DEVELOPMENT TEAM

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1. Introduction

Recent globalization of the economy has led to a rapid growth in population in the coastal cities by providing more employment opportunities and energizing the economy for housing and infrastructure development. The twin threats of development and overexploitation of the coastal and marine resources have led to severe development pressures along the coast world over. This has resulted in substantial loss to coastal wetlands, mangrove forests, seagrass beds, coral reefs, biodiversity and increased coastal accretion / erosion and so on.

The coastal zone is unique and is spatially and temporally dynamic. Thus, it has resulted in divergent perspectives on Integrated Coastal Zone Management (ICZM) and shown us as to how it should be implemented. ICZM has been recognized to be the most essential pre-requisite in developing tropical countries, which have rich and diverse marine resources but high population density along the coastal zone. Compared to developed countries, they have more prevalent incidents of environmental degradation. Such incidents have been brought about by a plethora of unregulated activities that directly or indirectly affect the coastal areas.

Considering these aspects and in line with the provision in the Agenda 21, Chapter 17 of UNCED, which emphasizes the necessity for protection and conservation of coastal and marine ecosystems, the Department of Ocean Development (DOD) initiated an Integrated Coastal and Marine Area Management (ICMAM) programme during 1998, with the establishment of a Project Directorate on this subject with special emphasis on Capacity Building. The programme is assisted by the IDA through World Bank funding for a period of six years.

One of the four components of this project is "Development of Critical Habitat Information System (CHIS)" using Geographic Information System (GIS) for selected critical habitats along the Indian coastline, to study the status of critical habitats like mangroves, coral reefs and areas of rich marine biodiversity and to aid decision support for their conservation and management. Eleven critical habitats were chosen for the development of CHIS, taking into consideration their uniqueness and diversity. They are Gulf of Kachchh and Gulf of Khambhat (Gujarat), Malvan (Maharashtra), 7 Islands off Karwar (Karnataka), 3 Islands off Cochin (Kerala), Kadmat Island (Lakshadweep UT), Gulf of Mannar and Pitchavaram (Tamilnadu), Coringa (Andhra Pradesh), Gahirmatha (Orissa) and Sundarbans (West Bengal).

The CHIS for Karwar and the group of 7 islands off Karwar had been developed with the help of the spatial database derived from land survey / record maps, remote sensing and nonspatial data collected from field data. Significant inputs for the CHIS have been collected by involving the Department of Geology, Mangalore University, Mangalore.

2. Objectives

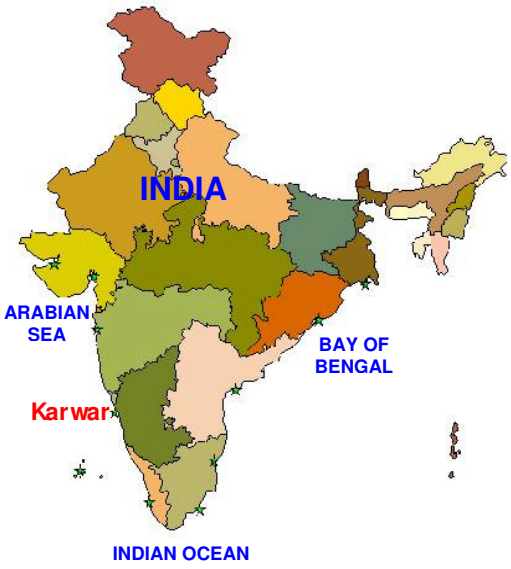
The objectives of developing CHIS for Karwar and its group of islands are:

(a) To collect, compile and collate baseline data/information on the present status of the Karwar Islands and Karwar, particularly with reference to rocky and sandy interstitial zone.

(b) To assess the present status and changes that have occurred in the habitats, in comparison to the past with the help of GIS.

(c) To identify and apply suitable measures including management actions for protection and conservation of the islands.

3. Study area – General Description



Karwar is located in the west coast of India in the Uttar Kannada district of Karnataka (Fig. 1). Coastline of Karwar extends to a distance of about 30 km. The study area, Karwar coast and seven islands covering an area of 270 sq. km is situated in the Arabian sea between 14° 45' - 14° 55' N Lat. and 74° - 74° 07' 30" E Long (Fig. 2).

Fig. 1 - Location of Karwar

The seven islands are located in a 10-km north-south stretch, within 17 m depth off the Karwar coast. They are Kangigudda Island, Kurmagadagudda Island and Shimisgudda Island with a maximum elevation of 32-61 m, north of Karwar coast; Karkalgudda Island and Mandalgudda Island with an elevation of 20-41 m off mid Karwar coast; and, Mogeragudda Island and Anjadeep Island with an elevation of 13-46 m in the south Karwar coast.

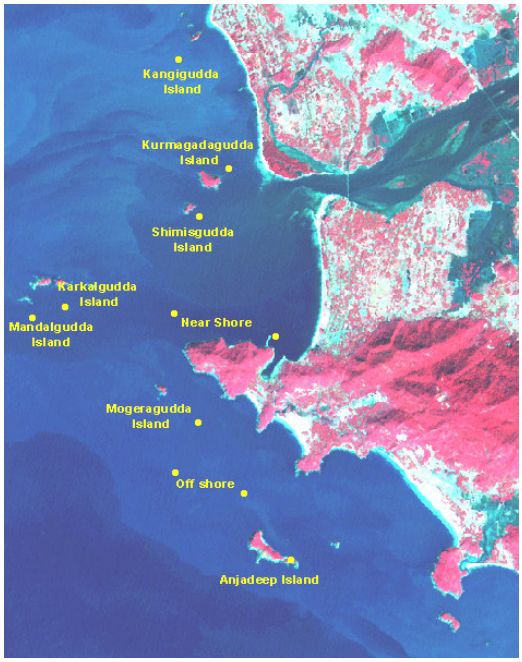


Fig. 2 - Location of Islands off Karwar

Karwar town can be reached by road (National Highway No. 17) or by rail (Kongan railway) from Mangalore. There is an all weather port at Karwar. Nearest airports are Mangalore in the south and Dabolim in the north. The islands off Karwar can be reached only by boats. Electricity is not available in any of the islands except Devagadagudda Island, located near Karkalgudda Island, as it has lighthouse. Telephone facility is available only in the main land Karwar town. All the islands, except Kangigudda and Anjadeep Islands, are categorized as reserved forests.

4. Climatic Conditions

Karwar and the 7 islands off Karwar are in tropical climatic zone. They receive copious rainfall during southwest monsoon season (June to August). The average rainfall varies year to year. The monthly maximum rainfall recorded was 1421 mm during July '99. Monthly mean-maximum temperature was 37.2°C during November '99 and monthly mean-minimum temperature was 17.6°C in February '97. During 98-99, minimum relative humidity recorded was 66% in the month of December '99 and maximum humidity recorded was 92% in the month of September '98. Mean high wind speed of 16.1 km/h was recorded during July '97, and mean low wind speed of 3.0 km/h was recorded during November '99. Predominant wind direction was SW to NE during May-August and NW to SE during October. Rest of the season the wind direction was shifting between the above two directions. Details

on atmospheric temperature, rainfall, humidity and wind speed and direction recorded during 1997-99 are given in Table 1.

5. Ecological Importance

The Karwar group of islands are rocky with sandy shore and proximal to intertidal, estuarine region forming an ideal location for diverse marine organisms characteristic of rocky, sandy inter-tidal and estuarine regions. As very few groups of islands in India are having this unique combination, Karwar islands are ecologically very significant. Presence of halophytes and mangroves in a few islands, occurrence of endangered organisms, such as Olive Ridley turtles, *Lepidochelys olivacea*, dolphins, a wide variety of benthic flora and fauna make the region ecologically significant and diverse. The nearshore waters are productive as run off from the islands and main land brings in rich nutrients.

Table 1 - CLIMATIC CONDITIONS: KARWAR (FOR THE YEARS 1997, 1998 AND 1999)

MONTHS	AIR TEMPERATURE (°C) MONTHLY MEAN						RAINFALL (mm)			MONTHLY MEAN RELATIVE HUMIDITY (%)			MONTHLY MEAN AVERAGE WIND SPEED (km/ hr)			WIND DIRECTON		
	1997		1998		1999		1997	1998	1999	1997	1998	1999	1997	1998	1999	1997	1998	1999
	Min	Max	Min	Max	Min	Max												
JAN	19.2	32.3	20.7	32.9	**18.2**	32.3	0.8	0.0	0.0	80.0	76.0	74.0	6.5	7.3	6.3	NW-SE	NW-SE	NW-SE
FEB	**17.6**	31.0	**19.9**	32.9	20.3	33.6	0.0	0.0	0.0	79.0	75.0	73.0	8.0	8.4	6.1	NNW-SSE	NNW-SSE	NW-SE
MAR	23.1	33.5	22.3	32.5	23.5	32.7	1.3	0.0	0.0	81.0	79.0	82.0	7.7	8.7	8.2	NNW-SSE	NNW-SSE	NNW-SSE
APR	23.9	33.3	26.1	34.4	25.9	32.7	0.0	0.1	1.5	**71.0**	74.0	76.0	10.2	11.2	11.7	NW-SE	NW-SE	SW-NE
MAY	26.7	**33.6**	28.1	**35.0**	25.1	31.3	2.9	38.7	328.2	72.0	**73.0**	84.0	13.4	12.1	9.6	NNW-SSE	SW-NE	SW-NE
JUN	25.0	31.6	25.5	31.2	24.5	30.0	802.8	1372.4	1373.7	83.0	88.0	87.0	12.9	13.7	11.1	NW-SE	SW-NE	SSW-NNE
JUL	24.8	29.9	25.1	29.8	24.3	29.0	1258.1	728.7	1421.0	89.0	89.0	**89.0**	**16.1**	**15.5**	**14.5**	NW-SE	SW-NE	SSW-NNE
AUG	24.4	29.5	25.1	30.1	24.6	29.8	853.7	510.3	201.7	**90.0**	91.0	87.0	14.6	8.2	11.2	NNW-SSE	SW-NE	SW-NE
SEP	24.4	31.5	24.4	29.8	24.1	30.2	128.0	641.3	159.8	87.0	**92.0**	**89.0**	7.3	7.2	6.6	NE-SW	SSW-NNE	SW-NE
OCT	24.7	33.5	24.1	30.1	24.4	31.9	47.5	307.4	227.3	82.0	87.0	87.0	6.2	8.1	6.2	SE-NW	NE-SW	NE-SW
NOV	24.2	33.3	22.3	32.0	22.1	**37.2**	56.1	83.7	TRACE	79.0	77.0	73.0	**5.2**	**5.4**	**3.0**	SE-NW	NNE-SSW	NNE-SSW
DEC	22.4	32.4	20.3	33.0	19.8	34.4	106.0	31.8	0.0	83.0	69.0	**66.0**	6.5	5.9	6.5	SSE-NNW	NE-SW	NNE-SSW

Due to high productivity and rich biodiversity in near and offshore waters, Karwar has been one of the busiest fishing ports in India with six landing centres namely, Majali, Karwar, Binaga, Arga, Chendiya and Kodar within a stretch of 18 km. The area yields more than 30 varieties of fish. In the mainland of Karwar, Anashi National Park and Wild life sanctuary are situated.

6. Methodology

In the process of development of an information system on critical habitat, several steps are involved, viz., 1. Collection of relevant data on physical, chemical and biological parameters of ambient water and bottom sediments, meteorology, geology, geomorphology and socio-economic data relevant to the island ecosystem, 2. Organization of the data using database, 3. Generation of the spatial information from satellite data by visual interpretation and digital classification techniques, 4. Integration of multilayer thematic maps derived from digital processing, 5. Integration of attribute information and analysis of each subsystem by GIS techniques, and 6. Decision-making.

Department of Geology, Mangalore University, Mangalore collected the primary and secondary data required for the development of the information system during pre-monsoon (May '98), post-monsoon (December '98) and summer (April '99) seasons.

Physico-chemical and biological parameters were studied both in aquatic, eulittoral, intertidal and sedimentary environment, in selected sampling locations covering the islands along the coastline (Fig. 3). All the sampling stations were within 1-17 m depth. During the sampling, station positions were fixed using GPS.

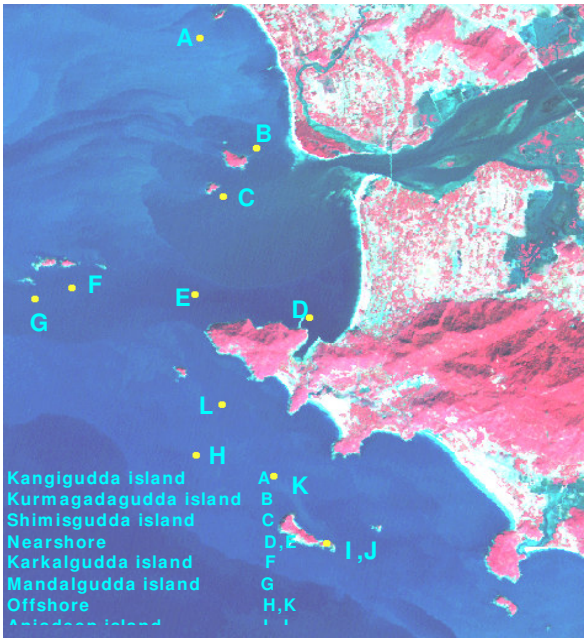


Fig. 2 – Sampling Locations

Data on physical, chemical and biological parameters were collected using standard methods. The wide range of physical parameters such as wave height, wave period and wave directions; tidal amplitude, wind speed and directions were collected. The water quality parameters studied were turbidity, temperature, salinity, pH, total suspended solids, conductivity, pigment concentration, nitrate, nitrite, silicate and phosphate. Sediment samples were collected and analysed for size and composition, as per the standard procedures.

Socio-economic data on population, literacy, occupation, agriculture, aquaculture, fishery resources, industries and tourism were collected from Karnataka State Census Department as well as through field survey. Data were stored as Oracle tables and used in GIS in required format.

Land use / land cover thematic maps for Karwar and Karwar islands were prepared using IRS-1 D LISS III data of January 1998.

7. Relevance of Remote Sensing and GIS to CHIS

The Geographic Information System (GIS), is an excellent tool to store, manipulate, analyse, retrieve and present the data in a geographical and spatial manner. It can hold both spatial and non-spatial data. It allows holding various information as separate themes. Overlay facility in GIS enables analysis of relationship and changes between different themes. GIS also helps as cartographic tool to generate maps with positional accuracy. The use of Global Positioning System (GPS), a modern technique to determine the accurate sample position in the field up to a few metres, improves the precision of spatial data and distribution of desired parameters. Remote Sensing data, in conjunction with conventional data help in mapping the land use and land cover changes. With the use of high resolution multispectral satellite data (IRS-1D, PAN 5.8 m and LISS 23.5 m resolutions), various thematic maps on geomorphology, land use - land cover, geology and coastline change deduction, could be generated by digital image processing techniques.

Using GIS software, thematic maps could be generated from digitally classified satellite data or manually digitized from the analogue maps. The advanced GIS tools, further enhance the capability of spatial data analyses by overlay, interpolation, 3D graphics, etc. Further, customization of the information system is accomplished with windows based user-friendly view design and navigation.

8. Geomorphology of Karwar and the islands

The coastline of Karwar is arc shaped with intermittent rocky and sandy beaches (Fig. 4). The main land has three major landforms namely, coastal, fluvial and denudation plains. The coastal landforms are sandy and rocky beaches, tidal flats and estuaries. The fluvial landforms are river Kali, flood plains of Kali River and channels. The denudation landforms are mountains and pediplains.

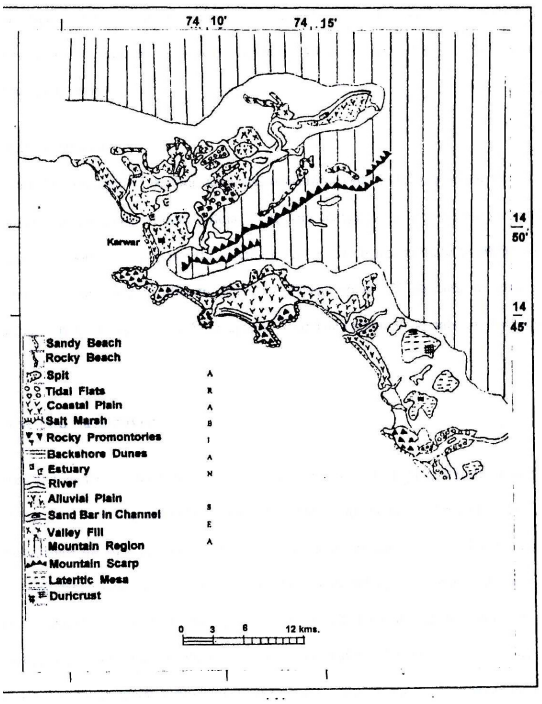
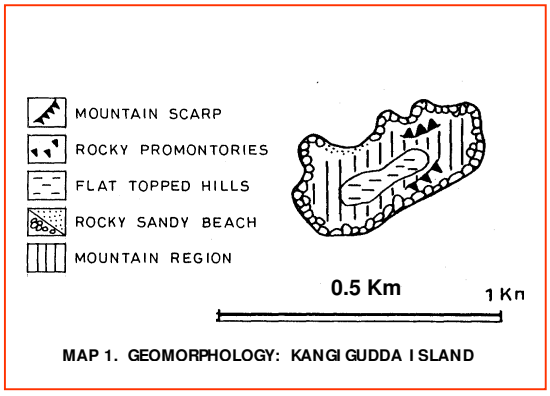


Fig. 4 - Geomorphology of Karwar mainland

Karwar islands are tropical with steep rock hills of about 20-60 m height jutting out of the sea. The coast of the islands is rocky and there are pockets of beaches in Kangigudda islands due to accretion process (Fig. 5). There are no sand-dunes. Migmatitic gneiss and Granitoid with basaltic dykes are the rock types that constitute the hills of Karwar islands with intermediate lateritic soils.

The littoral zone of the islands is dominated by silt followed by sand and clay; the carbon content ranges from 0.033% to 3.7% and organic matter varies from 0.06% to 6.4%. The soil types of the Karwar islands are alluvial and lateritic. The soils represent typical tropical fericrete. *

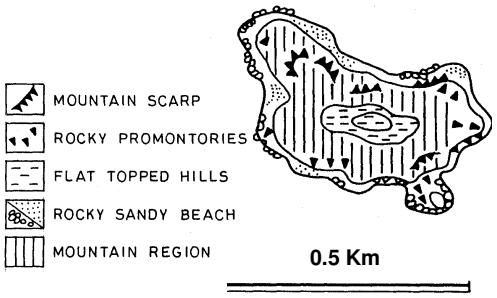


MAP 1. GEOMORPHOLOGY: KANGI GUDDA ISLAND

The shoreline of Karwar islands does not show any phenomenal change, but in the northern portion of the mainland at the mouth of Kali river in the vicinity of Kurmagadagudda and Shimisgudda islands and in southern coastline there are small changes in the coastline due to erosion and accretion. Similarly Anjadeep and Shimisgudda islands having sandy beaches show variation in the coastline. The rocky substratum of the islands and sandy composite serve as ideal habitats for a variety of sessile and intertidal flora and fauna. Fig. 5 shows the geomorphology of the seven islands.

Kurmagadagudda Island (5.3 km^2)

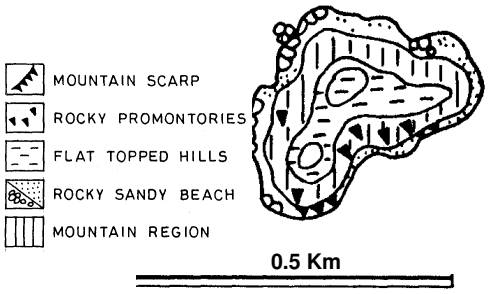
5B



MAP 2. GEOMORPHOLOGY: KURMAGADAGUDDA ISLAND

Shimisgudda Island (1.8 km^2)

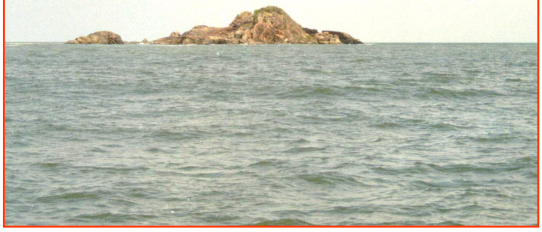
5C

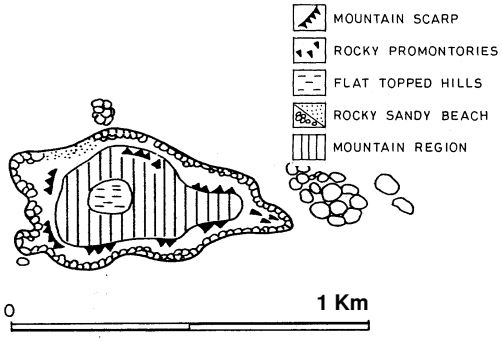


MAP 3. GEOMORPHOLOGY: SHIMISGUDDA ISLAND

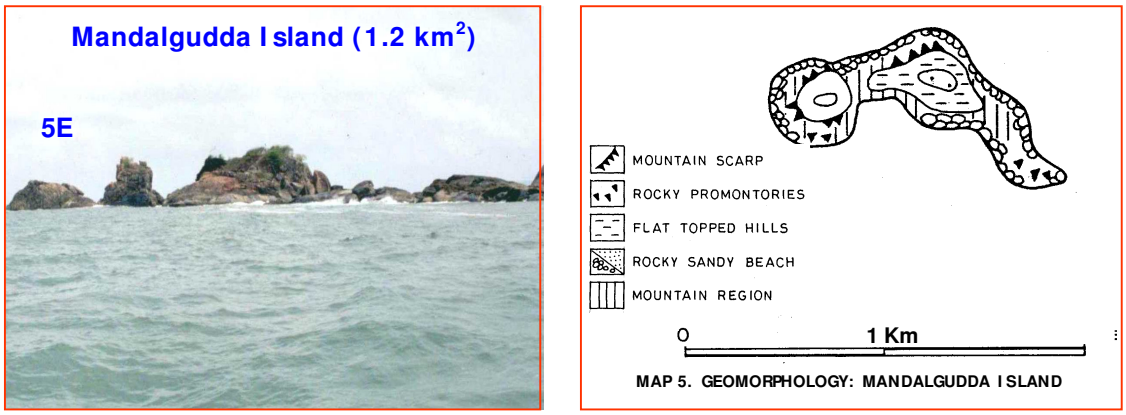
Karkalgudda Island (1.8 km^2)

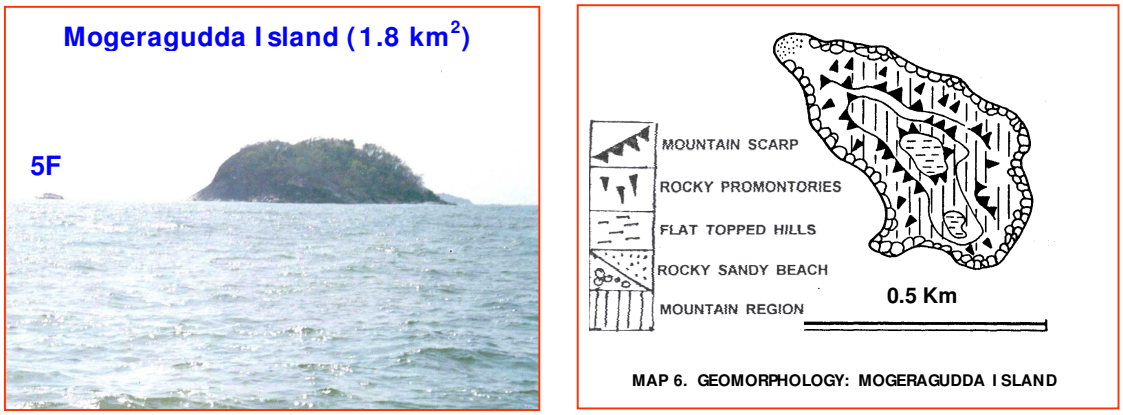
5D





MAP 4. GEOMORPHOLOGY: KARKALGUDDA ISLAND





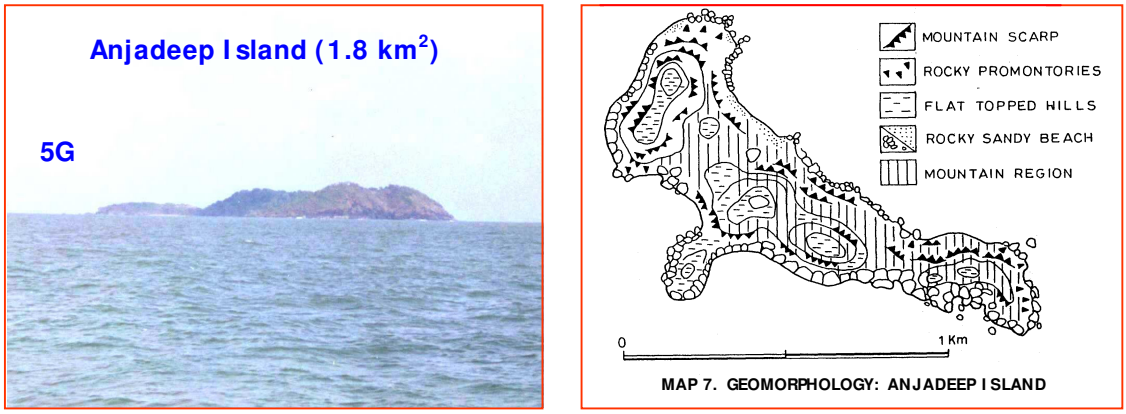


Fig. 5 A-G - Geomorphology of Karwar islands and their panoramic view

9. Land use and Land cover of Karwar and Islands

Study of the current status of landuse and landcover can be related to the cause and effect of geomorphologic processes in the coastal region. Each of these land cover changes can be linked to the land use practice and their impact on the habitat. With the advent of

satellite remote sensing, generation of various thematic maps in time series has become possible even for inaccessible areas.

The major landuse and landcover of mainland are, tropical rain forests, rocky boulders, agricultural land, urban settlement and estuarine land with spotted mangrove vegetation. The islands consist of semi-evergreen vegetation and grasslands. The mainland has a large forest cover of 55,427 sq. km, crop land of 9,785 sq. km and barren land of 8,411 sq. km as per the statistics. The coastal landforms constitute creek, beach/sand, wetland, coastal vegetation, coastal plantations, island vegetation, etc (Fig. 6).

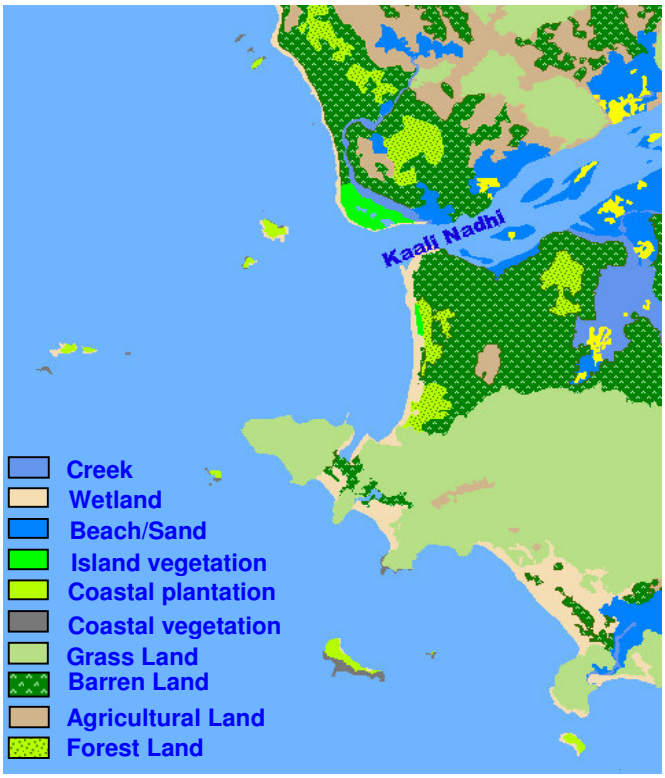


Fig. 6 - Land use / cover map of Karwar and its islands

The presence of vast vegetative cover with good drainage system is suggestive of nutrient rich humus supply to the coastal waters. The land use and land cover map does not show any conspicuous urbanisation and industrial activities impacting the coastal areas in and around Karwar. Based on the satellite data, classified output for different coastal land use and land cover features shows an estimated area of 3.62 sq. km of creek, 5.87 sq. km of beach, 8.08 sq. km of wetlands, 0.76 sq. km of coastal vegetation, 0.96 sq. km of coastal plantation, 0.66 sq. km of island vegetation and 9.2 sq. km of barren land.

10. Water Quality

The sea surface temperature of Karwar ranged from 25.5 to 35.5°C (Table 2). In general, offshore waters in both surface and bottom were warmer than the coastal waters. The salinity ranged between 22.99 and 36.9 PSU. Figure 7 shows the spatial distribution of salinity in different stations during summer alongwith temperature.

Table 2 - Major water quality parameters of Karwar coastal waters

Parameter		Pre-monsoon		Post-monsoon		Summer	
		Min	Max	Min	Max	Min	Max
Salinity (PSU)	S	30.1 (D)	36.7 (F)	25.9 (L)	35.5 (B)	22.99 (E)	36.9 (H)
	B	34.0 (H)	38.7 (A)	33 (K)	40 (E)	34.98 (A)	40.23 (K)
pH	S	7.70 (H)	8.04 (L)	6.7 (D)	9.1 (J)	7.4 (J)	8.8 (A)
	B	7.87 (G)	7.94 (E)	7.7 (D)	8.8 (K)	7.8 (D)	8.7 (F)
DO mg/l	S	5.6 (A)	8.0 (F)	5.9 (J)	11.7 (L)	6.4 (C)	10.3 (H)
	B	5.4 (A)	7.6 (D)	5.4 (A)	11.4 (L)	3.7 (A)	9.7 (H)
BOD mg/l	S	2.81 (A)	4.06 (D)	0.7 (J)	5.2 (E)	2.3 (C)	6.4 (H)
	B	1.83 (A)	5.25 (K)	1.1 (G)	4.3 (L)	1.01 (A)	5.8 (H)
TDS mg/l	S	21.0 (A)	58 (D)	28.4 (D)	36 (G)	8.4 (B)	33.9 (K)
	B	24.4 (K)	38.2 (D)	27.2 (A)	58 (D)	3.6 (D)	34.7 (C)
Temperature °C	S	29.5 (A)	33 (H)	25.5 (L)	32 (K)	31.2 (G)	35.5 (J)
	B	26 (A)	28.9 (G)	27 (A)	30.4 (L)	29.6 (G)	33.2 (L)

A: Kangigudda Island, B: Kurmagadagudda Island, C: Shimisgudda Island, D,E: Near Shore F: Karkalgudda Island, G: Mandalgudda Island, H,K: Off Shore, J: Anjadeep Island, L: Mogeragudda Island

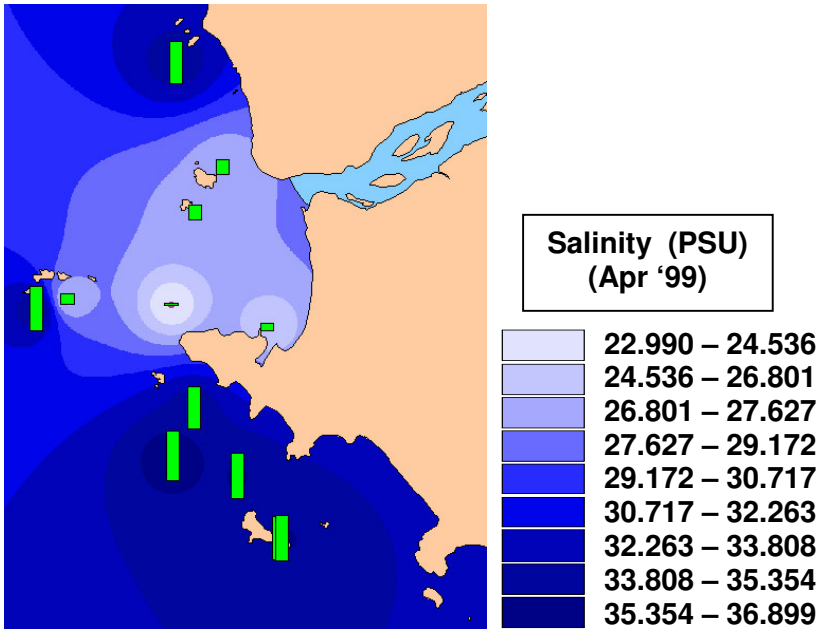


Fig. 7 - Spatial distribution of Salinity at surface (with SST) during summer

The pH ranged from 7.7 to 8.04 during pre-monsoon, from 6.7 to 9.1 during post-monsoon and from 7.4 to 8.8 during summer. The low pH in the coastal waters may be due to the influence of land based discharges.

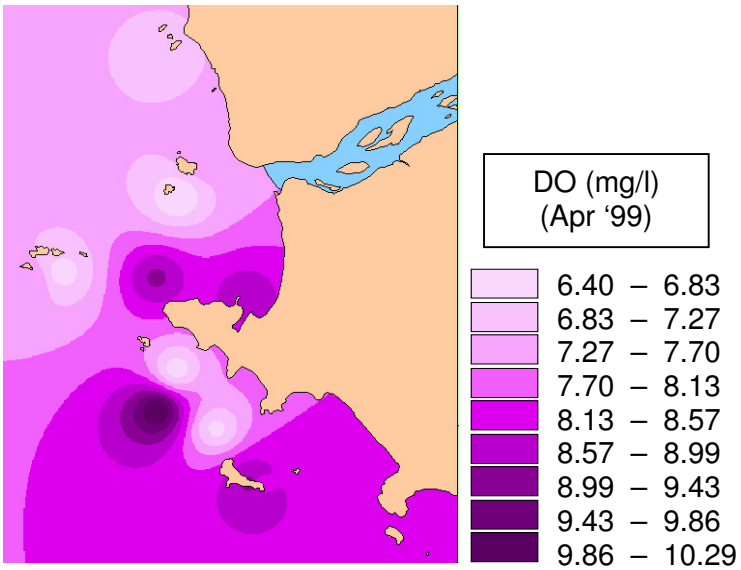


Fig. 8 - Spatial distribution of DO at surface during summer

Dissolved oxygen ranged from 5.6 to 8.0 mg/l during pre-monsoon, from 5.9 to 11.7 mg/l during post-monsoon and from 6.4 to 10.3 mg/l during summer. The offshore waters showed higher levels of DO than the near shore waters. Figure 7 shows the spatial distribution of DO during summer.

The concentration of nitrite, nitrate, silicate and phosphate in the coastal waters of Karwar islands showed seasonal variations (Table 3). Figure 9 shows comparative distribution during pre-monsoon season.

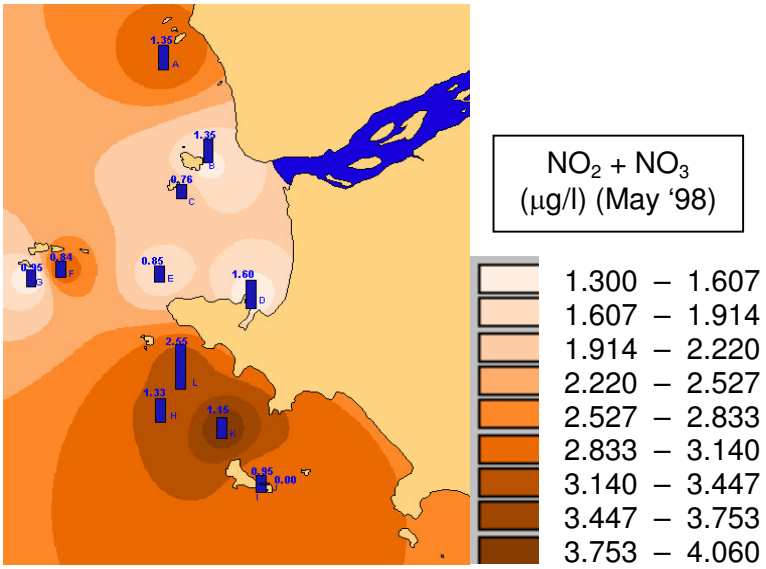


Fig. 9 - Spatial distribution of nutrients at surface during pre-monsoon

Table 3 - Distribution of nutrients during three seasons

Depth	Nutrients	Pre-monsoon		Post-monsoon		Summer	
		Min	Max	Min	Max	Min	Max
Surface	NO_2	0.25 (D)	0.7 (L)	1 (D)	1.5 (C)	0.6 (B)	2.1 (L)
Bottom	µ mol/l	0.15 (J)	1.2 (B)	1.25 (H)	2 (B)	0.87 (H)	1.4 (L)
Surface	NO_3	0.82 (K)	3.5 (G)	1.36 (E)	3.75 (K)	1.3 (E)	3.6 (K)
Bottom	µ mol/l	1.68 (A)	9.7 (L)	1.93 (C)	9.6 (K)	2.15 (A)	9.2 (L)
Surface	PO_4	0.76 (C)	2.55 (L)	0.85 (C)	3.7 (L)	0.8 (F)	2.46 (L)
Bottom	µ mol/l	0.89 (C)	3.80 (L)	1 (C)	5 (L)	0.96 (C)	3.66 (L)
Surface	SiO_2	4 (B)	5.1 (D)	4.5 (B)	5.75 (D)	4.2 (A)	5.32 (D)
Bottom	µ mol/l	3.7 (B)	4.75 (D)	3.96 (E)	5.3 (D)	3.60 (L)	4.8 (F)

Sampling Stations: as in Table 2

Higher concentration of nutrient distribution was observed during post-monsoon and summer than pre-monsoon (Fig. 10). Spatial distribution of nutrients was high in the south around Anjadeep Island and low in the north, near Kali river mouth, especially during pre-monsoon when the river discharge was low.

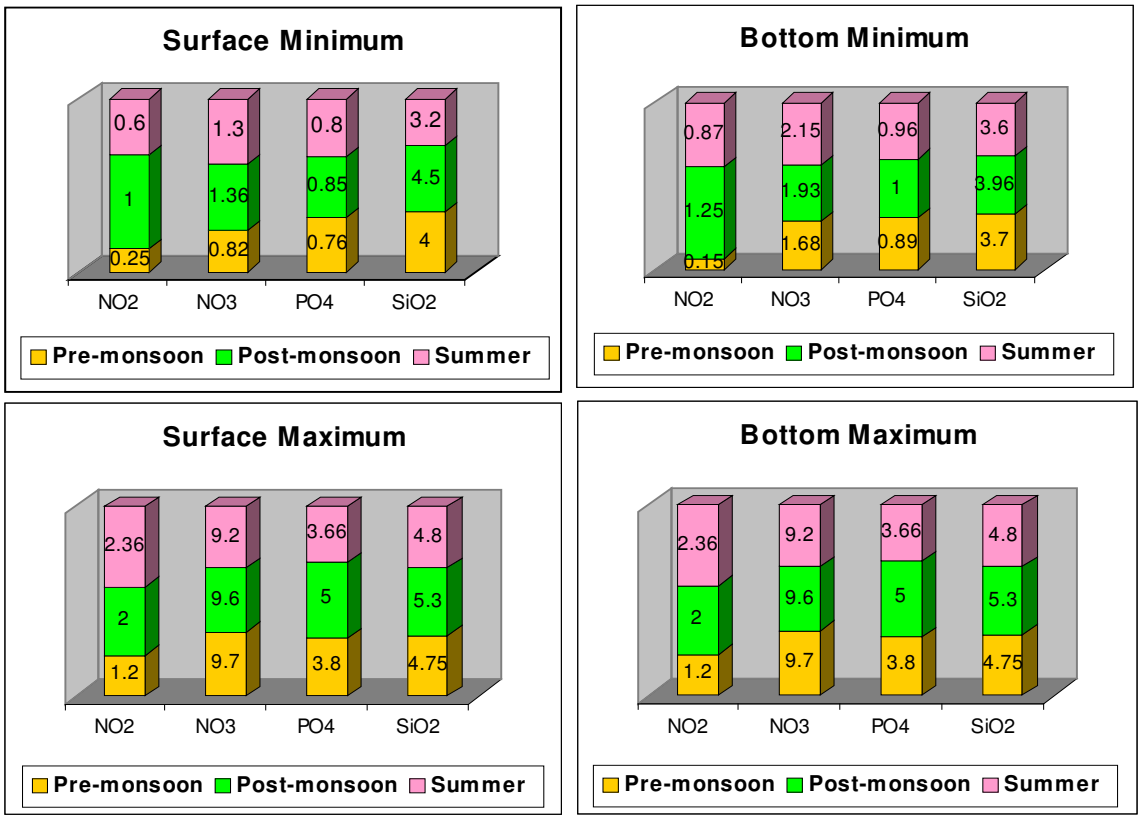


Fig. 10 - Seasonal distribution of nutrients at different depths

11. Biodiversity

The biodiversity of the Karwar Islands can be grouped into terrestrial and marine flora and fauna. Terrestrial flora of seven islands are restricted to small areas, except hard rock and sandy beaches. About 62 species of plants belonging to 42 genera of 28 families have been identified in the seven islands. Several species of butterflies, moths, grasshoppers, ants, chordates, chameleon, garden lizards and birds like black drongo, brahminy kites, pariah kites, crows and pigeons were found in these islands.

The marine environment of Karwar islands, being an open aquatic system, is subjected to good influx of sediments rich in nutrients from Kali river and surface runoff from the islands. Rich and diverse flora and fauna were observed in these areas. The biotic composition of coastal water and their abiotic environment interact and exchange their produce through near shore circulation and upwelling.

During the study period (1998-99), flora and fauna of neritic and benthic (intertidal, eulittoral) environments of Karwar Islands and adjoining waters were studied. 10 species of macrophytes (seaweeds) and 1 species of mangrove were recorded. 58 species of phytoplankton and 40 species of zooplankton constituted the planktonic forms. A total of 60 species comprising gastropods, bivalves, echinoderms, crustaceans and others formed the intertidal faunal composition. 34 species of macrobenthos comprising polychaetes (16), gastropods (17), etc, and 64 species of meiobenthos comprising foraminifers (38), ostracods (12), polychaetes (6), etc, were recorded.

11.1 Macrophytes

Fig. 11 - View of macrophytes

In the intertidal areas of Karwar islands, 10 species of macrophytes, *Enteromorpha sp, Ulva sp, Caulerpa racemosa, Hypnea sp, Sargassum sp, Padina gymnosphora, P. tetrastomatica, Gracilaria sp, Porphyra vietnamensis* and *Bangia fucopurpurea* were recorded (Fig. 11). *Sargassum* dominated all the species in terms of biomass (wet weight) in all the islands during Dec'98 and Apr'99.

11.2 Phytoplankton

During the study period (1998-99), a total of 58 species of phytoplankton comprising Bacillariophyceae (38 species), Dinophyceae (17) and others (3) were observed. More number of species was observed in May'98 (46), than in Dec'98 (38) and in Apr'99 (28). Abundance ranged from 5 to 13 lakh cells/m^3 in May'98, from 354 to 1286 lakh cells/m^3 in Dec'98 and from 519 to 1250 lakh cells/m^3 in Apr'99.

Important species were of the genera, *Coscinodiscus, Ceratium, Fragilaria, Trichodesmium, Protoperidinium, Planktoniella,* etc. Diversity index ranged from 0.125 in Dec'98 to 1.198 in May'98. In general, diversity was more in pre-monsoon and summer

seasons. Diversity index of phytoplankton in different locations during the study period is given in Fig. 12.

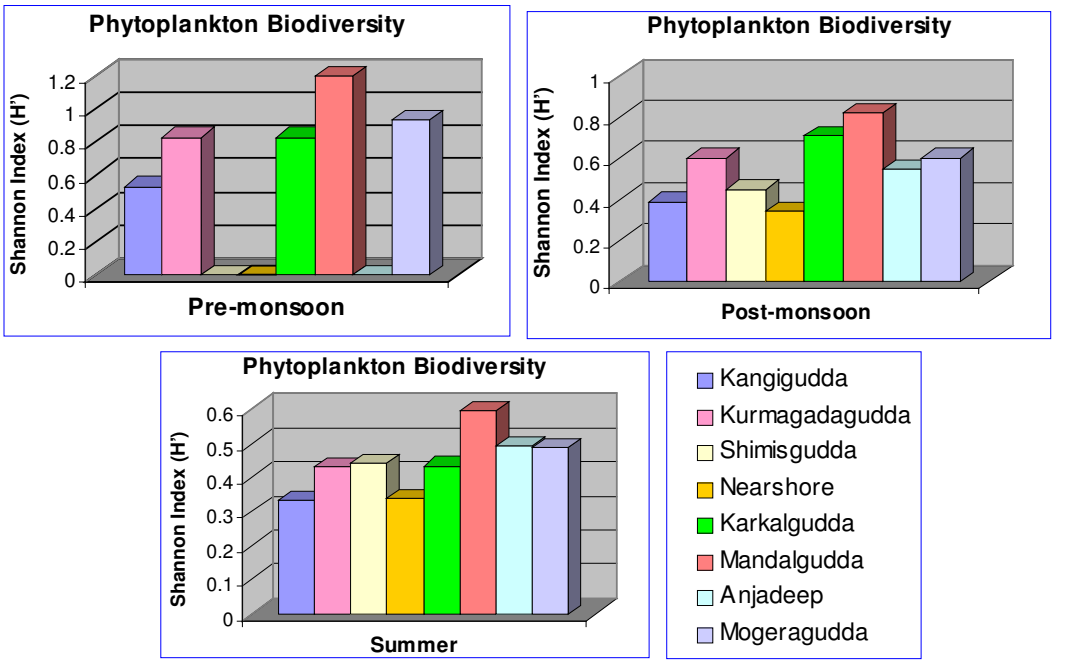


Fig. 12 - Diversity index of Phytoplankton during 1998-99

11.3 Zooplankton

A total of 40 species comprising Arthropoda (30 species), Chaetognatha (2) and other taxa (8) were recorded during 1998-99. The number of species observed was more in Apr'99 (36 species) than in May'98 and Dec'98 (28).

Copepods dominated the zooplankton composition in May'98 and Apr'99. In Dec'98, copepods and siphonophores were the dominant constituents. Dominant species were of the genera *Acartia, Paracalanus, Acrocalanus, Temora, Oithona, Lucifer* (crustaceans), *Tintinnopsis, Favella* (protozoans), *Diphysis, Vogtia* (coelenterates) *Sagitta* (chaetognaths) and *Oikopleura* (appendicularians).

Diversity index ranged from 0.854 to 2.552. In general, diversity was more during May'98 than other seasons. Diversity index of zooplankton in different locations during the study period is given in Fig. 13.

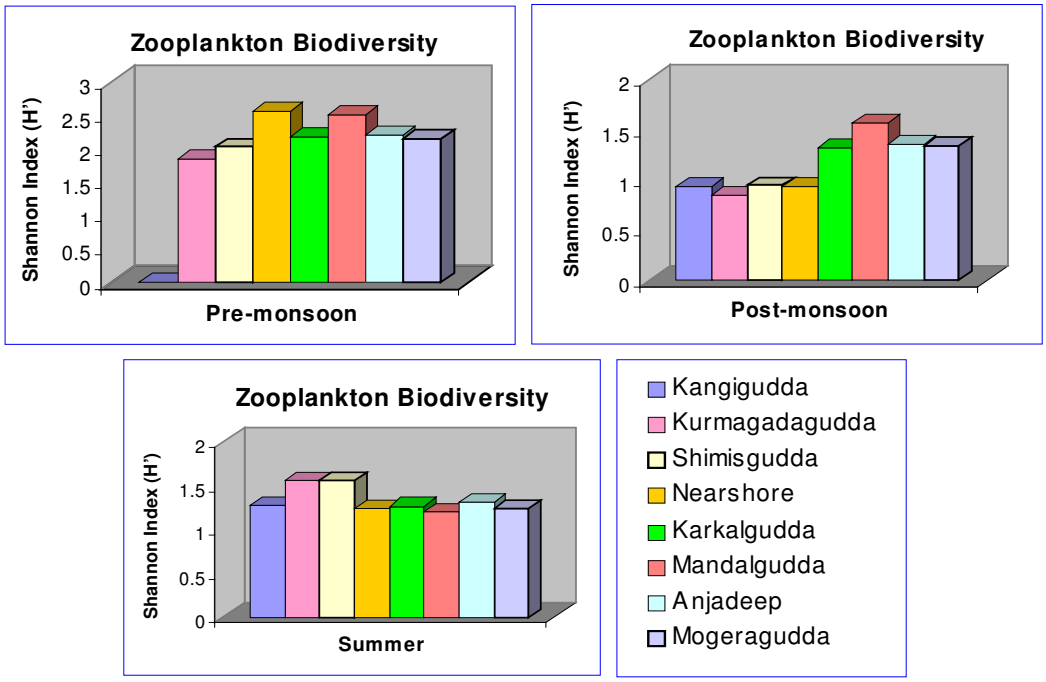


Fig. 13 - Diversity index of Zooplankton during 1998-99

11.4 Benthic Organisms

Benthos were studied in the intertidal areas of islands and eulittoral areas near the islands. Based on size, the benthos were classified as meiobenthos and macrobenthos.

A total of 60 species of **intertidal fauna** (Fig. 14) were found distributed in all the islands comprising 32 species of gastropods, 10 species of bivalves, 8 species of crustaceans and 10 species of other taxa. No significant seasonal variation was observed. Number of species was more in Anjadeep Island and low in Mogeragudda Island throughout the study period.

Fig. 14 - Gastropods and bivalves

A total number of 34 species of **macrobenthos** comprising polychaetes (16), gastropods (17), etc, were recorded in intertidal and eulittoral samples. No significant difference was observed on the species composition between intertidal and eulittoral macrobenthos. More number of species was observed in the eulittoral samples than intertidal samples. No significant seasonal variation was observed in these groups.

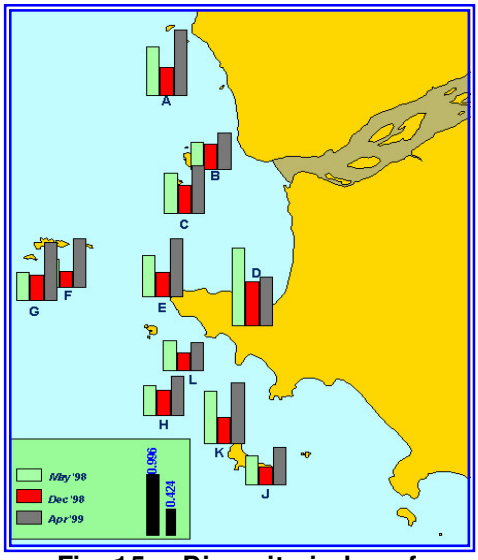


Fig. 15 - Diversity index of Eulittoral macrobenthos

Number of species and abundance was more in May'98 and Apr'99 and less in Dec'98 among the eulittoral macrobenthos. Diversity index ranged from 0.44 to 1.33 in May'98, from 0.42 to 1.12 in Apr'99 and from 0.24 to 0.74 in Dec'98 (Fig. 15).

A total number of 64 species of **meiobenthos** comprising foraminifers (38), ostracods (12), polychaetes (6), etc, were recorded in intertidal and eulittoral samples.

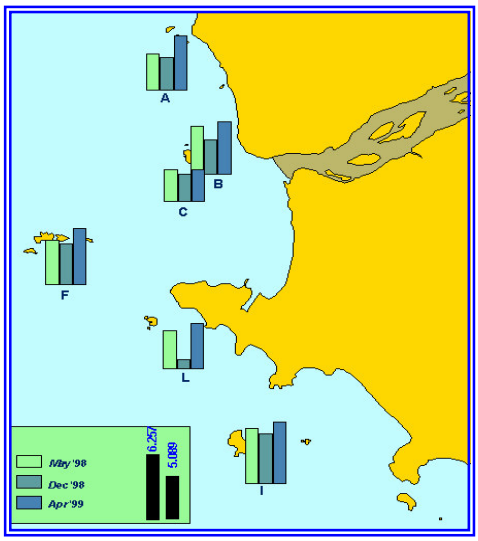


Fig. 16 - Diversity index of intertidal meiobenthos

Among the intertidal meiobenthos, diversity index was more in Anjadeep Island throughout the study period. Low diversity was observed in Shimisgudda Island in May'98 and Apr'99. Diversity index ranged from 4.6 to 5.9 in May'98, from 3.4 to 5.6 in Dec'98 and from 4.6 to 6.2 in Apr'99 (Fig. 16).

Among eulittoral meiobenthos, nematodes and protozoans dominated the composition. Other taxa observed were arthropods, polychaetes, coelenterates, lamellibranchs, etc. Number of species and abundance were more in May'98 and Apr'99 and low in Dec'98. Diversity index ranged from 6.71 to 8.48 in May'98, from 4.9 to 7.78 in Dec'98 and from 6.39 to 8.65 in Apr'99. The benthic organisms found in the vicinity of Karwar Islands were diverse and found in the soft substratum and hard rocky bottom; a few visuals of which are in Fig. 17.

Fig. 17 - Macrobenthos of Karwar islands

11.5 Fishes

In Karwar there are about 30 varieties of fishes landing at the six landing centres. Fishing is done near and offshore waters of Karwar and the landed varieties also represent the fishes caught around the islands. Among them sharks, rays and skates, white sardines, tuna, mackerel, oil sardine, clupeids, seer fish, *Lactarius* sp., mullets (estuarine), carangids, pomfrets, sciaenids**,** flatfish, *Anchoviella*, cat fish, jaw fish, shrimps, crabs and squids, are commercial food fishes.

Comparison of past data on biodiversity with the present study is given in Table 4.

Table 4 - Comparison of biodiversity with past data

Group	Past Data	Present study
Bacillariophyceae	27*	38
Dinophyceae	11*	17
Foraminifers	35#	38
Coelenterates	10*	2
Chaetognaths	6*	2
Arthropods	18*	30
Polychaetes	--	16
Molluscs	--	17

* - Ramamurthy (1965); # - Bhatia & Kumar (1976)

Previous studies on Karwar environment such as water quality, hydrography (Annigeri, 1980; Noble, 1980), plankton (Ramamurthy, 1965), fishery resources, etc., reveal that the aquatic environment of Karwar is highly productive. Upwelling is one of the important factors for high productivity. Oil sardine and mackerel form the important groups of fisheries. Largest sized mackerel (of length 421 mm and weight 859 g) in India has been recorded from Karwar waters (Kakati and Gowda, 1999). Salinity, temperature, rainfall and upwelling are some of the important factors that govern the fishery resources in this environment. Eventhough mass nesting of marine turtles has not been observed, occurrence of a few turtles along the beaches of some islands has been recorded.

12. Fishery Resources

Fishing is a major activity along Karwar coastal region. Fish landing is more in Karwar than other landing centres. Average fish catch was observed to be between 37 and 98 tonnes/day (during Oct-May) from 1994-95 to 1998-99. Fish catch and their value during 1994-97 are given in Table 5.

Table 5. Quantity and value of fish catch from Karwar taluk during 1994-97
(Catch – in tonnes; Value – Rs. in lakhs)

Landing centre	1994-95		1995-96		1996-97	
	Catch	Value	Catch	Value	Catch	Value
Majali	298	19	545	34	498	37
Karwar	7795	516	12714	838	20752	1212
Binaga	93	10	231	23	178	19
Arga	47	3	152	14	117	9
Chendia	302	26	252	24	197	20
Kodar	284	121	264	29	315	70

13. Socio-Economic Aspects

The density and composition of human settlement along the coastline play a major role in coastal zone management. Conception and implementation of conservation measures for coastal zone management by any agency or organization will not be fulfilled, unless the participation of local coastal communities in the relevant programme is ensured. Hence, the socio-economic aspects are the most vital parameters in working out the strategies for conservation and management measures in the coastal zone.

Details of craft and gear employed and fishermen engaged actively in 6 landing centres are given in Table 6. Major types of crafts include purse seiners, trawlers, gill netters, long liners and others. The fishing gears comprise gill nets, trawl nets, drag nets, cast nets, shore seines, purse seines and others.

Table 6 - Fishermen population, crafts and gears engaged during 1998-99

Landing centre	Active Fishermen	Crafts	Gears
Majali	2340	170	851
Karwar	3100	137	909
Binaga	312	49	537
Arga	242	24	344
Chendia	610	34	422
Kodar	690	47	722

There is no human inhabitation in the Karwar Islands. The population of Karwar taluk was 1.403 lakhs during 1991 with a growth rate of 1465 persons/ year. Increase in population and more demand for food, shelter, occupation and other activities will have impact on these coastal ecosystems and their resources. Among the total population, 85% are literate. There are 206 primary schools and 40 high schools, 2 Junior Colleges, 7 Colleges and 4 Polytechnic Colleges in the Karwar taluk. There are primary health centres in the taluk headquarters and electricity is available in all the villages.

Aquaculture is gaining importance in the area with 21 aqua farms over an area of 113.22 ha. Agriculture is another major activity. There are many small scale and cottage industries in the area providing employment to a large number of people. They are textile, wood, leather, rubber, glass, ceramic, plastic based factories, caustic soda industry in Binaga and white cement industry in Manjali. Comparison of revenue from 6 major sectors in Uttar Kannada district is given in Figure 18. Though Karwar area has many scenic beauties, tourism has not picked up so far.

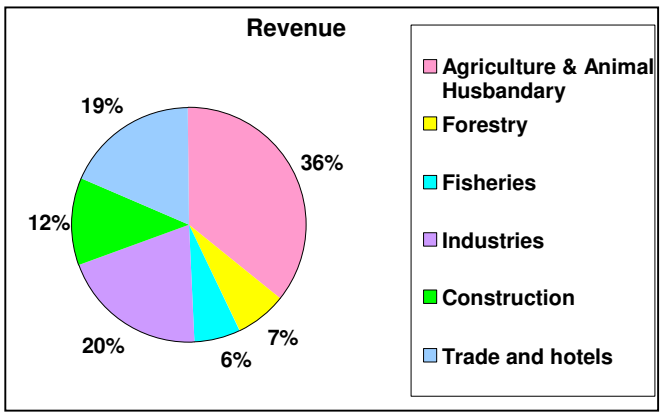


Fig. 18 - Revenue status of Uttar Kannada from 6 major sectors

14. Suggestions

"Sea-Bird" Naval Project, which aims to provide the Indian Navy with a totally integrated base on the western seaboard, is coming up in the vicinity of Mogeragudda and Anjadeep Islands (Fig. 19).

Currently, 180 m, north breakwater from Binaga Bay to Anjadeep island and the south breakwater from Round Island to Arga have been constructed. Impacts of the project on environmental quality and biodiversity need to be studied.

Fig. 19 Hinterland view of Sea Bird project site

Data on the physico-chemical parameters of water, sediment and biological diversity do not indicate any adverse environmental conditions. However, considering the ecological significance of these ecosystems as areas of rich biodiversity, as habitats of endangered animals such as marine turtles and dolphins and as areas of rich fishery potential, efforts are needed for conservation of these areas.

In view of the good water quality, rich productivity and fishery resources, further regular monitoring of these parameters is needed in detail to assess the interaction and inter-relationship among the climatological, physical, chemical and biological aspects of these waters for sustainable utilisation of the resources and long-term conservation of these areas.

15. Conclusion

Considering the dimension, accessibility, dynamism of the habitat and frequency of observation, to draw up management plans, efficient tools are required to handle the data. Development of CHIS using database and Geographic Information System has been found to be the efficient way to analyze the status of the critical habitats.

CHIS on Karwar islands provided qualitative and quantitative status of various parameters governing the critical habitat and the associated habitants. The status of physical and chemical parameters around islands off Karwar is conducive for good productivity and biodiversity. Water quality data also does not suggest any serious concern owing to land

based sources of pollution. Display of data on all parameters using GIS has facilitated comparison of status of these parameters in a snapshot manner. It has helped in deriving location specific data and information which is essential for long term monitoring of crucial parameters like dissolved oxygen and biodiversity, as they help in the assessment of the health of these island ecosystems. Efforts need to be taken for maintaining and improving the coastal water quality by way of mitigating the impacts of upland activities such as agriculture, aquaculture, mining, industrial activities, etc., in order to protect and conserve these coastal habitats and for sustainable utilisation of their resources.

16. References

Annigeri, G.G., 1980. Further studies on the hydrography of the inshore waters off Karwar. J. Mar. Biol. Ass. India 22 (1&2): 77-84.

Bhatia, S.B. and S.Kumar, 1976. Recent benthonic foraminifera from the inner shelf area around Anjadiv Island, off Binge, West coast of India. Proc. 1st Intl. Symp. On Benthonic Foraminifera of continental margins, Part A. Ecology and Biology, Maritime sediments, Sp. Publ. 1: 239-249.

Kakati, V.S. and N.C. Gowda, 1999. Record-sized mackerel, *Rastrelliger kanagurta* caught from Karwar waters on the west coast of India. J. Mar. Biol. Ass. India 41 (1&2): 133-134.

Noble, A., 1980. A study on the near-shore water of the Karwar Bay in the North Kanara coast. J. Mar. Biol. Ass. India 22 (1&2): 70-76.

Ramamurthy, S., 1965. Studies on the plankton of North Kanara coast in relation to the pelagic fishery. J. Mar. Biol. Ass. India 7 (1): 127-149.