State of the Environment Report

2001

Republic of Maldives

Ministry of Home Affairs, Housing and Environment

CONTENTS

List of Figures and Tables

1 INTRODUCTION

This state of the environment report is the first in a series of reports to be produced in response to the strategy of environmental assessment outlined in the second National Environment Action Plan. NEAP II calls for continuous assessment of the state of environment of Maldives, including impacts of human activities on land, freshwater, lagoons, reefs and the ocean and the effects of these activities on human health.

In the Maldives, the principle of sustainable development is fully embraced by the government and the people. Pursuing sustainable development is not possible without adequate and accessible information. In achieving sustainable development, there is concern about aspects of environmental quality such as climate change, loss of biodiversity, quality of water resources and erosion of beaches. Decision makers need reliable data on these and other key indicators of the state of the environment. The public also needs to know how the environment is changing.

State of the environment reporting is one of the most useful tools for informing about the environment. It describes the present conditions and trends in the environment as well as pressures or stresses and strains on the condition of the environment caused by human activities. It also provides an opportunity to track performance levels of response measures undertaken to address the pressures.

This state of environment report has three main chapters. The state of the physical environment: the atmosphere, the land, marine and coastal areas, freshwater and biological diversity is described in the first chapter. The second chapter identifies the main pressures on the environment such as population, housing, human settlements, waste disposal, freshwater use, energy use, transport, sewage disposal, fisheries and tourism. The pressures chapter also covers issues such as climate change and natural disasters. The third chapter of the state of the environment report contains the responses taken in the Maldives over the last five years to address the critical environmental concerns.

The Maldives first produced a state of the environment report for the United Nations Global Conference on the Sustainable Development of Small Island States in Barbados in 1994. This report presented a descriptive overview of trends in development and

environmental conditions at that time. The present state of the environment report builds on the first report and presents new data sets and new information. The present report uses the best available scientific information and presents accurate data and information in a balanced way and without bias or modification.

The state of the environment report 2001 is produced by the Ministry of Home Affairs, Housing and Environment, in close consultation with relevant government agencies as well as private institutions. The report uses a range of data sources including those presented in the Statistical Year Book 2001 published by the Ministry of Planning and National Development.

This report also serves to meet some of the reporting requirements of international organizations of which Maldives is a member. The decision of the meeting of the Environment Ministers of the South Asian Association for Regional Co-operation (SAARC) and the Global Environment Outlook process of the United Nations Environment Programme (UNEP) brings with it reporting obligations on the condition of the Maldives environment. The Regional Office for Asia and the Pacific of the United Nations Environment Programme through their Environment Assessment Center provided technical assistance to the reporting process.

This report attempts to provide comprehensive and useful information on the state of the environment of Maldives. The Ministry of Home Affairs, Housing and Environment will welcome any comments the reader may have on the reported data, the framework or on the approach.

2 STATE OF THE ENVIRONMENT

2.1 Geography and Land

The Maldives consists of a chain of coral atolls, 80-120km wide, stretching 860km from latitude $7^0$6'35"N to $0^0$42'24"S, and lying between longitude $72^0$33'19"E to $73^0$46'13"E. These coral atolls are located on the 1600km long Laccadives-Chagos submarine ridge extending into the central Indian Ocean from the south-west coast of the Indian sub-continent. The Maldives shares boundaries of its Exclusive Economic Zone (EEZ) with Sri Lanka and India on the northeast and the Chagos Islands on the south.

It is believed that the Maldives was formed about 65 –225 million years ago in the Mesozoic Era (Maniku 1990). There is more than a single theory on how the Maldives was formed, and one of them suggests that the Maldives grew above foundered continental crustal segments (Maniku 1990). Gardiner (1902, 1903) hypothesises that the main Maldives plateau was formed by current erosion and then subsequently atolls were formed by the growth of organisms on this plateau.

There are 26 geographic atolls in the Maldives and they vary enormously in shape and size. The largest atoll is Huvadhu Atoll with an area of approximately 2800km^2 (MPND 2000) and the smallest atoll Thoddoo Atoll has an area in the order of 5.4km^2 (MHAHE 2001). The characteristics of the atolls, reefs and reef islands vary considerably from north to south. The northern atolls are broad banks, discontinuously fringed by reefs with small reef islands and with numerous patch reefs and faros in the lagoon (Woodroffe 1989). In the southern atolls, faros and patch reefs are rarer in the lagoon, the continuity of the atoll rim is greater, and a larger proportion of the perimeter of the atolls is occupied by islands.

A total of 1192 islands are found in the chain of 26 geographic atolls, and the islands differ depending on location, form and topography (Woodroffe 1989). The islands vary in size from 0.5 km^2 to around 5.0 km^2 and in shape from small sandbanks with sparse vegetation to elongated strip islands. Many have storm ridges at the seaward edges and a few have swampy depressions in the centre. The largest island is Gan in Laamu Atoll with an area 5.16 km2 (MPND 2000). A detailed land survey of the entire Maldives has

not been undertaken yet and according to rough estimates, the total land area of the Maldives is about 300 km2. The distribution of inhabited islands by island size is shown in figure 2.3 and the ten largest islands in the Maldives are given in table 2.1.

Figure 2.1: Location Map

Figure 2.2: Map of Maldives

Figure 2.3: Distribution of inhabited islands by island size

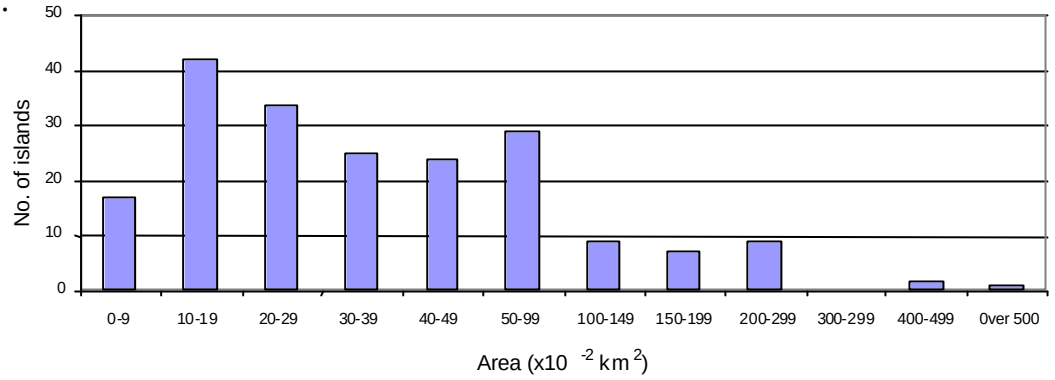


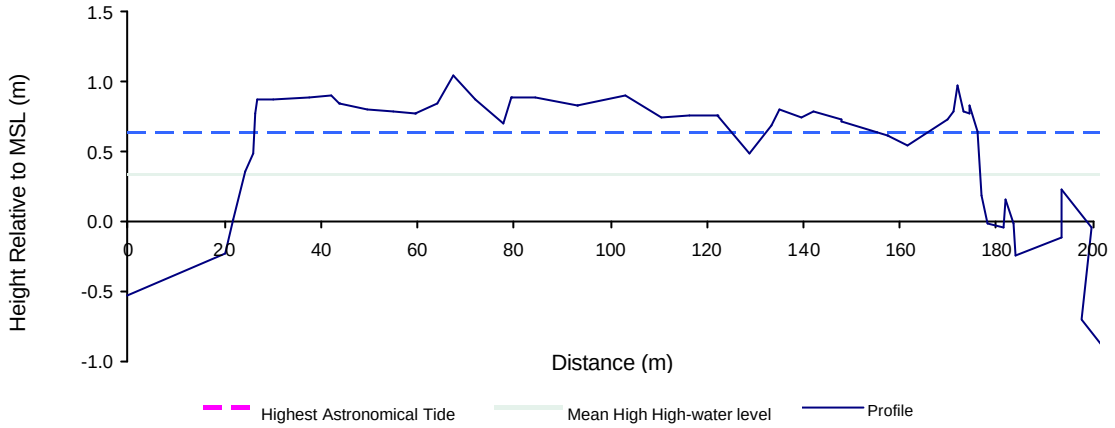
Table 2.1: Ten largest islands of the Maldives

Atoll	*Island Name*	*Area (km^2)*	*Population (2000)*
1. Laamu	Gan	5.166	2244
2. Seenu	Hithadhoo	4.673	9461
3. Gnaviyani	Fuvah Mulah	4.200	7528
4. Laamu	Isdhoo	2.937	1432
5. Kaafu	Kaashidhoo	2.765	1572
6. Seenu	Gan*	2.649	-
7. Gaafu Dhaalu	Gan**	2.636	-
8. Haa Dhaalu	Hanimaadhoo	2.595	1009
9. Haa Alifu	Baarah	2.488	1270
10. Haa Alifu	Filladhoo	2.256	659

** - industrial / airport*
*** - uninhabited*

The maximum height of land above mean sea level within the Maldives is around 3 metres and around 80% of the land area is less than 1 metre above mean high tide level (MHAHE 1999). Figure 2.4 shows a cross-sectional profile across an island (Dhekaambaa) showing the typical height of an island with respect to the tide levels.

Figure 2.4: Elevation of a typical island of the Maldives



The 26 geographical atolls in the Maldives are grouped into 20 administrative regions. These administrative regions are also referred to as atolls. The capital, Male' forms a separate administrative unit (table 2.2). Out of the 1192 islands 199 are inhabited (MPND 2000) and 86 have been developed as tourist resorts (MoT 2001).

Table 2.2: Administrative Regions, Atolls and Islands

Atoll Code	Atoll Name	Alternative Atoll Name	Inhabited Islands	Industrial Islands	Airports	Resorts (2000)
A	Thiladhunmathi Uthuru Buri	Haa Alifu	16	2		
B	Thiladhunmathi Dhekunu Buri	Haa Dhaalu	16	7	1	
C	Milandhunmadulu Uthuru Buri	Shaviyani	15	5		
D	Milandhunmadulu Dhekunu Buri	Noonu	13	4		
E	Maalhosmadulu Uthuru Buri	Raa	15			1
F	Maalhosmadulu Dhekunu Buri	Baa	13	4		4
G	Faadhippolhu	Lhaviyani	5	8		4
H	Male'	Kaafu	9	7	1	43
U	Ari Atholhu Uthuru Buri	Alifu Alifu	8			11
I	Ari Atholhu Dhekunu Buri	Alifu Dhaalu	10	1		16
J	Felidhe Atholhu	Vaavu	5			2
K	Mulakatholhu	Meemu	9	1		2
L	Nilandhe Atholhu Uthuru Buri	Faafu	5	1		1
M	Nilandhe Atholhu Dhekunu Buri	Dhaalu	8	1		2
N	Kolhumadulu	Thaa	13	5		
O	Hadhdhunmathi	Laamu	12	7	1	
P	Huvadhu Atholhu Uthuru Buri	Gaafu Alifu	10	1		
Q	Huvadhu Atholhu Dhekunu Buri	Gaafu Dhaalu	10	2	1	
R	Fuvahmulah	Gnaviyani	1			
S	Addu Atholhu	Seenu	6		1	
T	Male' (Capital)		1			
	MALDIVES		199	56	5	86

2.2 Marine and Coastal Areas

The dominant natural environment of the Maldives is the marine environment. Outside the atolls the deep ocean covers a large area, and the Exclusive Economic Zone (EEZ) and the territorial waters of the Maldives cover an area of 859,000km^2 and 115,300km^2 respectively. Lagoons, reefs and to a lesser extent sea grass and wetland areas make up the marine environment inside the atolls. The lagoon and reef areas make up about 21,300 km^2 (MPHRE 1998).

The water depth varies considerably within the Maldivian waters. Lagoon waters within the atolls have depths ranging from 30 – 80m with the depth generally increasing from northern to southern atolls. Most lagoons of the atolls open into the Indian Ocean, and channels through the atoll margin are in some instances as deep as the lagoon itself. At the outer margins of the two atoll chains the ocean floor falls abruptly to great depths measuring up to 2000m or more. However, at the inner side of the two atoll chains the ocean floor has less depth. The main channel separating the eastern and western chain of atolls is generally between 250 and 300m deep. The east-west channels that separate the atolls are deeper with depths more than 1000m.

Atoll lagoons enclose a variety of reef structures including faros, micro-atolls, patch reefs and knolls. Faros are ring shaped reefs emerging during tidal low water, each with their own sandy lagoon and a rim of living coral consisting of branched and massive corals. Deep channels surround these reefs and faros are unique to the atolls of the Maldives. Patches rise to 30m above the lagoon floor the top of which have robust wave-breaking corals. Knolls do not reach the surface and often support profuse coral growth (Naseer 1997).

The reefs associated with islands have the general characteristics described by Bianchi et al for the fringing reef around Alimatha island (Risk and Sluka 2000). The island itself is sand, changing to coral rubble as the reef edge is approached. The outer slopes are very steep and area down to about 15m is covered with lush coral on a healthy reef. The outer reef slope is characterised by a series of reef terraces at depths of 3-6m, 13-30m, and a deeper one at 50m representing past sea level still strands. The modern coral growth is veneer over older reef rock, but the existing community is constructional down to a depth of at least 50m. In the upper levels reef building is by

zooxanthellate corals. In deeper zones reef building is sometimes by azooxanthellate branching coral. Boring organisms found in Maldivian corals include several species of *Lithophaga* , various *polychaete* worms and several species of boring sponges. The blue boring sponge *Cliona schmidtii* is very common in the Maldives.

A geochemical analysis of the reefs emphasized the relatively pristine nature of the Maldives marine environment. Analysis of coral skeletons for common heavy metals showed values that were below detection limits in all cases. Values for extraneous organics in coral tissues were found to be typically low except for hydrocarbon residues found in corals near an island which stores fuel (Risk and Sluka 2000).

The white sandy beaches and the vegetation found on the island periphery are very important in the Maldives island ecosystem. They form an important protection for the housing and infrastructure near to the shore, and are the main source of income for the tourism industry. Of the tourists visiting the Maldives, it has been identified that 70% visit primarily for beach holidays.

Beach erosion is now among the most serious environmental issues facing the islands of Maldives. On many islands, the sand at the beach and shoreline are being washed off at a greater rate than it is accreted. The process of coastal erosion and accretion is extremely complex with interrelations to climatic, geological, oceanographic, biological and terrestrial processes affecting the growth and stability of the reefs and island structures. As the beach systems are highly dynamic in nature, the prevailing seasonal conditions may gradually shift the shape as well as the position of the island by strong beach erosion and accretion on either side of the island. The general and natural movement of sand and sediment is that during one monsoon the sand and sediments are gradually washed off (eroded) from one side of the island and are carried along the shoreline to the other end of the island. This process reverses during the next monsoon with sand being deposited (accreted) at the previously eroded side of the island.

Since, almost all human settlements, vital infrastructure and industry lie very close to the beach, coastal erosion threatens to damage houses, schools, and other infrastructure. According to records kept by the Ministry of Home Affairs, Housing and Environment, at present nearly 50 percent of all inhabited islands and nearly 45 percent of tourist

resorts suffer varying degrees of coastal erosion (MHAHE 2000). Islands that have reported severe beach erosion since 1990 are given in box 2.1 and 2.2.

Box 2.1: Islands that have reported severe beach erosion

South Thiladhunmathi	Malé Atoll	South Nilandhe Atoll
Neykurendhoo	Thulusdhoo	Meedhoo
Nolhivaranfaru	Guraidhoo	
	Huraa	Kolhumadulu
North Miladhunmadulu	Maafushi	Buruni
Bilehfahi	Villigilli	Dhiyamigili
Firubaidhoo		Gaadhiffushi
Funadhoo	North Ari Atoll	Guraidhoo
Komandoo	Bodufolhudhoo	Hirilandhoo
	Himandhoo	Kandoodhoo
South Miladhunmadulu	Mathiveri	Kibidhoo
Holhudhoo	Rasdhoo	Madifushi
Kuredhivaru	Thoddoo	Omadhoo
Maalhendhoo	Ukulhas	Thimarafushi
Velidhoo		Vandhoo
	South Ari Atoll	Veymandoo
North Maalhosmadulu	Dhangethi	Vilufushi
Angolhitheemu	Dhigurah	
Fainu	Hangnaameedhoo	Hadhdhunmathi
Inguraidhoo	Maamigili	Kalhaidhoo
Maduvvari	Mahibadhoo	Kunahandhoo
Meedhoo	Omadhoo	Mundoo
Vahfushi		
	Felidhe Atoll	North Huvadhu Atoll
South Maalhosmadulu	Felidhoo	Dhevvadhoo
Dhonfanu	Fulidhoo	Kanduhulhudhoo
Eydhafushi	Thinadhoo	Kolamaafushi
Hithaadhoo		Kooddoo
Kamadhoo	Mulakatholhu	Villigili
Kendhoo	Kolhufushi	
Kihaadhoo	Mulaku	South Huvadhu Atoll
Kudarikilu	Naalaafushi	Hoadedhdhoo
Maalhos	Raiymandhoo	Nadallaa
		Rathafandhoo
Faadhippolhu	North Nilandhe Atoll	
Felivaru	Biledhdhoo	Fuvahmulah
Gaaerifaru	Bodu Finolhu	Fuvahmulah
Kurendhoo	Feeali	
Maafilaafushi	Magoodhoo	Addu Atoll
Vavvaru	Nilandhoo	Feydhoo
		Hulhudhoo

Box 2.2: Resorts that have reported severe beach erosion

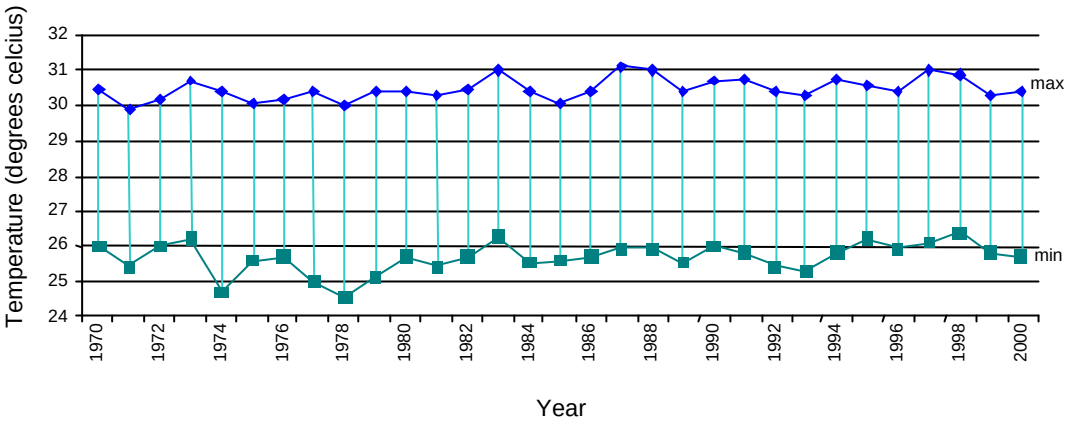
North Maalhosmadulu	North Ari Atoll
Pearl Island	Nika Hotel
	Velidhu Island Resort
South Maalhosmadulu	Gangehi Island Resort
Coco Palm Resort	Veligandu Island Resort
Kihaadhuffaru Tourist Resort	Maayafushi Tourist Resort
Reethi Beach Resort	South Ari Atoll
	Angaga Island Resort
Faadhippolhu	Ari Beach Resort
Kanuhuraa Beach and Spa Resort	Athurugau Island Resort
Komandoo	Lily Beach Resort
	Mirihi Island Resort
Male Atoll	Moofushi Island Resort
Banyan Tree	Sun Island Resort
Club Rannalhi	Thundufushi Island Resort
Emboodhoo Village	Vilamendhoo Island Resort
Fun Island Resort	
Hembadhoo	Felidhe Atoll
Ihuru Tourist Resort	Alimatha Aquatic Island
Makunudhu Island Resort	Dhiggiri Tourist Resort
Olhuveli View Hotel	
Paradise Island Resort	Mulakatholhu
Fun Island Resort	Hakuraa Huraa
Reethirah Resort	
Rihiveli Beach Resort	South Nilandhe Atoll
Taj Lagoon Resort	Vilu Reef Resort
Tari Village	

2.3 Climate

The Maldives has a warm and humid tropical climate. The weather is dominated by two monsoon periods: the south-west (rainy) monsoon from May to November; and the north-east (dry) monsoon from January to March when winds blow predominantly from either of these two directions. The relative humidity ranges from 73% to 85%.

Daily temperatures of the country vary little throughout the year with a mean annual temperature of 28°C. The annual mean maximum temperature recorded for Male' during the period 1967-1995 was 30.4°C and the annual mean minimum temperature for the same period was 25.7°C. The highest recorded temperature for Male' was 34.1°C on 16th and 28th of April 1973. The hottest month recorded was April 1975 with a maximum monthly average temperature of 32.7°C, the next highest being 32.6°C in April 1998. The lowest minimum average temperature of 23.7°C was recorded in July 1992. The average annual maximum and minimum temperature for Male' is shown in figure 2.5.

Figure 2.5: Mean Annual Average Temperatures for Male'



Rainfall patterns are measured throughout the country by eight rainfall stations and it is evident that there are variations in rainfall from north to south through the atoll chain, with the north being drier and the south wetter. Average monthly and annual rainfall for Male' are 162.4mm and 1,948.4mm respectively. There has been considerable inter-annual variation in rainfall from 1,407mm to 2,707mm over the last 30 years. Figure 2.6 shows average annual rainfall for Male' and Gan over the last 30 years. The wettest months are May, August, September and December, and the driest January to April. The wettest year was 1978 with an annual rainfall of 2707mm and the driest 1995 with 1407mm. The wettest month on record is October 1994 with 588mm and the heaviest daily rainfall recorded was on 11th October 1999 with 200mm.

Figure 2.7 shows the wind direction pattern for Malé International Airport. Winds from the north-east and the east-north-east are predominant during December to February. During March to April the direction varies with the general direction being westerly. Strong winds are associated with the southwest monsoon season. Gales are uncommon, and cyclones are very rare in the Maldives. The stormiest months are typically May, June and July. Storms and squalls producing wind gusts of 50-60 knots have been recorded at Malé. Figure 2.8 shows the average annual wind speeds for Malé.

Figure 2.6 Mean Rainfall for Malé and Gan

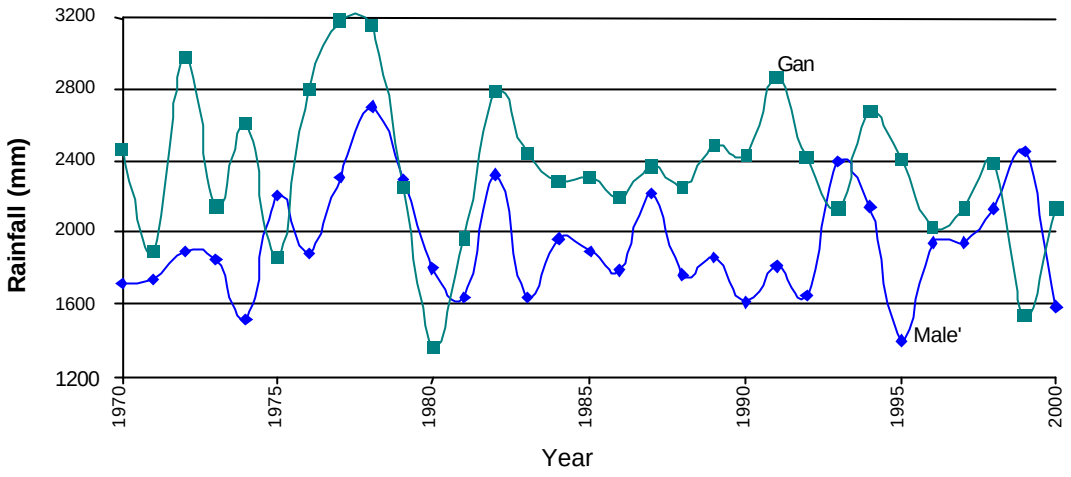
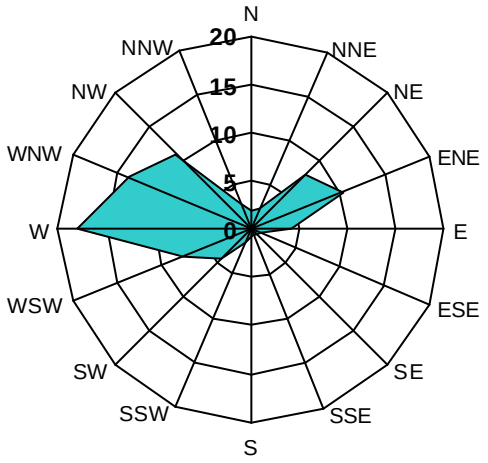


Figure 2.7: Percentage of wind direction for the Malé International Airport (1980 - 1999)



The current regime in the Indian Ocean is strongly influenced by the monsoon climate. In the region of the Maldives, the currents flow westward during the Northeast monsoon period, and they flow eastward during the South-West monsoon period. The ocean currents flowing through channels between the atolls are driven by the monsoon winds. Generally, the tidal currents are eastward in flood and westward in ebb.

The swells and wind waves experienced by the Maldives are conditioned by the prevailing biannual monsoon wind directions, and are typically strongest during April-July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 seconds have been reported in the region. However, the Maldives also experiences swells originating from cyclones and storm events occurring well south of the equator. It is reported that the swell waves

from south-east to south-south-east occur due to strong storms in the southern hemisphere in the area west of Australia with direction towards the Maldives. The swell waves that reached Male'and Hulhule in 1987 had significant wave heights in the order of 3 metres (JICA 1987). Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves.

The tides observed in the country are twice daily (semidiurnal/diurnal), and typical spring and neap tidal ranges are approximately 1.0m and 0.3m respectively (table 2.3). Maximum spring tidal range in the central and southern atolls is approximately 1.1m. There is also a 0.2m seasonal fluctuation in regional mean sea level, with an increase of about 0.1m during February - April and a decrease of 0.1m during September - November.

Table 2.3 Tidal recordings from Male' International Airport

Tide level	*Referred to Mean Sea Level*
Highest Astronomical Tide (HAT)	0.64
Mean Higher High Water (MHHW)	0.34
Mean Lower High Water (MLHW)	0.14
Mean Sea Level (MSL)	0.00
Mean Higher Low Water (MHLW)	-0.16
Mean Lower Low Water (MLLW)	-0.36
Lowest Astronomical Tide (LAT)	-0.56

Hydrographically the Maldives is characterised by a seasonal fluctuating mixed layer of relatively saline water from the Arabian Sea (360/00) and less saline water from the Bay of Bengal (340/00). A rapid downward decrease in temperature to below 20°C occurs at 90 –100 metres depth. The sea surface temperatures (SST) do not vary much through out the year. Average monthly SST generally ranges between 28 -29oC with maximum temperatures rarely over 30oC. Mean monthly SST rises from a low in December/January to high usually in April/May. In the central atolls the average seasonal rise is about 1.3oC. However, during May 1998 mean monthly SST was 1.1oC above the highest mean monthly SST (30.3oC) expected in any 20 year period (Edwards et al 2001).

2.4 Biodiversity

The extent of biological diversity including flora and fauna present in the islands of the Maldives is not adequately documented or thoroughly researched. Therefore, the degree of understanding on biological diversity in the country is restricted to the information available.

The main types of ecosystems found are coral reefs, islands, sea grass, swamps and mangrove areas. Coral reefs are the major type of ecosystem that exists in the Maldives in terms of area as well the diversity of life that exists in the system. This diversity is amongst the richest in the region and the corals reefs of the Maldives are significant on a global scale as well, being the 7th largest in the world, covering a total area of 8,920 km2 and contributing 5% of the worlds reef area (Spalding et al 2001).

As the Maldives is an island nation, the extent of terrestrial biological diversity is much confined to the small island environments. The floral composition is considerable taking into account the absence of diverse terrestrial ecosystems and the poor and infertile nature of the soil. Islands in the south, particularly Fuvahmulah and Hithadhoo, demonstrate a richer diversification of plants than the north. The terrestrial faunal diversity is generally poor in the Maldives and is understandable in the absence of huge landmasses, forests and associated ecosystems.

2.4.1 Terrestrial

The close proximity of all land to the sea results in comparatively high soil salinity and as a consequence the natural vegetation contains a high proportion of salt tolerant species, both shrubs and trees. Based on published plant species lists and vegetation descriptions, 583 species of plants are found in the Maldives and, of these 323 are cultivated species and 260 are native or naturalized species (Adams 1984). Over 300 plant species are known to have medicinal values, (ERC 2001) and are utilized for traditional medicinal practices.

In comparison to the rich terrestrial faunal diversity of the region, the Maldives demonstrates a rather small proportion of the representatives. Webb (1988) noted that islands of the Maldives are not known for their abundant wildlife.

Webb (1988) described some constituents of the Maldivian reptilian fauna including: 2 gecko (*Hemidactylus spp*) commonly seen throughout the country; 2 agamid lizard including the common garden lizard or blood sucker, *Calotes versicolar*, the snake skink, *Riopa albopunktata*, and 2 species of snakes including the common wolf snake *Lycodon aulicus* and *Typhlops braminus*. One species of frog is known, the short-headed *Rana breviceps*, and a larger toad, *Bufo melanostictus* has also been found. During a study co-ordinated by Holmes on fruit bats and birds of the Maldives, a collection of insects, arachnids and mollusk specimens were made and spiders were found to be particularly rich. In the same study four species of bumblebees, which were very much a feature of the islands, were also collected (Holmes 1993).

The only native mammals endemic to the country are the two subspecies of fruit bats, *Pteropus gigantus ariel* and *Pteropus hypomelanus maris*. The latter one is very rare and has only one record from the Maldives from Addu Atoll (Holmes 1993). The other mammals, all probably introductions, are the house mouse, black rat, Indian house shrew and cats (Webb 1988).

Over 190 bird species have been recorded from the Maldives including seabirds, shorebirds and terrestrial birds (Zuhair and Shafeeg 1999): most of which are seasonal visitors, migrants, vagrants, introductions, and imported as pets. Very few reside in the country, most of which are seabirds. Terrestrial birds are very minimal compared to other tropical islands and most are probably introductions. A complete study on the ornithology of the Maldives has not been undertaken, however, some information is available regarding the distribution and status of a few species from researches undertaken by foreign and local experts.

Seabirds are widely seen throughout the country and are extremely important to the local communities as they have been keeping a very close relationship with them. Most of them are directly related to fishing in the Maldives. Tuna schools chase small fish and other marine life such as shrimps up to the surface where they are preyed on by several species of seabirds, and as many as 90% of the tuna schools are located this way (Anderson 1996). At least 40-50 species of seabirds are seen in the Maldivian waters, of which only 13-15 are known to nest and breed in the country. Some of them are terns *Sterna sumatrana, S. albifrons, S. anaethetus, S. dauglli, S. bergi, S. bengalensis,* and *S. fuscata, S. saundersi*; two species of noddies *Anous stolidus* and *A.*

tenuirostris, the white tern *Gygis alba monte* which is known to breed only in Addu Atoll (Anderson 1996). Others such as frigate birds, white-tailed tropic birds, boobies and some shearwaters are also known to breed in the Maldives (Shafeeg 1993). Most of the shorebirds found are common winter visitors to the Maldives; however, there are some resident and immigrant species.

2.4.2 Marine

In contrast to the terrestrial biological diversity found in the country, marine biological diversity shows an outstanding richness, especially in the coral reefs, making the area one of the world's most diverse marine ecosystems (Pernetta 1993). However, documented information on the species diversity is limited (Ahmed and Saleem 1999). Available literature record relatively few species compared to the high diversity that exists in the marine environment.

The two groups of marine lives that are most studied are the fishes and the corals. Most recent accounts recognize 187 species of stony corals recorded in the Maldives (Sheppard 2000). To date a total of 1090 fish species have been officially recorded (Anderson et al 1998 and Adam et al 1998).

Marine algae including some 21 species of *Cyanophyceae* (blue-green), 163 *Rhodophyceae* (red), 83 *Chlorophyceae* (green) and 18 *Phaephyceae* (brown) have been recorded in the country (Hackett 1977). Other groups include; 36 species of sponges (Thomas et al 1991 and 1992), a little over 400 species of molluscs (Smith 1906, Coleman 2000), about 350 species of marine crustaceans (Borradaile 1903a, Borradaile 1903b, Borradaile 1903c, Borradaile 1906a, Borradaile 1906b, Wolfenden 1906, Walker 1906, Alcock 1906, MRS 1995 and Nomura 1996) and over 80 species of echinoderms (Joseph 1991 and Coleman 2000).

There are 5 species of turtles all of which are endangered, including loggerhead turtle *Caretta caretta*, green turtle *Chelonia mydas*, Hawksbill turtle *Eretmochelys imbricata*, Olive Ridley turtle *Lepidochelys olivacea*, and leatherback turtle *Dermochelys coriacea* (Frazier et al 1984). Marine mammals recorded include 7 species of dolphins and 9 species of whales (MRC 1998).

2.5 Freshwater

2.5.1 Groundwater

In the Maldives, water is a very scarce resource. The hydrogeology of the country is that of typical coral islands. The small islands are surrounded by large expanses of sea water, and the freshwater aquifer lying beneath the islands is a shallow lens, no more than a few meters thick, formed by the percolation of rainwater through the porous sand and coral. Freshwater being lighter than saline water, the lens floats atop the saline water. The aquifers change in volume with season and rise and fall with the tide. Such aquifers form the main source of water for human consumption and agricultural purposes. Increased extraction, exceeding natural recharge through rainfall has dramatically depleted the freshwater lens in Male' and other densely populated islands.

The superficial hydrogeology of the groundwater aquifers also result in ease of pollution by sewage, chemicals and pathogens. Water quality testing carried out to date shows that bacterial contamination of point source water supplies (dug wells) is widespread and that faecal contamination exists in many of these sources on the inhabited islands. The level of faecal contamination is higher on the more densely populated islands, Malé being regarded as having the highest level of bacterial contamination of the groundwater aquifer. However, the controlling factor is not the size of the population of the island, but the house plot size in combination with the presence of cesspits and their interaction with the groundwater aquifer. On the basis of World Health Organisation (WHO) drinking water guidelines there are few groundwater sources in the Maldives fit for potable use without disinfection.

The microbiological quality of well water in many growth centres of the Maldives is usually above 50 coliforms per 100ml which renders the water even unfit for bathing under WHO recreational or bathing water quality guidelines. Improper sewage disposal facilities are the major cause of poor groundwater quality in these islands.

Chloride and electrical conductivity varies both from island to island and within an island. On a few islands chloride exceeds the WHO guideline of 250mg/l. Data collected in the past points to the fact that the chloride concentration is not necessarily related to the level of extraction or population density, but also to underlying hydro-geological aspects of the aquifer. Islands without wetland areas show low chloride

levels than those with wetlands, as wetlands contribute to the increased chloride levels of the true groundwater lens of the island. Generally, however, the greater the extraction, the higher is the chloride from island to island and within an island. Chloride levels of the groundwater aquifer may not be particularly important in many islands because well water is hardly used for potable needs. During early 2000, about 60% of the wells in the country were reported to have freshwater (MWSA 2000).

The groundwater in Malé is severely depleted. The 5600 household wells have been supplying the water needs of the population of Malé, in the past. At present, the water provided by these wells is so saline that it is not fit even for bathing and washing purposes. The situation is further aggravated by the amount of chemicals in the water such as hydrogen sulphide and hydrocarbons. A recent chemical analysis of ground water in Malé shows that it contains high amounts of nitrates and sulphates. In a few wells ammonia was detected at elevated levels (0.4 - 0.6 mg/l) indicative of sewage pollution and raised pH levels (7.5 - 8.0) tended to confirm that the results were significant. Hydrogen sulphide or sewer gas has also been a major threat to well water users in Malé resulting in acute poisoning of two and death of one person in 1997. Hydrogen sulphide makes the water stink and poses different health risks at different levels of exposure. Many household wells have shown elevated levels (0.5 to 3.5 ppm in water and above 100 ppm in the air) of hydrogen sulphide. Hydrogen sulphide in the sewers has also been a major problem for people living near pumping stations around Malé. The situation has improved in many areas since household venting started in 1999.

Hydrogen sulphide has also been detected in some wells in Kulhudhuffushi and Hithadhoo, the designated growth centres under the first Regional Development Project.

2.5.2 Rainwater

In many islands, rainwater is mainly used for drinking and cooking purposes. Recent and past water quality tests on rainwater have shown that rainwater in the Maldives is of acceptable potable quality. However, a full analysis of rainwater may be required before impacts of trans-boundary air pollution can be assessed.

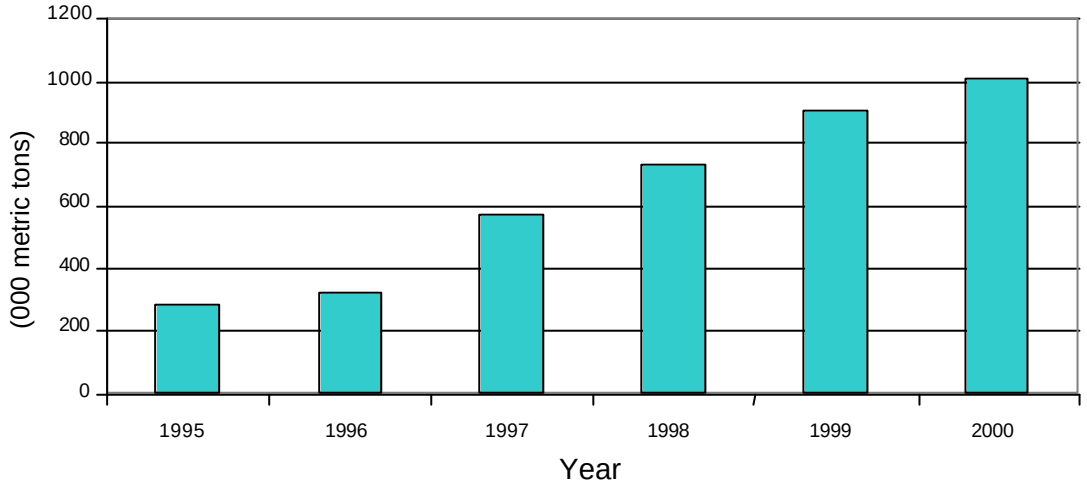
Many people practice safe collection and storage of rainwater. However, there have been a few incidents when rainwater has been tested positive for faecal coliforms. Rainwater is hardly disinfected, and very few people boil it.

Rainwater collection is also encouraged in resorts islands by the Ministry of Tourism to reduce the need for desalination.

2.5.3 Desalinated water

Desalination or desalting became necessary when the sustainable yield of the existing groundwater aquifer on some islands was exceeded. Desalinated water is now supplied to almost all households in Malé and Villingilli, the fifth ward of Malé. About 4,000 tonnes of desalinated water are produced in Male' everyday using the reverse osmosis (RO) process to serve a population of about 74,000 people (figure 2.8).

Figure 2.8: Annual Supply of Desalinated Water in Male'



At present, Kandholhudhoo is the only other inhabited island that is served with desalinated water via taps in standbays. The need for desalination arose during the dry season of 1998 when the inhabitants of Kandholhudhoo had to fetch water from nearby islands. Kandholhudhoo, the most densely populated island in the Maldives, is served by a reverse osmosis desalination plant with a capacity of 50 cubic meters. The island community operates and maintains the plant. When the population of Kandholhudhoo was served by desalinated water in May 1999, about 28% of the population of the Maldives had access to desalinated water and over 20% of the population almost entirely depended on desalinated water.

All tourist resorts rely on desalination to cater for their water needs as the island aquifers could not be tapped and also would not provide sufficient yield. In most resorts, a total production capacity based on 250 litres per capita per day is established.

2.5.4 Fresh or brackish water ponds

Surface freshwater is generally lacking throughout the archipelago with the exception of a few swampy areas, shallow freshwater lagoons, and some fresh or brackish water ponds in some of the islands in the northern and southern atolls (Box 2.3). In heavily populated islands such as Thinadhoo and Kulhudhuffushi, the marshy area has been used for waste disposal and to create land. In Baarah, the wetland or brackishwater ponds became a nuisance by being a breeding ground for certain mosquitoes. Freshwater ponds like the one in Fuvahmulah œuld serve as an important reservoir for freshwater supply.

2.6 Atmosphere

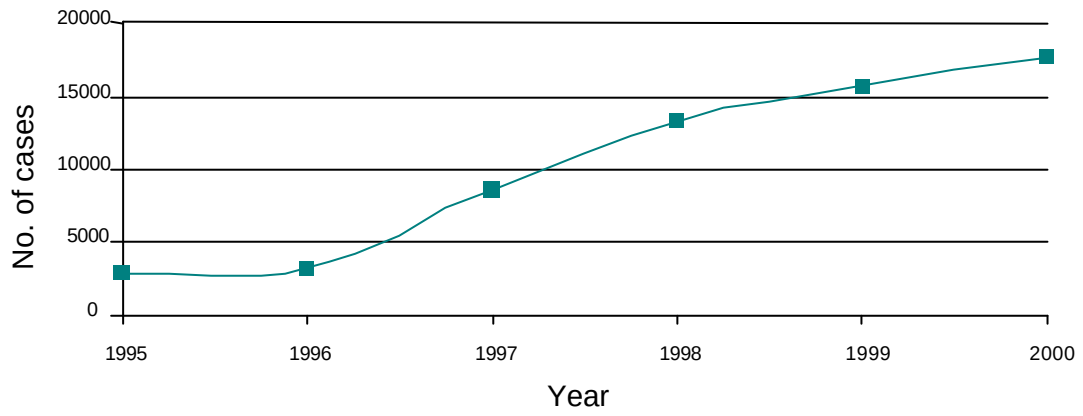
Air quality of the Maldives is generally considered to be good and is in pristine state. As the islands of the Maldives are small, the sea breezes flush the air masses over the islands and keep air over the islands fresh from the sea. However, recently it has been observed that transboundary air pollution is affecting the air quality of the Maldives. Local air pollution in Male' is also a growing concern.

Transboundary air pollution in the Maldives became first known in 1997, when large parts of the country were affected by haze caused by forest fires in Indonesia. The haze layer blanketed the country between October 1997 and December 1997 and significantly affected the routine lives of the Maldivians. The actual state of the transboundary movement of air pollutants over the Maldives was measured in the Indian Ocean Experiment (INDOEX). INDOEX was carried out by a team of more than 200 international scientists and was led by the Centre for Clouds, Chemistry and Climate (C4) of the University of California. INDOEX results showed widespread pollution over large sections of the Indian Ocean. In March and April 1999, the scientists were surprised to find a dense brownish pollution haze layer stretching an area of more than 10 million square kilometers over the Indian Ocean tropical region. Because of the pollution, visibility over the open ocean dropped below 10 km, a

visibility which is typically found near polluted regions in the eastern United States and Europe (C4 2000).

Local air pollution in Male' is mainly due to particulate emission from vehicles, power generation, and construction related activities. Particulate includes a range of materials such as soot and coral dust. High rise buildings and congestion in Male has disrupted cross circulation of air and emissions from the increasing number of motor vehicles on the roads are deteriorating the urban air quality of Male'. Though the pollution is visible in certain times, no numerical measures of the level of pollution are available. Elevated particulate levels are implicated in a range of respiratory problems such as asthma, allergic respiratory responses, bronchitis and emphysema. The Health Master Plan identifies outdoor air pollution as a major contributor to respiratory problems in the Maldives (MoH 1998). From the health records, it is seen that the number of cases reported with respiratory problems has been on the increase for the past 5 years (figure: 2.9).

Figure 2.9: Acute Respiratory Infection Cases Reported from Male'



Box: 2.3 Islands with wetlands in the Maldives

Island	Atoll	Size of Wetland (hectares)
Filladhoo	Haa Alifu	3.6
Thakandhoo	Haa Alifu	1.8
Baarah	Haa Alifu	5
Mulhadhoo	Haa Alifu	-
Maafari	Haa Alifu	0.8
Nolhivaranfaru	Haa Dhaalu	0.35
Neykurendhoo	Haa Dhaalu	-
Finey	Haa Dhaalu	-
Nolhivaramu	Haa Dhaalu	4
Kulhudhuffushi	Haa Dhaalu	16.1
Maakandoodhoo	Shaviyani	8.28
Feydhoo	Shaviyani	-
Funadhoo	Shaviyani	-
Maroshi	Shaviyani	-
Nalandhoo	Shaviyani	2.49
Milandhoo	Shaviyani	1.6
Medhukuburudhoo	Shaviyani	7.88
Farukolhu	Shaviyani	1.3
Eriadhoo	Shaviyani	1.1
Eskasdhoo	Shaviyani	29
Bomasdhoo	Noon	2.3
Kedhikolhudhoo	Noon	31.1
Tholhendhoo	Noon	3.7
Medufaru	Noon	5.9
Karinmavattaru	Noon	0.3
Kuredhdhoo	Lhaviyani	2.4
Kolhufushi	Meemu	5.3
Gan	Laamu	-
Isdhoo	Laamu	-
Gaadhoo	Laamu	-
Viligili	Gaafu Alifu	-
Kadulhudhoo	Gaafu Alifu	-
Madaveli	Gaafu Dhaalu	4
Nadallaa	Gaafu Dhaalu	3.7
Thinadhoo	Gaafu Dhaalu	3
Fuvahmulah	Gnaviyani	8.5
Hithadhoo	Seenu	11.9
Hulhudhoo	Seenu	2.8
Meedhoo	Seenu	-
Herethere	Seenu	4.7
Viligili	Seenu	2.3

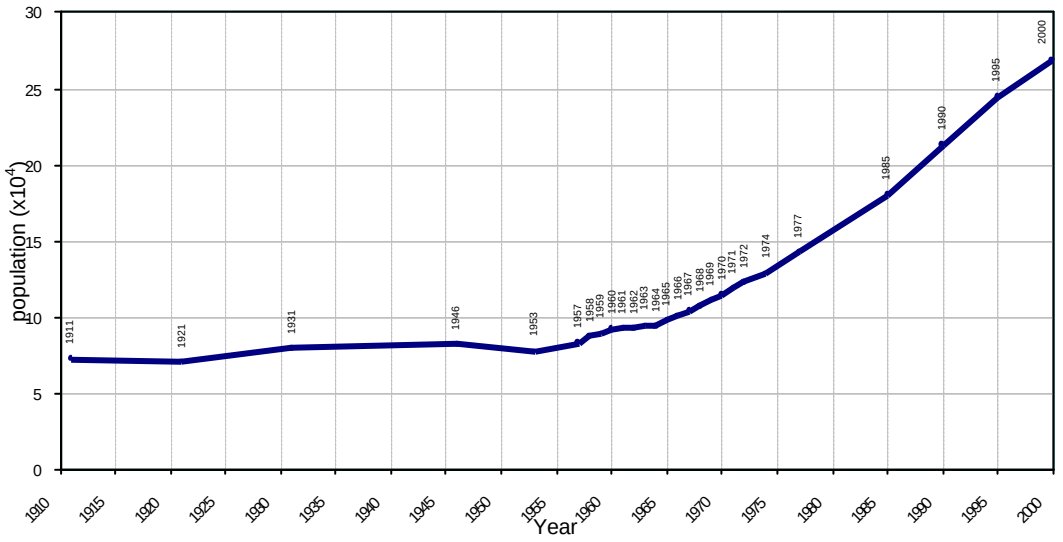
3 PRESSURES ON ENVIRONMENT

3.1 Population

The relationship between population and the environment lies in the increased demand for resources as population grows. Though such relationships are complex and cannot be generalized, it is important to recognize the impact the increased demand for resources can have on the environment as population increases.

Population censuses have been regularly undertaken in the Maldives since 1910 and accurate data on the growth and distribution of population in the Maldives are available (figure 3.1). Over the last five years, the population of the Maldives has grown from 244, 814 in 1995 to 270,101 in 2000, an increase of 10%. The population of Male' in the same period increased from 62,519 to 74,069 and that of the atolls increased from 182, 295 to 196,032.

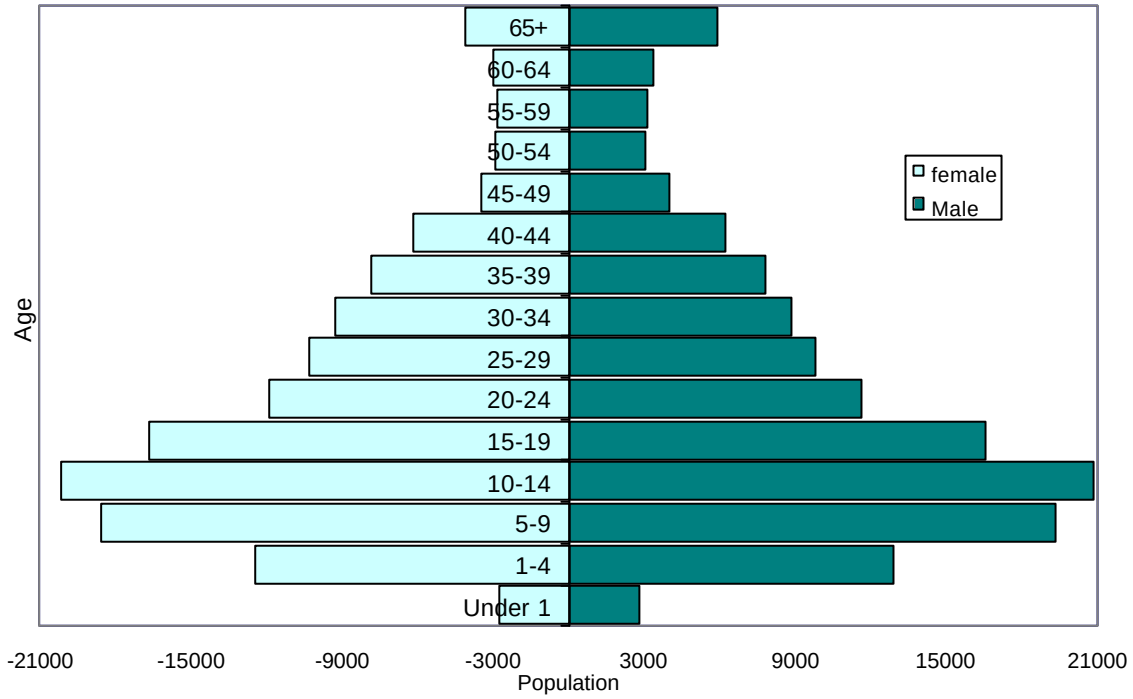
Figure 3.1: Population of Maldives (1911-2000)



Even though population is increasing the growth rate of population is declining. The population growth rate for the country declined from 2.79 % per annum over the census period 1990 to 1995 to 1.96 % per annum over the period 1995 to 2000. Though the national population growth is declining, there is a significant increase in population growth rate of Male' from 2.8% to 3.5% between 1995 and 2000.

Along with the changing population growth rates, there have been significant changes in the population structure over the last census period 1995 to 2000 (figure 3.2). The changes in the age profile of the population show that approximately 50 % of the total population was between 15 and 64 years in 1995 and in 2000 the population within this age group had increased to 55%. The percentage of population below 15 years declined from 46.15% in 1995 to 40.70% in 2000 (MPND 2001). The sex ratio defined as males per 100 females has remained relatively constant. The 1995 estimate of total population accounted for 124, 622 males and 120, 192 females with a ratio of 103.69. The 2000 estimate of total population accounted for 137, 197 males and 132, 904 females with a ratio of 103.23 (MPND 2001).

Figure 3.2: Population structure in 2000.



As the population grows and the potential for environmental degradation increases, an important instrument that can be used to mitigate the impact of adverse effects on the environment is education. The Maldives has a literate population with an adult literacy rate of 98.19%. The student enrolment in educational institutions has been increasing as well. Figure 3.3 shows student enrolment in educational institutions over the last six years. Table 3.1 shows school enrolment in Male' and in the atolls by sex.

Figure 3.3: School enrolment in 2000

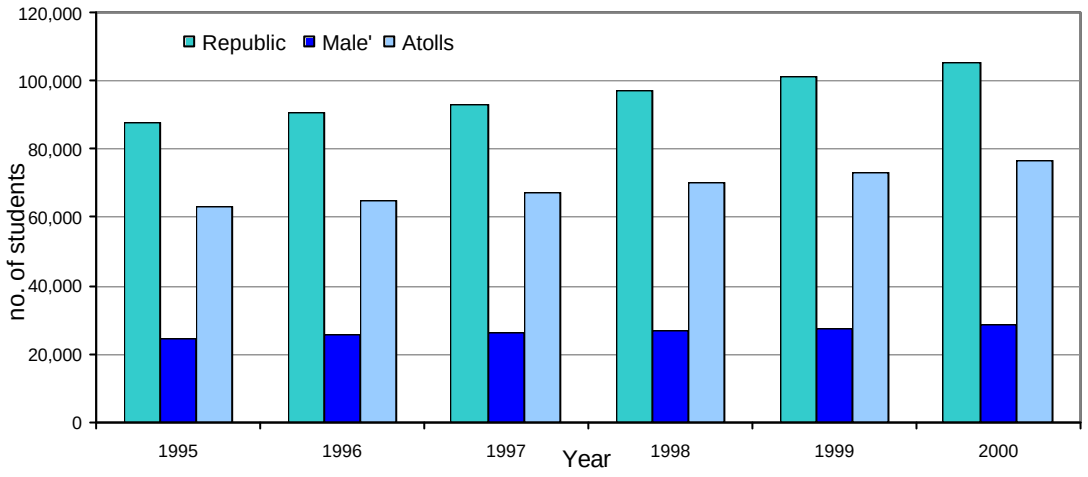


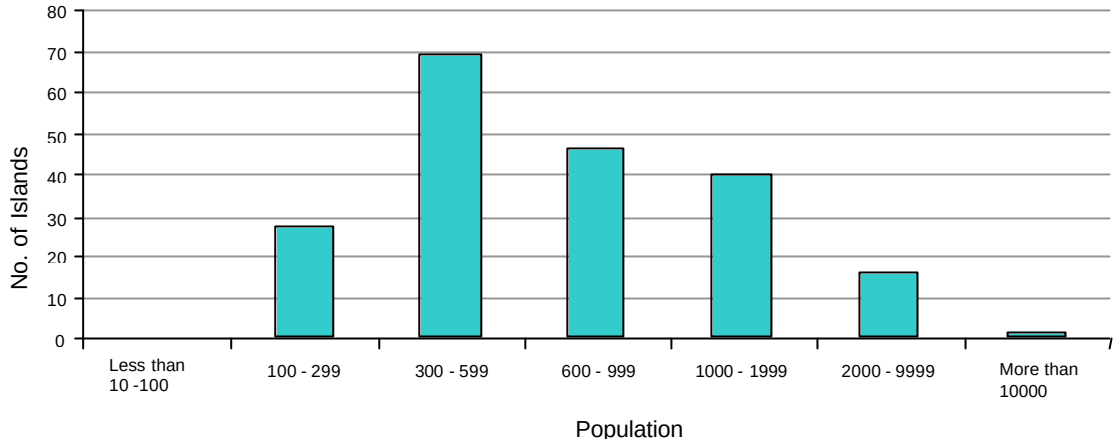
Table 3.1: School enrolment by sex

	1999		2000	
	Male	**Female**	**Male**	**Female**
Republic	51,394	49,687	53,455	51,901
Male'	14,041	13,673	14,341	14,206
Atolls	37,353	36,014	39,114	37,695

In 1995, 44% of the population 12 years of age and over was economically active and in 2000 it was 48 %. Expatriates form a significant part of the labour force in the Maldives. In 1995, 21.7 % of the total labour force amounting to 18, 510 were expatriates and in 2000, there were 27, 716 expatriates employed. In 2000, 30.9 % of the expatriates were employed by the tourism industry.

The geographic distribution of population is unequal and density among the atolls and the islands differs greatly across the country. At present, over a quarter of the population, 27.4% (74,069) live in Male' (MPND 2000). Addu Atoll has the next highest population at 18,515, while Vaavu Atoll has the smallest population at 1,753 (MPND 2001). There are only three islands that have a population greater than 5,000. They are Kulhudhufushi (6,581), Fuvahmulah (7,528) and Hithadhoo (9,461). The overall distribution of population over the 199 inhabited islands is shown in figure 3.4. According to 2000 census, 54 islands have a population between 1000 and 5000 people, 66 islands between 500 and 1,000 people and 76 islands have a population less than 500 people (MPND 2001).

Figure 3.4: Population distribution on inhabited islands



In terms of population density, the most densely populated atoll is Vaavu Atoll with a population density of 41.84 persons/ha and population density is lowest in Laamu Atoll with 8.7 persons/ha. At island level, population density is highest in Kandholhudhoo in Raa Atoll with 617.5 persons/ha and it is lowest in Maafilaafushi in Lhaviyani Atoll with 2.20 persons/ha. Capital Male' has a density of approximately 383.77 persons /ha. The ten most populated islands and the ten least populated islands and their densities are given in tables 3.2 and 3.3 respectively.

Table 3.2: Ten most populated islands and densities in 2000

Island	***Atoll***	***Population***	***Population density persons/ha***
Male'		74,069	383.77
Hithadhoo	Addu	9,461	20.25
Fuvahmulah	Fuvahmulah	7,528	17.92
Kulhudhuffushi	Thiladhunmathi dhekunuburi	6,581	38.22
Thinadhoo	Huvadhu atholhu dhekunu buri	4,893	84.22
Naifaru	Faadhippolhu	3,707	259.78
Hinnavaru	Faadhippolhu	3212	443.65
Feydhoo	Addu	2,892	60.61
Dhidhdhoo	Thiladhunmathi uthuruburi	2,766	54.63
Kandholhudhoo	Maalhosmadulu uthuruburi	2,717	617.5

Table 3.3: Ten least populated islands in 2000

Island	Atoll	Population	Population density persons/ha
Maafilaafushi	Faadhippolhu	108	2.20
Dhidhdhoo	South Ari Atoll	113	8.43
Thinadhoo	Felidhu Atoll	114	12.53
Madifushi	Mulakatholhu	122	11.19
Berinmadhoo	North Thiladhunmathi	124	8.50
Dhiyadhoo	North Huvadhu Atoll	139	2.85
Fehendhoo	South Maalhosmadulu	149	7.23
Hathifushi	North Thiladhunmathi	150	36.59
Faridhoo	South Thiladhunmathi	159	6.83
Raiymandhoo	Mulakatholhu	171	7.92

The significance of these statistics and trends for creating environmental pressures are clear. If the trend towards growing populations on a limited number of islands continues, increasing pressure will be placed on the natural resources of those islands. A clear example of this kind of pressure is Male', where the population has more than doubled in less than 25 years from 29,522 in 1977 to 74,069 in 2000. Although infrastructure improvements in Male' such as a sewerage system and a desalinated water supply system have reduced environmental pressures in recent years, previous groundwater over-extraction, sewage disposal and waste disposal have resulted in a contaminated aquifer with possibly irrecoverable damage. The lack of space for housing, social services and recreation, and severe social strains due to overcrowding have become issues that are directly related to the rapid growth of population in Male'.

3.2 Households, Housing and Human Settlements

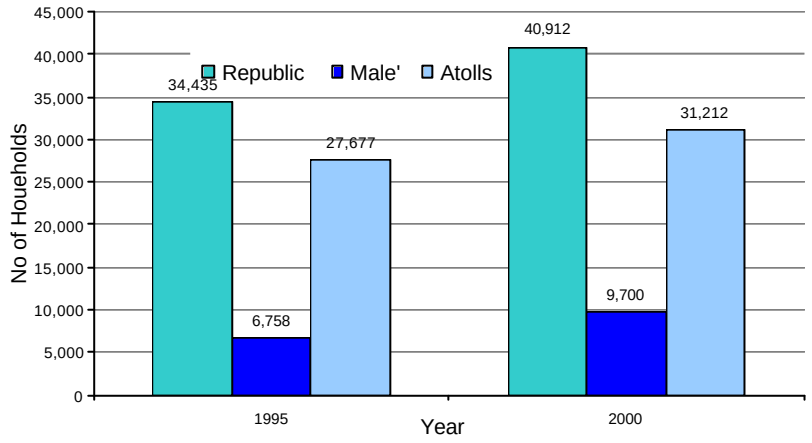
In terms of possible pressures on environmental resources, the demand for some resources such as water, energy, construction materials and possibly independent means of transport are more related to the number of households than the number of people. The demand for additional housing also places pressure on vegetation and development on environmentally sensitive areas such as near beaches.

Figure 3.5 shows the increase in households between 1995 and 2000. The total number of households increased from 34, 435 in 1995 to 40,912 in 2000 (figure 3.5). In Male' it increased from 6,758 to 9, 700 and in the atolls, there was an increase from 27,677 to 31, 212 in the same period. Even though the number of households has increased

significantly, there has been no significant change in the average household size for the same period. Between 1995 and 2000, the average household size for Male' has been 9 and 8 respectively.

It is estimated that over the census period 1995 to 2000, the number of households increased at a faster rate (19%) than the increase in population (10%) reflecting a lifestyle change of people wanting to live in nuclear families rather than extended families. By the year 2020, the population of Maldives is projected to reach the half million mark. If the present distribution of population remains constant, another almost 180,000 people need to be absorbed within the settlements of the atolls and almost 60,000 people will need to be added to Male', the already dense capital of the country. With the number of households projected to increase at a faster rate than the population growth such an increase in population will have significant pressures on the resources in the Maldives.

Figure 3.5: Increase in the number of households



It has also to be noted that the increase in the number of households and the population in the past have placed significant burdens on the environment in densely populated islands. The starkest example of this is in Male'. The original land area of Male' covered about 100 hectares and in 1969 Male' had only 13,336 people with a density of 133.36 persons per hectare. Since 1970s, there has been a rapid increase in the population and number of households in Male'. To cater for the additional households in Male', a land reclamation programme was initiated in the south west lagoon and the land area of Male' was almost doubled to 192 hectares. But even with the doubling of

land area the density has reached nearly 400 persons per hectare in 2000 with a population of about 74,069 Maldivians and several thousand expatriates. Given the land shortage, the land inheritance and subdivision patterns in Male', housing plots have become smaller and smaller. Male' Municipality restricts subdivision to a minimum plot size of 55.74 m2 but in the past there have been instances of plots divided into 35 m2. Municipality regulations also restrict heights of buildings to 10 floors or 30.48m. As a result, Male' has become divided into very small housing plots, consisting of extremely narrow buildings rising to several floors.

There are several other islands confronted with similar problems of overcrowding and congestion as in Male'. A total of 35 out of 200 inhabited islands have a density equal to or more than 50 persons per hectare. Six islands were recorded to have densities in excess of 200 persons per hectare. In Kandholhudhoo island in Raa Atoll, 2717 people live on 4.4 hectares at an estimated density of 617.5 persons/ha. In some overcrowded islands, virtually all land is occupied leaving no space for roads and recreational infrastructure.

While overcrowding and congestion remains a serious problem, the predominant problem in the atolls is housing. Housing development has taken place in the islands in two ways: by the allocation of housing plots by the government for construction of houses, and by allocation of housing in selected uninhabited islands where population has to be resettled due to problems like absence of additional land, high density or environmental vulnerability. In the first instance, housing development takes place on the initiative of the families themselves. There is no housing finance system to obtain credit or an organized provision of building materials. The house builder has to purchase and transport the building materials, and find his own finance. As a result, housing conditions in most islands and in all overcrowded islands are of poor quality. They are too small in size relative to the number of inhabitants, poor in the quality of construction and poor in accessibility to services especially water and sanitation. In the second category, housing is constructed and provided to the new settlers by the Government.

Undoubtedly, there are both social and environmental consequences of such housing conditions. In some extreme instances, families have been forced to undertake their domestic chores like washing in the streets because no space is available within their

houses. In many islands, roads have been reduced to narrow paths between over-extended houses. It is also reported that residents of some overcrowded islands like Raa Kandholhudhoo had to travel for over one and half hours by dhoni to nearby uninhabited islands to obtain their day's supply of drinking water during dry periods. In Hinnavaru, the settlement resembles a rabbit warren, with small houses and narrow paths running between them. An average house in some of the overcrowded islands accommodates over 12 persons excluding small children. However, the standards of cleanliness in even the most crowded settlements are impressive. Unclean drains, collection of wastewater, or use of roads for dumping of waste do not exist.

The impact on the environment due to the housing problems discussed above is quite severe. In many islands, demand for housing plots increases with the expansion of the population. Natural vegetation is cleared for settlement and infrastructure. In islands like Kandholhudhoo, Naifaru, Hinnavvaru, and Kihaadhoo, it is reported that the number of trees has fallen below a sustainable level, forcing the authorities to embark on tree planting exercises to replenish the vegetation stock.

Coral mining for housing, although declining, has been another cause of environmental degradation. In addition to having adverse impacts on the reefs itself, it affects the islands as well as biodiversity. Coral reefs offer strong coastal protection against ocean currents, waves and tides. Mining of corals have resulted in the destruction of this protection layer in some islands causing considerable amount of beach sand to wash away from the island into the sea. As the protection layer is destroyed, waves and tides directly enter into the island causing damage to the vegetation and intruding into the freshwater aquifer. The other associated impacts on the reefs include loss or migration of residential reef fish communities and other living organisms, loss of bait fish that are important for the local tuna fishery, and reduced coral percentage cover. Most importantly, these reefs may take several years to recover.

Cement blocks are increasingly replacing the use of coral for housing. In addition, alternatives such as cement and sand bags are being utilized for construction of seawalls and harbour walls. However, the practice of using coral for buildings and for sea walls does continue to some extent.

As population grew in crowded islands and when available land area was no longer sufficient to meet the demand for housing, reclamation of shallow reefs adjacent to the islands has been carried out. Land reclamation activities have negative implications such as destruction of shallow lagoons, sea grass and reef flat communities, and adverse effects on nearby coral reef communities through suspended sediments.

Therefore, housing issues and congestion in the face of a growing population continues to deplete the natural resources such as stock of ground water, plants and coral reefs of the fragile ecosystem. Additionally, it has increased the variety and magnitude of pollution created by human settlements.

3.3 Water Use

In Malé and other islands the rapidly expanding population coupled with the changing culture of more use of fresh water has exacerbated the problems associated with the supply of water. Water usage has been far greater than the natural rate at which the aquifer is recharged. In Malé, for instance, the lens has dwindled from over 30 meter of depth in the 1970s to a mere meter to date, and the water is totally unfit for drinking or cooking. The households of Malé are now supplied with desalinated water. Since the introduction of the piped desalinated water network, the groundwater seems to have improved in different areas of Malé.

The quality of groundwater in Gan, Addu Atoll has also rapidly declined in the past few years. Gan has a few garment factories and a regional airport. However, as almost all general purpose water used on Gan originates from two boreholes located on the western side of the island, there is excessive extraction above the demand. Leakages in the distribution network also contribute to the problem in Gan.

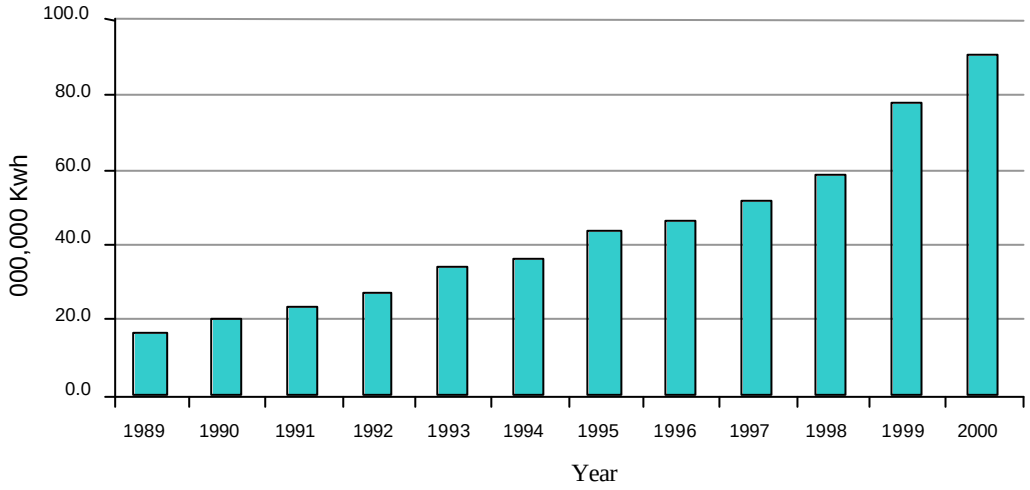
Increased extraction exceeding natural recharge through rainfall has dramatically depleted the freshwater lens in Malé and other populated islands. This increased extraction is linked with technology and lifestyle. Although, many households in Malé and in other islands of the Maldives use low flush toilets and other water saving devices, water conserving lifestyles can be said to be rare.

3.4 Energy Use

In the Maldives, pressures on the environment from the energy sector arise from the generation and use of energy. According to the first Greenhouse Gas Inventory of the Maldives, it is estimated that 129 Gg of carbon dioxide was emitted to the atmosphere by the energy sector in the Maldives in 1994. This amounts to 0.54 tonnes of CO2 per capita (MHAHE 2001). However, a very significant number of inhabited islands still do not have access to 24 hour electricity. In 1998, more than 60 islands had electricity for 24 hours, accounting for only 55% of the population (MPND & UNDP 1998).

There is a marked imbalance in the usage of electricity between Malé and atolls. In 2000, 14,920 MT of diesel were consumed to produce 90,479,023 Kwh of electricity in Malé by State Electric Company Limited (STELCO), while in the atolls 26,421 MT of diesel was consumed to generate 116,512,316 Kwh of electricity by STELCO. The demand for electricity is on the rise as can be interpreted from the graph on the supply of electricity (figure 3.6) (MPND 2001). Diesel is the main fuel type consumed to meet the energy demand in the Maldives. In 2000, 138760 MT of diesel were imported to the Maldives and electricity production by STELCO owned power houses consumed 30% of the imported diesel fuel. Data on the generation of electricity in the resorts and private and community generated electricity in the islands are not available.

Figure 3.6: Electricity Utilisation in Male'



Firewood, kerosene and liquid petroleum gas (LPG) are the main sources of energy used for cooking in the country. In 1990, 94% of the population in the atolls used firewood for cooking while in 2000 the figure dropped to 54%. To balance out this

large drop, the use of kerosene for cooking increased. In 1990, only 6% of the population used kerosene for cooking while in 2000, 42% of the atoll population used kerosene for cooking (MPND 2001). LPG is mainly used in Malé and in 2000, 52% of population in Malé used LPG for cooking, while in the atolls 4 % depended on LPG for cooking. In 1994, 3.4 Kt of LPG were used in the Maldives.

3.5 Transport

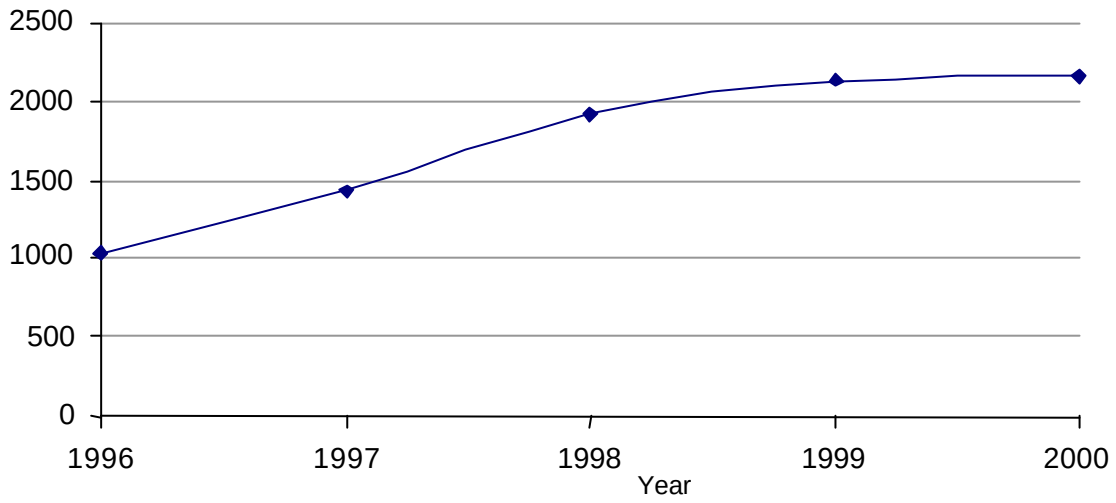
The isolated inhabited islands and resorts are linked by the air and sea transportation system existing in the Maldives. Air transportation consists of a network developed on the four regional airports and the Malé International Airport and a seaplane network operated in the central region of the country. The seaplane network caters mainly for the tourism industry. In 2000, 59,366 domestic passengers travelled between the regional airports on 2,183 flights. In 2000, the seaplane network carried 515,949 tourists and operated 41,291 flights (MPND 2001). The domestic air transportation sector is developing fast and the total domestic passenger movement has increased to 575,315 in 2000 from 85,017 in 1994 (MPND 2001).

Sea transportation is still the largest mode of transportation in the country. In 2000, more than 9,372 vessels were registered and operated in the Maldives (MPND 2001). The major transportation is between islands and Malé and between Malé and the growth centres in the atolls. It was found that on average 18 boats travelled to the atoll capital at least three times in a month and 29 boats travelled once or twice to Malé from the atolls (MPND & UNDP 1998). The islands of the Maldives are well protected naturally by house reefs. This reduces the accessibility of the island by boats. In order to facilitate sea transport, the lagoons of many inhabited islands have been dredged to develop harbours. From 1995 to 2000, the lagoons of at least 53 islands have been dredged. Dredging of lagoons have pressures on environment such as loss of natural habitat, destruction of shallow lagoons, sea grass and reef flat communities and adversely affects nearby coral reef communities through suspended sediments.

Land transport exerts pressures on the environment in many ways. Vehicles emit carbon dioxide, carbon monoxide, oxides of nitrogen, sulphur dioxide, lead, particulate materials and volatile organic compounds (VOCs). Traffic noise is also a nuisance associated with land transport. As can be seen from the figure, in a period of not more

than two and half years from 1996 the population of vehicles registered in the Maldives more than doubled (figure 3.7). Cars represent a very significant number among the registered vehicles and in 1994, 128 new cars were registered and this grew to 315 in 2000 (MPND 2001). From 1990, the import of motorcycles has increased at an average of 14% per annum. In 2000 alone, 1860 motorcycles were registered (MPND 2001). The smallness of the islands and infancy of the land transportation sector has limited the land transport system mainly to Malé and some regional growth centres such as Hithadhoo and Kulhudhuffushi. The increased use of vehicles in Male' is causing not only congestion on the narrow street system but is deteriorating the urban air quality as well.

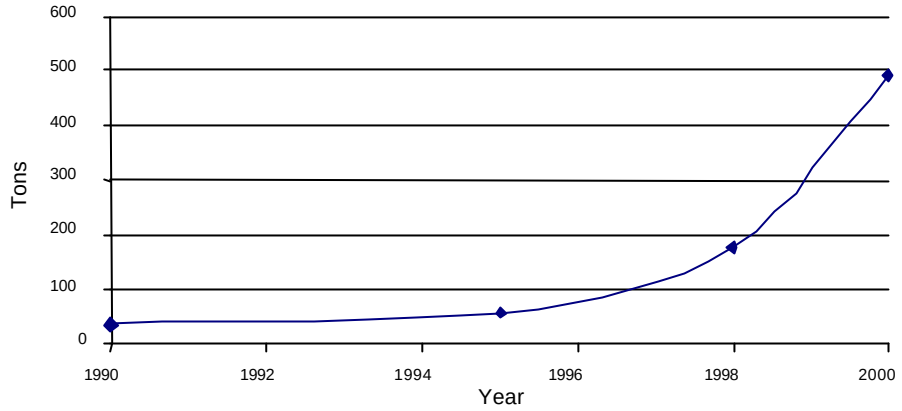
Figure 3.7: Registered New Vehicles



3.6 Pollution and Waste

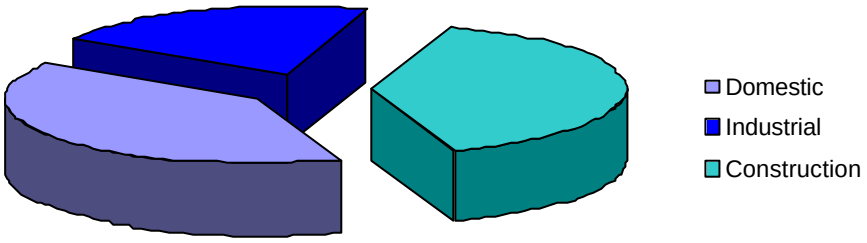
A major pressure on the environment arises from the wastes and pollutants produced as a by-product of domestic and industrial activities. Solid waste disposal is now one of the most critical environmental issues in the Maldives. The amount and the rate of solid waste generated vary throughout the country and there is a significant difference between the amount of waste generated in Male' and that of in the atolls. The amount of solid waste generated in Malé has been increasing at an alarming rate over the past 10 years. Figure 3.8 shows that the solid waste generated almost doubled within the period 1990 to 1995 and in the next five years (1995 to 2000) the amount of waste generated increased by eight fold.

Figure 3.8: Amount of Solid Waste Generated Daily in Male'



On average 2.48 kg of waste are generated per capita per day in Malé while in the atolls this value is around 0.66 kg of waste per capita per day. Average waste generation in the resorts stands at 7.2 kg per guest per day (JICA 1998). Figure 3.9 shows the composition of solid waste generated in Male. The rapidly developing construction industry is contributing significantly to the composition of the waste.

Figure 3.9: Sources of Solid Waste for Male'



The large quantity of waste generated coupled with limited land area and technology makes the disposal of waste a challenge for the country. Until 1991, solid waste generated in Malé was used for land reclamation in Male'. Presently, solid waste generated in Male is collected and taken to a transfer station. From the transfer station, the waste is transported to Thilafushi, a municipal landfill, located 5 km away from Malé. The Thilafushi landfill site has now become a landfill for the central region of the country. In addition to waste from Male', it now receives waste from islands in Male' atoll, the resorts and the Malé International Airport.

Solid wastes generated in the atolls are disposed using various methods. Organic wastes are composted at home backyards in most of the islands. Non-biodegradable waste such as plastics is dumped near the beach in many islands and buried in a few islands.

Burning of combustible waste at designated areas in the islands is also widely practised in many islands.

Current waste disposal practices adversely affect the environment through habitat destruction and pollution. Often, wetland areas such as swamps and mangroves are considered as "useless" areas and therefore dumping of solid waste in such areas is acceptable practice and reclamation of such areas to increase land space often takes place. Dumping of solid waste near beaches also has adverse effects on the reefs and lagoons of the islands.

The amount of hazardous waste generated in the Maldives is very small. In 1998, it was estimated that 0.4 ton of hazardous waste was generated daily in Malé. Though figures for hazardous waste generated for the atolls have not been estimated, it is believed that the generation of hazardous waste would be very small. Hazardous waste mainly includes clinical wastes and waste oil from electric generators and vehicles. At present, hazardous waste generated in Malé is transported to Thilafushi.

Like many small coastal communities of the world, Maldivians also traditionally used the "bush or the beach" for human excreta disposal. A designated area in the household backyard for shallow burial of faeces (handas buri or gifili) and defecation along the beach (athirimathi) have been common practice in the past. These practices, especially the defecation in the gifili, are known to damage the environment through contamination of groundwater aquifers which were directly used (especially during dry period) for potable purposes.

One of the main concerns surrounding such sewage or excreta disposal practices in the past was the morbidity and mortality from diarrhoea, which still continues to be so. With the construction of rainwater tanks both in Malé and the atolls, and the introduction of a comprehensive sewerage scheme in Malé and intensive health education on the use of oral rehydration, the situation has improved tremendously. Deaths from diarrhoea have dropped considerably, although the morbidity situation has not improved significantly. Serious epidemics of diarrhoea occurred in 1978 (Cholera) and in 1982 (Shigella) claiming several lives. The cholera epidemic affected 50% of the islands with more than 15000 cases reported and 200 deaths. Between 1992 and 1993, there has been a reduction in the reported cases of diarrhoea in the country as a whole.

Although almost universal access to sanitation has been achieved in Malé and a comprehensive sewerage system is in place, there are critical design and long-term maintenance concerns that has contributed to rapid faecal contamination of Malé groundwater aquifer. Male' Water and Sewerage Company is working to rectify these problems and bring the system to an acceptable level of performance.

Pollutants reaching the water resources, especially groundwater aquifers come from point sources and non-point sources. Point sources that mainly include sewage disposal and discharges from sub-industrial activities have contributed to contamination of groundwater aquifers in Malé and other industrial or populated islands. A study carried out by MWSA in Malé showed that petro-chemical pollution of the groundwater aquifer is quite prominent in many areas of Malé. This pressure is due to vehicle washing garages and engine repair and maintenance workshops scattered all over Malé. The oil spillages in Malé had contaminated the ground water to the point where tests conducted by MWSA showed the water at the area unfit for any use (MWSA 1995). The scale and significance of water pollution problems caused by the power stations and oil storage at other islands has yet not been assessed so far. However, spillage had been observed in many oil handling areas (such as in powerhouses) in other islands too.

The agricultural sector in the Maldives does not use a significant amount of chemical fertilisers and pesticides. Thus groundwater and seawater contamination from agricultural run-off is at present not a problem. However, in the last few years there has been a marked increase in the amount of fertilisers and pesticides used although it is not significant.

Issues facing coastal waters are mainly related to disposal of untreated sewage and wastewater effluent. Of the seven islands provided with central small bore sewerage systems, only three islands have secondary treatment facility (i.e. septic tanks). The rest disposes raw sewage into the coasts making coastal waters unsuitable for bathing or general use. In Malé, the capital, sewage is disposed untreated into the near shore waters via nine outfalls at six locations. The pollution load from these sewer outfalls probably exceeds the dilution capacity of the receiving waters. The Malé sewers not only carry sewage but also different chemicals and potentially harmful substances.

3.7 Fisheries

The fisheries sector is extremely important in the economy since it forms the bulk of exports and is the second largest contributor to the national GDP (table 3.4). The share of fisheries in GDP has declined further in the past 6 years from 7.8% in 1988 to around 6.0% in 2000. However, total recorded fish catch increased from 104,472 metric tons in 1995 to 118,964 metric tons in 2000 (MPND 2000). Total revenue from export of marine products was 481 million Rufiya in 2000 (MOFAMR 2000).

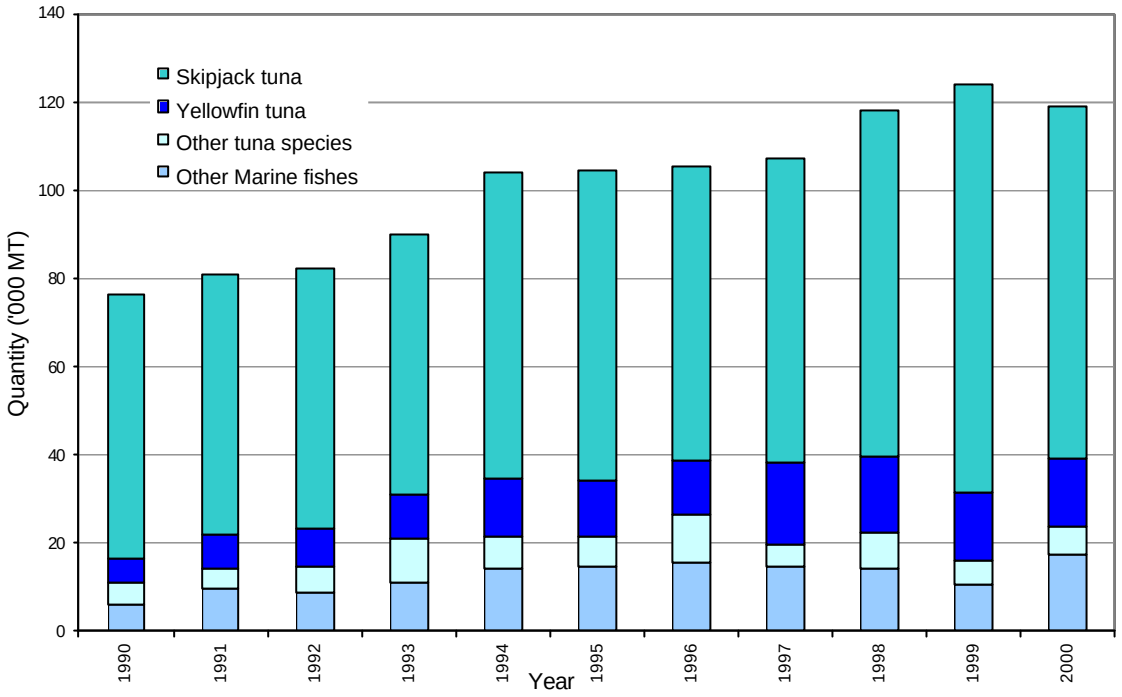
Table 3.4: Fisheries Contribution to GDP (1995 –2000)

Year	***% Share of Fisheries Contribution***
1995	7.8
1996	7.3
1997	6.7
1998	6.7
1999	6.5
2000	6.0

Fishing is an economic activity that has direct impact on marine biodiversity. Fishing is widespread throughout the archipelago and local fishing practices form a large part of the traditional lifestyle. Tuna and tuna-related species comprise over 85% of the total fish catch. In the year 2000, out of the 118,963 metric tons of fish catch, tuna and tuna related species comprised 101,728 metric tons (figure 3.10).

Tuna species, especially skipjack and yellowfin tuna which form the greater part of Maldivian catch, are highly migratory and thus stock status is not affected by Maldivian fisheries alone. The Indian Ocean skipjack tuna stocks are generally believed to be large (Adam and Anderson 1996). However, some researchers are pointing to signs of potential problems in the skipjack resources that are being exploited by the Maldivian fishery. These indications include, decline in both Maldivian skipjack catch rates and average size of fish (Adam and Anderson 1996, and Anderson 1997).

Figure 3.10: Composition of fish catch (1990-2000)



Baitfish fishery is directly related to the tuna fishery in the Maldives. Small species of fish that school close to the reef are targeted as bait fish for the tuna fishery. The most commonly used variety of bait fish is the silver sprats (table 3.5).

Table 3.5: Varieties most commonly used live bait in order of quantity used

Spratelloides gracilis	Silver Sprats
Apogonidae	Cardinal fishes
Caesionidae	Fusiliers
Other species include:	
Spratelloides delicatulus	Blue Sprats
Engraulidae	Anchovies

The status of the stocks of live bait species is not known. However they do not seem to be over fished (Anderson 1997). The total catch and catch rate of live bait species have increased greatly in recent years (table 3.6) as a result of an increase in tuna fishing effort and increase in the quantity of bait used per day (Anderson 1997).

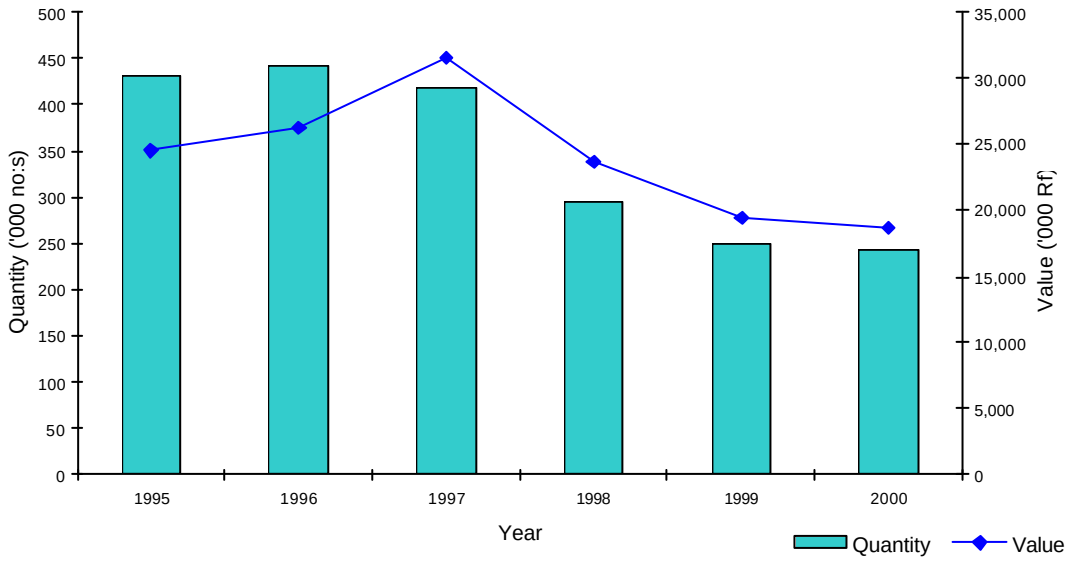
Table 3.6: Estimated quantities of live bait used annually in the pole and line tuna fishery

Time Period	*Live bait Used*
1978-1981	3000 ± 8000 t
1985-1987	4800 ± 1200 t
1993	10500 ± 2600 t
	10600 ± 2700 t

Although tuna has historically been the major fish resource and little use was made of reef fish resources, over the last decade or so, exploitation of reef resources in the Maldives has become an important component of the country's fisheries sector. Demand for marine products such as lobsters and reef fish increased locally with increase in demand for the tourist resorts. High demand in the international market for certain reef species has increased pressure on these reef resources. Reef resources that are exploited mainly for export include groupers, sea cucumber, sharks and ornamental varieties.

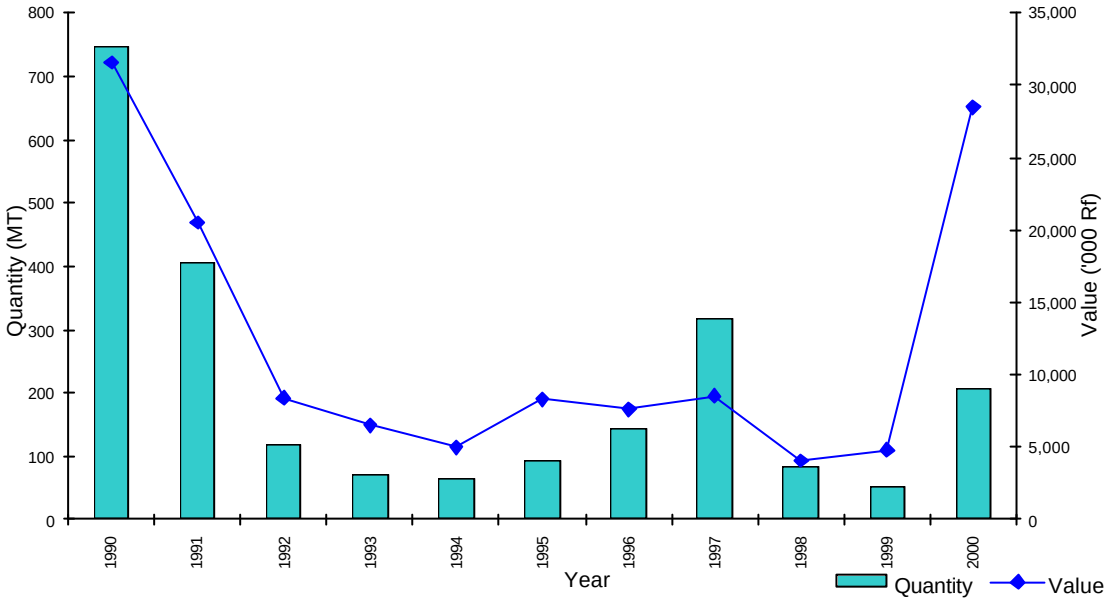
A specific fishery for grouper started in the Maldives in 1992. The maximum sustainable yield for all grouper species is estimated at 1800+700 tons (Shakeel 1994). However, these are crude estimates to be used cautiously. Export figures show a declining trend in the quantity of groupers exported as well as total value of exports (figure: 3.11). Given the pressure on the grouper resources, it is highly likely that grouper resources are being over fished.

Figure 3.11: Live Grouper Exports and their Value



Export figures for dried sea cucumber show a much lower bulk of exports in mid and late 1990's compared to the peak years during early 1990's, with correspondingly low value for exports. However, the total value increased considerably in 2000 (figure 3.12).

Figure 3.12: Dried Sea Cucumber Exports



The live ornamental species export trade (Aquarium Fish) exploits about 100 species of marine organisms, majority of which are reef fish. Of these, about 20 species contribute to more than 75% of the catch (Adam 1997). The total quantities of ornamental species exported by the "Ornamental Fish" industry too have declined in recent years.

Edwards and Shepherd (1992) found that some species were being, locally over-exploited or exploited close to maximum sustainable levels in the area around Male'. Some species exploited by the aquarium fish trade are known to be limited in distribution or rare or not yet described for the Maldives. The Clown Fish (*Amphiprion nigripes*) is quasi-endemic with the Maldives as its centre of abundance (Adam 1997). The species is quite commonly exported from the Maldives and 8000 Maldives Clown Fish and 500 anemones were exported in 1994 alone. The angel fish *Apolomichthys armitagei* is known to be rare in the Maldives.

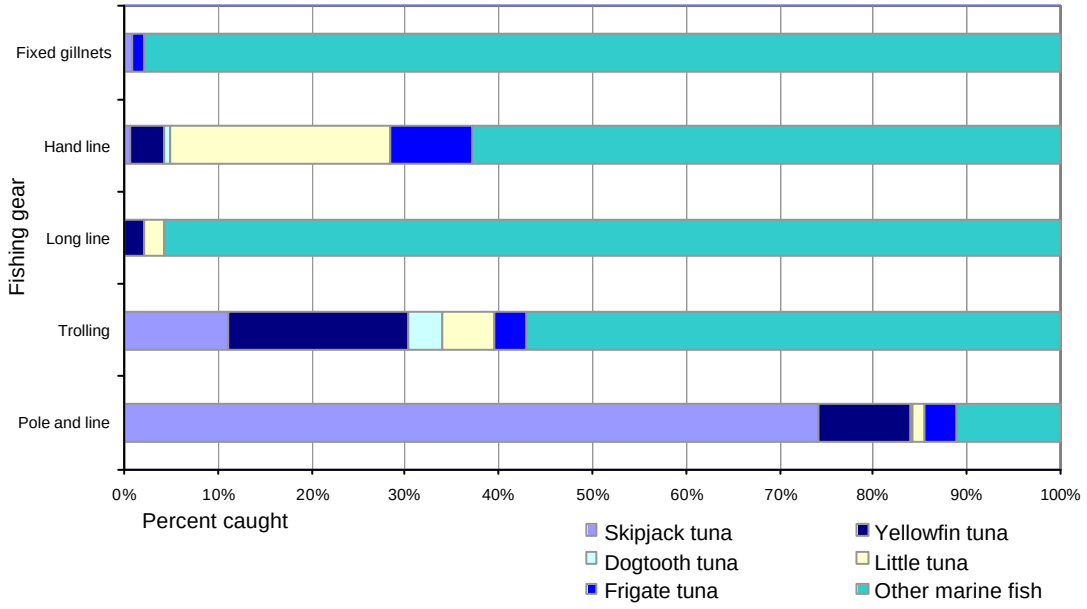
Reef sharks as well as oceanic sharks are exploited mainly for the fins. Dried shark fins fetch good prices in the international market. Anderson and Ahmed (1993) suggested that reef sharks were being fished at moderate levels of fishing effort, which was

probably sustainable at the time of study. However, an increase in fishing effort from that of 1993 levels would adversely affect stocks. The current status of reef shark stocks is unknown.

Threat of over-exploitation is the biggest environmental problem posed by commercial exploitation of reef resources. The export quantities of most of the reef species have declined. Since stock status is not monitored regularly it is not known if stocks are over-exploited.

Fishing methods generally practised in the Maldives are not destructive for the environment. Figure 3.13 provides details of fish catch by fishing methods. Although the fisheries industry expanded through the mechanisation of the traditional fishing fleet, fuel distribution and fish collection systems, the fishing practice remained traditional. Most fish are caught using lines which target a certain species and thus by-catch which is wasted is almost non-existent. The tuna fishery is largely based on pole and line fishing from mechanised dhonis, thus producing a "dolphin friendly" product. Other species such as groupers are caught using hand lines and sea cucumbers are collected by hand or using lines. Gillnets are mainly used for targeting reef sharks.

Figure 3.13: Fish Catch by Gear



Some bait fishing practices are known to have adverse effects on the habitat. When catching species closely associated with the reef, sometimes poles or a “scarer” (palm

fronds or steel chain) are used to chase the fish. This can result in damage to the coral (Anderson 1997). In recent years, the method of catching live bait have changed from the traditional method of collecting bait during the day to using light at night to attract bait. The environmental implications of this change are being studied. Although not widely practised, some isolated cases of illegal use of chemicals, which can be detrimental to the reefs, are reported. These include use of household bleach or chlorine to catch octopus.

3.8 Agriculture and Timber

Since soils are poor and land for agriculture is scarce in the Maldives, agricultural production is low. Unlike many other developing countries, agriculture's share of GDP is low (table: 3.7), declining from 3.6% in 1995 to 2.8% in 2000 (MPND 2001).

The most widely grown agricultural product in the Maldives is coconut. Coconut production in 2000 was about 18 million (MPND 2001). Some islands grow root crops such as taro, cassava and sweet potato as well as other crops such as banana, papaya, watermelon, melon, mango, cucumber, pumpkin, betel leaves, chillies, limes, breadfruit and egg plant. Some of these crops are now grown commercially at islands leased on long term basis for agriculture. Nonetheless, almost all of these are subsistence crops.

Table 3.7: Agricultural Contribution to GDP (1995 - 2000)

Year	*% Share of Agricultural Contribution*
1995	3.6
1996	3.4
1997	3.2
1998	3.0
1999	2.8
2000	2.8

There is strong demand for locally grown agricultural products, both from tourist resorts and from an expanding local population. It has been estimated that the total arable land area is less than 30 square kilometres, with production limited to 60 specially designated agricultural islands (MPND 1998).

The threat to biological diversity from agriculture is the clearance of natural vegetation and resultant destruction of habitat and reduction in natural vegetation. In addition, increased use of chemical fertilizers in agriculture has potential to adversely affect the groundwater resources.

Introduction of pests and diseases through imported fruits, vegetables and agricultural products such as fertilizers, soil and plants adversely affect the terrestrial biodiversity (Zuhair 2000). Incidences of disease often incur considerable costs to the country. All the lime trees in the country were wiped out in an incidence of a disease (canker) about 15 years back. In 1997, the coconut trees in an island were highly affected by a species of worm. An incidence of a disease locally known as 'hudhu koodi' (Spiralling White Fly) in 1998 resulted in many trees being cut down in the country.

Timber is harvested mainly for construction of boats as well as buildings. In recent years, the number of requests for timber harvesting licenses has decreased (table: 3.8). The cause for this reduction has not been established. However, it is speculated that buying imported timber may be easier and cheaper or the availability of the timber trees could be decreasing (Zuhair 2000).

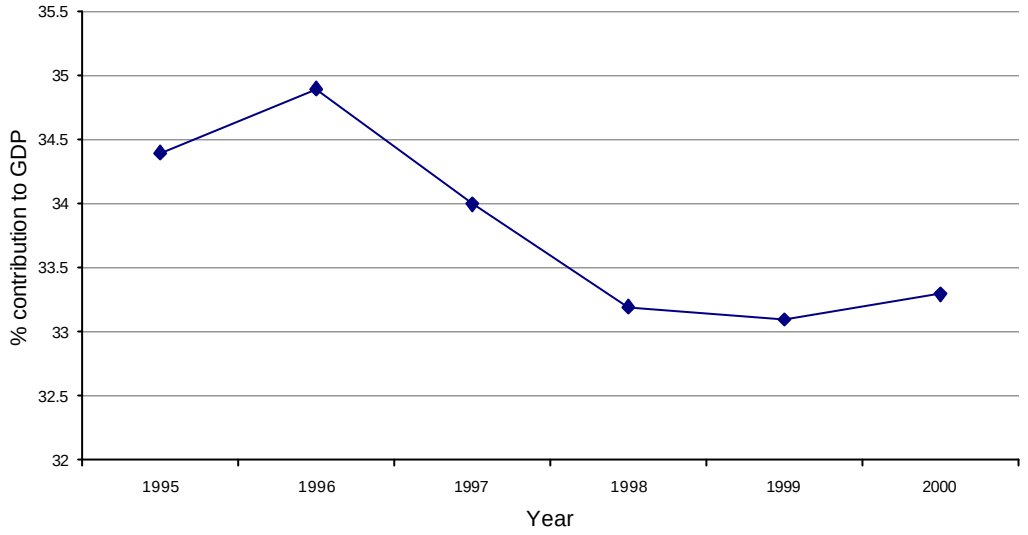
Table 3.8: Timber harvest from uninhabited islands

Common name	***Local Name***		***1993***	***1997***	***1998***	***1999***	***2000***
Coconut Palm	Ruh	(no:s)	3363	1453	683	375	269
Iron wood	Kuredhi	(no:s)	58855	41576	52707	35975	27599
Nit pitcha, Country almond, Sea hibiscus	Uni, Midhili, Dhigga	(meters)	3121	1711	954	617	309
Alexander laurelwood tree, Sea trumpet	Funa, Kaani	(meters)	24	0	11	0	26
Banyan tree,	Nika Alhoa	(meters)	719	310	206	88	34

3.9 Tourism

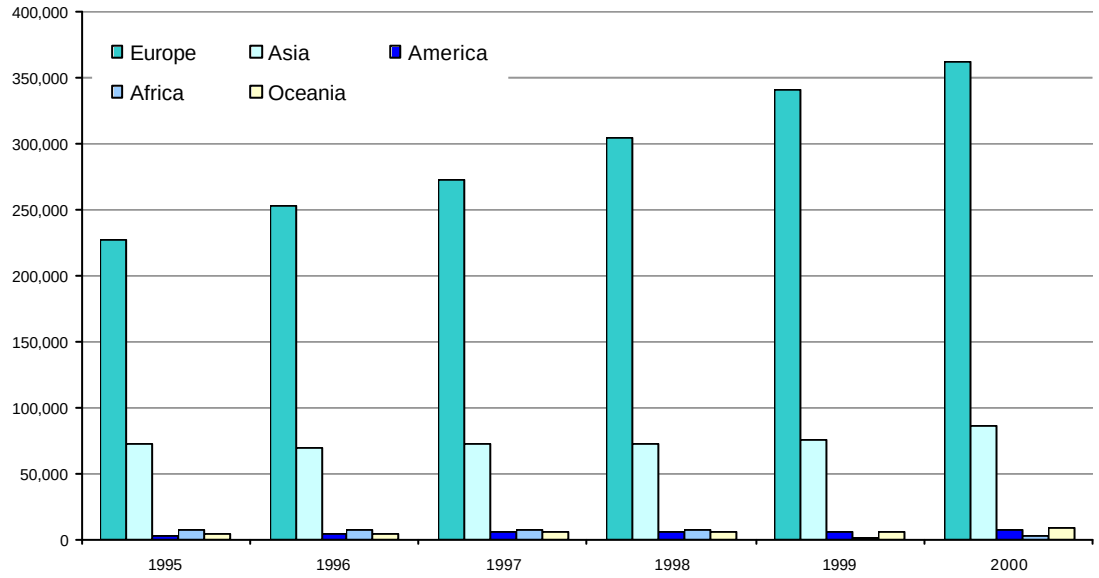
In 2002, the Maldives tourism industry will celebrate 30 years of tourism in the international market. Over this period, the tourism industry has been the main contributor to the economic development of the country. Figure 3.14 shows contribution of tourism to GDP as a percentage of GDP for the period of 1995 to 2000.

Figure 3.14: Contribution of Tourism to GDP



The importance of the tourism to the Maldives economy is also evident in the number of tourists who visit the country each year. Figure 3.15 shows the flow of tourist arrivals by nationality for the period of 1995 to 2000. The major attractions for these visitors include beaches, diving, water sports, recreational fishing, sailing and excursions.

Figure 3.15: Flow of Tourist Arrivals by Nationality



As the tourists come in search of peace and tranquillity, the main source of tourist accommodation is in resorts. Each resort is developed on a separate island and is equipped with modern amenities based on the resort's rating. The number of tourist

resorts has been increasing over the past years and currently, there are 86 resorts, 60 of which are owned locally, 8 foreign owned, 8 jointly owned by foreigners and locals and the remaining 10 are government owned. These resorts are stretched over 10 atolls. Other sources of accommodation include hotels, guesthouses and vessels. Due to the ban on provision of accommodation to tourists in inhabited islands other than Male', guesthouses and hotels are located only in Male'.

The total registered bed capacity provided by resorts, hotels, guest houses and vessels are given in table 3.9.

Table 3.9: Total registered bed capacity

	1995	1996	1997	1998	1999	2000
Resorts	10,688	11,472	11,958	13,740	13,740	15,878
Hotels	312	312	276	418	418	744
Guest Houses	400	246	313	293	321	356
Vessels	912	1278	1484	1577	1577	1,716

The bed capacity utilization rate is not consistent with the increase in bed capacity. Figure 3.16 shows the total bed capacity utilization rate for the period of 1995 to 2000.

Figure 3.16: Bed Capacity Utilisation Rate

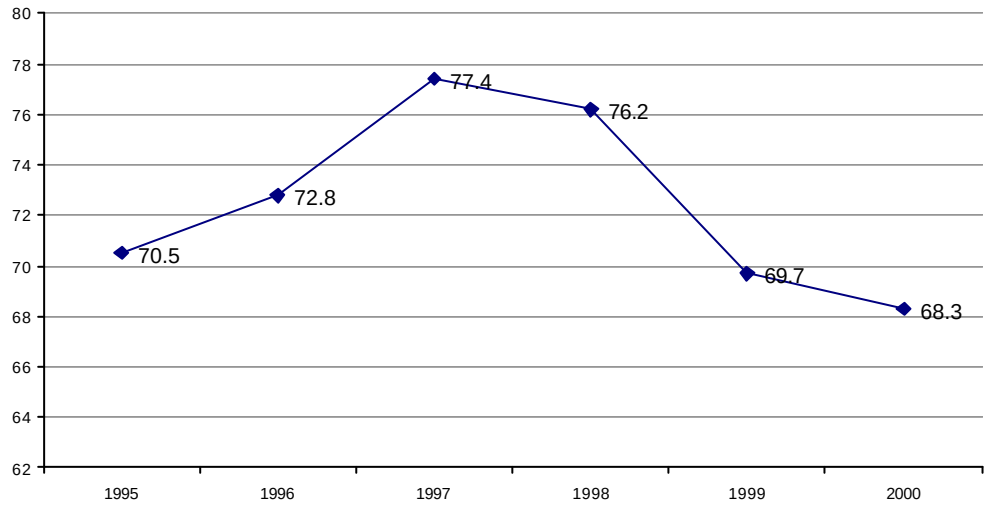
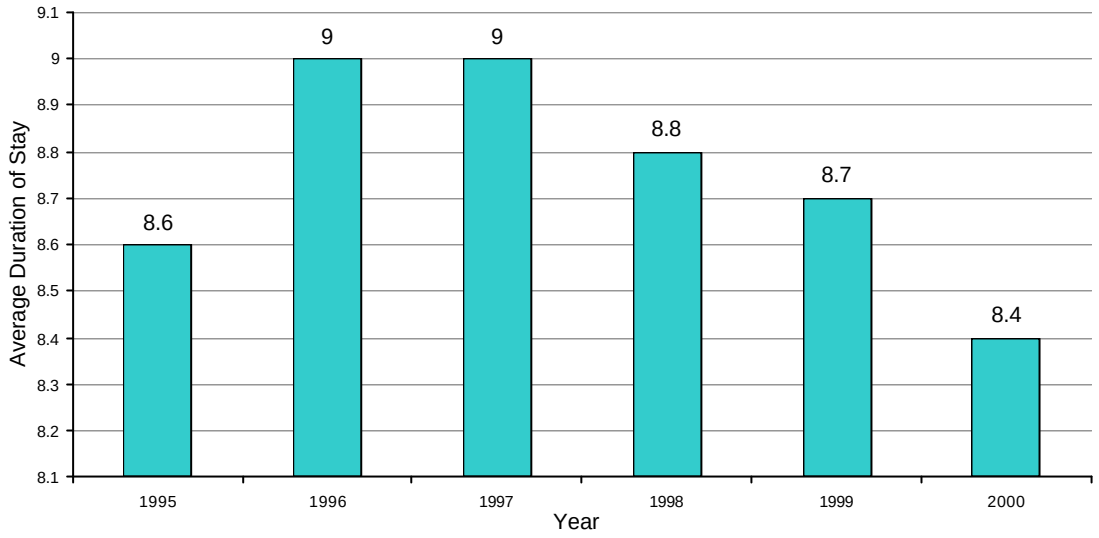


Figure 3.17 shows the average duration of stay by tourists for the period 1995 -2000.

Figure 3.17: Average duration of stay by tourists



Tourism in the Maldives exists largely due to the physical and geographic features of the coral islands and the peace and security that prevail in the country. The beauty of the underwater world at the reefs, clean water in the lagoons, white and pristine sandy beaches, a rich island vegetation and ideal tropical climate are the main features that attracts tourists to the Maldives.

Environmentally unsound practices in solid waste and sewage disposal pose the most serious threat from tourism to the delicately balanced coral reef ecosystem of the Maldives. Though solid waste is a cause of environmental concern, at current levels it is more of an aesthetic problem. In the past, waste and garbage which could not be burned was dumped into the sea. This practice is now prohibited by law and waste incinerators and crushers have to be used in all resorts. Sewage effluent is discharged into the sea by the resorts. However, the discharges from resorts are very small and the evidence on reef degradation from sewage discharges is inconclusive. Some of the resorts are now turning to the latest technology in sewage treatment using ultra violet radiation to produce virtually pure water.

The Maldives has developed a very suitable form of tourism, appropriate for the small island environment. The present form of tourism development has not generated any serious environmental impacts. This has been accomplished through appropriate policies, legislation and plans and instituted mechanisms to apply strict standards and regulations. However, the increasing number and magnitude of coastal modifications

on the islands, including reclamation, harbour dredging and beach replenishment are serious environmental issues that need to be addressed in the tourism sector.

3.10 Climate Change and its Associated Impacts

The Maldives being a fragile low lying small island ecosystem, it is very vulnerable to climate change and its associated impacts especially the predicted sea level rise. Although the Maldives contributes minimally to the global greenhouse gas emissions: 0.001% (MHAHE 2001), it is among the most susceptible to impacts of the changes in climate.

The Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report estimates a projected sea level rise of 0.09m to 0.88m for 1990 to 2100 (IPCC 2001). With more than 80% of the land area of Maldives less than a meter above mean sea level, the slightest rise in sea level will prove extremely threatening. This is further aggravated by the variation of the tide. Many islands already suffer inundation and shoreline erosion because of its low elevation. The inundation often leads to freshwater shortages and disease outbreaks. The magnitude of rise in sea level projected in the IPCC Third Assessment Report threatens the very existence of life and livelihood in the Maldives.

A particular concern of the Maldives is the impact of climate change on the groundwater availability. In the islands rainwater lenses lie atop salt water. As sea level rises, the thickness of the freshwater lenses decreases, and the volume of freshwater decreases. Sea level rise would also increase the likelihood of storm over wash of the islands, causing increased incidence of saltwater contamination of the freshwater lenses.

The tourism industry relying heavily on the marine ecosystems is also under threat from the impacts of climate change. An increase in temperature can very easily bring the reef growth and reef ecosystems to an alarmingly poor status. Although almost all the reefs have recovered from the coral bleaching event of 1997, the impacts of bleaching were felt on around 90% of the reefs of Maldives, bleaching them totally or partially (Naeem et al 1998). The corals already growing at highest tolerable temperatures (approximately 30°, Celsius) have a very grim possibility of survival given the predicted rises in temperature of 1.4 to 5.8°C for the period of 1990 to 2100.

The islands of Maldives are reef-based and coral reefs serve as natural breakwaters. With damage to the coral reefs comes the bigger danger of loosing the natural protection of the islands from the waves and currents. An island with a degraded reef is more open for coastal damages such as beach erosion and more susceptible to inundation by uncontrolled waves reaching the shore.

Fishery is also expected to suffer from the impacts of climate change. Tuna fishery is the main fishery and tuna is a migratory species. A possible change in temperatures can drive the tuna stock to more favourable temperatures. This can lead to a decline in the fisheries industry as the fishermen loose their fishing grounds. The tuna fishery is based on pole and line method using bait fish. Any changes to the availability of bait fish caused by damage to the reefs would also affect the tuna fishery.

A major concern in the country related to the climate change phenomenon is the lack of knowledge and awareness on the issue as well as the lack of necessary resources to properly asses the possible impacts. There is a need for research on localised climate changes and its impacts. There is also an urgent need for the development of resources to adapt to possible impacts of climate change.

El-Nino events and other climate variations also have considerable pressures on the fragile ecosystem of the Maldives. One of the major threats to coral reef biodiversity is coral bleaching associated with increased seawater temperature. The Maldives experienced large-scale coral bleaching during 1998 El-Nino event. Reef monitoring show that live coral cover decreased to a mean of 2.1% from pre-bleaching levels of 30-45% (MRC 1999). Subsequent observations in 1999 showed early signs of recovery with recruitment of highly affected varieties such as acroporids and pocilloporids (Edwards et al 2001). The study states that "despite the severity of mortality, recovery appears to be proceeding much faster in the Maldives than in the species poor eastern Pacific after the 1982-1983 ENSO warming event".

3.11 Natural Disasters and Episodic Events

In April 1987, a storm centre in the southern Indian Ocean resulted in long-distance wave transmission that passed through much of the Maldives archipelago. The waves caused enormous economic losses through damage to infrastructure, land and

vegetation. Male' and the International Airport were among the worst hit with extensive flooding and erosion.

While the rehabilitation work on this damage was still in progress, the country again was faced with storm surges in June and September the same year. Although these surges was less extensive than the one in April that year, many of the agricultural fields were inundated by seawater and some causeways linking islands were badly damaged.

The island of Thulhaadhoo faced inundation in 1988. This was caused by high SW waves (2-2.5m high; duration 12-15 seconds) in association with a high spring tide and south-westerly winds.

The most severe recorded storm event in the Maldives so far was on 30th of May 1991. During the storm, the atmospheric pressure fell down to 997 hpa and the maximum squally winds reached 90 kts per hour (DoM 2001). The most severe weather from this storm was experienced in the southernmost atoll, Addu Atoll. However, most parts of the country were affected, with 4,081 houses in 13 atolls damaged (SAARC 1992).

The resort island of Bolifushi was hit by similar but a very much more localised freak storm in 2000. This storm lasted about 12 hours and caused US$ 1.2 million worth of damages.

Coastal flooding has been experienced in the past and the risks of flood damage resulting from high tides have not reduced in recent years. The degree of severity of some of these events has been thought to have increased due to improper coastal zone management and construction of poorly designed coastal structures. Proper management methods of the coastal zone are now gradually being introduced in the Maldives, and some research and consultations are now carried out in the construction and design of seawalls and coastal structures, as well as in the reclamation of land. The country still needs to increase its capacity in such research and design.

With the prediction by the IPCC of possible increase in extreme events of weather, there is a growing need for enhancing the local capacity in predicting such events as well as for preparedness to face them.

4 RESPONSES

The Government has given priority to develop environmental policies, laws and institutions to deal with the major environmental issues facing the country. The Second National Environment Action Plan of Maldives was adopted in 1999 to address the pressing environmental challenges. The second National Environment Action Plan identifies the need to take an integrated approach to the management of the environment and to work towards the goal of sustainable development. The aim of NEAP II is to protect and preserve the environment of the Maldives, and to sustainably manage its resources for the collective benefit and enjoyment of present and future generations. The NEAP identifies climate change and sea level rise; coastal zone management; biological diversity conservation; integrated reef resources management; integrated water resources management; management of solid wastes and sewage; pollution control and managing hazardous wastes; sustainable tourism development; land resources management and sustainable agriculture; human settlements and urbanization and sustainable fisheries management as the key issues to be addressed.

The Environmental Protection and Preservation Act of Maldives (Act 4/93) was enacted by the People's Majlis in 1993. This act established a framework upon which regulations and policies can be developed to protect and preserve the natural environment and resources for the benefit of present and future generations. Act 4/93 contains important provisions on environmental advice, environmental policy formulation, biodiversity conservation, environmental impact assessment, waste disposal and hazardous wastes. A programme for strengthening of national environmental legislation began in 1996.

The mandate for environmental protection and management was transferred to the Ministry of Home Affairs, Housing and Environment which was formed in November 1998. The Environment Research Unit under the then Ministry of Planning, Human Resources and Environment was elevated to the status of Environment Research Center as well.

The following sections identify some of the major responses to the critical environmental issues facing the country over the last five years.

4.1 Biodiversity

Due to the lack of natural resources and wealth, biodiversity particularly marine biodiversity is the most significant and vital resource base for the country. The livelihood has traditionally been marine-based as well and marine resources still continue to be the main generator of food, earnings, employment, protection and shelter. Recognising the importance marine biological diversity plays in sustainable development, the government has adopted a number of measures for protection and conservation of biodiversity.

The second National Environment Action Plan adopted in 1999, recognises biodiversity conservation as one of the priority issues to be addressed to achieve environmental protection and sustainable development. Other related priority issues identified in NEAP II include coastal zone management and integrated reef resources management.

The first National Biodiversity Strategy and Action Plan (NBSAP) of the country has been adopted in 2001. It was undertaken with extensive stakeholder participation throughout the country, and the draft NBSAP was discussed and endorsed at a national level workshop in April 2001. The Maldives is party to the United Nations Convention on Biological Diversity and the first country report on biological diversity to the Convention Secretariat will be prepared in 2001.

Recognising the importance of healthy coral reefs to the two major industries of the Maldives, tourism and fisheries and the need to address the problems resulting from increased reef resource usage, the Maldivian Government commenced promoting a policy of integrated reef resources management. The Ministry of Fisheries, Agriculture and Marine Resources with assistance from the Bay of Bengal Programme (BOBP) initiated the Integrated Reef Resources Management programme. Under this programme, a workshop was held in Male' in March 1996 with extensive stakeholder participation and national and international advisors, to "identify key issues and objectives for the IRRM process, and make recommendations for its implementations" (BOBP, 1997). The Fisheries Advisory Board endorsed the recommendations made at this workshop, in 1996.

The Government has also initiated several measures for the protection of important habitats and threatened species. The Government designated 15 marine protected areas in 1995 and 10 more areas in 1999 (Box 4.1). Other measures include banning export of important bait fish as aquarium fish; banning fishing from the house reefs of tourist resorts; and the protection of threatened marine resources such as sharks, sea turtles, giant clams, and black coral (table 4.2 and 4.3).

Table 4.2: Protected Marine Life

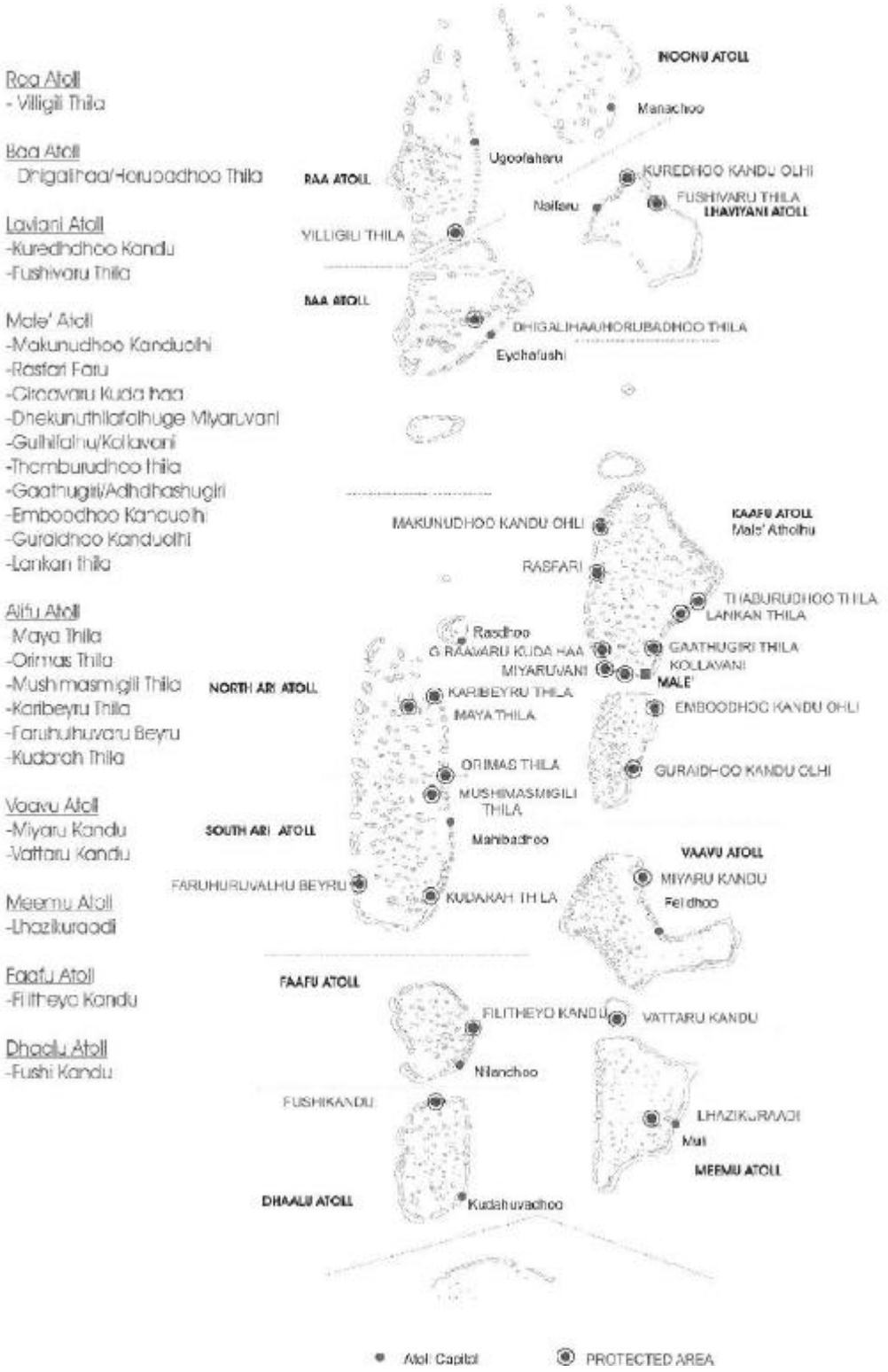
Species	Effective from
Marine Turtles	24 June 1995 for 10 Years
Napoleon Wrasse	24-Jun-95
Whale Shark	24-Jun-95
Black Coral	1-Jan-95

Table 4.3: Marine Products that are banned for export since 1996

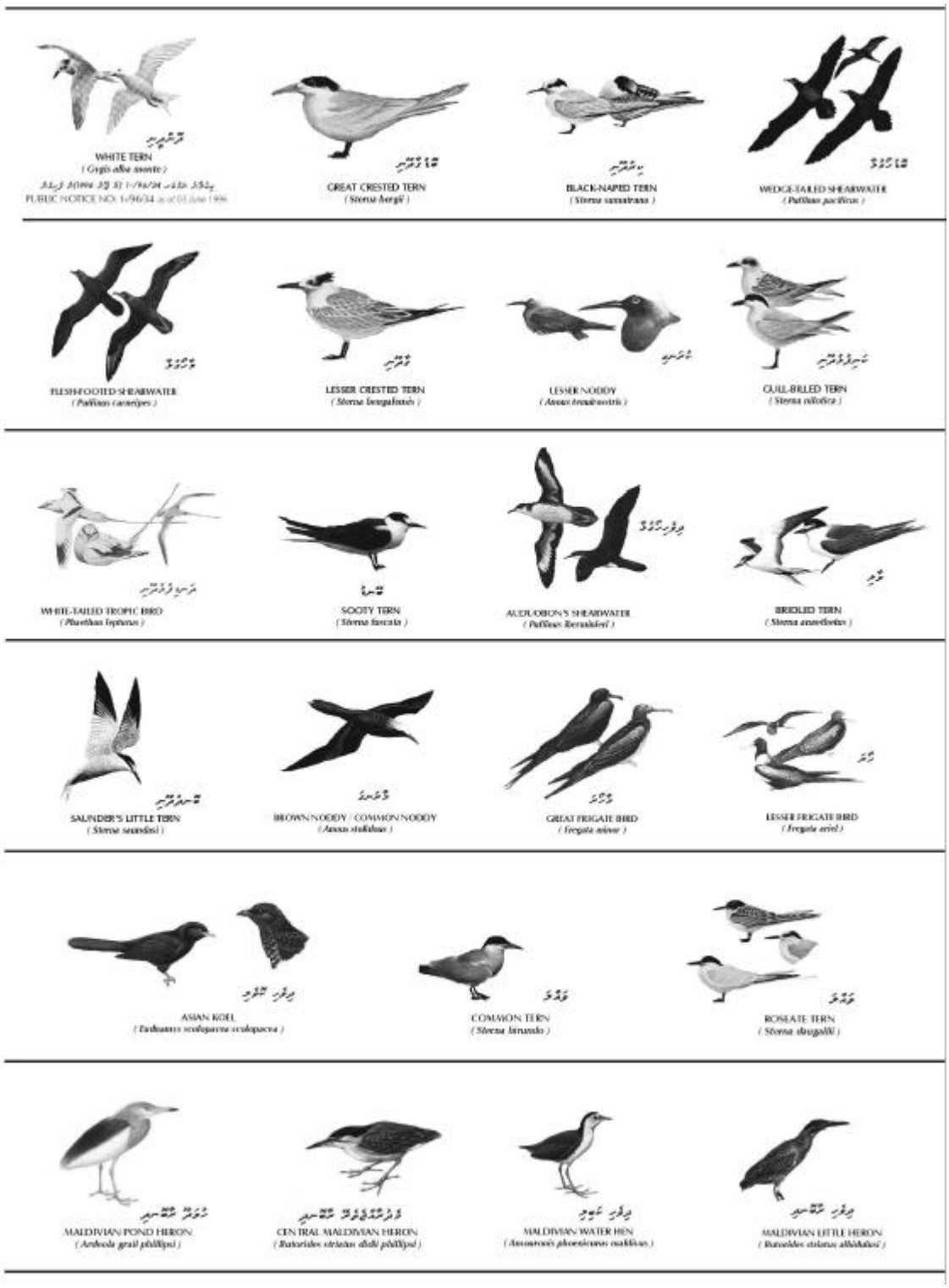
Species
Marine Turtles
Dolphins
Whales
Eels
Puffer Fish
Parrot Fish
Skates and Rays
Bigeye Scad less than 6"
Baitfish
Lobsters
Triton Shell
Trochus Shell
Pearl Oysters
Black Coral
Storny Corals

Protected species include the bird White Tern *Gygis alba monte* in 1996 and 22 additional bird species protected in 1999 under the Environmental Protection and Preservation Act, of which some are important for the local tuna fishery and others are endemic to the Maldives at subspecies level (Box 4.2).

Box 4.1: Marine Protected Area



Box 4.2: Protected Bird Species



A tree planting programme was launched nation-wide during the year 1996 with the aim of adding a million trees to the island ecosystems within 3 years. The tree planting programme was a concerted effort to conserve, rehabilitate and manage the environment. The Ministry of Fisheries and Agriculture was selected as the nodal agency for the implementation of the program under the guidance of the Presidents Office. Due to the extensive support the programme received the initial target of one million trees was almost achieved by the end of 1996 itself. Therefore a new target of 2 million trees was set.

Following on from the two million-tree programme, a 3 year fruit tree planting programme was launched nation-wide in June 2000 by the Ministry of Fisheries, Agriculture and Marine Resources, in an effort to increase fruit trees in the country. The objectives of the programme include increasing awareness and interest in growing fruit trees, increasing local production and generating the spirit of growing trees in all islands.

In order to protect and conserve biological diversity of the country, a pilot project on the establishment and management of protected areas has been initiated with the assistance of the Government of Australia through AUSAID.

Legal measures for protection of timber resources were established through regulations under the Law on Uninhabited Islands (Law no: 20/98). Under this law timber from uninhabited islands can be logged only after getting written approval for the purpose from the Ministry of Fisheries and Agriculture, and in the presence of a representative from the atoll office and a representative of the lessee. In addition, every coconut palm that is logged has to be replaced with 2 coconut palms and every tree that is logged has to be replaced by a tree under the direction of the Ministry of Fisheries and Agriculture.

The Marine Research Centre of the Ministry of Fisheries Agriculture and Marine Resources has undertaken three different coral reef monitoring programmes in collaboration with different institutions or agencies. Coral reef monitoring to assess the extent of coral bleaching is been carried out in collaboration with the Global Coral Reef Monitoring Network (GCRMN). The overall objective of the Maldives/GCRMN project is to improve management and sustainable use of coral reefs and related ecosystems by providing information on the trends in biophysical status, social cultural

and economic values of these ecosystems (Anon 1999). Marine Research Centre (MRC) has also participated in the Reef Check programme since 1997; a volunteer effort carried out world-wide by recreational divers and led by experienced marine scientists. In addition MRC has an ongoing program on identification and cataloguing of fish species in Maldivian waters.

4.2 Climate Change

In order to reduce the emission of greenhouse gases, the Maldives has started pilot projects on alternate sources of energy. Solar power has been used to power telecommunication sets, navigational aids and government office buildings and mosques in the islands. The main constraint to the widespread use of solar energy is the lack of technical backup and high installation costs. While wind is a regular feature of the Maldives, existing wind speeds are considered marginal for electricity generation, unless high towers are erected at high capital cost. Supplementing conventional energy supply by alternate energy sources, wherever viable, has been included in the energy sector objective and strategy in the National Development Plan.

As the Maldives is very vulnerable to the predicted climate change and sea level rise, attention is given to adaptation measures. Various programmes have been designed and implemented in areas such as coastal protection, freshwater management and coral reef protection. The breakwater around the capital Male' cost around 30 million US Dollars. The government has taken very important measures to protect the coral reefs by reducing import duty on construction materials and prohibiting use of coral for government buildings and tourist resorts and by banning of coral mining from house reefs.

The flooding in 1987 triggered concern in the Maldives about the possible impacts of climate change. President Gayoom played an important role in bringing the issue to the attention of the world community by addressing the UN General Assembly, Commonwealth Heads of Government Meeting in Langkawi, and the SAARC Summit held in the same year. On the request of the President, the Commonwealth and the SAARC established expert groups to study the impacts of greenhouse effect and global warming. A United Nations Environment Programme mission visited the Maldives and recommended training of local personnel to monitor and evaluate impacts of expected

environmental changes and the development of strategies that would permit sustainable development.

The Maldives has played a leading role in encouraging the small island states to band together to devise a unified stance on global climate change problems among small island states. In 1989, with the help of the Commonwealth Secretariat, the Maldives hosted the Small States Conference on Sea Level Rise at Ministerial Level, the outcome of which was the Male' Declaration on Global Warming and Sea Level Rise. This declaration called for negotiations for a framework convention on climate change to start as soon as possible after the adoption of the interim report of the IPCC. It also called upon all states to reduce or limit the emission of greenhouse gases and called upon the international community to assist small states to tackle environmental problems.

The Maldives participated in the Second World Climate Conference in 1990 and was instrumental, along with other small island states, in ensuring that the resulting Ministerial Declaration mentioned the special problems faced by small states. The Declaration notes that the present rate of climate change "could even threaten survival in some small island states" and recommends that "adequate and additional financial resources should be mobilised and best environmentally sound technologies transferred expeditiously in a fair and most favourable basis."

The Maldives was instrumental in the formation of the Small Island Action Group that eventually at the Second World Climate Conference in Geneva, in 1990, became the Alliance of Small Island States. The Alliance of Small Island States commonly known as AOSIS is a group of developing countries that share common objectives on environment and sustainable development. The group comprises of small island and low-lying coastal developing countries which are members of island regional groupings or organisations. The members of AOSIS are particularly vulnerable to the adverse consequences of climate change such as sea level rise, coral bleaching and the increased frequency and intensity of tropical storms.

The Maldives is a party to the United Nations Framework Convention on Climate Change (UNFCCC). The Maldives signed the Convention on 12th June 1992 and ratified the same on 9th November 1992. The Maldives played a very important role

with AOSIS in the negotiation process that started in Berlin and culminated in Kyoto. The Maldives, though disappointed with the low targets agreed for in the Kyoto Protocol, looks for early implementation of the Protocol. The Maldives was the first country to sign the Kyoto Protocol on 16th March 1998 and it ratified the Protocol on 30th December 1998. The first National Communication of the Maldives to UNFCCC was submitted at the 7th Session of the Conference of the Parties to UNFCCC held in Marrakesh in 2001. The National Greenhouse Gas Inventory, National Mitigation Plan, Vulnerability Assessment and Adaptation Options are included in the national communication of Maldives.

4.3 Population

The mandate for population related activities was given to the Ministry of Planning and National Development in 1998. In 1998, a project, "Support to the Population Programme Coordination Unit" was undertaken by the Maldivian government and UNFPA, with the aim of supporting the population programme coordination and bringing about population trends consistent with the national policies of sustainable development. Under this project, the Population Programme Coordination Unit (PPCU) or the Population Section was formed on 1 January 1999.

The Fifth National Development Plan identified the formulation of a National Population Policy as an objective to controlling population growth during the Plan period. On 24 March 1999, a Population Programme Coordination Committee (PPCC) was formed in Ministry of Planning and National Development. The Committee is in the process of drafting a population policy statement.

Atoll Population Committees (APC) have also been formed in all the atolls with the aim of spreading awareness on population control in the islands and the first workshop of these committees have been conducted in Noonu, Raa, Dhaalu, Haa Alif, Meemu and Baa Atoll.

One of the new policy initiatives pursued by the Government is the Population Development and Consolidation Programme. This is an ongoing Programme that aims to minimize the diseconomies of scale faced by the country in the provision of socio-economic activities by facilitating the migration of inhabitants in smaller and more remote islands to larger islands. Such population concentrations on large islands will

enable the provision of better socio-economic services and economic opportunities and thereby lead to a better standard of living. The people of Hdh. Hondaidhoo have been resettled in Hdh. Hanimadhoo, while the people of Sh. Maakan'doodhoo are in the process of moving to Sh. Milandhoo and Sh. Funadhoo. Part of the population of Sh. Firun'baidhoo have also been moved to Sh. Funadhoo and the rest will be resettled in the near future.

Another significant policy is regional development, and the first Regional Development Project is aimed at more equitable development of the country and it involves developing two regions, the Northern Development Region (NDR) (Haa Alifu, Haa Dhaalu and Shaviyani Atolls)and the Southern Development Region (SDR) (Gaafu Alifu, Gaafu Dhaalu Gnaviyani and Addu Atolls).

In 2001 a family law covering marriage, divorce, and guardianship was passed. There is a need for such a law due to the ease of divorce and remarriage in the Maldives, the divorce rate in the Maldives, is one of the highest in the world.

The World population Day is marked each year in the Maldives through awareness raising activities. Such activities include island level activities in the atolls, population seminars for secondary school students, clinic programmes, Population Day Quiz and Internet Chat Room on Population Development. The main objective of the clinic programme is to provide reproductive health services to mothers and children and to create awareness on reproductive health, family planning, safe motherhood and other population issues.

4.4 Households, Housing and Human Settlements

The Fifth National Development Plan recognized management of human settlements as a critical issue for national development. The Government has also identified the preparation of a National Shelter Strategy as one of the high priority areas at the Sixth Round Table Meeting between the Maldives and its development partners (Project No:6 Policies and Strategies for a National Shelter Development Programme) This illustrates the Government's commitment to provide adequate shelter and sustainable human settlements for the people. The project profile goes on to say "housing problems in Maldives are related to both the availability of housing and the quality of available accommodation".

In the context of the specific problems in Male' and the urgency to find a solution to the continued growth of the national capital, the "Selected Islands Development Strategy" was launched by the Government. Villingili in the vicinity of Male' has already been developed under this programme as the new and fifth ward of Male'. A UNCHS/UNDP Villingili Island Development Plan was prepared and the Villingili development includes three main housing development activities: allocation of housing plots to the selected needy families for the construction of houses by themselves, the construction of flats for service personnel, to be allocated on a rental basis and the construction of high rise residential flats. Currently, 383 housing plots of 130 m2 each have been allocated out of a possible 454. According to the 2000 census, the population of Villingili has increased from 300 in 1995 to 4291 in 2000. The number of households increased from 44 in 1995 to 601 in 2000.

The other priority project inititated by the Government to address the Male' urban issue is the Hulhumale Land Reclamation and Development Project. Hulhumale has been described as the largest and most complex land reclamation and development project ever to be undertaken in the Maldives. The overall objective of the project has been stated as "to find in the context of national settlement consolidation strategy, a longer term solution for the consolidation of the central area of Maldives and physical expansion of Male', particularly in terms of the new land required for housing and industrial expansion and to create an environmentally protected land reserve capable of meeting national needs in the next century. This project envisages the reclamation of approximately 12.8 km2 of reef and lagoon in Hulhule. Hulhule lagoon, because of its large area, closeness to Male', ease of reclamation due to shallowness and the possibility of a land link to Male' which is only 4.6 km away, has been identified as the most appropriate choice. After reclamation, the project area is to be zoned for residential, mixed and industrial uses as well as for the Airport and Port uses.

Housing and settlements development on uninhabited islands is being undertaken by the Ministry of Atolls Administration under the project "Enhancing Atoll Human Settlement Opportunities in Maldives". In recent years the residents in a number of islands have expressed an increasing desire to be resettled in another island, in the context of growing population and because of many logistical difficulties experienced by the residents in the context of the conditions of the islands that they live in. In some

islands, construction of jetties is restricted by the too narrow or even non-existent reef and the residents of those islands find it almost impossible to eke out a living without facilities for their boats and request for transfer to other islands. Then there are other islands where residents have to move out, for environmental and health reasons such as the absence of ground water. In view of the above, the Government through the Ministry of Atolls Administration has launched a programme for the resettlement of families in under populated islands or uninhabited islands. Under this programme, settlers receive new houses constructed through contractors. They are allowed to take fixtures and movable assets from their original homes and in addition will receive compensation for all assets located in the old property such as water tanks and trees, at the time of their departure.

In the context of the present housing issues in Male', the Government has given priority to the implementation of a Male' Housing Development project as well. Under this project, 128 flats have been developed and leased to the residents of Male'.

4.5 Solid Waste Management

The management of solid wastes is identified as a key environmental issue in the Second National Environment Action Plan. In 1998, a study on The Solid Waste Management for Malé City in the Republic of Maldives was carried out with the assistance of Japan International Co-operation Agency (JICA), to assess the solid waste disposal problems in inhabited islands and resorts.

The Ministry of Home Affairs, Housing and Environment is currently in the process of developing a national waste management strategy for the country. An interagency technical committee was formed in April 2000 to advice the Ministry on the national waste management strategy.

Under the South Regional Development Project, and with the guidance of the technical committee, work is underway to develop a solid waste disposal site in Hithadhoo. A similar site is being developed under the Northern Regional Development Project in Kulhudhufushi. These waste disposal sites are expected to become operational in 2002.

Barging of solid waste collected at the transfer station from Male to Thilafushi has proved practical and efficient. The experience gained from this operation is planned to

be utilised in all the inhabited islands of Malé Atoll in 2002. Plans are underway to barge the solid waste collected from the inhabited islands in Malé atoll to the Thilafushi landfill. When this project is implemented, the problem of solid waste disposal in Malé Atoll would be significantly improved.

4.6 Hazardous Waste

Maldives is party to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. The Environment Protection and Preservation Act of the Maldives (Law 4/93) provides a statutory framework enabling the control and regulation of the transboundary movement of hazardous waste controlled under the Basel Convention in the Maldives.

4.7 Air Pollution

As air pollution is an emerging environmental issue in South Asia, on the initiative of United Nations Environment Programme a declaration to promote regional co-operation in the area of air pollution was agreed in 1998. The Malé Declaration on Control and Prevention of Air Pollution and its Likely Transboundary Effects for South Asia was adopted by Ministers of Environment at the seventh meeting of the Governing Council of South Asia Co-operative Environment Programme (SACEP) in Male'.

In 2001, the Government adopted, Addressing Air Pollution - National Strategy for Action with the aim to establish the necessary framework for addressing air pollution to protect the environment of the Maldives. The action plan calls for regular monitoring of air pollution and to assess the impacts of air pollution on human health and assets, introduction of preventive and management measures for air pollution at the source level, development of suitable coordinating mechanisms for the successful implementation of the air pollution action plan and for building adequate capacity to address the issue of air pollution.

As a means of reducing the traffic problems and improving the air quality in Male', the Government has banned in December 2000, the import of reconditioned motorcycles which have an engine capacity of less than 150 cubic meters into the country. Similarly, a ban was introduced on the import of cars more than 5 years old into the country.

In 1998 and 1999, the Maldives contributed to the Indian Ocean Experiment (INDOEX) which was carried by an international group of scientists. A climate observatory was established at Kaashidhoo in 1998 as part of the Indian Ocean Experiment (INDOEX). The station was developed as a model station for frontline atmospheric research in the tropics. It was aimed at providing an excellent venue for scientists to study a range of critical issues of general interest to the climate research community. The station was shutdown in July 2000 due to technical problems. The observatory is planned to be relocated in Hanimadhoo to continue the climate research under the second phase of INDOEX as Asian Brown Cloud (ABC) with assistance from UNEP. This station will monitor the impact of pollutant emissions in the region.

4.8 Freshwater

In 1995, the Government of Maldives transferred the water supply and sewerage management of the city of Malé from the Maldives Water and Sanitation Authority (MWSA) to a private company, Malé Water and Sewerage Company Ltd., which was set up for this purpose. MWSC is a joint venture company with Government majority shareholding. In order to protect the interests of consumers as well as the environment, the Maldives Water and Sanitation Authority was given the mandate to act as a regulatory body for the company. The regulatory body is responsible for setting standards and regulations for water quality in the Maldives and to monitor and enforce them.

Optimizing rainwater catchments is a priority policy of the Government. In the atolls, rainwater is collected in tanks in individual houses and well water is used for washing and other needs. The Government initiated a programme of providing tanks to the islands to alleviate the water situation and provide safe drinking water to the rural population. With financial assistance from UNICEF, the Government has constructed 1,9255 ferro-cement tanks with a total capacity of over 6,000 cubic meters for community use. In addition, 222 households have been provided with construction materials for the construction of private rainwater tanks. Since 1994, the programme has focused on providing high density polyethylene (HDPE) tanks instead of the ferro-cement tanks. For community use, 588 HDPE tanks with a total capacity of 2,940 cubic meters had been distributed free of charge by the end of the year 2000. For household use, 2,809 HDPE tanks with a total capacity of 6,506 cubic meters have been

distributed on a cost recovery basis under a revolving fund scheme. However, these are not sufficient to serve all the island population.

The Government has also initiated programmes to address the sewage disposal related issues. At present, MWSC is improving the performance of the existing sewerage system in Malé. Efforts are underway to reduce the level of hydrogen sulphide gas in sewers by sewer ventilation. Leaking catch-pits are being replaced by plastic (HDPE) pits to ensure strength and longevity and to virtually eliminate leaks and reduce groundwater contamination. The small bore sewerage systems installed on 7 islands have had several problems related to design, construction and maintenance. Consequently, a study to find practical options and develop selection and management criteria is now underway.

Water quality surveillance is given special focus by the Maldives Water and Sanitation Authority. The Public Health Laboratory carries out daily tests on desalinated water produced in Malé and Villingili by MWSC. Water test kits have also been provided to regional hospitals. Appropriate training on how to use these test kits have also been given to concerned persons at the regional hospitals. Bathing water quality in Malé Swimming Track (or fathaa sarahaddu) is tested regularly to protect swimmers who swim in the area, which is close to sewer outfalls for PS2 and PS9 behind Dharubaaruge. Water quality monitoring is also carried out for 64 groundwater wells in Malé and water resources of selected islands of selected atolls are assessed every year.

5 GAPS AND NEXT STEPS

This state of the environment report shows that we still lack understanding of the interactions and impacts of human activities on the environment of Maldives. Information on the current state of the environment is weakened by lack of data on important components.

Whilst the overall state of the environment is unclear, beach erosion, climate change and sea level rise, loss of biological diversity, solid waste disposal, and freshwater degradation can be seen as the critical environmental concerns facing the Maldives. Transboundary air pollution is also a major concern. A number of response measures have been undertaken to address these issues. However, there is a need to find out whether the environmental policies are having the desired results. There is also the need to identify the root causes of environmental problems which are not adequately addressed by environmental policies.

State of the environment and policy effectiveness can be assessed only if quality data are routinely collected through monitoring systems. Over the coming years, the Government will give due attention to improving the collection of data and strengthening the monitoring systems. A database for state of the environment reporting will be established within the Ministry of Home Affairs, Housing and Environment and will be made accessible over the World Wide Web at www.environment.gov.mv. Special attention will also be given to develop suitable indicators for state of the environment reporting and this process will complement the national testing of sustainable development indicators in the Maldives.

REFERENCES

Adam S. and Anderson R. C. (1996) *Skipjack tuna (Katsuwonus pelamis) in the Maldives* pp. 55-69. In: MRS (1996) The Maldivian Tuna Fishery: A collection of Tuna Resource Research Papers, Maldives Marine Research Bulletin 2: 176pp

Adam, D.D. (1984) *Report to the Government of the Maldive Islands on Floral Identification*. Report No. RAS/79/123. Rome: FAO. 40p.

Adam, M.S., Merrett, N.R. and R.C. Anderson. (1998) *Additions to the fish fauna of the Maldive Islands: Part I: And annotated checklist of the deep demersal fishes of the Maldive Islands.* Ichthyological Bulletin of the J.L.B Smith Institute of Ichthyology, No. 67, pp1-19.

Adam, S. (1997) *The aquarium fishery of the Maldives.* Pp: 93-115. In: Nickerson, D. J. and M. H. Maniku (eds) Report and Proceedings of the Maldives/FAO National Workshop on Integrated Reef Resources Management in the Maldives. Male', 16-20 March, 1996, BOBP, Report No. 76, Madras. Pages 250+VI.

Ahmed, A.H. and M.R. Saleem, (1999) *Marine Flora and Fauna of the Maldives*. Biodiversity theme paper prepared for the Ministry of Home Affairs, Housing and Environment. Unpublished manuscript.

Alcock A. (1906) *Marine crustaceans*. XIV. Paguridae. In Gardiner (1903-06), 2: 827-835.

Anderson (1996) *Sea birds and the Maldivian tuna fishery*. Rasain 16: 134-147

Anderson R. C. (1997) *The Maldivian tuna livebait fishery*. 69-92pp. In: Nickerson, D. J. and M. H. Maniku (eds) Report and Proceedings of the Maldives/FAO National Workshop on Integrated Reef Resources Management in the Maldives. Male', 16-20 March, 1996, BOBP, Report No. 76, Madras. Pages 250+VI.

Anderson R.C. and H. Ahmed (1993) *The shark fisheries in the Maldives*. Min. of Fisheries and Agriculture, Male' and FAO Rome. 73pp.

Anderson, C (1997) "Sharks Mean Business" *Scientific American.* pp: 72-73

Anderson, R.C., Randall, J.E. and R.H. Kuiter. (1998). *Additions to the fish fauna of the Maldive Islands: Part II: New records of fishes from the Maldive Islands, with notes on other species*. Ichthyological Bulletin of the J.L.B Smith Institute of Ichthyology, No. 67, pp 20- 32, 4 plates.

BOBP (1994) *An Environmental Assessment of the Bay of Bengal Region.* In Staffan, H. (eds) SWEDMAR-BOBP XII

BOBP (1997) *Report and Proceedings of the Maldives/FAO National Workshop on Integrated Reef Resources Management in the Maldives*. Nickerson, D. J. and M. H. Maniku (eds) Madras BOBP, Report No. 76. Pages 250+VI.

Boehlert, G.W. (1987) *A Review of the Effects of Sea Mounts on Biological Processes, Geophysical Monograph* 43:405

Borradaile, L. A. (1903a) *Marine Crustaceans*. I on varieties II. Portunidae. In Gardiner (1903-06), 1: 191-208.

Borradaile, L. A. (1903b) *Marine Crustaceans*. III The Xanthidae and Some Other Crabs. In Gardiner (1903-06), 1: 237-271.

Borradaile, L. A. (1903c) *Marine Crustaceans*. Some Remarks on the Classification of the crabs. V. The Crabs of the Catometope families. VI. Oxystomata. VII. The barnacles. In Gardiner (1903-06), 1: 424-443.

Borradaile, L. A. (1906a) *Marine Crustaceans*. IX The sponge-crabs (Dromiacea) In Gardiner (1903-06), 2: 574-578.

Borradaile, L. A. (1906b) *Marine Crustaceans*. XIII. The Hippidea, Thalassinidea and Scyllaridea. In Gardiner (1903-06), 2: 750-754.

C4 (2000) *C4- INDOEX Final Report*. California: University of California.

Coleman N. (2000) *Marine life of the Maldives*. Atoll Editions. Australia. 328 pp

Customs (1994) *Statistical Year Book 1994.* Male': Customs.

DoM (2000) *Meteorology Data.* Male': Department of Meteorology

Edwards A. J., S. Clark, H. Zahir, A. Rajasuriya, A. Naseer and J. Rubens (2001) *Coral bleaching and mortality on artificial and natural reefs in Maldives in 1998, sea surface temperature anomalies and initial recovery.* Marine Pollution Bulletin. Vol 42: 7-15.

Edwards, A.J. (1989) *The Implications of Sea Level Rise for the Republic of Maldives.* Commonwealth Secretariat.

Frazier J., Salas S. and Didi N.T.H. (1984) *Marine turtles in the Maldive Archipelago*. Unpublished report, Min. of Fisheries, Maldives. 58pp.

Gardiner J. S. (ed) (1903-6) *The fauna and geography of the Maldive and Laccadive archipelagos, being the account of the work carried on and the collections made by an expedition during the years 1899 and 1900*. Cambridge University Press. 2 vols.

Gardiner, J.S. (1902) Expedition to the Maldives: Narrative and Route of the Expedition. *Tropical Agriculturalist, Volume 21.*

Gardiner, J.S. (1903) *The Fauna and Geography of The Maldive and Laccadive Archipelagoes, being the account of the work carried out and collections made by an expedition during the years 1899 and 1900.* Volumes 1 & 2. Cambridge University Press

Hackett, H. E. (1977). *Marine algae Known from Maldive Islands*. Atoll Research Bulletin. 210: 1-30

Hanson, H.B. (1995) *Republic of Maldives Land Study.* Maldives: Ministry of Planning, Human Resources and Environment

Holmes, M (1993) *The Maldives Archipelago, Indian Ocean, a report on an investigation of fruit bats and birds.* Male', Maldives. (Unpublished report)

Hoyle W. E. *The Cephalopoda*. In Gardiner (1903-06) 2: 975-988.

IPCC (1998) *The Regional Impacts of Climate Change, An Assessment of Vulnerability.* In Watson, R.T., Zinyowera, M.C. and Moss, R.H. (eds). New York: Cambridge University Press.

JICA (1999) *The Study on Solid Waste Management for Male' City in the Republic of Maldives.* Male': Japan International Cooperation Agency

Joseph, L. (1991) *Study of Beche de Mer (sea cucumber) Fishery in Maldives*. FAO/Bay of Bengal Programme. (Unpublished report). 44pp.

Maniku, H.A. (1990) *Changes in the Topography of the Maldives.* Male': Forum of Writers on Environment

MHAHE (1999) *Second National Environment Action Plan.* Male'. Ministry of Home, Affairs, Housing and Environment.

MHAHE (2001) *First National Communication of the Republic of Maldives to the United Nations Framework Convention on Climate Change*. Male'. Ministry of Home, Affairs, Housing and Environment.

MOFAMR (2001) Direct communication with Ministry of Fisheries, Agriculture and Marine Resources.

MoH (1998) *Health Master Plan 1996- 2005.* Male': Ministry of Health

MoH (2000) *Maldives Health Report 2000.* Male': Ministry of Health

MoT (1999) *Tourism Statistics: 25 Years of Sustainable Development of Tourism.* Male': Ministry of Tourism

MPHRE (1995) *Statistical Yearbook of Maldives*. Male': Ministry of Planning, Human Resources and Environment

MPHRE (1996) *Statistical Yearbook of Maldives 1996.* Male': Ministry of Planning, Human Resources and Environment.

MPHRE (1998) *Fifth National Development Plan 1997- 2000.* Male': Ministry of Planning Human Resources and Environment.

MPND (2000) *Statistical Yearbook of Maldives*. Male': Ministry of Planning and National Development.

MPND (2001) *Statistical Yearbook of Maldives 2001*. Male'. Ministry of Planning and National Development.

MPND and UNDP (1998) *Vulnerability and Poverty Assessment 1998*. Male': Ministry of Planning and National Development and UNDP

MRC (1999). *Maldives/GCRMN pilot coral reef monitoring study*. Unpublished report, Marine Research Center, Ministry of Fisheries, Agriculture and Marine Resources. Maldives 28pp.

MRS (1997) *Review of the Status of Maldivian Living Marine Resources*, 1996-1997. Unpublished report, Marine Research Section. 25pp.

Naeem, I. Rasheed, A. Zuhair, M. and Riyaz, M. (1998) *Coral Bleaching in the Maldives- Survey Carried out in the North and South Male' Atolls.* Male': Marine Research Section and Environment Research Unit.

Naseer, A. (1997) *Status of Coral Mining in the Maldives: Impacts and Management Options* 169-186. In Nickerson, D. J. and M. H. Maniku (eds) Report and Proceedings of the Maldives/FAO National Workshop on Integrated Reef Resources Management in the Maldives. Male', 16-20 March, 1996, Madras BOBP, Report No. 76. Pages 250+VI.

Nomura K. (1996) *A preliminary List of Shallow Water Polychaetous Annelids Decapod Crustacea in the Vadoo, South Male' Atoll, Maldives Islands*, Collected by K. Nomura during 17-22 April 1996. (Unpublished Report) Kushimoto Marine Park Center, Japan.

Pernetta, J. C. (1993) ed. *Marine Protected Area Needs in the South Asian Seas Region*, Vol 3: Maldives, IUCN Marine and Coastal Areas programme, Gland, Switzerland.

Pratt E. M. (1906) *The Alcyonaria of the Maldives*. II. The genera *Sarcophytum, Lobophytum, Sclerophytum* and *Alcyonium*. In Gardiner (1903-06), 2: 503-539.

Randall, J.E. and R.C. Anderson. (1993). *Annotated checklist of the epipelagic and shore fishes of the Maldive Islands.* Ichthyological Bulletin of the J.L.B. Smith Institute of Ichthyology, No. 59, pp47, 8 plates.

Risk, M. J. and R. Sluka (2000) *The Maldives: A nation of atolls*. Pp 325-351: In T.R. McClanahan, C. R. C. Sheppard and D. O. Obura (Eds) The Coral Reefs of the Indian Ocean. Their Ecology and Conservation. Oxford University Press.

Riyaz, M. Shareef, M. and Elder, D. (1998) *Coral Bleaching Event: Republic of Maldives, May 1998*. Unpublished Report.

SAARC (1992) *Regional Study on the Causes and Consequences of Natural Disasters and the Protection and Preservation of the Environment*. Kathmandu: South Asian Association for Regional Cooperation Secretariat.

Shafeeg, A (1993) *Sea birds of Maldives*. Association of Writers for the Environment, Male', Maldives.

Shakeel H. (1994) *Study of grouper fishery and live grouper holding operations in the Maldives*. Unpublished report, Marine Research Section. 53pp.

Sheppard C. R. C. (2000). *Coral reefs of the western Indian Ocean*: An overview. Pp 3-38. In T.R. McClanahan, C. R. C. Sheppard and D. O. Obura (Eds) The Coral Reefs of the Indian Ocean. Their Ecology and Conservation. Oxford University Press.

Spalding, M.D. Ravilious, C. and Green, E.P. (2001) *World Atlas of Coral Reefs*. California: University of California Press

Thomas P. A., Bakus G. J. and Wright M. T. (1991) *Marine sponges of North and South Male' Atoll*, Maldive Islands, Indian Ocean.

Thomas, P.A., Bakus G. J., and Gulko, D. A. (1992) *A second collection of Marine Sponges from North and South Male' Atolls*, Maldive Islands, Indian Ocean.

Walker, A. O. (1906) *Marine crustaceans*. XVI. Amphipoda. In: Gardiner 1903-1906, 2: 923-932.

Webb, P.C. (1988) *People and environment of Maldives*, Novelty Press Pvt Ltd. Male', Maldives

WHO (1995) *Health and Environment in Sustainable Development*. Geneva: WHO

Woodroffe, C. (1989) *Maldives and Sea Level Rise: An Environmental Perspective*. Australia: University of Wollongong

Zahir, H., Naeem, I., Rasheed, A. and I. Haleem. (1998) *Reef Check Maldives*: *Reef Check 1997 and 1998*. Unpublished report, Marine Research Center, Ministry of Fisheries and Agriculture.

Zuhair, M., (2000) *Conservation of biological diversity – Terrestrial flora.* Paper presented at the regional meeting on conservation of biological diversity. 11-12 August. H.Dh. Kulhudhuffushi. Ministry of Home Affairs, Housing and Environment. Unpublished Dhivehi manuscript. 9p.