Bufo stomaticus*) are also commonly found on high grounds, but under more or less disturbed conditions close to human settlements.

The *Rhacophoridae* (tree frogs) naturally occur in an arboreal habitat. The unidentified *Philauthus sp.* is a tiny (2 cm) animal, found throughout the area among the low bushes. *Rhacophorus (Polypedates) maculatus* is also a common tree frog in the area. *Rhacophorus (Polypedates) cruciger* is a large, endemic species, that is less often seen because of its more retiring behaviour. Both *Rhacophorus* species build foamy nests, attached to foliage hanging over water. When their eggs hatch, the tiny tadpoles drop into the water, where they spend their larval stage.

It can be firmly stated, that the high incidence of amphibians in Muthurajawela is caused by the presence of a large variety of water-related micro-habitats of sufficient extent in the area.

TABLE 11 - AMPHIBIANS RECORDED FROM MUTHURAJAWELA

SCIENTIFIC NAME	ENGLISH NAME	STATUS*	REMARKS**
Bufo melanostictus	toad	VC	
B. stomaticus	toad	R	
B. atukoralei	Atukorali's dwarf toad	C	END/THR
Rana hexadactyla	frog	VC	
R. c. cyanophlyctis	frog	VC	
R. tigrina crassa	frog	C	
R. l. limnocharis	frog	VC	
R. (Tomoptera) breviceps	frog	C	
R. (Hylarana) temporalis	frog	C	
Rhacophorus (polypedates) cruciger	greater hourglass tree frog	C	END/THR
R. (P.) leucomystax maculatus	tree frog	VC	
Philautus sp. (P. hayli?)	tree frog	VC	
Kaloula pulchra taprobanica		C	
Uperodon systoma		C	
Microhyla rubra		C	

*E = Endangered; VR = Very Rare; R = Rare; C = Common; VC = Very Common; SU = Status Unknown
** END = Endemic species; THR = Threatened species; PRO = Protected under Wildlife Ordinance

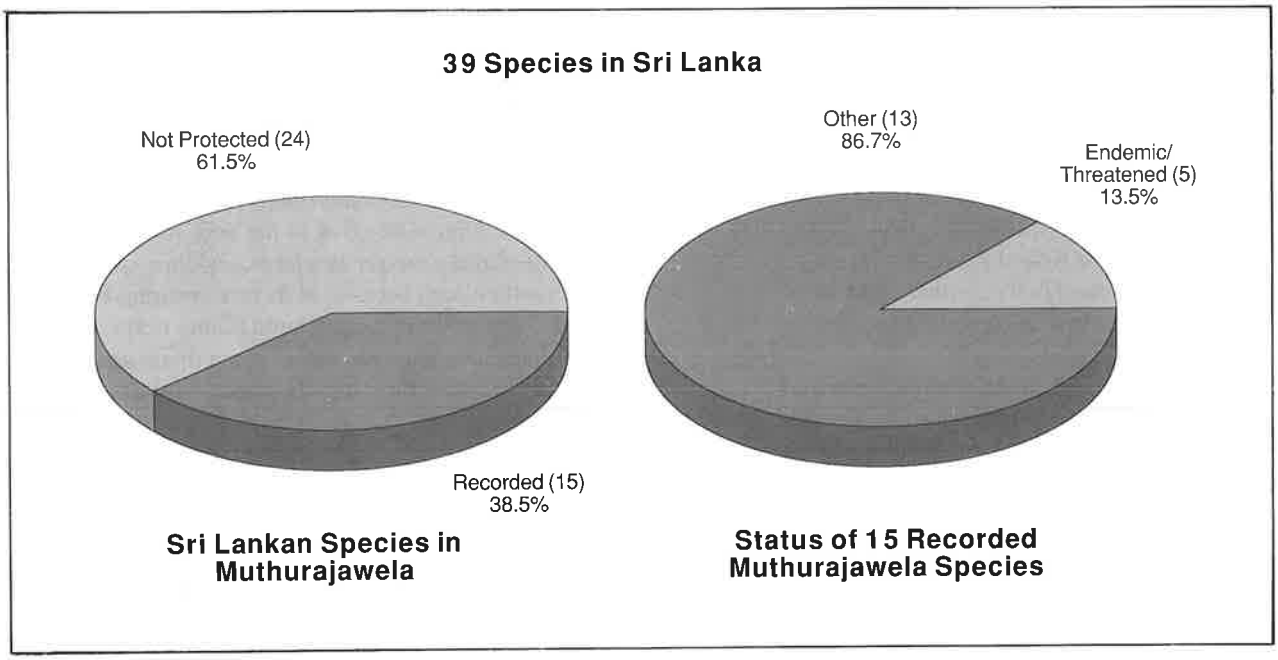


Fig. 40 Status of the amphibians of Muthurajawela

8.5 Fish

The ichthyological diversity in Sri Lanka's fresh and brackish waters is said to be lower than expected for a tropical country close to a mainland (Fernando, 1971). 73 Teleost fish species have been recorded, of which 51 species are indigenous to Sri Lanka (Wijesinghe et al, 1989). The balance 22 species are introduced from elsewhere for fisheries purposes. Of the indigenous species, 42 are believed to be typically riverine, and the rest are marsh-dwelling. 17 Species (30%) are endemic to Sri Lanka including the estuarne sprat, *Ehirava fluviatilis* (Wijesinghe et al 1989; Pinto, 1991). The majority of the endemic species are found in the wet region: 15 out of 17 occur in the southwestern area.

Recent developments have had adverse effects on the habitats of indigenous fish. Deforestation, land cultivation without soil conservation measures, and the increasing use of agrochemicals have already taken their toll. Other factors that threaten the remaining biotopes are the large-scale capture of ornamental fish for trade, reclamation of marshes, dynamiting of fish in river pools, and damming of rivers without construction of fish-passage ways.

During the Muthurajawela ecological survey fish were collected from the marsh waters in September, 1990,- February, 1991, even during this short period 21 species were found (see Table 12). Although not collected in the survey, rare endemic species such as the Smooth-breasted snake-head (*Channa orientalis*), the Leaf lates (*Belontia signata*), Cuming's two-banded barb (*Barbus cumingii*) and the De Kretser's fish (*Malpulutta kretseri*) have a distribution pattern that makes it very probable that they will be encountered in the Muthurajawela area. It can also be expected that a more extensive survey would yield some of Sri Lanka's 16 threatened fish species. Muthurajawela, in its present state, is an important fish habitat not only because of its extent, but especially because of its series of interconnected different biotopes: pools, canals, rivers, and the southern part of the Negombo Lagoon. General abundance and distribution of fish are shown in Fig. 41.

In the pools typical freshwater species were found, such as *Ophiocephalus striatus, Heteropneustes fossilis, Trichogaster pectoralis, Anabas testudineus, Puntius vittatus, Sarotherodon mossambicus* and *Etroplus suratensis*. In the canals the common species were *Ambassis dayi*, (Pinto, 1991) *Puntius vittatus, Etroplus suratensis, E. maculatus and Panchax panchax*. There were also a few individuals of *Caranx sexfasciatus, Heteropneustes fossilis, Elops echinata* and *Megalops cyprinoides*. Although not collected, mullets and halfbeaks were also seen in these canals.

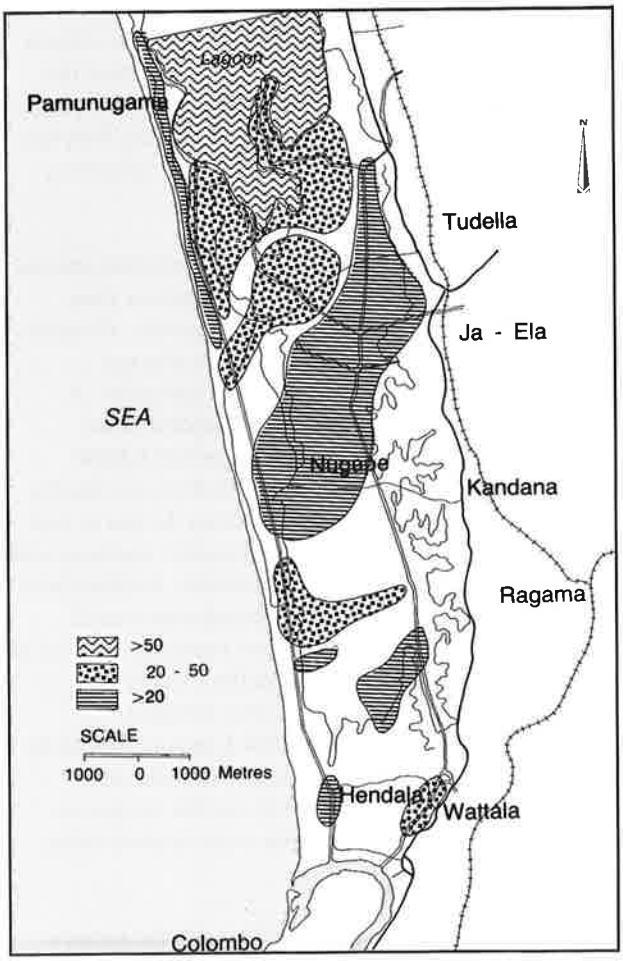


Fig. 41 Generalized distribution of fish species in Muthurajawela marsh according to density (Pinto, 1990)

TABLE 12- FISH SPECIES SAMPLED IN MUTHURAJAWELA IN SEPTEMBER - OCTOBER, 1990

SPECIES	SIZE RANGE (cm)
Ambassis dayi	3.4 - 8.8
Anabas testudineus	5.2 - 8.0
Caranx sexfasciatus	10.0 - 13.0
Eleotris fusca	5.0 - 13.0
Etroplus suratensis	4.0 - 17.0
Etroplus maculatus	3.0 - 4.0
Elops echinata	15.5 - 16.0
Gerres abbreviatus	5.0 - 7.5
Heteropneustes fossilis	4.5 - 16.5
Lates calcarifer	22.0 - 26.0
Leiognathus equulus	2.3 - 3.0
Lutjanus argentimaculatus	23.0 - 25.0
Megalops cyprinoides	28.0 - 30.0
Oligolepis acutipennis	6.0 - 10.5
Ophiocephalus striatus	23.0 - 42.0
Panchax melastigma	2.0 - 2.2
Panchax pancha	1.5 - 1.6
Puntius vittatus	1.0 - 3.0
Scatophagus argus	8.5 - 13.5
Sarotherodon mossambicus	3.7 - 10.0
Trichgaster pectoralis	2.5 - 11.3

In the rivers the abundant species were *Etroplus suratensis* and *Sarotherodon mossambicus*. Also regularly present were *Ambassis dayi, Tachysurus sp., Gerres abbreviatus, Lutjanus argentimaculatus, Eleotris fusca, Oligolepis acutipennis, Puntius vittatus* and *Panchax melastigma*. In the Hamilton Canal the abundant species was *Ambassis dayi*. The other species caught there included *Oligolepis acutipennis, Panchax melastigma, Gerres abbreviatus, Etroplus suratensis* and *Scatophagus argus*.

In the southern part of the estuary the abundant species was Ambassis dayi, and the common species were *Leiognathus equulus, Oligolepis acutipennis, Etroplus suratensis, Eleotris fusca, Epinephelus tauvina, Lutjanus argentimaculatus* and *Lates calcarifer*. A much higher fish diversity can be expected in the estuary, since at least 133 different species inhabit Negombo Lagoon. More than half of these are marine species that move into the estuary from the sea to feed or to spawn. Some of these "anadromous" species move even deep into the canals in the marshes; without these freshwaters this marine migrant population would quickly diminish. Among them are numerous species of economic importance, such as mullets, seabream, snappers and groupers. But also less common anadromous species use Negombo Lagoon, such as the moray eel (*Thyrosoidea macnura*), the snake eel (*Ophichthys rhytidodermatoides*) and the conger eel (*Muraenesox cinereus*): all three were reported from earlier surveys.

Also "catadromous" species are found in the estuary: species that migrate from fresh to marine habitats for reproduction. Among them are the eels (*Anguilla bicolor bicolor*), that are regularly found in the estuary.

Some important fish species occurring in the wetland are shown in Fig. 42.

8.6 Invertebrates

The Sri Lankan fauna include huge numbers of invertebrates, representing practically all taxonomic groups. They range from minute planktonic organisms to large lobsters, and from noxious mosquitoes to useful bees and beautiful butterflies. In the framework of the ecological survey of the Muthurajawela-Negombo Lagoon area a comprehensive study of the invertebrate fauna could not be made: years of painstaking field work would be required for a reliably complete listing. To get at least an impression of the importance of the area for invertebrate life, some important aquatic and terrestrial groups were surveyed; the results are summarized below. A picture of the incidence of insect-vectors of human parasites and diseases is presented in 8.7.

8.6.1 Aquatic invertebrates

The freshwater zooplankton of Sri Lanka is well documented; probably all occurring species have been recorded, except, perhaps, in the *Rotifera*. Over 40 species of protozoans, about 140 species of rotifers, 68 species of cladocerans, 27 species of copepods, and numerous planktonic larvae have been listed. Most of the species are cosmopolitan or widely distributed in the tropics, none are endemic, and only some of the cladocerans are mentioned as threatened in the National Status Report.

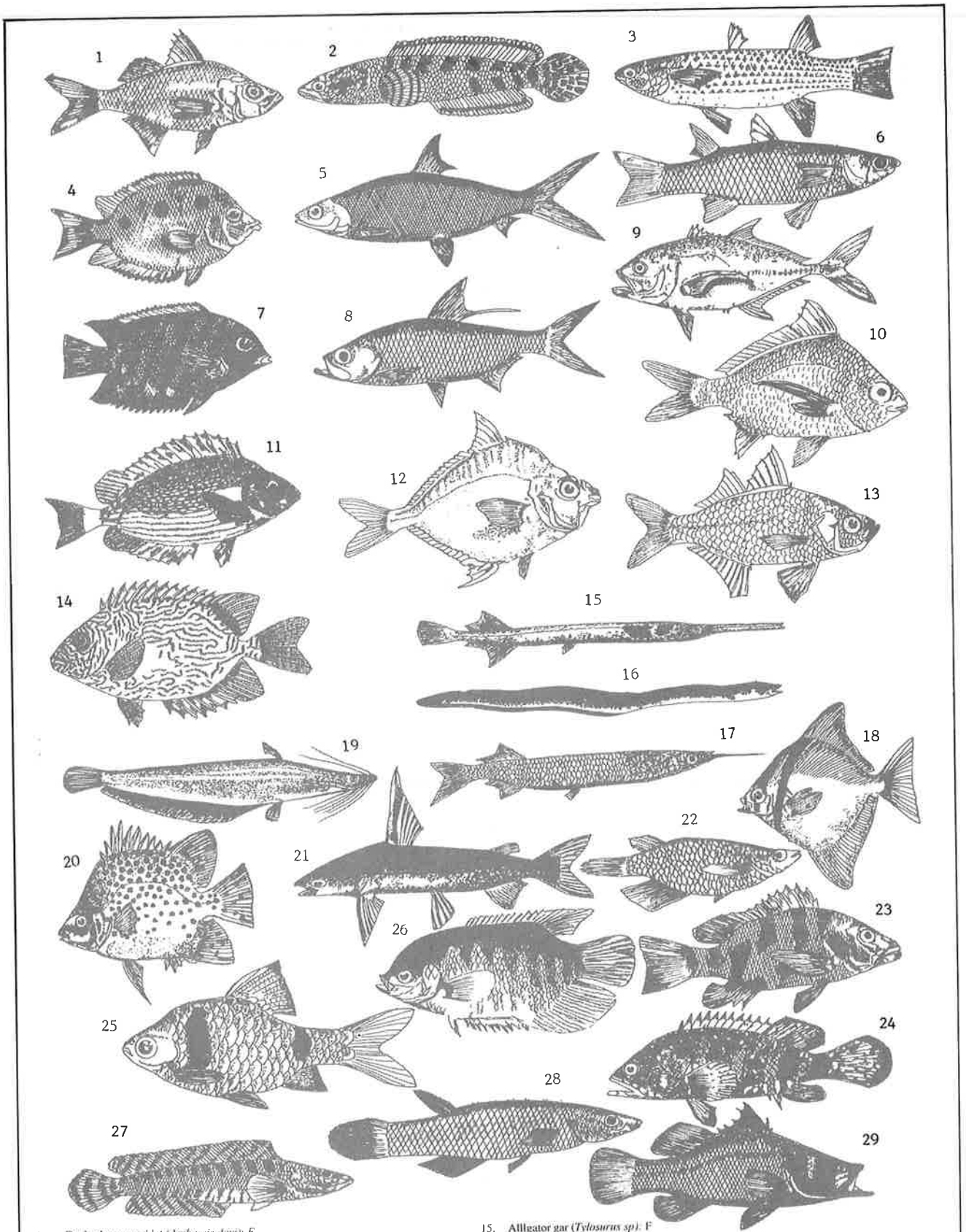
Zooplankton species are important in the Muthurajawela - Negombo Lagoon area, since they are a source of food for fish, crustaceans and some birds, and because the larvae of commercially important fish and shrimp species are part of the plankton. The zooplankton of Muthurajawela is composed of cycloid copepods, nauplii larvae, rotifers, cladocerans, juvenile fish and larval prawns. Copepods are extremely common and abundant; the general distribution pattern indicates that their abundance decreases with salinity. The most important fish species of the marshes, *Ambassis dayi*, depends on copepods as its primary source of food. Nauplius larvae of crustaceans were most numerous in the Tarakuliya and Dalature areas, but were virtually absent in Pol Ela, Tudella, Dutch Canal, Welisara Ela, Depa Ela and the southern part of the Hamilton Canal.

Rotifers were also abundant in the Tarakuliya and Dalature areas, but they are also widely distributed in the rest of Muthurajawela. Cladocerans, on the contrary, show a rather narrow distribution, being restricted to Mudun Ela and Kudagahapitiya Ela. Of the 19 sites that were sampled for zooplankton in the framework of the present ecological survey, Mudun Ela, in the Uswetikaiyawa area, showed the highest diversity. Zooplankton diversity was very low in those places of the canals where bathing and washing of laundry takes place (Fig. 43).

The most important groups of freshwater and brackishwater macro-invertebrates include the crustaceans, molluscs, worms, insects and insect larvae.

The fresh and brackishwater crustaceans of Sri Lanka comprise of 31 species of *Ostracoda*, three species of *Anostraca*, five species of *Conchostraca*, two species of *Amphipoda* and 41 species of *Decapoda* (10 shrimps, 11 freshwater prawns and lobsters, seven freshwater crabs, and 13 penaeid prawns). 10 Decapods species are endemic to Sri Lanka; these are all considered threatened.

A large number of these crustacean species are reported from Muthurajawela, although not many exact records are available. During the present ecological survey the



1. Day's glassy perchlet (*Ambassis dayi*): F
2. Smooth-breasted snakehead (*Channa orientalis*): F
3. Diamond-scale mullet (*Liza sp*): F
4. Orange Chromide (*Etropbus maculatus*): F,OX
5. Milkfish (*Chanos chanos*):F
6. Grey Mullet (*Mugil cephalus*) : F
7. Pearl Spot, green chromide (*Etropus suratensis*) : F
8. Tarpon (*Megalops cyprinoides*) : F
9. Trevally (*Caranx sp*) : F
10. Silver biddy (*Gerres oyena*) : F
11. Rabbit fish (*Siganus jarvus*) : F
12. Pony fish (*Leiognathus sp*) : F
13. Commerson's glassy perchlet (*Ambassis commersoru*) : F
14. Rabbit fish (*Siganus vermiculatus*) : F
15. Alligator gar (*Tylosurus sp*): F
16. Cel (*Anguilla sp*):F
17. Halfbeak (*Hyposrhampus sp*): F
18. Mono angel, silver batfish (*Monodactybus argenteus*) : OX
19. Stinging catfish (*Heteropheustes fossilis*) : F
20. Spotted butterfish (*Scatophagus argus*) : F,OX
21. Estuarine cat fish (*Tachysurus sp*) : F
22. Estuarine top-monnow (*Panchax melastigma*)
23. Grouper (*Epinephalus spp*) : F, AX
24. Grouper (*Epivephalus spp*) F, AX
25. Cummings two-banded barb (*Barbus cummings*) : OX
26. Gouramy (*Osphronemus goramy*) : F
27. Striped snakehead (*Ophiocephalus striatus*) : F
28. Topminnow (*Panchax panchax*)
29. Sea-bass (*Lates calcarifer*) F, AX

F: Food Fish; **OX: Ornamental Fish export** **AX: Aquaculture Seed Fish export**

Fig 42 Some important fishes of the Muthurajawela marsh- Negombo Lagoon wetland

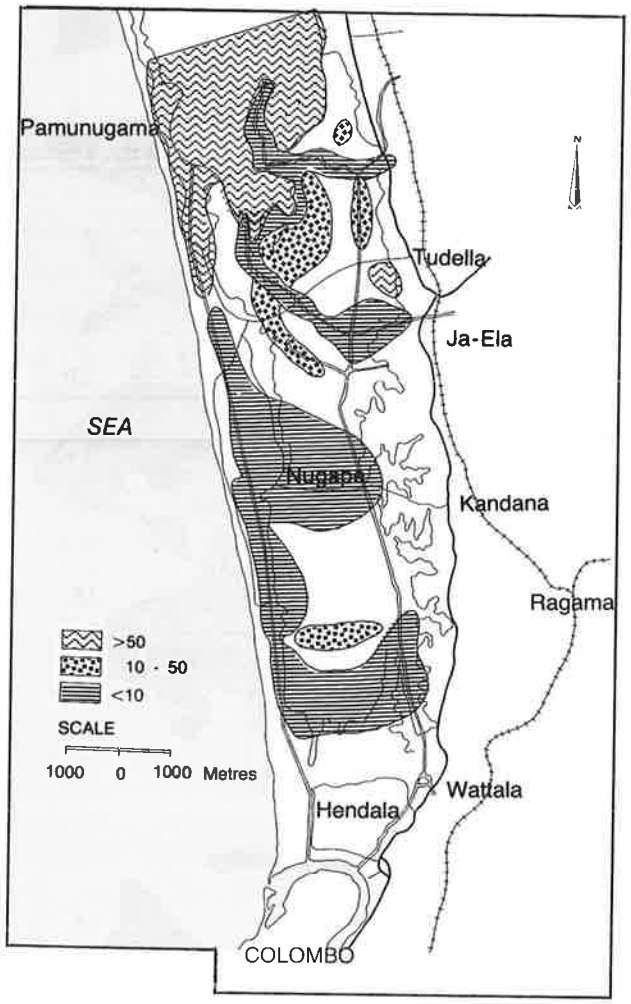


Fig. 43 Generalized distribution and abundance of zooplankton in the Muthurajawela marsh (Pinto, 1990)

small estuarine shrimp *Metapenaeus dobsoni* and the large white shrimp *Penaeus indicus* were found in the northern part of the marshes and in the lagoon. The giant freshwater prawn *Macrobrachium rosenbergii* occurred further south in Dandugam-Oya, Ja-ela and the Dutch Canal. For this commercially important species the canal connections are important: it spends its larval stages in the brackish estuary and moves as a postlarva back to fresh waters. The mangrove crab *Scylla serrata* has been found to move as far south as the Uswetikaiyawa area. The crab *Neosernatium malabaricum* occurs on the banks of Kerawalapitiya and midway in the Hamilton Canal. In general, most freshwater crustacean species are encountered in places where water flow is relatively low and where bathing and washing activities are scarce. Aquatic vegetation favours the occurrence of crustaceans, and also of other macro-invertebrate life, both free living and benthic (bottom-dwelling).

Insect species commonly found in Muthurajawela include numerous dragonfly and mayfly larvae, the Diving beetle (*Cybister confusus*) and its larvae, and the Creeping water bug (*Holeocaris bengalensis*). The latter two were found in Mudun Ela and Welisara Ela. In these two canals also the leech (*Hirudinaria manillensis*) is common; other worms have not been surveyed specifically, but numerous annelids were recorded from the substrate of various waters (Fig. 44).

The molluscan fauna of Muthurajawela includes the gastropods (*Pila globosa*) an important food source of the open-bill stork, *Indoplanorbis sp., Faunus ater* and *Melanoides sp.* So far, none of Sri Lanka's 12 endemic molluscs have been found in the area.

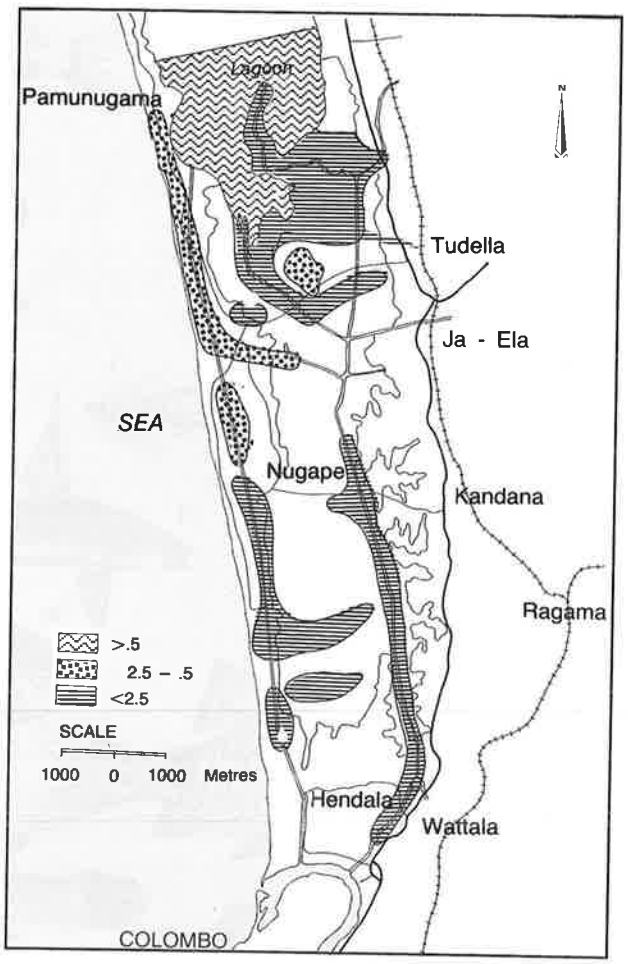


Fig. 44 Generalized distribution and abundance of benthos in the Muthurajawela marsh (Pinto, 1990)

TABLE 13 - BUTTERFLIES OF SRI LANKA AND OF MUTHURAJAWELA

FAMILIES	ISLAND WIDE				MUTHURAJAWELA			
	TOTAL SPP	SPP	ENDEMIC SUBSPP	THREATENED SPP	TOTAL SPP	SPP	ENDEMIC SUBSPP	THREATENED SPP
DANEIDAE	12	1	6	1	8	-	4	-
SATYRIDAE	16	3	3	-	4	-	1	-
AMATHUSIIDAE	1	-	-	1	-	-	-	-
NYMPHALIDAE	40	-	10	9	17	-	1	-
LYCAENIDAE	81	3	1	8	14	-	-	-
PIERIDAE	29	-	1	1	9	-	-	-
PAPILIONIDAE	15	-	6	5	9	-	3	1
HESPERIIDAE	48	1	4	12	6	-	-	-
TOTAL	242	8	31	37	67	-	9	1

TABLE 14- DRAGONFLIES OF SRI LANKA AND OF MUTHURAJAWELA

FAMILIES	ISLAND WIDE			MUTHURAJAWELA		
	TOTAL SPP	SPP	ENDEMIC SUBSPP	TOTAL SPP	SPP	ENDEMIC SUBSPP
EUPHAEIDAE	1	1	-	-	-	-
CHLOROCYPHIDAE	4	3	-	2	2	-
CALOPTERYGIDAE	2	-	1	-	-	-
LESTIDAE	5	2	1	-	-	-
PLATYSTICTIDAE	17	17	-	2	2	-
PROTONEURIDAE	7	7	-	3	3	-
PLATYCNEMIDAE	1	-	-	1	-	-
COENAGRIONIDAE	14	1	1	12	1	-
GOMPHIDAE	14	13	-	1	-	-
AESHNIDAE	5	-	-	-	-	-
CORDULIIDAE	2	1	1	-	-	-
LIBELLULIDAE	41	3	-	13	-	-
TOTAL	113	48	4	34	8	-

8.6.2 Terrestrial invertebrates

In Sri Lanka a total of 265 species of land snails has been recorded, the number of spider species is estimated to be close to 1,000, and the insect species amount to a multiple of that. All of these groups include endemic species as well as species that are under threat of extinction. And also certainly a number of the threatened species can be found in the Muthurajawela area. For the present survey, however, data collection was restricted to two insect classes that are popular for their beautiful appearance: the butterflies (*Lepidoptera*) and the dragonflies (*Odonata*).

Butterflies: the butterflies of Sri Lanka comprise eight families with 242 species; of these eight species and 31 subspecies are endemic. 38 Species are listed as threatened in the 1989 National Status Report. From Muthurajawela seven families and 67 species of butterflies are recorded (27% of the national total), including nine endemic subspecies. One species appears in the list of threatened butterflies: the blue mormon Papilio polymnestor parinda. Several additional species have been observed in the area, but they could not be identified. 28 Species of the Muthurajawela butterflies are migratory: these are only found in the area during the migratory seasons March-April and October-December. Often these migratory species are dependent on a specific area for completion of a part of their live-cycle.Of the eight species of *Danidae encountered*, four are endemic: *Danaus similis expromta, Euploea phaenareta corus, E. core asela* and *E. sylvester montana*. The most interesting of these is *Euploea phaenareta corus*: the largest of the genus and restricted to the southwestern coastal belt. Though this butterfly is rather rare elsewhere, it appears to be common in the whole Muthurajawela area. Four species of the Satyridae are known from the marshes. They are all common; one of them (*Elymnias hypermnestra fraterna*) is endemic to Sri Lanka. Of the Nymphalidae, representing some of the large and most beautiful

butterflies, 17 species are found in the area, including the endemic *Vanessa canace haronica*. The *Lycaenidae* are present with 14 species, and the *Pieridae* with nine.

Of the swallow-tails (*Papilionidae*), large and colourful butterflies, nine species are recorded from Muthurajawela (of the 14 species in Sri Lanka), including three endemics (*Atrophaneura aristolochiae ceylonicus, Chilasa clytia lankeswara,* and the earlier-mentioned threatened blue mormon). Of the small, usually brown skippers (*Hesperidae*) six species are presently known to occur in the marshes.

Table 13 shows the status of the present knowledge on the butterflies of Muthurajawela, in comparison with the situation country-wide.

Dragonflies: the total number of dragonflies recorded from Sri Lanka is 113 and 48 of these are endemics. Hardly any inventorization of dragonflies has been done at Muthurajawela; the present data form an original contribution, based on literature and museum surveys and field observations. The results indicate that the area contains at least 34 species (30% of the national total), including eight endemics: two chlorocyphids (*Libellago adami and L. greeni*), three protoneurids (*Elattoneura bigemmata, E. caesia and Prodasineura sita*), two platystictids (*Drepanosticta walli and D. nietneri*) and one coenagrionid (*Mortonagrion ceylonicum*). The status of the present knowledge is summarized in Table 14.

Most of the dragonfly species were found in marshy waters with heavy aquatic vegetation; the lagoon is a less preferred habitat. Dragonflies play an important role in keeping a check on insect pests: their larvae feed generally on small aquatic fauna (including insect larvae), and their adults prey on other adult insects.

8.7. Disease Vectors and Pathogens

The most prominent disease vectors are rats (*Rattus norvegicus* and *Rattus rattus*) and mosquitos. The rats are responsible for the spread of leptospirosis which is a potentially fatal disease caused by the bacterium Leptospira ictiohaemorrhagica (Fig. 45) The most important mosquito vectors of disease belong in the genera *Culex, Anopheles* and *Aedes*, for which Muthurajawela in its present condition provides a wide range of breeding habitats (Fig. 46). The diseases caused by the pathogens transmitted by these mosquitos include dengue, dengue haemorrhagic fever, filariasis, Japanese encephalitis and malaria. Although, the established vector of malaria, *Anopheles culicifacies*, did not occur at the sampling stations, other species capable of transmitting this disease were present: A. *subpictus*.

Pathogens which cause bowel diseases and contribute to anaemia which is highly prevalent at Muthurajawela are generally associated with unsanitary conditions that provide pathways for faecal contamination of food and water used for domestic purposes. The transmission relationships of these pathogens are shown in Fig. 47.

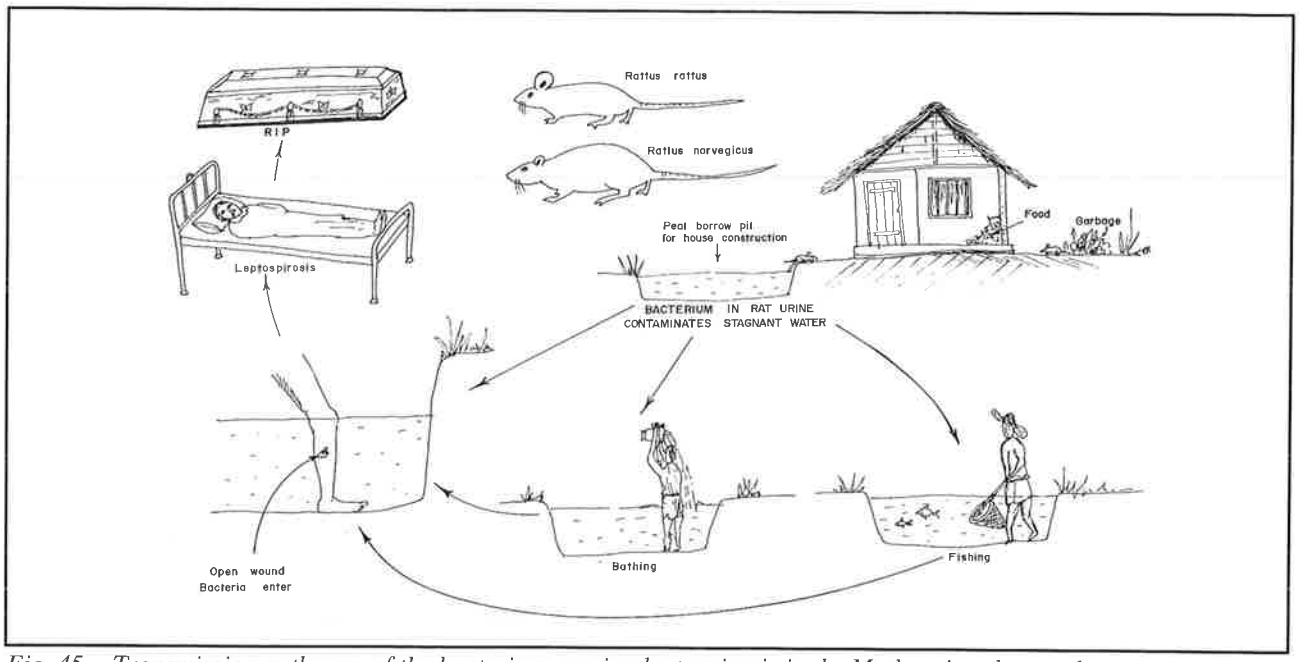


Fig. 45 Transmission pathways of the bacterium causing leptospirosis in the Muthurajawela marshes.

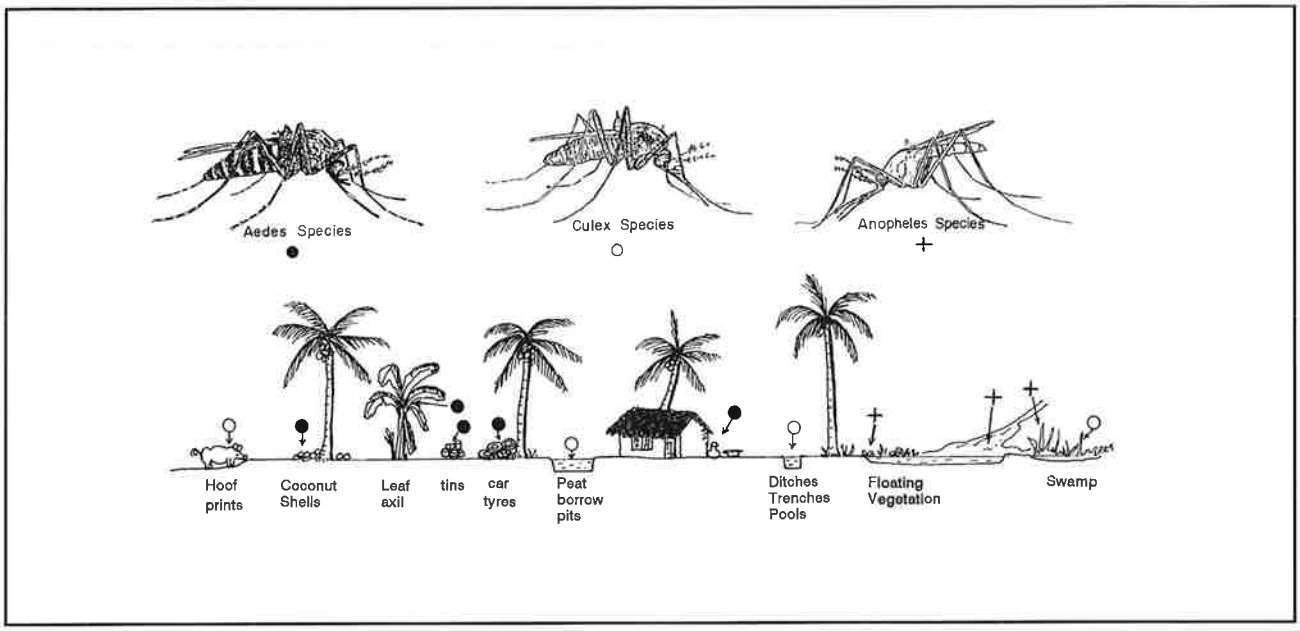


Fig. 46 Breeding habitats of three species of disease vector mosquitos at Muthurajawela (after Eddington and Eddington, 1976)

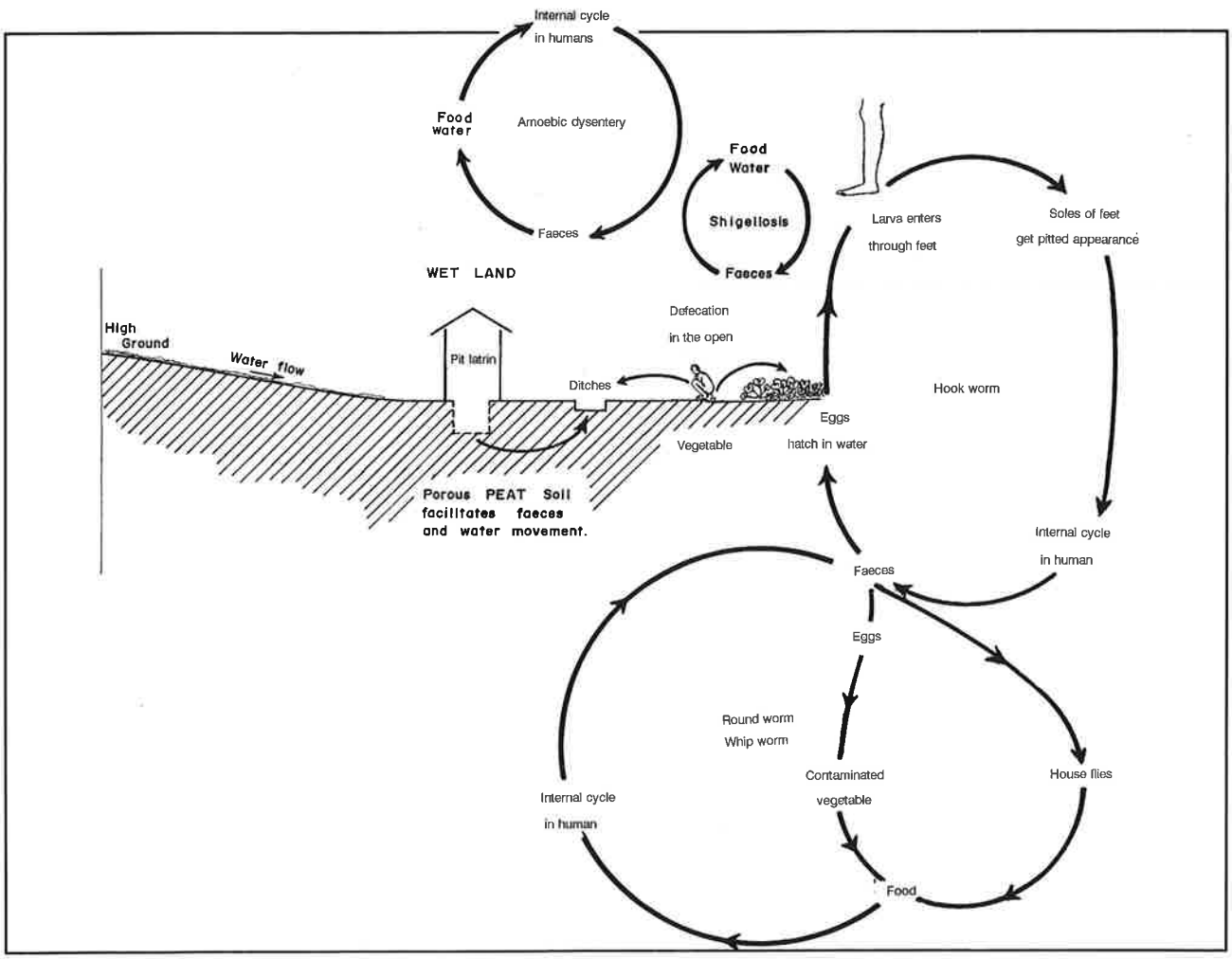


Fig. 47 Transmission pathways of common pathogens causing bowel infections at Muthurajawela

9. ECOSYSTEM FUNCTIONING

It has been estimated that up to 50% of the world's wetlands have been lost or degraded since the beginning of this century. In 1990, Sri Lanka signed the International Convention on the Conservation of Wetlands of International Importance, especially as Waterfowl Habitat, also known as the RAMSAR Convention. The Directory of Asian Wetlands (Scott, 1989) lists 41 wetlands for Sri Lanka, including the Muthurajawela Swamp (No. 31) and the Negombo Lagoon (No. 32). Together, the marsh and the lagoon form a large wetland system covering some 6000 ha.

The study area contains the wetlands of the Muthurajawela marsh (marsh proper), the brackish water mangrove swamps, and the estuarine ecosystem of the Negombo Lagoon. Centuries of human interference for a variety of purposes have left their mark on these wetlands. Yet even today the ecosystem continues to provide its "free of charge" services where significant natural values can still be found. For these reasons alone, the area would qualify as "unique", having survived in a more or less natural state under the smoke cap of the largest urban center in the country (Colombo) within a densely populated coastal zone.

About 6,000 years ago, a lagoonal environment prevailed in the area and as the Muthurajawela sand barrier along the coast was formed towards the north, an intertidal ecosystem appeared at the southern end. In more recent times the intertidal environment spread northwards paving the way for the present ecological situation (see A-5).

In the marsh proper, the substrate consists mainly of peat. The geological history of the area can be read from the stratification of peat layers, which has been described in A-5.2.

The distribution and abundance of the more important plant and animal groups occurring in the Muthurajawela marsh-Negombo Lagoon wetland have been described in sections A-7 and A-8. Their relative ecological significance has been indicated based upon available information. Among the most important plant formations for maintaining the existing distribution and abundance of the diverse animals are the water reeds, mangroves and the seagrasses. The animals themselves constitute populations of commercial as well as nutritional importance. However, the most important issue is not the protection of unique species of plants and animals but the conservation of their essential roles in the context of the entire ecosystem in supporting and maintaining the productivity of the lagoon and the adjacent coastal zone, from which large numbers of people make their livelihood. In order to achieve this both ecosystem function and ecosystem yield must be sustained.

An ecosystem consists of an interactive and integrated unit formed by the combination of the physicochemical (non-living) environment and its living communities (NRC, 1982). In the case of the Muthurajawela marsh-Negombo Lagoon wetland ecosystem, the major non-living components include tidal inflow, river discharge, rainfall, evaporation, nutrients, sediment and decayed material from living organisms (detritus). The living communities include microorganisms, plants and animals. The role of the human population on the ecosystem will be presented in Part C.

The Muthurajawela marsh-Negombo Lagoon wetland constitutes an interlinked system which is influenced by freshwater discharge from the rivers and tidal inflow, from the sea. Both the freshwater and the seawater influences are essential to maintain the brackish water condition that prevails in the wetland and thereby enables its characteristic plants and animals to exist in abundance to be harvested for food and income. The ecosystem relationships and linkages pertaining to this wetland are schematically shown in Fig. 48.

With the exception of larger mammalian species, bio-diversity is high, which is not surprising considering the variety of land forms, ecotones and habitats: freshwater peat swamp, brackish marshlands, brackish to saline lagoon, mangrove forest, and this in the proximity of coastal dune formation and under the varying influence of rivers and the sea. Animal species have adapted perfectly to the variety of food types available, as for instance demonstrated by the wide range of bills of wading birds that feed on sand shoals (Fig. 49). By reaching into various depths, and because of the forms of their bills, these birds can capture a wide range of animals that live in these sand shoals.

However, age-long human occupation has brought about many changes in the natural plant and animal communities. Most of the larger mammal species have disappeared and of the larger reptilian fauna, the fate of the few surviving estuarine crocodiles is precarious Plates 15. However the area has retained its value as an important foraging station for large numbers of migratory birds from the Indian subcontinent on their way to and from their winter range elsewhere in southern and south-eastern Asia. In particular, large numbers of duck and teal, both resident and migratory, use the lagoon and adjacent marshes Plate 16.

The major roles of plants and animals in ecosystem functioning is as producers (plants) and consumers (animals). Plants fix the energy of the sun as material that can be eaten by animals. A wide range of plants automatically means that there would be a wide range of animals also feeding on them. The plant material is transferred by the plant eaters (herbivores) into animal material which then becomes food for other animals

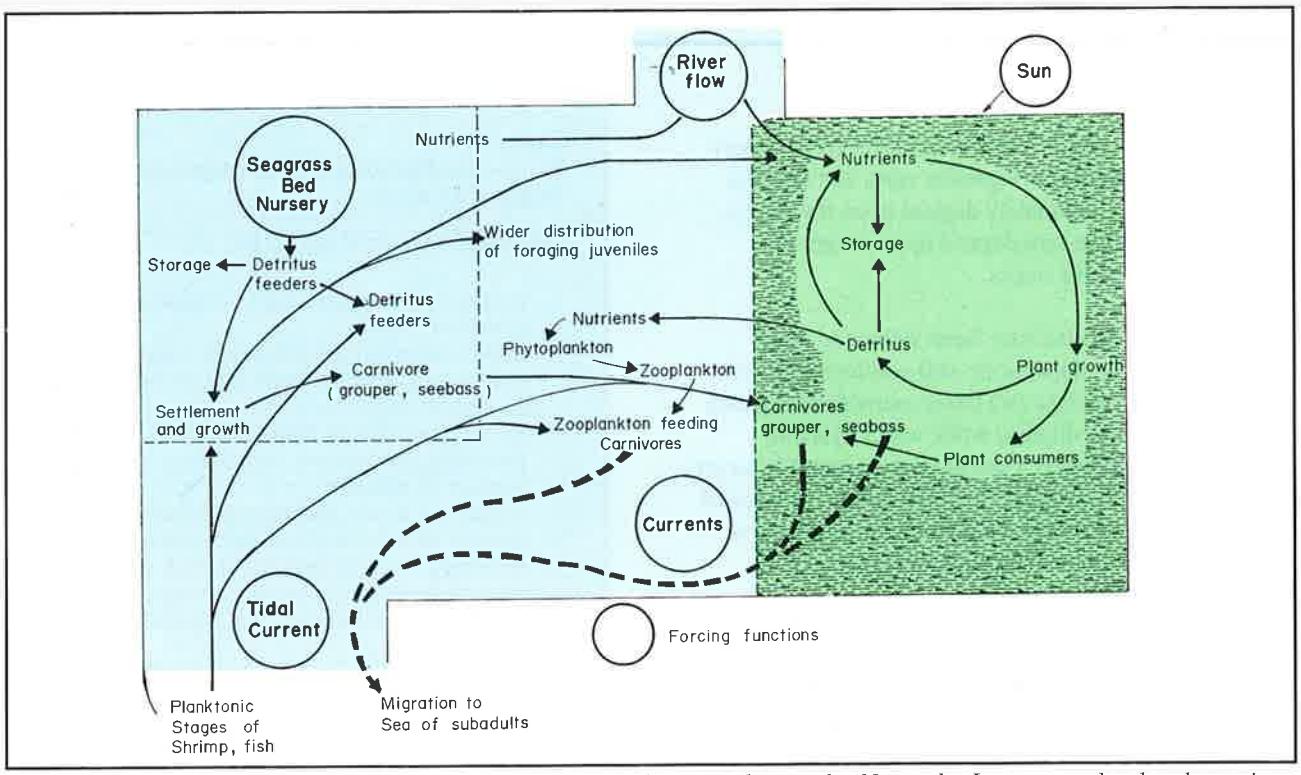


Fig. 48 Ecosystem relationships and linkages for the Muthurajawela marsh - Negombo Lagoon wetland: schematic representation

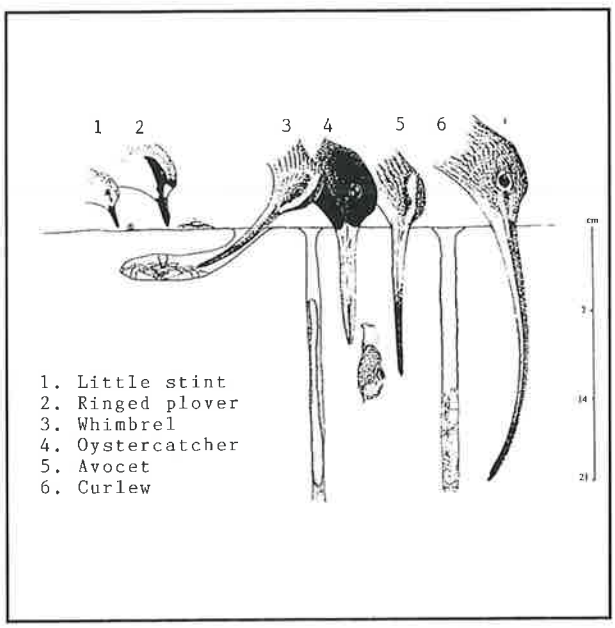


Fig. 49 Structural adaptations of bills of wading birds for feeding at different depths on a sand shoal

that feed upon them (predators). In this manner a complex food web is supported by a ecosystem. Some feeding relationships of the marsh animals are shown in Figure 50.

The species of great significance for fisherfolk of Muthurajawela and Negombo Lagoon are among crustaceans: the penaeid shrimps and mud-crabs and among fish: seabass, grouper, angels, scats and grey mullet. The shrimps and crabs are mainly exported, the larger stages of the fish generally sold for food in the local market, while the younger stages except grey mullet, are also exported as ornamental fish or for cage culture. Many of these species have an obligatory brackish water stage. The adults breed at sea and their larval floating stages are passively carried into the Negombo Lagoon by the tide. Within the Lagoon these floating stages settle among the seagrasses, intertidal mangroves, reeds and rushes which constitute their critical nursery habitat and as they grow, they become dispersed over a wider area including the lower reaches of Dandugam Oya and the water ways in the Muthurajawela marsh (Fig. 51). The maintenance of lagoonal stocks of these organism depends critically on the connection between the sea and the freshwater discharge which dilutes seawater adequately. In several instances in Sri Lanka where the connection between the sea and a brackish water body became blocked, or where the freshwater discharge was altered, the fishery has collapsed, as in the Kalametiya Lagoon, Lunama Kalapuwa and several others (Bird, 1985).

The continued existence of abundant populations of fishery organisms in the wetland also depends upon feeding relationships. In this instance some of the earliest stages of shrimps, and fish feed upon tiny floating plants (phytoplankton). As they grow, they begin feeding on plants such as seagrasses, decaying plant material (detritus), and organisms growing upon other plants (epiphytes). Some feeding, relationships on

a seagrass bed are shown in Fig. 52. Fundamentally, therefore, even for the fishery organisms, plants constitute the fundamental food source.

The larger, commercially important sizes of predatory fish such as grouper (*Epinephalus spp*), and sea bass (*Lates calcarifer*) ultimately depend upon their prey-organisms, which in turn depend upon seagrasses during their early life stages.

The aquatic plants also have been subject to many changes and some impacts are still continuing. Exotic aquatic weeds (*Salvinia sp.*) cover many former paddy fields and drainage ditches, while water hyacinth (*Eichornia crassipes*) is a noxious weed found in larger canals. Most of the mangrove forests along the edge of the lagoon, although officially protected by forestry legislation, are subject to felling for brushwood, fuelwood and other purposes .

Tall sedges such as *Lepironia sp.; Typha sp.* (pung) and Pandanus sp. (wetakeiya) are used for mat and basket weaving. Reeds are used for making fishing screens and traps, etc. Yet, despite this exploitation both marsh and lagoon still contain important plant communities, many of which are of actual and potential economic importance. For the maintenance of the present high levels of productivity, it is essential that the ecological integrity and the bio-diversity of the area be preserved. The seagrass beds in Negombo Lagoon provide a critical nursery area (forcing function) in this wetland.

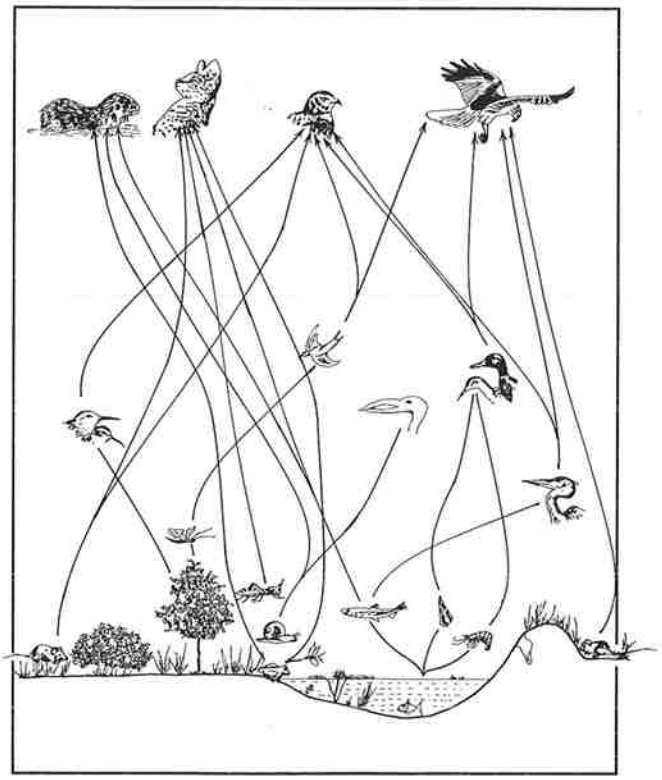


Fig. 50 A food web at Muthurajawela marsh

The various functions of the marsh and lagoon ecosystems are summarized in Table 15.

Table 15
Ecosystem Functions Muthurajawela Marsh and Negombo Lagoon

PRODUCTION FUNCTION

- primary production : micro-organisms, plankton, plants
- maintenance of nutrient balance and food chain
- mangroves, sedges, reeds also of direct economic importance
- as raw materials or commodities
- providing production: vertebrates, invertebrates
- support of wildlife
- support of marsh and lagoon fisheries
- support of fisheries in adjacent costal area
- spawning area for fish and shrimp species
- nursery function for young shrimps and fish
- nesting habitat for birds and reptiles

REGULATION & BUFFER FUNCTION

- trapping nutrients from inflow of river and sea water
- acting as a silt trap (mangroves, marsh vegetation)
- erosion prevention: sand and soil fixation
- soil and water conservation, stabilisation of sediment
- water retention, regulation of flow, flood protection
- maintenance of groundwater table of adjacent uplands

PURIFICATION FUNCTION

- mineralization of organic material
- purification of certain toxic compounds and pollutants
- maintenance of oxygen-carbondioxide balance in atmosphere and coastal waters
- prevention certain pests and diseases
- prevention of acid-sulphate soil formation
- maintenance of water quality

INFORMATION FUNCTION

- signal function on possible deterioration of the environment
- Scientific studies and educational programmes
- genetic reservoir
- recreational experience, nature studies

CONSERVATION FUNCTION

- conservation of evolutionary processes
- flora and fauna conservation
- bio-diversity conservation
- conservation of ecosystem functions for the maintenance of all other functions listed above

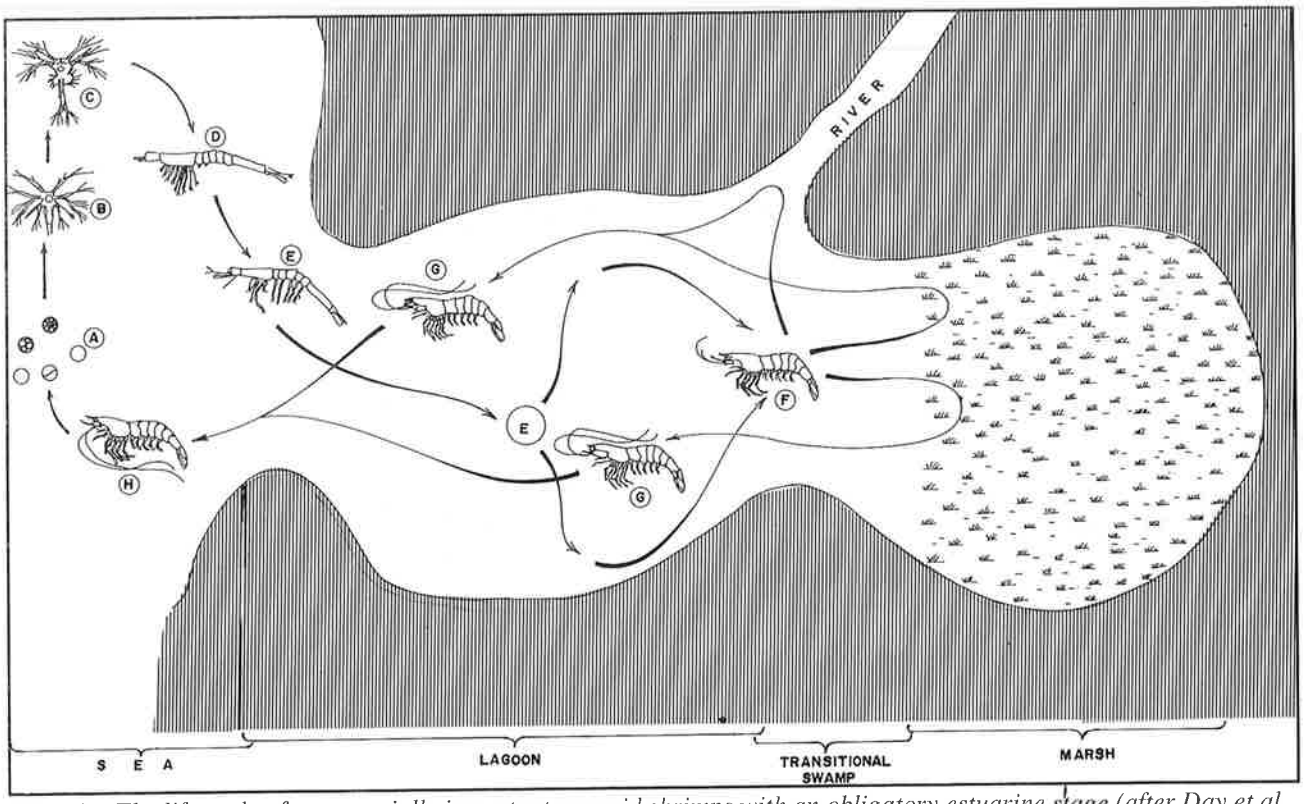


Fig. 51 The life cycle of commercially important penaeid shrimps with an obligatory estuarine stage (after Day et al, 1989)

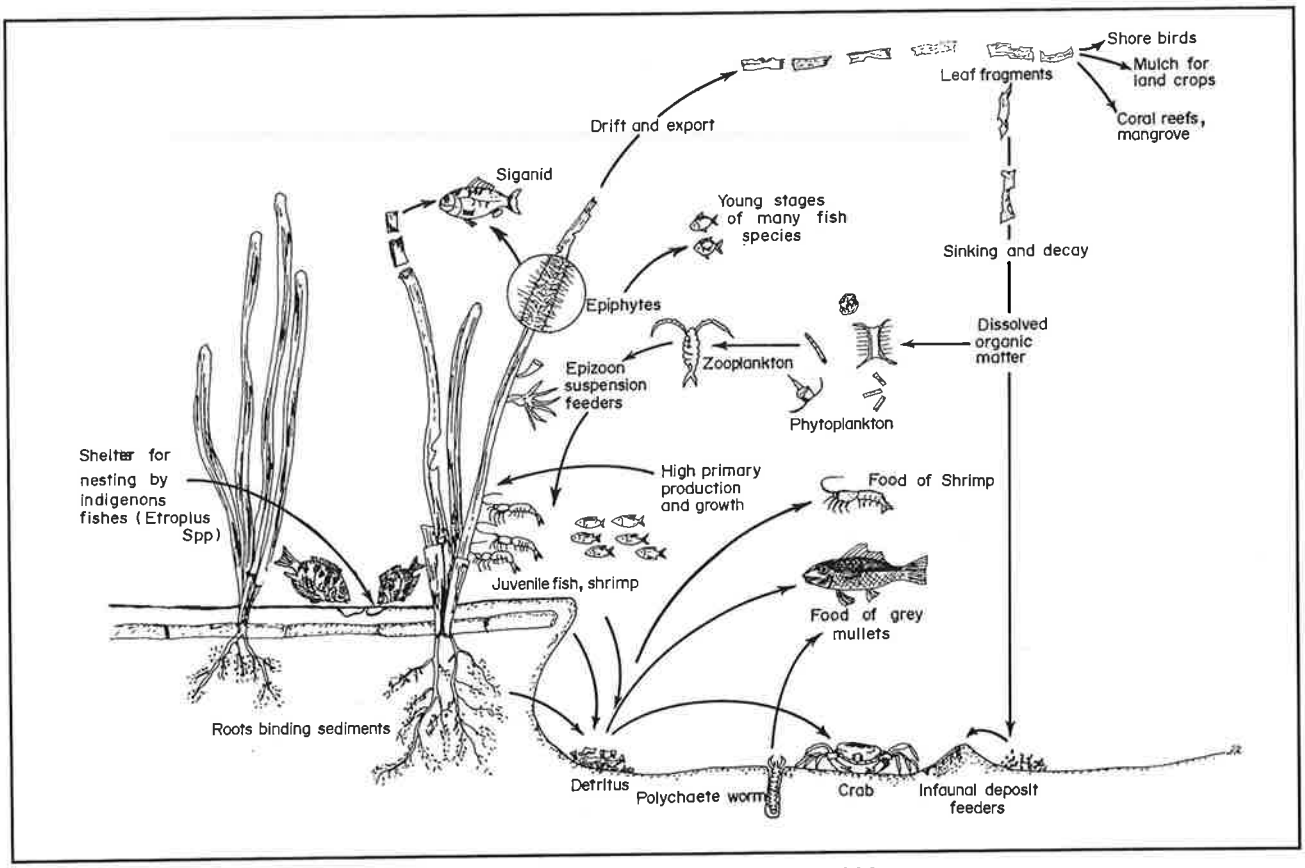


Fig. 52 Ecosystem relationships on a seagrass bed (adopted from Fortes, 1990)

Plate 14

The mangroves in the foreground and background have been planted in the channel segment of Negombo Lagoon to facilitate landfill for housing in intertidal areas.

Plate 15

The estuarine crocodile (Crododilus porosus) is protectedby law. But it is hunted both for its flesh and skin.

Plate 16

The Muthurajawela marsh-Negombo Lagoon wetland is primehabitat for flocks of waterfowl such as whistling teal.

10. SOCIO-ECONOMICS

The data pertaining to socio-economics were obtained mainly from a questionnaire completed by the Grama Seva Niladaris from their personal knowledge of all the residents in their respective division and constituting the study area and the marsh proper (Fig. 53) verified subsequently by the chief investigator, relevant literature and records available at GCEC (Mahanama, 1990; 1991).

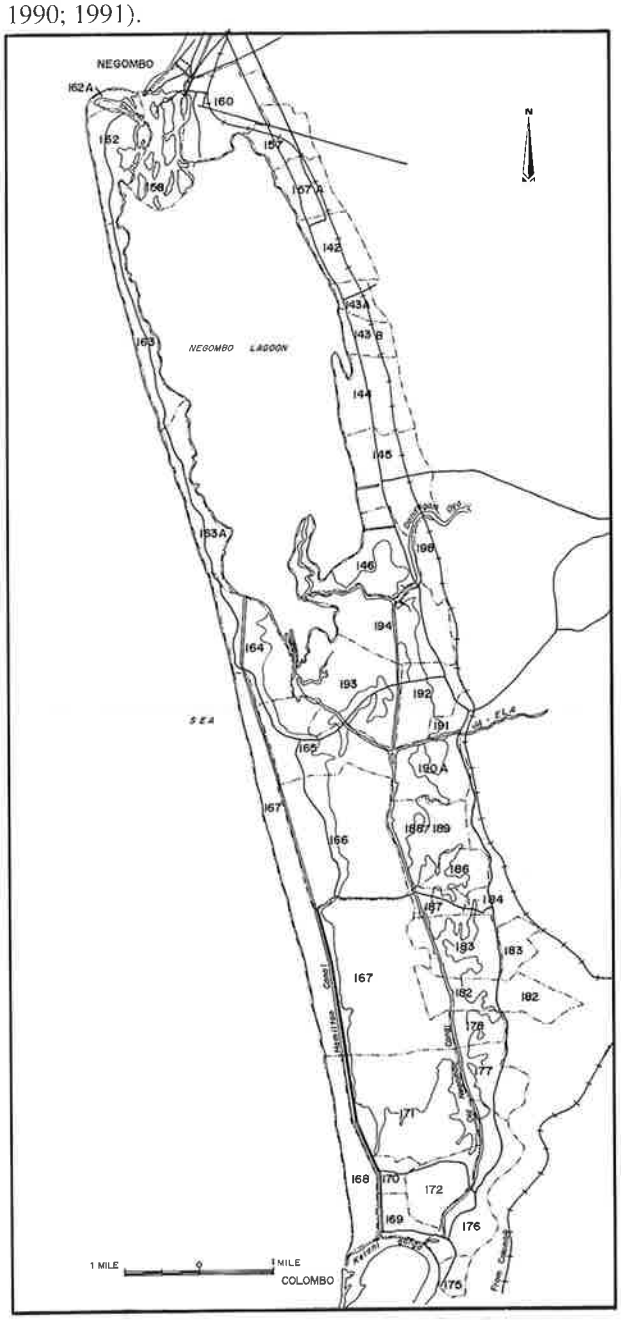


Fig. 53 The 43 Grama Seva Niladhari Divisions constituting the study area and Muthurajawela Marsh

10.1 Population

The information given in this section brings out features that characterize the people living in the marsh, their socio-economic conditions, level of dependency upon the natural resources of the area, their health status relative to those in the study area, in a manner that would enable planners to consider their needs in relation to ecosystem functioning.

10.1.1 Population Growth

The total population of the study area was 169,669 in 1981 and it had increased to 208,615 in 1990 at the rate of 2.3% per annum. This rate was higher than the national average of 1.6% per annum and the Gampaha District rate of 1.7% per annum. Immigration was the main reason.

In 1989 the total population in the marsh proper was 3366 distributed among 10 settlements (Fig. 54). Most were encroacher who had immigrated in the 1960s. This population increased gradually from 1960 to 1975 by continued immigration. From 1975 the population increased steeply till 1989 (Fig. 55). The GCEC took steps to arrest migration into the marsh from the beginning of 1989.

10.2 Age-sex composition of the population

Age structure of the population in the marsh proper is based on 4 year cohorts. The population in the squatter settlements consists predominantly of persons less than 30 years of age. This is a feature common to most squatter settlements, such as in the city of Colombo. This is attributable to the fact that it is the 'youth' segment of the population that encroaches on 'free' land, state owned or private, to meet the need of setting up a shelter for a new-formed family unit (Fig. 56). The role of reduced life expectancy as a consequence of squatting on marginal areas is not known. However, above average prevalence of potentially fatal diseases attributable to the living conditions in the marsh indicates a negative role (see A-8.7; A-10.10; B-6).

The proportion of infants, age 0-5 yrs, in the population, in the study area as a whole is comparable with district and national statistics. However, the proportion of infants in the marsh proper is relatively low. The age structure is not precisely analyzable because of the smallness of the area under consideration, i.e. the marsh proper.

The school-going age group, 5-14 years constitutes, 23% of the total population in the marsh.

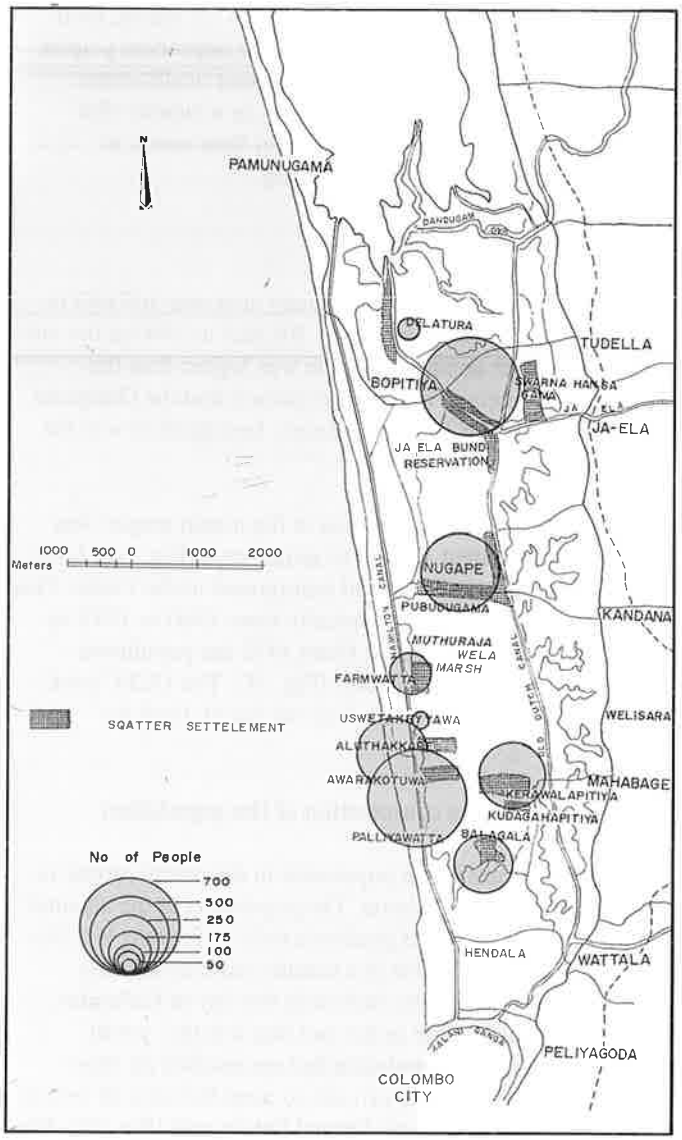


Fig. 54 Distribution of squatter settlements in the Muthurajawela marsh

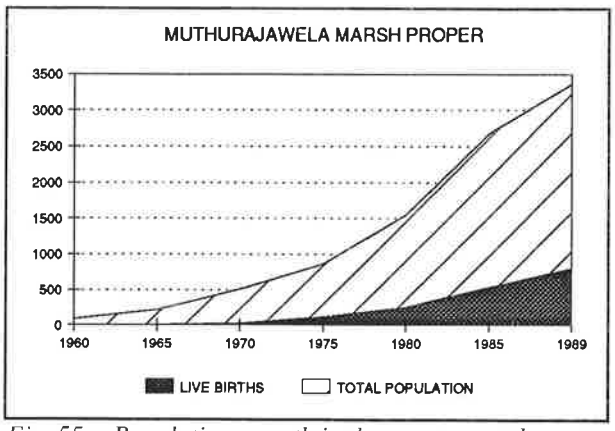


Fig. 55 Population growth in the squatter settlements in the Muthurajawela marsh

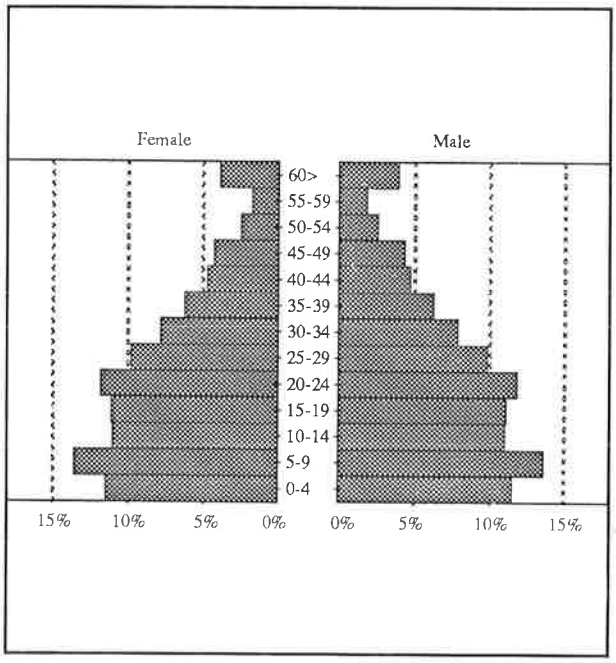


Fig. 56 The age structure of the squatter population in the Muthurajawela marsh

The age group 15-59 years, constitutes the work force, and accounts for 62% of the marsh population. This segment of the population is important in terms of the projected economic development of the area.

The population of females in the childbearing ages of 15-49 is 55% of the total female population in the marsh proper. This is slightly higher than the district and national figures which were 54.5% and 52.0% in 1981. This segment of the female population is important since it reflects high potential for population growth.

10.3 Ethnic and religious composition of the population

The majority of encroaches in the marsh proper are Sinhala Catholics constituting 98% of the total population, and the balance mainly Sinhala Buddhist. Numerous Catholic Churches are also located throughout the study area (Fig. 57). The small Sinhala Buddhist population is concentrated in the Balagalawatte and Kudagahapitiya settlements. The predominance of catholics in this area corresponds to their general concentration along the western coastal belt.

Several types of natural resources are being exploited by the people in the study area for consumption and commercial purposes:

- fishing (marine and lagoon)
- hunting specially tortoise, crocodile
- extraction of reeds and grasses,
- timber extraction

The majority of the fisherman in the study area are Catholic and they engage in fishing activities either marine or in the lagoon. In the marsh proper also, almost all the fishermen are Sinhala Catholics and engage in lagoon fishing and tortoise hunting in the northern area of the marsh. Exploitation of other resources such as timber, mainly mangroves, is associated with fishing activities.

10.4 Migration pattern

Two-thirds of the total families in the marsh proper immigrated there from 1960 to 1989 from the adjoining areas. The average distance between their present and previous residences is 3km (Fig. 58). 8% immigrated from outside the Gampaha district. The main reasons for immigration were:

- non-affordability of better housing in the high ground areas, and high housing rent ("push" factor).

- availability of `free' land, mainly state owned, at relatively low cost (main "pull" factor).

- local political influence: it is claimed that some politicians encouraged landless families to settle on state lands within their electorate especially in the marsh (e.g. Ja Ela reservation and Mel bemma).

10.5 Education

Almost 50% of the population of school going age and above had acquired education upto the primary and secondary levels while about 10% had even completed schooling upto the General Certificate of Education (Ordinary Level) stage. The school going population was 22% while, those at school going age who were not attending school constituted about 10%. The latter proportion varied by settlement: poverty was the main reason for children of school going age not attending, even though schools were within accessible distance. Parents of such children could not spend on the basic necessities of their children for attending school.Only about 10% of the adult population was illiterate, being unable to read or write.

The overall education pattern in the marsh was comparable to that in the study area (Fig. 59).

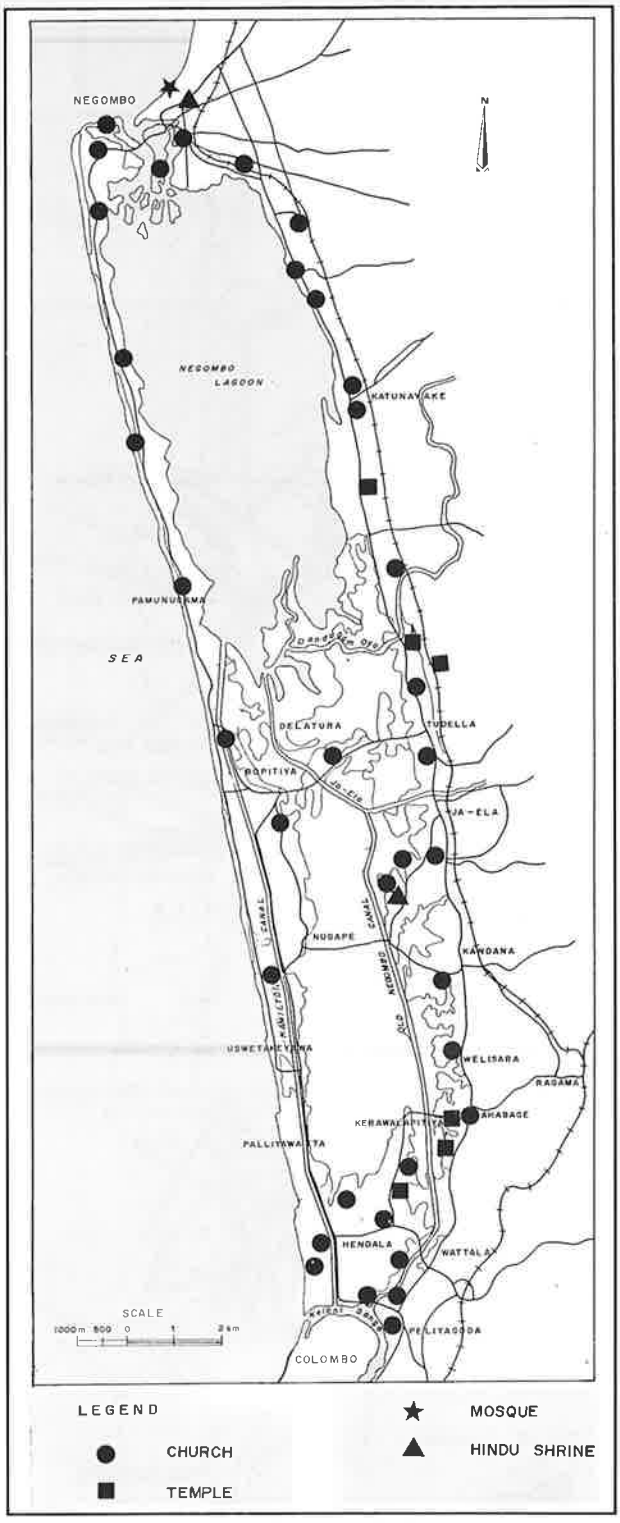


Fig. 57 Distribution of places of religious worship in the study area

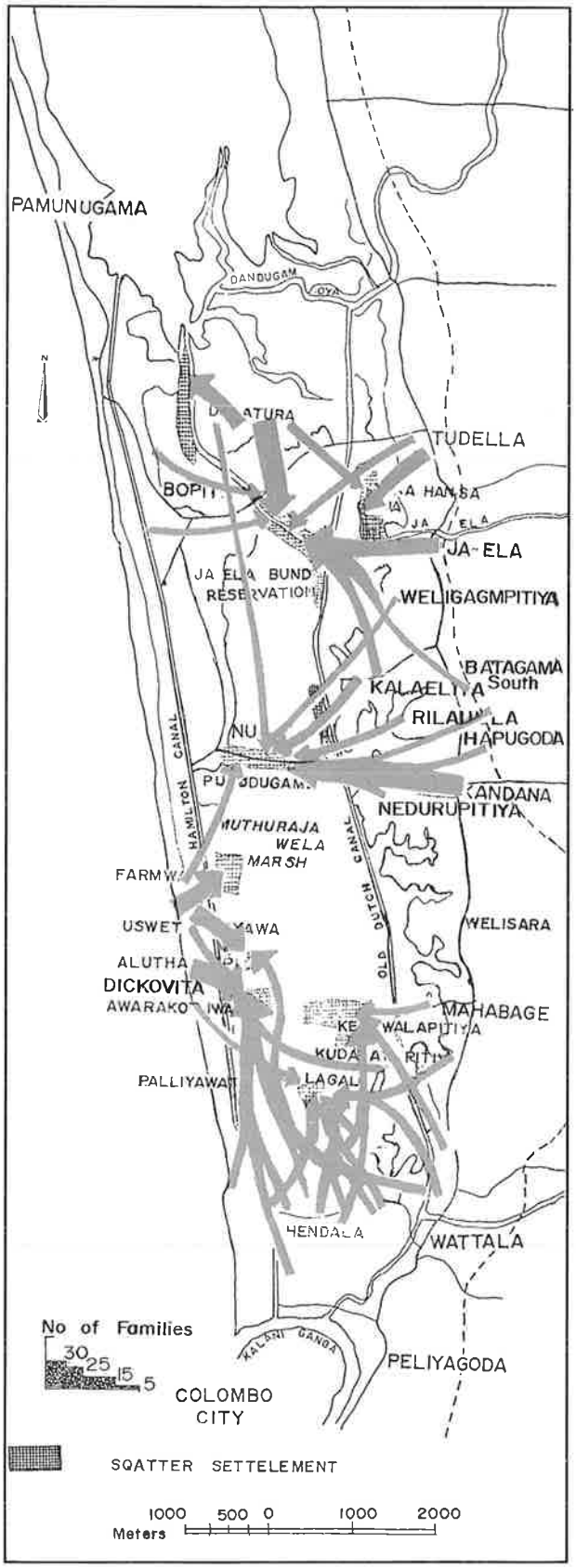


Fig. 58 The relationship of squatter households to the previous residence of the head of the household

The relatively high educational level in the marsh was attributable to:

- free education services provided by the central government.
- availability of primary and secondary schools within accessible distance in the study area (Fig. 60).
- the services given by the church (conducting missionary schools)

10.6 Income and expenditure

Since income data from questionnaires are generally unreliable, entitlement for food stamps was used as a more objective indicator of income level. Families with a total income less than Rs. 750/- per month are regarded as being below poverty level and become entitled to food stamps. The proportion of food stamp receiving families in each encroacher settlement in the marsh proper is given in Fig. 61.

A pattern is clear. The proportion of food stamp receiving families increases in the settlements from south to north. This is attributable to the greater availability of wage employment for members of settlements closer to urban centers. 100% of the families at Kadola received food stamps since they did not have regular wage employment. The members of the settlements toward the north of the marsh, whose poverty level as indicated by food stamp recipience is higher; nevertheless, they have alternative sources of income. The majority in these settlements engage in fishing in the transition zone in particular, and Negombo Lagoon in general. Income from capture of shrimps is reasonably substantial.

The members of encroacher settlements spent 98% of their income on consumption; food 80%, balance on fuel (kerosene), firewood, clothes, medicine, education, etc. An insignificant proportion was spent on gambling and liquor.Minimal expenditure was incurred on housing. It is evident that the majority of members in the encroacher settlements obtain the marginal nourishment they now acquire by expending their income almost entirely on purchasing food.

In the study area, in contrast, less than 60% of total household income is spent on food.

Generally, it a reported that households that are ultra poor in Sri Lanka spend 80% or more of their income on food which also indicates that they are also not meeting their basic calorie requirements (Sessional paper, No. 12, 1988).

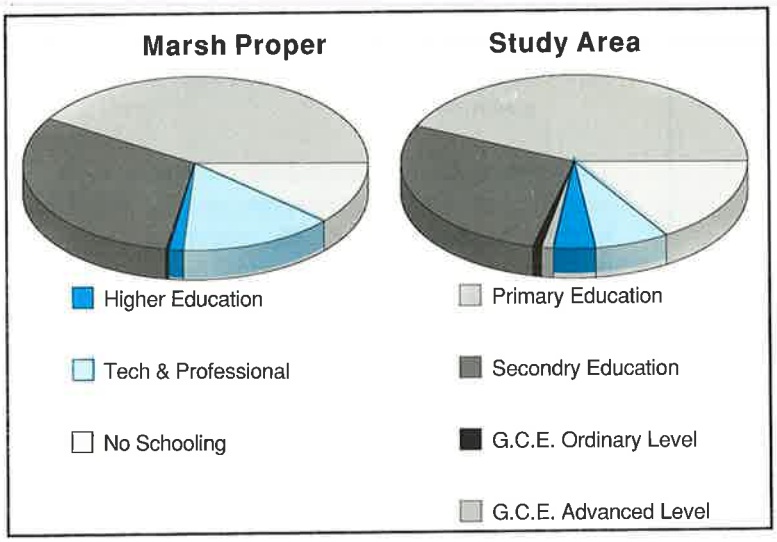


Fig. 59 *Education level of squattrs in the Muthurajawela marsh and for the study area*

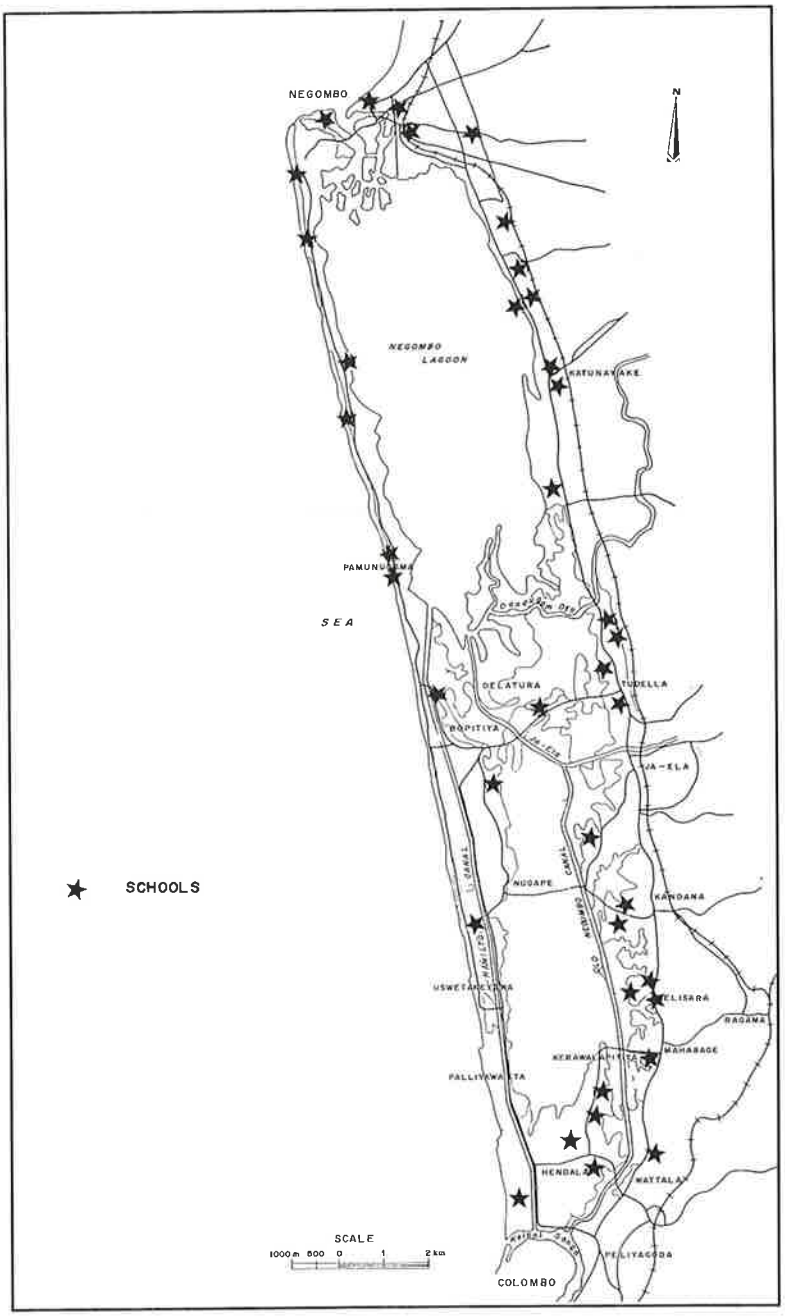


Fig. 60 *Distribution of schools in the study area*

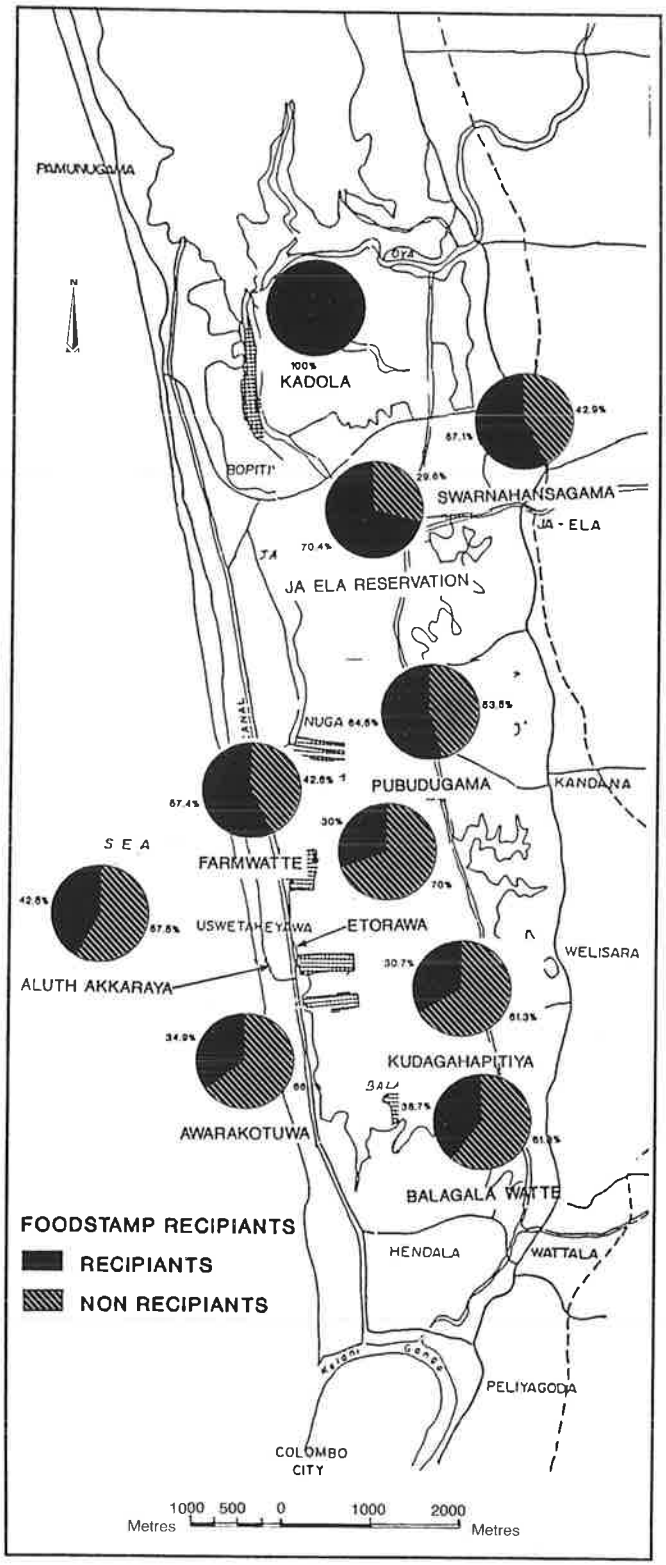


Fig. 61 Distribution of foodstamp recipient families in the 10 squatter settlements

10.7 Labour force, employment and unemployment

The labour force in the encroacher settlements constitutes 50.4% of the total population. 61.9% of this labour force is unemployed. The proportion is high relative to that in the study area (38.5%), and the Gampaha District: 27% (Sessional Paper, No. 12, 1988).

The majority of employed in the encroacher settlements are engaged in manual labour, generally for a daily wage of Rs. 60.00-75.00. They work in the nearby urban centers or on nearby coconut estates.

Daily wage labour, however, is unpredictable. The proportion of manual labourers constituting the labour force varies by settlement. At Kadola only 11.2% of the employed labour force is engaged in manual labour, while the proportion in other settlements varies between 40 and 78%. The majority of the employed labour force in Kadola (83%) engage in fishing mainly in Negombo Lagoon and the transition zone Fig. 62.

Farmers constitute less than 1% of the labour force in the marsh proper.

A striking feature of unemployment in the encroacher settlements is that 65% of the unemployed are in the 15-29 years age group, while 78% of the total unemployed have primary and secondary level education, suggesting that less qualified persons with appropriate skills have better prospects of employment.

The female unemployment rate is relatively high, which is 43% of the total unemployed. This is because most females are engaged in household work and their participation in wage employment which takes them away from the house, is low.

10.8 Community problems

The questionnaire survey revealed that the inhabitants of the area considered their main problems to be:

- absence of roads, toilets and electricity to the houses, and the area
- lack of safe drinking water in the area
- lack of security of tenure for land and housing
- lack of permanent income and employment
- poor housing conditions
- flooding during the rainy seasons
- mosquito nuisance

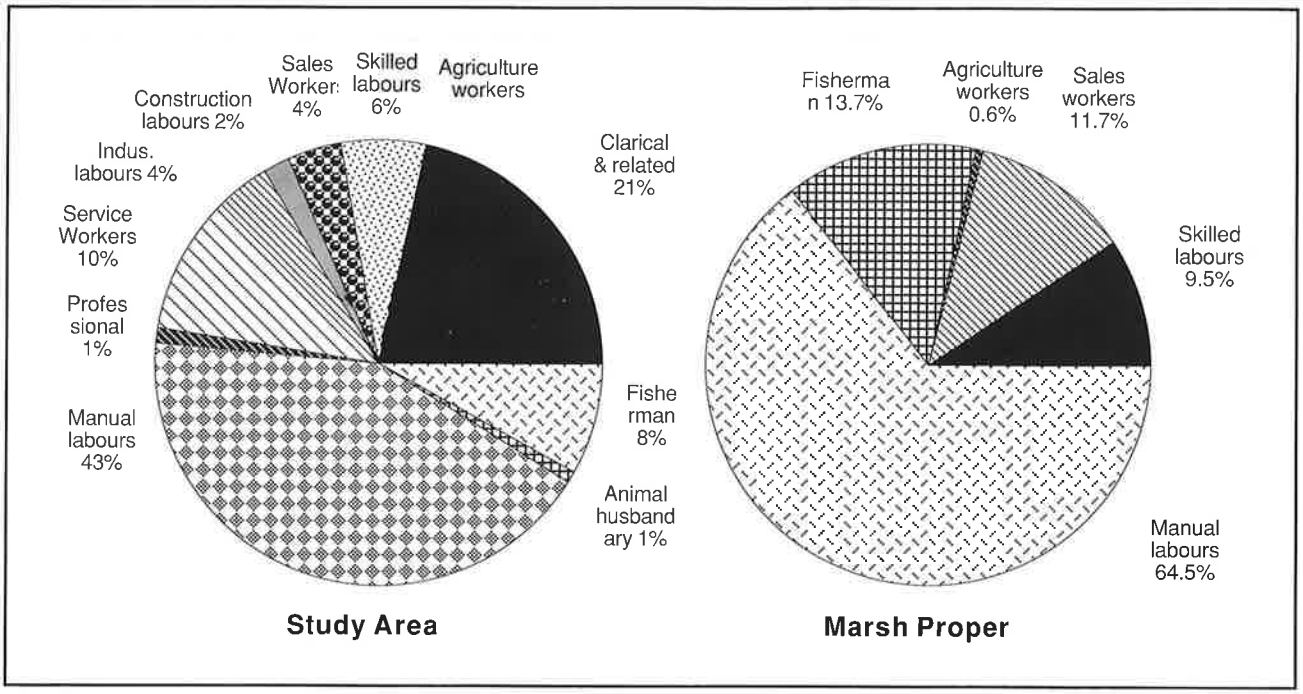


Fig. 62 Employment pattern of the population in the study area and in the marsh proper

10.9 Housing and amenities

10.9.1 Housing

In the marsh proper, 90% of the houses are temporary structures: 97% with cadjan roofs and plank walls (Fig. 63). Most of the houses are constructed on raised beds prepared with excavated peat soil. The result is a ditch with stagnant water, an ideal breeding habitat for mosquitos, contiguous with the house (Plate 17) wasted automobile tyres are used to construct pathways to the houses. In the rainy seasons, the floor gets weak and boggy. This type of peat fill land reclamation for housing could be seen in most settlements in the marsh except Ja-ela reservation area.

The prevailing housing is attributable to:

- compatibility of these houses (light structures) with the soil condition of the marsh, and
- affordability of these houses for low-income families. The cost of a house is in the range of Rs. 10,000 to 20,000.

Almost all houses get flooded in the rainy season and the floors remain submerged for one to three weeks.

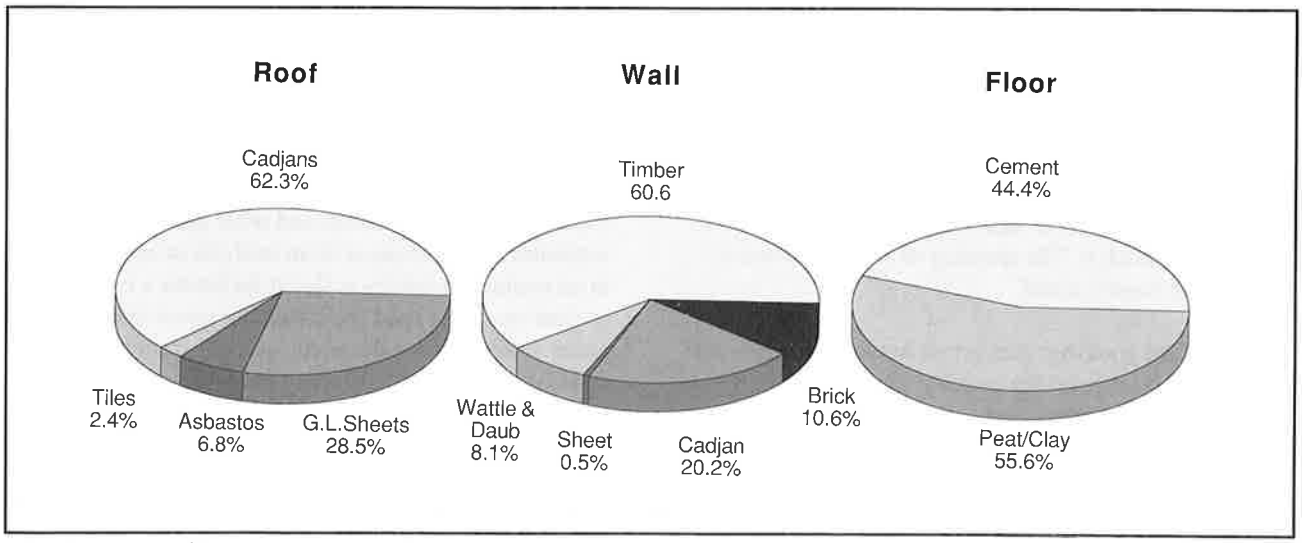


Fig. 63 Type of housing in the marsh proper

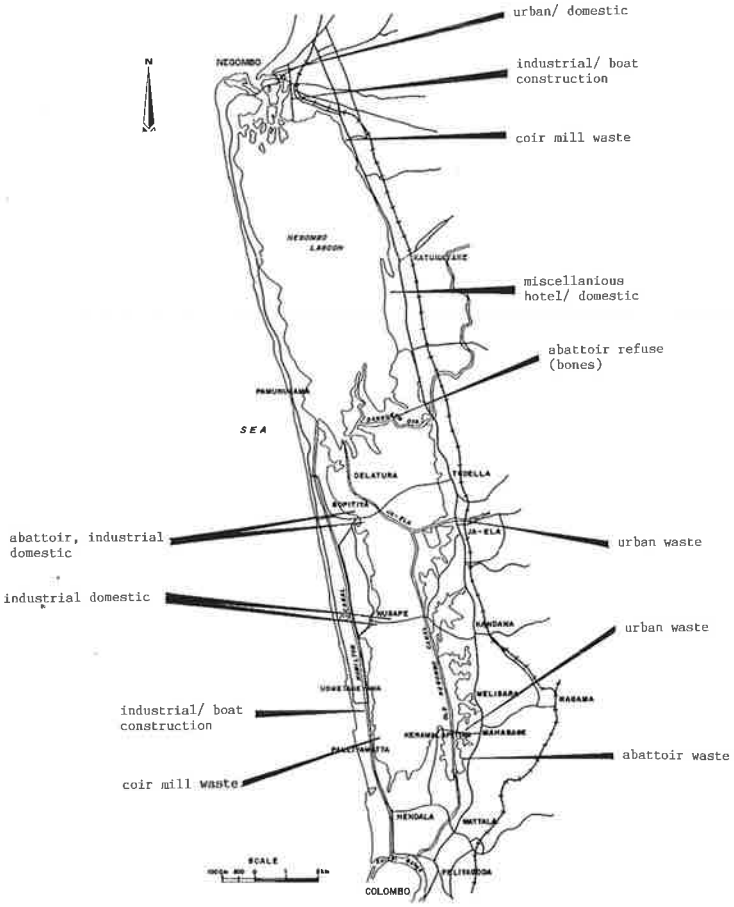


Fig. 64 Solid waste dumping sites in the study area

10.9.2 Housing amenities

Water: More than 60% of the households in the study area generally utilize water from wells for drinking and cooking. Pipe borne water is available only upto Hendala local authority limits. All households in the marsh proper obtain water for drinking from the roadside taps or wells in adjoining areas and travel at least 1km to fetch it. The majority of marsh residents bathe in the nearest canal.

Lighting and cooking: Almost all houses use kerosene for lighting. Fuelwood for cooking is sometimes purchased and at other times collected from the marsh.

Latrines: Pit latrines situated away from the house, and with a raised squatting platform constitute the general type. During the dry seasons it may be possible that faeces remain confined to the pits. However, with each rain the canals and other water bodies in the encroachment areas become hydrologically connected to the latrine pits. Water quality analysis revealed excessively high faecal coliform levels in water bodies in proximity to these housing areas (Annex).

Where latrines do not exist in encroachment settlements defecation is in open unoccupied areas.

Waste disposal: Household waste disposal is haphazard. Tyres empty metal and plastic containers scattered at random constitute a varied habitat for breeding mosquitos (Fig. 46).

10.10 Health and health services

Health of a population is commonly associated with particular environmental relationships. The indicators of prevailing poor health as well as the relevant ecological relationships stem from poverty. The Medical Research Institute carried out a preliminary survey to provide information regarding public health environment relationships that would be useful for planning, focussing mainly on vector borne diseases and nutritional status. The findings are presented in greater detail in part B-6. Relevant ecological relationships are given in A-8.7. The most prevalent diseases and infestations at Muthurajawela marsh include, leptospirosis, dengue, and bowel infestations such as shigellosis among others. The nutritional survey revealed a high incidence of anaemia, malnutrition and clinical signs of malnourishment.

The health facilities available in the study area are shown in Table 16.

10.11 Urbanization and industrialization.

10.11.1 Urbanization

Urbanization in the context of this report means the growth of towns with their associated populations, commercial and trading centers, amenities and services. An inevitable consequence of urbanization of an area is the growth in demand for space for residential needs, expansion of infrastructure and other associated urban attributes. The relevance of an analysis of urbanization in an ecological survey is that it facilitates a balanced evaluation of the need for allocating space from the area under study to serve the needs of urbanization in a contiguous area. It has already been stated in a previous plan for development of Muthurajawela that the housing needs of 70,000 to be relocated from Colombo City would have to be satisfied by landfill in the marsh (Sessional Paper 1966).

For purposes of the ecological survey the Urban Development Authority identified specific areas of

Table 16 : Health facilities/services available in the study area

	Nr. of Doctors	Nr. of nursers	Nr. of beds	Nr. of patients treated in February 1991 indoor	outdoor
Kanadana District Hospital	4	16	105	3,200	13,300
Negombo Base Hospital	28	90	396	15,00	16,00
Pamunugama Peripheral Unit	3	6	63	812	3,460

Source :Data collected from the relevant hospitals, 1991

MOH/Local Authority	Nr of PHI	Nr of Midwises	Nr of Nurses
Hendala MOH	5	18	-
Negombo MOH	2	8	2
Mahabage MOH	2	2	-
Negombo MC	2	2	-
Ja Ela UC	1	2	-
Wattala Mabole UC	2	2	-
Seeduwa Katunayake UC	2	2	-
Katana PS	4	-	-
Ja Ela PS	4	-	-
Wattala PS	4	-	-

* MOH : Medical Officer of Health
* PHI : Public Health Inspector
Source : Data collected from relevent Local Authorities, 1991

impact and influence based upon factors such as commuting pattern, supply of goods and services etc. The area of direct and immediate impact of development was regarded as Gampaha District within which inner and outer regions were demarcated. The inner region includes the area of authority of the GCEC, excluding the A.G.A's Division, Biyagama. However, in this report the entire area of authority of the GCEC is included since it facilitates analysis of available information.

The GCEC was established to promote collaborative investments in export oriented industries. Since its establishment, population growth as well as industrial growth in this area has been the highest in the nation.

Three demographic attributes of urbanization analyzed in this report are migration, natural increase (excess of births over deaths) and reclassification of rural areas as cities (Brown and Jacobson, 1987). Generally populations in urbanizing areas increase mainly because of immigration, while the contribution of natural increase diminishes. Also the urbanization trend is generally reflected by the tendency to reclassify rural areas as urban, as they acquire relevant attributes.

Migration: Gampaha District is one of the net immigration districts in the country. The share of immigrant population was 16% of the total district population in 1981. Out of this 7.5% immigrated to the urban centers in the GCEC area of authority. But, after 1981, the relative concentration of real estate property developments has been in rural environs in the hinterland, and away from the coastal belt. As a consequence, migration is away from the urban centers contiguous with Muthurajawela, and toward the property developments (Mahanama, 1991).

Natural increase: The average rate of population growth in Sri Lanka attributable to natural increase declined from 2.8% per year in the intercensal period 1946-1953 to 1.7% per year in the intercensal period 1971-1981. Gampaha District records a rate below the national average (CEMP, UN/ESCAP, 1985), and

reflects a high level of urbanization since population growth in this district is mainly attributable to immigration.

Reclassification of rural areas: The rural areas in the GCEC area of authority have been supplied with services and amenities that are generally associated with towns. However they are still classified officially as rural (village councils).

Two other aspects of urbanization that are relevant to ecology during development planning for Muthurajawela are its roles in supplying feeding needs and nutrient recycling (waste disposal) needs of a contiguous urbanizing area.

Feeding needs: Natural areas are increasingly transformed into agricultural areas for supplying the food needs of urban centers. Clearly, Muthurajawela is increasingly being used for cultivation of "keerai", the leafy vegetables that constitute a standard item in Sri Lankan cuisine (see 11.1). It is anticipated that coconut cultivation at Muthurajawela could substitute supplies which are at present brought from Kurunegala and Puttalam Districts (Coconut Development Authority, 1990). However the most important supply relevant to the urban needs in the area is fish from the wetland. Therefore, it would be important to ensure that the integrity of the fishery function of the wetland is maintained from the point of view food needs of the urban centers in the GCEC area.

Nutrient recycling: A conspicuous consequence of urbanization is the enormous production of organic and solid wastes. Particular effort has to be made for its adequate disposal. Natural areas become easy targets as waste disposal sites, particularly if they have waterways. One reason why the channel segment of Negombo Lagoon attracts large numbers of squatters is the ease with which faecal wastes are discharged directly into the water to be carried away by the tidal currents. A general habit of most cities is to locate themselves in a way that facilitates waste disposal into waterways, generally rivers and estuaries (Brown, 1985). In the absence of effective solid waste disposal systems in the urban centers contiguous with the study area, much dumping occurs in the wetland (Fig. 64). However, the need for the Muthurajawela marsh to function as a site for large scale urban nutrient cycling at the present time appears to be non-existent.

It is important to note that, a development plan for Muthurajawela encourages immigration, and the supply of housing needs on a scale indicated in the opening paragraph of this section (housing for 70,000). Hence, one of the essential infrastructure facilities will be adequate waste disposal. It would be essential to ensure that waste disposal/treatment facilities do not discharge into the Negombo Lagoon. Otherwise eutrophication would necessarily follow, resulting in the collapse of fishery production.

10.12.2. Industrialization.

Industrialization in the context of this report means expansion of manufacturing, commercial and trading activities. An analysis of industrialization is required in this report since the planners will need to assess the value of Muthurajawela in terms of ecological function for the supply of raw materials, as well as the services it can provide such as supply of space for structures, the absorption of industrial wastes, and the supply of water for industrial use among others. The distribution of industries in the Katunayake Export Processing Zone and the GCEC area of Authority are shown in Fig. 65.

Raw materials. The major industries dependant on raw materials from the wetland are those exporting seafood, live ornamental fish, and fish seed for aquaculture. NARA has estimated the annual value of these raw materials from the Muthurajawela marsh-Negombo Lagoon wetland to be in excess of Rs. 50 million (Jayakody, 1990).

Industrial wastes. The majority of industries in the GCEC area of authority utilize the "free services" provided by the flowing water of the wetland for discharge of treated and untreated industrial effluents. No clear picture is available as yet on the adverse impact of industrial waste disposal on the marsh and lagoon ecosystems or on individual biota. Episodes of fish kills in Ja Ela canal have been reported, as for

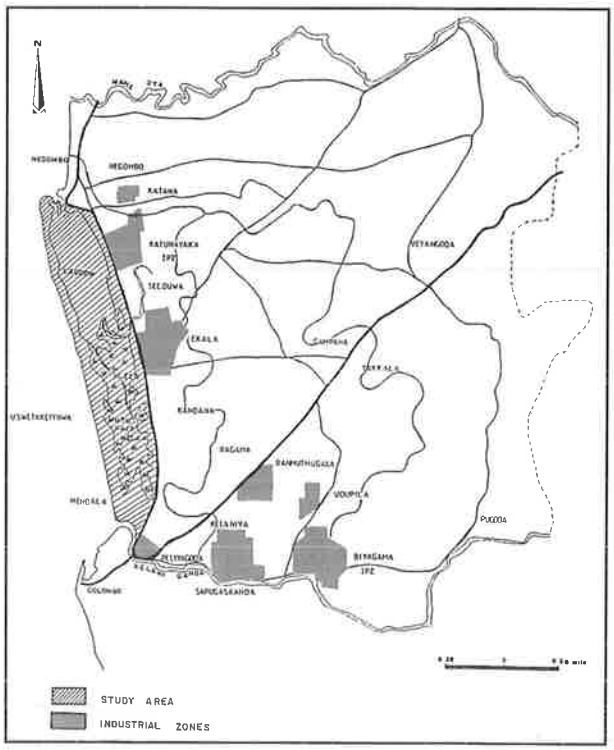


Fig. 65 Locations of industrial zones in the GCEC area of authority

instance, that which occurred in October 1990 as a result of brine discharge from a gherkin factory. Such negative impacts are also difficult to take into account in industrial production economics. It would be reasonable, however, to include in economic considerations, the value of the free services on the basis of opportunity costs.

Space requirement: An important space requirement related to industrialization is substantial open space for storage of containers. Because of the proximity of Muthurajawela, to both the Colombo Port and the EPZs at Katunayake and Biyagama, this location is regarded as a promising candidate site.

Illicit liquor distillation: Clandestine production of liquor (kassippu) in the marsh proper is an activity that occurs on small industry scale involving production from 5-10, 200 L distillation units per operation (see Fig. 74). The discharge of wastes from these operation appears to have an impact upon the fishery productivity of canals, which are used for cooling the distilling coils.

Brush pile fishery: The brush pile fishery constitutes a traditional fishing method based upon a fish aggregating device constructed from mangrove branches (Plate 18). These brush piles are the major source of ornamental fish for export. This industry makes a valuable contribution to national foreign exchange earnings, but at the same time mediates destructions of mangroves which are valuable as nursery areas supporting fishery productivity. The relationship between the ornamental fish export industry, the brush pile fishery and the utilization of mangroves should be included in a management programme for the fishery in the wetland.

11. LAND USE

The study area consists of:

-	Marsh proper	3164 ha
-	Negombo Lagoon	3068 ha
-	High ground	4462 ha

Fishing is the most important economic activity in the study area. The land use pattern in the marsh and high ground area is shown in Fig.66, and summarized in Table 17.

11.1 Agriculture

Agricultural production is predominantly from privately owned homegardens and consists of coconut, banana, jak, bread fruit, vegetables and other fruit types. These crops are generally grown on raised beds to improve soil drainage and also to protect against salinity intrusion.

In the marsh proper the significant agricultural activities are cultivation of coconut and leafy vegetables (keerai). Paddy cultivation has declined since the 1960s and now exists only as a marginal activity (Fig. 66).

Coconut. Approximately 60 ha of marsh have been planted with coconut since about the beginning of the previous decade, i.e. approximately 3 ha/yr. The end result of this form of coconut cultivation is that while a patch of marsh gets filled up a contiguous area, more than twice the extent from where the soil was excavated, becomes a pond.

Table 17 Exsisting land uses in the study area

Land use	Area in ha	%
Natural condition		
-Marsh vegitation	2,688	25.1
- Negombo Lagoon	3,164	29.6
sub-total	5,852	54.7
Agriculture		
- Homestead gardens	543	5.1
- Coconut	430	4.1
- Paddy	30	0.3
- Horticulture	30	0.3
- Pastures	6	0.2
sub-total	1,039	9.7
Built-up area		
- residential, industry, infrastructure, etc.	3,803	35.6
Total	10,694	100.0

Source: Socio-economic Survey, 1990

This type of coconut cultivation is labour intensive. Sixty per cent of the manual workers in Delature and Pamunugama are engaged in soil excavation. This process is shown in Fig. 67.

The dwarf variety of coconut used (Plate 19) bears fruit within 3-4 years and yields about 100 nuts/tree/year. Since 300-400 trees are planted on a hectare of filled land, the average annual harvest is about 30,000 nuts/ha. At current prices the value of production is Rs. 90,000/=, farmgate, and about Rs. Rs. 150,000/=, retail.

It is evident that this type of coconut cultivation is associated with land speculation.

Small scale toddy tapping is done on some coconut land.

Keerai cultivation: Raised beds, about 25 cm above water level, of variable dimensions, 10 sq. m and more, are formed from excavated marsh soil, fertilized with heavy applications of organic manure, and planted with several types of leafy plants. Pesticides such as "quinalphos" is generously used to protect against a wide range of insect pests. Once grown, harvesting becomes possible at frequent intervals for a period of one year. Profitability, however, is marginal because of very high costs of agrochemical inputs to overcome the low natural productivity of soil (see A-5.3).
The produce is generally sold in the urban markets.

Livestock: Animal husbandry is an insignificant activity in the marsh since hooved stock cannot roam freely. Some residents rear swine in pens with wooden floors, and poultry in cages. However, swine constitute a major health hazard as a intermediary for the Japanese Encephalitis virus. MRI records the uninnocculated population of swine as having the potential for causing a serious outbreak of Japanese encephalitis.

11.2. Fisheries

Fishery, the business of catching and trading in fish is entirely a small scale, partially modernized activity in the marsh and in the lagoon. Some of the gear are operated on foot while others are operated from traditional craft, outrigger canoes (oru) and log platforms (teppam) without motors (Fig. 68). By convention motorized craft are not used for fishing in the wetland, whereas such craft anchored there are used for fishing at sea.

Precisely because of its traditional and small scale nature, the fishery in the wetland can provide employment and income to a substantial segment of the population of the study area. An estimated 3000 fishermen obtain their sole or major income from fishing in the wetland (NARA, 1991). Since there is no registration of gear and only boats are registered, the number of fishermen obtaining income from this wetland tends to be underestimated. Nevertheless, the inference based even on casual observation any time of the day or night is that this wetland is an extremely busy place.

The fishery productivity of Muthurajawela marsh-Negombo Lagoon wetland is outstanding by international standards since its annual yield exceeds 150 kg/ha Table 18. The mean fishery yield of highly productive coastal waters is about 50 kg/ha/year, while the mean for highly productive estuarine and lagoonal systems is 100 kg/ha/yr (Kapetsky, 1984). The extremely high yields recorded for the food fishery in this wetland totally ignores the harvesting of ornamental fish and aquacultural seed for export which can be represented only in terms of numbers collected and not by their weight. The estimated number of fish collected for live export exceeds 10 million per year (NARA, 1991), estimated value Rs 35 million/yr.

The fishing methods used in the wetland are highly specialized in some instances and generally well adapted to the ecological conditions. Some of the more important gear and methods are shown in Fig. 69. Their locations of operation are shown in Fig. 70.

The important species captured, their annual production and estimated value are given in Table 18.

11.3. Aquaculture

A survey done by NARA in 1987 showed that 82% of pond aquaculture projects started at Muthurajawela under the subsidy scheme of the Ministry of Fisheries had been abandoned because of extremely low yield and fish kills. Production of fish, milkfish (Chanos chanos) under the prevailing conditions at Muthurajawela rarely exceeds 450 kg/ha/yr. Shrimp production is a dismal 200 kg/ha/yr, while at other locations in Sri Lanka, the harvests exceed 1600 kg/ha/yr (see B-2.3).

In the Negombo Lagoon area 15 persons are engaged in pond brackish water aquaculture
(Fig. 71).

11.4. Infrastructure

The relevance of infrastructure development to an ecological survey is that, use of a natural area for construction of roads, power lines, canals involves drastic transformation of the area, and alterations, particularly in a wetland, of water flow patterns. This is

already evident from past infrastructure development at Muthurajawela marsh. For instance the east-west roads, Jayasuriya road and Tudella-Pamunugama road divide the marsh into segments, thereby obstructing the north-south movement of water and many animal species. Large scale infrastructure development was proposed for this area as recently as 1984, but not implemented (SLLRDC, 1984).

Existing infrastructure including roads, canals, power and water supply, telecommunication facilities are shown in Fig. 72. Access into the marsh is generally along footpaths. A comprehensive map of all irrigation and other engineering works at Muthurajawela are shown in Map. M5.

An excellent road network links the study area and the marsh with the Gampaha District and the rest of the island (Fig.73).

The service infrastructure including hospitals and schools is given in section A-10.5, A-10.10.

11.5. Other economic activities

In addition to the main activities, other minor productive activities are based on the use of the natural resources of the marsh. Secondary activities include toddy-tapping, illicit brewing (kassippu), buffalo rearing, hunting of crocodiles and tortoises, timber and reed extraction. Illicit brewing is done in less accessible areas of the marsh with rudimentary equipment that can be easily hidden or sacrificed during a police raid. Although this is a highly remunerative activity it is done on a small scale because it is illegal. Timber of any value, mangroves, have already been exploited. What remains is mainly of the scrub type. Even these are being steadily cut down as fuelwood and for other purposes. Tortoise meat is highly valued as an accompaniment to liquor and fetches attractive prices. The general locations of these activities are shown in Fig. 74. These activities would require control in a development program.

Table 18 **Estimated annual yields of fish and crustaceans from the channel and basin segments and the transition zone of Negombo Lagoon - Muthurajawela wetland**

SEGMENT / ZONE	SPECIES	ESTIMATED ANNUAL YIELD kg/y	ESTIMATED YIELD PER UNIT AREA kg/ha/y	ESTIMATED VALUE (Rs)	SOURCE
CHANNEL					
	Penaeus indicus	60,000	20	3,000,000	Jayakody
Kattudel	*Metapenaeus dobsoni*			(Rs.50/= per kg.)	(1990)
BASIN					
Brush piles	*P.indicus* *Mugil spp* *Etroplus suratensis* *Siganus spp* *Lates calcarifer*	48,000		960,000 (Rs. 20/= per kg)	Jayakody (1990)
Encircling nets and other nets	*Mugil spp.* *Liza spp.* *Scylla serrata*	40,000	13	1,200,000 (Rs. 30/= per kg)	Wijeratne (1984)
Crab traps		40,000	13	8,000,000 (Rs. 200/= per kg)	Jayamanne (1990)
Trammel nets cross nets	*P. indicus*	60,000	20	9,000,000 (Rs. 150/= per kg)	Kuruta and Nishida (1988)
TRANSTITION ZONE					
Encircling nets	*Lates calcarifer*				
Other grill nets		18,000	6.0		
Trammel nets	*P.indicus*	26,000	9.6		Wijeratne (1990)
Crab traps	*Scylla seriata*	1,500	0.5		
TOTAL		293,500	97.5		
Ornamental fish/Aquaculture seed fish	*Monodactylus argenteus* *Scatophagus argus* *Lates calcarifer* *Epinephalus spp:* *Av.wt.2.0g;* *total exported* *15 million fish/y*	30,000	10.0	50,000,000	NARA Jayakody (1990)

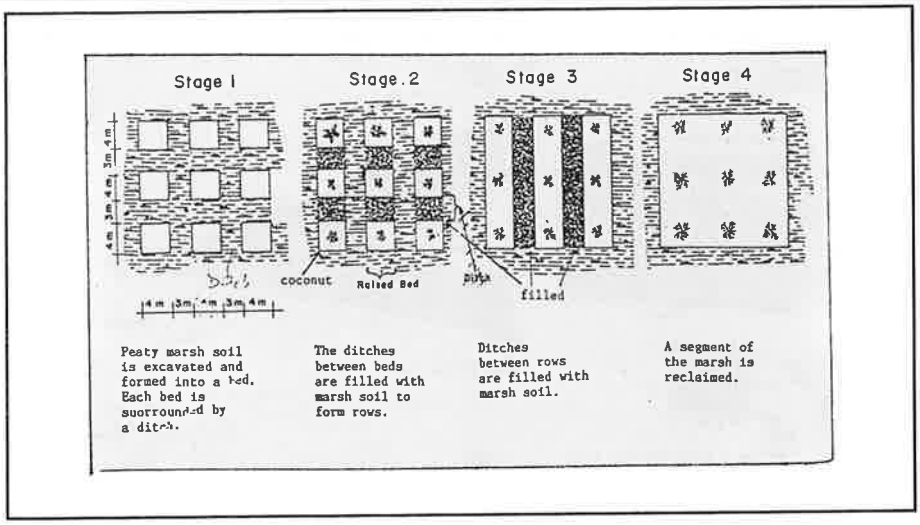


Fig. 67 Stages in the cultivation of coconut and land reclamation in the Muthurajawela marsh

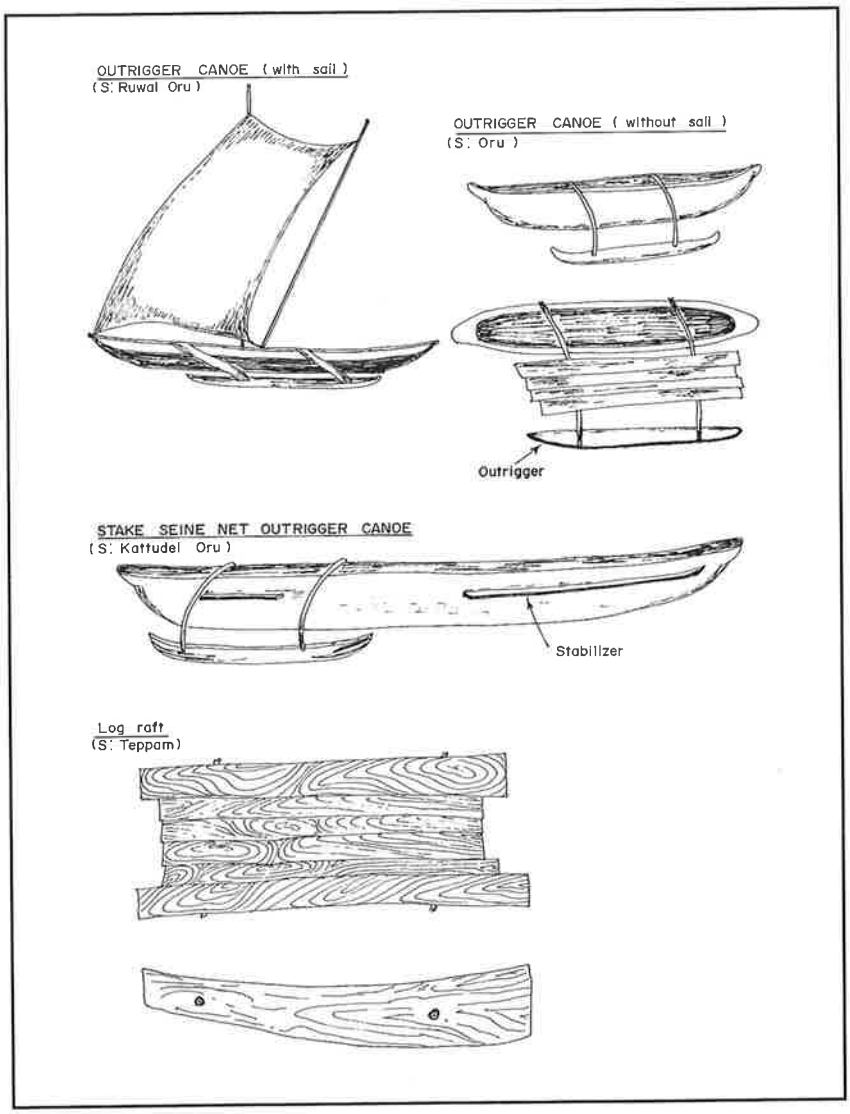


Fig. 68 Traditional fishing craft used in the Muthurajawela marsh - Negombo Lagoon wetland

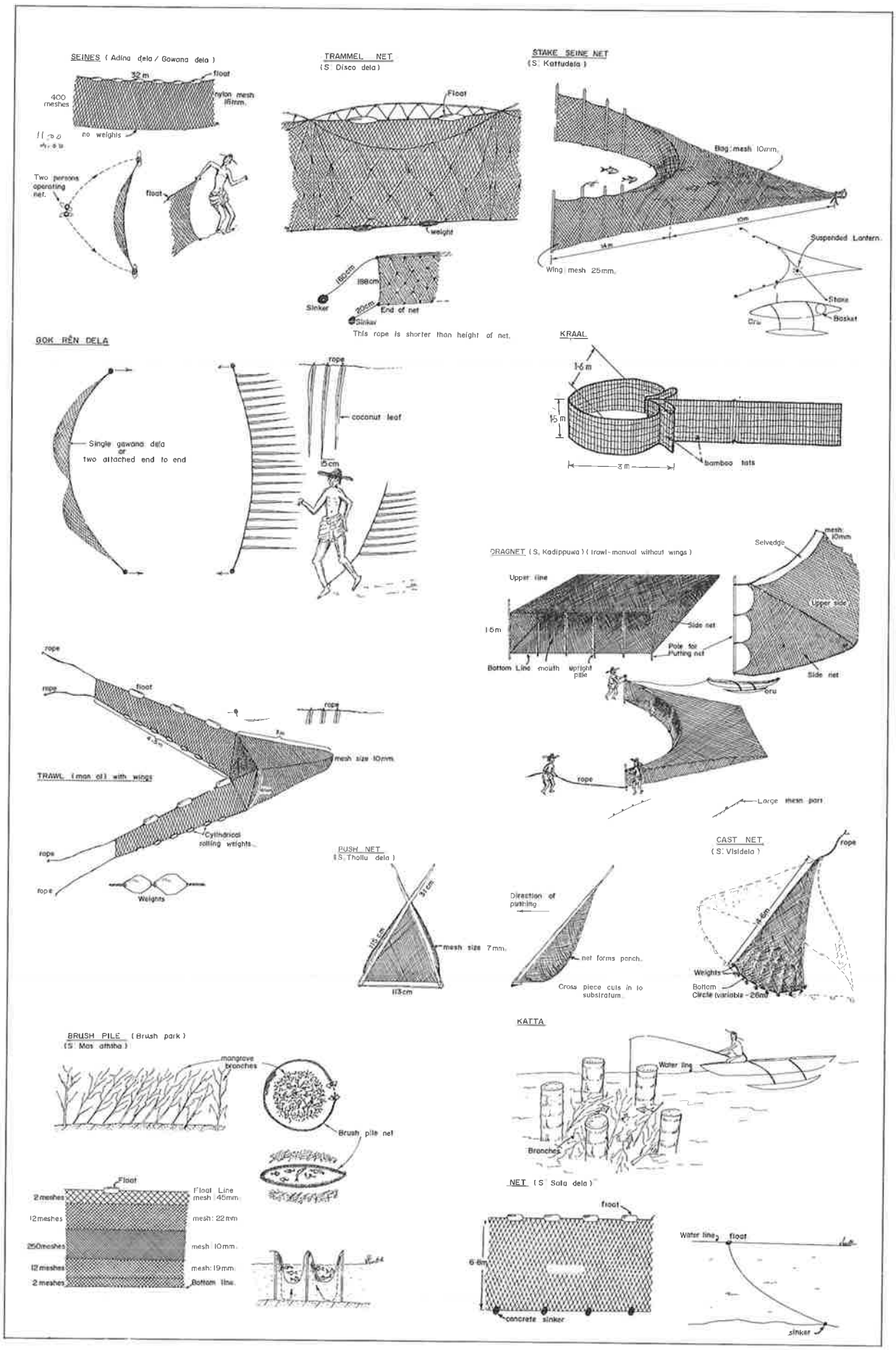


Fig. 69 Some important fishing gear and methods used in the Muthurajawela marsh Negombo Lagoon wetland

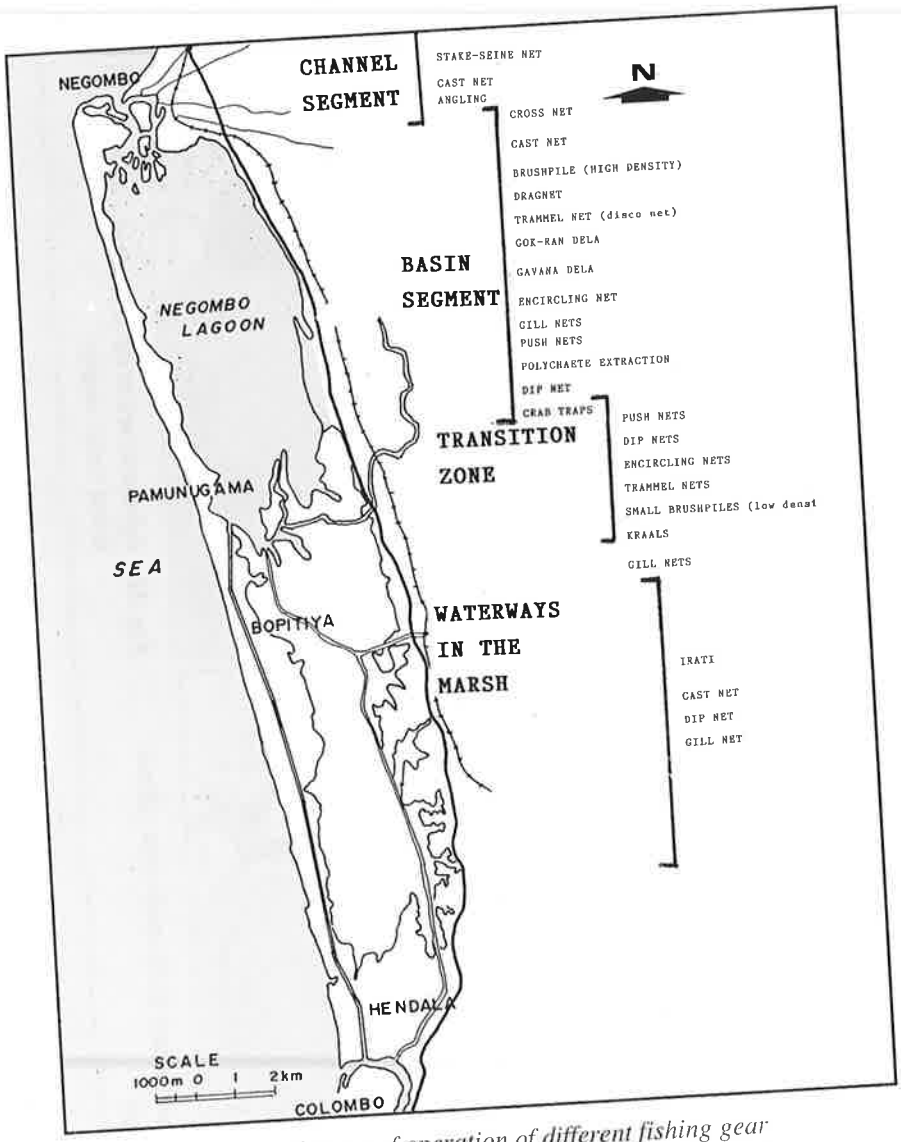


Fig. 70 *Generalized zones of operation of different fishing gear and methods used in the Muthurajawela marsh Negombo Lagoon wetland*

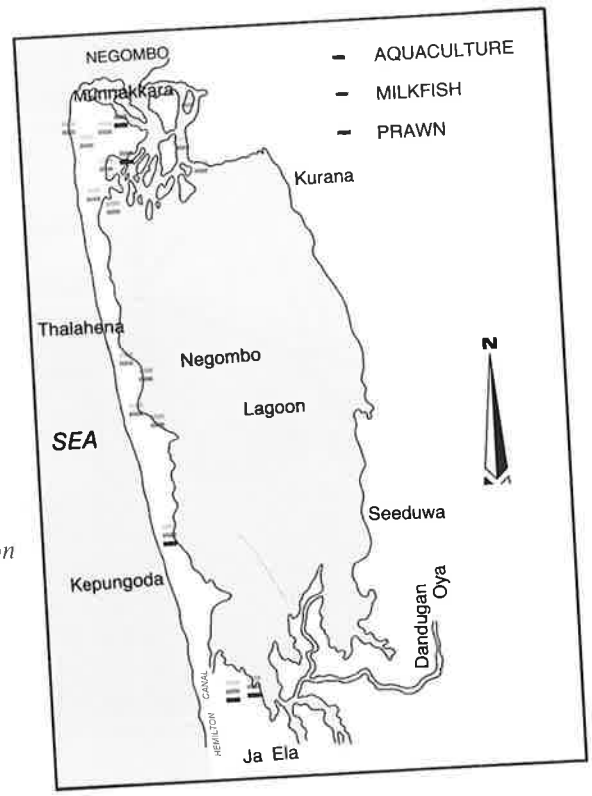


Fig. 71 *Pond aquaculture sites in the vicinity of Negombo Lagoon (Jayamanne, 1990)*

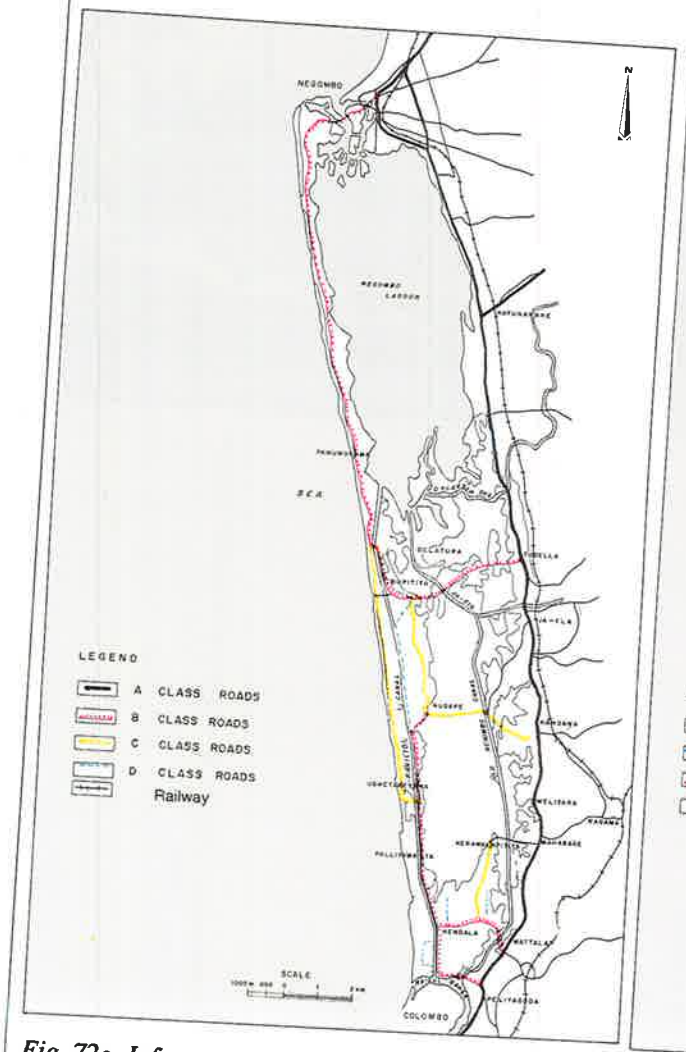


Fig. 72c. Infrastructure in the study area - roads

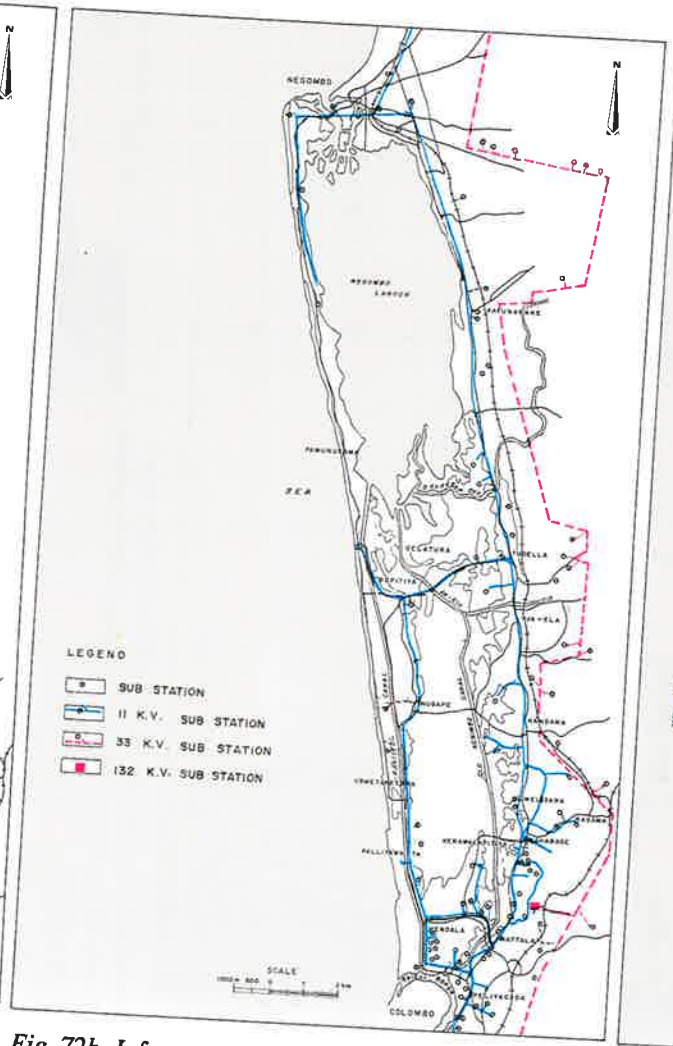


Fig. 72b. Infrastructure in the study area - power supply

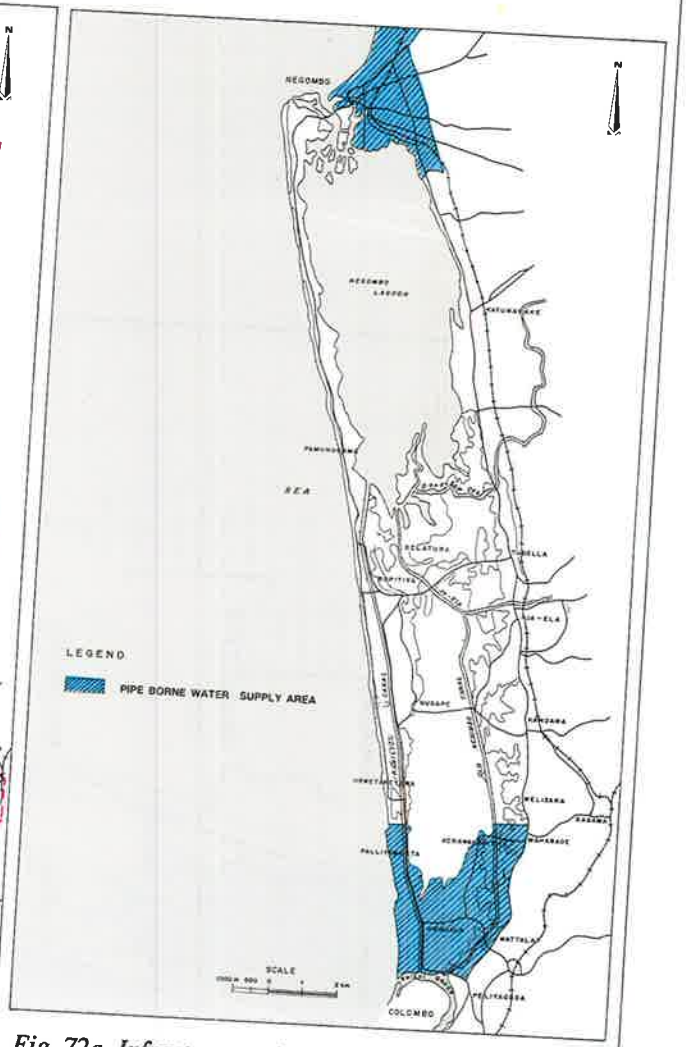


Fig. 72a Infrastructure in the study area - pipe borne water supply.

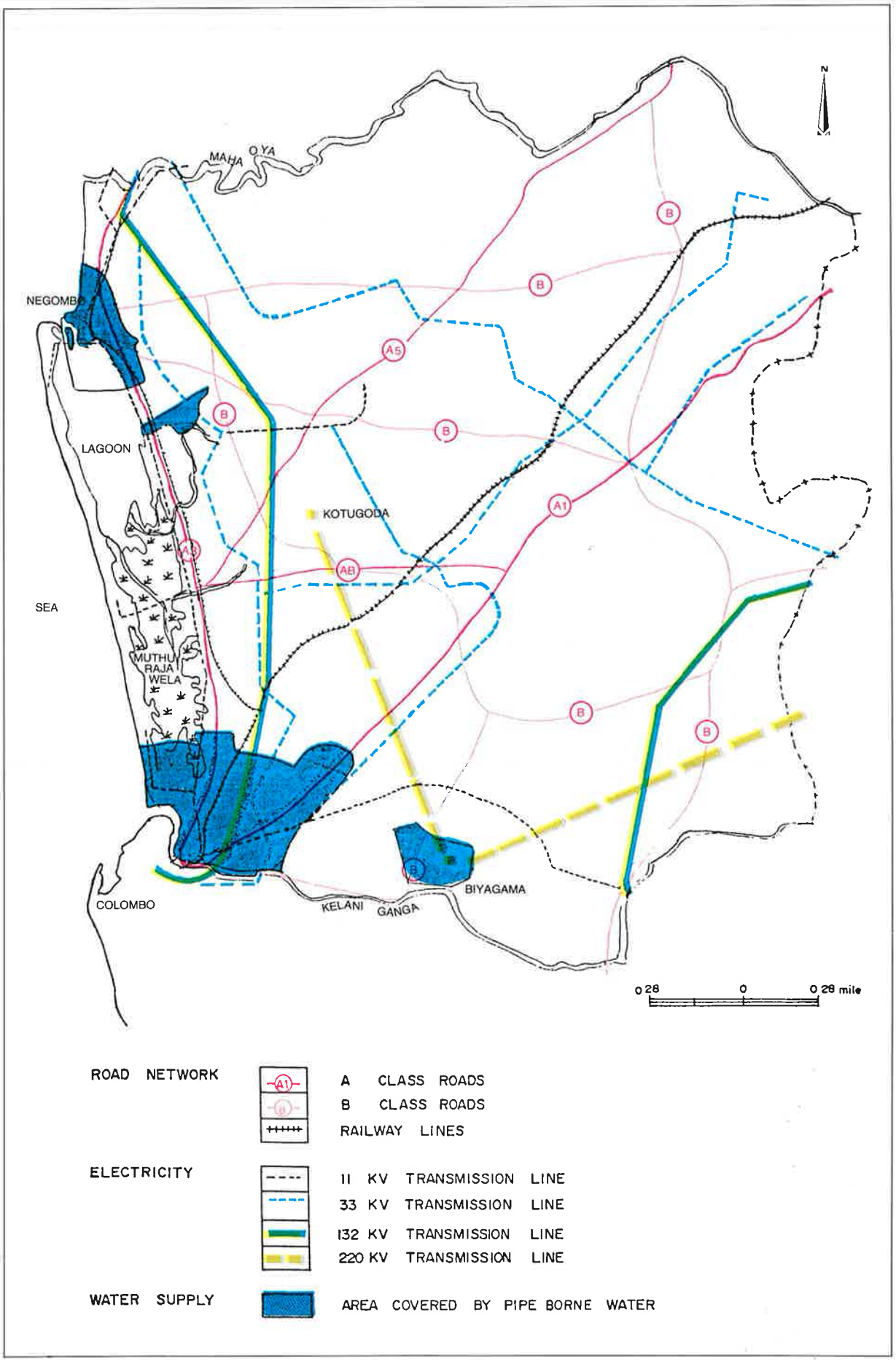


Fig. 73 Main infrastructure in the Gampaha District

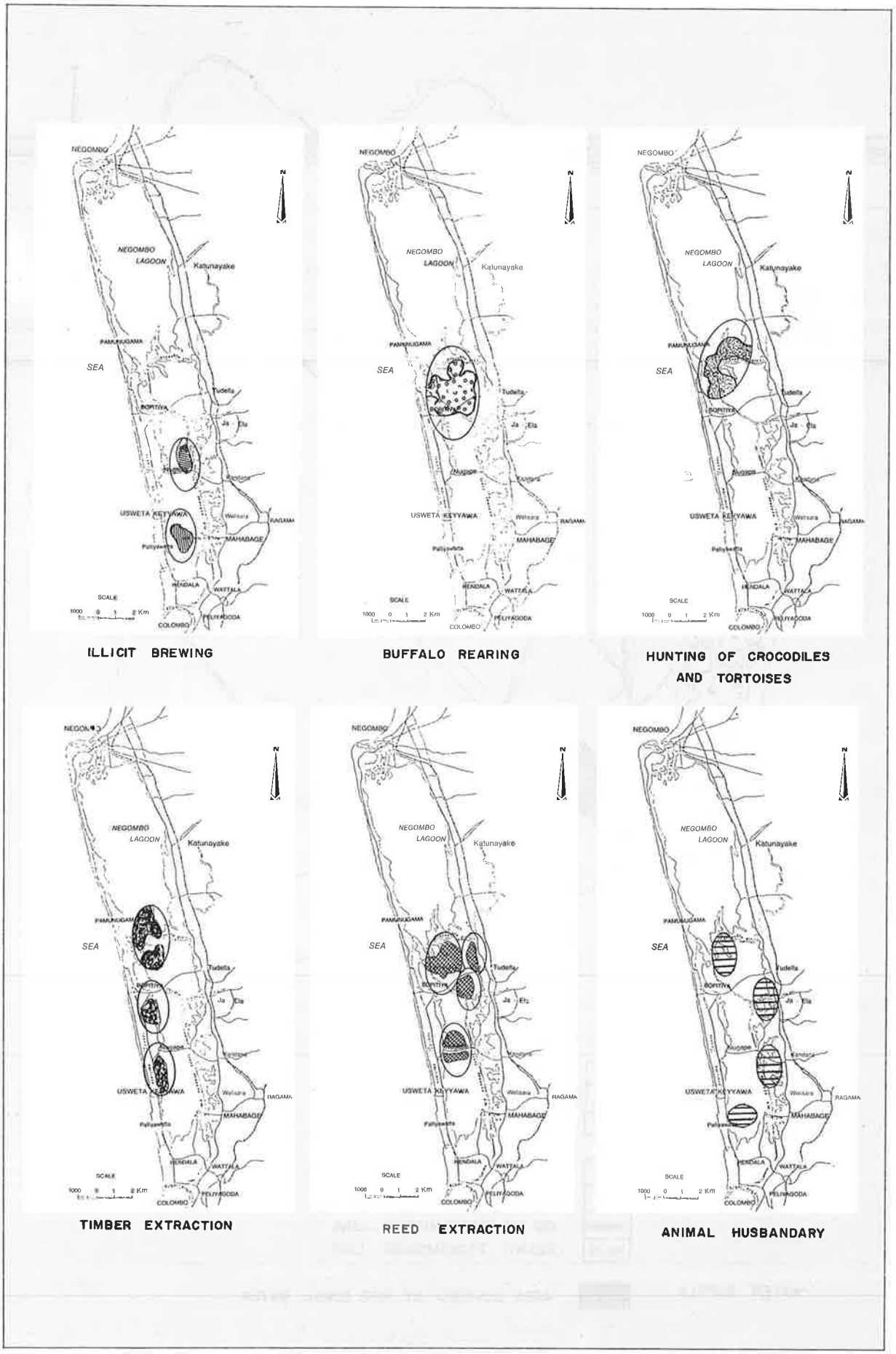


Fig.74 Locatins of minor economic activities in the Muthurajawela marsh

Plate 17

House construction in the marsh by squatters invariablyresults in a stagnant pool of water which is excellenthabitat for disease vectors.

Plate 18

Brush pile fishing, is common in the wetland. This fishaggregating device is constructed mainly with mangrovebranches.

Plate 19

A dwarf variety of coconut is planted on dykes constructedwith marsh peat. Eventually this reclaimed land will beused for housing.

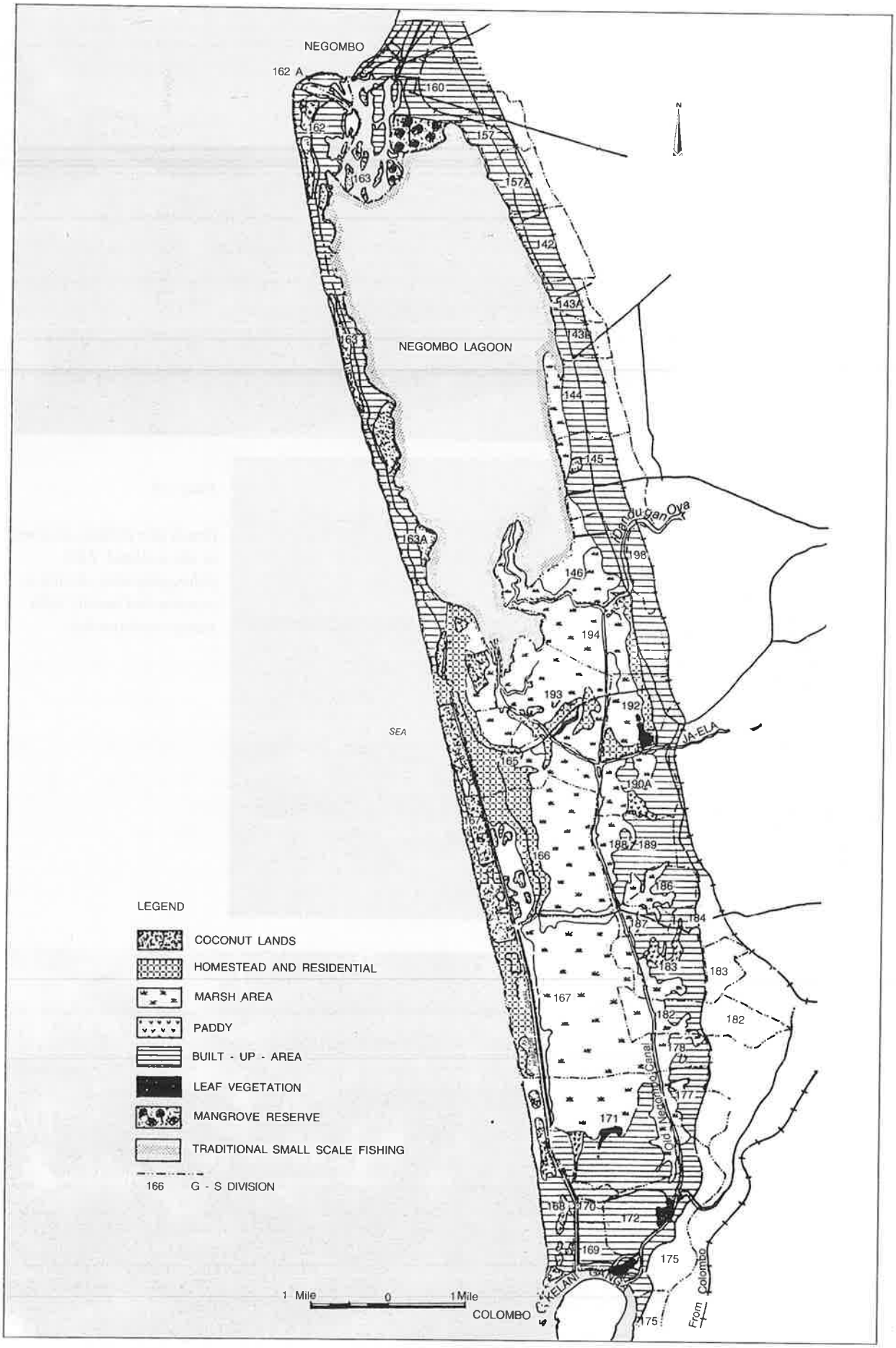


Fig 66 Existing Land use in the study area

PART B : CHANGES IN THE NATURAL ENVIRONMENT AND THEIR IMPACTS

The purpose of this part of the report is to analyze the natural changes that have occurred in the past to produce the Muthurajawela marsh-Negombo Lagoon wetland system as we know it, the natural changes that are continuing, and the manner in which human activities are interacting with them resulting in various impacts. The analysis is based mainly on the information given in Part A, and where information was inadequate, a logical judgement has been made based upon the experience of the editors. The conclusions of this part constitute the ecological and to some extent the socio-economic conditions for the Master Plan. A schematic framework for the analysis in this part is given in Fig. 75.

1. NATURAL CHANGES: CAUSES AND INTERRELATIONSHIPS

1.1 Geo-morphological Development

1.1.1 General observations

Present trends in the geo-morphological development of the area, must in the first place, be regarded as a continuation of the geological process of the recent past. The main factors playing a role include: the variations of sea level, the movements of sediments and the growth of peat. Man has already intervened with the latter two and he may do so with all three in the future. The predicted global warming will lead to a greater rate of sea level rise. Deforestation, dam building, irrigation and sand mining in the catchments of rivers have changed the supply of sediments. Drainage has stunted the accumulation of bio-mass in the marsh. Soil has been brought to the area as landfill.

After a discussion of the present views on the expected sea level rise in the next century, a brief assessment will be made of the developments to be expected in the geo-morphological units which make up the area under consideration, viz.

- the coast along its entire western side
- the marsh in its southern part
- the tidal delta with its swamps in the middle, and
- the lagoon with its inlet in the north.

Further socio-economic development will certainly interfere with these processes. Care must be taken to plan in such a way that large scale adverse effects are avoided, if necessary with the implementation of mitigating measures.

1.1.2 Expected sea level rise

The most recent assessment of predictions of future sea level rise is given by Warrick and Oerlemans (1990) under the auspices of the Intergovernmental Panel on Climatic Change.

A review of a great number of estimates based on many sea level records all over the world leads to an average rate of eustatic sea level rise of 1.2 mm/year during the past century. The relative sea level rise may hardly differ from this figure in a tectonically stable area as Sri Lanka.

A review of the estimates of sea level rise in the future leads to the low, best and high projections as shown in Fig. 76 upto the year 2100 AD. The best estimate is 0.30 m in 2050 and 0.66 m in 2100. The low estimate is about half of it and the high estimate almost double.

These estimates constitute a considerable development when compared with:

- the present trend of 0.07 m in 2050 and 0.13 m in 2100.
- the tidal ranges of 0.2 -0.6 m at sea and 0.07-0.2 m in the lagoon, and
- the present altitude of the greater part of the marsh being between 0.1 m below and 0.2 m above mean sea level.

Possible effects will be discussed in more detail in the following sections.

1.1.3 Development of the Coast

The geological history of the area already shows a general recession of the coast. The appearance of beach rock on the beach is a sign of recent erosion because it has been formed within the sand body of the beach ridge. The coast has even receded past the beach ridge over a stretch north of Dickowita, near the Pegasus Reef Hotel.

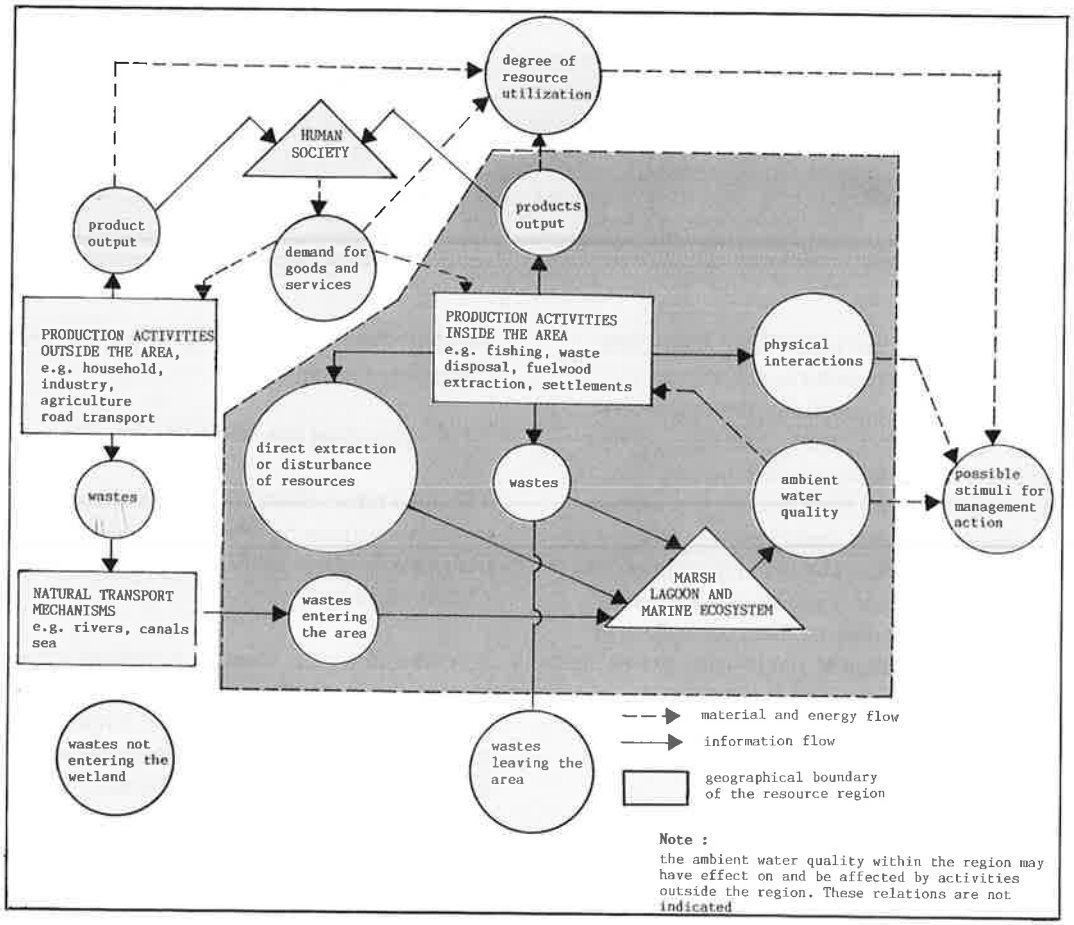


Fig. 75 Schematic framework for the analysis of changes in a natural system and human impacts.

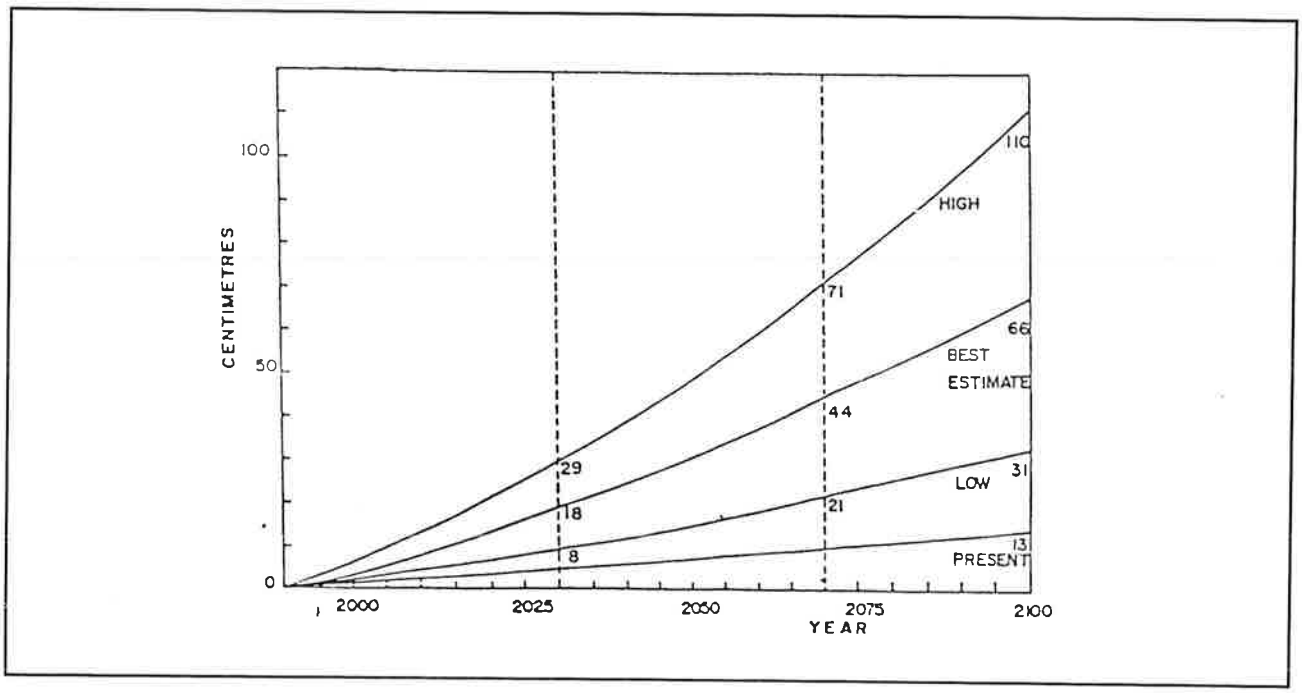


Fig. 76 Estimated sea level rise upto 2100 AD.

A shore protection of groynes and a revetments exists along the southern part of the coast, at Palliawatte and around the spit into the mouth of the Kelani Ganga.

Fig. 77 shows some characteristic cross sections of the coast. The relict reefs off the southern 8 km of the coast appears in the profiles. The coast appears to become steeper when going northwards.

Observations of the recession along the southern part of the coast (Perera, 1991) lead to an average rate of 2.3 m/year (with a local maximum of 3.9 m/year) over a beach length of 1,100 m between 1956 and 1981. No observed rates of recession are available for the rest of the coast, but the impression is that it is much less.

Rough estimates of the balance of sediments of the coast are given in Table 19, for three conditions, viz:

- the former conditions, say around the middle of the 19th century,
- the present conditions with some sea level rise and sand mining in the Kelani Ganga, and
- future conditions with extra sea level rise.

The average recession of the 25 km long, and 3-15 m high coast has been calculated from the loss of sediment.

No sand is said to be supplied to the coast from the south past Colombo Harbour. The Kelani Ganga is estimated to have supplied 100,000 to 200,000 cu m/yr out of its annual sediment load of 1.4 million tons. Reported sand mining in its estuary at a rate of 260,000, or even 600,000 cu m/yr is supposed to have stopped this source of sediments. The future sediment contribution from this source is not known.

A very rough estimate of transports perpendicular to the coast (off-shore, inland by wind etc) is based on experience elsewhere (Holland, Egypt). The submergence of the 1000 m wide active coastal area leads to a virtual loss of sediments. The littoral transport past Pitipana, into the Negombo Lagoon, is estimated to be 100,000 cu m/yr. Summation leads to the annual losses of sediments and estimates of the rate of recession, averaged over the entire coast.

The estimated present average recession of the coast is reasonably in accordance with the observations. It is considerably higher than it was in former times and it will be accelerated by the expected increase of the rate of sea level rise.

The only source of sand which compensates for the underwater losses of sediments are the sands contained in the dunes above sea level. Cross sections of these dunes (Perera, 1991) indicate values of 200 to 300 cu m/m and over in **healthy** dunes, 150-200 cu m/m in **unstable** dunes, and 80-150 cu m/m in **erosion-prone** dunes. Comparison of these values per unit of length with the estimated losses in Table 19, shows that the coast is very vulnerable and that more and serious breaches may be expected in the next century.

Even before the dunes are fully eroded, they will be overtopped by high waves and sediment will be carried inland by washovers. Extreme, tidal high waters reach to about 0.45 m above mean sea level. Local engineering practice (Perera, 1991) adds 0.3 m to this figure for effects of storm surges leading to a still water level of 0.75 m above M.S.L under extreme conditions.

The wave run-up, almost equal to wave height, has to be added to this level. The waves at sea (A-5) are modified when they approach the coast, especially by the reef off the southern part of the coast. This limits the waves at the coast in that area to heights of about 1.5 m under present conditions. They can be considerably higher along the northern, more exposed part of the coast. Table 20, gives estimates of the limit of wave run-up under present and future conditions of mean sea level.

Considering the heights 4.5 m to 10 m in healthy dunes, 3 to 4 m in unstable dunes and 2 to 3 m in erosion-prone dunes along the southern part of the coast, the threat from sea level rise will be most pronounced in the latter area and relatively low in the north.

The reef of beach rock apparently protects the coast; retarding its erosion appreciably and leading to considerable depths at short distances from the coast. Once this reef (underlain by sand) is destroyed, the coast will become very vulnerable and will recede at an accelerated pace as can presently be seen near the Pegasus Reef Hotel.

The most vulnerable parts of the coast are its southern one third and some narrow parts of the dune between the lagoon and the sea. A breach will lead to intrusion of salt water and sand into the low lying land behind the dune ridge. Raising of the dunes, zoning, prohibiting construction and mining in the dunes and sea defence works are means to reduce the natural recession and other damage to the coast.

1.1.4 Development of the marsh

The surface of peat in a marsh only grows vertically if the remains of dying plants are directly conserved by immersions in the water. Even temporary emergence will lead to compaction of the peat and to its decomposition. The main requirement for a healthy marsh is such poor drainage that its surface remains wet throughout the year. These conditions had barely

Table 19 Sand balances of the coast

	Former	Present	Future	Unit
Sea level rise	0	1.2	6	mm/y
Kelani Ganga	Suply	dredged	?	
Kelani Ganga	100,000 to 200,000	0	0 to 150,000	m 3/y
Sea level rise	0	-30,000	-150,000	m 3/y
Cross shore	-100,000	-100,000	-100,000	m 3/y
Littoral transport	-100,000	-100,000	-100,000	m 3/y
Balance	-100,000 to 0	-230,000	-330,000 to -230,000	m 3/y
Loss (average)	4 to 0	9.2	13.2 to 9.2	m3/m/y
Recession	0.3 to 0	0.7	1.0 to 0.7	m/y

Table 20 Wave attak on the coast

Sea Level rise	Present		0.15m		0.30m		0.65m	
	South	North	South	North	South	North	South	North
M S L	0	0	0.15	0.15	0.3	0.3	0.65	0.65
Storm(m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Wave run-up (m)	1.5	3.5	1.6	3.5	1	3.5	2	3.5
Total	1.8	3.8	1.95	2.95	2.4	4.1	2.95	4.45

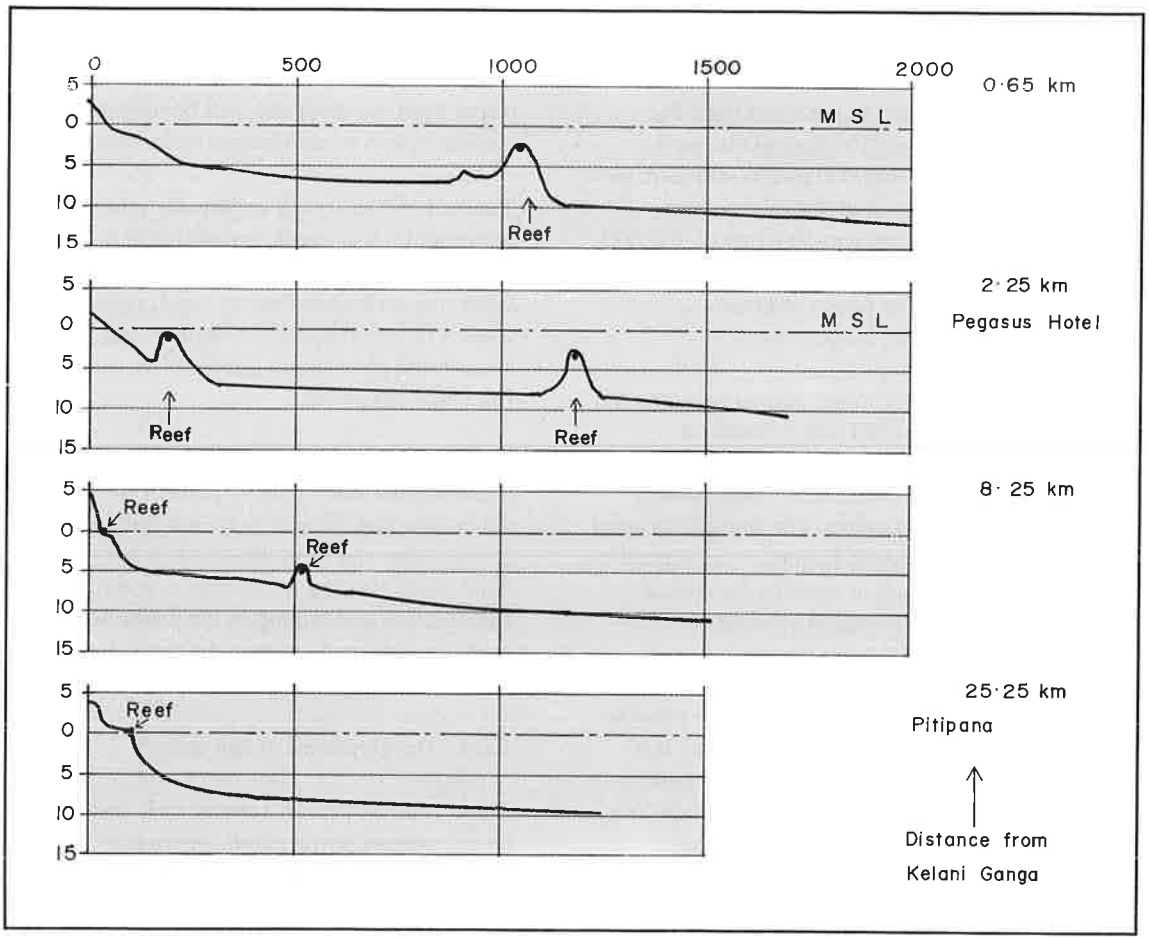


Fig. 77 Some cross sections of the coast

prevailed during the past centuries, leading to its surface remaining around mean sea level in its present state (see A-5).

Preservation and further development of the marsh will require **restoration of poor drainage** ; certainly in view of the expected increase of the rise of sea level. **This may require an almost complete hydrological separation of the marsh from its surroundings.** The maintenance of optimum ecological conditions possibly requires a limited inflow of river water.

1.1.5 Development of the tidal delta

The tidal delta of the Dandugama Oya and the Ja-ela is formed by accumulation of sediments supplied by these rivers and probably some from the lagoon, mainly during high waters caused by the floods and the tides. These processes are expected to continue in the future but the accretion will be slowed down by an accelerated sea level rise. This may even lead to some recession of the shore of the lagoon. The available information does not allow for a quantitative assessment.

1.1.6 Development of the lagoon and the inlet

The sediment balance of the Negombo Lagoon has been discussed in A-5. It is expected to silt up at a rate of 1.5 mm/y, slightly faster than the present rate of sea level rise but far below the rise of sea level expected in the future. This means that the **existence of the lagoon will not be in jeopardy in the next few centuries.** Some accelerated sedimentation will occur in parts where seagrasses occur and bind silt during some periods.

The tidal inlet of the lagoon and its inner flood delta will continue to grow slowly. Its exact pace is not known. **It is accelerated by the inhabitation of islands as soon as they emerge from the water.** A narrowing of the inlet channel must certainly be prevented in order to maintain the tidle exchange and the salinity in the lagoon. Extreme discharges of the rivers will help in maintaining this cross-sectional area.

1.1.7 Summary

The present trends in the geo-morphological development of the area appear to be:

a. an expected considerable rise of mean sea level in the future,

b. a recession of the coast mainly caused by this rise of sea level and the mining of sand from the Kelani Ganga estuary, possibly leading to breaches of the coastal barrier,

c. a considerable reduction or even cessation of the accumulation of peat in the Muthurajawela marsh leading to its vertical growth to lag behind the rise of sea level,

d. a growth of the tidal delta of the Dandugam Oya and the Ja Ela into Negombo Lagoon which is expected to be retarded by future sea level rise,

e. a net sedimentation in Negombo Lagoon which, however, is expected to be less than the increase of volume caused by sea level rise, and

f. a rather stable situation in the inlet of the lagoon under tidal and fluvial flows with, however, a tendency of narrowing caused by socio-economic development on channel banks.

Only points **b, c and f are of serious concern.**

1.1.8 Conclusions

The coast is expected to require considerable sea defence works to protect the inhabited area along the landward side of the dunes as well as (in the long run) the low lying marsh and the lagoon against the attack of the ocean.

With respect to the marsh, a **policy** decision has to be made as to **whether the marsh should be maintained,** and provide the conditions for the formation of peat, or to let it further deteriorate into a shallow body of brackish water. **The interrelated system of the tidal river delta and the Negombo Lagoon** needs attention to keep conditions conductive to a further harmonious development serving this intricate ecological system. The **inlet channel to the lagoon may require protection** against further encroachment along its banks in order to maintain the exchange of water between the lagoon and the sea at a proper level.

1.2 Hydrological Changes

The hydrological system and its history have been described comprehensively in A-6. This chapter serves only to reiterate some present trends in the external and internal processes of the system and to explore future developments autonomous as well as optional.

Most of these considerations can be of a fairly general nature because no definite and detailed plans already exist with respect to the socio-economic development of the area.

1.2.1 Changes in the climate

The anticipated global warming is expected to change the pattern of climates on earth to some degree. Very

little definite and quantitative information is available about its impact on a small area as the western flank of the island of Sri Lanka. It seems prudent to assume that precipitation and evaporation, the main climatic factors in hydrology, remain essentially the same.

More quantitative projections are available about one global effect of the warming, the eustatic sea level rise as has been discussed in Section B-1.1.2.

1.2.2 Changes in the catchments

Various man induced changes have occurred in the catchments of rivers leading to changes of the yields of water and sediments. Deforestation has caused a more rapid drainage of water carrying more sediments. Water management structures,in the form of reservoirs, canals and irrigation schemes, have been (and will be) implemented to tame floods and divert the water for useful purposes.

Such interventions reduce the total run-off, cut off the peaks of floods, depress minimum flows and reduce (dams) or increase (deforestation) the sediment yield. The last may have been the main effect in the relatively small Attanagalu catchment. No quantitative information is available. Further economic development may lead to a slight reduction of the total yields of water and sediments.

1.2.3 Drainage structures

The whole drainage system in the area, except the Hamilton Canal, the Old Dutch Canal below the confluence with the Kalu Oya, the Ja-ela and the Dandugam Oya, are in a dilapidated state: the result of complete negligence during the past quarter of a century. The drainage canals in the whole Muthurajawela area are filled with plants and the sluices draining the water to the Hamilton Canal are almost without gates. No plans seem to exist to stem the decay of the general drainage system. Squatters have built some local devices to keep their feet and their tiny fields dry. Similar small structures exist near villages.

Gravity drainage is the rule except for a few pumps between the marsh and the Ja Ela. Bad experiences with pumping appears to have led to a general aversion for such devices. Considering the future rise of sea level, this policy will lead to more water logging and increased intrusion of saline water.

1.2.4 Land reclamation

Land reclamation by filling has been a marginal activity in the area upto now. Pumped drainage has not been applied. The large drainage and settling plans of half a century ago have completely been abandoned. No definite plans seem to exist beyond some marginal filling for industrial purposes. The suggestion of filling a larger area with sand from the sea has encountered opposition leading to this study.

The effect of land fill is that an area with little storage of water and rapid drainage is created. The storage in the receiving water body may be reduced by the fill and its input increased. Only a better drainage system can save such an area from extra flooding. This means that the drainage capacity, probably up to the sea, has to be adapted in order to mitigate the effects of a land fill on its surroundings.

The large quantities of sand required for the filling of a large area can only be found at sea. The depth of borrowing should not be less than 20 m in order to avoid damage to the coast. Salt water will accompany this sand in the process of filling. **Care must be taken to remove it from the area in order to avoid damage.** The layer of sand will compress the peat underneath; squeezing out the water. The latter may be harmful to the environment since it is likely to be acidic and may be loaded with heavy metals, and therefore must be handled with care.

1.2.5 Water quality

It has been discussed in chapter A.6. that an equilibrium exists between the inflow of fresh water and the intrusion of salt from the sea. Sea level rise will increase the tendency of the salt to intrude if no measures are taken to prevent it. The penetration takes place from the Negombo Lagoon in the North and via the Hamilton Canal in the South-West. How much comes in via the ground water is not known; probably the quantity is limited because the head is small and will remain so if no pumping is applied.

Acid water emerges from the marsh and spreads into other waters. The same water probably also carries useful nutrients.

Pollutants enter the waters from a great number of sources such as squatters, villages, touristic facilities, agriculture, industry etc, within the area, as well as via the rivers. Economic development is expected to cause an increase of this load unless water treatment is applied to sewage and industrial waste. The effects of pollutants greatly depend on their nature, their quantity as well as the state of the receiving water.

The Environmental Department, GCEC, carried out a survey of selected water quality parameters for a period of 5 months. The findings are given in Appendix 1.

The limited scope of the survey and the techniques for measurement allowed only limited interpretation. Two findings of importance for planning were:

- all sampling locations in the vicinity of encroachment settlements, in the marsh and in the lagoon, recorded unacceptably high levels of fecal coliforms.

- a high level of chromium was recorded in a water body in the vicinity of which solid waste dumping occurs.

- episodic discharge of industrial wastes occurs into Ja-ela in quantities that cause fish kills (brine discharge in October, 1990).

1.2.6 General trends

The **main trend** that can be observed in the hydrological system of the Muthurajawela area is the **deterioration of the drainage works leading to even more water logging in certain areas and increased intrusion of salt;** both exacerbated by an increasing rate of sea level rise in the future. There are no definite plans to halt or reverse this development. Others include:

- breaching of the coastal barrier at one or more places may worsen the situation on the long term.

- the present equilibrium of saline and fresh water in the lagoon seems adequate to serve the ecological system; extremes would cause some, quite natural, damage.

- the tidal delta of the Dandugam Oya and the Ja-ela grows naturally into the Negombo Lagoon under the influence of the tides and the river flows.

- pollution is on the increase because of economic development around the area and in the catchment of the Attanagalu river.

Preservation of the marsh will require almost **complete impoundment** to prevent unwanted drainage and salt penetration, and to maintain a proper water balance for peat growth.

Contrarily, the hydrological regime for agriculture requires faster drainage, a lower water level and a proper timing of water supply to the plants. Soils and hydrological conditions seem adequate for this purpose only in the north eastern part of the area. The marsh could to a certain extent serve as a reservoir of irrigation water.

The salt balance in the lagoon and the adjacent delta of the two rivers should be maintained in a proper functioning of the complex ecological system. The latter requires fresh deposits of soil and, therefore, sedimentation in the delta.

To avoid damage to the ecological system as well as to health, the emission of pollutants in the area itself as well as in the catchment, should be limited.

Reclamation of land should be **accompanied by drainage measures** to avoid damage to areas which receive drainage water from the raised and better drained fills. Care must be taken for the removal of saline transportation water during the filling process and of the ground water squeezed out during the subsequent compression of the peat.

1.3 Impact of population growth

The population of the study area doubled during the period 1946 -1981 (UNEP/ESCAP/CEMP, 1985). The impact of this population growth on the natural changes that are occurring in the Muthurajawela marsh-Negombo Lagoon wetland is analysed in this section in terms of its relationship to the fundamental processes of deterioration of marsh peat and filling up of the lagoon.

Attempts to cultivate the Muthurajawela marsh on a large scale was one of many responses to national population growth. The attempts to drain the marsh, and the partial success of cultivating the area for brief periods necessarily accelerated the process of peat drying and subsidence.

The impact of population growth on filling up of the lagoon is distinctly visible. It stems from two processes:

- **inhabitation of intertidal shoals, and**

- **mangrove planting to facilitate landfill.**

The squatters who generally inhabit the shoals, spillover from the densely populated areas in the vicinity, to the free land, and sand shoals, (Plate 20) in the channel segments of the lagoon. Restriction of flows by these stabilised shoals, and the building up of intertidal areas reduces the flushing action during tidal exchange and thereby accelerates sedimentation within the lagoon. The presence of seagrasses in the Negombo Lagoon further accelerates soil buildup since seagrasses-mangroves constitute a continuum where climax state is mangroves (Fig. 78). The rate of sediment build up in seagrass beds in Negombo has occurred at an average rate of 5 mm/year since 1957 (Dharmasiri and Samarakoon unpublished data).

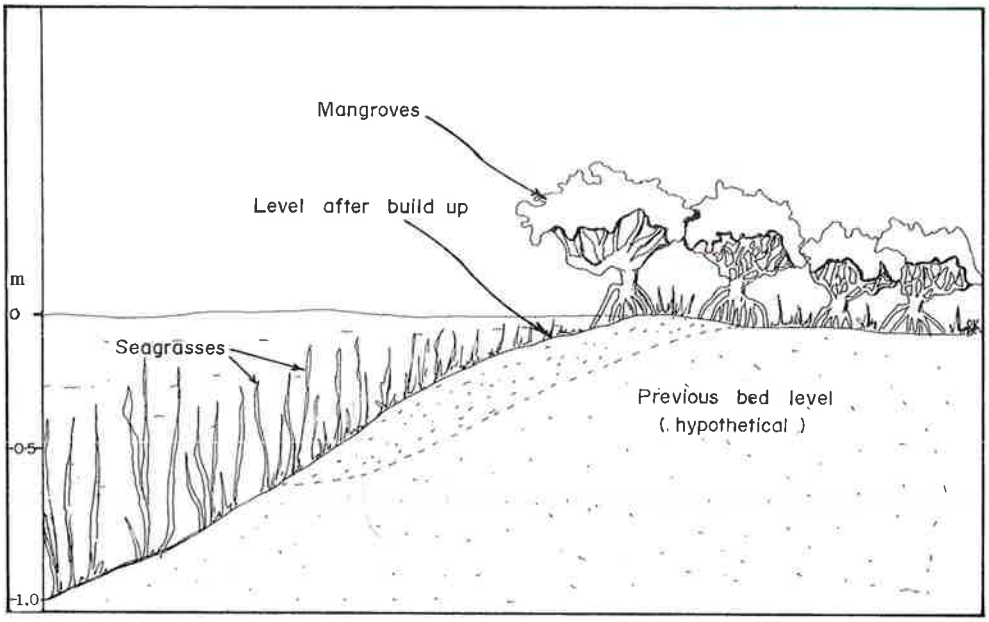


Fig. 78 Seagrasses bind and build up sediment onto which mangroves encroach

Plate 20

Intertidal sand shoals in the channel segment of Negombo Lagoon become the sites of squatter housing.

Plate 21

The municipal water line is extended to supply the squatters with drinking water.

Plate 22

The roadway extends beyond the pipe stand

Plate 23

Lateritic soil is brought for land fill

Plate 24

The mangrove island across the narrow intertidal channel is the next target.

2. DEVELOPMENT OF RESOURCE EXPLOITATION

2.1 Agriculture

Initial efforts to develop rice cultivation at Muthurajawela by irrigation and engineering intervention began with the Dutch in the **18th century.** Prior to that floodplain rice cultivation existed on the soil periodically enriched by alluvial deposition by the Kelani Ganga and the Dandugam Oya in flood. The objective for development of Muthurajawela for rice cultivation by the Dutch was for supplying the **feeding needs** of the growing population of Colombo which was then beginning to be **urbanized.** Reportedly, the excessive investment in this effort contributed to the downfall of the Dutch Administration. The construction work at that time included diversion of fresh water from the Dandugam Oya via Ja-ela into Muthurajawela to flush salt from the soil, sluices and bunds to prevent salt water intrusion from Negombo Lagoon (Part A-6).

Subsequently, under the British, the Hamilton Canal was completed. This was satirized as "Hamilton's folly" by the local residents because it facilitated salt intrusion, the reverse of the desired effect which was to be drainage of water from the marsh.

The most recent efforts were the major canal-building efforts by the Irrigation Department in the 1930s and 1940s, when the 28 east-west-running canals between the Dutch and Hamilton canals along with numerous water control structures were completed. This effort brought the area under cultivation again, and appears to have been sustainable at that time primarily because of the great need for rice production during the war when imports were disrupted. It appears that yields have never been high in the marsh, at least by modern standards, and so operation and maintenance of the irrigation system was not kept up. In recent years, the system has fallen into disrepair, and the total area under paddy has decreased systematically, as described in section A-11.1.

Agricultural production in the marsh proper has not disappeared, but changed in character to the small-scale mixed farming and livestock raising approach of the family farmers, and some commercial coconut planting (see A-11).

Coconut Cultivation: This existing form of coconut cultivation has adverse impacts upon the habitat structure as well as water quality. The raised beds are formed with peat extracted to a depth of 25-50 cm. The immediate impact is that a fresh excavation now occurs in the marsh where water would stagnate. If, however, the peat is excavated from an area where tidal flow occurs, such would not be the case. The peat, once formed into a raised bed becomes dry and in the process, the pyrites contained in it become oxidized to sulphuric acid and subsequently, into yellowish jarosite crystals (see A-5). The acid leached by rainwater necessarily enters the water body, depending upon the scale of operation, there is a likelihood that the water in the Negombo Lagoon may become acidic sporadically. The result of acidification would be a massive release of heavy metals which at present are trapped in sediment because of the alkalinity of the lagoon water (NARA, 1991).

The long term productivity of coconut grown on peaty soil is not known (Ranbanda et al, 1990). Should the coconuts fail to yield at a profitable level, the filled up land would be available for other uses. It is apparent that persons who are engaged in this form of coconut cultivation do have land reclamation as their long term objective (Fig. 67). During a period of almost 30 years, only 60 hectares of marsh have been transformed in this manner. Some ecological relationships of coconut cultivation on marsh soil are shown in Fig. 79.

The use of fertilizers appears to be very low in this sort of production, and probably what is used does not create a problem. Enrichment of the marsh waters generally is far more likely to be a result of human habitation and the total lack of sewage facilities.

According to the Department of Agriculture of Gampaha, pesticide use may be causing environmental problems primarily in the production of leafy vegetables, in the central region of the marsh and in the area around Jayasooriya Road.

There appears to be no reason to believe that these trends in agricultural land use - reduction in rice area, planting of coconuts for land reclamation cum coconut production and garden crops for (small) cash income and home consumption-will be reversed under the present conditions. The underlying technical realities of low-fertility soils with acid and salt problems combined with flooding/drainage problems will remain. The result is that the yields from paddy production will be too low to be economically interesting. The mixed-farming approach of the inhabitants around the edge of the marsh proper and of the squatters within the marsh is evidently more suitable to their needs. The existing extent under agricultural use in the area are shown in the Fig. 66. The relevant soil conditions at these locations are indicated in Figure 17.

The primary concern of the residents of the marsh proper is survival in the short run and gradually improving their lot in the long term. To do this they must secure housing, if necessary by creating the land through the coconut-planting land reclamation process, produce their own food as far as possible and find a cash income, generally through a combination of small-

scale farming activities and outside wages. Most of these people are at, or only slightly above, subsistence level. It is clear from the socio-economic survey that their income level is low and their use of the natural resources and the unclaimed space in the marsh fits into the bigger pattern of in-and out- migration described in section A-10.

Some of the families will amass enough money to be able to move out of the marsh, to higher ground elsewhere. Some will not, and they will stay in roughly the same circumstances. In some instances, the families have become comfortable enough with their homesteading that they will likely prefer to stay in their present locations, even if offered the possibility of relocating. They will continue their mixed gardening, coconut growing and animal husbandry homesteading. The pattern of willingness to relocate is clearly related to existing economic activity. Members of encroachment settlements in Swarnahansngama are engaged in small scale homesteading which they prefer to continue. At Kadola, the residents have access to the Negombo Lagoon for fishing and again would prefer to continue residing at a location that provides ready access to the lagoon. In contrast, at Ja-ela reservation access to an exploitable natural resource as well as cultivation hold limited possibility. The majority would prefer relocation. In the other settlements, access to wage labour in nearby urban centers appears to be a major determinant of willingness to be relocated.
In any case, all present trends suggest that it is highly unlikely that out-migration will exceed in-migration in the marsh, but rather the reverse, if it is not controlled, as it is at present by the Cabinet directive that any development in the marsh should stop until the Master Plan is completed. This sort of small-scale land use is difficult to monitor and control. At the present time, the "watchers" appointed and paid by GCEC assist in enforcing this directive. The encroachment into the marsh and the gradual reclamation of the marsh land by building up with excavated marsh peat and coconut planting will continue if this control is not maintained.

At the present time large areas of the marsh proper remain uncultivated, some small proportion being used for vegetable growing and subsistence fisheries by immigrant marsh dwellers. Perhaps the most important type of cultivable vegetation could consist of tall sedges (boru pan,: a natural growth, and gal-ehi: cultivated) used for mat weaving, and reeds for making fish traps and fishing screens used in combination with brush pile fishing. Cultivation of other types of vegetation that could supply natural fibre for producing a wide range of consumer products also could be explored.

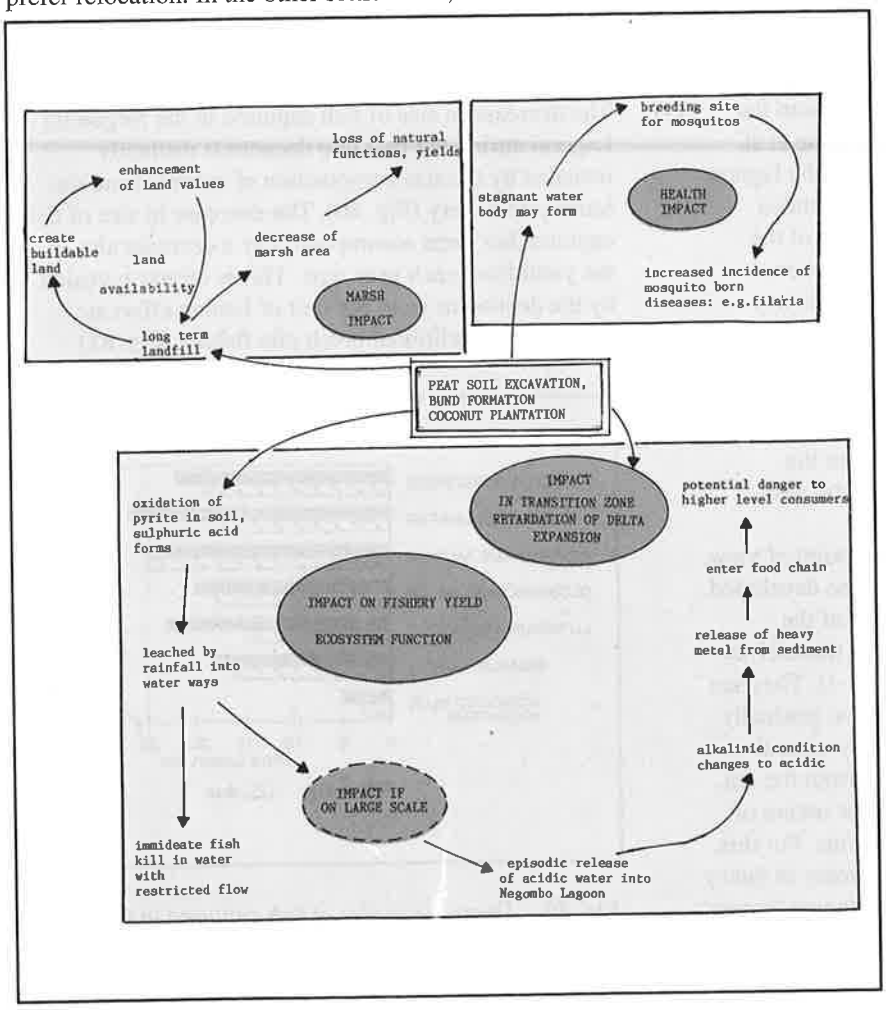


Fig. 79 Impacts of coconut cultivation on dykes built with excavated peat soil.

2.2 Fisheries

The discussion of fisheries and the current trends involves, of necessity both the lagoon and the marsh proper. This is for two reasons:

- the marsh and the lagoon are ecologically linked as described in A-9, and
- a number of the inhabitants of the marsh actually fish in certain parts of the lagoon, primarily the southern most part.

The lagoon is threatened at the moment by several activities, the effects of which can be summarized as

- choking and
- polluting.

A major cause of choking is the filling in of the channel segments of the lagoon by squatters who use a simple silt-catching landfill system with mangroves (Plate 13). Their housing conditions at present are extremely poor: small shanties that inundate with any rise in water level as they are built within a few inches of MSL, and with no sanitation facilities whatsoever.

The primary cause of polluting is the lack of proper sewage handling facilities for the residents, the industries and hotels in the area, the consequence of which is that waste materials are introduced into the lagoon and the marsh. NARA (Wickremaratne et al, 1990) has calculated that while the water of the lagoon flushes in a short period (2-4 days), the suspended matter in the water that settles on the bottom of the lagoon stays an average of 5-6 years. This material already contains unacceptably high levels of heavy metals which could, if re-introduced into the water rapidly, by inadequately-planned dredging for example or acidification as a result of landfill with peat (See B-2.1) cause contamination and fish-kill. The accumulated heavy metals may have been responsible for the occasional fish kills that have occurred in the past.

From an environmental and public health point of view, a strategy for lagoon management should be developed as part of the general plan of development of the Muthurajawela Marsh. Lagoons are not of themselves inherently stable systems (see A-9, A-5, B-1). They are gradually created over time and may also be gradually filled in or destroyed through breaching, by natural forces of sand barriers that separate them from the sea. Human use also affects this process, but the nature of the effects can be directed to suit human aims. For this, a management plan is needed. Further increase of heavy metals and other pollutants might well endanger human health through bio-accumulation in the food chain.

The trend in fisheries during the past two decades has been distinctly the overexploitation of both fish and crustacean stocks Samarakoon (1990). This trend is reflected by:

- the increased number of fisherfolk now operating in the study area,
- the decrease in the size of fish captured by different gear and methods,
- increase in value of ornamental fish and their exploitation level.
- the progressive decrease in mesh size of nets used, and
- multiplication of fishing gear types and the addition of gear types which are known to be destructive to early stages of fish and shrimp.

The estimated number of fisherfolk operating in this wetland is 3000. However, there is no registration of fishermen or fishing gear. Registration is generally confined to craft. However, in the case of the stake seine fishery, both craft and gear are registered. The number of stake seine nets in operation has increased by about 25% during the past 40 years (Atapattu, 1985; Panditharatne, 1981). A similar situation is evident with regard to other fishing activities too.

The decrease in size of fish captured in the Negombo Lagoon during the past two decades is distinctly revealed by the size composition of catches from the brush pile fishery (Fig. 80). The decrease in size of fish captured has been accompanied by a decrease also in the yield from each gear type. This is clearly revealed by the decline in yield per unit of fishing effort as reflected by traditional brush pile fishing (Fig. 81).

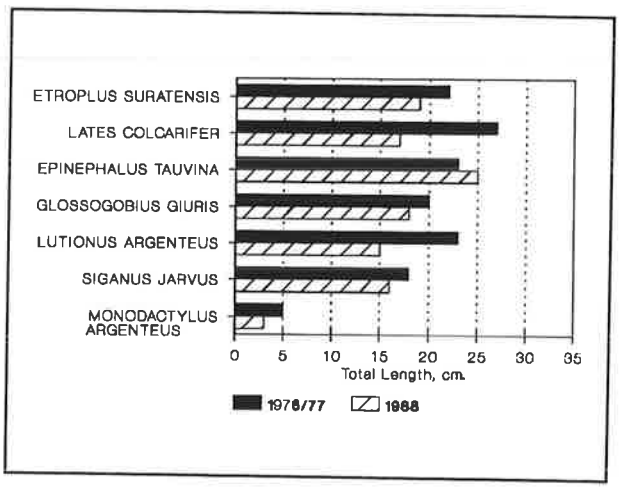


Fig. 80 Decrease in size of fish captured in the brushpile fishery since 1976/1977.

A brush pile is a fish aggregating device which passively attracts fish until a community of prey and predatory fish develops (Plate 18). It is harvested at intervals of 2-30 days. An interval of 30 days enables a community to develop while harvesting at very short intervals only enables capture of transients.

The progressive decrease in mesh size of gear used is based on a comparison of the mesh sizes of some nets presently in use and those that were in use during the early part of this century (Pearson, 1922; Samarakoon, 1990).

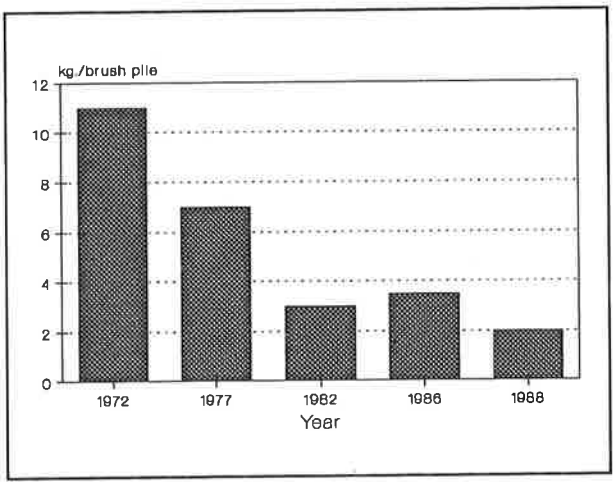


Fig. 81 Decrease in fish yield from brush piles in Talahena from 1972-1988.

The three most prominent recent additions to the range of fishing gear in use in this wetland are the trammel net (disco-net), push net and the trawl. These gear, and most of the other gear, partition the existing stocks (Fig. 69). Evidently the increased number of fishermen operating in the wetland still find it profitable to continue their activity despite depleted catches. This situation has been brought about by the high export demand for shrimp, crab, ornamental fishes and seed fish for aquaculture. The relative price increase of food fishes and the export categories show a very wide disparity (Fig. 82).

The immediate consequence of the use of gear types that rake the seagrass bed and disturb the bottom, such as push nets, dragnets, trawls has been the near extinction of the indigenous cichlid fish, the orange chromide (Etroplus maculatus) from the Negombo Lagoon (Jayakody, 1990). The reason for this impact is the dependance of this species on the seagrass bed for nest building, breeding and raising of offspring. Both parents tend the offspring with astounding diligence, not abandoning them even when disturbed by fishing nets (Samarakoon, 1981). Because of this, they are captured easily by fishing gear that are moved along the bottom. This fish is rare in Negombo Lagoon now, but it was there in abundance as recently as 1977 (Ward and Wyman, 1976; Ward and Samarakoon, 1981). The orange chromides now occurring in this wetland breed almost exclusively in the relatively undisturbed waters of the marsh and swamp areas.

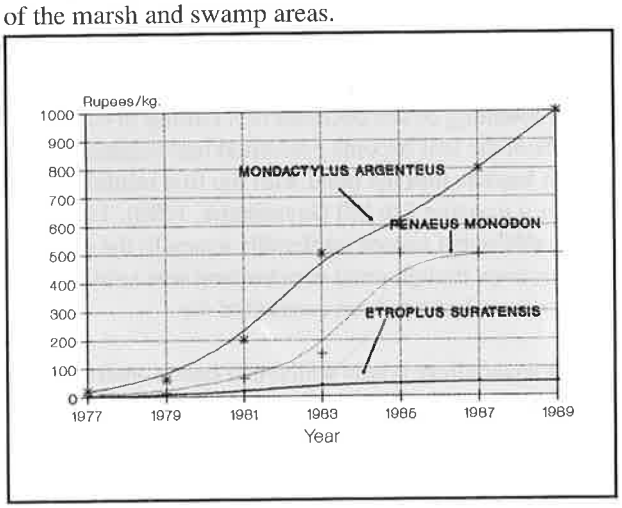


Fig. 82 The relative price increase of a food fish (Etroplus suratensis), and exportable shrimp species (Penaeus monodon) and an exportable ornamental fish (Monodactylus argenteus).

The overexploitation of the fishery in the Negombo Lagoon will not only adversely influence the 3000 fishermen who are actively engaged in lagoonal fishing, but also their dependants, and those who are engaged in marketing of the collected fish. The adverse impact on the nursery function of the lagoon is already reflected by the declining proportion of catches of penaeid shrimps, that have an obligatory estuarine stage (spent in the Negombo Lagoon), recorded from coastal shrimp catches. (Jayakody and Jayawardena, 1989).

2.3. Aquaculture

Development of pond aquaculture was pursued by the Ministry of Fisheries during the preceding decade by initiating various incentive schemes: subsidy schemes for small-scale pond construction, and both subsidization of land costs (long term land leases at nominal fees) and tax benefits for export ventures such as shrimp/giant freshwater prawn culture. Evidently the trend in aquaculture development in the study area has been one of increasing abandonment of small-scale ponds, and marginalization of the production activities of the export oriented ventures. In 1987, it was found that 82% of small ponds constructed under the subsidy scheme were non-functional (Jayasinghe, 1990).

Successful pond aquaculture is above all a matter of appropriate site selection. The aquatic medium in a culture pond is the product of interaction of water and soil, the water being only as good as the soil in which the pond is constructed. Pond aquaculture has become

an unsustainable activity in the Muthurajawela marsh mainly because of the fundamental error of improper site selection.

Soils in the Muthurajawela Marshes are all potentially acid sulphate (see A-5). After pond construction involving excavation and dyke formation, the soil of the water retaining dykes becomes dry. During drying the pyrites in the soil become converted into sulphuric acid which leaches into the pond with the first rainfall, and causes a massive fish kill (Jayasinghe, 1990). This inevitable event causes intolerable losses to the pond owner; even though pond construction was subsidized, labour costs had not been accounted for.

Some aquaculture ponds which had been constructed 5-10 years ago, are today, reported to have achieved profitable production levels (Wijeratne, 1990). However, this is again with a measure of government subsidization such as supply of free fish/shrimp seed. Evidently the desirable production levels could be achieved only after the soil acidity has been flushed out after years of repeated filling and draining.

The impacts of abandoned aquaculture ponds could be alarming since they provide potential breeding areas for disease causing insect vectors. Generally, it is too expensive to refill an abandoned pond with soil.

Research is continuing into aquaculture systems that could be profitable while serving more integrated functions. One such system, the brush pile-mini pen (BP-MP) system has produced results that suggests its potential for development as a part of a rural integrated development project. The BP-MP system is based on the traditional brush pile fishing method but incorporates an enclosure within which the cultured stock is placed. The initial trials, each lasting, 120 days, yielded an average of 20 kg of tiger shrimp (Penaeus monodon) per harvest for 50 sqm (this production translates to 4000/kg/ha/4 months). Later trials have shown that costs of production can be reduced by relying upon naturally recruited white shrimp (P. indicus) seed shrimp instead of hatchery produced tiger shrimp postlarvae. Profitability certainly may be enhanced by stocking ornamental fish in the pens (Plates 25, and 26).

The benefits of this system from an environmental standpoint is that the BP-MPs provide protection to the seagrass beds against large scale operation of push nets, dragnets and trawls by obstructing their operation over the seagrass bed. As explained in A-9, this vegetation constitutes a critical nursery area in the Muthurajawela marsh-Negombo Lagoon ecosystem (Fernando and Samarakoon, 1989).

The chief danger is that ornamental fish exporters could finance the operation of clusters of pens for rearing the smallest, collectable sizes and thereby depress current prices. This would cause an intolerable economic crisis for hundreds of poor fisherfolk whose main source of income is ornamental fish for which they now receive a reasonable price.

2.4 Other economic activities

Peat mining was started on a commercial scale in 1847 by a private company which acquired a large portion of the marsh for this purpose. Within a short period it became uneconomical, probably because of the poor quality of the peat and transport and marketing constraints. The land was sold to private owners.

The minor extent of mangrove still existing are being steadily cut down for fishery associated needs, and for firewood. Generally, mangroves are replaced by the invasive species, Anona glabra (wel attha) and the fern, Acrostichum aureum. Loss of mangroves entails a reduction of nursery areas for fishery organisms. However, in some areas such as the swamp segment, mangroves are replaced by reeds and sedges which also provide an adequate nursery area Plate 28 and 29.

Animal husbandry appears to be gaining favour among the marsh residents since, stock such as swine, find a ready market at nearby urban centers. This activity could entrain catastrophic incidence of Japanese encephalitis unless the swine are inoculated (MRI, 1990).

2.5 Conclusions and recommendations

- Efforts to re-start rice production should not be made.

- It is suggested that the current small-scale land reclamation cum homesteading is not a high-value use of the land. It is not recommended as a dominant activity for using the marsh. The system may have its place in an overall mixed land use strategy. If the strategy is to develop certain areas for housing via land-fill, making these areas no longer marsh, and to keep other areas for conservation as a marsh, it will be necessary to create a buffer zone between the two, and there may be a place for low-intensity land use via mixed farming as a part of the buffer zone as long as the location of this kind of activity is controlled.

- In those areas of the marsh that are considered environmentally critical, new squatting should not be allowed. Current residents should be offered alternative low-income housing.

Plate 25

Experimental brush pile-mini pen aquaculture based upon traditional brush piles (middle right)

Plate 26

A brush pile mini pen being harvested after 4 months

Plate 27

The harvest of tiger shrimp (20 kg/50 m2) could become profitable with reduced feeding costs.

- In order to preserve the productivity of the lagoon, a lagoon management plan is needed. It is also necessary that part of the management plan would be a set of initial measures designed to bring about a better ecological balance than now prevails in the lagoon.

These measures could include:

- dredging and clearing the mouth of the lagoon to allow a better exchange of water and clear the "choking" effect,

- relocation of squatters who are contributing to its "choking" away from the channel segment of the lagoon.

- prohibiting the use of the lagoon for dumping of any kind of industrial wastes

- prohibiting certain types of fishing practices within the lagoon e.g. push nets.

The management plan itself would include: provisions for avoiding choking off the lagoon's water circulation, for monitoring and controlling pollution of the lagoon, for keeping the fish and shrimp catch within sustainable levels. Some of the provisions necessary for such a management plan are now clear.

They are-:

- integrated management of the fishery in the Negombo Lagoon in order to ensure that the coastal stocks, including shrimps and several important fish species do not collapse.

- provide alternative low-income housing for the relocation of those squatters currently blocking the mouth of the Negombo Lagoon with their land reclamation activities.

- in the event that the Lagoon and coastal, fisherman lose their occupations and income because of non-management, alternative jobs would have to be created. In 1988, the estimated cost of creation of a job in this sector was Rs. 10,000 (Sessional paper 12, 1988).

- exploitation of the reeds and grasses in the marsh does not present a problem. The demand for mats etc. is not high enough to cause over-exploitation, and the reeds and grasses regenerate easily and quickly. This small-scale activity can continue unregulated

- mangrove exploitation and tree-cutting in general has reached a point where there are no important tree resources left. There is no real possibility of replanting mangroves since the limited extent of land available for such planting would make it uneconomical. However, certain critical areas at the north and south of the Negombo Lagoon must be protected from wood extraction. While prohibiting mangrove cutting, it will be necessary to develop alternative sources of fuelwood for the households.

- pond aquaculture, under prevailing soil conditions, cannot be undertaken profitably and should not be promoted.

- small scale pen culture deserves development on a well organized basis, taking measures to ensure that it does not depress the incomes of fisherfolk through oversupply.

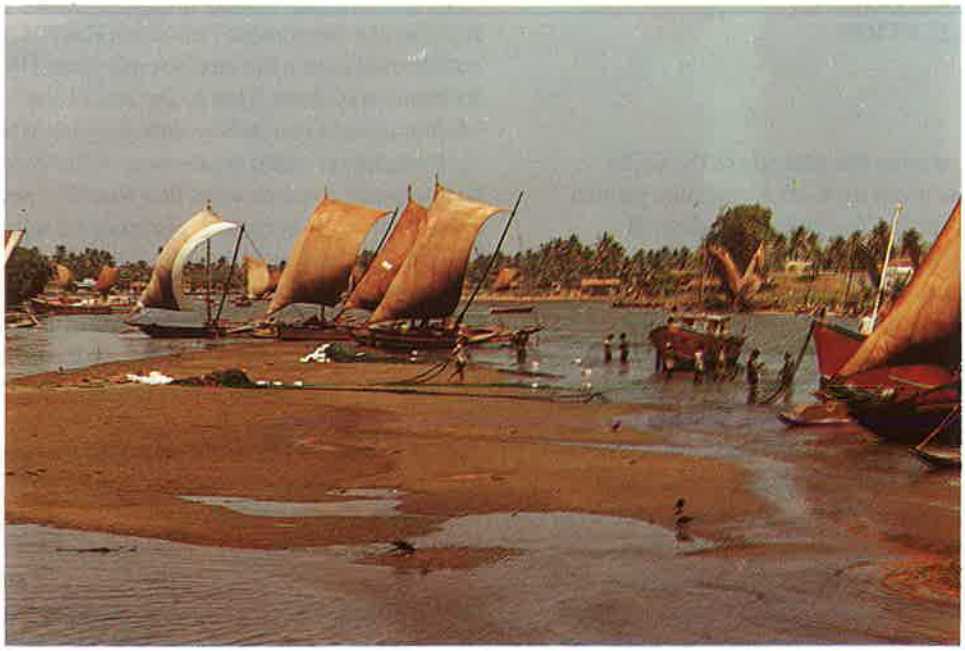


Plate 28 *Shoaling is increasing in the channel segment of Negombo Lagoon and contributes to choking.*

Plate 29 *Solid waste dumping in the channel segment of Negombo Lagoon contributes to choking of this critical passagefor fish and shrimp larvae.*

3. URBANIZATION AND INDUSTRIALIZATION

3.1 Urbanization

The rationale for confining the analysis to the GCEC area of authority was given in A-10. Population growth accompanies urbanization. The siting of industrial developments, in keeping with government policy serves as a pacemaker for immigration to an area and of consequent population growth. The siting of major industrial developments in the GCEC area of authority has, since 1970s been a major stimulus for population growth in the study area (Marga, 1978). The trend of population growth in the urban centers contiguous with the study area, however, has not been uniform. Three levels of population growth are recognizable (Table 21). In the local authorities already designated as urban (Municipal, Urban and Town Councils), growth has been low, medium and high. In those that are designated as rural (village councils) growth has been medium and high. The highest being recorded for, Biyagama, Katana and Dandugamperuwa, all being locations more toward the hinterland (Fig. 7). Evidently the trend of population growth is low and medium in the urban centers contiguous with or constituting a part of the study area, with the exception of Hendala. For all local authorities situated further to the east of the study area, the population growth rate has been high. In terms of population growth, therefore, the trend in urbanization is towards the hinterland.

According to population projections, the population of the urban areas will be exceeded by the population of the rural areas (as classified in 1981). However, the population density of the urban areas, 51.54/ha will be two fold greater than that in the rural areas; 21.99/ha. These data suggest that, if immigration into the study area is to be promoted as a part of the Master Plan, the existing spontaneous trend may have to be changed. This may be achieved by making settlement at Muthurajawela adequately attractive by providing the necessary infrastructure and amenities.
This trend is further reflected by the demand for land subdivision for residential purposes (Table 22). The highest ranking is acquired by local authorities that are toward the hinterland.

Roads: The most recent road expansion was the construction of the road to the Biyagama Investment Promotion Zone, and its bridge across the Kelani Ganga, at Kaduwela, giving easy access to the suburban areas south of Colombo city.An analysis of settlement pattern may indicate an increasing trend in the areas served by these road connections.

The proposed expressway linking Colombo port to the Katunayake Investment Promotion Zone is likely to be constructed within the next several years (JICA, 1984.). Its location is about 3 km to the east of the Muthurajawela marsh-Negombo Lagoon wetland (Fig. 7). Completion of the expressway is likely to attract development towards areas that would be served by the exits from the expressway. The existing trend, a shift toward the hinterland, may therefore be accelerated by the expressway. The existing main highway from Colombo to the Katunayake Investment Promotion Zone is congested, and container yards associated with the highway further aggravate the situation .

Power supply: The most recent high tension supply (132 KV) from the national grid was to Biyagama and Kotugoda. This is consistent with the pattern of road expansion (Fig. 73).

Water supply: The National water supply and Drainage Board is in the process of improving the Greater Colombo Water Supply Scheme.When it is completed, the existing transmission capacity of 6 million gallons a day will double. The expanded capacity will be fully utilized to supply new areas, like Kandana and Ja-ela, urban centers contiguous with the study areas, and Ragama, 5 KM to the east. The new water supply is for already urbanized centers to which irrigating is diminishing. However, water supply may trigger a fresh spurt of immigation.

3.2 Industrialization

The GCEC area of authority has undergone rapid industrialization with the setting up of the Katunayake Investment Promotion Zone in 1978, and more recently, the Biyagama Investment Promotion Zone in 1982. Road expansion, power and water supply constituted the basic infrastructure that accompanied the establishment of these investment promotion zones. The applications received by local authorities in the GCEC area for construction of industrial buildings parallels availability of infrastructure. Pamunugama situated in the study area recorded a poor performance in receipt of industrial building applications. It is inferred that both unusability of land and poor infrastructure contributed to this poor performance (UDA, 1991).

3.3 Conclusion

An urgent need does not appear to exist for development of Muthurajawela as a response to current trends in urbanization and industrialization. However, if the marsh is developed as a matter of policy, urbanization of the area may be stimulated mainly because of proximity to Colombo city where agglomeration of commercial and administrative establishments has already occurred.

Table 21 Population growth and for local authorities in the G.C.E area (Mahanama, 1991).

Local Authority	Area Hectars	Population			Population Growth (%)			Estimated Growth	Estimated Population
					Low	Medium	High		
		1963	1971	1981	<1.0	1.0-2.0	>2.0	1981-2000	2001
URBAN									
Kelaniya (PSU)	714		32667	36738	0.59			2.50	57403
Peliyagoda (UC)	409	23247	24403	25466	0.60			2.50	39791
Negombo (MC)	1155	46908	56795	60762	0.70			2.50	94941
Kochchikade (PSU)	380		8642	9642	0.87			2.50	15066
Wattala-Mabole (UC)	512	14316	18037	19957		1.06		2.50	31183
Ja-ela (UC)	751	5121	21717	24485		1.23		2.50	38258
Kandana (PSU)	815	20038	18980	21662		1.49		2.50	33847
Dalugama (PSU)	854		42573	47723		1.56		2.50	74567
Seeduwa-Katunayake(UC)	2538		23411	31491			2.20	3.00	53220
Welisara (PSU)	1059		20800	26770			2.44	3.00	45241
Hendala (PSU)	1155	21531	29660	36927			2.62	3.00	62407
Ragama (PSU)	984		17421	22238			2.69	3.00	37582
TOTAL URBAN	11326		315106	363861		Average Growth rate 1.50%			583506
RURAL									
Andiambalama (PSU)	1629		13635	15237		1.17		2.50	23808
Pamunugama (PSU)	2222		13852	15756		1.36		2.50	23141
Thalahena (PSU)	629		13852	15756		1.37		2.50	24619
Batuwatte (PSU)	2533		26236	30928		1.79		3.00	86792
Biyagama (GCEC)	5257		6578	81195			2.98	3.00	137220
Katana (PSU)	6329		50081	64867			2.95	3.00	109625
Dandugamperuwa (PSU)	3234		27827	35926			2.91	3.00	60715
Mahara (PSU)	1973		41452	52819			2.74	3.00	89264
Naranwala (PSU)	3910		27936	34778			2.45	2.50	54341
TOTAL RURAL	27716		221449	347262		Average Growth rate 2.19%			609525

Source: Dept; of Census and Statistics and Mahanama, 1991

Table 22 Land sub- divisions for residential purpose by the G.C.E.C. from 1980 to 1989.

LOCAL AUTHORITY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	TOTAL 1980/1989	% OF TOTAL	RANK
NEGOMBO MC	0	0	0	1	1	2	1	2	2	0	9	3.36	10
KATANA PS	0	0	0	0	2	4	4	4	2	1	17	6.34	5
SEDUWA KATUNAYAKE	0	0	0	2	9	9	7	7	4	5	43	16.03	2
KOCHCHIKADE PS	0	0	0	0	0	0	1	0	0	0	1	0.40	19
THALAHENE	0	0	0	0	1	1	0	1	0	1	4	1.50	17
ANDIAMBALAMA PS	0	0	0	0	2	3	3	2	0	1	11	4.10	9
PELIYAGODA UC	0	0	0	0	0	0	0	0	0	0	0	0.00	0
DALUGAMA UC	0	0	0	0	0	1	5	5	2	0	13	2.85	6
KELANIYA PS	0	0	0	0	1	2	1	1	0	0	5	1.86	15
MAHARA PS	0	0	0	0	1	2	2	0	2	0	7	2.61	12
NARNWALA PS	0	0	0	0	1	0	1	0	0	0	2	0.74	18
BIYAGAMA (GCEC)	0	2	1	0	8	3	8	6	17	15	60	22.40	1
WATTALA-MABOLE UC	0	1	2	0	0	1	0	0	0	1	5	1.86	13
JA ELA UC	0	1	1	1	3	1	3	1	5	2	18	6.71	4
WELISARA PS	0	0	0	0	0	2	1	2	0	0	5	1.86	14
HENDALA PS	0	0	0	1	2	1	3	3	0	1	11	4.11	8
KANDANA PS	0	1	1	1	3	1	3	0	2	0	12	4.47	7
DANDUGAMPERUWA PS	0	0	0	1	5	3	5	4	13	1	32	11.93	3
BATUWATTE PS	1	0	0	0	0	0	2	3	2	0	8	3.00	11
RAGAMA PS	0	1	1	0	0	0	1	0	1	0	4	1.50	16
PAMUNUGAMA PS	1	0	0	0	0	0	0	0	0	0	1	0.40	20
TOTAL	2	6	6	7	39	36	51	41	52	28	268	100.00	

MC : MUNICIPAL COUNCIL

UC : URBAN COUNCIL

PS : PRADESHIYA SABAHA

4. SOCIO-ECONOMIC IMPACTS

The current value of fish and shrimp caught in the lagoon (see A-11 and B-3) is significant and the number of people depending on the lagoon directly or indirectly for their livelihood as fisherman is important for the area. For this reason, those forces currently threatening fishing production, the strangling of the mouth of the Negombo Lagoon and the polluting of the lagoon and marsh with heavy metals and possibly other contaminants, have potential adverse economic impacts. Another, possible scenario of damage to the fishing industry is even more alarming: pollution by heavy metals or other contaminants could be slow in being recognized if it only reduced but did not destroy the fishing catch, and human health could be affected if the contaminants came into the food chain in any concentration. Such events have occurred elsewhere in the world, and make dismal reading, chronicles of the rising incidents of birth-defects, etc. It is not necessary to try to estimate the damages in financial terms of such an outcome. This should clearly be avoided at all costs.

The present trends in agricultural land use will most likely continue and the area affected enlarged if no other activities or interventions are planned by the authorities. The socio-economic significance of this is that the marsh proper will remain an area of opportunity for low-income, primarily rural people mostly from the surrounding area, not uncommonly, the second generation of the families living in areas adjoining the marsh. Gradual expansion of small-scale cropping, animal husbandry and very slow land reclamation by planting of coconut will continue.

The newest arrivals are generally the most marginal, they are the ones who can be expected to be most ready to relocate if alternative housing is offered. They are the ones who have been described, in newspaper articles and other publications as living in nearly sub-human conditions: children wading through deep mud toget home in the rainy season, etc. It can be assumed, however, that the same sort of (lack of) economic possibilities that brought these immigrants into the marsh area (see section A-10) will bring in new immigrants if squatting is not prohibited. The provision of low-income housing alternatives may help stem this tide. The implication for land use in the marsh is that the gradual marsh reclamation will continue and expand if not actively prohibited.

The recognizable socio-economic trends and impacts in relation to the ecology of the Muthurajawela marsh-Negombo Lagoon relate mainly to exploitation of natural renewable resources, health and housing.

4.1 Exploitation of Natural Resources

All renewable natural resources that have nutritional or commercial value including, fish, fuelwood, wildlife (tortoises, crocodiles, birds such as quail, teal), material for mat and basket weaving are exploited. It is evident that the marsh residents and others directly dependent on the natural resources for nutrition and income are already experiencing the effects of over exploitation, in that they generally complain about the meager catches and the scarcity of economically important wildlife.

Fish As explained in B-2.2 the contribution of fish to nutrition is apparently diminishing mainly because the major effort is directed towards exploitation of exportable species, and the size of fishery organisms captured is rapidly becomming smaller.

It is reported that members of the community who previously did not purchase fish as food since it was readily available in the lagoon, now, regularly purchase small pelagic fishes such as herrings and sardines from vendors selling marine fish (Samarakoon, 1990). It is unlikely that this trend will change.

Fuelwood: Very little fuelwood is available particularly in the marsh area as whatever usable wood available is being steadily cut down (also see 3.5). There is increasing dependence on firewood brought to the marsh area from outside.

4.2 Health

The prevailing poor health conditions of squatters in the marsh stems mainly from poverty (see B-6).

4.3 Housing

Housing is one of the essential components of socio-economic development of communities in Sri Lanka. Arrangements are being made through various programs for construction and ownership of houses (NHDA, 1991). Housing development programs in the study area, however, are having distinctly adverse impacts on ecosystem functioning of the Muthurajawela marsh-Negombo Lagoon wetland: as has been described in B-1.2.4, B-1.2.6: housing requires drainage, and drainage destroys marsh ecosystems. On the other hand, unplanned housing, mainly without drainage and sewage disposal, creates severe health problems. This is particularly evident at encroachment settlements in the marsh, and in the channel segment of Negombo Lagoon where expansion of housing is occurring on islands and inter-tidal areas. This pattern of housing development in inter-tidal areas is progressively 'choking' the Lagoon. Since many of the members of these households make a living from the lagoon, their income must necessarily decline if fish/shrimp stocks become depleted.

Although house construction on 'free' land immediately provides a solution to those without houses, in the long term, both health problems and decline in ecosystem yield will further aggravate poverty. Furthermore, in view of the impending sea-level rise, there is likely to come a time when state intervention will be required either for protection of houses on the lowlying lands, or relocation, or both (Plates 20, 21 and 22).

4.4 Conclusions

- The existing trend is toward intensification of exploitation of all economically important renewable natural resources. As a result, the present level of income will decline. Alternative income generating activities need to be promoted.

- Immigration will resume if not controlled, since in the absence of alternatives the marsh will be seen as an area of opportunity.

- Although encroachment into the marsh gives immediate relief by providing 'free' land for housing, the environmental changes created and the health problems entrained diminish the quality of life in the longer term (increased incidence of disease).

- Encroachment into the intertidal shoal of the Negombo Lagoon provides both free land for housing and entrains dependance on the fishery resource. It appears that most encroachers immediately begin to use destructive fishing methods (push nets, dragnets, excavation for polychaete worms), since using them requires minimal experience, and they are relatively cheap to construct.

- In view of the expected sea level rise, the state will in any event, have to relocate people from the marsh as well as intertidal shoals.

5. PUBLIC HEALTH

In the framework of this study, a preliminary survey on the public health situation in the project area was carried out by the Medical Research Institute (MRI, 1990). Special surveys were conducted on parasitology (Seneviratne, 1990), viral infections (MRI, 1990), entomology (Jayasekera, 1990) and nutritional status of the population (Dep. of Nutrition, MRI, 1991).

Surveys were carried out at different localities in the marsh , i.e. Lankamathagama, Kadola , Pamunugama etc. Estimates of infection rates were partly based on statistics from the Ministry of Health, records from hospitals adjacent to the project area (in particular from the Peripheral Unit p.u at Pamunugama) and on previous MRI records. It should be realized that estimates derived from these records are biased. For instance, leptospirosis and Japanese encephalitis (JE) are not recorded as such at P.U.Pamunugama, because of lack of laboratory facilities and transfer of acutely ill patients to specialised health centers before a definite diagnosis was made. It is also probable that cases of leptospirosis, JE, dengue fever, typhoid etc. have been listed under "pyrexia of unknown origin" and cases of giardiasis, shigellosis etc. under "ill defined intestinal infections". Further, essential data on the presence, distribution and density of animal disease-vectors is lacking. In spite of these deficiencies, the summary below gives a preliminary overview of present and potential health hazards in the project area.

5.1 Diseases

Bacterial, protozoan an helminthic diseases

Recorded bacterial diseases include leptospirosis, shigellosis, and enteric fever (typhoid and paratyphoid).

Leptospirosis: This **potentially fatal** disease appears to be the most widespread bacterial disease in the project area. It is a water-related disease transferred to humans through the urine of infested rats and mice. The most likely animal-vectors in the project area are Rattus norvegicus and R.rattus (see A-8). Known as "Muthurajawela fever", outbreaks of epidemic proportions have occurred in 1973, 1986, 1987, 1988, and 1989 (MRI-records). The incidence is related to prolonged human contact with infested water, i.e. periods of flooding, canal clearing etc. The highest infection rates have been recorded in recent years, at Wedamulla in 1988 : 190 sero-positives from 640 tested cases; and in 1989, 27 out of 69 specimens.

Shigellosis: The symptom of this disease is mucous diarrhoea and is caused by Shigella bacteria. Regional hospital records show that it is quite common in the area, 855 cases in 1989, see Table 23. Infection is spread by consuming water and food contaminated with faeces and is potentially fatal. Man is the only host and there are no animal reservoirs.

Enteric Fever: Typhoid and Paratyphoid are intestinal disorders caused by Salmonella typhi and S.paratyphi A. Like shigellosis, it is spread through consumption of faeces contaminated water and food. Over the past five years, 569 cases of typhoid and paratyphoid have been recorded in the area, see Table 23, qualifying the disease as "common".

In 1985, one case of cholera has been reported from Negombo township. Nation-wide, cholera seems to be under control. However, Vibrio parahaemolyticus, an organism known to thrive in saline environments, has

been reported from western coastal waters from contaminated fish and from the Beira Lake, and is known to cause clinical symptoms not dissimilar to those produced by V.cholera. The possibility that it occurs in the brackish waters of the Muthurajawela marsh and Negombo Lagoon should not be ignored.

Common parasitic infections include intestinal protozoa (amoebic dysentery, giardiasis), blood protozoa (malaria) and helminthic (worm) intestinal infestations (round worm, whip worm, hook worm, pin worm) and helminthic blood infestations (filariasis).

Amoebic dysentery: Amoebic dysentery is caused by the protozoan species Entamoeba histolytica. A total of 1466 cases have been reported from the area from 1985-1989, see Table 23a, 23b and 23c. The parasitological survey indicated a 3.3% infection rate from 61 tested individuals in Kadola, no incidence being found in Pamunugama and Lankamathagama Fig. 83.

Giardiasis: Survey data indicate that Giardia lamblia occurs in all surveyed areas, albeit in only 1.3-3.3% (average 2.1%) of the tested cases. It sometimes causes a severe mucous diarrhoea.

Entamoeba coli was found in only 1.6 % of 188 tested individuals (3 sites) and Endolimax nana in only 0.5% of the same sample.

Malaria: It is not possible to assess the incidence of malaria in the region from hospital records, because the majority of cases could be infestations from outside the area. The blood parasitic survey conducted by MRI (1990) did not show any malaria parasites, but the timing and the representativeness of the sampled persons could have biased the results. According to Dr. P. Fernando, Dep. Director, Anti-Malaria Campaign, some cases have undoubtedly been transmitted within the project area.

The limited entomological survey of the area did not reveal the presence of Anopheles culicifacies, the principal mosquito vector-species of malaria in the region (Jayasekara, 1990). However, potential mosquito vectors found in the area included A. subpictus, A. nigerrimus, A. jamesi and A. vagus (also see A-8).

Intestinal Helminthic: Infestations: The parasitological survey (Seneviratne, 1990) revealed high worm infestation rates among Muthurajawela dwellers, see Fig. 83. Whipworm (Trichuris trichura) and roundworm (Ascaris lumbricoides) are the most common, whereas hookworm (Necator americanus) parasites were less commonly found. Pinworm (Enterobius vermicularis) was only found in 1 out of 188 tested cases. The high worm infestation rates reflect the generally poor sanitation facilities.

Blood Helminthiasis (Filariasis): Muthurajawela lies in a belt where filariasis is endemic. Yet, filarial infection is not of high prevalence according to hospital records and MRI-survey data (only 2 out of 300 blood films examined were positive). However, the entomological survey results give much reason for concern: the established mosquito vector of Bancroftian filariasis, Culex quinquefasciatus, was found to be the predominant species inside human dwellings. Some mosquito's were found to be harbouring infective larvae as well as developing stages of Wuchereria bancrofti. The infection rate was as high as 5%. These vectors were found breeding mainly in **stagnant polluted water near Lankamathagama.**
Although filariasis has not yet reached a high prevalence rate in the area, it is evident that it could become a serious health hazard justifying preventive health care programmes and close monitoring.

Viral Diseases

Vectors of four potentially dangerous viral diseases occur in the project area: Japanese encephalitis, Dengue & Dengue Haemorrhagic Fever, Sindbis and Korean Haemorrhagic Fever.

Japanese Encephalitis (JE): JE is an arboviral infection spread to humans mainly by culicine mosquito's, Culex tritaeniorhynchus and C. gelidus. The former seems to prefer ponds and ditches (pig wallows) for breeding. The MRI survey results clearly indicate much JE activity in the project area (Table 23) The mosquito's were found at high density in Lankamathagama, where pig rearing is common. There appears to be a potential threat of an outbreak of JE in the area.

Dengue fever: Dengue Haemorrhagic Fever (DHF) is also an arboviral infection transmitted by Aedes mosquito's, i.e Ae.aegypti and Ae.albopictus. These mosquito's breed in small puddles of clear stagnant water ("container habitats" such as empty tins, used car tyres, etc.). The MRI-survey revealed the presence of much dengue fever infection in the area (Table 23). This was supported by the results of the entomological survey showing both mosquito species breeding freely in most man-made container habitats at Lankamathagama. The community was largely ignorant of the health risks these breeding sites presented (see A-8.7). Even in communities that have been exposed to one or more dengue serotypes, subsequent attacks with a more virulent serotype can lead to severe DHF which **could be fatal to young children.** Vector control programmes through community involvement should be organised.
Sindbis: A significant antibody titre was detected in three persons for this hitherto unrecorded virus. In India, this arbovirus produces a dengue-like fever and is

transmitted by the mosquito Cocquellittidia crassipes. It has been suggested that migratory birds from India have brought this virus to Sri Lanka, but further studies are needed to verify this hypothesis. However, the mosquito's were detected by the entomological survey team at Lankamathagama.

Korean Haemorrhagic Fever: This infection, also known as Haemorrhagic Fever with Renal Syndrome (HFRS) has recently been identified near Colombo and is caused by a hantavirus. Its principle hosts are rats, mice and voles in which it produces pneumonia. In man, the virus produces a leptospirosis-like illness which **can be fatal** when accompanied by liver and kidney infection and haemorrhages. A HFRS-like epidemic was investigated in 1988-89 at Eriyabedda in the Muthurajawela area. Although the epidemic proved to be due to Leptospira, three of the blood samples had an antibody titre to hantavirus, indicating that the virus does occur in the area, these cases being old infections.

5.2 Mosquito fauna

The preliminary Entomological Study results (Jayasekera,1990) revealed that, as could be expected, the Muthurajawela marsh provides a variety of mosquito breeding habitats. At Lankamathagama, a village in the marshes, a total of 26 different mosquito species were collected during a ten-day period, 16 of which being actual and potential human disease vectors of these the most important species have been mentioned above. Because of the short sampling period sufficient data were not available but it was thought that more species could occur in the areas. This is supported by the results of a more intense survey carried out during 1981-82 in comparable ecosystems in Sri Jayawardenepura marshlands where 45 different species were recorded (Jayasekera et al, 1986).

The recorded species at Lankamathagama include vectors of malaria, filariasis, dengue and dengue haemorrhagic fever and Japanese encephalitis.

5.3 Sanitation

Inside the marsh proper toilet facilities are virtually non-existent. In most areas, piped water supply is not available and garbage disposal and collecting facilities non-existent. Consequently, most human wastes enter the marsh waters, giving rise to eutrophication and pollution, and subsequently, excessive aquatic weed growth (Salvinia Eichhornia sp). Such polluted water bodies sheltered by dense vegetation provide suitable breeding habitat for certain human disease vectors including rats, mice and mosquito's. On the other hand, inadequate waste disposal creates small, clear water "container habitats" for other mosquito species known to transmit serious diseases. Marsh dwellers include fishermen and members of very poor communities. Many families occupy temporary make-shift dwellings with no toilet or other sanitary facilities. They often live on "islands" amidst stagnant pools of water and grass-, sedge-, fern- and bulrush swamps. Frequent and sometimes prolonged contact with infested water occur during fishing, peat mining, land reclamation, canal clearing, etc., enhancing infections, both bacterial and parasitic (worms and protozoa). For instance, the transmission of whipworm, roundworm and intestinal parasites, which is by faecal-oral route, and hookworm infestation (by skin penetration) is directly related to unhygienic and unsanitary conditions. As such, improvement of the living conditions, supply of piped drinking water of safe quality, sanitary provisions and health and hygienic educational programmes, and wearing protective clothing (foot wear) are essential to reduce the incidence rates of these diseases. On the other hand, vector control programmes will be needed to reduce infection risks of vector-borne diseases. A summary of preventive measures is given in Part C-4.10.

5.4 Nutritional Status

A preliminary survey on the nutritional status of Muthurajawela marsh dwellers (Dep.of Nutrition, 1991) revealed that in the 11 homesteads sampled nutritional anaemia and deficiencies in protein, iodine and vitamin-A occurred to a varying degree. In particular, the prevalence of anaemia (more than 50%) gives reason for concern, in fact it is as bad as in urban slums. The commonest cause is insufficient intake of iron, which could be caused by a lack of animal protein in the diet, or by worm infestation. Iodine deficiency was reflected in a fairly high prevalence of goitre. A lack of iodine could result in mental and physical retardation in the growing foetus and children. The prevalence of vitamin-A deficiency was fairly high in most of the sampled area. It can be a cause of blindness.

Of the adult women, the body length of 40.8% of the sampled individuals was below normal and indicated stunting. The national average for stunting is 36.58% (Sessional Paper 12, 1988).

5.5 Conclusions

This preliminary list of debilitating, and, in combination with sub-optimal nutritional conditions (see B-5.4), often fatal diseases, more than justify extreme precaution in development planning and the need for public health programmes.

- The general conclusion of the survey is that the nutritional status of the population studied is unsatisfactory relative to national averages, and that a general improvement of living conditions is

necessary, including a safe drinking water supply, sanitation and dietary improvements. However, it was felt that more detailed studies based on larger, more representative samples would be required to get a reliable picture on nutritional deficiencies, its causal factors and remedial measures.

- The existing conditions are favourable to an aggravation of the disease status: threat of an outbreak of JE. introduction of malaria, therefore due consideration would be necessary with respect to the above, in case expansion of settlements is planned in the marsh area.

Table 23a - Statistics on Bacterial Diseases (Typhoid andShigellosis) from Hospitals Neighbouring Muthurajawela, Source: MRI, 1990

HOSPITAL	TYPHOID						SHIGELLOSIS					
	1985	1986	1987	1988	1989	Total	1985	1986	1987	1988	1989	Total
Ja ela	9	8	-	-	-	17	-	-	-	-	-	-
Pamunugama	-	1	-	10	1	12	-	-	-	-	-	-
Negombo	4	2	10	22	3	41	-	-	-	378	477	855
Gampaha	144	90	73	12	7	331	360	72	-	30	185	647
Mahara (Prison)	-	-	-	-	-	-	-	-	-	101	42	143
Kelaniya	64	21	19	24	40	168	-	34	-	108	151	291
Total	226	122	102	68	51	569	360	106	-	615	855	1936

Table 23b - Statistics on Parasitic Diseases (Amoebiosis and Filariasis) from Hospital Records Neoghbouring Muthurajawela , Source: MRI, 1990

HOSPITAL	AMOEBIOSIS						FILARIASIS					
	1985	1986	1987	1988	1989	Total	1985	1986	1987	1988	1989	Total
Ja ela	10	10	9	8	5	42	-	1	2	1	2	6
Pamunugama	1	20	15	24	12	72	-	9	14	7	3	33
Negombo	127	14	-	69	32	242	4	-	-	20	18	42
Gampaha	368	145	7	4	25	549	195	134	41	16	1	387
Mahara (Prison)	-	-	235	144	122	501	-	-	28	-	-	28
Kelaniya	-	15	50	8	10	83	13	46	56	32	45	192
Total	506	204	316	257	206	1489	212	190	141	76	69	688

Table 23c - Statistics of Vital Diseases from Hospitals Neighbouring Muthurajawela, Source: MRI, 1990

HOSPITAL	ARTHROPOD BORNE ENCEPHALITIS INCLUDING JAPANESE ENCEPHALITIS						OTHER VITAL DESEASES					
	1985	1986	1987	1988	1989	Total	1985	1986	1987	1988	1989	Total
Ja ela	-	-	-	-	-	-	20	19	18	50	103	210
Pamunugama	-	-	-	-	-	-	-	-	-	-	35	35
Negombo	-	-	9	-	-	9	1019	1175	-	171	116	2481
Gampaha	-	-	-	-	-	-	1145	581	855	1182	686	4399
Mahara (Prison)	-	-	244	-	-	244	34	-	-	-	52	86
Kelaniya	-	-	-	-	-	-	237	287	356	162	251	1293
Total	-	-	253	-	-	253	2455	2602	1229	1515	1243	8509

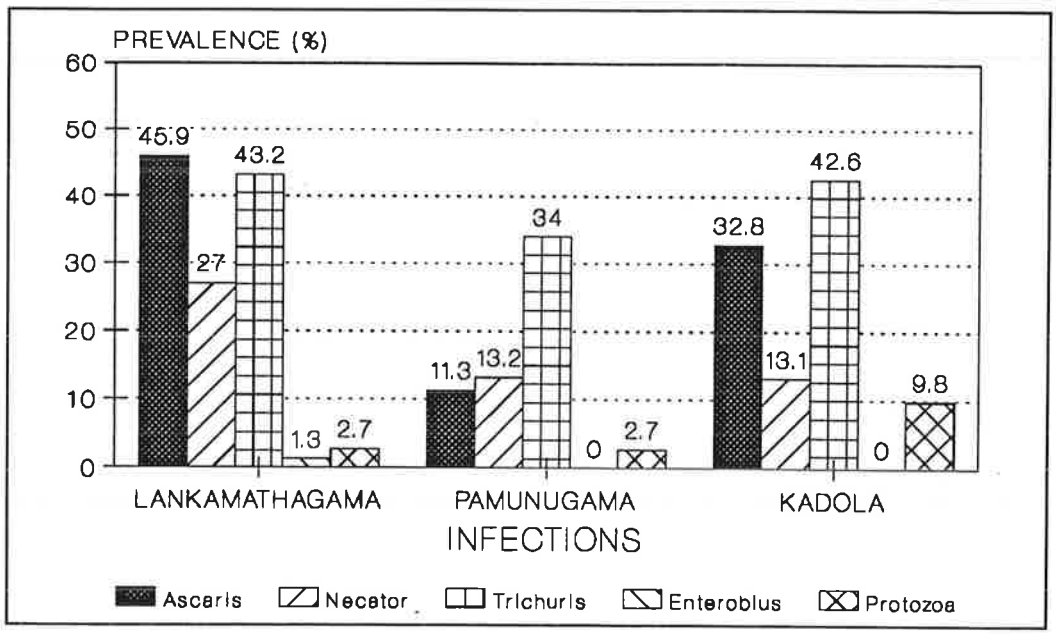


Fig. 83 Prevalence of intestinal infections at three squatter settlements.

PART C : INTEGRATED DEVELOPMENT: SUSTAINABLE USE OF NATURAL RESOURCES

1. GENERAL OBJECTIVES

The development of Muthurajawela has been the subject of discussion for a long period of time. Although minor and major infrastructural works have been carried out in the past, none of these actually stimulated large-scale development. Recently, the pressure on the area has increased, mainly because of its proximity to rapidly expanding urban centers, i.e Colombo and Negombo, to an industrialized development area and to the international airport. Various authorities have identified the marsh (or part of it) as a suitable site for reclamation to meet the increasing demands for terrain for housing and industry, and for tourism development. None of the recent development proposals have been implemented, not only because of the compellingly high capital investments involved but also because of the potential negative environmental effects such development would entail. However, small-scale resource exploitation is taking place and human encroachment during recent years has been on the increase. The present unplanned, and to some extent, illicit, activities threaten to become unsustainable, undermining the valuable ecological functions, eventually depleting the natural resources and leading to environmental degradation and irreversible losses in productivity of renewable natural resources. Recently, this trend has prompted GCEC to introduce a patrolling system to curb further illicit settlements and to call for the present study as a basis for Master Planning.

The planning proposals collected during this study can be grouped into a number of potential development options. Each of these is treated in the following section (C-2.) and will be worked out in the Master Plan. In the master planning process the guiding principle should be to ensure sustainable use of natural resources and maintenance of important ecological functions. The ecosystem functions have been described in A-9, only the most important ones are repeated here:

- the lagoon provides major breeding and nursing grounds for commercially important fish and crustacean species and supports an important fishery benefitting mainly low-income rural population groups;
- the productivity of the lagoon is maintained by an interaction of sea- and freshwater flows, complex nutrient balances and food webs, supported by both the marsh, the transitional brackish water swamp, the lagoon and the sea coast adjacent to the lagoon outlet;
- both marsh and lagoon provide habitat for an important wildlife spectrum, in particular resident and migrant aquatic and semi-aquatic bird populations and a considerable number of threatened and some endemic species of mammals, amphibians, reptiles and fish.
- the buffering and filtering function of the marsh and swamp area are undeniably important in the maintenance of the hydrological balance, the water quality and in the regulation of sedimentation and nutrient flow. In particular the "sponge effect" of the peat marshes appears as a most critical factor, which, if disturbed, is likely to have negative effects on the economic feasibility of large-scale development options (Maltby, 1986; Duggan, 1989).

The implementation of development options as listed in the next section will have various effects on the ecosystem functions. Some effects will be positive, others will be minor, temporary and manageable, but many could be negative, permanent and irreversible. Levels of impact depend on the scale, location and technical implementation of development options. Practically all options will conflict with one or more of the ecological functions (see C-4). This means that utmost care is required in planning development. Clearly, some options can only be pursued on a limited scale in order not to interfere with the feasibility of other options (e.g. land filling versus conservation, fisheries), or with important traditional forms of resource use. **Also, implementation of selected development options should take place in a phased manner with constant monitoring of pre-selected environmental and socio-economic indicators.** Such an approach is essential if economic development of the region is to take place in harmony with the conservation of important renewable natural resources and natural values, and with due attention to environmental protection. The relationships among resources and functions of the area, and the effect of development on them and oneach other is shown in Table 24. The inter-relationships between ecosystem function and human activities are also schematically shown in Fig 84.

2. DEVELOPMENT OPTIONS

This section constitutes the most important component of the report from the viewpoint of the planning purpose it must serve:

- inform the Master Plan preparation team of the ecological framework within which the development options may be formulated
- convey relevant messages to government agencies, non-governmental organizations, users of the resources of the area, specialists and concerned individuals who must become participants in the evaluation of the development options that would be submitted to the decision makers, and

- inform the politicians, the decision makers, who need to be convinced that the development options are based on a technically acceptable analysis that is aimed at sustainable development, although some options may not be politically attractive in the short term.

Sustainable development as interpreted for purposes of preparation of this report incorporates three concepts (WCED, 1987; Burbridge, 1988; NRC, 1982; McNeely, 1988; Brown, 1987; IUCN, 1980):

Sustainability of yield: the planning area and study area at the present time provide a wide range of products (goods) and services to which a financial interpretation could be given. The supply of these products must be maintained or enhanced, but not allowed to be depleted.

Sustainability of function: the planning and study areas constitute parts of ecological systems whose linkages and processes cannot be financially interpreted, but the continuity of which is essential for present and future yields. e.g. seawater-freshwater mixing, poor drainage, genetic resources, dune stability etc. and,

Sustainability of investment: any development option selected for implementation by the decision makers should necessarily mean that finances allocated to it will result in the **anticipated benefits** envisaged without merely transforming existing conditions irreversibly in a manner that could lead to abandonment of projects. The development options considered from an environmental viewpoint are:

- **CONSERVATION:** protection and preservation where necessary and wise (sustainable) use of physical, biological and cultural resources, including public education and research

- **HOUSING AND INDUSTRY:** housing and industry are considered together because both involve landfill

- HOUSING :increased inhabitation

- INDUSTRY: development of various forms of small to large scale production activities including agroindustry.

- **TOURISM/RECREATION:** controlled utilization of natural resources and development of facilities for international and local visitation for sport/rest and amusement.

- **INFRASTRUCTURE**: development of roads, channels, and public services that facilitate human presence.

- **AGRICULTURE:** development of cultivation including horticulture and animal husbandry (excluding aquaculture).

- **FISHERIES:** production by capture of aquatic organisms from natural environments, their processing and marketing.

- **AQUACULTURE:** rearing of aquatic organisms in enclosures where ownership of stock is legally ensured.

- **FORESTRY:** fuelwood and utility wood production.

- **PEAT EXTRACTION:** extraction of marsh peat for energy and other purposes.

- **WATER RESOURCES:** alteration of stream flow and/or water retention patterns (see C-3)

- **EDUCATION/RESEARCH:** promote knowledge relevant to wise use of wetland resources.

2.1. Conservation.

The calls for the preservation of Muthurajawela as a conservation area come from several quarters within Sri Lanka, and at least one international convention (the Ramsar convention, see section A-9).Within Sri Lanka, the following agencies have expressed concern that specific areas within the marsh proper or, the marsh and lagoon seen as one integrated ecological/hydrological system should become a conservation zone for the purposes mentioned:

- **Natural Resources, Energy and Science Authority of Sri Lanka-** regulation of water quality and general regional sanitation, research on marsh evolution.

Table 24 **Relations among resources and functions of the area and development options. (+ postive effect; - negative effect; o no major effect)**

RESOURCES / FUNCTIONS OF THE AREA	CONSERVATION	HOUSING	INDUSTRY	TOURISM / RECREATION	INFRASTRUCTURE	AGRICULTURE	AQUACULTURE	FISHERIES	FORESTRY	PEAT EXTRACTION	EDUCATION	WATER RESOURCES MANAGEMENT
	DEVELOPMENT OPTIONS											
A PHYSICAL RESOURCES												
A1 Surface water quantity	0	-	-	0	-	-	0	0	0	-	0	+
A2 Surface water quality	+	-	-	-	0	-	-	0	0	-	0	+
A3 Groundwater	+	-	-	0	0	-	-	0	0	-	0	+
A4 Soils / mineral resources	+	0	0	0	0	-	0	0	0	-	0	+
A5 Topography / geology	0	+	+	0	-	0	0	0	+	-	0	+
A6 Erosion	0	-	-	0	0	-	0	0	+	+	0	+
A7 Siltation	0	-	-	0	-	-	-	0	+	-	0	+
B ECOLOGICAL RESOURCES												
B1 Fisheries / acquaculture	0	-	-	0	-	-	+	+	+	-	+	-
B2 Aquatic biology	+	0	-	0	0	-	-	0	+	0	0	-
B3 Terrestrial fauna	+	-	-	-	-	-	0	-	+	-	0	+
B4 Estuarine ecology	+	-	-	0	0	-	-	-	+	-	+	-
B5 Vegetation	+	-	-	0	-	-	-	0	+	-	+	-
C HUMAN USE VALUES												
C1 Water Supply	0	0	+	0	0	+	0	0	0	0	0	+
C2 Agriculture	-	+	-	0	+	+	0	0	-	-	0	+
C3 Navigation / transport	0	+	+	+	+	0	0	-	0	0	0	0
C4 Flood control	+	-	-	0	-	+	0	0	+	0	0	+
C5 Mineral development	+	-	0	0	0	0	0	0	0	-	0	-
C6 Industry (large - scale)	0	0	+	0	+	-	0	0	0	+	0	0
C7 Industry (cottage-)	+	+	+	+	+	+	0	+	+	-	0	0
D QUALITY OF LIFE VALUES												
D1 Socio-econ. / employment	0	+	+	+	+	+	+	+	+	+	0	+
D2 (Re) settlement	-	+	+	0	+	-	0	0	0	-	0	0
D3 Public Health	+	0	0	+	0	+	0	0	+	0	0	0
D4 Vector-borne diseases	0	-	0	0	0	-	0	0	0	-	0	0
D5 Nutrition	+	0	0	0	0	+	+	+	0	0	0	0
D6 Recreation / aesthetics	+	-	-	+	0	-	0	0	+	-	0	+
D7 Historical treasures	+	0	0	+	0	0	0	0	0	0	0	0
D8 Education / research	+	0	-	+	0	-	+	0	0	-	+	-

- avoidance of the loss of production of fish and shrimp in and associated with the lagoon (which includes some of the sea catch) and the employment associated with fishing and aquaculture; this loss could be caused either by the severe hydrological changes and changes in salinity that would occur if the lagoon were "choked off" at the mouth or by the catch of fish and shrimp becoming unfit for human consumption because of the effects of continuing or increasing pollution, particularly heavy metals, and human faeces, and

- a safe and non-disturbing landing and take-off way for aircraft, since aircraft do not have to pass over dense settlements.

It is suggested here that the above two measures for lagoon and marsh management should be considered as a minimum needed to preserve the important commercial and biological functions of the area. They should be considered as a minimum because the losses associated with not implementing them would be socially too high. A second question is then, what part of the marsh should be kept as a conservation area, if any, and what would be the costs (direct and indirect) and benefits of such conservation?

The results of the environmental investigations indicate that the following are the most important areas of the marsh and associated functions: (see Fig. 85).

- the area of transition between the lagoon and the marsh, that is the northernmost portion of the marsh, from the southern edge of the lagoon, south to the edge of the densely populated area on the Tudella-Pamunagama road, is the most critical ecologically. It is also one of the least-developed areas. The squatters who now live there are few in number and largely dependent upon fishing. Most have lived there for a number of years. Some (perhaps 40 families) abandon their housing every year in the high-water season, when their small houses are inundated and no longer habitable, and go to live in a church on charity. These people could be offered alternative housing. If they prefer to stay as they are, their numbers should not be allowed to increase by immigration while the children of the present residents would become priority candidates for relocating. They do relatively little environmental damage, but some of their activities should be curtailed, specifically path construction on any scale and tortoise-hunting.

  a central area of the marsh should remain open: free of heavy settlement and not filled in by land-fill and construction. This area would remain as a corridor for the movement of fauna between the marsh and the lagoon areas. This area should include some small water bodies and it should also retain the natural flora of reeds, sedges, etc and remain a habitat for marsh species. This central open area should be linked to conservation at the northern edge of the marsh. From an economic point of view, these areas are the least interesting to develop for the high intensity uses of landfill and housing and/or industry because of:

- higher development costs to provide good access and necessary infrastructure due to relative inaccessibility and

- likelihood of higher costs associated with fill, because both areas are generally the wettest, semi-submerged areas at present. This is, however, not an assurance that they are the areas that have the deepest peat layers.

The important question now becomes how large should these two (linked) conservation areas be, and the task in hand is to delineate their location and extent more precisely. At the master planning discussions three potential development scenarios for the area, high-low- and intermediate-intensity development are being considered. **All three will include some conservation area, based on the principles expounded here, but the extent of the total conservation area within the marsh proper will be quite different in the three scenarios,** relatively smaller conservation areas for the high-intensity development scenario, much larger total conservation area for the low-intensity development scenario, and a medium-sized area for the intermediate-intensity plan. **The actual demarcation of zones, taking into consideration ecological findings will be a part of the Master Plan preparation.**

2.2 Housing and Industry

The major push for development of the Muthurajawela Marsh is the demand for land for housing and for industrial uses. The question of concern for analysis is whether the Muthurajawela Marsh offers a reasonable site for housing and/or industrial site development in itself in comparison with alternative sites. The specific questions from an economic point of view are:

- How much land is needed for housing and for industry, and how much is available?
- How high are the costs of creating housing or industrial land in the Muthurajawela Marsh proper compared to the price which can be expected for sale of the land? These costs will include the costs of the land filling process necessary to reclaim the land, the costs of creating infrastructure (some of which will also require fill) and costs of installing sanitary engineering facilities to secure the other functions of the area, including conservation. It can

be assumed that the land fill area itself will need drainage canals, but in addition, it may be necessary to construct drainage facilities to compensate for the lost water-holding capacity of the land to avoid flooding in surrounding areas (see B-1.2.3).

- How do the costs of developing Muthurajawela for housing or industrial land compare with costs of developing land and land prices in other regions around Colombo?

It is clear that the demand for land close to Colombo is, in any case, high, and Muthurajawela appears to offer a large area that could be developed if the technical constraints do not make the effort too expensive nor other considerations outweigh the demand for land.

The central issue for developing some part of the Muthurajawela Marsh for housing and or industrial development is landfill. This is because of the soil conditions and the elevation of the land. The very soft, low-density, waterlogged peat soils and peat and clay soils of the marsh totally lack bearing capacity for the construction of buildings or of roads. Various reports, particularly that of Volker, van der Veen and de Glopper (1976) have described the "extremely poor soil and foundation conditions." The following paragraphs are excerpted from their report:

"The Bog Soils are characterised by a high organic matter content, being at least 30%, but in this area going up often as high as 80 to 90%. By nature, such soils are waterlogged throughout the year, apart from the topmost 2.5 cm to 5 cm during the somewhat longer dry spells. The pore spaces are high, up to 80% to 90% (void ratios 4 to 9). All the pores are filled with water. As a result of the high pore spaces and the low specific weight of organic matter, the unit weight is low. Another consequence of the high pore spaces and the spongy structure is that the soils are very soft and extremely compressible, have a low bearing capacity and are hardly passable (in places even impassable by man)". Most of the marsh proper consists of these bog soils. The rest is "half bog" soils and "poorly drained alluvial soils" occurring in small areas along the fringes of the area where conditions are somewhat better, but still poor for building.

"The average thickness of the peat layer is about 3.6 m. It varies from nearly nil to 6 m in places, according to the data of the Geological Department. In general, the borings of the Shell Company indicate a greater thickness, even up to 9 m.

"Due to the very high pore spaces (void ratios), these soils will subside largely after a possible lowering of the water table, at least for the first 25 cm to 50 cm of lowering. Next to this, soil material will simply disappear, due to the oxidation of organic matter, so increasing the already considerable subsidence. The oxidation rate will decrease, when the sinking soil surface comes closer to the water table." (Volker et al, p. 7 & 8). After soil quality, the land elevation is the second big problem as far as construction goes.

"... The area appears to be very flat and low lying. The elevation ranges from 100 cm -M.S.L. to 50 cm +M.S.L. Only a very minor part (2%) has an elevation below 25 cm -M.S.L. The greater part (58%) of the surface is found between 25 cm -M.S.L. and M.S.L., whereas the surface of a smaller, but still important area (34%) has an elevation between M.S.L. and 25 cm +M.S.L. Finally, a rather small area along the fringes (6%) is found between 25 cm and 50 cm +M.S.L.

"So the greater part (94%) of the project area appears to have an elevation below 25 cm +M.S.L. Adequate drainage by gravity is, considering the low tide levels, possible only for areas lying above 50 cm +M.S.L. Hence nearly all of the project area cannot be drained in this way. ..." (Volker et al, p.10) The net result of this combination is that landfill is necessary if the area is to be developed for housing and/or industry to:

- supply an adequate bearing capacity, and
- allow for a sufficient distance between the groundwater table and the surface level,

For roads, "in order to arrive at a sufficient bearing capacity, a sandfill should be applied on top of the existing soil layers with a thickness of say 100 cm, and even more in case of heavy traffic. Construction should not start within 2-3 years after application of the sandfill, so that settlement can occur by its own weight for the greater part..."

"For urban development, there should be sufficient distance in height between the groundwater table and the surface level to prevent the water from rising above the surface level during heavy rainfall. If at regular distances open water, e.g. canals, is available, a distance of about 100 cm between water level and surface level, which is taken to be 25 cm +M.S.L., is necessary.... (In more definite calculations the variation in surface level should be taken into account.)" (Volker et al, p. 15-16)

Volker et al looked at four technical options for meeting the above requirements:

- Raising the surface level by application of a sandfill of sufficient thickness on top of the existing soil to such an elevation that gravity drainage becomes possible.

- Total removal of the soft peat layers and replacement by a sandfill to such an elevation that gravity drainage becomes possible.

- Total removal of the soft peat layers and replacement by a sandfill in combination with lowering of the water table by pump-lift drainage and embankment.

- Raising the surface level by applying a sandfill on top of the existing soil in combination with lowering of the water table by pump-lift and embankment.

Their calculations showed that the first option offered the best combination of least cost and most safety against flooding, although they included provisos that additional studies were necessary to be sure of the amount of fill needed. They also noted that "attention should be drawn to the fact that settlement will continue after the 3-year period, so that for more important buildings pile foundations will be necessary." (p. 20 Volker et al).

The report by Volker et al has been quoted here at some length because it is their specifications (for option 1) that have been the basis for the estimates made subsequently for the requirements of landfill on which costs estimates have been made. Cost estimates made by Volker et al in 1976 were in the order of Rs 61,000 - 75,000 per acre. In 1991, these estimates are Rs million 2.4-3.0 per acre (US$ 60,000 - 75,000 per acre).
It is important to note here, that the conclusions of Volker at (1976) were drawn at a time when effects of sea level rise were not known; presently all negative aspects are more serious.

The overall picture of the economics of developing land for housing and for industry that emerges is the following:

- Cost of land-fill and of providing services for housing and/or industrial development to the areas within the marsh proper are considerably high. Due to the depth and quality of the peat soils found within the marsh and the high water table, these soils require relatively large amounts of fill, prolonged settling times, substantial drainage measures, protection against sideways loss of soils and subsequent subsoil collapse.

- The relatively high-cost of land can be offset somewhat by the high demand for land particularly in the regions closest to Colombo and for relatively high-value uses. The existence of privately financed, high-value housing developments where developers are paying full costs of land fill and development, and building and selling lots with houses suggests that certain combinations of costs and value-added can be profitable.

- There is evidence of a land boom in the Colombo area and of land speculation, buying land with the intention of holding on to it and selling in the future when land prices are even higher. Both rapidly rising land prices and the current rate of utilisation of industrially zoned land support this hypothesis. The implications of this for land reclamation are that government-reclaimed lands should not be sold at a rate below the true costs of their development as this will only encourage speculation and create a windfall for those purchasers able to buy. If the goal is to stimulate industry and job creation in the private sector in newly developed areas, tax breaks and assistance with loans and foreign exchange may be better instruments than selling government-reclaimed land at subsidized prices.

- Social considerations will presumably require that a proportion of the land developed for housing be available for low-cost housing, to allow for the relocation of some of the marginal squatters in the marsh and at the mouth of the Negombo Lagoon (see section C-2.1, above) and possibly to accommodate some of the low-income, landless and houseless people of Colombo. The costs ofland-fill and development will be too high to be borne by the inhabitants of low-income housing. These costs will be further increased by measures required for protecting the rest of the area from the negative effects of housing development (flooding, sanitation, increased pressure on natural resources). The costs will therefore need to be either borne completely by the government or (partially) recovered in the form of higher prices, or an outright tax, levied on the purchasers of the higher cost land. A careful analysis of the reclamation and development costs vs. land prices will be needed to determine whether this is feasible or whether the government must simply count on bearing these costs.

- From a budgetary and cost-recovery point of view, landfill for low income housing in the Muthurajawela marsh is an expensive proposition. One solution may be to provide relatively high-density low-income housing in the most southerly area of the marsh, close to the Colombo-Negombo road with relatively good access to public transportation. As a number of the most marginal squatters in the marsh leave during the day to find work, often paid day-labor, completely outside the marsh, this location would be suitable.

- Another solution to meet (some of) the need for low-income housing may be to allow the continued homesteading of small plots of land with the coconut planting/land reclamation technique that now takes place around the edges of the marsh to continue in other specified areas too. Here too proper sanitation would have to be provided to ensure an acceptable quality of life, in this event to the legal dwellers. These areas would act as a transition zone between the more intensely developed, land-fill areas and the low-impact uses of tourism and recreation.

- Because of the density of population and of increasing economic activity along the Colombo-Negombo road, this area requires a better level of infrastructure and services than it now has. Drinking water is currently available from standpipes and some buildings have domestic water connections. Electricity is available along the main road and in one area of the marsh proper. The growing need for sewage handling is evident. For residential areas on higher ground adjoining the marsh (eg. between the marsh proper and the Colombo-Negombo road), septic tanks may provide adequate sewage disposal. For housing along the road and for industries this is no longer the case. As mentioned above in section C-2.1, the provision of adequate sewage handling facilities along the Colombo-Negombo road should take place with or without the development of land within the marsh proper for the benefit of the area already developed - as well as to reduce pollution and contamination of the marsh and the lagoon.

- Land servicing costs will generally be lower where hook-up distances to major water, electric and sewage lines are shortest, in other words, nearest to the Colombo-Negombo road. Access to major transportation arteries to bring in materials and to ship out goods to markets is crucial for industries as increasing shipping distances increases operating costs. This is one (strong) argument for the location of any new industrial areas in close proximity to Colombo and to major transport lines as possible.

- There appears to be room within existing industrial areas, within and outside of the EPZs for expansion and new housing (see Figure 7). What may be in short supply, however, is land for space-consuming industries such as warehouses and container storage sites. It may be that some of these industries could afford to pay for the land fill necessary to make the sites possible.

The ideal sort of industry for the Muthurajawela Marsh area would be:

- labour intensive, demanding local unemployed workers,

- high value, and

- low impact on the environment.

The currently booming garment industry, with proper pollution controls, could meet these criteria, but it is not clear that there would be advantages for garment manufacturers in moving into Muthurajawela (see section C-2.4 on infrastructure, below). Fig. 86 shows the areas of interest for housing and industry development as expressed by various agencies.

2.3 Tourism and recreation

The general situation for tourism in Sri Lanka is mixed. The beginning of a tourism boom in the early 1980s set off an enthusiastic wave of hotel construction, including high-quality, multi-star hotels in Colombo. Various factors, particularly ethnic violence in the country combined to discourage tourists shortly thereafter, and the occupancy rate of the hotels has been disappointing generally.

In early 1991, Sri Lankan tourism income was hit, as has all international tourism revenue, by the war in the Gulf, and the general fear of travel that affects both business travellers and tourists. Nonetheless, tourism has been gradually picking up, and there is reason to project that, in the long run, business will return, particularly if the domestic political violence stops. Sri Lanka is a good bargain for travellers, with pleasant people, interesting cultural sites, excellent national parks and beautiful beaches at reasonable prices. The difficulties are that Sri Lanka is a relatively long journey from most of the wealthier countries and that it is not as widely known as a tourist area as some of the more developed countries.

Muthurajawela's advantages as a tourist area are limited, but there are certain possibilities. Muthurajawela is well located, being near the airport and between Colombo and Negombo, both of which draw tourists. The Airport Garden Hotel on the edge of Negombo Lagoon (which should be renamed, as "airport hotels" have a bad name with travellers around the world, associated with forced layovers and business meetings where the participants never get further than 5 miles from the airport) has a potentially interesting setting which would become more interesting if some of the developments suggested below were to take place.

The beaches along the coast from Colombo to Negombo are attractive, but too dangerous for swimming and allow no competition to other, safer beaches immediately to the north (above Negombo) and

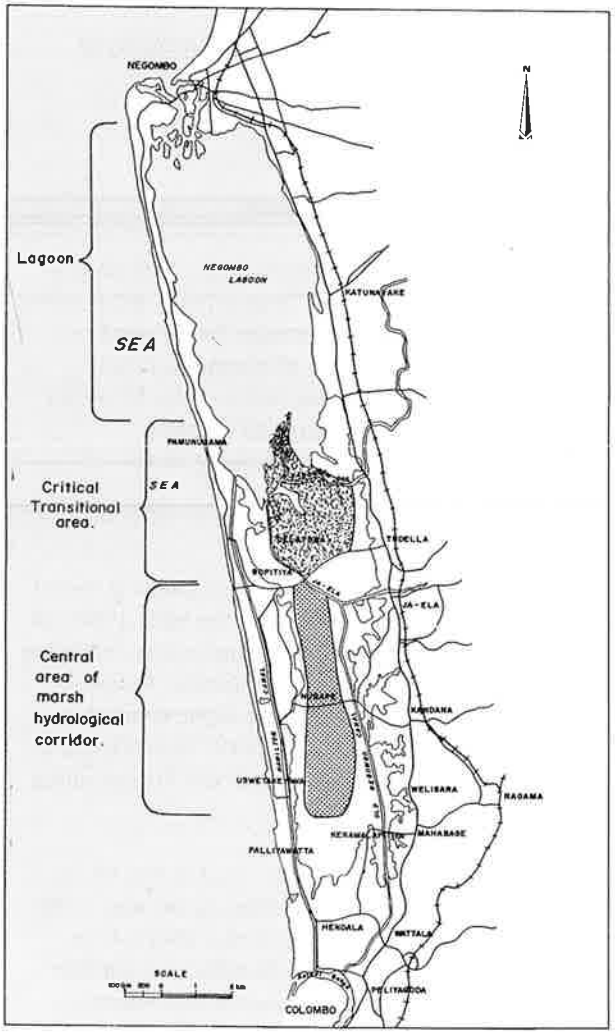


Fig. 85 The subareas of the study area that were identified as ecologically critical (see text for explanation).

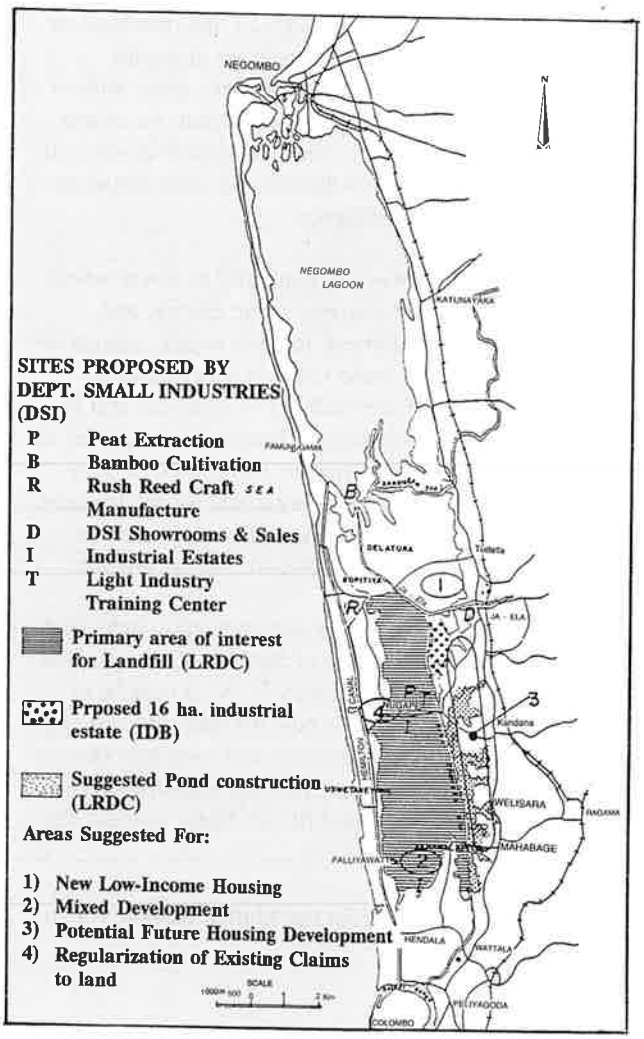


Fig. 86 Sites proposed for landfill for various uses.

south (below Colombo). Two broad categories of tourists might be attracted to the area:

- nature-buffs, and
- sports fans.

The first includes those who would come for the wildlife in the national parks and who would be attracted by the bird watching, the wilderness and the general peace and quiet of the Negombo Lagoon, the marsh and the beaches. It would help if visiting the lagoon and the marsh for nature walks were made easier, and if the Muthurajawela area were to be advertised as part of a nature tour of Sri Lanka as a whole. Actual development investments in this line would not be high, but marketing would require a careful campaign. This type of tourist is currently a relatively small part of the market, but may grow as ecological consciousness is generally increasing world wide.

The second category of tourist would require more investment to attract, and more specific feasibility studies should be done first: those who come for sports vacations. The Negombo Lagoon already offers good windsurfing, and it is an excellent placeto learn the sport: a shallow, enclosed waterbody with nearly constant wind. Windsurfing is a rather specialised sport, attractive mostly to the relatively fit. It does, however, have a certain prestige and as a part of a selection of sports possibilities it would have a strong appeal. Golf is a more lucrative sport, with a larger market, and there would be space in the marsh, in the "buffer zone area" to develop a good-sized golf course. It would require some landfill, but not fill that need carry heavy loads. It should also be possible to develop good quality tennis courts, bring in coaches, and develop a high-quality tennis camp. The marketing possibilities and the techniques needed to develop good facilities on these soils should be examined by specialists. The combination of easy access from the airport with golf, tennis and windsurfing in quiet surroundings close at hand and good beaches for swimming within easy reach could be developed for a large and growing affluent Asian market as well as for tourists from farther away.

From an environmental point of view, a golf course and tennis courts, and perhaps additional park or nature trails are an ideal sort of environmentally-friendly activity for a "buffer zone" between a nature reserve area and area with greater human inhabitation (provided herbicides for golf course maintenance are kept under control).

Facilities to attract high-paying tourists should be balanced by facilities for use by local people, preferably free or for low fees. As Colombo continues to grow, the value of a greenlung space near the city may become greater for urban dwellers. Cricket fields, soccer fields and a park area for general family outings are all interesting possibilities in the long run. An aquatic bird park, facilities for "nature walks" and for education on the environment could also find a place. Such a location could be an excellent one for the Colombo Zoo, offering another low-impact land use, potentially more green-space for the zoo animals, and a part of a general park and natural environment for the residents of Colombo that would also appeal to tourists.

The Ceylon Tourist Board has expressed interest in supporting development of water sports on the northern side of the Negombo Lagoon, a golf course on 200 acres south of the Jayasooriya Road and a Theme Park and Folk Art Centre on 4 ha just west of Ja-ela. Carson Cumberbatch & Co. Ltd. has expressed an interest in developing a Country Club and Championship Golf Course of international standards on approximately 100 ha (247 acres) of "a mix of canals, waterways, developed areas and controlled development areas as close as possible to the Pegasus Reef Hotel on the North Western side." These areas are shown in Fig. 87.

2.4 Infrastructure

The need for infrastructure relevant to the supply and demand for housing and industrial land are treated above under section C-2.2. An additional infrastructure issue of major importance affecting development of the area generally is the new highway being built, with Japanese (JICA) assistance, between Colombo and the airport, to the east of the existing Colombo-Negombo Road. It has been decided that this highway will be a limited-access toll road to facilitate travel and transport of goods, primarily between the city of Colombo, the Katunayake Export Processing Zone (KEPZ) and the Katunayake International Airport. Access to the highway will be possible in between these end destinations via additional exits Figure 7.

The existing Colombo-Negombo road is highly congested, particularly, as one gets closer to Colombo. Travel along the road during daylight hours is very slow. By syphoning off some of the traffic, the new highway should also relieve a part of the congestion of the Colombo-Negombo road, but the more local and slower traffic as well as smaller scale shipment of lower value goods will remain.

Given that the effect of this new major road will be to shift the major transport of manufactured goods for export and imported equipment, materials and goods eastward to the new highway, then the most desirable location for industrial development of any scale will also shift to the east, closer to the new road. For some industries, an ideal location to make transportation, and

access to infrastructure and services as inexpensive as possible, would be between the Colombo-Negombo road and the new highway.

The net effect of these changes may be to shift industrial development generally to the east and leave the area immediately bordering the Colombo-Negombo road to the small-scale entrepreneurs and traders and the area to the west of the road more sustainable for housing development than for industry. Given the difficult nature of the soils and the environmental sensitivity of the marsh-lagoon complex, this may be a positive development overall.

Any development scenario for the area will necessitate the upgrading of existing transportation facilities and the development of some new roadways to serve whatever new developments are proposed, whether they be housing complexes or a nature park. The planning for road development will also be affected by the new highway and the change of traffic on the Colombo-Negombo road.

The other major infrastructure question is the cost of providing water, electricity and sewage handling services to the study area generally and to the residents of the marsh proper. The overall availability of water suitable for drinking and the way in which the demand for this water could be met in the context of its need in the Greater Colombo area, including areas to the east and south of Colombo should be investigated.

The Ambatale Treatment Facilities Extension Project, scheduled to commence in 1991 and to be completed in 1994 will increase the water available to the Colombo Municipal Area and to several surrounding areas, including part of the study area, ie. Ragama, Kandana, and Ja-ela. Additional supply of drinking water to the marsh proper must be seen in the light of the demand and supply of water in the area as a whole, the long-term water availability and the plans of the National Water Supply and Drainage Board.

2.5 Agriculture

It is clear that restoration of rice production in Muthurajawela is not feasible for economic reasons. Yields are consistently low due to a number of factors, relating to soil and water (see Fig. 17).

The world market for rice has, become more reliable and the commodity more reasonably priced in recent years. This is likely to remain the case as various Asian countries have reached or surpassed the point of self-sufficiency in rice. Relying on imports for a certain percent of rice consumption is no longer seen as risky by some countries, but rather as economically sound, while efforts to develop other, more economically interesting crops or crops specific for certain locations take place.

It is to be noted that wild varieties of rice that may prove to be genetically important may be found in the Muthurajawela marsh. Efforts should be made to preserve these. Preserving some of the areas of their range as conservation areas will also be of help.

The most viable agriculture appears to be the combination of coconuts, vegetables, other trees and small livestock as practiced by a number of farmer-homesteaders in the marsh proper and particularly around the edges of the marsh at present. It was suggested above, in section B.5, that this small-scale land reclamation cum homesteading is not a high-value use of the land, but that the system may have its place in an overall mixed land use strategy. If the strategy is to develop certain areas for housing via land-fill, making these areas no longer marsh, and keeping other areas for conservation as marsh, it will be necessary to create a buffer zone between the two, and there may be a place for low-intensity land use via mixed farming as a part of the buffer zone.

There may also be some particular possibilities for production of specialty crops or specialty livestock rearing that should be developed. Reports of a Chinese proposal to raise ducks (at least partly for export) on a large scale within the marsh should not be dismissed off hand. Duck raising has its specific demands, and the market would have to be investigated, but under certain circumstances, duck breeding can be a lucrative business.

2.6 Fisheries

Stocks of all fishery organisms, food fish, shrimps, crabs, ornamental fish are being exploited in a manner that is not sustainable (B-2.2). Therefore development of fisheries based upon enhanced production would not be possible, if the intention is to maintain production levels based upon harvesting optimum sizes of fish and other commercially important aquatic organisms. On the other hand, given the high value of export earnings from the ornamental fishery, it would be possible to further increase the number of small fish harvested at the cost of table size fish and shrimp. The key issue then is identification of the appropriate management objectives for the fishery and to implement relevant management activities. Management should include curtailment of all fishing methods that destroy the nursery areas such as the seagrass beds (see A-9).

The perceptions of fisherfolk toward the ecological processes that maintain the year to year stocks of fishery organisms so important to them, is at variance with the real ecological processes. For instance the

majority of fisherfolk believe that shrimps, ornamental fish and some food fishes are regenerated from decaying plant matter, and from polychaete worm egg cases incorrectly identified by them as the egg cases of shrimps. Therefore a management program should include public education and awareness components (Palliaguru and Samarakoon, 1990).

An appropriate fishery management program, for the wetland must necessarily be based upon an ecosystem approach, rather than only on management of fishery stocks. Such ecosystem approaches have been effectively used for freshwater fisheries, but would be beset with certain problems when applied to estuaries (Pitcher and Hart, 1982). However, it is necessary to recognize that properties of relatively enclosed freshwater ecosystems, and open situations as in coastal marine ecosystems combine in estuaries. For instance, there are seasonal patterns of recruitment of larval stages from the sea into an estuary such as the Negombo Lagoon. During the growth period of these larval stages within the estuary, definable components of the estuarineecosystem determine stock dynamics. The extent of nursery area provided by the seagrass bed, feeding relationships, water quality will directly influence stock size. By selecting an appropriate model, perhaps the dynamic pool approach, the relevant aspects of the fishery stock, environmental factors, fishing gear, locations with respect to nursery areas, behavioural aspects of fisherman could be given due consideration. The most appropriate combination of protected areas, gear specifications, fishing seasons, territorial use rights if applicable would have to be identified by relevant agencies, e.g. Department of Fisheries, NARA, CCD in consultation with the fisherfolk. The basic information for such a planning process is already available in the CCD Technical Report entitled 'Ecological History of Negombo Lagoon' (Samarakoon, 1990).

2.7 Aquaculture

Many developers have regarded the Muthurajawela marsh as being suitable for large scale development of aquaculture while some research has been conducted on this aspect. However, pond aquaculture in the marsh proper should not be an option for serious consideration since the soil is potentially acid sulphate. If however pond aquaculture is identified as a development option, it must be noted that the following interventions and management practices should be included in a cost benefit analysis (Jayasinghe, 1990):

- Neutralization of the pond bottom at least to a depth of 10 cm using agricultural lime in excess of 14 metric tons/ha, where soil pH is 4.0.
- Removal of toxic aluminum, iron and manganese compounds by repeated drying, filling, flooding and draining before liming.
- Fertilization of ponds with organic manure at rates of about, 2-5 metric tons/ha.
- Treatment of pond dykes by intensive, forced leaching out of acidity.
- Stocking with late stage seed material which would increase production costs.

However, the feasibility of drying ponds, which is an essential ingredient of management of acid sulphate soils may be impractical because of seepage and subsidence. The most important contributor to successful aquaculture is proper site selection. Selecting the Muthurajawela marsh for pond aquaculture would involve a continuous battle with the environment: a situation which should be avoided.
If pond aquaculture is to become a sustainable development activity, it must be profitable. Therefore it becomes essential to select high value species for culture, such as penaeid shrimps or giant freshwater prawn for export. The economics of small scale shrimp culture in Puttalam District where conditions are more favourable could be used as a guideline for planning for Muthurajawela.

Generally the small scale shrimp culture ventures are profitable in the Puttalam District because of low land value, and the relatively low costs of pond preparation and maintenance. However at a location such a Muthurajawela, land value would be considerably

Table 25 Necessary conditions for succesful development of aquaculture (Ben Yami, 1986)

- Fevourable natural and market conditions
- People's needs and attitiudes favouring change and consequently, candidates to become the prospective aquaculturists
- Political will to enable equitable access of the prospective aquaculturists to natural resourses
- Access of aquaculturists to feed, seed and other materials
- Convincing indication of personal economic benifits evident to the prospective aquaculturist as an to their family
- Financial-commercial viability of both the individual farms and the supporting services

higher adding to the very high cost of pond construction, preparation and maintenance. Profitability therefore would be low or doubtful.

An alternative form of aquaculture, shrimp culture in brushpile-mini pens, 50 sq m in extent, has indicated profitability in trials conducted at the Negombo Lagoon (Samarakoon and Fernando, 1990). This may be practicable in the waterways in the transition zone between the marsh and the Negombo Lagoon.

However development of aquaculture must take into consideration other relevant factors before it could be promoted as a planned development option, particularly if the objective is to improve the economic conditions of the poor (Table 25).

The present stand of the government to withdraw state support for aquaculture, however, will be a major disincentive. An alternative to indispensable state support will have to be identified if aquaculture is to be organized and developed.

2.8 Forestry

Forestry development is an important option considering the scarcity of woody species in the area, the general shortage of fuelwood, utility and construction wood, and the non-sustainable exploitation of remaining forest resources which is taking place, in particular in the few remaining stands of mangrove. The Forestry Department proposed the following activities:

- Protection of existing mangrove vegetation;
- Social forestry projects in selected settlement areas;
- Coastal zone planting.

Mangroves: The remaining mangrove trees are subject to intensive cutting and felling mainly for branches for brush pile fishing, and for fuel and utility wood. The estimate of 430 ha of "major mangrove area" as given by the Forestry Department seems too optimistic (see A-7.8). It is probably closer to the potential mangrove area than the actual coverage which is much less. For instance, most mangroves along the east lagoon bank have disappeared, (Plate 30).

Total protection of the remaining mangrove forest is essential (see Fig. 88). Depleted stands could then regenerate and some of the virtually destroyed stands could be restocked, the required technical knowledge being locally available. Although extension programmes on mangrove conservation are deemed important to achieve popular participation in this conservation effort, it would still be necessary to appoint forest guards to enforce protection. It is also necessary to erect clear boundary markers around some of the mangrove areas, especially around those under natural regeneration and around the replanted or rehabilitated areas.

Social forestry projects: At certain permanent settlements at the periphery of the marsh and lagoon, social forestry activities could be developed. The marsh proper and the brackish water swamp are not suitable for this purpose. Social forestry activities would also be an option at low income housing sites to be developed on reclaimed land. It is not clear whether all areas suggested by the Forestry Department as suitable for social forestry projects have been thoroughly surveyed. A re-assessment is probably required, as the success of such projects depends in large measure on active involvement and participation of communities from the very start of the planning stage. Areas to be surveyed are indicated in Fig. 88.

Homestead planting of fast-growing fuelwood species on drier peripheral lands in permanent settlements seems more promising. On a small scale such plantings are already taking place (mainly fruit trees). Supply of fuelwood seedlings at low prices, or free of charge, and technical assistance from the Forestry Department or NGO's would be required. A survey was carried out on the required planting stock for homestead plantings in the Grama Niladari Divisions (Table 26). In this area, home gardens range from 250-750 sq.m and there is a general shortage of fuel wood which is currently being purchased from dealers. However, considering the limited area available for this purpose, the fuelwood problem would only be partly alleviated by these plantings.

Coastal zone plantations: Most of the coastal dune ridge has been planted with coconut and most of the land is in private hands. This leaves little room for the establishment of dune-fixing forest plantations. The Forestry Department identified a suitable area of some 10 ha between Pulluhena and Pamunugama, (Fig. 88), which could be planted with Casuarina equisetifolia.

Vegetational protection of the dune is especially urgent in view of anticipated coastal damage (see B-1.1.3). The original beach forest formation has long gone, and, although coconut palms provide some degree of soil protection, in most places, the trailing natural protective cover of the Ipomoea pescaprae-Spinifex-Vigna foreshore vegetation has also disappeared, making the dune ridge very vulnerable to wave action, particularly during spring tide (Plate 31).

2.9 Peat Extraction

2.9.1 Peat as Energy Source

Large peat deposits are found in the marsh area but its composition and structure make it very doubtful whether commercial exploitation is feasible. Moreover, the expected environmental impacts, resulting from peat extraction as well as from its use as fuel, are seriously questionable.

In 1847, a private entrepreneur embarked on peat mining for fuel but within a year, he had to give up due to a variety of constraints.

A Russian study carried out in 1960/61, in cooperation with the Geological Survey Department, indicated peat deposits of 2.18 million tonnes spread over 460 ha of marsh with less than 30% ash content and 40% moisture. The average thickness of the peat layers was estimated to be 2 m. Elsewhere in the marsh, peat layers were deemed too shallow for exploitation and, because of a high clay mixture, the calorific value of the peat was very low, ash content being as high as 45-70% .

In 1985, EKONO (Finland) carried out a more detailed survey and reported that the total usable peat land with layers over 1.5 m amounted to 165 ha, representing 3.14 million cu.m of usable peat, 94% in layers thicker than 2 m, 52% in layers thicker than 3 m. The potential energy equivalent was calculated at 4.79 PJ (1.31 TWh). As to the different types of peat found in the marsh (see A-5.1), the following breakdown was given:

- 64% grass and sedge-type (fibric) peat;
- 31% trees and shrubs-type peat;
- 5 % humified (amorphic) peat.

However, the EKONO study also revealed that the low calorific value and the high sulphur content would **disqualify** the peat as a good domestic and industrial energy source. Average sulphur content was measured to be 5.06% which would produce **intolerably high emissions of sulphur dioxide**, causing a bad smell and presenting serious health hazards when used as domestic fuel. The same would hold when using the peat for small industries such as brick and tile factories. If used as fuel for large industrial plants, compliance to CEA-emission standards would be necessary, which means that emission treatment by adding large quantities of limestone in **fluidized-bed technology** in steam or hot water boilers would be required to capture sulphur dioxide. It should be noted that the **sulphur content of peat in Finland is 25 times lower, i.e. 0.2%.**

Apart from these investment requirements, the high ash content (i.e. low calorific value) of the Muthurajawela peat, make doubtful, the economic feasibility of using peat as an industrial fuel. Ash content varied from 5.3 to 44.7%, whereas a maximum ash content on dry matter basis of 14.9% would make peat an interesting fuel for industry. It is noteworthy that **ash content in Finnish peat ranges from 1.5 to 7.2%.**

The total theoretical energy value of the usable peat deposits in the Muthurajawela marsh was estimated at 4.7 PJ or 1.31 TWh. This is equivalent to the energy contained in 120,000 tonnes of oil. It means, that the peat reserves could only support a small, 2-3 MW electricity plant for a relatively short period of 20 years.

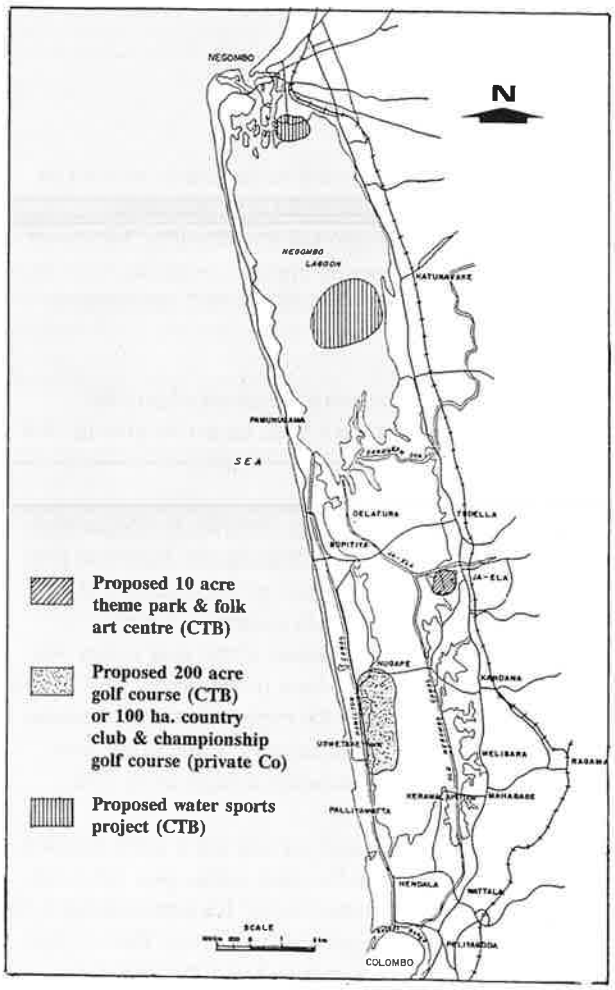
The EKONO study does not mention the need for an Environmental Impact Assessment which is surprising as these impacts could be very serious indeed, in particular the effects on seepage and drainage and, most importantly, on the hydrology and water quality of the Negombo Lagoon and its important fisheries (see B-2.1 regarding oxidation of pyrites in the soil to sulphuric acid, and potential asidification of water in Negombo Lagoon). The study identifies however, that drainage could be a problem: "uncertainties regarding the possibility of draining the bog by pumping"..."seepage waters from underground being the biggest unknown factor"...This indeed is a point requiring utmost attention. The average moisture content of the peat in Muthurajawela is 90%, most areas being constantly water-saturated. Gravity drainage seems impossible and with pumped drainage, the risk of salt water infiltration and seepage is real. The transport of excavated peat presents additional problems: the costs of safe road construction for motorized transport of excavated peat are prohibitive. Other issues requiring further study are the relatively high concentrations of heavy metals in the bog, including mercury (90 ppm) known to be of high toxicity to man and animals.

In summary, the high sulphur content (which altogether rules out its use for domestic and small-industry purposes), the high ash content and the limited quantity would not be conducive towards maintenance of industrial energy production. Furthermore, the losses from environmental damage related to peat extraction in the Muthurajawela marsh (see C-4) would most likely far outweigh the economic benefits.

2.9.2 Other Uses of Peat

Potting Mixtures: A further use of peat is for horticulture (potting mixtures, composts and soil conditioner). Some peat extraction is taking place for the overseas market. The extraction is done manually by temporary labour.

Fig. 87 Areas of interest for tourism and recreation.



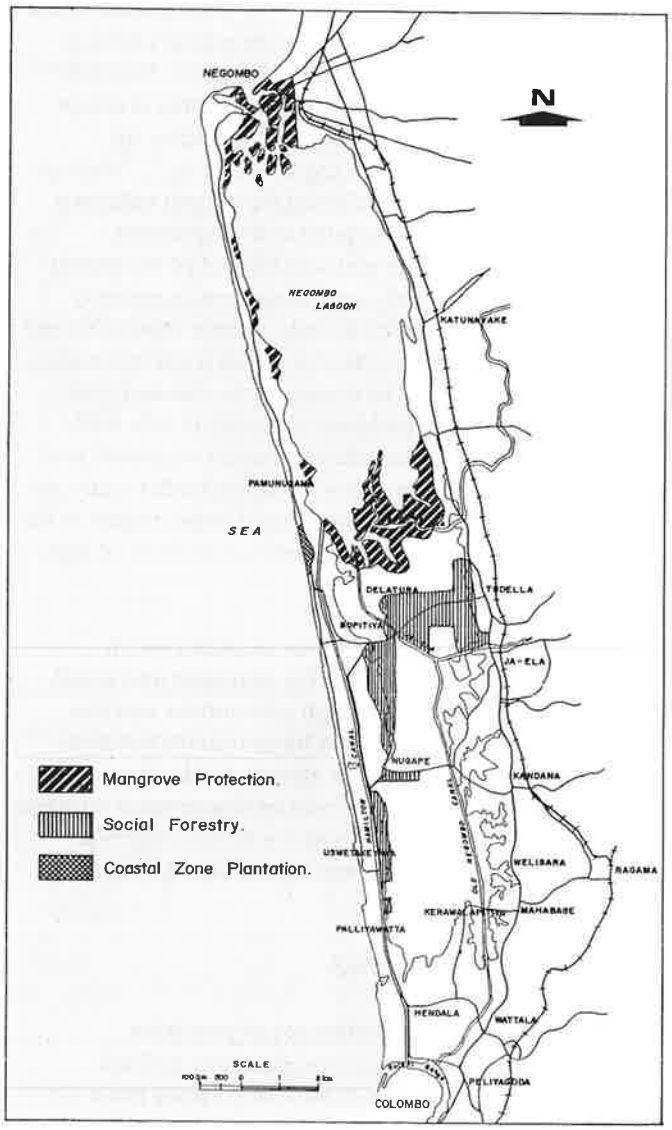


Fig. 88 Areas of interest for forestry development and mangrove protection.

Table 25 - Required number of planting stock for selected Grama Seva Niladhari Divisions

AGA-DIVISION	GS-AREA	Sub-area number	No. of families	Population	No. of families with land	Average size of a home garden (perches)	Estimated Requirement of planting stock for: fruits	fuel wood	timber	Other
WATTALA	Delathura (east)	10	295	988	205	4	62	64	57	14
	Delathura (west)	10	437	1148	350	15	399	410	362	89
	Pattiyawala	18	383	1750	233	20	430	441	391	96
	Kerawalapitiya	18	1250	2855	718	20	1091	1120	991	244
	Balagala	18	998	2350	525	20	798	819	725	179
	Bopitiya	14	287	1183	263	23	460	472	417	103
	Uswetakeyiyawa	18	810	3668	725	20	1102	1131	1001	247
	Parana Ambalama	14	590	2385	527	20	801	822	727	179
	Nugape	14	246	1130	211	10	160	165	146	36
JA-ELA	Dandugama	11	441	2500	210	10	160	164	145	36
	Thudella (west)	16	104	337	42	30	96	98	87	21
						Total	5559	5706	5047	1244

* 1 ha = 400 perches

SOURCE: FOREST DEPARTMENT, SRI LANKA, 1990

Calculations:

Total plants required:		17556
Total cost (raising, transport, and distribution Rs. 4/- per plant):	Rs.	70223
Travelling expenditure	Rs.	25000
Total: :	Rs.	112779

The high levels of pyrite in the peat-soil mixture of the marsh would require special attention as to potential acidity of the oxidized peat mixture. However, provided this activity is carried out on a small, home-industry scale in small demarcated areas, the environmental effects of this activity could be minimized and mitigated through extension and control.

Fertilizer: In Sri Lanka phosphate deposits are estimated at 40 to 60 million tones, all of it of heterogeneous composition and difficult to use because of its structure. A few years ago the idea was launched to bury large quantities of this phosphate in the marsh where the mixing with peat and slightly acid water would turn it into a useful fertilizer.

It was also suggested to excavate peat deposits near Bopitiya for use as fertilizer and soil conditioner. Transport by rafts via the Hamilton Canal was planned. After excavation the peat would be mixed with imported ammonium sulphate and muate of potash, to be sold in 50 kg polytene bags. Excellent results were reported from trials in tea plantations. The operation was planned on 200 ha of government land to be leased to a private enterprise for a period of 30 years. Peat would be excavated in 25x100 m trenches separated by 6 m wide raised bunds. Eventually, the trenches were to be converted into fish ponds but because of the expected salinity and acidity of the water (pH=5), the choice of aquacultural species would be limited to certain tilapia, mullet, Chinese carp and milkfish. The raised bunds could be used for the planting of 1300 coconut seedlings and for livestock and duck raising.

However, at a pH of 5, the water would have very low productivity, while growth of the above species would be negligible. The food for mere survival itself would have to be maintained incurring heavy feeding costs. Therefore, fish culture in peat holes would not be profitable.

This proposal could possibly be considered in the future after an interested party has shown its economic feasibility. Equally important is an Environmental Impact Assessment, emphasizing the expected changes in the productivity of the marsh-lagoon ecosystem, in the buffer storage capacity of the marsh, and in water quality. Other environmental issues to be taken into account are given a C-4.6.

2.10 Education

The present distribution and accessibility of schools in the area has ensured appreciable educational levels of the people up till the secondary level. In case middle class housing is to be developed in the area, existing educational facilities would need to be upgraded with supplementary facilities, while secondary educational facilities would need to be developed too. For this reason, part of any planned landfill should be set aside for schools and other educational facilities. It is recommended that elements of conservation education, with direct relationship to the marsh and the lagoon environment, should be included in the school's curricula.

The Muthurajawela marsh-Negombo Lagoon wetland is in close proximity to 4 universities, Viz. Universities of Kelaniya, Colombo, Sri Jayawardenapura and Moratuwa. All these universities have teaching and research programs related to natural resources management, environmental science, planning and fisheries. A management and development program for this wetland could obtain substantial support from these universities if appropriate arrangements are made as a part of the implemented program of activities.

Establishment of field research facilities by universities could be encouraged by providing various incentives such as free land for construction of laboratories. These could then serve as units that could get linked to an integrated planning and management program for the wetland (see C-6.3). Such field research in turn would provide feedback for revision and reorientation of university curricula in keeping with practical needs.

3. INTEGRATED WATER MANAGEMENT

3.1 Resources and Demands

3.1.1 Hydrological resources

A comprehensive description of the hydrological system of the Muthurajawela marsh - Negombo Lagoon wetland and the surrounding area is given in A-6. Present trends and expected future developments have been discussed is B-1.2.

There, it appears that about 1,500 million cu m of fresh water are entering the area per year; 1,325 million cu m/y from the Dandugam Oya and the Ja- Ela and the remaining 175 by precipitation. About 75 to 100 million cu m/y are lost to the atmosphere by evaporation and transpiration. The remaining 1,400 million cu m/y leave the area to the sea; mainly through the inlet of Negombo Lagoon and a small part (say 50 million cu m/y) through Hamilton canal and the estuary of Kelani Ganga.

An estimated 1,300 million cu m/y of sea water are entering the area; mainly through the inlet of Negombo Lagoon and a small part (say 70 million cu m/y) through Hamilton Canal. The salt mixes with the fresh water and is subsequently flushed to the sea. In the long run, no water and salt accumulate in the area.

The main body of open water in the area is the Negombo Lagoon with an estimated volume of 20 million cu m. Its salinity varies with the seasons. A thin but variable sheet of water covers the greater part of the marsh. The volume is estimated to vary between two and ten million cubic meters; the latter only during heavy rain. Some salt penetrates into this area during the dry seasons.

The flow volumes of the Muthurajawela marsh - Negombo Lagoon wetland are schematically shown in Fig. 89.

The ground water under the area is presumed to be saline except at the higher grounds along its borders (A-5). The latter aquifers are thin; a lens of fresh ground water, with an estimated 1-1.5 million cu m volume, probably floats on the salt water in the dune sands along the coast. This means that ground water resources are very limited, **barely enough for present domestic use.**

The salinity of the water has already been mentioned in the discussion of the quantitative characteristics of the system. It is a positive qualitative factor in the lagoon but it is generally regarded as detrimental in other parts of the area viz. the marsh in agriculture.
Domestic sewage and effluent from industry and touristic facilities cause some localized, and temporarily excessive pollution. The general state of pollution seems still to be within acceptable levels. Turbidity is an inevitable consequence of the transports of sediments.

3.1.2 Ecological Demands

The main ecological systems in the area are the Negombo Lagoon with the adjacent tidal delta of the Dandugam Oya and Ja-ela, and the Muthurajawela marsh.

The lagoon and the delta form an interrelated system exchanging water, dissolved matter, sediments and biomass. A considerable, although seasonally variable, salinity is imperative for aquatic life. Sedimentation and erosion play a vital role in the development of vegetation (i.e seagrasses) in the Lagoon and mangroves of the swampy delta. The inflow of large amounts of fresh water maintains the variable salinity in the lagoon and prevents the delta from becoming too saline. The rivers supply fresh sediments.

Some naturally detrimental effects are caused by extreme conditions viz. low supplies of fresh water in dry seasons and extreme floods; the former causing high salinities even in the delta and the latter flushing out almost all of the salt.

The connection with the sea, via the tidal inlet near Negombo, is **vital** to the ecological system of the Lagoon and the delta.

Muthurajawela marsh in its natural state, receives water from precipitation and occasionally, during flood from the rivers Dandugam Oya, Kelani Ganga and Kalu Oya. The surplus, after evapo-transpiration, drains very slowly to the Lagoon and the estuary of the Kelani Ganga. Intrusion of water and salt from the sea is minimal.

A few centuries of trials of socio-economic development have drastically **increased the drainage capacity,** reduced or even halted the accumulation of dead biomass, caused subsidence of its surface and facilitated the intrusion of salt during the dry season; without achieving much of their aims. The surplus water now flows off rapidly to the sea causing a shortage during the dry seasons.

Restoration of (parts of) this marsh would require almost complete impoundment to restore its lack of drainage as well as its buffer capacity. It could absorb some excess water from the rivers during extreme floods and it might release a few millions of cubic meters of water of reasonable quality during the dry seasons.

3.1.3 Socio-Economical Demands

The most demanding of economic activities in the area, in combination with the ecological system, is fishing supported by the nursery and the breeding function of the lagoon. Much fresh water is needed to maintain the proper salinity and other qualitative factors in the lagoon.

Agriculture is another activity that requires large amounts of water, e.g. paddy. Two successive crops per year require about 3 million cu.m of water per square kilometer; 40 percent of it flowing through as percolation water. Other crops are somewhat less demanding. Modern agriculture also releases various pollutants.

Housing, industry, tourism, infrastructure and educational activities use relatively little water, but generally of good quality, an exception being water for cooling. That, however, is not consumed but its quality (temperature) is changed. Housing, industry and tourism have a tendency to pollute the water. The reclamation of land and construction of roads may change the drainage system, storage area, and the drainage capacity.

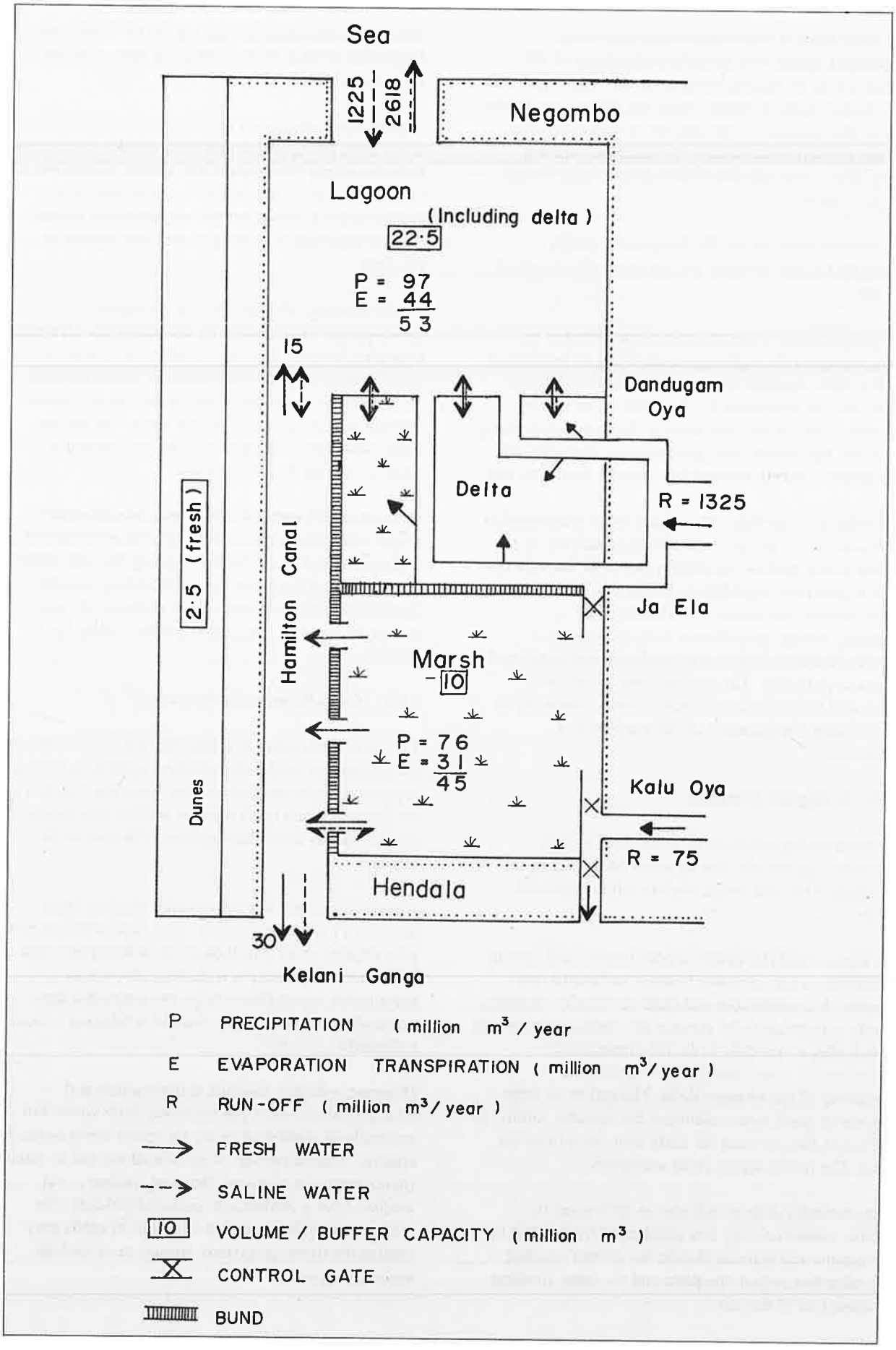


Fig. 89 The flow volumes in the Muthurajawela marsh - Negombo Lagoon wetland.

3.1.4 Demands of Sustainability

Sustainability in the hydrological sense means that the demands on the system should not, at any time and location, exceed the capacity of the resources. This should include quantity as well as quality, taking into consideration the relationship between these two factors. This will require the properbalancing of the water budget with proper compensating measures in the case of certain demands exceeding the specific resource.

It is important to avoid chronic shortages of water with the required quality as well as the initiation of progressive deterioration.

3.1.5 Boundary Conditions

Not only the phenomena within the area but also external developments do and will continue to influence the resources. The most important factors are:

- the sea with its mean level and salt water,
- the closed dune ridge along the coast,
- the inflow of water from the rivers, and
- climatological factors via the atmosphere.

Of these, the salinity of the water and probably the climate can be regarded as invariable. The sea level is expected to rise slowly but at an increasing rate during the next century, **nothing can be done to stop or reverse this tendency.** Ongoing erosion may lead to breaches in the dune ridge if the necessary (technically feasible) defence measures are not taken. Perforation of the coast would induce an increase of the penetration of salt into the area. No fresh water is available to counter this threat.

The run-off from the rivers can be influenced, for better and for worse, by human intervention. The management of their combined basins should be coordinated with water management in the Muthurajawela and Negombo Lagoon area.

3.2 An Integrated Approach

3.2.1 One Hydrological System

The hydrological system of the Muthurajawela marsh and the Negombo Lagoon must be considered as one system consisting of the following sub-systems:

- the Negombo Lagoon, with the tidal delta and its inlet to the sea,
- the Muthurajawela marsh, and
- the Hamilton Canal with a narrow strip of low land, connecting the former two and the estuary of the Kelani Ganga.

An intervention in any one part of this system will cause effects in the whole system, the larger the intervention, the more serious the effect. The totalamount of water, although variable in time, is limited and quality disturbances can spread rapidly with the moving water.

3.2.2 Constraints

The main constraints on further development of water resources are:

- the limited amount of water available,
- the large quantity already required for maintaining the proper salt balance in the lagoon and in the southern end of the Hamilton Canal,
- the limited buffer capacity of the marsh for water as well as for dissolved matter,
- the low level of the land precluding proper gravity drainage and probably justifiably, aversion against pumped drainage,
- the expected accelerated rise of sea level which penetrates into the area, and
- the norms, existing or to be set, with respect to the pollution of the water.

The objective of **sustainability imposes a general constraint.**

3.2.3 Integrated Development

Development, and the planning of it entails the reconciliation of various, often conflicting interests. This must be done in a balanced way considering all demands, constraints and effects in an integrated approach. The water, common to many of the interests in the entire area, constitutes a basic forcing function in a wetland and, therefore, must be one of the most important considerations in an integrated policy analysis. Some aspects even exceed the boundaries of the project area but they should not be ignored, as their function affects the project area proper.

3.2.4 Basic Information

An analysis of the effects of socio-economic development can only be made on the basis of adequate information about the state and the processes of the hydrological system.The best way to make such

information operational is an integrated model which can simulate the processes in the area or parts of it. Attempts have been made by the Irrigation Department and the National Aquatic Resources Agency to model specific parts of the systems. Some of their results were used to construct the picture of the hydrological system given in A-6.

A model has to be based on observations in nature and common scientific knowledge. Some quantities (e.g the geometry) can be measured quite accurately and they vary little with time. Others (e.g rainfall, river discharges, water levels) are highly variable in time and space; they must be observed over long periods to obtain statistically reliable data. In view of this, the available information is very variable in quality. Efforts should be made to fill the gaps and to keep the information upto date (see C-6.4).

3.3 Implications of Development Options

3.3.1 General Considerations

The various development options,listed in C-2, make demands on the hydrological resources and they will also have effects on the hydrological system. Generally, these implications will be more or less proportional with the size of the project. Mitigating measures can help to avoid or ease detrimental effects.

Combination of options may amplify or compensate each others' effects. This aspect is difficult to assess because it greatly depends on the relative location of the projects in the hydrological system.

A general picture of the demands of the development options on some hydrological resources is given in the matrix of Table 27. A discussion on each of the options follows in the next Section.

3.3.2 Implications per option

Conservation

The lagoon and the delta: Conservation of this system generally means management of the status quo, and development which will be sustainable in the long run. Some benefit could be gained from an increase of the minimum inflows and a decrease of extreme floods. Regulation of the rivers could achieve this. High floods could possible be diverted to the Muthurajawela marsh for occasional flushing. As the possible intervention is relatively small, its effects will be of the same order of magnitude.

Muthurajawela marsh: The conservation of this area could take the extreme forms of leaving it in its present dilapidated state or restoring it to its former status of a healthily growing marsh which can keep pace with the rising sea level.

The first alternative will leave it in almost open connection with the Hamilton Canal and the rising sea. It may partly develop into a shallow brackish lake. Some areas in the east and the north may be able to continue their status as a marsh as a result of their poor drainage. The existence of a large body of brackish water will have a detrimental affect on water quality in its vicinity; probably requiring mitigating measures. The marsh will completely loose its function as a buffer of fresh water. **Not enough fresh water can be made available** for the option of keeping the marsh fresh by flushing.

The second alternative requires i**mpounding** of the marsh combined with a management of the water level that restores the conditions of storage and poor drainage as they once were in the original state of the marsh. Then it will be allowed to grow vertically, possibly in pace with the rising sea level. In this case, the buffer capacity of the marsh could absorb an occasional peak of a flood in the Ja-ela and it could act as a limited **source of fresh water** to its vicinity during some parts of the year.

Summarizing, the conservation option demands considerable increases in the water budget, fresh as well as saline. It takes, and provides a large buffer capacity. emission of pollutants should be limited; the option releases no pollutants.

Housing and Industry

Housing: This option claims an area of dry land with good drainage. It demands a part of the buffer capacity and it burdens the vicinity with its run-off. Mitigating measures may include an improvement of the drainage system towards open water. The domestic water supply is relatively small but the quality should be good. **Sewage units from housing projects should be studied with care to avoid pollution of the waters.**

Industry: This activity poses similar demands as housing with respect to dry ground and drainage. The required quantity and quality of water supply greatly depends on the type of industry. The same applies to the quantity and quality of the effluent. Not only the mean flow of pollutants but also sudden high peaks can cause disastrous harm. The treatment of the effluent should be tailored to its nature as well as to the absorption capacity of the receiving water.

Tourism and Recreation: The demands and effects of the lodging of tourists and recreation are of the same category as in the case of housing. Recreational

activities, such as boating, fishing, swimming, etc., require space and quality but they hardly influence the functioning of the hydrological system. However,in the absence of a sewage disposal system for the entire study area, the danger of release of mature cess pit material into the lagoon exists.

Infrastructure

Infrastructural works generally require a limited amount of space but they (especially roads) may constitute a barrier for the flow of water. Care must be taken to mitigate these effects. Demands and effects on water quality are imperceptible.

The rise of the sea level may require the construction of bunds to protect presently dry areas against flooding. Such works will prevent the increase of buffer capacity which otherwise might be expected as an effect of sea level rise.

Agriculture

Agriculture occupies land and it demands a considerable quantity of water per unit of area at the right time. The water should be fresh and otherwise of reasonable quality. Exact demands depend on the type of crop.

Considerable quantities of fertilizers and other chemicals used in modern agriculture can be released and act as pollutants in the rest of the hydrological system, being toxic, causing eutrophication or otherwise. The supply of water to and drainage from agriculture land must be designed with care, in view of quantity as well as quality.

Aquaculture

The demands of this option resemble agriculture but the quantities are smaller and the water may be fresh or saline (not variable) depending on the kind of fish. Purity is important. Effluent in the particular case of pond construction on potentially acid sulphate soil could have detrimental effects (see B-2.1; B-2.3). Depending on scale and intensity of aquaculture practice, nutrient loaded effluent could cause eutrophication.

Fisheries

The demands and effects on the hydrological system are similar to tourism sand recreation. A healthy ecological system is required.

Forestry

Its demands and effects are generally equal to agriculture.

Peat Extraction

Digging of peat from the marsh will create areas of open water of considerable depth within the marsh. The water in these lakes will be more or less acid depending on the amount of flushing. The latter would pose a demand on water quality and would be conducive to dispersion of the acid into other parts of the hydrological system.

The process of extraction is expected to create locally high acidity and turbidity in the water.

Education

Education and scientific investigations are expected to be of such minor volume that no perceptible implications for the hydrological system are expected.

3.3.3 Effects of reclamation

Reclamation of land by raising its surface by the dumping of a layer of sand on the existing surface prevents inundation during floods, and decreases retention capacity. Water (possibly saline) will be used to transport the sand to its place of deposition (sand pumping from the sea). The heavy layer of sand will compress the underlying peat and squeeze the ground water out.

The Irrigation Department (Dharmasena, 1991) used a model to simulate the effects of reclamation of 1.4, 3 and 5.3 sq km in the Muthurajawela area of 23 sq km as described in A-6. The main results are given in Table 28, all based on an initial level of mean sea level at the onset of the period of heavy rainfall. The reduction of the storage areas and the reduction of drainage capacity appears to lead to higher water levels, less retention and lower rates of outflow. Starting from a higher level at the beginning of the period leads to higher maximum levels, less retention and higher rates of outflow.

The conclusion is that filling of an area should be carried out with a network of drainage channels within the area in order to maintain the natural drainage without changing the water levels.

Deposition of 3 m of sand on a peat layer of 2.5 m thickness will cause a compaction of the peat to about 1.25 m and a land surface 1.8 m above mean sea level. Three million cu.m of sand are required for each sq km of land to be raised in this way. Its transportation will require about 6 million cu m of sea water and about 1.25 million cu m of water will be squeezed out of the peat, also per sq.km of land.Although **such quantities are small** compared with the general water balance of the area, the local effects of the salt and other dissolved matter in the water can be considerable. Therefore, a

Table 27 - Demands of development options on hydrological resources

	OPTIONS	QUANTITY			QUALITY			
		FLOW		STORAGE	FRESH	SALT	FREE OF	
		Suppl	Drain	Area			Poll.	Turb.
1	Conservation							
	-Lagoon + Delta	+	+	++	+	++	-	+
	-Marsh	+	- -	+	++	- -	-	+/-
2a	Housing	+	++	+	++	- -	- -	- -
2b	Industry							
	-Cooling	++	++	0	+/-	+/-	+/-	-
	-Process	+	+	0	++	- -	-	- -
3	Tourism & recreation	0	0	++	+/-	+/-	-	-
4	Infrastructure	0	+	+	0	0	0	0
5	Agriculture	++	++	++	++	- -	- -	+/-
6	Aquaculture	+	+	++	+/-	+/-	-	-
7	Fisheries	0	0	++	+/-	+/-	+	-
8	Forestry	+	+	++	++	- -	-	+/-
9	Peat extraction	0	0	- -	0	0	0	0
10	Education	0	0	0	0	0	0	0

++	high demand	++	imperative	+/-	indifferent
+	low demand	+	required	-	detremental
- -	low or negative	0	aaaairrelevant	- -	intolerable

Table 28 - Flows and storage in the marsh without and with reclamation

RETURN PERIOD	(yrs)	50	100	200
Maximum inflow	*(cu.m/s)*	70.3	77.7	85
A. NO INFILL				
Max. storage	*cu.m*	11.4 m	13.8 m	14.5 m
Max. level (M.S.L)	*m*	0.56	0.61	0.66
Max. outflow	*cu.m/s*	19.20	21.70	24.50
B. INFILL 1.5 sq. km				
Max. storage	*cu.m*	11.10	12.20	13.5 m
Max. level (M.S.L)	*m*	0.59	0.63	0.69
Max. outflow	*cu.m/s*	13.80	17.30	22
C. INFILL 3 sq. km				
Max. storage	*cu.m*	10.9 m	11.8 m	12.8 m
Max. level (M.S.L)	*m*	0.61	0.66	0.70
Max. outflow	*cu.m/s*	10.70	14.80	16.60
D. INFILL 5.3 sq. km				
Max. storage	*cu.m*	10.2 m	11.4 m	12.4 m
Max. level (M.S.L)	*m*	0.62	0.68	0.73
Max. outflow	*cu.m/s*	0.80	10.80	12.20

proper way of **discharging the water from transport and** compaction must be included in the project.

3.3.4 Gravity Drainage and Pumping

The two main systems of drainage available for water management of a confined area are:

- gravity drainage, and
- drainage by pumping.

Gravity drainage is relatively cheap and it requires only attention in case that the flow needs regulation. The tides in the area under consideration hardly allow for the maintenance of a water level at present mean sea level which is already 0.12m above the survey datum of 1884. An acceleration of the eustatic sea level rise will gradually lead to more problems in view of the general level of the area.

Drainage by pumping can maintain any level. The cost is roughly proportional with the level and the quantity to be removed. In the case of Muthurajawela marsh, the head is small but the climate demands a high capacity. To remove the 200 mm of water from rain of one day (not unusual in Colombo) from an area of 1 sq km (100 ha) in 2 1/2 days, a capacity of 1 cu m/s is required.

The operation of a pumped drainage system requires alertness in the case of sudden rain and reliability. The former means attendance or automatic control, and the latter requires proper maintenance and reliable power supply. Non-compliance with the latter requirements seems to have led to the bad experiences of the past.

Higher demands on the water management and sea level rise may, however, lead to more and more pumping, possibly in combination with gravity drainage.

4. ENVIRONMENTAL IMPACTS

4.1 Impacts of Conservation

No negative environmental impacts can be expected from the implementation of this option.

4.2 Impacts of Land reclamation for Housing and Industrial Development

4.2.1 Environmental impacts of Hydraulic Sand Fill

In 1988, congruent with the SLLRDC Master Plan (1985 and 1988) and the Muthurajawela Development Prospects study (CEA,1988), a proposal was presented to reclaim an area of approximately 250 ha in the most southerly part of the marsh by means of hydraulic sand fill (Zanen Verstoep, 1988). The reclaimed area would be developed for housing and industrial projects. Delft Hydraulics (Waterloopkundig Laboratorium, 1988) prepared a preliminary Environmental Impact Statement which was definitly not meant as an environmental impact study. The following is largely based on this study and supplemented with additional information.

Possible environmental impacts resulting from hydraulic sand fill of marsh areas are related to:

- loss of natural values and ecosystem functions
- hydrological changes
- subsidence and collapse of peat substrate
- saltwater loads during fill

In addition, a number of environmental effects could occur at the sand borrowing site (5 km offshore) and the adjacent coastal area. These include:

- effects on coastal geo-morphology
- increased turbulence from suspended sediment.

Loss of natural values and ecosystem functions: The natural vales of the reclaimed area, i.e. flora and fauna communities, aquatic wildlife habitat and breeding sites, as well as natural wetland functions (production-, purification and buffering functions) will be irreversibly lost. It should be noted that, in the case of the Muthurajawela marsh, the most important issue is not the possible loss of rare or unique species but the disturbance of the ecological system of which the marsh land forms a part. If reclamation would seriously disrupt the ecological integrity and productivity of the fresh- and brackish water marsh lands and the Negombo Lagoon, this would be ecologically as well as economically unacceptable. Whether this will happen depends on the size and the location of the reclaimed area. In the ZV-proposal the area to be reclaimed comprises less than 10% of the marsh, and the selected site will border immediately to dry land in an area where human influences are already noticeable. As such, it will be unlikely that this reclamation project would entail major losses and disruption of ecological values and functions.

However, possible impacts on the ecosystems of Muthurajawela and the lagoon should not only be assessed on proposed reclamation but should consider the whole set of proposed development interventions for the entire area. For this, it will be necessary to determine the required minimum area of marsh to be preserved including bufferzones to maintain its functioning, and to determine the maximum permissible degree of parcelling and disturbance, see C-2.1.

Hydrological Changes: Expected hydrological changes resulting from sand fill reclamation are given in C-3.

Susbsidence and collapse of peat substrate: (see C-3.3.3) A sand fill in two steps has been suggested, to allow for partial subsidence after the first fill. This is deemed necessary to reduce the risk of subsoil collapse. This risk will be highest along the edges of the reclamation area and along the banks of any storage pond. Special measures may be required to prevent these calamities.

It is felt that further geo-technical studies on the behaviour of peat under reclamation are justified. The quoted subsidence rate is not supported by factual data and little or no data are available on the risk and extent of peat soil collapse. In this respect, the following observations might be of importance:

- most peat in the marsh area seems to be permanently water-saturated,

- structure and texture of peat in the marsh are very variable, ranging from mixtures with heavy clay to a loose watery muck of plant detritus.

Salt water load during fill: (see C-3.3.4) Hydraulic land fill with sand sucked from the sea bed entails large quantities of salt water being sprayed onto the area to be reclaimed. The amount of salt water to be discharged has been estimated at 2 m/s on average (WL, 1988). By constructing a low bed-storage pond, and by pumping the salt water load back into the sea, negative effects on the marsh and canals (Hamilton Canal) can be avoided. These flow beds could later be developed as permanent storage ponds for drainage water.

Effects on coastal morphology: The morphological changes which can be expected outside the sandstone barrier as a result of sand extraction by suction from the sea bed depend on wave period, depth of borrow site and its distance from the coastline. In the ZV proposal, 8 million cubic metres of sand fill are required for 250 ha and the borrow area is planned 5 km offshore. Given the presence of a sand stone barrier along the shoreline and the prevalent wave period of 10 seconds or more, a borrow site 5 km offshore at 20 to 30 m depth would unlikely affect coastal morphology (Waterloopkundig Laboratorium 1988). However, WL also recommends that attention should be given to the shape of the borrow pit.

The impacts on marine communities caused by sucking large quantities of sand from the sea bottom are difficult to assess, but there is little doubt that disturbance will take place.

Turbidity by suspended sediment: The turbidity caused by sand sucking from the ocean floor and from the discharge of salt water load back into the sea could have negative effects on coastal fisheries and ecosystems. It is not possible to quantify these effects. In the case of coral reefs, reduced light penetration caused by increased turbulence would have disastrous effects, but these do not occur along the Muthurajawela coast.

4.2.2 Other Land Fill Operations

Reclamation by means of truck loads of lateritic soil fill would have similar environmental effects as listed above. However, the risk of substrate collapse would probably be higher, as filling by truck loads would be less gradual as compared to jet-discharged sand fill.

Positive effects: Apart from economic development options reclamation of part of the marsh area would also have a positive effect on public health: it would reduce the breeding area of certain vectors of water-related human diseases. On the other hand, development activities on the reclaimed land area could also give rise to additional problems, unless adequate sanitary and health care provisions are integrated as part of the development programmes (C-4.3).

4.2.3 Impacts of housing projects

Environmental considerations in housing projects are mainly of sanitary nature. Some mitigatory measures have been listed in C-4.3 and include:
adequate drainage of run-off;

- adequate waste disposal and collection facilities;

- piped water supply;

- closed sewerage system and sewage treatment facilities;

adequate and safe road infrastructure;

4.2.4 Impacts of Industrial Development

Industrial development projects on reclaimed lands could give rise to environmental problems, unless adequate measures are enforced. These include:

- adequate provision of waste disposal and effluent discharge;

- adequate storage of raw materials, in particular in case seepage of toxic compound might occur;

- treatment of effluent water and emissions, noise levels etc;

- prevention of fire hazards and accidents;

- sfety regulations for workers and industrial traffic.

4.3 Impacts of Tourism and Recreation Development

Tourism and Recreation development would not necessarily cause detrimental effects on the natural environment, provided due attention is given to planning, site selection, design and enforcement of rules and regulations. The following conditions are of particular importance:

- siting of resorts, amenities, and facilities: prevent further encroachment on remaining mangrove forests, important vegetation types, erosion-prone sites. Limit the loss of wildlife habitat as much as possible and prevent undue disturbance of wildlife. Ensure adequate disposal of waste and effluent (no sewage disposal or mature cess pit material to discharge into the lagoon) and prevent undue noise pollution,

- boating, windsurfing: prevent undue disturbance to fisherman, exclude boating and surfing from conservation areas and from seagrass beds (some demarcation of such areas would be required); use of speed boats and water skiing in the shallow lagoon waters should be prohibited, it would cause undue disturbance of fishing activities and wildlife, and many accidents would undoubtedly occur,

- golf course: an adequate solution to the discharge of run off and drainage water from the reclaimed land is essential. The land fill should not cause excessive flooding or impeded drainage elsewhere in the marsh and should not disturb thehydrological interdependence between lagoon and swamp area. Loss of wildlife habitat should be kept at a minimum.

It could be considered to provide nature tours (guided boat tours) for nature lovers (bird watching). Information leaflets or booklets on the marsh-lagoon ecosystem, its flora and fauna and traditional fishing practices, could be provided. A "code of conduct" for visitors, containing conservation education elements could be prepared and provided to people visiting the lagoon for recreational purposes.

4.4 Impacts of Infrastructure Development

Possible environmental impacts relate to impeded drainage, soil erosion and public health hazards.

Drainage: infrastructure development should not disrupt the interlinked flow of water and nutrients between the marsh and the lagoon. It should not lead to excessive flooding and drainage problems in areas adjacent to construction sites. This implies that adequate structures should be included in the design of works to guarantee proper discharge of drainage water and run off and maintenance of natural flow patterns: culverts, drifts, drains, bridges etc.;

Erosion: care should be taken to prevent accelerated erosion from construction sites, in particular during the construction phase but also after completion. In constructing roads, canals or drainage ditches, special attention should be given to the stabilization of embankments (re-vegetated banks and slopes, lined canals). Other exposed surfaces should be re-vegetated as far as possible; erosion hazards in borrow sites, quarries etc. should also be avoided;

Public health: borrow pits could collect run off, become pools of stagnant water invaded by aquatic weeds and provide habitat for human disease vectors (mosquito's, rats). Inadequate disposal of polluted drainage and waste water from buildings etc. could cause similar problems at discharge sites in the marsh and the lagoon (see also C-4.2). Moreover, water quality could deteriorate to the extent that its use by humans and other uses are no longer possible and the ecosystem's production and filtering functions would be impaired. Finally, in case of road infrastructure development, due attention should be given to road safety (design, speed limits).

Most of these impacts can be avoided or minimized by careful planning and design of structures and works, selection of construction and borrow sites, adequate disposal of spoils, timing of cut-and-fill operations (dry season) and by surfacing or stabilization of exposed sites. Other measures include: limiting earth moving as much as possible, adequate provisions for drainage water and effluent discharge.

Infrastructure development should not interfere with other land use options, i.e. nature conservation:

Wildlife: It should not lead to unacceptable losses of important vegetation types and wildlife habitat, whereas disturbance of wildlife and interference with wildlife movements should be avoided.

4.5 Impacts of Agricultural Development

Based on soil survey results and water quality data, it appears that the area's potential for economically viable agricultural development is low. Although it is unlikely that large-scale agricultural projects will be part of the development options in the Master Plan, it is worthwhile to list the likely environmental impacts of agricultural development in an area such as the Muthurajawela marsh. These include:

Expected increase in use of agro-chemicals: residue from pesticides could enter the marsh and lagoon water causing pollution which would have an impact on man,

fauna and flora, and, in particular, on aquatic productivity. Use of products with less residual toxicity, adherence to CEA's list of prohibited products and to safety prescription for use, dosage and disposal of packing material, would greatly reduce these negative impacts. Residual run off of chemical fertilizers could enrich receiving waters, giving rise to massive aquatic weed growth (already a problem in some sectors of the marsh), creating breeding habitat for human disease vectors;

Irrigation development: in case of irrigation development, the total area of standing, vegetated shallow water would increase and water quality would be affected. This could give rise to the proliferation of existing disease vectors and the establishment of new vectors (Japanese encephalitis, Korean Hemorrhagic Fever, see C-4.10). Regular clearing of drains and canals would reduce these health risks;

Monoculture crops: the establishment of monoculture crops, in particular cereal crops and fruits, could give rise to a rapid proliferation of pests and pest animals causing serious crop damage requiring costly control measures. In this respect, the already abundant rodent (rats, etc.) populations are of particular interest, not only as notorious raiders of cereal crops but also as transmitters of serious human diseases. Other possible animal problems include crop damage inflicted by fruit-eating bats andin monitoring implementation of projects coming under the Master Plan.

Impeded drainage: the practice of coconut plantation establishment on raised bunds seems a viable option in certain parts of the marsh. So far, plantations have been established without much regard for the important ecological functions of the marsh and swamp areas, in particular in relation to natural drainage and nutrient exchange. It is essential that these considerations are taken into account in future expansion of this type of land use,

Biodiversity: in planning agricultural projects, one of the criteria should be to minimize the losses of important conservation values and loss of biodiversity. This would include measures to safeguard sufficient area of important plant communities and to minimize disturbance of wildlife and wildlife habitat. On the other hand, site and crop selection, and cropping systems should be such that the chances of crop damage by animal pests remain small.

4.6 Impacts of Aquaculture Development

Aquaculture development in coastal zones could lead to environmental degradation, unless adequate mitigating measures are taken. In Indonesia, shrimp and fish pond development in Western Java and elsewhere has been identified as one of the factors causing the destruction of a protective mangrove greenbelt. But other possible impacts should not be neglected. A summary is given below:

- the remaining mangrove vegetation along the edge of the Negombo Lagoon should be preserved because of its important nursery function (see A-7);

- the construction of ponds should not impede the natural drainage pattern;discharge of nutrient-rich "used" water from the ponds into the lagoon and the swamp should be avoided as this could enhance noxious aquatic weed growth which would affect the water quality and the productivity of the lagoon;

- as new ponds are usually stocked with shrimp seed (post-larval stage) collected from the lagoon, unless cheaper seed from a hatchery are readily available, a serious depletion of the lagoon stockcould result, affecting the catch of many lagoon and coastal fisherman;

- the current practice to dig up polychaete worms from the sea grass bed of the lagoon to be used as broodstock feed in hatcheries, is very destructive to the sea grass beds which are essential habitat for commercially important shrimp seed and euryhaline fish species ;

- richly stocked ponds will obviously attract fish-and shrimp eating birds which abound close by in the lagoon and in the marsh area, giving rise to serious birdlife-aquaculture conflicts; cormorants, and to a lesser extent, herons and egrets, are a particular case in point;

Clearly, careful planning and control in aquaculture development is required if it is not to backfire on the economic importance of fisheries in the swamp, the lagoon and in the adjacent coastal zone.

4.7 Impacts of Fisheries Development

- Fishing in the brackish waters swamp and in the lagoon generate already appreciable income to many families mainly of the low-income group. The main question is not "development" of fisheries but guaranteeing a sustainable catch to the fishermen presently involved. Recent trends in fishing practice are not supportive to sustainable exploitation of the fish and shrimp stock, and may nullify benefits of development. The problems are:

- The use of "more efficient" fishing gear (draw nets, push nets, trawls) is destructive to the sea grass beds in the lagoon. These nets not only cause

mechanical destruction but also cause increased turbidity by churning up the silt at the bottom of the lagoon which chokes the sea grass beds. It could eventually destroy the most important nursing, feeding and sheltering chambers of most of the commercially important fish and shrimp species;

- lack of effective control of mesh size of fishing nets combined with the tendency to use smaller mesh sizes, leads to the removal of younger age-classes on which fish and shrimp biomass production depends

- introduction of novel and more efficient fishing gear, such as trammel nets (disco nets) which in competetion with less efficient traditional methods acquire higher catches. This entrains abandonment of traditional methods, adoption of more efficient methods and finer partitioning of an unchanging stock, leading to lowering of income.

These trends are serious enough to warrant "control measures" before thinking of "development options". Urgent action seems justified as the modern techniques also affect traditional fishing practice (screens, traps, brush pile fishing) which have proved to be sustainable and which are the main source of income of many poor fisher folk. Such control measures should include:

- restrictions of fishing areas
- regulations and control of allowable fishing gear and mesh sizes;
- regulations and control of minimum sizes of harvestable species;
- registration of gear;control of catch of ornamental fish species;fisheries extension programmes.

As mentioned before, the productivity of the lagoon and marsh area depends in part on the daily inflow of sea water through the northern lagoon outlet. This outlet becomes gradually filled up with sediment, a process which is enhanced by small-scale reclamation for settlement. Drastic changes will occur in the ecosystem if this process continues unabated. In terms of fisheries development in the lagoon and the coastal zone, this requires careful attention. If the objectives of fisheries development are the maintenance and improvement of the catches of the present spectrum of shrimps and fish, the lagoon ecosystem should be maintained, which would require, amongst others, measures to guarantee the inflow of sea water (Samarakoon, 1990).

4.8 Impacts of Forestry Development

No negative environmental impacts are expected to result from the proposed forestry activities in the project area if locations are carefully selected and boundaries of planted areas are maintained. In fact, mangrove protection is one of the key issues in maintaining the productivity of the lagoon. However, mangrove planting must be considered in the perspective of entire estuarine ecosystem function. Many poor members of the community who have encroached onto intertidal shoals, grow mangroves with the intention of subsequent landfill (Plate 14). Since this is occurring in the channel segment of the Lagoon every effort should be made to prevent housing expansion into channels under the guise of mangrove planting. Otherwise, water flow would be impeded and fishery productivity would collapse.

4.9 Impacts of Peat Extraction

World-wide, proposals for large-scale peat extraction are met with considerable resistance. This opposition is voiced not only by nature lovers, an increasing number of development planners are now joining their ranks. Peat is a non-renewable resource and, in particular in the case of tropical coastal peat deposits, the mining of peat is, at best, only marginally feasible in economic terms. There is little doubt that this statement is still too optimistic: present-day economic thinking is not capable of putting price tags on irreversible losses of peat bog ecosystem functions and underestimate or neglect the price to be paid to repair the damage or to create alternatives for the lost functions and resources. Removal of coastal peat deposits like those in the Muthurajawela marsh, which have evolved under the influence of the sea and rivers seeking an outlet to the sea, has far-reaching irreversible environmental effects, removing the base of existing land and resource uses. These effects can be summarized as follows:

- disturbance of the interlinked and interdependent marsh-lagoon ecosystem: disruption of the hydrological balance, major changes in water quality and disruption of nutrient flow from the marsh into the lagoon; resulting in a dramatic drop in the productivity of the transitional swamp and the lagoon;

- loss of buffer storage capacity of the peat, loss of buffering, filtering and purification function of the peat layers; resulting in water-logging, flooding, drainage problems;

- in peatlands separated from the sea by a very narrow dune ridge such as in Muthurajawela, infiltration of saline water through the dune ridge into the lowered marsh will be the result, excluding all uses of water for human, agriculture and other purposes;

- where the subsoil becomes exposed after peat extraction or oxidation, the pyrites in the soil give rise to the development of acid-sulphate soils, often

combined with aluminium toxicity, which makes these soils totally unsuitable for cropping and other purposes. Run off from these soils is also acid, and when collected in drainage ponds, these waters are unsuitable for aquaculture development. The claim that they are suitable for aquaculture is incorrect. Water quality further deteriorates when brown-orange colloidal iron hydroxide is formed.

- loss of rich plant communities and valuable wildlife habitat.

Considering the price to be paid to substitute the losses caused by nature's reaction to peat extraction in the Muthurajawela marsh, and the average poor quality of the peat, large-scale peat mining options should be rejected. Small-scale use of peat as outlined in C-2.9 could be considered provided control on site selection and operations can be enforced.

For the maintenance of the ecosystem it is essential that a substantial part of the peat marsh is maintained in its quasi-natural state and that connecting corridors between the marsh, swamp and lagoon are kept open. This means that development planning should proceed from the southern end of the marsh and from the uplands west and east of the marsh, leaving the central wedge of peat deposits intact.

4.10 Impacts on Human Health

The development objectives and options as listed in C-1 and C-2 should be considered against the possible impact on the public health situation. To give an example, in locating housing projects, the proximity to the nearest marshy areas should be taken into account to minimize the transmission of mosquito-borne diseases, most mosquito's (except the vector of dengue) breeding in marshy areas have a limited flying range.

The development activities would also involve the inflow of people from other areas, which could mean the **introduction of new diseases** or strains hitherto unknown to the area. On the other hand, whereas longterm residents, may have developed some degree of immunity to prevalent diseases, new arrivals may lack immunity and may cause certain diseases to reach epidemic proportions. A similar event appears to have occurred in the Mahaweli Development Scheme with the advent of settlers from outside.

The impacts of the development programmes on the public health situation could be positive as well as negative, however, detrimental effects can be prevented or minimized by incorporating adequate mitigatory measures in development programmes, (see following section). In summary the expected impacts include:

Expected Positive Impacts

- Reclamation of marsh lands will reduce the breeding area of animal disease vectors, hence the incidence of certain water-related diseases.

- Infrastructure development, paralleled by community development programmes, will improve access to prophylactic and curative drugs and to health care centers and hospitals.

- Resettlement of marsh dwellers presently living in shanty houses without any sanitary provisions surrounded by extensive swamps and pools ofstagnating water would greatly reduce their susceptibility to infectious diseases.
- Economic and agricultural development could improve the general nutritional status of the residential population and hence increase immunity.

Potential Negative Impacts

- Unless adequate drainage facilities are provided, land filling and road construction could impede the natural drainage pattern giving rise to pools of stagnant water, which could become breeding sites for disease vectors; (Plates 32 and 33)

- Development of housing and industrial complexes will produce large quantities of solid waste, sewage, effluent and emissions causing pollution. Waters from drainage canals and marshes could become polluted and invaded by dense aquatic weed growth, providing ideal breeding habitat for a variety of animal disease vectors. It would also have a negative effect on water quality and fish productivity. Waste dumps could become breeding sites for important disease carriers, such as rats and culicine mosquito's. These negative effects could be reversed by providing adequate waste disposal, sewerage and sewage treatment facilities;

- In the advent of new arrivals, new diseases could be introduced. On the other hand, serious outbreaks of prevalent diseases could occur among new arrivals lacking immunity to these diseases;

- ncreased and improved agricultural production could lead to an increase in the use of pesticides and fertilizers, which could result in residual pollution of soils and waters. When products of high residual toxicity are used, this could become a public health hazard and could effect the productivity of aquatic ecosystems;

- Road construction, housing and industrial development could give rise to higher accident rates amongst the residential population.

Preventive and Prophylactic Measures

A variety of preventive and prophylactic measures are possible to reduce health hazards related to development programmes. These measures include:

- public awareness, nutrition education and personal hygiene programmes;
- adequate sanitation and waste disposal facilities, mosquito and rodent (rats and mice) proofing in new housing projects;
- providing sewerage and sewage treatment facilities in housing and industrial projects;
- immunization programmes;
- supply at reasonable prices of prophylactic drugs and extension programmes on their use;
- agricultural extension programmes with emphasis on the safe use of agro-chemicals and residual toxicity;
- enforcement of existing environmental protection legislation, i.e. effluent and emission standards for industry, water quality standards, wildlife and nature protection legislation;
- disease-vector control programmes.

In addition, special preventive measures can be taken for specific pathogens. These include:

Leptospirosis: evidently, most waterways and marshes have already been contaminated by leptospiral organisms via rodent urine. It is at present the most common and important public health problem in the area (see A-8.7). The disease is difficult to contain when the daily activities of the population brings them in frequent contact with infested water and soil. Special measures to be taken include: avoiding of cuts and abrasions, wearing boots and other protective clothing when working in water and rat proofing of houses. Adequate waste disposal, hygienic measures, rat proofing and rat control measures would greatly assist in leptospirosis control. These measures would also be useful in the control of Korean Hemorrhagic Fever.

Bowel infections: these infections are directly transmitted from person to person via contaminated food or faeces-polluted water, soil or flies and include shigellosis, typhoid and paratyphoid, amoebic dysentery, cholera and worm infestations. Evidently, the incidence of these diseases can be greatly reduced by hygienic measures such as the provision of adequate toilet facilities and instructions as to their proper use, boiling of drinking water, using purified water for washing and cleaning (vegetables!), personal hygiene, protection of food from flies and fly control measures (see A-8.7).

In the case of typhoid/paratyphoid and cholera, vaccination could be adopted.

Filariasis: efforts should be made to eliminate breeding sites of the mosquito Culex quinquefasciatus, which include stagnant polluted water puddles, waterlogged garbage dumps and borrow pits, blocked drains, etc. Other measures include indoor mosquito control (screening of windows, using mosquito netting, spraying with insecticides of low residual toxicity, and prophylactic use of di-ethyl carbamazine.

Malaria: although malaria is not a major problem in the area, it could reach epidemic proportions if there is parasite and vector build-up (MRI,1990). Control measures would include indoor mosquito control and use of prophylactic anti-malaria drugs.

Japanese Encephalitis: effective vaccines are available for immunising susceptible people. As the virus is amplified in pigs, swine vaccine could be used to immunize pigs. Control of the culex mosquito vectors would be difficult as these breed in marshes and pool of stagnant water. Also, mosquito proofing of piggeries would be impractical if not impossible. MRI suggests that, in case a sustained campaign of human and pig vaccination is not possible, pig rearing should be discouraged and replaced by buffalo and cattle rearing as the latter are less efficient amplifiers of the JE-virus as compared to pigs.

Dengue and Dengue Hemorrhagic Fever: removal of "container habitats", i.e water in empty tins, coconut husks, old tyres, pots and pans around human dwellings, and mosquito proofing and use of mosquito screens.

A summary of preventive measures is given in Table 29.

5 DEVELOPMENT CONDITIONS

As explained above certain conditions must be met to ensure that yields from the ecosystem functioning of Muthurajawela marsh-Negombo Lagoon are sustained while development activities are implemented. This should be considered as essential because the **losses associated with not doing so would be socially too high.** The important questions then are: what part of the marsh should be kept as a conservation area, if any? What would be the costs (direct and indirect) and benefits of such conservation? What ecosystem management measures should be implemented?

Table 29 - Summary of measure to minimize the incidence of infectious diseases (*)

	lep	shi	tpt	amd	gia	mal	wor	fil	je	dhf	sin	khf
Siting of housing	o					o		o	o	o	o	o
Public education	o	o	o	o	o	o	o	o	o	o	o	o
Mosquito proofing						o		o	o	o	o	o
Mosquito control						o		o	o	o	o	o
Rat proofing	o											o
Rodent control	o											o
Aquatic weed control	o					o			o		o	o
Personal hygiene	o	o	o	o	o		o	o		o		o
Adequate sanitation	o	o	o	o	o		o	o				o
Adeq. waste disposal	o	o	o	o	o		o	o		o		o
Piped water supply	o	o	o	o	o		o					o
Pig vaccination (JE)									o			
Vaccination			o						o			
Prophylactic drugs						o		o				
Health care facilit.	o	o	o	o	o	o	o	o	o	o	o	o
Monioring, surveys	o	o	o	o	o	o	o	o	o	o	o	o

* lep : leptospirosis
shi : shigellosis
tpt : typhoid / paratyphoid
amd : amoebic dysentery
gia : giardiasis
mal : malaria
wor : worm infections
fil : filaria
je : Japanese encephalitis
dhf : dengue haemorrhagic fever
sin : sindbis
kfh : Korean haemorrhagic fever

The results of the environmental investigations indicate that the following are the most important areas and associated functions:

The stability of the coastal dune system should be regarded as a prerequisite for management andevelopment of the wetland, since its survival is dependent upon continued existence of this coastal barrier, already known to be under threat.

- The area of transition between the lagoon and the marsh, that is the northernmost portion of the marsh, from the southern edge of the lagoon, south to the edge of the densely populated area on the Tudella-Pamunagama road is the most critical ecologically. It is also one of the least-developed areas. The squatters who now live there are few in number and largely dependent upon fishing. Most have lived there for a number of years. Some (perhaps 40 families) abandon their housing every year in the high-water season, when their small houses are inundated and no longer liveable, and go to live in a church on charity. These people could be offered alternative housing. If they prefer to stay as they are, their numbers should not be allowed to increase by immigration. They do relatively little environmental damage, but some of their activities should be curtailed, specifically path building on any scale and tortoise-hunting.

- A central area of the marsh should remain open: free of heavy settlement and not filled in by landfill and construction. This area should include some small water bodies and it should also retain the natural vegetation of reeds, sedges, etc and remain a habitat for marsh species mainly birds.
- the maintenance of fishery stocks in the Negombo Lagoon is an essential condition fore socio-economic stability of a large segment of the community dependent upon the wetland. Recruitment of planktonic stages through an open channel segment at the northern (inlet) of the lagoon is essential for stock stability.

- An Environment Impact Assessment (EIA) will be mandatory for each major development project. Adherence to CEA guidelines on content and format is required. In none of the development proposals presented to date, has sufficient attention been given to this requirement. The present study would facilitate the establishment of EIA's for most development projects.

- in design of projects, infrastructure, housing, industrial plant and buildings, due attention should be given to environmental standards set by the CEA. This is particularly important with respect to the effluent and emission standards, water quality standards, waste disposal, erosion control etc. Proposed projects should also comply with other environmental legislation as listed in C-6.2.

The ecosystem relationships including human activity are given schematically in Figure 84, and should constitute a framework for planning.

The segments of the wetland that should be protected from damage stemming from development, and the areas that need to be developed from a public health viewpoint are summarized in Fig. 90.

6. IMPLEMENTATION ARRANGEMENTS

6.1 Institutional Aspects

The identification of required institutional structures should be based on the principle of sustainable development of the Muthurajawela marsh and Negombo Lagoon. At present, three levels of authority dealing with development planning and implementation, and community level development can be identified:

- Central Governmental Agencies, including the GCEC.

- District and Local Governmental Agencies.

- Non-Governmental Organizations.

Aside from these organized structures, land ownership and land use rights becomes a significant issue since areas identified as critical for conservation and protection may already be privately owned. In terms of development planning the following potential constraints can also be identified:

- Lack of coordination between the three levels of authority.

- Conflicting development targets pursued by each.

- Lack of enforcement of existing legislation related to natural resource use and environmental protection.

- Socio-economic, i.e. a wide range of people's needs to support, and provision of incentives for participation in proposed development projects.

The Master Plan will address these issues in detail and will develop the required institutional structure for the implementation of proposed development activities. However, two essential conditions should be fulfilled if these recommendations are to become effective:

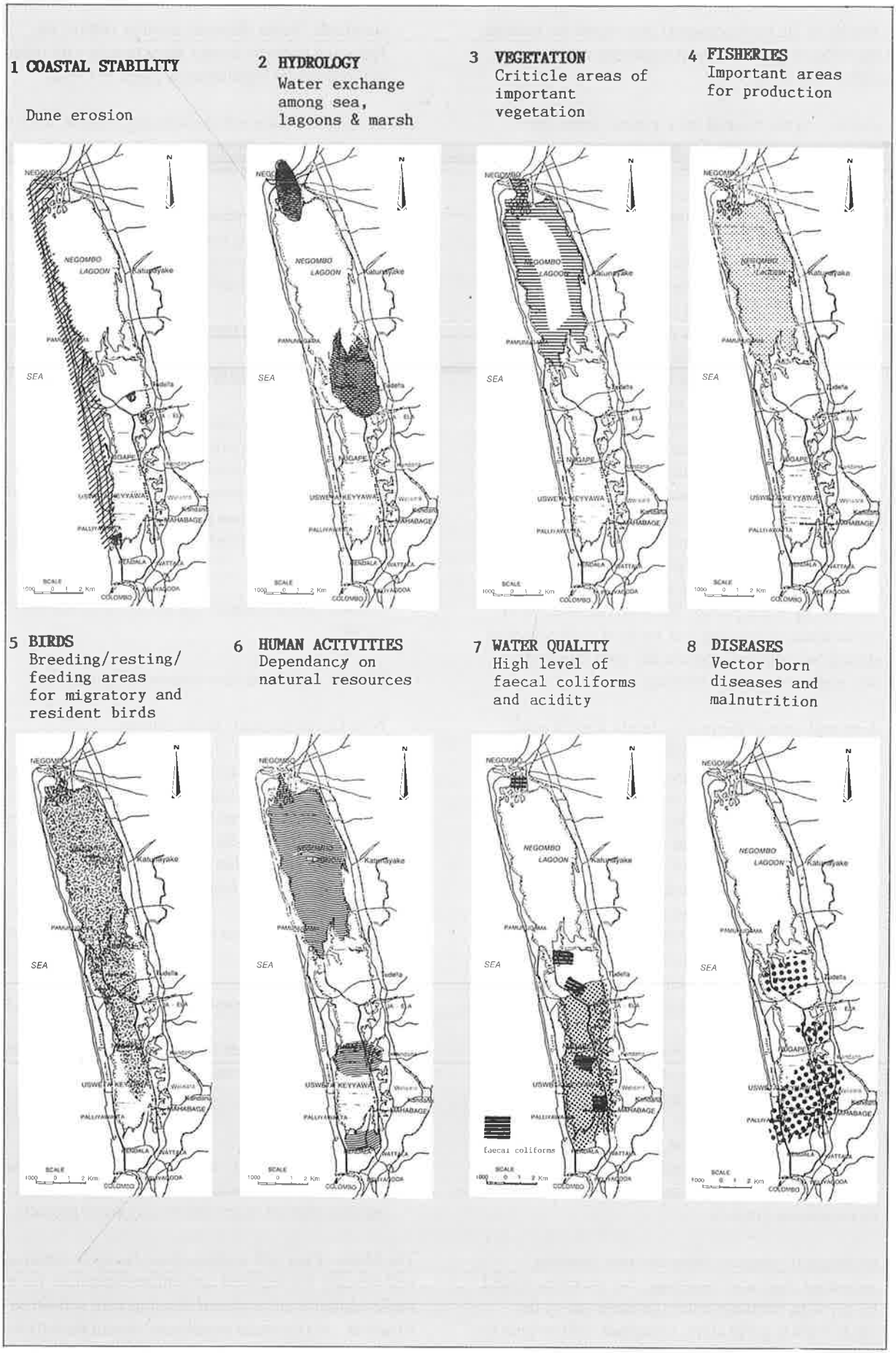


Fig. 90 The critical areas of the wetland requiring protection 1-6, and development from a public health viewpoint 7 and 8.

Plate 30

Fringing mangroves give way to an expatriate holiday home

Plate 31

Dune re-vegetation is an urgent task for protecting the eroding coastline

Plate 32

This type of squatter housing is a public health hazard.At such locations sanitation would be impossible.

Plate 33

Homestead coconut cultivation appears to be an acceptable activity in the buffer zone. Sanitation would be a necessity.

- clear and unambiguous description of development objectives, and

- acceptance of the Master Plan as an authoritative planning document by all levels of authority and affected community groups.

It is not recommended to create a new parastatal body of authority unless it is well integrated into the existing government organization. Rather, a formula should be worked out to achieve consensus among all parties involved by means of regular meetings or workshops.

"In reflecting on implementation gaps in natural systems management, it is useful to begin by noting the fundamental mismatch between the organization of natural systems and governmental organizations to manage natural systems. The central characteristic of nature is that it is a system - a highly interrelated structure of many complementary functions. An ecosystem comprises communities of plants and animals with their nonliving surroundings of soil, air, and water plus the dynamic flows of energy and nutrients. By natural systems we mean the renewable natural resources and the health and quality of the air, water, and landscape - that is, ecosystems including human beings.

The central characteristics of government organization for natural systems management is fragmentation: jurisdictional gaps, polarization of interests, jurisdictional conflicts, incompatible policies, conflict of uses, lack of coordination and communication" (Lowry and Carpenter, 1984).

In the implementation process, the Central Environmental Authority (CEA) should play a key role. For larger development projects Environmental Impact Assessment (EIA) are now mandatory. The CEA should also play a coordinating role in the Monitoring Programme as proposed in C-6.4.

6.2 Legal Aspects

Population growth and recent environmental degradation has prompted the government to pay attention to environmental protection in development planning. The population has doubled over the last 25 years and stands now at 16 million, which means an average of 240 inhabitants per square kilometer. Basic environmental legislation is provided by the National Environmental Act (NEA, Act No.47 of 1980), which was amended by Amendment Act No.56 of 1988. The NEA also provided for the creation of an environmental protection and management body, the Central Environmental Authority (CEA). However, before gazetting of the National Environmental Act in 1980, there were already nearly 50 laws and regulations in force with some bearing on the environment. Many of these are now obsolete,ineffective or redundant and few, set environmental standards.

CEA is a policy-making and co-ordinating body for environmental protection and management. Initially, it had no regulatory powers and was dealing principally with environmental education, research, training and policies. At present CEA is responsible for Environmental Impact Assessments (EIA) and pollution control. As of January 1st, 1984, EIA has become mandatory for all development projects. CEA has powers under the National Environmental Act to prescribe environmental standards, for the discharge of effluents/emmissions into water, air or soil and has gazetted national standards in Gazette 596/16 of 02nd February, 1990. These could be updated or ammended as required. It has been instrumental in the drafting of a National Conservation Strategy. CEA has also played a central role in the establishment of the Sri Lankan Environmental Congress, an umbrella organization for all environmental NGO's in the country. In summary, it can be said that effective legislation is now available, imposing the need to include environmental dimensions in economic planning.

Focal points of CEA include the growing population, in particular the number of displaced urban and rural poor, who, in combination with increasingly scarce land resources, are contributing to environmental degradation and depletion of natural resources. Large urban centers such as Colombo are faced with expanding marginal settlements at its periphery, where education opportunities, water supply, waste disposal and health care are inadequate. The control of this haphazard growth of marginal settlements near urban centers would, amongst others, require accelerated development of new housing complexes with adequate sanitary and health care facilities.

Most of these issues have a direct bearing on development planning in the Muthurajawela marsh and the Negomb Lagoon. Therefore, CEA will have a vital role in monitoring implementation of projects coming under the Master Plan.

Other environmental legislation pertaining to development planning in the area, and relevant institutions, include :

- **Coast Conservation Act (1981):** The Coastal Zone Management Plan for Sri Lanka was prepared under this Act, and provides policies for management of coastal habitats including wetlands.

- **Control of Pesticides Act (1983)**

- **Crown Lands Ordinance (1947):** provides for the declaration of crown (state) lands as reservations for the source, stream bed of rivers and streams, springs, tanks, reservoirs, lakes, ponds, creeks, canals and foreshores, and this, in order to prevent soil erosion and to guarantee the preservation of vital water resources. Section 62 of the Act stipulates rules and regulations for the removal of sand, stones, coral or other substances.

- **Fauna and Flora Protection Ordinance (1937):** amended by Act no.44 of 1964 and Act no.1 of 1970; stipulates the protection of flora and fauna species.is

- **Fisheries Ordinance (1940)**

- **Forest Ordinance (1907):** (amended by act no.13 of 1966, Act no.56 of 1979 and Act no.13 of 1982) provides legislation for preventing damage to forest reserves and water resources.

- **Greater Colombo Economic Commission Law (1978).** - Planning and implementing authority in the study area is assigned to the Greater Colombo Economic Commission since it occurs in the GCEC are of authority (Fig.7)

- **Land Development Ordinance (1935):** provides for the mapping out of state land for the prevention of soil erosion and for the protection of forests, catchments and ecological functions.

- **National Water Supply and Drainage Board Act (1974):** deals with sewerage treatment and disposal and with the problem of impeded drainage.

- **National Environmental Act (1980):**see above.

- **National Aquatic Resources Agency Act (1981):** Provided for the establishment of the National Aquatic Resource Agency (NARA) which has carried out various studies in the marsh and the lagoon.

- **Plant Protection Ordinance (1924)**

- **Soil Conservation Act (1951)**

- **Sri Lanka Land Reclamation and Development Corporation Act (1968):** amended in 1976 and 1982.

- **Tourism Development Act (1968):** deals also with the protection of scenic beauty.

- **Urban Development Authority Act (1978):** The Urban Development Authority is responsible forplanning urban development in general, including the Gampaha District, but excluding the GCEC area of authority.

- **Water Resource Board Act (1964)**

6.3 Future Studies

The ecological survey constituted a multi-disciplinary and integrated overview of the study area. Further studies of a similar nature would be wasteful of time, energy, manpower and money. Therefore future studies here connotes deeper analysis of problems (research) related to development and management of the Muthurajawela marsh-Negombo Lagoon wetland as an ecosystem including renewable natural resources, the quality of air, water and landscape, and health and quality of life of human beings. The relationship between future studies and management/development of this wetland are shown in Fig. 91. The objective of research, as portrayed here, is not merely to understand the system, but also to provide information to the Manager of the wetland to deal with management problems and to ensure that projects are implemented in a manner that will yield the anticipated benefits.

Future studies identified in this section in no way places a hurdle for implementation of the Master Plan. Instead, the future studies should be undertaken as a part of a management and development program of activities.

The four critical areas of study are:

- **Coastal stability:** The relevant problems are to be identified with reference to the Coastal Erosion Master Plan, and the Coastal Zone Management Plan of the Coast Conservation Department.

- **Hydrology:** In order to serve the monitoring needs of the implemented Master Plan, preparation of a mathematical model, based upon which problems may be identified for analysis. The information already available with government agencies need to be synthesized first.

- **Fishery productivity:** Preparation of a model which relates characteristics of fishery stocks, ecosystem relationships and fishing effort which then could be used for development of a database that allows generation of management measures for sustained production.

- **Socio-economic:** The objectives of this research should be primarily to identify novel activities dependant on the healthy functioning of the wetland ecosystem that could contribute toincreased income

and to enhancement of the quality of life of resource users (Mc Neely, 1989). With adequate economic incentives stemming from wise use of natural resources, socio-economic development could be coupled with sustainability of ecosystem function and yield.

6.4 Monitoring

In this chapter a number of Environmental Indicators will be identified which would require continuous monitoring, no matter which of the development options and development intensity options are eventually selected for implementation. The trends and values recorded in assessing these indicators would serve as an early warning system, allowing planners, decision makers and managers to take timely, appropriate mitigatory or preventive action. Preferably, the information should be made operational in the form of one of more mathematical models. The identified environmental indicators include:

- **Coastal Recession:** The Coast Conservation Department should design a special long-term coastal recession monitoring programme for the Muthurajawela marsh and the Negombo Lagoon. At selected points, spread uniformly along the coastal dune ridge, permanent measuring stations would be required. For practical reasons these could be numbered beacons along the coastal road and cross sections from these beacons to the shoreline at low tide could be measured and plotted in standard scale profile graphs. These measurements should be taken at least once a year after the monsoon period.Suspended Load:

- **Suspended load:** of main water courses entering and leaving the marsh and the lagoon, should be monitored at a statistically adequate frequency. For this purpose, permanent measuring stations should be marked and both the sampling as well as the analysis techniques should be fully standardized. This monitoring programme should be carried out by NARA.

- **Water Levels and Flows:** Water levels and flows should be monitored at various points in the project area to assess patterns of flows and water level variations as caused by tides, wind, density currents, rainfall and river discharges. By this, long term changes and trends should be detectible. Permanent recording gauges are needed at the boundaries of the area and at a few strategic points within. Temporary gauges could be separated at longer intervals during simultaneous measuring campaigns of various parameters. Responsible agencies: NARA and the Irrigation Department.

- **Salinity:** Changes in salinity levels of marsh and lagoon water should be monitored at the end monsoon and end dry season using standard calibrated conductivity meters. A permanent series of marked measuring points would be required and results should be mapped and compared with the salinity measurements reported in this study. Responsible agency: NARA.

- **Acidity:** Changes in acidity resulting from runoff from oxidized pyrite containing marsh soils, which could occur after peat removal, bund construction etc. should be monitored by regular pH measurements using standard equipment. This monitoring could be combined with salinity measurements but the location of such stations should follow sites in the marsh and swamp area indicated for early implementation of development projects, e.g. reclamation areas, sites for agriculture and aquaculture development. Obviously, the timing of the monitoring work would be subject to adjustments in case visual symptoms and events indicate that a danger exists; excessive fish or shrimp mortality in aquaculture ponds after onset of the rains, development of colloidal iron-hydroxide in drainage water, yellow-white colouring of the soil etc. Responsible agency : NARA.

- **Water quality:** The monitoring of water quality in the project area is essential for long-term sustainable development. Sampling techniques and analysis should be attuned to currently used standard techniques and quality standards (CEA,Water Board). Special attention should be given to toxic agro-chemical and industrial residues in areas where development of these sectors is planned and implemented. Water samples should be taken at regular intervals not exceeding 3 months. Obvious signs of water pollution, i.e. human health problems, excessive fish and bird mortality, massive growth of algae or aquatic weeds, bad smells, discolouring, etc. would require additional sampling. Responsible agency: NARA/GCEC.

- **Disease Vectors, Incidence of Diseases:** The monitoring of the spread of disease vectors such as larvae of mosquitos, rats and mice, could be undertaken by non-medical personnel. However, the monitoring of public health situation, i.e. the analysis in trends in the incidence of diseases, including new diseases introduced as a result of development implementation, would be the task of specialist-agencies, such as the Medical Research Institute. It would be essential to establish such health monitoring programmes, using standardized, representative, stratified sampling at selected localities, reliable identification of vectors and diagnosis of diseases, and standardized recording.

Special attention would be required in case of epidemics of serious diseases, but adequate vector monitoring combined with vector control measures, would probably mitigate most serious public health problems in the marsh and lagoon. Responsible Agency : MRI.

- **Fauna and Flora:** The maintenance of habitat of flora and fauna is part of the development packages proposed in this study and the monitoring of their status and trends forms part of the overall monitoring programme. Such management oriented studies should be carried out on an annual basis. Responsibility: university faculties, schools and NGOs. It should include :

- monitoring of the spread of noxious aquatic weeds,

- monitoring of undue encroachment of introduced plants,

- trend in numbers and distribution of birds, both residents and migrants,

- monitoring of the rehabilitation and protection of mangrove vegetation (Forestry Department),

- monitoring of habitat changes in areas assigned to conservation,

- monitoring of other selected flora or fauna elements, e.g. the vigour and growth of seagrass beds, the status of estuarine crocodiles,

- enforcement of environmental protection and nature conservation legislation (Dept. of Wildlife and Nature Conservation, CEA),

- **Sustainibility of Resource Uses:** Monitoring and control of the fish and shrimp catches in the lagoon is urgently needed. It would require enforcement of lagoon fisheries regulations (types of nets, minimum mesh size, minimum sizes of harvestable species) and adequate registration of catches. This type of monitoring would be most effective when organized on the basis of self-responsibility among traditional fishermen, which could be stimulated by means of extension programmes, technical advice and logistic support from the Fisheries Department.

The eventual monitoring program ideally should be integrated into the management and development program such that measurements of different variables or of the same variable in different compartments are coordinated in time and space to provide a comprehensive picture of the system under study (UNEP, 1980). In designing a successful monitoring program it would be best to keep in mind some of the important reasons for their failure (Hanson, 1987).

- **clash in objectives** between **ecologists** seeking to understand system functioning and **managers** seeking reliable information for immediate decisions

- questions asked that are not adequately addressed by the monitoring program

- emphasis on descriptive data, without clearly stated objectives and well-defined hypotheses

- insufficient data analysis (descriptive approaches may answer "what" but rarely address "how" and almost never "why" (Walsh, 1983)

- lack of data sets sufficient to compare natural variability compared to project effects

- qualitative differences in characteristics of systems disturbed by natural forces compared to the effects of human influences (especially important in comparing baseline and project monitoring data sets)

- incorrect selection of monitoring variables

- lack of controls to establish causality

Coordination of financial support for a comprehensive monitoring program as stated above could most likely be carried out by a management and development authority that is well integrated into the existing institutional system.

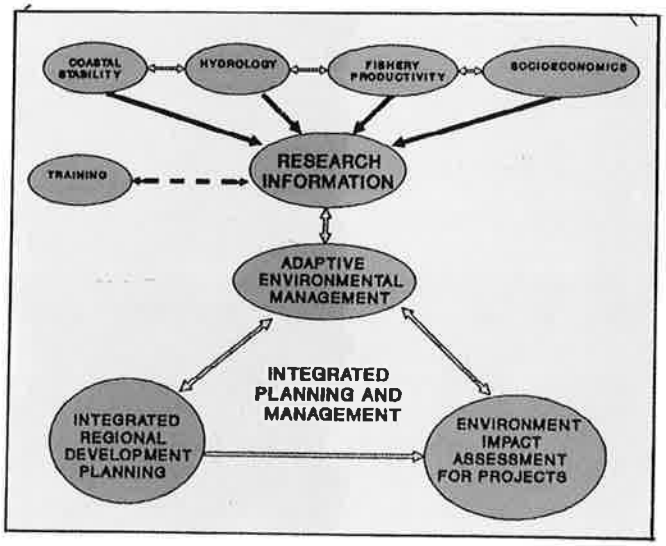


Fig. 91 Future studies for the Muthurajawela marsh - Negombo Lagoon would have to be problem oriented and closely linked to management and development.

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ANNEX 1

BASELINE VALUES FOR WATER QUALITY

The Environment Department of the GCEC carried out tests of water quality at 22 stations in he study area and at relevant points outside of it. The tests were confined to surface water.The sampling stations and the reasons for their selections are given in Fig.A I. The findings are summarized in Table A I.

The following inferences could be made from above values.

- The water in Muthurajawela marsh is generally acidic while in the Negombo Lagoon alkaline conditions prevail. The heavy metal levels in the marsh and lagoon are generally similar. In some instance s however, higher levels were detected in the marsh which may be a consequence of the acidic conditions facilitating their release form sediment into the water. However, more refined analysis using atomic absorption spectrophotemery is necessary in order to determine the pattern more precisely.

- The fecal coliform and total coliform levels were unacceptably high at all locations where defecation was near the water or in the vicinity such that contamination was possible. In the marsh, water in canals and pools in the vicinity of squatter houses are used for washing and bathing and therefore could transmit intestinal diseases. Note that at Nugape, in a natural body no fecal coliform occurred, and also that there are no squatter settlements in he vicinity, The high level of chromium at this location is most likely associated with solid waste dumping.

- During the study period, in October 1990, a fish kill occurred in Ja-Ela Canal, This was caused by the discharge of briny waste water form a gherkin processing factory into the canal.

- Perhaps the high level of chromium, a toxic heavy metal at Leuwela culvert is related to some industrial effluent from the same source Ekela Industrial Estate.

- Pesticide types and levels were not measured since the necessary equipment was unavailable. The general trend in pesticide use, however, is a decrease in application levels since th agrochemical prices, reportedly, have increased during recent months.

- There was evidence of discharge of mature cess pit material into Negombo Lagoon in the vicinity of Airport Garden Hotel. However, fecal coliform level at this site was nil.

Fig.A1. Sampling Stations in the study area for water quality and reason for their selection.

Fig. Sampling Stations in the study area for water quality and reason for their selection.

9. Duwa
Segment of Negombo Lagoon with restricted flow, low income housing in the vicinity with poor sanitation (comparison with 5, 6, 7, 8, 9).

8. Pitipana Lelluma
Channel segment of Negombo Lagoon with good tidal exchange, rapid flow at low tide (comparison with 5, 6, 7, 9, 10).

10. Pitipana-Basiyawatte
Open water area of Negombo Lagoon with good mixing, old settlement in the vicinity with reasonable sanitation (comparison with 5, 6, 7, 8, 9).

11. Delature bridge
Lower segment of Ja-ela where water is used by the residents for bathing and washing

12. Kadola Para
Swampy inlet of Negombo Lagoon with low income settlement, poor sanitation

13. Nugape
A stagnant pond with much aquatic vegetation situated in the marsh, solid waste dumping in the vicinity.

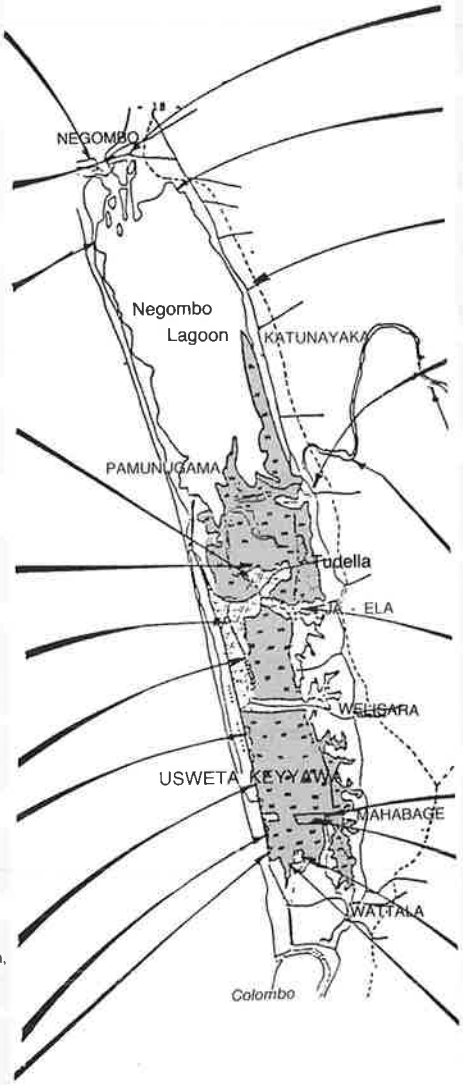
14. Pubudugama
Shallow pool in the marsh in the vicinity of squatter settlement.

16. Farawatte
Canal in the marsh in the vicinity of squatter settlement.

15. Hamilton Canal, Uswetikeiyawa
Canal linking Kelani Ganga and Negombo Lagoon, into which water from the marsh drain by way of canals. Canal used for bathing and washing.

17. Aluthakkare
Canal in the marsh with poor flow, squatter settlement in the vicinity, used for bathing and washing.

18. Awarakotuwa
Stagnant canal water used for bathing and washing, squatter settlement in the vicinity.



7. Rest House
Channel segment of the Negombo Lagoon with good tidal exchange, rapid flow at low lide (comparison with 5, 6, 7, 8, 9, 10)

6. Kadolkele bokka
Open water in the vicinity of low income settlement, poor sanitation (comparison with 5, 7, 8, 9, 11)

5. Airport Garden Hotel
200 m west of the hotel, open water of the lagoon, hotel discharges matured cess pit material, no settlements in the vicinity (Comparison with 6, 7, 8, 9, 10)

4. Dandugam Oya bridge
A site downstream of the discharge point of treated waste from the Katunayake Investment Promotion Zone.

2. Muthuwadiya Ferry
Site upstream of the discharge point of the Katunayake Investment Promotion Zone, treated wastes.

3. Leuwela culvert
A streamlet receiving industrial effluents from the Ekala Industrial Estate.

1. Ja-ela canal
Partially drains the Ekala Industrial Estate, fish kills reported, discharges into the transition zone of the lagoon.

22. Lankamatha
Many excavated pits retaining stagnant water, squatter settlement in the vicinity.

21. Kudagahapiliya
Many excavated pits retaining stagnant water in the vicinity of squatter settlement

20. Balagala 2
Canal with poor flow in the vicinity of squatter settlement, used for bathing and washing.

19. Balagala 1
Canal with poor flow in the vicinity of squatter settlement, used for bathing and washing.

Table A 1 - Minimum andmaximum values recorded for selected water quality indicators.
Nos. 1-22 refer to sampling sites shown in Fig. A1

INDICATORS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
pH at 25C	9.1 5.4	8.4 5.8	7.1 5.5	6.8 5.6	8.1 6.4	8.6 7.1	7.9 7.1	8.2 7.1	9.2 7.8	8.1 7.6	6.8 6.2	6.8 8.1	7.0 8.4	7.1 8.2	7.0 8.3	8.8 8.1	7.1 8.1	8.8 8.1	8.5 8.1	8.5 5.8	7.2 5.8	8.2 5.6
Turbidity (NIU)	30 6.0	28 3.0	15 2.0	36 2.0	24 3.0	13 3.0	20 3.0	15 4.0	15 2.0	25 3.0	25 7.0	12.0 4.0	7.0 3.0	26.0 4.0	8.0 2.0	26.0 2.0	20.0 3.0	33.0 3.0	41.0 10.0	30.0 6.0	7.0 3.0	97.0 9.0
Condctivity (ms/cm)	0.35 0.04	0.22 0.06	<.04	<.26	38.8 11.9	32 31.7	22.2	26.6	30	25.9	0.17	1.08	1.1	0.79	4.0	2.8	1.58	1.38	0.39	0.2	0.2	0.5
Salinity (g/1)	<5.85	<5.85	<5.85	<5.85	40 13.0	35	43	43	37	29	5.85	<5.85	<5.85	<5.85	14.2	<5.85	<5.85	<5.85	<5.85	<5.85	<5.85	<5.85
Total Coliforms per ml		-	-	-	4510 -	6000	11200	8010	5200	3200	2100	11200	18000	6500	23000	26000	25000	6000	24000	15000	20000	15000
Fecal Coliforms per 100 m/l	-	-	-	-	1500 Nil	2510 1500 90	2500 Nil	3500 50	150 73	1200 750	1250 200	6000 600 60	1100 Nil 110	4000 Nil	3000 450 70	8000 1080	4700 5000 200	4000 850	30 1500 20	500 170	3840 500 50	300 3000 40
BOD 3 days at 30C	40 11	22 18	25 15	20 16	35 6	38 10	40 18	24 18	40 7	40 10	50 20	48 11	32 10	53 32	30 8	50 30	40 10	50 10	80 20	32 10	40 12	50 35
Total Phosphat mg/1	0.58 0.18	0.51 0.21	1.14 0.05	0.58 0.22	0.56 0.06	0.24 0.03	0.28 0.01	0.35 0.02	1.98 0.02	1.03 0.04	0.61 0.29	0.70 0.09	0.58 0.11	0.56 0.51	1.02 0.04	1.21 0.6	2.15 0.11	1.78 0.02	1.29 0.09	3.44 0.11	1.23 0.05	0.96 0.02
Zinc m/1	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.12	0.04	<0.01	0.01	<0.01	0.01	0.01	0.15 0.02	0.01	0.11	0.1	0.01	0.02
Chromium m/1	<0.01	<0.01	0.62 0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.1	0.86 0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper mg/1	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.02	0.03	0.02	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.02	0.01	<0.01	<0.01	0.01	0.01
Amonia mg/1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Nitrate Mg/1	0.26 0.12	<0.01	0.41 0.05	0.24	0.10	0.12	0.06	0.11	0.40	0.10	0.05	0.15	0.21 0.04	0.18 0.05	0.11	0.10 0.05	0.12	0.03	0.12	0.10	0.10	0.01
Nitrite mg/1	0.003	0.002	0.001	0.003	0.002	0.001	0.002	0.003	0.001	0.001	0.002	0.001	0.002	0.002	0.001	<0.001	0.002	0.003	0.002	0.001	0.001	0.002
Cadmium mg/1	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.02	0.03	<0.01	0.02	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01
Mercury mg/1	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

GLOSSARY OF TERMS

Aquaculture	:	Production of aquatic plants and animals which involves intervention at some stage in their life cycle other than at harvest, and where ownership of the stock is legally ensured.
Beach rock	:	A consolidation of beach sand by secondary deposition of calcium carbonate at about the level of the water table.
Benthos	:	Plants and animals that are associated with the bottom of water bodies.
Brackish	:	Mixture of seawater and freshwater.
Carnivore	:	An animal that feeds upon other animals.
Crustaceans	:	Backboneless aquatic animals with an outer skeleton such as shrimps and crabs
Current	:	A flow of water within and relative to the larger body of water through which it flows.
Detritus	:	Decaying parts of plants and animals.Disease vectorAn animal that serves in transmitting a pathogen among other animals.
Ecological Linkage	:	Processes, living and non-living that connect ecological units (ecosystems) e.g. tidal currents link an estuarine wetland to the sea.
Ecosystem	:	An interactive and integrated unit formed by the combination of the physiochemical (non-living) environment and its living community (microorganisms, plants and animals).
Endemic	:	Plant and animal species which at present occur only in Sri Lanka.
Epiphytes	:	Plants and animals that exist attached to the surface of other plants such as seagrasses.
Eustatic	:	Upward and downward movement of sea level world-wide.
Eutrophication	:	Addition of nutrients to an aquatic system which results in excessive production of plants eventually resulting in a breakdown of the plant-animal relationship.
Funa	:	Animals
Flandrian Transgression	:	The oscillating rise of sea level beginning about 18,000 years ago which has been interpreted through radiocarbon dating.
Flood buffer	:	The ability of an area to receive and retain water in a manner that prevents flooding in adjoining areas.
Flora	:	Plants
Herbivore	:	An animal that feeds on plants.
Holocene (Holocene epoch)	:	The past 10,000 years during which the existing geomorphological systems became established.

Hydrology	:	The science that treats of water
Impoundment	:	To confine within a boundary structure such as a dyke.
Intertidal	:	An area that is submerged during high tide and exposed at low tide.
Laterite	:	A reddish weathering product of many rock types in wet tropical regions.
Mangroves	:	Salt tolerant, woody, seed-bearing plants which occur in association with brackishwater. Although mangroves occur on saline soils they have the usual plant requirements of freshwater, nutrients and oxygen.
Nutrients	:	The simple chemical substances required for plant growth released from soil and decaying parts of plants and animals.
Pathogens	:	Disease causing organisms.
Peat	:	An accumulation of partially decomposed plant material
Pen	:	An aquaculture device involving an enclosure made of net or other permeable material.
Plankton	:	Tiny plants (phytoplankton) and animals (zooplankton) that occur in water and are transported by currents.
Pleistocene	:	The first 500,000 years of the past 1 million years constituting the Quartenary period.
Pre-Cambrian	:	Rock older than 570 million years.yriteIron sulphide an important source of sulphur.
Pyrite	:	Iron sulphide (FeS_2). an important source of sulphur.
Recruitment (tidal)	:	Transport of early, floating stages of fish and crustaceans into the estuary from the sea by tidal currents. These floating stages grow to become the fishable stock.
Seagrasses	:	Rooted, seed-bearing, salt tolerant, plants that occur as under-water meadows and provide prime living conditions for a wide range of organisms.stuaryA semi-enclosed coastal body of water, which has a free connection with the sea, and within which sea water is diluted by freshwater derived from land drainage.
Shoaling	:	Formation of shallow areas by settlement of silt and sand.
Soil, potentially acid sulphate	:	Soils with a high pyrite content which on exposure to air, oxidizes forming sulphuric acid.
Sustainable Development	:	A balance struck between the demands placed upon a natural resource system, the inputs committed by a society and the continuing ability of the natural resource system to support the demands.