REGIONAL SEAS

UNITED NATIONS ENVIRONMENT PROGRAMME

Environmental problems of the marine and coastal area of Sri Lanka: National Report

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PREFACE

The Regional Seas Programme was initiated by UNEP in 1974. Since then the Governing Council of UNEP has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of regional action plans.

The Regional Seas Programme at present includes ten regions[1/] and has over 120 coastal States participating in it. It is conceived as an action-oriented programme having concern not only for the consequences but also for the causes of environmental degradation and encompassing a comprehensive approach to controlling environmental problems through the management of marine and coastal areas. Each regional action plan is formulated according to the needs of the region as perceived by the Governments concerned. It is designed to link assessment of the quality of the marine environment and the causes of its deterioration with activities for the management and development of the marine and coastal environment. The action plans promote the parallel development of regional legal agreements and of action-oriented programme activities[2/].

In May 1982 the UNEP Governing Council adopted decision 10/20 requesting the Executive Director of UNEP "to enter into consultations with the concerned States of the South Asia Co-operative Environment Programme (SACEP) to ascertain their views regarding the conduct of a regional seas programme in the South Asian Seas".

In response to that request the Executive Director appointed a high level consultant to undertake a mission to the coastal States of SACEP in October/November 1982 and February 1983. The report of the consultant on his mission was transmitted to the Governments of the South Asian Seas region in May 1983, and the recommendations of the Executive Director were submitted to the Governing Council at its eleventh session.

By decision 11/7 of 24 May 1983, the UNEP Governing Council noted "the consultations carried out in accordance with Council decision 10/20 of 31 May 1982" and requested "the Executive Director to designate the South Asian Seas as a region to be included in the regional seas programme, in close collaboration with the South Asia Co-operative Environment Programme and Governments in the region, and to assist in the formulation of a plan of action for the environmental protection of the South Asian Seas".

1/ Mediterranean Region, Kuwait Action Plan Region, West and Central African Region, Wider Caribbean Region, East Asian Seas Region, South-East Pacific Region, South Pacific Region, Red Sea and Gulf of Aden Region, Eastern African Region and South Asian Seas Region.

2/ UNEP: Achievements and planned development of UNEP's Regional Seas Programme and comparable programmes sponsored by other bodies: UNEP Regional Seas Reports and Studies No. 1. UNEP, 1982.

As a first follow-up activity to decision 11/7 of the Governing Council, the Executive Director convened, in co-operation with the South Asia Co-operative Environment Programme (SACEP), a meeting of national focal points of the States of the region in order to seek their views on how to proceed in developing a comprehensive action plan for the protection and management of the marine and coastal environment of the South Asian Seas region (Bangkok, Thailand, 19-21 March 1984).

The meeting discussed the steps leading to the adoption of an action plan and reached a consensus on the items to be considered for further development of the action plan[3/].

The meeting recommended that the Governments, with the assistance of UNEP and other organizations as appropriate, should initiate the preparation of country reports reviewing their:

- national environmental problems defined as priority areas of regional concern;

- activities which may usefully be carried out under the action plan to resolve or mitigate these problems; and

- national institutional and manpower resources which are, or may be, involved in dealing with these problems, including the identification of the need to strengthen their capabilities.

It was also recommended that UNEP prepare in cooperation with SACEP, and other organizations as appropriate:

- a draft overview report, based on the country reports, reviewing the environmental problems of the region defined as priority areas;

- a document addressing the essential legislative aspects relevant to the action plan; and

- a draft action plan reflecting the conclusions of the country and regional reports.

The present document is the country report on environmental problems in Sri Lanka prepared by experts designated by the Government of Sri Lanka. The assistance of a consultant, A.H.V. Sarma, was provided to the Government of Sri Lanka to facilitate the preparation of this report. The authors' contributions are gratefully acknowledged.

3/ Report of the meeting of national focal points on the development of an action plan for the protection and management of the South Asian Seas region, Bangkok, 19-21 March 1984 (UNEP/WG.105/5).

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INTRODUCTION

Sri Lanka lies off the Southern tip of peninsular India between 5°55' and 9°51 North and 79°41' and 81°54' East. The island covers an area of 640,000 sq km and is separated from the Indian sub-continent by a narrow strip of sea, which at its narrowest is about 40 km wide. The Bay of Bengal lies to the North with no land mass right down to the South Pole. The island is 435 km long with a maximum width of 225 km. The central part of the Southern half of the island is mountainous with several isolated hills arising abruptly from the Eastern plain; the rest of the country is flat and is known as the coastal plain.

The island has a coastline of 1700 km, of which nearly 9/10 consists of sandy beaches. In the country's coastal areas are located a multiplicity of human activities vital to the life of the nation. The capital city as well as most of the major urban centres are located along the coastline.

One of the features of the coastal environment is the presence of extensive fresh and saltwater lagoons along both Eastern and Western coasts, at the Northern extremity of the island and to a limited extent on the Southern coast. Along the greater part of the South-western and Eastern shoreline, beaches are located between rocky headlands and many of the beaches are backed by lagoons and estuarine deltas, and marshes indicating progradation. High cliff formations are rare. Coral reefs are found scattered along the Northern, South-western and South-eastern coasts. A considerable part of the South coast is fringed by a shallow reef of sedimentary sandstone. Along the Northwestern coast, deposits of sedimentary limestone of miocene origin is found.

A variety of coastal resources (finfish, shellfish and a variety of other invertebrate fauna, coastal vegetation including seaweeds and coastal minerals, beaches etc.) provide the resource base for a number of economic activities such as fisheries, mining, coastal recreation and tourism, the construction industry and coconut-based industries.

The most prominent feature of the marine environment of Sri Lanka is the continental shelf which extends for a distance varying from 8 to 40 km. and at an average depth of 65 m. below sealevel. The outer edge of the shelf is a comparatively steep shelf (the continental slope) falling to 1,800 m or more, and taking 20 km to reach the general level of the Indian Ocean. Notched into this cliff are several submarine valleys, where deep water occurs within a few kilometers of the coast near Tricomalee, Kumana, Matara and Panadura (Cooray 1967).

The continental shelf is narrow around the Southern part of the island, but towards the North it widens out and merges with the platform that surrounds India. On this Northern area of the shelf there are three elevated areas, viz;

- Pedro Bank, stretching northwards from Jaffna Peninsula to the coast of India;

- Pearl Banks (off the coast of Mannar) and Adam's Bridge - a narrow and long sand bank between Mannar and the Indian coast which makes the Palk Straits impassable for ships; and

- Wadge bank around the Southern extremity of India.

The resources presently exploited in the marine waters are fishery resources, especially tuna, but there is no commercial exploitation of marine minerals at present. These waters are used for maritime traffic entering Sri Lankan ports, as well as for traffic around the South Asian Region.

Serious concern for environmental problems is a relatively recent phenomenon in Sri Lanka. For a long time, there has been little awareness of the close relationship between development and environment; much of the already existing legislation could not be effectively enforced because of socio-economic considerations. The lack of environmental considerations in Sri Lanka's economic development planning in the past is clearly manifested in the problems emerging today in the coastal and marine environment.

Because of population growth, accelerated industrial and commercial development and rapid urbanisation, the coastal and marine ecosystems and their resource base has been greatly affected. Over-exploitation of resources, both renewable and nonrenewable, and the degradation of the coastal and marine waters are the most urgent problems the country is facing today.

With the creation of specialised agencies and environmental legislation, a more positive approach has been taken in recent times towards integrating environmental dimensions in the development planning process at the national level. Important recent legislation pertaining to the protection and management of the coastal and marine environment include the National Environmental Act, Coast Conservation Act, National Aquatic Resources, Research and Development Act, Amendments to the Forest Conservation Act, etc.

The recognition of the need for an integrated environmental policy in the country is also reflected in the work already being undertaken for the preparation of a National Conservation Strategy, a National Science Policy and a National Energy Policy. The role of regional co-operation in environmental management especially that of the coastal and marine environment has also been recognized. This is clearly indicated in Sri Lanka's participation in the South Asia Co-operative Environment Programme and the South Asian Seas Regional Programme.

This report reviewing the status of the coastal and marine environment in Sri Lanka, together with similar reports from other countries in the South Asian Seas Region will provide an overview of the situation regarding this environment in the region for the preparation of an action plan directed towards the protection and management of the Seas of South Asia.

THE PHYSICAL ENVIRONMENT

Climate and seasons

Separated from the continental land mass of India by relatively shallow seas, and situated in the equatorial belt, Sri Lanka has a mean annual temperature which shows little variation over the island, and the annual thermic amplitude is below 5°C at any given altitude. The temperature is around 27°C at sea level, 20°C at 1200m and 15°C at 1800m (Gaussen et al 1968). The humidity is generally high, and while there are no clearcut seasons, the island is subject to rainy and dry periods due to the effects of

two monsoons, the South-west (May to October) and the North-east (December - March). These seasonal airflows which reverse direction are related to regional atmospheric changes associated with the heating and cooling of the Indo-Asian land mass and adjoining oceans (Swan, 1981). The general climatic conditions of the equatorial belt are characterized by heavy rainfall presenting two maxima according to latitudinal zonation. In Sri Lanka, however, the S.W. monsoon and high frequencies of cyclonic depressions aided by the insularity, and geological reliefs in the form of a central backbone of high ridges and plains, results in a variety of climatic regimes based primarily on rainfall. Three principal types are:

(a) The equatorial regime - showing two maxima of annual rainfall;

(b) Sub-equatorial regime - derived by the diminution of one or both of the rainfall maxima; and

(c) Tropical regime - with only one marked rainfall during the November-January months characteristic of the tropical inverted type.

All types of transitions exist between these three principal types (Gaussen et al 1968). On the basis of rainfall distribution, the island can be divided into two distinct areas - the wet and dry zones. The wet zone has two rainy seasons, an annual average rainfall of 242 cm and lies along the South-west coast of the island. The rest of the island consists of the dry zone with an average annual rainfall of 145cm and only one rainy season from October to March (Arumugam, 1969).

Wind patterns and cyclonic disturbances

Sri Lanka experiences two monsoons, namely the North-east (December to early March) and South-west (late May to October). Winds are usually of less than 50km/hr velocity and gale force winds of significant duration are rare, although early SW monsoon squalls have gusts with velocities between 80 - 100 km/hr. Inter-monsoonal periods are characterized by weak variable breezes, landwards by day and seawards by night (Swan, 1981). Throughout the season, winds intensify and often change direction during the afternoon. By early March the trade winds (locally the NE monsoon) cease to blow over the island. The winds of the Northern Inter-tropical Convergence Zone (ITCZ) now operate from South to North and typical equatorial convergence storms are experienced all over the country usually during late afternoon. During May, the ITCZ passes to the North towards Southern India and rainfall is received all over the country, but concentrated over the South-western reliefs. In June, when ITCZ is over Northern India, the SW monsoon is at peak force, and the South-western quarter of the island and the windward slopes receive all the rain, while the Northern and Eastern parts only get occasional rains from convection storms formed during the periods of calm called the 'monsoon breaks' (Gaussen et al 1968). Although both the Bay of Bengal and the Arabian Sea are areas of cyclogenesis, the majority of tropical convection storms with winds in excess of 120km/hr follow paths North of the island. However, once every ten or fifteen years, cyclones come closer and cross over the island, apparently because of the persistence of the Northern ITCZ close to the island in November-December and March-April. Considerable damage along coastal areas, such as that wrought upon the Northern and Eastern coasts by the cyclones of December 1964 and November 1978, are ample evidence of the violence of these storms (Swan, 1981 : Gaussen et al 1968). The fringing coral reefs along the coastline are particularly damaged by such cyclones, as shown by the large quantities of coral rubble washed ashore. Normally, ITCZ retreats to the South

during December to February, with the re-establishment of the trade winds. The persistent disturbances coming in from the East often make January the rainiest month along the South-east coast of the island (Gaussen et al 1968). The Sri Lanka navy maintains a cyclone early-warning system in Trincomalee, utilizing computer-enhanced radar telemetry, for minimizing loss of life and property in the event of a major cyclone off the East coast.

Waves, tides and ocean current regimes

Much of the swell that affects Sri Lanka originates in the South Indian Ocean (40^{o} - 50^{o}S), under the influence of westerly depressions and storms. This moves northwards and is felt most along the coasts of the Southern half of the island. Most large waves have a southerly component, but they rarely reach a height of over two metres. The highest waves are during the SW monsoon season, but the effective fetch is only about 800km between the Maldive Island chain and Sri Lanka. During the NE monsoon, the northerly winds blow over short stretches of water from the North, and even when blowing across the bay of Bengal, are not steady enough to generate large waves. By and large, the energy of the waves are relatively low during this period as well as during the inter-monsoonal periods (Swan, 1981).

Several types of currents are found around Sri Lanka. This is because many currents from the Bay of Bengal and the Arabian Sea as well as the equatorial region meet in this area and are affected by the monsoons. The strongest currents are felt along the Southern coastline. Coastal currents over the continental shelf are parallel to the coastline and are stronger off the East coast than off the West coast. In addition to the distinctive patterns of currents in the Bay of Bengal and the Arabian Sea, the equatorial oceanic zone is characterized by easterly and westerly flows (Figure 1 from Swan, 1981). These massive water exchanges result in current velocities of about 1 metre per second or more between October and January around the Little Basses Reef off the Southern coast of Sri Lanka. Strong currents (2.5 - 3.0m/sec) are also experienced, especially during the monsoons in the waters between Sri Lanka and India. The coastal currents are complicated by the interaction of shelf topography, contour of coastline, water depth, wind intensity and direction as well as wave incidence and tidal influences (Swan, 1981).

The period between tides is approximately 12 hours and is thus semi-diurnal. The seas of Sri Lanka are micro-tidal with a tidal range of within 75 cm during spring tide and 25 cm at neap tide. The tidal range is higher around Colombo and is least around Delft and Trincomalee. Weather conditions can give rise to monthly tidal level variations. Tidal waves move southwards along the West coast of India, towards Sri Lanka twice a day so that the West coast of the island experiences high tide synchronously. The tidal crest which arrives at Galle in about 12 minutes time then moves anti-clockwise heading eastwards and northwards reaching the East coast port of Trincomalee and the North-eastern coast some six hours later (Swan, 1981).

Soils, sands and sediment

The beach sands of Sri Lanka vary in their minerological composition, specific gravity, texture and shape. They are predominently quartose, being derived from quartz containing silica rocks, and are considerably resistent to weathering. Natural concentrates of weathering resistent heavy minerals such

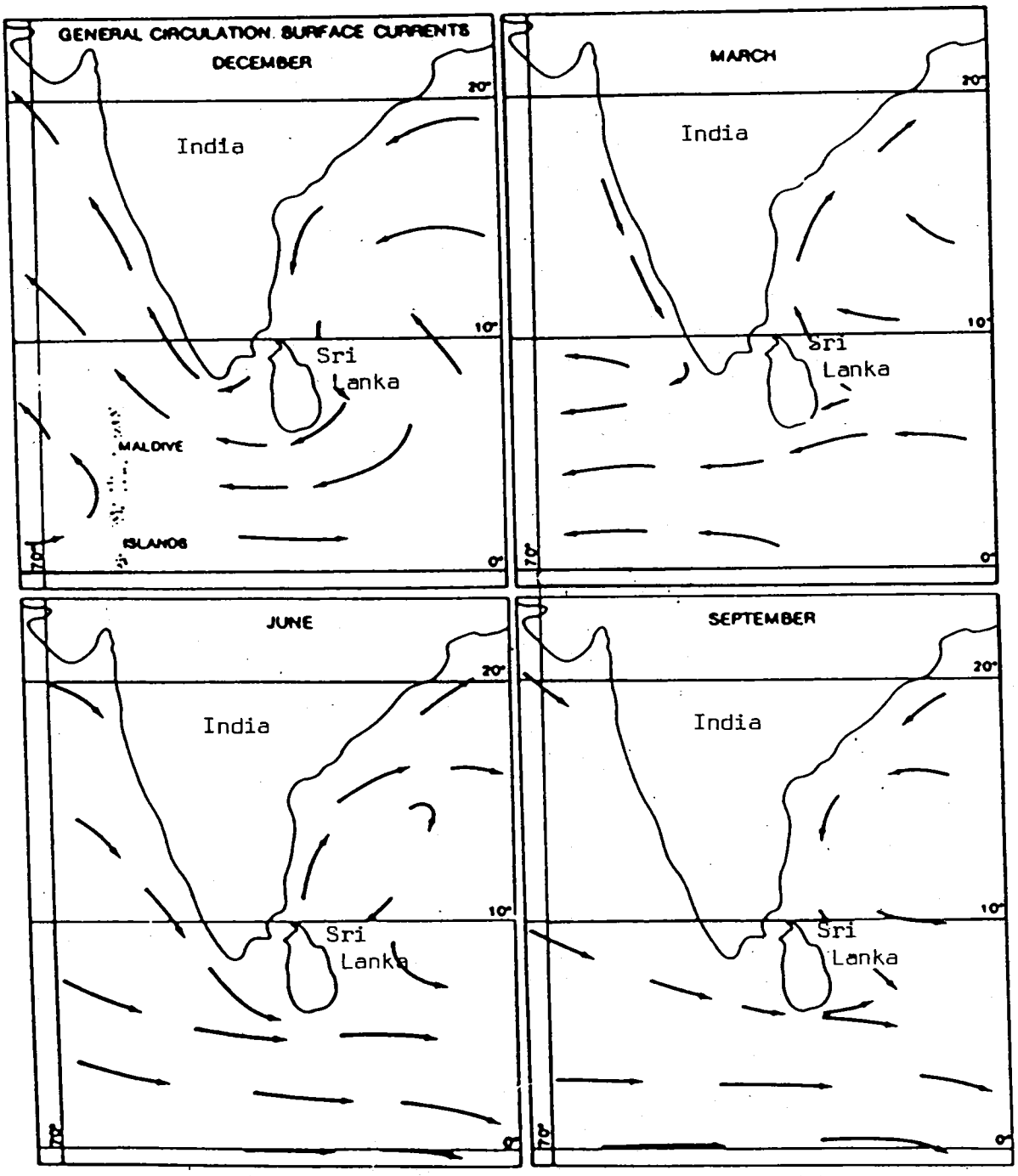

Figure I: Surface currents around Sri Lanka

(Source: H.M. Hydrographic Office, London)

as zircon, monazite, rutile, ilmenite, spinel and garnet are found everywhere along the entire coast, but extensive deposits that could have commercial importance are localised. These minerals are all common as accessories in the crystalline rocks. Feldspars and micas are also found, generally in close proximity to river outlets and in sheltered localities, where they are deposited, but being more weatherable, are less common. Least persistent minerals such as pyroxenes and hornblends are rarely encountered.

Textural differences are observable along the shore profile. The zone of maximum particle size and of widest size range (i.e. poorest sorting) is the breaker zone. Size usually diminishes and sorting improves shorewards towards the upper beach zone, to the berm and dunes beyond. Seawards of the breaker zone, size decreases and sorting is optimal (Swan 1979). They also tend to be coarser and poorly sorted at increasing depths.

At present, the major source of sand and sediment supply to the coastal areas is fundamentally the material which is brought down from land towards the coast by eroding forces of rain, storm-water run-off, streams, rivulets and rivers. The sand supply to the Eastern and Western littoral between Hambantota and Point Pedro and, between Hambantota and Puttalam was estimated to average 100,000 and 250,000 m^3 per year respectively. More information on relationships between rainfall incidence, vegetation, land use lithology, etc., would be required to make more accurate estimates.

Not all rivers deliver their full load to the sea. Many cross wide flood plains in their lower reaches where part of the load is deposited, or enter lagoons which act as traps for coarser materials including sand. The Mahaweli Ganga, for example, discharges its sediment into Koddiyar Bay which has a submarine canyon at the river mouth that collects most of the sand load, and only some silt and clay are carried in suspension to other parts of the Bay. Most of the larger rivers that make substantial contributions of sand to the littoral zone are located between Chilaw and Kumana along the South-west coast.

Shoreline geomorphology

Beaches

Over three fourths of the coastline is beach-fringed, the principal determinants of their characteristics being wave energy, supply of beach material, contour and lithology of the coastline, and nature of coastal and sub-marine landforms. Most of the island's beaches are barriers, backed by lagoons, swamps and ill-drained terrains, and are sometimes contained between headlands or river outfalls. Some barriers are islands free at both ends, e.g. Karativu Island. Cheniers characteristic of shorelines destroyed by erosion are found at Akurala and East of Weligama.

Most of the beaches in the island are sandy although beaches of pebble, rubble and boulders sometimes occur along restricted stretches, e.g. Galle Buck. Pocket beaches formed by deposition of sand in small embayments of coastal bedrock stretches are also found, e.g. between Dondra and Tangalle.

Owing to the small tidal range and relatively low wave energy, the beaches in Sri Lanka are generally narrow. The beach deposits increase in width from the South-western corner of the island in both directions attaining maximum width on the West coast near Chilaw and on the East coast near Kalkudah. The berm which is a reservoir of sand which supports the coastline against wave attack is variable around the island depending on the effective-

ness of constructive waves; where the waves deliver large quantities of sand the beach develops a negative gradient landwards. The width of the seaward sloping swash zone which is constantly washed by waves is also variable depending on the presence of a berm and energy of the waves. Swash zone gradients range from 2 - 6°; steep swash zones are characteristic of beaches undergoing accretion and also indicates degrading berms (Swan, 1979). While the swash zone and berm usually seem parallel to one another, at times the boundary between them may be thrown into seaward facing concave cusps. Beach cusps may be observed during the monsoon and inter-monsoon seasons especially where the swash zone is developing at the expense of the berm.

Absence of prominent sand dunes along the South-west coast has been attributed to the poor sand delivery and the lack of bedrock relief conducive to the development of stable beaches.

Rocky shorelines

Rocky shorelines of bedrock-related in situ materials comprise only a small proportion of the coastline. They occur along the Northern margin of the Jaffna Peninsula, the coastline opposite Karativu Island and Portugal Bay, Beruwela, between Balapitiya and Ambalangoda, around Weligama Bay, between Dondra and Tangalle, Trincomalee and at several headlands interspersed between beaches. Most rocky shores comprise of crystalline bedrock, but some are characterized by shores that are low-lying and relatively flat, and are associated either with limestone or coral deposits quite similar to bedrock, as at Akurala.

Sand bars and spits

Sand bars and sand spits are common at the mouth of rivers, lagoons and bays, and usually grow in the direction of predominant drift. Along the South-west coast, from Matara to Colombo, sand bars enclose lagoons, which are typical drowned valley systems, characteristic of a submerged coastline. In contrast, the sector from Colombo northwards is characteristic of a stationary emergent shoreline and contains several narrow spits up to 25 miles in length, connected with the land at the Southern end and enclosing wide lagoons which run parallel to the spit.

Sand dunes

Sand dunes formed by accumulation of wind-blown sand are found along most of the shoreline except in the South-west sector. They are widely developed along the North-east coast between Mullaitivu and Point Pedro; reaching a maximum width of two meters just South of Point Pedro. Extensive sand dunes are also found between Elephant Pass and Chavakachcheri across the Mannar Island and Pooneyn Peninsula, on the West coast between Battulu Oya and Kalpitiya Peninsula, and on the Southeast coast from Kirinda to Sangamakanda Point.

Older, highly weathered dunes, sometimes reddened due to a coating of iron oxide, are usually fixed by dense monsoon scrub forest. The less weathered younger dunes are more active.

Sandstone deposits

A band of corse to fine sandstone which is exposed at low water along the toe of the beach slope is characteristic of the Western coast. The rock is

composed of quartz grains and shell fragments with a calcareous cement and frequently encloses paralled bands of ilmenite and garnet grains (Coates 1935).

These sandstone reefs often occur on the edge of lagoons enclosed by sand spits; in some places widening of the spit by accumulation of sand covering lagoons, tends to conceal their original relations. One of the most conspicuous sandstone reefs is the Pamunugama reef, which fringes the shore almost the whole way from the mouth of the Kelani River to the headland off Negombo and runs out to sea for a short distance beyond it. On the East coast between Kalmunai and Batticaloa and at Mullaitivu, a sandstone bed exists a short distance inland and does not extend to the present shoreline.

Coral reefs and deposits

Coral reefs of late Holocene origin occur along sections of the South-western coastline where the beaches are usually poorly developed and where large rivers do not enter, e.g. between Ambalangoda and Matara. Coral reefs are also found along the Southern and Eastern coasts, near headlands such as Dondra, Tangalle, Kalkudah, Elephant Point, Foul Point, and between Nilaveli and Mullaitivu. On the Western coast they are found North of the Kalpitiya Peninsula in the Gulf of Mannar. They also fringe the Northern margin of the Jaffna Peninsula.

Coral reefs of Sri Lanka usually grow in patches and discrete colonies forming small platforms. Fringing reefs adjoining the shore and incipient fringing reefs (apron reefs) are also common, while lagoon reefs and barrier type reefs are rare, and atolls are not found. Over a hundred species of corals have been reported of which about 65 species are hermatypic.

(see further in document for more detail)

Lagoons, brackish-water lakes and wetlands

Sri Lanka's coastline of 1,770 km is broken by extensive lagoons, bays, brackish-water lakes and wetlands. These are formed by (a) inunduation of flood-plains or river courses, such as in Bentota, Hikkaduwa, Dedduwa, Valaichchenai etc., (b) inundation and barrier formation as in Jaffna, Batticaloa, Hambantota and Tambalagam; (c) beach formation as in Puttalam, Negombo, Mundel and Kalutara; and (d) destruction of beach as in Beruwela. The freshwater bodies include about 94,800 ha. of major and medium sized reservoirs with a perennial supply of water and 42,800 ha. of minor tanks and villi with a seasonal supply of water. An additional 18,000 ha of perennial water bodies will be added under the Mahaweli Development Project. The brackish-water area comprises about 80,000 ha of estuaries and large deep lagoons and about 40,000 ha of shallow lagoons, tidal flats and mangrove swamps.

Of the coastal lagoons, the smaller ones, especially, those along the Southwestern, Southern and South-eastern regions are mostly permanently enclosed water bodies. Some may, however, be connected with the sea for short durations. In some cases such as Batticaloa, Kokkilai and Nayaru lagoons on the East coast, sandbar formation occurs across the mouth during the dry season. Some of the larger lagoons, such as Puttalam and Negombo on the West coast and Jaffna in the North are perennially connected to the sea. Tidal flats and mangrove areas exist associated with Mannar and Kalpitiya lagoons.

Salinities of these lagoons vary to a great extent from about 15-40 ppt, depending on the area where they are situated and such factors as rainfall, evaporation and connection to the sea. In the South-western region where rainfall is high and evenly distributed throughout the year, discharge of water is high and salinity in the lagoon is comparatively low. In those regions where rainfall is low and river discharge is seasonal, salinities are relatively high.

Saltflats are found along the Northern and North-western coasts of Sri Lanka. Few such flats are also found in the South-eastern region. Many saltflats in the dry zone have been converted to saltpans to produce salt. Physical features of major lagoons in Sri Lanka are given in Annex I.

Continental margin and seabed characteristics

Sri Lanka has a fairly consistant continental shelf with an area of about 28,000 km. It is narrowest in the South between Matara and Dondra (6 km), moderately wide off the West coast North of Galle and near Tangalle-Pillinawa Point (20-35 km) and relatively narrow off most of the East coast. The shelf widens significantly North of Kalpitiya peninsula on the North-west and in the Palk Strait where it is contiguous with that of the Indian sub-continent.

A prominent feature of the shelf is a wide depression paralleling the coast at an average distance of 20 km (Sommerville, 1908). It is about 50-75 metres below sea level and lies about 10 - 18 metres below adjoining portions of the shelf. This is believed to be the result of isostatic changes that take place in response to continental separation and drift (Swan, 1981). The positive relief features of the shelf include islets, tors and large rock formations, reefs and coral patches, the most prominent feature being the Great and Little Basses Ridge off the South-east coast.

The continental slope in Sri Lanka is relatively steep averaging about 10^{o} and in one place near the Trincomalee Canyon, a slope of $43^{o}32'$ has been recorded, one of the steepest known (Stewart et al 1964). Another feature of the slopes is the slumping reported in the slope bordering the Gulf of Mannar and the West coast of the island. The Colombo Slump which occurs at depths of 1500 - 2600 m is about 35 km long, 50 - 60 km wide and about 500 - 600 metres thick (Swan 1981).

The continental rise extending beyond the shelf is bounded on the East by the Bay of Bengal with its complex meandering and braided net of valleys (Curray & Moore 1971) and the Ninety East ridge, and on the West by the Laccadive-Chagos Ridge, Carlsberg Ridge and the Arabian Abyssal Plains. The Southern extremity of the continental rise is bounded by the Ceylon Abyssal Plain and Central Indian Ocean Basin. The continental rise which extends to approximately $2^{o}S$ latitude is underlain by a substantial thickness of sedimentary rock ranging upto 4.5 - 5 km.

Drilling in the Palk Bay area has shown that the shelf is underlain by charnockitic gneisses and granites, the predominent rocks of the island. Overlying these rocks are sedimentary limestones, calcareous claystones and sandstones. The sediments covering the shelf are predominately quartzose sand, biogenic material, fossiliferous shells, coral fragments and mud. Sand increases North-west both off the East and the West coasts while mudbanks are found off Kochchikade, Chilaw, Kalpitiya, Pedro bank and Mullativu.

COASTAL/MARINE LIVING/NON-LIVING RESOURCES AND AREAS OF SPECIAL ECOLOGICAL INTEREST: THEIR STATUS, TRENDS IN THEIR UTILIZATION AND SOCIO-ECONOMIC IMPORTANCE

Offshore oil and gas

Exploration for offshore oil and gas has been given priority in the development strategy of the country and 13 off-shore concessionery blocks have been designated for exploratory activities on a production-sharing basis, of which eleven are on the continental shelf and the other two are in deeper waters. Based on seismic and other geological data collected during exploratory surveys, 4 off-shore wells have so far been drilled in Park Bay and the Gulf of Mannar.

Although these wells did not strike oil or gas, information gathered has been useful in reconstructing the tectonic and geological history of the area, and exploratory work is being continued. A seismic survey from Colombo to Mannar has been completed and interpretation of data is now in progress.

Offshore minerals

Major offshore minerals that are presently being exploited in the country are placers (ilmenite, rutile, zircon, monozite, garnet and sillimanite). Heavy mineral placers, usually called "black sand", occur in some localities along the Western and Eastern coast, but only the deposits at Kudremalai Point, Beruwela, Pulmuddai and Nayaru are of sufficient concentration for economic exploitation.

Deposits at Beruwela were mined until recently which was stopped only because of the coastal erosion hazard in that area. Deposits at Pulmuddai, estimated at over 4 million tons are mined by the Mineral Sands Corporation. The Corporation mines about 40,000 tons ilmenite, 10,000 tons of rutile, 5,000 tons of zircon, and about 30 tons of monozite annually. A recent survey has shown that 0.95 to 1.34 million metric tons of these minerals may occur in the offshore areas (Mayer, 1982).

Other offshore minerals reported in the vicinity of Sri Lanka are Barium nodules, glauconite and phosphorates. Concentrations containing over 75% Barium sulphate have been collected off Colombo at depths of 1235 metres. Glauconite is found characteristically as a continuent of green mud and sand along the Western, South-western and North-western coasts at depths ranging from 15 - 1300 metres. Phosphorite nodules have been reported off the South-east coast.

Information on deposits of economically useful offshore minerals in Sri Lanka is very limited, however, exploitation of these minerals will need an environmental study to minimize the damage which may be caused to the marine environment.

Construction materials

Principal construction materials found in the offshore waters are sedimentary limestone, coral and sand. The sedimentary limestone which is primarily used in the cement industry is most extensive in the Jaffna penin-

sula and extend along the Northwest coastal belt of the island as far as Puttalam. Two cement factories producing nearly 800,000 tons of cement per annum, are operating in these areas using Miocene limestone as raw materials. Deposits estimated at around 40 million tons of limestone are known, but in terms of output, mining for limestone is a large industry and strict conservation measures should be taken regarding its exploitation. Coral is another source of lime and the best known coral beds lie along the South-western coastal stretch from Ambalangoda to Matara.

The demand for lime is ever increasing in view of the Government policy of expanding the construction industry. At present, it is estimated that about 18,000 tons of coral-based lime is produced annually by about 20,000 - 22,000 people engaged in the mining/burning industry.

Removal of coral from areas where natural disequilibrium exits, results in coastal erosion (Swan 1974). Adverse consequences of coral mining are greatest along the South-west and South-east coasts (Salm 1979). Factors attributed to the continued removal of coral in these areas include attractive financial returns, tradition and problems in law enforcement (Amarasinghe and de Alwis, 1980).

Probably the most important commodity from a standpoint of tonnage mined in Sri Lanka is sand. The demand for sand for building and construction has increased rapidly over recent decades.

Sand is obtained by mining at river outfalls such as Kelani, Kaluganga and Mavi Oya, as well as from beaches. Uncontrolled removal of sand from either of these sources could cause damage to the coast as exemplified by sand deficiencies and beach problems North of Colombo, as it affects beach replenishment in those areas where the sand would have been carried and deposited by natural processes. Extraction of sand from the beach maintenance system creates or intensifies coastal erosion risks and should be effectively prevented.

Other coastal resources

Sea salt

In Sri Lanka salt is extracted from seawater by solar evaporation. Salt producing pans exist at Elephant Pass, Murunchative, Kallundai, Irupalai, Pulari, Mannar in the Northern and Western regions and at Hambantota Mahalewage, Palatapana and Bundala in the Southern region.

The state owned National Salt Corporation produces around 130,000 tons of salt per annum, which is quite sufficient to supply the annual requirement of salt in Sri Lanka. The Corporation also produce small quantities of refined epsom, iodised salt and gypsom. Plans are also underway for the construction of a plant to convert gypsom to Plaster of Paris and chalk, and for the manufacture of PVC.

Sand dunes

Dune sands are found along 22 percent of the coastline of Sri Lanka (Swan 1979). Well-developed dunes are mostly found along the North-east, West and South-east coasts. Less conspicuous, highly weathered dunes are found in the North and North-west.

Most coastal dunes vary in size and age and include isolated, undulating sand platforms, transverse, transgressive and hill top types and are aligned in the direction of locally dominant winds. (Swan, 1979). Dune-forming sands are mainly quartzose (Cooray, 1963). They include traces of heavy minerals, including rutile, zircon, hornblende, garnet, hypersthene, sillimanite and monazite. The dune around Hambantota is highly granetiferrous with applicable amount of spinel and corrundum and could be used as an abrasive material.

Strict conservation measures should be taken to prevent overgrazing by livestock and uncontrolled clearing of coastal vegetation that could cause migration of sands and dune erosion by wave overwash.

Seaweeds

174 species of seaweeds belonging to 35 families and 78 genera have so far been recorded from Sri Lanka. Of these species 47 are green algae (Chlorophyceae), 42 brown algae (Phaeophyceae) and the other 85 red algae (Rhodophyceae). Sargassum is the most common seaweed in Sri Lanka, extensive beds of which are found in Jaffna, Palk Bay, the Gulf of Mannar, Pearl Banks off Silavathurei and the South-west coast of Sri Lanka, extending from Ambalangoda to Galle. Most of the red algae occur in the South and West coasts of Sri Lanka where the coast is rocky and fringed with coral reefs.

Green algae are most abundant in the Northern coast, which is also rich in brown algae especially Sargassum. The red alga Gracilaria verrucosa is most abundant on the East coast, particularly in the Trincomalee area. Twenty species of Sargassum have been reported in Sri Lanka. Of these S.cervicone, S.tenerrimum and S. ciinereum are the most common and occur abundantly.

The most abundant red seaweed occuring in Sri Lanka waters is Gracilaria. The most common species include G. edulis (G.lichenoides), G. verrucosa, G.crassa and G.corticata.

Ulva is the most abundant and fairly widely distributed green alga in Sri Lanka. Several species have been recorded of these, U. fasciata, U.lactuca, and U.reticulata have been reported to be present in large quantities. Enterocarpha, Chaetocorpha, Canlerpa and Palimeda also occur commonly along Sri Lanka coasts. Commercial extraction of agar (from red algae) and alginic acid (from brown algae) has been carried out by various institutions in Sri Lanka. Antibiotic substances occuring in seaweeds also have been investigated.

At present, G. verrucosa is collected in large quantities from Trincomalee area, cleaned, dried and exported to countries including Japan. It is estimated that about 250 tons of G. verrucosa could be collected annually from Trincomalee area and 120 tons of S. cervicone from the coast extending from Beruwala to Ambalangoda.

As the presently available natural seaweed resources are limited the culture of seaweeds has to be practised to sustain a viable commercial operation. Research has been undertaken to investigate the culture methods and growth rates of seaweeds.