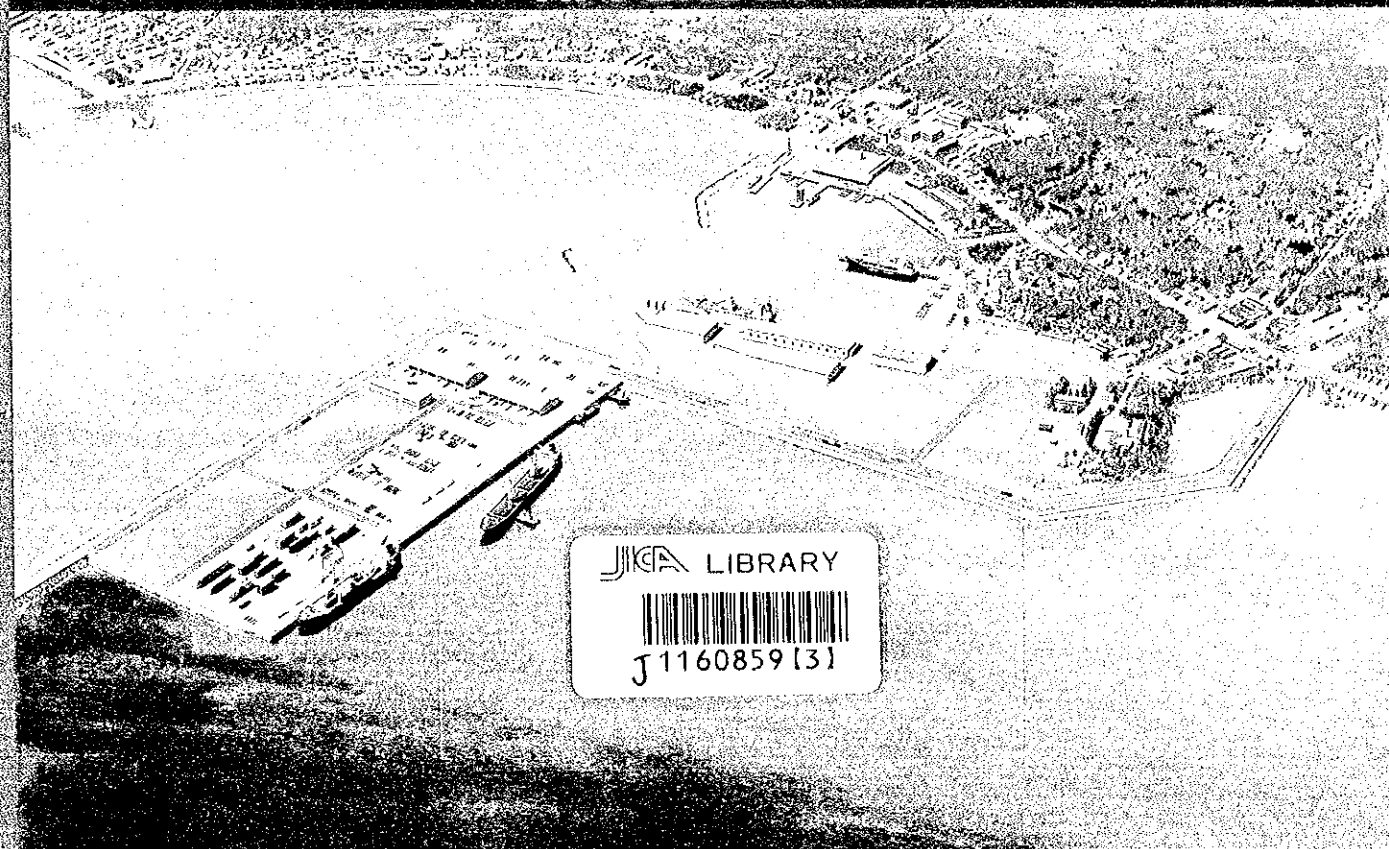


**FINAL REPORT  
FOR  
THE STUDY  
ON  
URGENT DEVELOPMENT OF THE PORT OF GALLE  
AS A REGIONAL PORT  
IN  
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA**

October 2000

**APPENDIX II**



**THE OVERSEAS COASTAL AREA DEVELOPMENT INSTITUTE OF JAPAN (OCAD)  
JAPAN PORT CONSULTANTS, LTD. (JPC)**

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## **CHAPTER 01**

### **GENERAL INTRODUCTION**



Little information is given here to avoid possible duplication. Therefore, the reader is requested to follow the main JICA report for more information.

Preliminary Environmental Study (PES) has been carried out in view of assessing the environmental issues that are related with the urgent development of Port of Galle as a Regional Port. This study has been entrusted to Department of Civil Engineering, University of Moratuwa from which eight consultants on different areas of environment have worked to make this study a success. Terms of reference for the entire study have been prepared according to the JICA guideline on the preparation of Environmental Impact Assessment (EIA) in the Harbour sector.

No attempt is however made to follow the local EIA guideline prepared by Central Environmental Authority as the present study follows the EIA process in accordance with JICA guidelines. Nevertheless, this report as a supplementary document would be a valuable source for subsequent EIA to be carried out in accordance with Sri Lankan regulations.

Four different, distinct harbour configurations have been considered for the entire study and the best possible alternative with minimum adverse impacts has been selected.

The study comprises the comprehensive assessment of existing environment, anticipated significant adverse impacts and their mitigation measures, monitoring plan together with conclusion and further recommendations

Chapter 2 describes the configuration of 4 alternatives. Details are given wherever possible, but lesser information was available for Alternative 4.

Chapter 3 elucidates environmental elements, which are likely to be affected in the project area. Comprehensive information is collected wherever possible to grasp the background condition of the project areas. They were collected in the form of tests, experiments and surveys etc.

Chapter 4 explains possible likely impacts on each and every environmental element. Only the adverse impacts are reckoned over beneficial impacts for the entire study. Impacts are studied in detail depending on their severity and are focussed on each alternative when it is really necessary.

Chapter 5 illustrates probable mitigation measures for significant impacts.

Chapter 6 gives the monitoring plan to be implemented for both construction and operation phases.

Chapter 7 briefs the conclusions and further recommendations to be studied during detail design stage.

This report has been prepared by the professional and support staff listed below.

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## **CHAPTER 02**

### **PROPOSED ALTERNATIVES FOR THE PORT**



Four distinctly different configurations have been considered for the entire study of which, three alternatives are on the same area whereas the fourth is located in a different area. All four alternatives are described below.

### **Alternative 1**

Approach channel to the proposed port starts close to the Watering Point and the direction is N-W (Fig. 2.1). Approach channel and the inner port area are to be dredged to -12.0 m and the dredging gives rise to 331,282 m<sup>3</sup> of soft material and 13,718 m<sup>3</sup> rock material respectively.

The outer breakwater which is 800 m in length is in the direction of S-E to N-W while the inner breakwater having a length of 350 m is in the direction of S to N respectively. Details of revetments and wharf could be obtained from the Figure 2.1. Further, turning circle of 400m diameter is provided.

Two berths having a length of 480 m are proposed in the direction of S - N for the alternative 1. The main entrance to the proposed port is through the revetment & which connects to the existing Galle – Matara road. No hindrance to the existing approach channel, port, Dewata area and coral reef is found with this alternative.

### **Alternative 2**

Approach channel to the proposed port starts from the Watering Point and the direction is from SW to NE (Fig. 2.2). Approach channel and the main port area are to be dredged to -12.0 m and the dredging includes 357,900 m<sup>3</sup> of soft material and 15,850 m<sup>3</sup> of rock material respectively.

In this alternative, there exists only one outer breakwater and is 500 m long. Details of revetments and wharf are given the Figure 2.2. 400 m, turning circle is provided for ships.

Two berths having a total length of 480 m are provided in the direction of S-N. The existing Galle – Matara road is connected to the port through Revetment & for access.

### **Alternative 3**

Approach channel to the port once again commences close to the Watering Point in the direction of SN to NE (Fig. 2.3). Approach channel and the main port area are to be dredged to -12.0 m and the dredging encompasses 508,800 m<sup>3</sup> of soft material and 15,850 m<sup>3</sup> of rock material respectively.

The outer breakwater having a length of 670 m is in the direction of SE to NW while the inner breakwater having a length of 500 m is in the direction of S-N respectively. Details of revetments and wharfs are given in the Figure 2.3. A 400 m tuning circle is provided for ships.

Two berths having a total length of 480 m is planned and the entrance to the existing road is through the revetment 4.

### **Alternative 4**

This alternative completely differs from the others. Approach channel is much away from the Watering Point but towards the existing Fort. Channel commences in the direction of SE and aligned towards NW until it reaches the present approach channel and there onwards, it exactly falls with the existing channel. (Fig. 2.4).

Marine outer breakwater having a length of about 1500 m is proposed. Another inner breakwater having a length of about 350 m in the direction of SW to NE is also proposed. The area of interest is to be dredged to -12.0 m and 2 berths are planned in the S-N direction. Other details are not given, as this alternative seems to be not viable both economically and environmentally.

## **CHAPTER 03**

### **EXISTING ENVIRONMENT**



### **3.1 Harbor Layout and Bathymetry**

#### **3.1.1 Bottom bathymetry of the Port of Galle**

The port of Galle is located in the south-west coastline of Sri Lanka about 120 km to the south of Colombo. The port is well confined within the central part of the Galle bay by two rubble mound breakwaters, 250 m and 200 m long respectively. Navigation access to the port is provided by a 160 m gap between the two breakwaters. The breakwaters cover a water area of about 0.2 km<sup>2</sup>. A fishery harbor is located towards western side of the Galle port. Figure 3.1 gives the layout of the existing port of Galle.

The basin of the Galle port has a varying bottom bathymetry where shallow depths prevail at the fishery harbor side. Water depth maintained in the eastern part of the basin near Gibbot Island is around 7-8 m.

The mooring basin provided in the middle of the port is about 9 m deep and covers a water area of 0.055km<sup>2</sup>. A water depth of 9-10 m is maintained in the navigation channel, which is positioned perpendicular to the entrance of the port.

#### **3.1.2 Sea bed bathymetry of the outer harbor in the Galle bay and its immediate vicinity**

The Galle bay is confined between the Galle peninsula to the northwest and the Roomassala Hill to the southeast. The bay extends about 2.5 km in the east-west direction and 1.5 km in the north-south direction. The entrance width of the bay is of the order of 1.75 km.

Several rock outcrops and coral patches can be seen within the bay. The bay is about 10 m deep on average and the water depth around the mouth of the bay is about 12-15 m. The sea bottom outside the bay extends towards south with a slope of around 1:50 and bottom contours outside the bay are almost parallel. Figure 3.2 shows the bottom bathymetry and topography of the Galle bay and the area outside.

## 3.2. Meteorology and Hydrology

### 3.2.1 Rainfall

The rainfall pattern in Sri Lanka is characterized by two tropical monsoons, southwest monsoon from May to September and northeast monsoon from December to February. There are two inter-monsoons in between the southwest and northeast monsoons. Accordingly, the period between January and March is the most dry period for area of Galle while maximum rainfall comes along with the south-west monsoon between August and October. The average annual rainfall of the Galle area falls within 2000 mm – 3000 mm range. Usually, more than 30% of the annual rainfall occurs during the southwest monsoon. Table 3.1 shows rainfall statistics for Galle averaged over a 30-year period from 1961 to 1990.

Table 3.1 30 year averaged Monthly rainfall in Galle (Concept Report, Development of the Port of Galle, Posford Duvivier Consulting Engineers,1999).

Month	Monthly Rainfall (mm)
January	85.1
February	70.5
March	111.3
April	206.8
May	290.4
June	188.2
July	163.2
August	185.9
September	255.8
October	322.7
November	321.0
December	176.9
Annual	2377.8

### 3.2.2 Temperature

Being a tropical country, daily and annual temperature variations in Sri Lanka are limited only to few degrees of centigrade. Galle area falls into the wet zone of Sri Lanka. From the analysis of 30 year temperature records collected in Galle, the highest monthly maximum temperature and lowest monthly maximum temperatures were found to be 30.6°C and 28.4°C. The highest and lowest monthly minimum temperatures during the same period were 25.5°C and 22.8°C respectively. The average annual temperature over a period of 30 years from 1961 to 1990 was found to be 27.4°C. The temperature variation within the day is around 3°C to 7°C with an average annual difference of 5°C. Table 3.3 shows 30 year averaged maximum and minimum monthly temperatures.

Table 3.3 30 year averaged maximum and minimum monthly temperatures (Concept Report, Development of the Port of Galle, Posford Duvivier Consulting Engineers, 1999).

Month	Maximum Temp (°C)	Minimum Temp (°C)
January	29.0	22.8
February	29.9	23.0
March	30.6	23.9
April	30.6	24.8
May	29.8	25.5
June	29.0	25.2
July	28.6	24.8
August	28.4	24.7
September	28.5	24.7
October	28.7	24.1
November	29.0	23.5
December	29.1	23.1
Annual	29.3	24.2

### 3.2.3 Humidity

The annual average humidity in the Galle area is around 80% during daytime and 88% during nighttime throughout the year. Daytime humidity increases in the months of July-August up to 85% and relatively low humidity of the order 70% occur in January-February.

### 3.2.4 Wind

The wind pattern in Sri Lanka is mainly associated with the monsoons. During the SW monsoon, western and southern parts of the island are normally subject to high winds. In the Galle area, wind speed occasionally reaches 15-20 knots during the southwest monsoon. From the analysis of wind data collected over a 3-year period at the Galle observatory during 1986-1988, it has been found that wind speeds at Galle exceeded 20 knots at a frequency of 0.1% and 10 knots at a frequency of 10.5% (JICA,1991).

Wind direction in Galle is mostly confined to SW sector. Figure 3.3 shows annual wind direction distribution in Galle.

During the northeast monsoon, wind speed and direction are not as regular as during southwest. However, the predominant wind directions during this season are found as N and ENE.

## 3.3 Tidal dynamics

### 3.3.1 Tidal fluctuations

It has been found that semi-diurnal tidal fluctuations predominate along the southwest coast of Sri Lanka. Admiralty tide tables give the following tide levels for Galle bay at spring and neap tides.

MHWS	+ 0.6 m
MLWS	+ 0.1 m
MHWN	+ 0.4 m
MLWN	+ 0.3 m

The levels are given in meters above chart datum level. The spring and neap tidal ranges in Galle bay indicated by the above values are +0.5 m and +0.1 m respectively.

### 3.3.2 Tidal currents

Tidal fluctuations induce ebb and flood tidal currents during the rising and falling tides respectively. Since the Galle bay area has a maximum spring tidal range around 0.5 m, it is expected that the currents associated with tidal fluctuations are small. However, tidal currents can be affected by wind and wave driven currents, especially during the monsoon seasons.

Lanka Hydraulics Institute (LHI) has undertaken a current measurement programme outside the Galle bay in January-March 1986. The measurements were done on behalf of the Coast Conservation Department (CCD). The currents measured during this period, which covers the north-east monsoon, showed that the predominant current direction during the monsoon is SSE and their speeds reached up to 0.4 m/s. Currents up to 0.3 m/s were recorded in NE direction but were much less frequent.

LHI in 1999 measured tidal currents at two locations inside and outside the Galle bay over a period of 4 weeks in February. Measurement locations are given in Figure 3.4. According to the measurements, very few current recordings within the Galle bay at 10 m water depth (point A) exceeded 0.12 m/s. The maximum current speed recorded outside the Galle bay at point B at 16m water depth was 0.2 m/s. It was also found that the predominant current direction outside Galle bay is S and NW. The currents measured within the bay were mostly in SW direction.

Both the above measurement programmes gave only spot currents inside and outside the Galle bay and there are no measurements available on the current distribution within the bay. Posford Duvivier Consulting Engineers (PDCE) together with LHI used a numerical model to simulate current distribution within the Galle bay corresponding to oceanic flood and ebb tides. From the results obtained over a one tidal cycle, it was observed that the current distribution within the Galle bay is largely influenced by oceanic currents.

According to the model simulations, the oceanic tidal flow was from east to west during the early stages of the rising tide. Following that, tidal flow entered the Galle bay around Roomassala Hill and left around Galle Fort. During the latter part of the rising tide near high tide level, the direction of the tidal flow in the open ocean reversed and directed from west to east. At this phase of the tidal cycle, the tidal flow within the Galle bay also reversed where water entered the bay around Galle Fort and left around Watering Point. During this period, water motion within the bay is entirely from west to east. Even though the tidal currents outside the bay were mostly between 0.1 and 0.2 m/s, the current magnitudes within the bay

during the rising tide was found to be less than 0.1 m/s on all occasions during both the rising and high tide phases of the tidal cycle.

In the early stages of the falling tide, the flow direction in the open ocean was from west to east. However, at this stage, strong westward outflow was observed around Galle Fort. During the latter part of the falling tide, the strength of the outward flow from the bay around Galle Fort increased and a westward bound flow was observed within the entire bay. At this stage, the tidal flow outside the bay reversed to the westward direction.

It was observed from these simulations that the tidal currents within the bay do not exceed 0.1 m/s throughout the entire tidal cycle and the tidal current in the inner bay regions where the present port is located, are extremely small and is insignificant.

The Master Plan for Coastal Erosion Management prepared by the Danish Hydraulics Institute in 1996 for the Coast Conservation Department (CCD) suggests that the currents along the west coast of Sri Lanka move parallel to the coastline mainly in northerly directions during south-west monsoon and in southerly direction during northeast monsoon.

### **3.4 Wave Climate in Galle**

#### **3.4.1 Offshore waves**

Offshore wave climate in the Galle area have been recorded from 1989 to 1992 and from 1994 to 1995 by the German Technical Corporation Study (GTZ) on behalf of the Coast Conservation Department of Sri Lanka (CCD). The measurements have been done at a site 8 km from the shoreline off Galle at 70 m depth.

It has been found from these measurements that the offshore wave climate at Galle is characterized by both wind waves and swell waves. Wind waves are strongly influenced by monsoons while swell waves are not significantly affected by the monsoons. Swell waves up to 3 m height with period between 10-20 seconds have been recorded during the measuring programme. It was found that the direction of swell waves is fairly constant all throughout the year and they approach Galle bay from the southerly direction. During the southwest monsoon season, swell waves distribute in SSW sector. Although swell wave heights are fairly constant throughout the year, it appears that the highest swell waves occur during the southwest monsoon. Table 3.4 shows the ten highest offshore swell waves recorded during 1989-1995 period. Figure 3.5 shows annual distribution of significant wave height and direction of offshore swell waves recorded during CCD-GTZ programme.

Wind waves are generated by local wind field in the Galle area and therefore, they are strongly influenced by the seasonal climatic changes, especially the monsoons. The highest wind waves were recorded during the southwest monsoon. The direction of local wind waves during the southwest monsoon was mainly WSW.

The maximum significant wind wave height recorded during a storm in June 1991 was 5.5 m. At all other times, wind wave heights were generally below 2.0 m. During the northeast monsoon, local wind waves approach the shore from SE direction. Table 3.5 presents highest offshore wind waves recorded during the measurement programme from 1989 to 1994. Figure 3.6 shows the distribution of significant wave height and direction of offshore wind waves.

Table 3.4 Ten highest swell waves measured during CCD-GTZ programme (Concept Report, Development of the Port of Galle, Posford Duvivier Consulting Engineers, 1999)

Year	Month	Wave Height (m)	Wave Period (sec)	Wave Direction
1994	September	3.02	12.99	SSE
1992	July	3.00	17.86	SSE
1994	September	2.95	12.35	SSE
1991	July	2.89	11.24	SSE
1989	August	2.89	11.63	SSE
1994	August	2.87	13.33	SSE
1990	June	2.86	12.50	SSE
1995	June	2.83	14.29	SSE
1994	September	2.81	12.05	SSE
1994	September	2.81	12.50	SSE

The overall wave climate consists of swell waves and wind waves acting together. The maximum overall wave height recorded during the measurement programme was 4.28 m. The predominant direction of overall waves was SSE to WSW.

It was seen from the measurements that the overall wave heights of 1.0 m, 1.5 m and 2.5 m were recorded with frequency of occurrence of 81.6%, 51.8% and 9.2% respectively. Figure 3.7 shows the distribution of significant wave height and wave direction of offshore overall waves.

Tables 3.5 Ten highest wind waves measured during CCD-GTZ programme (Concept Report, Development of the Port of Galle, Posford Duvivier Consulting Engineers, 1999)

Year	Month	Wave Height (m)	Wave Period (sec)	Wave Direction
1991	June	2.10	8.33	SEE
1991	June	2.15	8.00	SEE
1991	June	2.02	8.33	SEE
1991	June	2.27	7.63	SEE
1991	June	1.90	8.13	SEE
1991	June	2.40	7.63	SEE
1994	August	1.98	6.49	E
1994	August	2.02	6.67	NEE
1994	July	29.19	6.54	NEE
1989	August	11.15	7.35	NEE

### 3.4.2 Near-shore waves

It has been found that very rough seas including swell occur just outside the Galle bay during the period of southwest monsoon, which prevail from May to September. During this monsoon, waves reach near-shore areas mainly from southwest direction. Waves during the northeast monsoon are recorded mainly as moderate and the predominant wave direction is southeast.

LHI conducted wave measuring programmes outside the entrance of the Galle bay at 23 m depth. Records were taken intermittently from 1984 to 1986 and continuously from 1988 to 1995. Those measurements were done on behalf of the CCD and then of the Sri Lanka Ports Authority (SLPA). Only the wave heights and periods were recorded without reference to the wave directionality. However, it has been identified at a later stage that the mooring arrangement of the wave rider buoy was not as recommended by the manufacturer and therefore, the measurements may not truly represent the real sea state at the site (Posford and Duvivier Consulting Engineers, 1999).

During their study on the 'Development of the Port of Galle', PDCE together with LHI transformed some of the offshore waves measured during CCD-GTZ wave measuring programme to near-shore areas outside the Galle bay using a numerical model. Figure 3.8

show distributions of significant wave heights and directions obtained by numerical transformation of southwest monsoon offshore waves. (a), (b) and (c) refer to swell, wind and overall waves respectively.

It can be seen from these results that any of the swell and wind waves rarely exceed 3.0 m. Overall wave heights exceed 3.0 m only at few occasions. Predominant wave direction at near-shore areas during the southwest monsoon season remains SW.

The present JICA study has done wave forecasting for Galle bay in year 2000. They found that despite the offshore incident wave direction being W, WSW or SW, waves approach the Galle bay mainly from SW direction. They also found that the significant wave height with 50-year return period at the mouth of the Galle Bay is around 5.0-6.0 m. The maximum wave height with 50-year return period at the mouth of the bay is around 9.0-10.0 m. According to their simulations, the maximum values of significant and maximum wave heights with 50-year return period occur when offshore wave direction is WSW.

### **3.5 Environmental Considerations**

Environmental components in the project area in relation to the project activities are discussed in this chapter. The total environment is split into two major segments, namely natural and social environments. Natural environment includes water and sediment quality, air quality and noise level, flora and fauna whilst the social environment encompasses built environment, heritage buildings, marine archaeology, tourism, income of the people, population, fisheries, recreational activities etc.

#### **3.5.1 Water quality of the Galle Bay and its pollution**

##### **3.5.1.1 Background**

Water quality of the Galle bay including the present port has been checked with a view to understanding the degree of pollution. Pollution could be caused due to oil and hydrocarbons spill, dredging activities, sewage effluent from the inland, urban runoff, chemical processing and handling and litter and garbage etc.

### 3.5.1.2 Water quality of the Galle Bay

Five locations have been selected for the water quality analysis (Figure 3.9). W1 was selected in the bay while W2 was located in the existing harbour. W3 was close to the Fort where people bathe and W4 and W5 were both selected in Buona-Vista coral reef. All points except W3 were sampled at top and bottom of the water column. All samples were tested for temperature, pH, colour, dissolved Oxygen, BOD, COD, suspended solids, oil and grease, total and faecal coliform and secchi depth respectively. Table 3.6 shows the results of the analysis.

Temperature profiles manifest that water column is more or less mixed. pH has been recorded as typical for sea water and does not pose any potential threats. Colour too shows high clarity indicating less pollution. Dissolved Oxygen levels both at top and bottom indicate highly oxie environment causing no threat for ecosystem. BOD levels are some what low indicating that biodegradable matter are scarce. Nevertheless, COD levels are reported to be extremely high for which the exact reason/s are not clear. This could have been due to the chloride ions present in the samples. Suspended solid content is rather high in the sampling points perhaps due to the recent rainfall experienced together with the associated run-off.

However, high loading of suspended matters may be due to the crystallization of salts from the seawater. Levels of the SS therefore do not manifest actual pollution potential in the form of suspension. Oil and grease contents are reported to be nil except at W3 where there is a significant amount of oil probably due to the intense human usage as a bathing place. Total and faecal coliform levels yield no risk of faecal contamination in the sampling points. Secchi depth measurement has been found to be high indicating once again less pollution in the form of suspension.

In general, it could be inferred that the water quality of the Galle bay is very good as compared with to those stipulated for various water quality criteria.

Table 3.6 Water quality of the Galle Bay

Sample Number	Location	Parameters											Secchi Depth (m)	Depth (m)
		Temperature (°C)	pH	Colour (Hazens)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Suspended Solids (mg/l)	Oil & Grease (mg/l)	Total Coliforms per 100 ml	Faecal Coliforms per 100 ml			
W(1)	Surface	30	8.10	5	7.1	6.5	840	270	00	2	<2	4.5	12	
	Bottom	30	8.12	5	6.7	5.5	728	220	--	<2	<2			
W(2)	Surface	30	8.21	5	5.6	7.0	344	203	00	9	2	3.2	5	
	Bottom	30	8.20	5	5.2	11.5	728	197	--	34	14			
W(3)	Surface	28	8.29	5	7.1	13.5	900	182	32.07	8	2	*	*	
(4)	Surface	30	8.29	5	7.2	11.0	96	271	00	<2	<2	2.8	2.8	
	Bottom	30	8.28	5	7.1	13.5	144	269	--	<2	<2			
W(5)	Surface	30	8.26	5	6.7	4.5	680	182	00	<2	<2	4.5	5.4	
	Bottom	30	8.28	5	6.9	15.0	171	170	--	<2	<2			

\* Shallow depth

-- Not measured

### **3.5.2 Sediment quality of the Galle Bay and its pollution**

#### **3.5.2.1 Background**

Sediment quality of the Galle Bay including the present port has been checked with a view to understanding the degree of pollution in terms of heavy metals and organo-chlorides. Removal of the marine life causing temporary changes, contamination due to spillages and agitation due to port activities would be some of the major disasters that could occur with high level of pollutants. Furthermore, dredging and reclamation could also enhance the release of such pollutants if found in larger quantities. Hence, the present degree of pollution in relation to afore-said pollutants is thought to be evaluated with chemical analysis.

#### **3.5.2.2 Sediment quality of the Galle Bay**

Five locations have been sampled for the sediment quality analysis (Figure 3.10). S1 was selected in the middle of the bay where as S2 was at the entrance to the existing port. S3 was located near fishery harbour while S4 and S5 were both selected from the Buona-Vista Coral reef. All samples were tested for ignition loss, organic carbon and water content and for heavy metals such as mercury, zinc, chromium, cadmium, lead and nickel. Further, all samples were tested for pesticides of DDE, DDT and DDD and for persistent compound such as PCBs. Table 3.7 show the level of heavy metals and other organo-chloride present in the samples. The chemical analysis has been carried out at CISIR environmental laboratory.

Table 3.7 Levels of heavy metals and organo-chlorides

Test Parameter	Test value				
	S1	S2	S3	S4	S5
Ignition loss at 550°C, (%)	5.8	14.6	11.6	13.5	12.5
Water content at 125°C (%)	22	38	35	25	25
Mercury (as Hg) mg/Kg	<0.4	<0.4	<0.4	<0.4	<0.4
Zinc (as Zn) mg/Kg	8	57	38	13	20
Chromium (as Cr) mg/Kg	22	30	23	<10	<10
Cadmium (as Cd) mg/Kg	<4	<4	<4	<4	<4
Lead (as Pb) mg/Kg	<20	<20	<20	<20	<20
Nickel (as Ni) mg/Kg	<20	<20	<20	<20	<20
Organic Carbon (%)	0.2	1.2	0.2	0.5	0.5
P,P' DDE (µg/Kg)	<2	<2	<2	<2	<2
O,P' DDT (µg/Kg)	<2	<2	<2	<2	<2
P,P' DDT (µg/Kg)	<2	<2	<2	<2	<2
O,P' DDD (µg/Kg)	<2	<2	<2	<2	<2
P,P' DDD (µg/Kg)	<2	<2	<2	<2	<2
Total DDT, DDD,DDE (µg/Kg)	<2	<2	<2	<2	<2
PCB 28 (µg/Kg)	<2	<2	<2	<2	<2
PCB 52 (µg/Kg)	<2	2	<2	<2	2
PCB 101 (µg/Kg)	<2	<2	<2	<2	<2
PCB 118 (µg/Kg)	<2	<2	<2	<2	<2
PCB 138 (µg/Kg)	<2	<2	<2	<2	<2
PCB 153 (µg/Kg)	<2	<2	<2	<2	<2
PCB 180 (µg/Kg)	<2	<2	<2	<2	<2

Both ignition loss and organic carbon suggest that the loose material that is prone to absorb water is dramatically less indicating less organic pollution. Further the water content too suggests that the sediment contains less soft material. All the heavy metal concentrations are well below the recommended levels for harbours and hence, suitable for reclamation upon dredging. This has been justified once again with the levels of PCBs and DDTs. In brief, it could be inferred that there is no pollution in terms of heavy metals or organo-chlorides in the Galle Bay.

### **3.5.3 Major Point Sources of Pollution and their Water Quality**

Point Sources of Pollution discharging into the Galle Bay area, between Galle Station and the Watering Point were identified by discussions with SLPA officers, Galle Municipal Council Engineers and Public Health Inspectors, UDA officers and residents of the area.

#### **3.5.3.1 Major Outlets**

Three major outlets, with substantial discharges throughout the year, were identified. They are

Waggal Modera Ela (Lunuwila Ela)

Moragoda Ela

Kepu Ela

These are shown in Fig 3.10

#### **3.5.3.2 Other Outlets**

There is a waterway discharging into the Bay near the Watering Point, which is presently overgrown with vegetation and is therefore difficult to be sampled for quality. Galle Fort has a system of storm sewers. There are 11 outfalls draining the Fort area and the Esplanade into the sea, as seen in the map (Fig 3.11). It was suspected that there might be some unauthorised or faulty connections of sanitary sewage outlets to these storm sewers. However, on inspection, it was found that there was no significant flow coming out of any of these outfalls on a dry day (27/03/2000). Therefore, it could be inferred that there is no significant inflow of sewage into the sea from the storm sewer system of Galle Fort. During the rainy days, however, there will be a significant flow in these drains, which will be discharged into the sea through the outfalls.

Two other minor outlets discharging into the sea are present near the Fruit market on the Marine Drive. One of these outlets is a storm drain, which however may be carrying some wastewater from the markets. The other outlet is discharging sullage from a public toilet block, but the flow is insignificant

Samples of water were collected from Waggal Modera Ela (Sampling Point B), Moragoda Ela (Sampling Point C) and Kepu Ela (Sampling Point E) for analysis of water quality. Samples could not be collected from the storm water drains as there was no significant flow in these drains. The samples were tested in-situ for temperature and pH. The Dissolved Oxygen content was fixed at site, as it is very unstable. The samples were taken to the laboratory, and tested for the following parameters:

1. COD
2. BOD<sub>5</sub><sup>20</sup>
3. Turbidity
4. Colour
5. Total Suspended Solids
6. Conductivity
7. Dissolved Oxygen
8. Oil and Grease

The same sources were sampled for microbiological analysis too. The Total Coliform and Faecal Coliform counts were taken for all samples, using the multiple tube fermentation technique.

Sampling points B, C and E are shown in Fig. 3.11.

Table 3.8 Water Quality Analysis Results

Date of Sampling: 28/03/2000

Appearance of samples

Sample B- clear, but with settled sediments, lightly coloured

Sample C – clear, but with settled sediments, lightly coloured

Sample E – turbid, with settled sediments, coloured

PARAMETER	WAGGAL MODERA ELA (B)	MORAGOD A ELA (C)	KEPU ELA (E)	TOLERANCE LIMIT
Sampling Time	3.45 p.m.	4.00 p.m.	4.35 p.m.	-
Temperature	32°C	32°C	30°C	45°C *
pH	7.98	7.74	7.62	6.0-8.5
Dissolved Oxygen (mg/l)	7.5	5.4	2.4	**
Colour	30	40	80	**
Turbidity (NTU)	7.2	9.8	16.0	**
Conductivity (mS)	35.5	16.7	6.7	**
Suspended Solids (mg/l)	224	120	268	150
COD (mg/l)	160	120	80	250
BOD <sub>5</sub> <sup>20</sup> (mg/l)	75	62.5	77.5	100
Oil and Grease (mg/l)	171.76	275.71	16.92	20
Total Coliforms (per 100 ml)	170	30,000	13,000	**
Faecal Coliforms (per 100 ml)	17	11 × 10 <sup>4</sup>	2 × 10 <sup>4</sup>	**

\* - at point of discharge

\*\* - standards are not stipulated for these parameters.

Since the effect of these discharges on the marine water in the Galle Harbour is being considered, it is relevant to look at the above quality parameters in relation to the Tolerance limits of industrial and domestic effluents discharged into the Marine coastal areas, as stipulated in the Gazette notification of the National Environmental (Protection and Quality) Regulations, No.1 of 1990.

Comparing the quality of the three major point sources with the Tolerance Limits, it can be seen that the temperature, pH, COD and BOD<sub>5</sub><sup>20</sup> values of all three discharges are within the limits. The suspended solids content of Moragoda Ela is within the limits, while that of Waggal Modera Ela and Kepu Ela exceeds the limits. This shows that these discharges are adding excessive sediment loads to the sea. Kepu Ela is not discharging into the Galle Bay, but depending on the current patterns, the sediment may be drawn into the bay area. Waggal Modera Ela is discharging into the bay, close to where the project activities are proposed. The oil and grease content of the water in the Kepu Ela and Moragoda Ela exceeds the tolerance limits. Moragoda Ela is discharging into the Galle Harbour. Therefore, this discharge is affecting the water quality within the harbour even at present.

#### **3.5.4 Water Quality of Recreational Areas**

Unawatuna Beach is a very popular recreational area among the locals as well as foreign tourists. It is situated to the east of the Galle Harbour. Tourists use the beach for sunbathing, wading, swimming, surfing and boating.

The Old harbour area near the Galle Fort is another popular recreational area. There is a Naval Training School and the trainees use the sea near the old harbour for swimming practices. Some school children and lifeguards also use the area for swimming. There is also a yachting club, and yachts could be seen moored near the old harbour.

Quality of the coastal water at Unawatuna (Sampling Point A) and the old Harbour (Sampling Point D) was tested by collecting samples from the sea where the water depth was about 1.5 m. Oil and grease samples were collected from the surface, while samples for physical-chemical analysis, DO measurement and microbiological testing were collected at a depth of about 20 cm from the surface. Sampling points A and D are shown in Figure 3.13.

Table 3.9 Water Quality in Recreation Areas

Date of Sampling: 28/03/2000

Appearance of samples

Sample A- clear, but with settled sediments

Sample D – clear, but with settled sediments, oil film visible

Parameter	Near unawatuna (a)	Near old harbour (d)	Tolerance limit *
Sampling Time	2.20 p.m.	4.20 p.m.	-
Temperature	30°C	30°C	15-35°C
PH	8.32	8.25	5-9
Dissolved Oxygen (mg/l)	8.2	8.4	Should not be reduced by 20% of the original
Colour	5	5	**
Turbidity (NTU)	6.0	6.2	**
Conductivity (mS)	47.6	50.4	**
Suspended Solids (mg/l)	274	271	**
COD (mg/l)	-	-	**
BOD <sub>5</sub> <sup>20</sup> (mg/l)	-	-	**
Oil and Grease (mg/l)	88.57	2163.54	Not noticeable as a visible film
Total Coliforms (per 100 ml)	80	7	**
Faecal Coliforms (per 100 ml)	23	<2	150

\* - Australian Water Quality Guidelines, Nov. 1992.

\*\*- Standard Levels are not stipulated.

No Tolerance Limits have been gazetted for marine waters designated for recreational purposes in Sri Lanka yet. However, Tolerance Limits are available in other countries. One such set of guidelines available and practised in Australia and New Zealand are given in the Table 3.9 for comparison. (Australian and New Zealand Env. & Conservation Council, 1992.)

### 3.5.5 Noise Pollution

Noise levels in terms of equivalent Noise levels (Leq) were measured in and around the port area on 27<sup>th</sup> March 2000. The figure 3.14 shows the locations at which the noise levels were measured. Integrated noise level meter was used for the measurement and the measurement time was reckoned to be 15 minutes. Table 3.10 given below depicts the noise levels at 9 different places with the likely source/s.

**Table 3.10 Noise levels in and around the Galle Port**

Location	Noise level $L_{eq}$ [dB(A)]	Likely Source
N1	64	Galle Cement Factory
N2	63	Unloading from a ship & dredging
N3	68	Nearby Ship, very close to ship engine
N4	63	Dredging
N5	64	Vehicular noise
N6	75	Vehicular noise
N7	75	Vehicular noise
N8	74	Vehicular noise
N9	68	Breaking Waves

The locations from N1 to N5 were selected within the port premises while N6 to N9 were located outside the port premises. It is apparent from the measured noise levels that the existing port activities do not give rise to very high noise levels. The traffic noise in the town area is much higher, and even exceeds the environmental noise limits.

### 3.5.6 Air Pollution

The Ambient Air Quality studies have been carried out by the National Building Research Organisation for one location in Galle. The following parameters have been measured using the Air Quality Monitoring Station, during the period September 8-16, 1999, at a point about 2 km from the Galle Bus stand, on the playground of a school:

Nitric oxide ( $N_2O$ ), oxides of nitrogen ( $NO_x$ ), nitrogen dioxide, sulphur dioxide, carbon monoxide, Wind Speed, Wind Direction, Ambient Air Temperature, Vertical Wind Speed, Rainfall, Solar Radiation and PM-10.

The daily average values of PM-10 data, and one-hour averages and maximum values of all other parameters are given in the annexure. The Maximum Permissible Levels of air pollutants as stipulated by the Central Environmental Authority are given in Table 3.11. It can be seen that the air quality in Galle is within the permissible levels for these air pollutants.

Table 3.11: Maximum Permissible Levels of Air Pollutants

Pollutant	Averaging Time	Maximum Permissible Level	
		Kg/m <sup>3</sup>	ppm
SO <sub>2</sub>	8 hr	120	0.05
NO <sub>x</sub>	8 hr	150	0.08
SPM	8 hr	350	-
Lead	24 hr	2	-
CO	1 hr	30,000	26.0

Source: Central Environmental Authority, Sri Lanka

### 3.5.7 Construction material such as metal and sand, and their availability

The location of large quarry sites and their approximate quantities of metal available in each of the quarry in the vicinity of Galle, as estimated by RDA is given in Table 3.12. The adequacy of the material for the construction activities could be checked only after knowing the metal requirements for the project.

Table 3.12 Description of bigger quarries in the in vicinity of project area

Location	Present Status	Remarks
Unawatuna	Very old More than 30 yrs	
Ambalangoda (Kuleegoda)	Relatively new 10 yrs old	Biggest - Used by RCDC & Kiang Nam (Korea)
Yakkalamulla (Welandawawatta)	New Not started	

Sand will have to be obtained from offshore deposits, as has been proposed for many other construction projects. A permit from the Geological Survey and Mines Bureau, Sri Lanka, is needed for exploiting the sea sand. Sri Lanka Ports Authority has already initiated action to make arrangements to reserve an area south of Galle, identified as shown in Map 4.1, using "Metric Grid Unit Identification System", for sand mining for this project.

### **3.5.8 Sewage, Drainage and Other Wastewater Systems**

There is no domestic wastewater collection system in the Galle Municipal Council, or the Fort area. Sanitary wastewater and sullage is disposed of on site, in septic tanks and pit latrines. The Municipal Council operates Gully Bowsers for desludging of the septic tanks at the request of the residents. Earlier, the contents of the septic tank used to be emptied into the sea, but now, the residents have to provide a pit in their land to bury the septage.

There is, however, a drainage system for storm water. The Galle Fort area has a closed conduit system, with 9 outfalls that drain the water into the sea around the Fort, and two outfalls discharging the water into the old harbour (Please see Fig 3.11). The rest of the Galle municipality area has a system of open canals for storm drainage (Please see Fig 3.10). These canals discharge the storm water into the sea via the three point sources discussed in section 3.5.3.1 above. The Kepu Ela discharges into the sea on the western side of the Fort, Waggal Modera Ela discharges to the sea on the eastern side of the harbour, while the Moragoda Ela discharges into the harbour.

### **3.5.9 Solid Waste Disposal**

Solid waste is collected by the Municipal Council and disposed of on land. About 7-8 tons/day of solid waste is collected on an average, while the quantities are more during the holiday seasons and festival times. Waste from the markets, bus stand, station etc is collected two or three times a day. Collection from large establishments such as garment factories, Cement Corporation, Harbour, Fisheries Corporation, Light House Hotel etc. is done by the tractors, and paid for by the tractor load.

The waste was being dumped on a private land between Richmond Hill and Kaluwella until March, but a new disposal site was identified at Piyadigama, on Gintota-Karapitiya Road. The new site is an abandoned paddy field, and has better access for the vehicles, as it is by the side of the main road. It has an area of about 6.5 acres, and is expected to serve the present population for about 18 months. According to the Public Health Inspector who provided the information, the landfill site is maintained by covering the deposited waste by soil, building debris or some inert material every 3-4 days, while malathion (EC 10) is sprayed in the nearby residential premises and on the dumped waste, to prevent fly-breeding. However, the new site is located in an isolated area, and therefore fewer nuisances are expected.

### 3.5.10 Hazardous Material and Ship Discharges

The routine operations carried out at the harbour as well as accidental spills may cause some contamination of the harbour water, if precautions are not taken. The discharges from ships have been categorised into:

- oily wastes,
- noxious liquid substances that are carried in bulk,
- harmful and hazardous substances carried in packages such as tanks and containers,
- sewage and garbage.

In order to study the occurrence of ship discharges into the harbour, it is useful to look at the operation of ships in the harbour. At present, the number of ships operating at Galle Harbour is only around 90-100 per year. The types of cargo handled are:

- Flour
- General cargo
- Clinker
- Gypsum
- Bag Cement
- Fuel
- Sugar
- Frozen Fish
- Fly Ash
- Bulk Cement

If these materials are discharged into the sea, by accidental spills or negligent practices in cargo handling, various adverse impacts will be felt by the marine ecosystem, such as mortality of certain marine organisms and starvation of certain birds and fish due to the shortage of food. It could also result in social and public health impacts due to the contamination of fish, reduction in fish yields and other aquatic resources, pollution of the beaches and sea fronts which would affect the use of these resources for recreation. These effects will also lead to national socio-economic impacts, as the tourism trade will be affected.

The major source of pollution of the sea from ship traffic is due to the discharges of oil and oil mixed water from routine tanker operations as well as from tanker accidents and leakages.

When a tanker discharges its cargo at a port, it is usual to fill some of the cargo tanks with sea water in order to maintain the ship's stability and to ensure that the propeller and rudder are properly immersed for the voyage back to the port of loading. The seawater used for this purpose is referred to as "Ballast Water". It is generally contaminated with the oil that is remaining in the tank. If this oily ballast water were discharged at the port of loading, it would heavily pollute the water in the harbour. However, the chances of this operation taking place in Galle port is remote, since the quantities of liquid cargo being discharged at Galle are very much higher than those being loaded, which would result in the ballast water being taken from Galle port, rather than being discharged here.

Another source of oil mixed water is the "Bilge water", which is the water collected in the engine rooms and needs to be discharged regularly. Results of physical-chemical analysis of samples of the bilge water collected from four ships in Colombo in September, 1998, are shown in Table 3.13. These results show that there could be a wide variation in the characteristics of the bilge water discharged from a ship, particularly in respect of the oil and grease content and the cation contents. The COD of all four samples is above the tolerance limit for discharge into marine coastal waters, and therefore it can be generally stated that the bilge waters should be collected in reception facilities and discharged only after treatment. The sample from Ship 3 is heavily contaminated with oil and cations such as Copper, Zinc and Lead. The oil may be separated by skimming and handled with the waste oil, while the water should be treated to remove organic and metal content.

According to the IMO regulations, the bilge water may be discharged in the sea at a point more than 5 nautical miles away from the harbour if the oil content is less than 15 ppm, while it can be discharged at a point further than 20 nautical miles from the harbour if the oil content is between 15 and 100 ppm.

Table 3.13 Results of Physical and Chemical analysis of bilge waters obtained from four ships

Parameter	Bilge Water			
	Ship 1	Ship 2	Ship 3**	Ship 4
Temperature at collection		30°C	36°C	33°C
pH	7.4 at 28°C	7.1 at 30°C	7.0 at 30°C	8.5 at 30°C
BOD <sub>5</sub> at 30°C,mg/l *	40	60	70	80
COD mg/l	620	520	365	365
Oil & Grease mg/l	8	40	25x10 <sup>4</sup>	50
Sulphate (as SO <sub>4</sub> ),mg/l	1070	840	960	405
Iron (as Fe),mg/l	104	5.0	101	3.2
Copper (as Cu),mg/l	0.4	0.06	10.5	0.07
Zinc (as Zn),mg/l	6.0	0.7	27.3	0.3
Lead (as Pb),mg/l	0.1	< 0.1	33.8	<0.1
Nickel (as Ni),mg/l	<0.1	<0.1	0.23	<0.1
Chromium (as Cr),mg/l	0.1	<0.1	0.22	<0.1
Cadmium (as Cd),mg/l	0.03	<0.03	0.18	<0.03

\* sample was seeded with sludge from a biological treatment plant

\*\* For this sample, all the analyses (except for oil and grease content and heavy metals) were done after removing the oil.

In addition, ships need to empty their waste engine oils regularly, and also when there are engine repairs, the oil needs to be emptied from the engines. These waste oils need to be collected from the ships at the port and disposed of, by someone. However, in Galle harbour at present, there is no arrangement for collection and disposal of waste oil from ships.

The present practice at the Colombo Port is for private contractors, who are registered with the shipping agents and the MPPA to be notified when a ship in the port needs to discharge its waste oil. This is normally done by the shipping agent. The ships pay the collectors for the service rendered in receiving the waste oil. However, the collectors have to pay customs duty on the waste oil when it is taken out of the harbour.

The other very important source of pollution is the ever-present danger of accidental spills. Carriers of oils, chemicals and other hazardous substances that pass just south of Sri Lanka *en route* to the East/West industrial plants, and the increasing coastal traffic including the tankers that transport oil and fuels to Sri Lanka are some of the threats of such accidental spills of hazardous materials. In the event of an accident to a ship, the person in charge of the vessel is

required to take necessary steps to prevent and control any oil spills. If this cannot be done immediately, the Marine Pollution Prevention Act No. 59 of 1981 empowers the MPPA to take necessary measures such as removal of such a vessel, unloading any remaining oil, and even sinking of a part or whole of the ship. The MPPA has realised the possibility of such a disaster and prepared a Sri Lanka National Oil Spill Contingency Plan. The Galle Harbour has chemical agents to handle small accidental oil spills, but larger spills need to be reported to Colombo for clean up operations.

The Marine Pollution Prevention Act No. 59 of 1981 also empowers the MPPA to detain any ship if there is any reasonable cause to believe that it has discharged oil or any other pollutant into the Sri Lankan waters, and to keep it until a security to cover the expenses for clean up has been deposited.

According to the Marpol Convention 73/78, the ports in all countries that are signatories to it should provide reception facilities for collection of waste oil, sewage and garbage that need to be discharged from the ships that call at these ports. The ships are expected to inform the ports' authorities in advance, (before they enter the harbour) the types and quantities of waste that they need to dispose of. The port authorities should then make arrangements to receive and dispose of the waste during the period that the ship is anchored in the port (inner or outer harbour). If these facilities are not provided, it would not be possible to enforce the regulations on marine pollution prevention, as the ships will be justified in discharging their wastes into the ocean as the only option available. Marpol 73/78 (Consolidated Edition) published by the International Maritime Organisation (IMO) sets out the regulations for the prevention of pollution by oil, noxious liquid substances, harmful substances carried by sea in packaged forms, sewage from ships and garbage from ships respectively in its Annexes I to V.

At present, in the Galle Harbour, the only type of waste collected from ships is, parts of machinery, engines, etc, which is bought by a contractor and sold as scrap metal. Galle Harbour needs to make some investments on the improvement of the environmental pollution control, by providing facilities for reception of the wastes from ships, and proper disposal of the collected wastes. These facilities should be incorporated into the development plans for the port.

### 3.6 Flora of Rumassala cliff

#### 3.6.1 Introduction

Rumassala is situated in the southern coastline about 2 km east of Galle city limits (6° 02' N and 80° 15' E). It is bounded by the sea from the west and the south and Galle – Matara road from the east. Rumassala is a rocky hill and the altitude of the highest point is about 35 m from the mean sea level. The structure of the parent rock looks very similar to the rocks found in nearby areas. Soil layer is shallow in most areas of Rumassala and these areas are dominated by 'Pandanas (wetakeya) forest' and other shrubby vegetation. A closed canopy, evergreen lowland forest is also found in the inland where soil depth is adequate to support this forest formation.

According to the people of the area, about fifty years ago, Rumassala was a relatively undisturbed patch of forest. However, at present most of the area is highly disturbed due to human settlements and granite rock blasting. The total area of Rumassala is about 150 ha (Samarakoon, 1990) including homestead gardens, scrublands and the forest patch. However, the total area of government land in Rumassala was surveyed in December 1994 and the extent is 28.990 ha (plan No. GA/A38/94/351, Divisional Secretary, Habaraduwa) in six different blocks. The largest block is 13.223 ha where Ports Authority circuit bungalow is situated. Sri Lanka is divided into 14 floristic regions and the vegetation found in the area belongs to the floristic region *Coastal and marine belt*. The characteristic vegetation types in this floristic region include coastal vegetation, mangrove, and strand vegetation.

#### 3.6.2 Enumeration of Forest Plants

##### 3.6.2.1 Methodology

A floristic survey was carried out to investigate the flora of Rumassala for the environmental study on the urgent development of port of Galle as a regional port. An enumeration of flora was done using the transect method. A transect is a line along which samples of vegetation were taken. Transects are usually set up deliberately across areas where there are changes in vegetation and marked environmental gradients. Most transects are therefore biased in their location, although it is possible to locate the start and end of a transect at random and then take samples along the line connecting the two points. Two transects were selected for the present survey. The road from Unawatuna gama to the beach used as one transect and the other was footpath from the Ports Authority circuit bungalow to the beach. The plant species found in either side of transects were identified using the keys and information found in Revised

Handbook to the Flora of Ceylon (Dassanayake & Forberg, 1980- 1999, Vol. I- XII). Also the list of Endemic Plants of Sri Lanka, (Bandaranaike & Sultanbawa, 1993); the 1999 list of threatened list of fauna and flora of Sri Lanka (IUCN Sri Lanka) and the 1997 IUCN Red List of Threatened Plants (Walter & Gillett, 1998) were used to list the endemic and threatened plants found in Rumassala (see Table 3.14)

### 3.6.2.2 Observations

The transect from the circuit bungalow to the beach showed a closed canopy forest about 6-8 m tall with a dense understory. Both wet and dry zone plant species were surveyed in this forest patch. Some of these species are very common in lowland evergreen forest such as Sinharaja. There are few species common to the dry-mixed evergreen forest (monsoon forest) were also recorded in the same locality. For example, lowland rain forest understorey plant *Humboldtia laurifolia* (Galkaranda) and dry – mixed evergreen forest understorey plant *Dimorphocalyx glabellus* (Tenkuttiya) were established in the same locality which is uncommon in other forest formations. The number of plant species recorded from Rumassala (e.g. Kekuna, Gal Kina, Hedawaka, Goraka, Wal Del or Kele Del, Polhunna, Wewel Dawata, Badulla Kitul, Godapara, Walla patta, Gal karnada, etc.) are common to the lowland wet zone forest. However, few species found in the intermediate and dry zone forests were also found here (e.g. Munamal, Daminiya, Radeliya, Tenkuttiya). Species such as Ketakela, milla, Kudumiris, Kenda, Gedumba and several Nuga species found in the wet, intermediate and dry zone forests of Sri Lanka are also recorded from Rumassala. In addition, mangrove genera like Carapa and coastal species like Heenmadu and Mahamaduru are also recorded during the field survey.

It has been reported that the species such as Bakmi, Kontalam, Veniweelgeta, Aralu, Bulu and Milla as very rare plants in Rumassala (Samarakoon, 1990). However, these species are very common in other forests in the wet and dry zones of Sri Lanka. The above species may have been over exploited from Rumassala in the past and it may have been a reason that very few individuals of these species now present in the area. Species such as Aralu and Bulu were not recorded in the present survey. Samarakoon (1990) has reported that it is unlikely that these are taxonomically similar to real Aralu and Bulu found in the dry zone. All the species are represented in other forest formations in the island e.g. lowland rain forest, dry-mixed evergreen forest, mangrove vegetation and coastal vegetation. The pioneer plant species such as Kenda, Gedumba, Lantana, and several shrub species are common in disturbed sites in Rumassala.

Present surveyed recorded seven endemic species normally found in the lowland wet zone. These are *Artocarpus nobilis*, *Calamus digitatus*, *Calophyllum trapezifolium*, *Dillenia retusa*, *Garcinia quaesita*, *Canarium zeylanicum*, and *Phoenix zeylanica*. Only two species (*Calamus digitatus* and *Calophyllum trapezifolium*) are recorded in the list of threatened plants, Sri Lanka. Six of the endemic species are also listed in the Redlist of Threatened plants prepared by the World Conservation Monitoring Centre (WCMC).

Table 3.14 Plant species found in the Rumassala cliff

Species	Family	Local Name	Life form	S	E	RL
<i>Abrus precatorius</i>	Leguminosae	Olinda	Vine	-	-	-
<i>Achroynchia pedunculata</i>	Rutaceae	Ankenda	Treelet	-	-	-
<i>Alstonia macrophylla</i>	Apocynaceae	Hawari Nuga, Yakada Maran	Tree	-	-	-
<i>Alstonia scholaris</i>		Rukattana	Tree	-	-	-
<i>Anacardium occidentale</i>	Anacardiaceae	Kaju	Tree	-	-	-
<i>Annona squamosa</i>	Annonaceae	Anoda, Atta	Tree	-	-	-
<i>Aporosa lindleyana</i>	Euphorbiaceae	Kebella	Shrub	-	-	-
<i>Ardisia humilis</i>	Myrsinaceae	Balu dan	Shrub	-	-	-
<i>Artocarpus heterophyllus</i>	Moraceae	Kos	Tree	-	-	-
<i>Artocarpus nobilis</i>		Wal Del	Tree	-	E	R
<i>Asparagus falcatus</i>	Liliaceae	Hatawariya	Vine	-	-	-
<i>Atalantia ceylanica</i>	Rutaceae	Wal Dehi, Yak Dehi	Shrub	-	-	-
<i>Axinandra zeylanica</i>	Crypteroniaceae	Polhunna	Tree	-	-	-
<i>Azadiracta indica</i>	Meliaceae	Kohomba	Tree	-	-	-
<i>Bridelia retusa</i>	Euphorbiaceae	Ketakela	Tree	-	-	-
<i>Brucea javanica</i>	Simaroubaceae	Tittakohomba	Treelet	-	-	-
<i>Calamua digitatus</i>	Palmae	Wewel	Liana	T	E	V
<i>Calamus</i> sp.		Wewel	Liana	-	-	-
<i>Calophyllum inophyllum</i>	Clusiaceae	Domba	Tree	-	-	-
<i>Calophyllum trapezifolium</i>		Galkeena	Tree	T	E	R
<i>Carallia brachiata</i>	Rhizophoraceae	Dawata	Tree	-	-	-
<i>Carapa moluccensis</i>	Meliaceae	Konthalam	Tree	-	-	-
<i>Carissa</i> sp.	Apocynaceae		Scrambling shrub	-	-	-
<i>Caryota urens</i>	Palmae	Kitul	Tree	-	-	-

Ceiba pentandra	Bombacaceae	Kotta pulun	Tree	-	-	-
Cerbera odollam	Apocynaceae	Welkaduru	Tree	-	-	-
Chaetocarpus castanocarpus	Euphorbiaceae	Hedawaka	Tree	-	-	-
Clerodendron infortunatum	Verbeneceae	Pinna	Shrub	-	-	-
Connarus monocarpus	Connaraceae	Radeliya	Liana	-	-	-
Croton laccifer	Euphorbiaceae	Keppetiya	Shrub	-	-	-
Gmelina asiatica	Verbenaceae	Demata	Shrub	-	-	-
Dicranopteris linearis	Gleicheniaceae	Kekilla	Fern	-	-	-
Dillenia retusa	Dilleniaceae	Godapara	Tree	-	E	R
Dimorphocalyx glabellus	Euphorbiaceae	Tenkuttiya	Shrub	-	-	-
Drynaria quercifolia	Polypodiaceae	Benduru	Fern	-	-	-
Embelia ribes	Myrsinaceae	Embilla	Treelet	-	-	-
Eupatorium odoratum	Compositae	Podisinghomaran	Shrub	-	-	-
Euphorbia tirucalli	Euphorbiaceae	Nawahandi		-	-	-
Ficus exasperata	Moraceae	Nuga	Tree	-	-	-
Ficus callosa			Tree	-	-	-
Ficus benghalensis			Tree	-	-	-
Ficus mollis			Tree	-	-	-
Ficus hispida			Tree	-	-	-
Garcinia quaesita	Clusiaceae	Goraka	Tree	-	E	V
Gartnera vaginace	Rubiaceae	Perathambala	Shrub	-	-	-
Gloriosa superba	Liliaceae	Niyagala	Vine	-	-	-
Gomphia serrata	Ochnaceae	Bokera	Treelet	-	-	-
Grewia damine	Tiliaceae	Daminiya	Tree	-	-	-
Gyrinops walls	Thymelaeaceae	Walla patta	Tree	-	-	-
Hibiscus furcatus	Malvaceae	Napiritta	Vine	-	-	-
Hibiscus tiliaceus		Gamsuriya	Tree	-	-	-
Humboldtia laurifolia	Leguminosae	Galkaranda	Shrub	-	--	-
Imperata cylindrica	Gramineae	Illuk	Grass	-	-	-
Ipomoea angustifolia	Convolvulaceae	Hinmadu	Vine	-	-	-
Ipomoea obscura		Mahamadu	Vine	-	-	-
Ixora coccinea	Rubiaceae	Rathambala	Shrub	-	-	-
Canarium zeylanicum	Burseraceae	Kekuna	Tree	-	E	V
Lanea coromandelica	Anacardiaceae	Hik	Tree	-	-	-
Lantana camera	Verbenaceae	Gandapana	Shrub	-	-	-

<i>Leea indica</i>	Leeaceae	Burulla	Shrub	-	-	-
<i>Limonia accidissima</i>	Rutaceae	Divul	Tree	-	-	-
<i>Macaranga peltata</i>	Euphorbiaceae	Kenda	Tree	-	-	-
<i>Mallotus</i> sp1.		Otha	Shrub	-	-	-
<i>Mallotus</i> sp2.			Shrub	-	-	-
<i>Melastoma malabathiricum</i>	Melastomataceae	Bovitiya	Shrub	-	-	-
<i>Memecylon</i> sp.			Treelet	-	-	--
<i>Mimusops elengi</i>	Sapotaceae	Munamal	Tree	-	-	-
<i>Morinda tinctoria</i>	Rubiaceae	Ahu	Tree	-	-	-
<i>Mussaenda frondosa</i>		Walmussanda	Scrambling shrub	-	-	-
<i>Neolitsea cassia</i>	Lauraceae	Davul kurundu	Tree	-	-	-
<i>Nothopogia beddomei</i>	Anacardiaceae	Bala	Tree	-	-	-
<i>Pandanus odoratissimus</i>	pandanaceae	Wetakeya		-	-	-
<i>Phoenix zeylanica</i>	Palmae	Indi	Tree	-	E	-
<i>Piper</i> sp.	Piperaceae	Wal Gammiris	Climber	-	-	-
<i>Premna obtusifolia</i>	Verbeneaceae	Wal midi	Liana	-	-	-
<i>Psycotria nigra</i>	Rubiaceae		Shrub	-	-	-
<i>Rejoua dichotoma</i>	Apocynaceae	Divikaduru	Tree	-	-	-
<i>Schefflera stellata</i>	Araliaceae	Itta wel	Liana	-	-	-
<i>Semecarpus insignis</i>	Anacardiaceae	Badulla	Tree	-	-	-
<i>Smilax zeylanica</i>	Smilacaceae	Kabarossa	Vine	-	-	-
<i>Stachytapheta indica</i>	Verbenaceae	Balunakuta	Herb	-	-	-
<i>Symplocos cochinchinensis</i>	Symplocaceae	Bombu	Treelet	-	-	-
<i>Syzygium caryophyllatum</i>	Myrtaceae	Dan	Treelet	-	-	-
<i>Syzygium spissum</i> ?			Treelet	-	-	-
<i>Tarennia asiatica</i>	Rubiaceae	Tarana	Shrub	-	-	-
<i>Terminalia catappa</i>	Combretaceae	Kottamba	Tree	-	-	-
<i>Toddalia asiatica</i>	Rutaceae	Kudumiris	Liana	-	-	-
<i>Trema orientalis</i>	Ulmaceae	Gedumba	Tree	-	-	-
<i>Vernonia zeylanica</i>	Compositae	Pupula	Vine	-	-	-
<i>Vitex altissima</i>	Verbenaceae	Milla	Tree	-	-	-
<i>Zyzyphus</i>	Rhamnaceae	Eraminiya	Scrambling shrub	-	-	-

S- Status (T- plant species listed in threatened plant list of Sri Lanka- 1999), E- Endemic and RL- Red List categories of plants- 1998 (R- Rare, E- Endangered, V- Vulnerable, O- Out of danger, K- Insufficiently known) recorded in Rumassala.

### 3.6.3 Marine algae of the Galle Bay

Present survey carried out for the environmental study revealed 22 species of algae belonging to 18 genera and 12 families (Table 3.15). Previous study done by Karuanratne and Weerakkody 1993/4 recorded eighteen species of marine algae in Buona Vista coral reef. Algae species recorded by Karunaratne and Weerakkody (1993/4) given in Table 3.16 represent 16 genera and 8 families. A list of endemic and threatened algae is not prepared for Sri Lanka and it is not possible to say whether there are any endemic and/or threatened marine algae found in the coral reef.

Table. 3.15 Algae species identified in Buona Vista coral reef during the preset study

Chlorophyta (Green Algae)	Rhodophyta (Red Algae)	Pheophyta(Brown Algae)
<ul style="list-style-type: none"> <li>Ulva reticulata</li> <li>Ulva lactuca</li> <li>Ulva rigida</li> <li>Ulva faciata</li> <li>Valonia sp</li> <li>Halimeda sp</li> <li>Caulerpa racemosa</li> <li>Caulerpa clavifera</li> <li>Bryopsis sp</li> </ul>	<ul style="list-style-type: none"> <li>Gelidium sp</li> <li>Jania sp</li> <li>Cheilosporum sp</li> <li>Amphiroa sp</li> <li>Corallina sp</li> <li>Grateloupia sp</li> <li>Glacilaria sp</li> <li>Hypnea sp</li> <li>Ceramium sp</li> <li>Acanthaphora sp</li> </ul>	<ul style="list-style-type: none"> <li>Sargassum sp</li> <li>Tubinaria sp</li> <li>Padina sp</li> </ul>

Table. 3.16 Algae species recorded by Karuanratne and Weerakkody 1993/4

Chlorophyta (Green Algae)	Rhodophyta(Red Algae)	Pheophyta(Brown Algae)
<ul style="list-style-type: none"> <li>Ulva fenestrata</li> <li>Ulva lactuca</li> <li>Ulva sp</li> <li>Enteromorpha sp</li> <li><i>Halimeda opuntia</i></li> <li><i>Halimeda macroloba</i></li> <li>Halimeda sp</li> <li>Codium adherens</li> <li>Dictyosphaeria sp</li> <li>Chlorodesmis sp</li> </ul>	<ul style="list-style-type: none"> <li>Porphyra suborbiculata</li> <li>Halimena ? ceylonica</li> <li>Titanophora? Sp</li> <li>Neogonolithon</li> </ul>	<ul style="list-style-type: none"> <li>Dictyota sp</li> <li>Padina sp</li> <li>Turibinaria sp</li> <li>Sargassum sp</li> </ul>

(Source: Report on the status and Bio-diversity of the Buona-vista coral reef by L.Karunaratna and P.Weerakkody 1993-94)

Table. 3.17 Algae species recorded under the present study but not recorded by Karunaratne and Weerakkody 1993/4

Chlorophyta (Green Algae)	Rhodophyta(Red Algae)
<ul style="list-style-type: none"> <li>Ulva reticulata</li> <li>Ulva rigida</li> <li>Ulva faciata</li> <li>Valonia sp</li> <li>Caulerpa racemosa</li> <li>Caulerpa clavifera</li> <li>Bryopsis</li> </ul>	<ul style="list-style-type: none"> <li>Gelidium sp</li> <li>Jania sp</li> <li>Cheilosporum sp</li> <li>Amphiroa sp</li> <li>Corallina sp</li> <li>Grateloupia sp</li> <li>Glacilaria sp</li> <li>Hypnea sp</li> <li>Ceramium sp</li> <li>Acanthaphora sp</li> </ul>

Table 3.18 Algae species recorded by Karunaratna and Weerakkody 1993/4 but not represented in the present survey

Chlorophyta (Green Algae)	Rhodophyta (Red Algae)	Pheophyta(Brown Algae)
<ul style="list-style-type: none"> <li>Ulva fenestrata</li> <li>Ulva lactuca</li> <li>Ulva sp</li> <li>Enteromorpha sp</li> <li>Halimeda opuntia</li> <li>Halimeda macroloba</li> <li>Halimeda sp</li> <li>Codium adherens</li> <li>Dictyosphaeria sp</li> <li>Chlorodesmis sp</li> </ul>	<ul style="list-style-type: none"> <li>Porphyra suborbiculata</li> <li>Halimania ? ceylonica</li> <li>Titanophora? Sp</li> <li>Neogonolithon</li> </ul>	<ul style="list-style-type: none"> <li>Dictyota sp</li> </ul>

### 3.7 Rumassala coral reef and its associated marine fauna

#### 3.7.1 Introduction

The main coral reef habitat in the Galle Bay occurs at Rumassala. The Rumassala coral reef is one of the small fringing coral reefs in the southern coast of Sri Lanka and is situated in the eastern corner of the Galle Bay below the Rumassala hill. Recent reports and publications on the biodiversity and the status of the Rumassala reef are by the National Aquatic Resources Research and Development Agency (Rajasuriya and De Silva, 1988; Ohman, Rajasuriya and Svensson, 1998; Rajasuriya, Ohman and Svensson, 1998) and Nature Conservation Group

(Karunaratna and Weerakkody 1994). These studies have indicated that the Rumassala coral reef is high in diversity of corals and reef associated species and is probably higher than the adjacent reef areas at Unawatuna and the fringing reef below the Dutch Fort in Galle. Recent surveys and the present study indicate that although the reef has lost much of its coral due to bleaching in 1998, new corals have begun to recolonize parts of the reef relatively rapidly. Some of the larger coral domes that were damaged during the bleaching in 1998 have now recovered. Recent studies also indicate that the reef building corals at Rumassala is recovering relatively rapidly than adjacent reefs at Unawatuna and Galle.

#### 3.7.1.1 Coral reef habitat

The reef is small; its approximate length is about 250 m along the shoreline and about 150 m wide stretching outwards towards the center of the bay. A total of 16 coral genera were recorded within the Line Intercept Transects carried out by NARA (Rajasuriya et al, 1998). Karunaratna and Weerakkody (1994) had reported 36 coral genera for the whole reef area of Rumassala and a percentage of live coral cover of 70.94% for the shallow coral patches and the scattered coral area near watering point. They had also reported that a considerable amount of sediment settles on the reef during rainy periods due to increased freshwater flow from the canals close to Rumassala. Rajasuriya et al. (1998) reported live coral of 45%, which included the shallow coral patches and the spur and groove formations in deeper areas. The coral bleaching event in 1998 destroyed much of the live corals (Rajasuriya et al., 1999). During the bleaching event almost all colonies of branching and *Acropora*, as well as *Pocillopora* were destroyed which reduced the live coral cover drastically. However several species *Porites rus*, *Psammacora digitata*, *Montipora aequituberculata* were only marginally affected by the temperature changes that triggered off the bleaching event.

#### 3.7.1.2 Coral reef associated fauna

A total of 481 species of fish have been recorded from Rumassala out of which approximately 304 have been identified as resident species at Rumassala (Karunaratna and Weerakkody, 1994). In addition 121 species recorded at Rumassala have been identified as important for the food fishery as well as 43 species important in the subsistence fishery. In 1993-1994 period the ornamental fish industry had targeted 115 species (Karunaratna and Weerakkody, 1994). In addition approximately 64 species out of a total of the 481 recorded have been listed as new records for Sri Lanka (Karunaratna and Weerakkody, 1994). They have also recorded several damselfishes (*Pomacentrus pavo*, *Pomacentrus trilineatus*, *Plectroglyphidodon*

*johnstonianus*, *Plectroglyphidodon leucozonus* and *Chromis lepidolepis*) from Rumassala that have not been recorded for Sri Lanka before. However these species have not been sited elsewhere in Sri Lanka nor has there been any confirmation of these species as new records for Sri Lanka. Twenty-five species of butterflyfish has been listed for Rumassala. A study carried out by NARA (Rajasuriya et al. 1998) reported an average of 5 individual Chaetodontids (butterflyfish) or less per transect area (500m<sup>2</sup>) for Rumassala.

Commercially important species other than ornamental fish belong to the families of Carangidae (jacks), Sphyraenidae (Barracuda), Siganidae (rabbitfish), Lutjanidae (Snappers) and Lethrinidae (Emperors) and other reef associated organisms such as cuttlefish, octopus, spiny lobsters and molluscs. Soft corals, hydrocorals, sponges, tunicates, reef shrimps, sea anemones, nudibranchs (sea slugs), crabs, starfish, sea urchins, brittle stars and sea cucumber have also been recorded.

### 3.7.2 Survey methods

The methodology used for the study was according to the Survey Manual for Tropical Marine Resources (English et al. 1997). A total of seven 50m Line Intercept Transects (LIT) were carried out on the coral area to determine the percentage of live coral, dead coral and coral rubble (Fig.3.15). Fish abundance was estimated along the LIT by a scuba diver swimming the length of the transect and by counting fish in an area 2.5m on either side of the tape and in the water column. Thus 250m<sup>2</sup> area of the reef was covered for each fish abundance plot. Line Intercept Transects was not used on reef sections 'A' and 'E' due to extremely low live coral in section 'A' and as live coral cover could not be measured on vertical rock surfaces in section 'E'. The percentages of live coral in these two sections were estimated using the visual estimation technique [after Dahl (1981) in English et al, 1997] where the coral cover in the area covered by the field of vision was estimated. In addition a wide area around the coral reef was investigated using scuba to record the species diversity of corals and to obtain the condition of coral colonies outside the area of the LIT. Corals, fish and other organisms were recorded up to the level of genus and to the level of species wherever possible. Three sets of coral and sediment samples were collected near the coral reef to determine the content of heavy metals and pesticides.

### 3.7.3 Results

#### 3.7.3.1 Descriptions of reef sections

The reef area was divided into 05 sections namely A, B, C, D and E (Figure 3.15) in order to elucidate the characteristics of each section. Individual descriptions of these sections are given below. The reef is made up of four main areas with coral with the largest section (B) in the center flanked by two smaller sections (A & C) on either side. The depth range of the coral reef varied from very shallow coral patches near the surface to about 5m. The shallowest sections of the reef (A, B & C) are close to the shore. The other section (D) which is made up of spur and groove coral formations gradually deepens from 3 to 5m towards the northwest (center of the Galle Bay). Each spur has a low relief of less than 1m and is about 1.5m wide. The sandy grooves between the spurs are also about 1.5m in width. Beyond this section there were scattered coral colonies at a depth of about 5m.

##### Reef section 'A'

Prior to bleaching this section contained mainly massive coral formations (*Porites* spp., *Goniastrea* spp., *Favia* spp., *Favites* spp., *Platygyra* spp.) as well as a small area with branching corals of *Pocillopora* spp. At present this section is dominated by dead coral, except a few medium sized (about 0.5m diameter) colonies belonging to the families of Faviidae and Poritidae. Live coral cover was visually estimated to be less than 2%, as Line Intercept Transects was not carried out on this patch due to the scarcity of corals.

Fish abundance was studied in this section but the abundance was extremely low due to the poor quality of the reef. Less than 10 individuals of *Neopomacentrus asyzyon* were recorded as well as individual specimens of *Chrysiptera leucopoma* and *Chrysiptera unimaculatus*.

##### Reef section 'B'

Prior to bleaching this section contained the most amount of live corals among the shallow sections of the reef and was dominated by branching *Acropora* spp., *Pocillopora* spp. and *Montipora* spp. At present most of the branching *Acropora* spp. and *Pocillopora* spp. have been completely destroyed and live coral cover was about 6%. Dead coral now dominates this section of the reef. A few colonies of *Goniastrea retiformis*, *Pocillopora verrucosa* and *Montastrea valenciennesi* were present.

Damselfish (*Abudefduf vaigiensis* & *Neopomacentrus asyzyon*) were abundant. Only 02 butterflyfish (*Chaetodon trifasciatus*) have been recorded. A total of 14 species of fish were recorded within the transects.

#### Reef section 'C'

This section contained much live coral dominated by *Porites rus*, *Favites* spp., *Favia* spp., *Goniastrea* spp., *Platygyra* spp., *Montipora aequituberculata* as well as small patches of branching *Acropora* spp. After the bleaching this section has lost most of the formerly dominant species and species that were not affected by the bleaching (*Porites rus*, *Montipora aequituberculata*) have now become the dominant corals in this section. *Porites rus* has colonized much of the dead coral surfaces. The live coral cover in this section was about 33%.

*Neopomacentrus asyzyon* (damselfish) were abundant, over 200 individuals have been recorded within this section. Five individuals of two species of butterflyfish (*Chaetodon decussatus* & *Chaetodon trifasciatus*) were present during the survey. A total of 27 species were recorded within the transects.

#### Reef section 'D'

Section 'D' is at a depth of about 3 to 5m and contain spur and groove coral formations. Each spur has a low relief of less than 1m and is about 1.5m wide. The sandy grooves between are about 1.5m in width. The spurs were formally dominated by species of *Acropora*, *Montipora* and *Echinopora*. These corals were destroyed by the bleaching and are being recolonized mainly by *Acropora valida*, *Montipora aequituberculata* and *Echinopora lamellosa* corals among other species. There are also large *Porites* domes about 2 m in diameter and about 1.5 m high scattered among the deeper areas of the spur and groove formations. At present this section has the most vibrant coral growth and rapid colonization. Live coral cover was about 25%.

Damselfish *Neopomacentrus asyzyon* (46 individuals) and *Pomacentrus similis* (35 individuals) have been recorded. Five species of butterflyfish (*Chaetodon citrinellus*, *C. guttatissimus*, *C. trifascialis*, *C. trifasciatus* and *C. plebeius*) were also recorded. In total 32 species were recorded in section 'D' which was the highest number of species recorded in areas where transects were carried out.

## Reef section 'E'

Section 'E' contains a few large domes of *Porites* and many small (0.25m) and medium (0.5m) diameter massive corals (*Symphyllia*, *Platygyra*, *Oulophyllia*, *Hydnophora*, *Favites*, *Favia*, *Porites*). There were also colonies of *Turbinaria* spp. with a diameter of up to 1m. Large boulders on the edge of the cliff in Section 'E' support encrusting species such as *Acanthastrea echinata*, *Pavona varians*, *Plesiastrea versipora* and massive corals of *Diploastrea heliopora* and *Symphyllia radians*. A Line Intercept Transect was not carried out in section 'E' due to the corals growing on vertical and angled surfaces of rocks. A visual estimation of the live coral in this section was about 10%.

Transects for fish abundance and diversity was not carried out in this section due to the angled rock surfaces and the difficulties in observing fish due to the terrain.

The average live coral cover at Rumassala has been reduced from about 45% in 1997 (Rajasuriya et al. 1998) to 19.6% at present (Table 3.19). The loss of live corals can be attributed mainly to the bleaching event in April-May 1998. The Rumassala reef has a higher percentage of live corals at present when compared to the live coral cover at Unwatuna (< 1%) and Hikkaduwa (7%) indicating that the recovery of the coral reef at Rumassala after the coral bleaching event in 1998 has been better than at Unwatuna and Hikkaduwa. However low rates of recovery at Hikkaduwa could be due to other reasons such as sand and sediment accumulation, reef trampling by visitors, damage caused by glass bottom boats and excessive growth of *halimeda*. Strong wave action may inhibit settling and growth of new colonies at Unawatuna. A total of 45 species of corals divided among 30 genera has been identified at Rumassala during the present study (Table 3.20).

Fifty-two species of fish divided among 32 genera was listed within the belt transects. The most common fish within the study area were damselfishes (Pomacentridae) where 588 individuals have been recorded followed by 68 wrasses, 36 surgeonfish and 21 butterflyfish (Table: 3.21). *Neopomacentrus asyzyon* (damselfish) was the most common species where 446 individuals have been encountered within the study area. Most of the invertebrates have been recorded within section 'C' (Table 3.22).

Table 3.19 Percent cover of substrate components (results from a total of seven, 50m line intercept transects)

Category	Percentage
Live coral	19.6
Dead coral	43.0
Others (old limestone, coral rock, coral rubble & sand)	37.4

Table 3.20 Percent composition of live coral species on the line intercept transects at Rumassala

Species	Composition (%)
<b>Acroporidae</b>	
<i>Acropora valida</i>	1.314
<i>Acropora rudis</i>	0.057
<i>Acropora</i> spp.	0.086
<i>Montipora aequituberculata</i>	0.857
<i>Montipora</i> spp.	5.769
<b>Faviidae</b>	
<i>Favia favius</i>	0.143
<i>Favites</i> sp.	0.029
<i>Leptoria phrygia</i>	0.786
<i>Echinopora lamellosa</i>	0.543
<i>Echinopora</i> sp.	0.129
<b>Mussidae</b>	
<i>Acanthastrea echinata</i>	0.143
<b>Merulinidae</b>	
<i>Hydnophora microconos</i>	0.057
<b>Pocilloporidae</b>	
<i>Pocillopora verrucosa</i>	0.086
<i>Pocillopora damicornis</i>	0.623
<b>Poritidae</b>	
<i>Porites rus</i>	7.614
<i>Porites</i> spp.	1.343
Percentage of live coral	19.579

Table 3.21 Coral species diversity at Rumassala

Coral	Comments
<p>Acroporidae</p> <p><i>Acropora valida</i></p> <p><u><i>Acropora aculeus</i></u></p> <p><i>Acropora rudis</i></p> <p><i>Acropora</i> sp.</p> <p><u><i>Astreopora gracilis</i></u></p> <p><i>Montipora aequituberculata</i></p> <p><i>Montipora verrucosa</i></p> <p><i>Montipora danae</i></p> <p><i>Montipora</i> sp.</p>	<p>Sparsely distributed, app 50 –100 cm diameter</p> <p>Uncommon, colonies up to 10 cm diameter</p> <p>Uncommon, colonies up to 15 cm diameter</p> <p>Uncommon, colonies up to 15 cm diameter</p> <p>Not abundant, 100 cm diameter colonies in 3-5 m depth</p> <p>Mainly in the shallow parts of the reef</p> <p>Not abundant, occurs mainly 3 – 4 m depth range</p> <p>Not abundant, occurs mainly 3 – 4 m depth range</p> <p>Relatively common, 3-4m depth, colonies up to 100cm diameter</p>
<p>Agariciidae</p> <p><i>Pavona varians</i></p> <p><i>Pavona venos</i></p>	<p>Not abundant, up to 40 cm diameter</p> <p>Not abundant, up to 20 cm diameter</p>
<p>Dendrophyllidae</p> <p><i>Turbinaria peltata</i></p> <p><i>Turbinaria</i> sp.</p> <p><i>Denrophyllia</i> sp</p>	<p>Not abundant, 50 – 100 cm diameter colonies</p> <p>Relatively common in the 4 – 5 m depth range, colonies up to 30 cm.</p> <p>Mainly near watering point undersides of large boulders</p>
<p>Faviidae</p> <p><i>Favites abdita</i></p> <p><i>Favites chinensis</i></p> <p><i>Favites flexuosa</i></p> <p><i>Favia favius</i></p> <p><i>Cyphastrea chalcidicum</i></p> <p><i>Goniastrea retiformis</i></p> <p><i>Plesiastrea versipora</i></p> <p><i>Platygyra lamellina</i></p> <p><u><i>Platygyra pini</i></u></p> <p><i>Leporia phrygia</i></p> <p><i>Echinopora lamellosa</i></p> <p><i>Montastrea valenciennesi</i></p> <p><i>Oulophyllia crispa</i></p> <p><i>Leptastrea purpurea</i></p> <p><i>Diploastrea heliopora</i></p>	<p>Relatively common, colonies up to 30 cm diameter</p> <p>Relatively common, colonies up to 50 cm diameter</p> <p>Uncommon, colonies 20 – 30 cm diameter</p> <p>Relatively common, small colonies 8 – 10 cm diameter</p> <p>Common, small colonies at 3 – 5 m depth range,</p> <p>Not abundant, colonies up to 100 cm diameter</p> <p>Not abundant, colonies up to 50 cm diameter</p> <p>Not abundant, colonies up to 40 cm diameter</p> <p>Common, mainly in the shallow sections, colonies up to 50 cm diameter</p> <p>Common, colonies up to 100cm diameter</p> <p>Common, 1- 2 m diameter colonies at 3 – 4 m depth range</p> <p>Relatively common, 20 –30 cm diameter colonies</p> <p>Not common, colonies up to 50 cm diameter</p> <p>Common, colonies 8 – 10 cm diameter</p> <p>Not abundant, up to 70 cm diameter, mainly near watering point</p>
Fungidae	
<p><i>Fungia repanda</i></p> <p><i>Podabacia crustacea</i></p>	<p>Uncommon, about 15 cm diameter</p> <p>Common, up to 30 cm diameter</p>

Merulinidae <i>Hydnophora microconos</i>	Not abundant, colonies up to 100 cm diameter
Mussidae <i>Acanthastrea echinata</i> <i>Symphyllia radians</i>	Not abundant colonies up to 75 cm diameter, mainly near watering point Not abundant, colonies up to 100 cm diameter
Oculinidae <u><i>Galaxea fascicularis</i></u>	Small colonies up to 30 cm diameter common in the shallow sections
Pectiniidae <u><i>Echinophyllia aspera</i></u>	Not abundant, 20 50 cm diameter colonies
Pocilloporidae <i>Pocillopora verrucosa</i> <i>Pocillopora damicornis</i> <u><i>Pocillopora eydouxi</i></u>	Not abundant, colonies 10 – 12 cm diameter Not abundant, colonies 5 – 10 cm diameter Uncommon, colonies 20 to 30 cm diameter
Poritidae <i>Porites lutea</i> <i>Porites rus</i> <i>Porites</i> sp. <i>Goniopora</i> sp.	Common, some large (1- 1.5 m diameter) colonies Common in the shallow southern section Uncommon, 10 – 15 cm diameter Uncommon, 20 – 30 diameter
Siderastreidae <i>Coscinaraea</i> sp. <u><i>Psammacora digitata</i></u>	Uncommon, colonies up to 25 cm diameter Uncommon, colonies up to 30 cm diameter

Table 3.22 Fish species diversity at Rumassala, recorded within the seven study plots (Belt transects for fish counts)

Reef Fishes	Comments
<b>Angel fish</b> <i>Centropyge multispinis</i>	Only two specimens were recorded within the transects, however this species is common in Sri Lanka
<b>Damsel fish</b> <i>Abudefduf vaigiensis</i> <i>Chromis dimidiata</i> <i>Chromis opercularis</i> <i>Chrysiptera leucopoma</i> <i>Dascyllus reticulatus</i> <i>Dascyllus</i> sp <i>Dascyllus trimaculatus</i> <i>Neopomacentrus azysron</i> <i>Plectroglyphidodon lacrymatus</i> <i>Pomacentrus philippinus</i> <i>Pomacentrus similis</i> <i>Pomacentrus</i> sp.	A total number of 588 individuals were recorded within the study plots out of which 446 were <i>Neopomacentrus azysron</i> . The lowest abundance was recorded in <i>Chromis dimidiatus</i> , <i>Plectroglyphidodon lacrymatus</i> , <i>Pomacentrus philippinus</i> . Except for <i>Chromis dimidiatus</i> , which is widely distributed but not found in large numbers at any given location the other two, species are common in Sri Lanka.
<b>Butterfly fish</b> <i>Chaetodon citrinellus</i> <i>Chaetodon decussatus</i> <i>Chaetodon guttatissimus</i> <i>Chaetodon plebeius</i> <i>Chaetodon trifacialis</i> <i>Chaetodon trifasciatus</i>	A total of 21 butterfly fish were recorded within the study plots. <i>Chaetodon trifasciatus</i> was the most common species, 11 individuals were recorded.
<b>Surgeon fish</b> <i>Acanthurus blochii</i> <i>Acanthurus lineatus</i> <i>Acanthurus leucosternon</i> <i>Acanthurus pyroferus</i> <i>Acanthurus</i> sp	Among 36 individuals of surgeonfish <i>Acanthurus blochii</i> and <i>A. lineatus</i> were the most abundant.
<b>Snappers</b> <i>Lutjanus bohar</i> <i>Lutjanus gibbu</i>	Only two individuals were recorded in the 7 study plots
<b>Groupers</b> <i>Epinephelus hexagonatus</i> <i>Epinephelus longispinis</i>	Only 3 individuals have been recorded
<b>Wrasses</b> <i>Cheilinus chlorourus</i> <i>Gomphosus caeruleus</i> <i>Halichoeres marginatus</i> <i>Halichoeres hortulanus</i> <i>Hemigymnus melapterus</i> <i>Labroides dimidiatus</i> <i>Stethojulis</i> sp <i>Thalassoma hardwicke</i> <i>Thalassoma lunare</i> <i>Thalassoma</i> sp	Among 68 individuals <i>Thalassoma lunare</i> , <i>T. hardwicke</i> and <i>Halichoeres marginatus</i> were the most abundant. All species of wrasses recorded during this study are common in Sri Lanka.
<b>Goat fish</b> <i>Parupeneus barberinus</i> <i>Parupeneus indicus</i>	<i>Parupeneus barberinus</i> was the dominant species out of 15 individual goatfishes.

Reef Fishes	Comments
<b>Trigger fish</b> <i>Balistapus undulatus</i>	Only one specimen was recorded. This species is common in SL.
<b>Monocle Breams</b> <i>Scolopsis bimaculatus</i>	Seven individuals were recorded. A common species in SL.
<b>Parrot fish</b> <i>Scarus sp</i>	Only one parrotfish has been recorded. Parrotfish are common.
<b>Puffer fish</b> <i>Arothron meleagris</i>	Only one specimen has been recorded. Widely distributed in SL although not abundant.
<b>Emperors</b> <i>Lethrinus harak</i> <i>Monotaxis grandoculus</i>	Four snappers have been recorded. Both are common species.
<b>Squirrel fish</b> <i>Sargocentron sp</i>	Two individuals recorded. Mainly nocturnal therefore daytime sightings are not good indicators of squirrel fish abundance.
<b>Hawk fish</b> <i>Paracirrhites forsteri</i>	One individual recorded. Widely distributed but not abundant.
<b>Gobies</b> <i>Valenciennesia strigata</i>	Four individuals have been recorded. Common in SL
<b>Cardinal fish</b> <i>Apogon sp</i>	Nineteen individuals recorded. Common in SL
<b>Cornet fish</b> <i>Fistularia commersonii</i>	Five individuals recorded. Common in SL
<b>Lizard fish</b> <i>Synodus sp</i>	Five individuals recorded. Common in SL

Table 3.23 Fish density within the seven studies plots (07 Belt transects for fish counts)

Fish	Total No.	Density (m <sup>2</sup> )
Pomacanthidae (Angel fish)	2	0.001
Pomacentridae (Damsel fish)	588	0.336
Chaetodontidae (Butterfly fish)	21	0.012
Acanthuridae (Surgeon fish)	36	0.021
Lutjanidae (Snappers)	2	0.001
Serranidae (Groupers)	3	0.002
Labridae (Wrasses)	68	0.039
Mullidae (Goat fish)	15	0.009
Balistidae (Trigger fish)	1	0.001
Nemipteridae (Monocle Breems)	7	0.004
Scaridae (Parrot fish)	1	0.001
Tetraodontidae (Pufferfish)	1	0.001
Lethrinidae (Emperors)	4	0.002
Holocentridae (Squirrelfish)	2	0.001
Cirrhitidae (Hawkfish)	1	0.001
Gobiidae (Gobies)	4	0.002
Apogonidae (Cardinalfish)	19	0.011
Aulostomidae (Cornetfish)	5	0.003
Synodontidae (Lizardfish)	5	0.003

Table 3.24 Invertebrate diversity at Rumassala, recorded within the seven study plots (07 belt transects)

Organism	Comments
Cuttlefish	Common in SL
Nudibranchs	Unidentified species, Many species are present in SL
Octopus	Common in SL
Sea cucumber	<i>Holoturia atra</i> , Common in SL
Sea urchins	<i>Diadema setosum</i> , Common in SL
Tube worms	Common in SL

Table 3.25 Density of Invertebrates recorded within the seven study plots

Invertebrates	Total No	Density (m <sup>2</sup> )
Nudibranchs	1	0.001
Sea cucumber	9	0.005
Sea urchin	8	0.005
Tube worms	1	0.001

### 3.7.3.7 Occurrence of rare and vulnerable species

During the present survey corals or fish species specific to Rumassala were not encountered. But it must be emphasized that corals such as *Porites rus*, which resisted bleaching in 1998, is found mainly at Rumassala in the entire southern coast. Furthermore live coral has become scarce on many shallow water reefs after the bleaching event in 1998 and as such all corals should be considered as vulnerable organisms. A number of reef associated species, particularly butterflyfish have become very rare due to loss of live corals. One Hawksbill sea turtle (*Eretmochelys imbricata*) with a carapace length of approximately 60cm was present among the corals during the present survey.

### 3.7.3.8 Human activities

The Rumassala beach is a popular site for recreation among Sri Lankans; foreign tourists use the beach occasionally. Snorkeling is not a popular pastime among visitors to this site. The coral reef is used mainly for harvesting ornamental fish and invertebrates for the aquarium industry. Local fishermen use motorized as well as non-motorized small boats (02 catamarans and one 18ft-fiberglass boat) to harvest edible species. Rod and line fishing is carried out along the watering point. Karunarathna and Weerakkody (1994) had recorded Holocentrids (squirrel & soldierfish), Pempherids (sweepers) and Apogonids (cardinalfish) in the catch. According to them bottom set nets were used to harvest spiny lobsters and gillnets with mesh size of 38mm was used in the Rumassala bay. The use of handlines from the catamarans was also observed during surveys carried out by NARA. However there are unconfirmed reports of blast fishing at this location. Although most edible species are harvested outside the coral reef habitat, according to Karunarathna and Weerakkody (1994) large shoals of *Caranx* (jacks), *Rastrelliger* (Indian mackerel) and *Sphyrna* (Barracuda) were dynamited within the Rumassala reef in 1993-1994 and several dead fish killed by explosives had been observed during their surveys. A pearl oyster culture project was carried out in the late 1980's on the northern side of the watering point. NARA carried out experiments in growth rates and production of edible oysters at the same location in early 1990s.

In recent times the condition of the reef has been degrading steadily due to human activities such as walking on corals, removal of corals for souvenirs, uncontrolled collection of ornamental species and environmentally damaging harvesting techniques and sediment deposition. This degradation resulted in parts of the reef being colonized by a number of invasive organisms such as colonial tunicates and algae.

Further, three live coral samples were taken from Rumassala and analyzed for the Chemical contamination at CISIR (Figure 3.16). Table 3.26 shows the organo-chloride contents of 3 coral samples in terms of DDE, DDD, DDT and PCBs. Results manifest that all the samples are not contaminated with any pollutants.

Table 3.26 Organo – Chloride contents of 3 coral samples at Rumassala

Test Values, $\mu\text{g/kg}$			
Test	Specimen 6	Specimen 7	Specimen 8
P,p' DDE	< 2	< 2	< 2
P,p' DDT	< 2	< 2	< 2
P,p' DDT	< 2	< 2	< 2
P,p' DDD	< 2	< 2	< 2
P,p' DDD	< 2	< 2	< 2
Total DDT	< 2	< 2	< 2
PCB 28	< 2	< 2	< 2
PCB 52	< 2	< 2	< 2
PCB 101	< 2	< 2	< 2
PCB 118	< 2	< 2	< 2
PCB 138	< 2	< 2	< 2
PCB 153	< 2	< 2	< 2
PCB 180	< 2	< 2	< 2

Table 3.27 indicates the concentrations of heavy metals present in the coral samples. Results elaborate that the corals are not yet contaminated with the heavy metals at Rumassala.

Table 3.27 Heavy metal contents of 3 coral samples at Rumassala

Test Values, $\mu\text{g/kg}$			
Test	C1	C2	C3
Mercury (as Hg), mg/kg	< 0.4	< 0.4	< 0.4
Zinc (as Zn), mg/kg	9	6	9
Chromium (as Cr), mg/kg	< 10	< 10	< 10
Cadmium (as Cd), mg/kg	< 4	< 4	< 4
Lead (as Pb), mg/kg	< 20	< 20	< 20
Nickel (as Ni), mg/kg	< 20	< 20	< 20