A Comparative Study of Macro Faunal Community of Natural and Restored Mangrove Sites between Mahi and Dhadhar River Estuaries of Gulf of Khambhat

A Thesis Submitted To
The Maharaja Sayajirao University of Baroda
for the award of the Degree of

Doctor of Philosophy

in Zoology

by

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September-2014

CERTIFICATE

This is to certify that the thesis entitled **"A Comparative Study of Macro Faunal Community of Natural and Restored Mangrove Sites between Mahi and Dhadhar River Estuaries of Gulf of Khambhat",** submitted by **Shukla Manan Lalitkumar** for the award of the degree of Doctor of Philosophy has been carried out in the Department of Zoology, Faculty of Science, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat. The matter presented in this thesis incorporates the findings of independent research work carried out by the researcher himself. The matter contained in this thesis has not been submitted elsewhere for the award of any other degree.

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Research Guide
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DECLARATION

I hereby declare that the entire work embodied in this thesis has been carried out by me under the supervision and guidance of Dr. Kauresh Vachhrajani and to the best of my knowledge no part of this thesis has been submitted for any Degree or Diploma to this University or any other University or Institutes in India or abroad.

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Acknowledgement

I would first of all like to thank the person because of whom this distant dream of mine has been fulfilled. Words in my dictionary will be less to describe him. I owe my degree to my guru Dr. Kauresh Vacchrajani, Associate professor,Department of Zoology, M.S.University of Baroda who has been a real guide and the most calm person whom I have met in my life. He has always shown me the way when the ways were tough and hope had turned in to despair. At times I thought it will not be possible for me to make it but it is his inspiration which finally did wonders for me.

I would like to thank Dr. P.C.Mankodi, Head, Department of Zoology for his help and guidance through all the important stages of my work. Ever cheerful and ready to help nature of his made it very easy for me to get through the work. Always ready with solutions and helped for any problem during my study. I would also like to thank whole heartedly to Dr. Geeta Padate, Associate Professor, Department of Zoology for her encouragement at every point to complete the thesis. In addition to the above I would extend my thank to all the staff of the Department of Zoology who have directly or indirectly been involved towards completion of my work.

I would like to specially mention Dr. Dharmendra Shah, Associate professor, Department of Botany, who helped me whenever I required any information and also shared important literature related to mangroves and Prerna Sharma, a friend and Lecturer at Environment Science also provided help during the course of study.

Any work done with complete interest always leads to good results. I am thankful to my school teacher Mrs. Priti Patki, Principal,Shaishav School,Baroda who sowed the seeds in me towards liking and learning Science. It is because of her that I got interest towards Science. Also would like to thank my teacher Mrs. Passi who further cleared by concepts in Science and poured the quality of rational reasoning behind every process. Mr. Sachin Lathia who has always taught to be good whatever may be the conditions in life. I would thank all my teachers wherever you are and it is because of your learning's that I have achieved certain level in life.

I am really lucky to have got good persons at every stage of my life who have been kind enough to me and have showed me the correct path. This is the perfect stage to thank them all when I am achieving the highest degree of my life. I am thankful to Mr. D.C.Mehta, D.F.O, Forest department,Gandhinagar who at early stage of my professional carrier taught me the basics and till date is always ready to help me. I would also like to thank my colleagues Mehul Joshi, Rajesh Katudiya,Sunil Panchal at GEER foundation

The next stage I got a mentor Mr.Deepak Apte, Chief Operating officer at Bombay Natural History Society, Mumbai who I will credit for my learnings and leanings for Mangroves. It is he who gave me opportunity to work on project Mangrove when at that stage I had just the basic knowledge about mangroves. It is during this period that I had decided to undertake my Phd work on mangroves. During my entire work he has been great help and always showed readiness to help me personally or professionally. I would also like to thank Dr.Asad Rehmani,Director-Bombay Natural History Society and all my colleagues during that time Dr. Swapna Prabhu, Nishigandha Pednekar, Amruta Prasade, Pooja Nagale, Rushikesh Chavan, Vishal Bhave, Rajendra Pawar, Vishvas Shinde. I would like to Specially mention my Bombay Natural History Society Gujarat Field Station colleagues Rajesh Parmar, Kishore Patel who helped me during field work. Special mention of one very dear friend Bhavik Patel who has always supported me in thick and thin of time.

I would like to mention one special person, my mangrove teacher Dr. Kathiresan who gave me in depth knowledge about mangroves and always showed the belief and encouraged me to do some good work on mangroves in Gujarat. It is because of him that I will always remain a mangrover throughout my life and as he correctly said dedicate yourself for man and mangroves. I would like to also thank my other teachers at Center of Advanced Study in Marine Biology,Parangipettai, Annamalai University, Tamilnadu with special mention to Dr. Ajmal Khan and my friends Dr.A.Sarvanan, Dr. A.Gopalkrishnan,Dr.V.Ravi who have helped me and provided with necessary reference material on faunal diversity of mangroves during the course of my study.

I would like to mention the names of my spare wheels, my friends who have always been there whenever I wanted any help and who have firmly stood by me whatever

may be the result. Dr.Dishant Parasharya and his family who always helped me whenever I needed any help and at whatever time. Special thanks to my friend JigneshTrivedi who helped me a lot during the final stages of my work. I would specially thank Sumedha Arya, Khushali Pandya, Mayurdan Gadhvi,Palak Thakore,Virag Vyas,Jigar Modi,Ajay Rao,Twinkle Panchal,Vinod Gajjar, Shatrugna Jebalai,Dr.Rizwan Reza,Vilas Shirke, Tanvi Jain,Darsh Worah,Arpita gupta,Aditya Sarupriya who have been instrumental at various stages of the study and life. I would thank my friends Bhavik Patel, Jignesh Trivedi,Palak Thakore and Mayurdan Gadhvi for assisting me in photo documentation during my study work. Words are less to thank Mr. Jesang Thakore, VIKAS-Jambusar, a dear friend who has been ever ready to help me and has also guided me throughout my thesis. He provided me help whenever I got stuck. I would also like to thank my friends and preacher at Chinmaya Mission, Vadodara.

I cannot forget to thank my colleagues at Gujarat Maritime Board, Gandhinagar. My head Mr.Atul Sharma,DGM-Environment who always encouraged and provided me the time to complete the necessary work for my thesis. My friends Jaivik Shah,Dr.Gaurav Mehta, Rikesh Virda who inspired me to complete my Phd. They shared off my work so that I can concentrate on my submission. Thanks a lot for your help.

Finally to my lovely family who always showed there support in all the conditions. It has not been easy for them to manage without me with my handicapped brother but never did they show to me so that I don’t get disturb in my work. It is because of your support that I could achieve this feat. Special mention of my lovely wife Darsha, my super woman who not only managed the household works, my handicapped brother, my lovely son Divit but also helped a lot with my thesis work even though she is from all together another background. Never complaining nature and comprising with all the conditions of life is the thing I am still learning from her. Thanks a lot dear. I know once I am awarded this degree it will be you who will be most happy and feel more proud than anyone on the earth. I wholeheartedly thank you for your support and sacrifice over years. I owe this degree to you.

Last but not the least, I thank the almighty for providing me this beautiful life and beautiful people around me who at every stage of life has stood by me and helped me with all the odds of life and because of all you lovely people I am achieving one more

milestone in my life. I apologise if I have forgotten any of you in mentioning your name but I know it is because of your positive flow of energy that it has been possible for me to achieve whatever I have in my life.

Manan Shukla

1. INTRODUCTION

INTRODUCTION

Biodiversity is the basic need for human existence. In order to meet the need for food, health and other necessities of the growing human populations it is of prime importance. There are various biodiversity regions, but out of all, the coastal marine ecosystems are known to be the most productive, biologically diverse and significantly valuable areas. It has been estimated to cover more than double the number of species on land. Man depends on these ecosystems and it's organisms to harness energy, food, medicine, fertilizer, fuel and many other industrial products. A large number of world human populations are getting concentrated along the seacoasts. According to an estimate nearly 55% of the world's population lives in coastal areas. More than 70 % of the population in East Asia depends on coastal resources for food, employment and generation of income. If we consider Southern Asia, the residing coastal populations are surviving majorly on diminishing coastal resources. As a result of climate change and unplanned developmental activities the western Pacific region is suffering degradation of its coastal resources .It is estimated that the increasing human habitation in the coastal areas of the world will reach 6 billion by 2030 which clearly indicates towards inevitable need for biodiversity conservation. In most of the developing countries, food production and socio-economic development are given the first priority, which are often at the expense of biodiversity conservation (Adeel & Caroline, 2002).

In comparison to open seas, the Coastal areas have a greater variety of habitats which are subjected to various anthropogenic pressures related to developmental needs and so are over-exploited. This leads to overall reduction in productivity including degradation of ecosystems and destruction of species, which forms the important resources of biodiversity. During the mid l990's, there was a time when the level of seafood consumption in Asia and the Pacific regions exceeded that of the world's per capita seafood consumption. This was because fish prices were relatively lower than those of other sources of animal protein (Tan *et al.,* l997). However, the present scenario is very much alarming as nearly 50% of coastal mangroves which form vital nurseries for the life histories of many species of commercial importance have already been cleared, and because of

siltation and climatic changes nearly 10 % of coral reefs have been degraded which cannot be recovered. The top priority therefore should be given for preservation, sustainable utilization, and restoration of ecology through conservation of coastal habitats and their biodiversity.

1.1 Coastal Mangrove Ecosystems

Mangrove forests are among the world's most productive ecosystems. They are often termed as 'tidal forests', 'coastal woodlands' or 'oceanic rainforests. Mangroves are woody plants that grow in tropical and subtropical latitudes along the land-sea interface, bays, estuaries, lagoons, backwaters, and in the rivers, reaching upstream to the point where the water still remains saline (Qasim, l998). These plants and their associated organisms (microbes, fungi, other flora and fauna), constitute the 'mangrove forest community' or 'mangal'. The mangal in relation with its associated abiotic factors constitute the mangrove ecosystem, as has been illustrated by fig. 1.1 (Kathiresan and Bingham, 2001).

Mangroves are found in the intertidal zone along the interface between land and sea. Mangrove ecosystems support genetically diverse groups of aquatic and terrestrial organisms. They include various diverse habitats such as core forests, litter forest floors, mudflats, and adjacent coral reefs and seagrass ecosystems. The contiguous water bodies consist of the rivers, bays, inter tidal creeks, channels and backwaters. The mangroves can exist under various extreme conditions such as wide ranges of salinities, tidal amplitudes, winds, and temperatures, even in muddy and anaerobic soil conditions. Due to presence of highly variable habitat conditions they are profusely rich in biodiversity. The mangroves and their components have been studied extensively over a period of time but still remain poorly understood as far as their biodiversity is concerned.

The word "mangrove" is as old as 1613, and it is usually considered a combination of the Portuguese word "mangue" and the English word "grove". According to Marta Vannucci, the word 'mangue' derives from the national language of Senegal, and it was probably adopted by the Portuguese. The corresponding French words are "manglier" and "paletuvier" (Macnae, 1968), while a Spanish term is "manglar". The Dutch use "vloedbosschen" for the mangrove community and "mangrove" for the individual trees. German use

follows the English. The word “mangro” is a common name for *Rhizophora* in Surinam (Chapman, 1976). It is believed that all these words originated from the Malaysian word, “manggi-manggi” meaning “above the soil”. At present the word is not used in Malaysia, but is used in eastern Indonesia to refer to *Avicennia* species.

1.2 History and Evolution of Mangroves

Mangroves are quite old, possibly arising just after the first angiosperms (Duke, 1992). However, very primitive plant characteristics are not exhibited by mangroves. It is believed that the first appearance of mangroves is as early as 80 million years ago. *Avicennia* and *Rhizophora* were probably the first genera to evolve, appearing near the end of the Cretaceous period (Chapman, 1976). Mangrove evolution was more related to terrestrial or fresh water plant species rather than marine plants. These plants then got adapted to brackish water and became the “core” mangrove flora. However, it remains unclear that out of several plant groups only a few members got adapted to saline conditions. It is possibly believed that the break-up of continental land masses provided favourable conditions for the development of mangroves in the fringe areas. Several years ago, there existed only one continent known as Pangaea. Some 60 million years ago this broke up into subcontinents like Gondwanaland which then subsequently divided into South America, Africa, Antarctica, India and Australia. The island continent of India bore down upon Asia about some 50 million years ago. When the two met, new mountains began to rise, and biological species started spreading into the new extensions, some 40 million years ago. Similarly, other continents drifted over the surface of the globe, resulting into increased coastal habitats suitable for mangrove development. These geological changes along with evolution of flowering plants happened simultaneously during this long period. It is therefore considered that the mangrove species evolved and diversified due to the break-up of Gondwanaland.

There is still a debate over origin of mangroves. There are two theories over the origin and spread of mangroves based on fossils and pollen. In the first case it is believed that from the Malaysian peninsular it got spread to a region between

Australia and Papua New Guinea, and according to the second, it is believed that it got spread between Malaysia and Northern Australia.

Human culture and civilizations have been associated with mangroves since long. Spirit houses are common in Asian countries especially in India, Myanmar, Thailand and Cambodia. 'Bano bibi' temples are present for worship by local people at the entry point of Sunderbans. This temple consists of sacred Bano bibi for the Muslims, and 'vano devi' for the Hindu religious people. A Hindu temple of the mangrove *Excoecaria agallocha* carved on rock was erected in south India in the third century, (Fig.1.2), and the city where this temple was found bears the name of the mangrove species. In Kenya, shrines built in the mangrove forests are worshipped by the local people, who believe spirits of the shrine will bring death to those who cut the surrounding trees (Fig. 1.3). In the Solomon Islands, the bodies of the dead are disposed off and special rituals are performed in the mangrove waters (Vannucci, 1997). The Portuguese, probably the first Europeans to visit the mangrove forests of the Indian Ocean (around fourteenth century), learned the traditional Indian technique of rice-fish-mangrove farming, as demonstrated by letters from the Viceroys of the King of Portugal. Some six centuries ago, this Indian technology was also transferred by Jesuit and Franciscan fathers to the African countries of Angola and Mozambique (Vannucci, 1997). In the nineteenth century, the British used the practical knowledge gained over centuries by the Indians to manage mangroves at Sundarbans for commercial timber production (Vannucci, 1997).

A creative use of mangroves is described in a traditional story from India about two countries at war. The larger country planned to invade their small neighbours during the night. The smaller nation, which had mangrove forests on its coastline, plotted to discourage its enemies by placing lighted lamps on the aerial roots of mangroves. What appeared to be a large flotilla of ships discouraged the invaders and ended the hostilities (*e.g.* Kathiresan & Bingham, 2001).

Mangroves have been studied since ancient times. Descriptions of *Rhizophora* trees in the Red Sea and the Persian Gulf by Nearchus (325 BC) and Theophrastus (305 BC) are the earliest known records. Plutarch (70 AD) and Abou'l Abass (1230) wrote about *Rhizophora* and its seedlings (Macnae, 1968; Chapman, 1976). Rollet's (1981) bibliography of mangrove research illustrates

the spurt of interest in mangrove research after 1975 as only 14 references before 1600, 25 references from the seventeenth century, 48 references in the eighteenth century, and 427 in the nineteenth century. In contrast, there were 4500 mangrove references between 1900 and 1975, and approximately 4466 between 1978 and 2001.

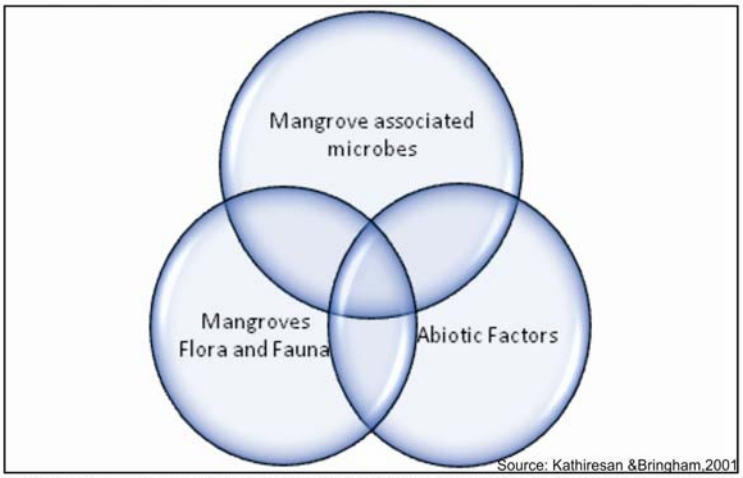


Fig. 1.1. Physical and biological components of mangrove ecosystems

Fig. 1.2. *E. agallocha* carved on rock for worship in a Hindu temple in South India.

Fig. 1.3. A shrine for worship, present inside a mangrove forest in Gazi Bay, Kenya

1.3 Global Distribution

Mangroves are distributed circumtropically, occurring in 112 countries and territories. Mangroves are largely restricted to latitudes between 30° N and 30° S. Northern extensions of this limit occur in Japan (31°22' N) and Bermuda (32°20'N); southern extensions are in New Zealand (38º 03' S), Australia (38° 45'S) and on the East coast of South Africa (32°59' S) (Spalding, 1997). Of the total mangrove coverage, 41.4% exist in South and Southeast Asia (Table 1). Total global mangrove coverage is 18 million hectares and this is just about 0.45% of world forests & woodland (Spalding, 1997).

Table 1: Aerial coverage of mangrove forests

Region	Area (sq km)	Percent
South and Southeast Asia	75,170	41.4
The Americas	49,096	27.1
West Africa	27,995	15.4
Australasia	18,788	10.4
East Africa and Middle East	10,348	5.7

Mangroves have broader ranges along the warmer eastern coastlines of the Americas and Africa than along the cooler western coastlines (Fig. 1.4). Presence of warm and cold oceanic currents leads to the difference in distribution.

1.4 Old and New World Mangroves

There are two main centers of mangroves: the Western hemisphere and the Eastern hemisphere (Fig.1.4). The Western hemisphere is the Atlantic East Pacific region that includes West America, East America and West Africa. The Eastern hemisphere is Indo-West Pacific region that includes East Africa, Indo-Malaysia and Australasia. The Eastern hemisphere is considered as a place of origin for mangroves, and hence the region is called as the Old World mangroves and the Western hemisphere as the new world mangroves. The

Western hemisphere has less species than the Eastern hemisphere. The number of mangrove species is 11 in the former and 49 in the latter (Duke, 1992). Some genera are specific to the regions. The genera like *Peliciera*, *Conocarpus*, and *Laguncularia* are present only in the new world, whereas *Osbornia* and *Camptostemon exist* only in the old world.

The largest mangrove area is present in Indonesia followed by countries like Australia, Brazil, Nigeria, Mexico, Malaysia, Cuba, Myanmar and India. These countries contribute 64% of the global mangrove cover. It indicates that mangrove forests are not uniformly distributed in various areas.

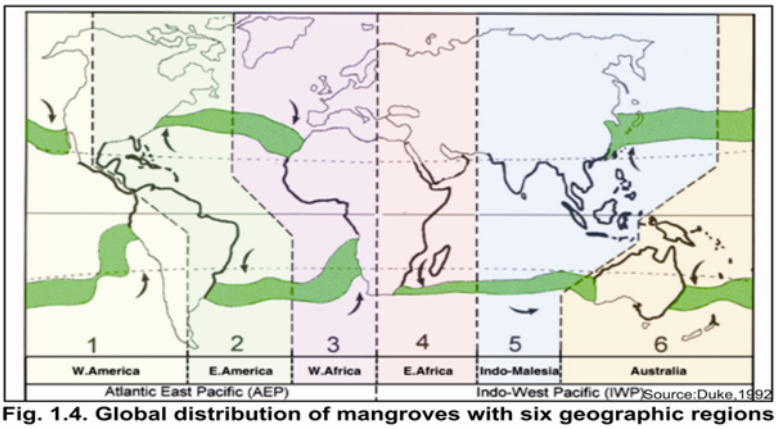


Fig. 1.4. Global distribution of mangroves with six geographic regions

Fig. 1.5. Continental distribution of mangrove cover

1.5 INDIA

Forests within India are found along the coastlines of 9 states and 3 union territories. Their overall cover has been estimated to be 4,628 km^2, of which about 60 % is along the east coast (Bay of Bengal), 27 % along the west coast (Arabian Sea) and the remaining 13% is on the Andaman and Nicobar Islands. The state of West Bengal has the maximum cover (2,097 km^2), followed by Gujarat (1103 km^2) and the Andaman and Nicobar Islands(604 km^2)(FSI, 2013

Table 1). The mangrove cover is large and widespread on the east coast of India due to the nutrient rich alluvial soil formed by the mighty rivers (Ganga, Brahmaputra, Mahanadhi, Krishna, Godavari and Cauvery) and the perennial supply of freshwater along the deltaic coasts. But deltas with alluvial deposits are almost absent on the west coast of India and their place is taken by the funnel shaped estuaries or backwaters (Gopal and Krishnamurthy, 1993). The east coast has a smooth and gradual slope which provides a larger area for colonization of mangroves, whereas the west coast has a steep and vertical slope due to the presence of the Western Ghats. Mangroves are present in the Andaman and Nicobar Islands where many tidal estuaries, small rivers, neritic islets and lagoons support a rich flora.

1.5.1 Coastal Marine Ecosystems

India has about 8,000 km long coastline surrounded by the Indian Ocean, Arabian Sea and the Bay of Bengal, that spans 13 maritime States and Union Territories (UTs) including Island UTs.

India has rich assets of a variety of coastal and marine ecosystems (Table 2), including considerable nationally and globally significant biodiversity. These coastal and marine ecosystems are extremely important from an economic perspective, as they provide a wide range of ecosystem goods and services to the entire country. Approximately 20% of India's population lives in coastal areas, a large proportion of them in urban centers such as Mumbai, Chennai and Kolkata. Some of the India's poorest people also live in the coastal belt and rely on coastal and marine resources for their immediate welfare and as a source of livelihood through fishing and other forms of economic activities. The December 2004 tsunami which struck the South East coast of India and the Andaman Islands reaffirmed the importance of maintaining healthy coastal and marine ecosystems for natural disaster risk management and post-disaster recovery, as well as for general human well-being.

Table 2. Extent of coastal ecosystems in India

Coastal Ecosystem	Extent (km2).
Tidal/ Mud flats	23,621
Sandy beaches/ bars/ spits	4,210
Mangroves	4,445
Coral reefs	2,375
Salt marshes	1,698
Lagoons	1,564
Estuaries	1,540
Other vegetation (including sea grass beds)	1,391
Aquaculture ponds	769
Salt pans	655
Creeks	192
Rocky coasts	177
Back waters	171
Total	**42,763**

(Source: MFF-NSAP2009)

1.5.2 Coastal and Marine Biodiversity

India has remarkable biodiversity in its coastal and marine ecosystems. The mangrove ecosystem alone has a total of 3985 biological species that include 919 flora and 3066 fauna. There are 199 coral species representing all the three major reef types (atoll, fringing and barrier reefs), 14 species of seagrasses and 844 species of seaweeds. A number of factors including the long coastline, tropical climate, and nutrients supplied by rivers along the coast, have combined to produce a variety of biologically rich and productive coastal and off-shore marine ecosystems (Table 2). Inter-tidal mudflats teeming with migratory birds in winter, dense mangrove forests inhabited by the endangered tiger, and delicate seagrass beds favoured by the enigmatic and elusive seacow (dugong), are just a few of the natural treasures to be found along India's coastline.

India is home for globally threatened species such as Royal Bengal tiger, sea turtles, fishing cat, estuarine crocodile, the Gangetic dolphin and river terrapin. Long term survival of the rare and endangered species depends on

health of the coastal and marine ecosystems. There is also tremendous resident and migratory bird diversity associated with coastal and marine ecosystems in India. Nearly 2 million water birds of about 200 species over-winter in India before heading back to colder northern climes in April. Five of the world's seven species of sea turtles are found in India, namely the Olive Ridley (*Lepidochelys olivacea*), Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*) and the critically endangered Leatherback (*Dermochelys coriacea*) turtles. Orissa on the east coast of India has the world's largest mass nesting Olive Ridley Turtles during the months of October to April supporting a nesting population of probably more than half a million of the species. The threatened whale shark (*Rhincodon typus*), the largest fish species in the world can be found off the coast of Saurashtra in Gujarat, while the last population of one of five threatened sub-species of Asiatic wild ass (*Equus hemionus khur*) occurs in the salt marshes of the Little Rann of Kutch in Gujarat.

1.5.3 Mangroves in India in relation to Global Status

FAO has recently given a list of the recent, reliable national/area estimated for each country or territory as shown in the table 2. Global mangrove area currently stands at about 15.2 million hectares in 124 countries. The most extensive mangrove area is found in Asia, followed by Africa and North and Central America. Five countries namely Indonesia, Australia, Brazil, Nigeria and Mexico together accounts for 48 per cent of the total global area. 65 per cent of the total mangrove area is found in just ten countries while remaining 35 per cent is spread over 114 countries and out of which areas of 60 countries have less than 10,000 hectares of mangroves each. Asia is the region with the lowest forest cover in terms of percentage of land area, but has the largest extent of mangroves (approximately six million hectares), about five of the ten countries with the largest extent of mangroves worldwide are found in this region.

Globally, mangrove ecosystems continue to disappear at an alarming rate. Twenty per cent, or 3.6 million hectares of mangroves, have been lost since 1980. More recently, the rate of net loss appears to have slowed down, although it is still disturbingly high. About 185,000 ha were lost every year in the 1980s; this figure dropped to some 118,500 ha per year in the 1990s, and to 102,000 ha per year during the period 2000-2005, reflecting an increased awareness of the

value of mangrove ecosystems, supplied by mangrove projects in a numbers of countries, including India.

Even though mangroves are often used for the collection of forest wood products, and as a source of subsistence for local populations, the removal of wood and non-wood forest products is rarely the main cause of mangrove habitat loss. High anthropogenic pressure on coastal ecosystems and the competition for land for aquaculture, agriculture, infrastructure and tourism are the major causes of the decrease in mangrove areas.

1.5.4 Mangrove covers in India

Mangroves in India account for about five per cent of the world's mangrove vegetation with green cover of 4628 km^2 along the coastal States and Union Territories (UT) of the country, which is 0.14% of the country's total geographic area. The Forest Survey of India has been assessing the mangroves using remote sensing since 1987. It published the first assessment report in 1987 and the area estimated was 4,046 km^2 (scale of assessment – 1:1 million). Thereafter, mangroves were assessed regularly on a two-year cycle from 1989 to 1999, where the scale of assessment was 1:250,000. The assessment from 2001 onwards has been done on 1:50,000 scale.

State/UT wise mangrove cover as assessed by FSI in different assessments is given in the table 3. West Bengal has the greatest area of mangrove cover in the country, followed by Gujarat and Andaman and Nicobar Islands. About 60 % mangrove cover is found on the east coast of India, 14 % on the west coast and the remaining on the Andaman and Nicobar Islands. On a macro scale, geomorphic settings of the mangrove ecosystems of the east coast of India are different from those of the west coast. The presence of larger brackish water bodies and a complex network of tidal creeks and canals characterize the mangrove ecosystems of the east coast. This is mainly due to the larger deltas created by east-flowing rivers and the gentle slope of the coast. On the other hand, the coastal zone of the west coast is narrow and steep in slope, due to the presence of the Western Ghats. Secondly, there are no major west-flowing rivers. As a result, the mangrove ecosystems on the west coast of India are small in size, lower in diversity and less complicated in terms of their

tidal creek networks. The tables 4 and 5 present State/UT wise and districtwise status of mangrove cover as estimated in the 2013 assessment.

Table3:State-wise mangrove cover* (Area in sq. km) Source: FSI, 2013

Sr. No	States/ Union Territory	1989	1991	1993	1995	1997	1999	2001	2003	2005	2009	2011	2013
1	A & N islands	973	971	966	966	966	966	789	658	635	615	617	604
2	Andhra Pradesh	405	399	378	383	383	397	333	329	354	353	352	352
3	Goa	3	3	3	3	5	5	5	16	16	17	22	22
4	Gujarat	412	397	419	689	901	1031	911	916	991	1046	1058	1103
5	Karnataka	0	0	0	2	3	3	2	3	3	3	3	3
6	Maharashtra	114	113	155	155	124	108	118	158	186	186	186	186
7	Odisha	192	195	195	195	211	215	219	203	217	221	222	213
8	Tamil Nadu	47	47	21	21	21	21	23	35	36	39	39	39
9	West Bengal	2109	2119	2119	2119	2123	2125	2081	2120	2136	2152	2155	2097
10	Puducherry	0	0	0	0	0	0	1	1	1	1	1	1.63
11	Kerala	0	0	0	0	0	0	0	8	5	5	6	6
12	Daman & Diu	0	0	0	0	0	0	0	1	1	1	1.56	1
	Total	**4255**	**4244**	**4256**	**4533**	**4737**	**4871**	**4482**	**4448**	**4581**	**4639**	**4663**	**4628**

A) Status of forest cover: In the FSI assessment, mangrove cover has been categorized into (i) very dense mangroves (canopy density of more than 70%); (ii) moderately dense mangroves (canopy density between 40-70%); and (iii) open mangroves (canopy density between 10-40%). The very dense mangroves comprise 1,351 km^2 (25.8% of mangrove cover), moderately dense mangroves 1,457 km^2 (36.6%), while open mangroves cover an area of about 1,819 km^2 (37.6%)(Table 4).

B) Trend of change: Compared to the 2011 assessment, there has been a net decrease of 34 km² mangrove cover in India. This change is due to decrease in mangrove cover in West Bengal mainly due to exclusion of creeks area within the mangroves on account of better radiometric resolution of satellite data. (Table- 4).

Table 4. Mangrove Cover Assessment 2013 (Area in km^2)

Sr.no	State/UT	Very Dense mangrove	Moderately dense mangrove	Open mangrove	Total	Change w.r.t 2011 assessment
1	Andaman & Nicobar	276	258	70	604	-13
2	Andhra Pradesh	0	126	226	352	0
3	Goa	0	20	2	22	0
4	Gujarat	0	175	928	1,103	45
5	Karnataka	0	3	0	3	0
6	Maharashtra	0	69	117	186	0
7	Odisha	82	88	43	213	-9
8	Tamil Nadu	0	16	23	39	0
9	West Bengal	993	699	405	2,097	-57
10	Puducherry	0	0.14	1.49	1.63	0.07
11	Kerala	0	3	3	6	0
12	Daman & Diu	0	0	1	1	0
	Total	**1,351**	**1,457**	**1,819**	**4,628**	**-34**

Table 5: District-wise Mangrove cover (Area in km^2)

Sr.no	State/UT	Very Dense mangrove	Moderately dense mangrove	Open mangrove	Total	Change w.r.t IFSR 2011
1.	**Andhra Pradesh**					
	East Godavari	0	63	125	188	0
	Guntur	0	28	21	49	0
	Krishna	0	35	74	109	0
	Nellore	0	0	5	5	0
	Prakasham	0	0	1	1	0
	Total	0	126	226	352	0
2	**Goa**					
	North Goa	0	16	1	17	0
	South Goa	0	4	1	5	0
	Total	0	20	2	22	0
3	**Gujarat**					
	Ahmedabad	0	1	35	36	6
	Amreli	0	0	2	2	1
	Anand	0	0	8	8	8
	Bharuch	0	21	22	43	1
	Bhavnagar	0	6	5	11	-8
	Jamnagar	0	28	139	167	8
	Junagadh	0	0	1	1	0
	Kachchh	0	118	671	789	11
	Navsari	0	0	13	13	12
	Porbandar	0	0	1	1	1
	Rajkot	0	1	3	4	2
	Surat	0	5	16	21	1
	Vadodara	0	0	3	3	1
	Valsad	0	0	3	3	1
	Total	0	175	928	1,103	45

4	**Karnataka**					
	Uttar Kannada	0	1	0	1	0
	Udipi	0	2	0	2	0
	Total	0	3	0	3	0
5	**Kerala**					
	Kannur	0	3	2	5	0
	Kasargod	0	0	1	1	1
	Total	0	3	3	6	1
6	**Maharashtra**					
	Mumbai City	0	0	2	2	0
	Mumbai Suburb	0	23	20	43	0
	Raigarh	0	10	52	62	0
	Ratnagiri	0	12	11	23	0
	Sindhudurg	0	2	1	3	0
	Thane	0	22	31	53	0
	Total	0	69	117	186	0
7	**Orissa**					
	Baleshwar	0	0	2	2	-2
	Bhadrak	0	7	14	21	-2
	Jagatsinghpur	0	2	5	7	0
	Kendrapara	82	79	22	183	-4
	Puri	0	0	0	0	-1
	Total	82	88	43	213	-9
8	**Tamil Nadu**					
	Cuddalore	0	0	7	7	0
	Nagapattinam	0	9	10	19	0
	Ramanathpuram	0	2	1	3	0
	Thanjavur	0	5	3	8	0
	Toothukudi	0	0	2	2	0
	Total	0	16	23	39	0
9	**West Bengal**					
	Medinipur	0	0	3	3	-8

	North 24 Pargana	13	11	1	25	-1
	South 24 Pargana	980	688	401	2,069	-48
	Total	993	699	405	2,097	-57
10	**A&N islands**					
	Andaman	276	256	69	601	-13
	Nicobar	0	2	1	3	0
	Total	276	258	70	604	-13
11	**Daman & Diu**					
	Diu	0	0.14	1.49	1.63	0.07
	Total	0	0.14	1.49	1.63	0.07
12	**Puducherry**					
	Yaman	0	0	1	1	0
	Total	0	0	1	1	0
Grand Total		1,351	1,457	1,819	4,628	-34

C) Total number of species

The mangrove ecosystem supports genetically diverse groups of aquatic and terrestrial organisms. Mangrove habitats include diversified smaller habitats such as core forests, litter-forest floors, mudflats, water bodies (rivers, bays, intertidal creeks, channels and backwaters), adjacent coral reefs and seagrass ecosystems wherever they occur. Mangroves can exist and flourish under wide ranges of salinities, tidal amplitudes, winds, temperatures and even in muddy and anaerobic soil conditions.

Indian mangrove ecosystems are known to have a total of 4,011 species that include 920 plant (23%) and 3,091 animal (77%) species (Table 6). The zoological component is about 3.5 times greater than the botanical component. No other country in the world has recorded so many species in mangrove ecosystems.

Table 6 . Total number of species in mangrove ecosystems of India

Flora	**No. of species**
Mangroves	39
Mangrove associates	86
Seagrass vegetation	11
Marine algae (Phytoplankton + seaweeds)	557
Bacteria	69
Fungi	103
Actinomycetes	23
Lichens	32
Fauna	
Prawns and lobsters	55
Crabs	138
Insects	707
Molluscs	305
Other invertebrates	745
Fish parasites	7
Finfish	543
Amphibians	13
Reptiles	84
Birds	426
Mammals	68
Total	4011

(Source: Kathiresan and Qasim, 2005; Kathiresan, 2009)

D) Religious faith and beliefs in conservation

Mangroves have long been regarded as ‘sacred groves’ in some places of India. There is an ancient temple at Chidambaram, nearer to Pichavaram mangrove forests in Tamil Nadu. In this temple, a mangrove species namely *Excoecaria agallocha* has been worshipped as a ‘temple tree’ by the Hindu

religious people, since the 3rd century. There was a belief that a 'holy' dip in the temple's pond water that was surrounded by the mangrove species cured even incurable human diseases. The medicinal properties of the plant species have recently been proved scientifically. There is another type of temples by the name 'Bano bibi' temples present at the entry points of Indian Sundarbans. Each temple has a forest god for the Muslims to worship, a forest goddess for the Hindus religious people, and a tiger god. Local people worship in the temple before entering the forest with a belief that the worship will protect them from the tiger attack.

In Gujarat, there are some religious sites of Muslims on the Islands of Mitha Chusna, Khara Chusna, Chhad and Pirotan. Muslims do not cut mangrove trees or molest animals on such Islands. The boat-loads of fishermen with their families arrive on certain festival days on those islands. There were about four dozen old trees of *Avicennia* on Chhas and Zindra and most of them were protected religiously because fishermen worship them. Such individual trees are seen marked by green cloth or flag as symbol of site for muslim's worship place. Shravan Kavadiya is another place of religious importance in Gujarat. Even though the place is located more than 100 km away from the coastal area, it has a mangrove area of 0.7 hectares near the temple "Shravan Kavadiya". These inland mangroves were identified as temple forest and nobody cuts or causes any damage to very old tress of *Avicennia* in the groves.

Besides mangroves, marine mammals like dolphins and whales are also worshipped in India. The fishermen in Tamil Nadu believe that dolphins save them if they happen to fall into the sea. The Kharwas community of Gujarat worships the whales as an incarnation of Lord Hanuman. However, the largest fish like whale sharks were hunted. Every year, at least 250 whale sharks were killed along the Saurashtra coast. Therefore, the Government of India put a ban on killing whale sharks in 2001. However, the forest department had struggled hard to implement it. A Hindu religious leader by name 'Morari Bapu' stepped to save the whale sharks in 2003. He touched the sentimental feelings of people by comparing the whale shark with a daughter who comes from as far as the waters of Australia and Mexico to give birth at home in the warmth of the Arabian Sea along the Saurashtra. As a result, most fishermen have stopped fishing the whale sharks and even if they get entangled, the fishermen cut their nets that often cost

up to Rs. 10000, to release the trapped fish. Corporate sectors like the International Fund for Animal Welfare and Wildlife Trust of India, Tata Chemicals and Gujarat Heavy Chemicals have also joined the campaign of the religious leader to save the rare fish in the sea.

1.6 Legal Framework in India for Conservation of Coastal Mangroves

Many countries have promulgated laws and regulations to protect the remaining mangrove areas and mitigate against further widespread loss. Effective enforcement of this legislation is, however, often hampered by a lack of financial and human resources. Several Asian countries have ratified the Ramsar Convention on Wetlands and have designated mangrove areas as Ramsar sites, or as National Parks, Reserves or Wildlife Sanctuaries. In India, mangrove forests that are declared as Reserve Forests, Reserve Lands or Sanctuaries are protected by the Forest Department of the concerned State/UT, but mangroves located outside these Reserves and on community lands have not been assisted so far. Such areas exist in Kerala, Karnataka, Andhra Pradesh and Maharashtra.

India is very strong on the policy front, as well as on the legal support available for the conservation of biological resources in the country. Environmental protection is enshrined in the Constitution of India. Article 48-A and Article 51-A (g) of the Directive Principles of State Policy in the Constitution of India states that "*the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife in the country, and it is a duty of every citizen to protect and improve thenational environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures*".

Under the system of democratic decentralization of responsibilities enshrined in Constitution amendment No. 73 of 1993, local bodies consisting of elected representatives, one third of whom are women, have been entrusted with the responsibility of safeguarding the local environmental capital stocks.

The National Forest Policy 1988 spells out very clearly that the principal aim of Forest Policy must be to ensure environmental stability and maintenance of ecological balance, including atmospheric equilibrium, which is vital for sustenance of all life-forms, human beings, animals and plants. The derivation of direct economic benefit must be subordinated to this principal aim. The National

Conservation Strategy and Policy Statement on Environment and Development (1992) highlight conservation and sustainable development of mangroves, including coastal areas, riverine and Island ecosystems. Similarly, the National Forest Policy and National Wildlife Action Plan emphasize the conservation of mangroves based on scientific principles, including social and cultural aspects.

India's National Environment Policy (NEP), approved by the Cabinet in 2006, seeks to achieve balance and harmony between conservation and development. The policy is intended to mainstream environmental concerns in all development activities. The dominant theme of this Policy is that while conservation of environmental resources is necessary to secure livelihoods and well-being of all, the most secure basis for conservation is to ensure that people dependent on particular resources obtain better livelihoods through conservation, than from degradation of the resources. The NEP prescribes that human beings are at the centre of concerns for sustainable development and they are entitled to a healthy and productive life in harmony with nature. The Policy recognizes that mangroves are an important coastal environmental resource. They provide habitats for marine species; protection from extreme weather events; and a resource base for sustainable tourism.

1.7.1 Current status of research on mangrove flora

Indian mangroves are diverse with 125 species, 39 mangroves and 86 mangrove associates (Kathiresan, 2008a). About 56% of the world's mangrove species occur in India. Mangrove associates have 30 tree species, 24 shrubs, 18 herbs, six climbers, four grasses and four epiphytes. Eleven mangroves and eight associates are rare in occurrence and restricted in distribution. Only one species, *Rhizophora annamalayana* Kathir, is endemic to India occurring at Pichavaram. Mangrove species diversity including associates is the highest in Orissa (101 spp.) followed by West Bengal (92 spp.), Andaman and Nicobar Islands (91 spp.), Andra Pradesh (70 spp.), Tamil Nadu (70 spp.), Kerala (64 spp.), Maharashtra (63 spp.), Karnataka (58 spp.) and Goa (53 spp.); the lowest diversity is observed in Gujarat (40 spp.) (Kathiresan, 2008a). An intensive floristic survey conducted in nine districts of Andhra Pradesh has recorded a total of 65 plant species belonging to 52 genera in 32 families (Swain and Rama Rao, 2008). Of these, 19 species under 12 genera and 10 families are mangroves.

Among the mangroves, the dominant family is Rhizophoraceae followed by Avicenniaceae. Among the mangrove associates, Chenopodiaceae, Fabaceae and Poaceae form the most dominant families. Two rare mangroves, *Aegialitis rotundifolia* and *Scyphiphora hydrophyllacea*, are present in Nachugunta Reserve Forest in Krishna district and Kandikuppa Reserve Forest in East Godavari district respectively. An important mangrove associate *Brownlowia tersa* is present in Ramannapalem of East Godavari, which forms an addition to the mangrove flora of Southern India (Venu et al., 2006; Swain and Rama Rao, 2008).

Biodiversity studies of mangroves in Ratnagiri and Sindhudurg districts of Maharashtra state reveal the presence of 24 mangroves, 11 halophytes and 9 associates. Sindhudurg district has more floristic diversity than Ratnagiri district (Bhosale, 2008). A similar survey was made in Kali estuary at Karwar of Karnataka state. This survey recorded a total of 130 species belonging to 106 genera and 50 families, which included three new records: *Bruguiera cylindrica, Lumnitzera racemosa* and *Acrostichum aureum* (Nayak and Andrade, 2008). The coast of Karnataka is predominantly occupied by *Rhizophora mucronata*, accounting for 56.3% of the total stand followed by *Avicennia officinalis* (15.6%), *Sonneratia apetala* (13.4%) and *Kandelia candel* (10.9%). The mean density of trees was 1,740.6 per hectare. The above-ground biomass ranged from 29.2 to 120.1 tons per hectare with a mean biomass of 71.9 tons per hectare. This suggests low biomass status that can be attributed to high human pressure. Carbon stock in these sites varied from 14.6 to 60.05 tons per hectare with a mean value of 35.9 tons per hectare. This low carbon stock indicates degrading status of the mangroves (Bhat et al., 2008). The mangrove forest of Puduvypu in Cochin, Kerala has 28 plant species, eight true mangroves, five semi-mangroves, five grasses, one fern, five herbs and four climbers. *Avicennia officinalis* is dominant with the maximum number of individuals in the height class of greater than three metres (Gopikumar et al., 2008). The mangroves of North Malabar have 14 true mangrove species and 40 mangrove associates (Khaleel, 2008). Kerala state has altogether 15 true mangrove species and 49 mangrove associates (Anupama and Sivadasan, 2004). Eco-anatomical characteristics of wood have been studied in 12 mangrove species: *Aegiceras corniculatum,*

Avicennia marina, A. officinalis, Bruguiera gymnorrhiza, B. cylindrica, B. sexangula, Excoecaria agallocha, Kandelia candel, Rhizophora mucronata, R. apiculata, Sonneratia caseolaris and *S. alba* (Neriamparambil et al., 2008). Vessel morphological characters such as vessel diameter, vessel frequency, vessel length, vessel vulnerability and vessel mesomorphy were used to characterize mangrove species as belonging to mesophytic or xerophytic sites. Values of vessel vulnerability and vessel mesomorphy can be used to arrange the mangrove species according to their tolerance to salinity and water stress. The information is also useful to find the zonation pattern of the mangrove species. Mangrove species arranged according to values of vessel vulnerability and vessel mesomorphy are zoned from the sea towards the land as follows: *Aegiceras corniculatum* < *Avicennia marina* < *Sonneratia alba* < *Sonneratia caseolaris* < *Bruguiera sexangula* < *Bruguiera gymnorrhiza* < *Bruguiera cylindrical* < *A. officinalis* < *Kandelia candel* < *Rhizophora apiculata* < *Rhizophora mucronata* < *Excoecaria agallocha* (Neriamparambil et al., 2008). Recently, the phenology and reproduction of mangroves have increasingly been understood. The flowers are not specialized for any kind of pollination in species of Bruguiera, Ceriops and Rhizophora. In these species, flowers persist for 2-8 days and pollen-ovule ratio is very high (1:18,000–1:1,00,000). Bruguiera and Ceriops are entomophilous while Rhizophora exhibit anemophilous adaptation. All the species exhibit low flower to fruit and seed to ovule ratios (0.01-0.02). Pollen fertility is over 80% in Bruguiera and Ceriops. However, Rhizophora exhibits inbreeding depression (70-80% pollen sterility). In general, reproductive success is very low in all the species (Nagarajan et al., 2008). However, reproductive success in *Bruguiera cylindrical* is high when compared to other mangrove taxa (Sophia et al., 2008). *Rhizophora annamalayana* exhibits high pollen sterility and premature fall of flowers (99.9%); as a result of which, fruit setting in this species is extremely poor (Kavitha and Kathiresan, 2008). However, in *Bruguiera sexangula*, pollen fertility is about 95% and isolated individuals show normal fruiting, which is an indicator of self-compatibility and moderate reproductive success. Species recovery is possible by conducting controlled pollination and developing ex situ conservation stands (Krishnamoorthy et al., 2008). Floral biological variations are significant between species of the genus Ceriops. Flower production per panicle varies in *Ceriops decandra* (2-10) and *C. tagal* (8-10).

Ceriops decandra flowers are mild scented, produce huge amounts of pollen (18-20 µm) and are pollinated by diverse insect taxa. *Ceriops tagal* flowers are highly scented. The pollen of *Ceriops tagal* (14-16 µm) are more fertile (95%) than that of *C. decandra* (65%). *Ceriops decandra* has high bud and flower abortion (83-90%) when compared to *C. tagal* (50-75%). Regeneration in the proximity of the mother trees is poorer in *C. decandra* than in *C. tagal* due to the varying architecture of the propagules (Pandiarajan et al., 2008).

Insect visiting flowers of *Rhizophora mucronata* and *Avicennia officinalis*, the major constituents of the mangroves on the Karnataka coast, have been studied by Chatterjee et al. (2008a). The flowering season, pollination biology and insect visitation are different for each species. *Rhizophora mucronata* has white coloured bell shaped flowers. They remain only for three days and produce a huge amount of powdery pollen as reward but no nectar. They are protandrous and attract Hymenopteran visitors like *Apis dorsata*, *Apis cerana* and species of Trigona and Amygella. A wasp and a species of Xylocopa are occasional visitors to this flower. *Avicennia officinalis* starts flowering in June and the season lasts till late September. The flower has a disc shaped landing site of 2-3 cm diameter, a bright yellow colour, pungent smell, sticky pollen and nectar. Members of seven Dipteran families visit this flower, the Caliphoridae are the major visitors followed by Arcophagidae, Tephritidae, Tabanidae and Drossophilidae (Chatterjee et al., 2008b).

Cyanobacteria are an important component of the microbial flora of mangroves. Six species dominantly occur in the root-soil of mangroves and they are *Spirulina subsalsa, Phormidium tenue, P. fragile, Synechocystis salina, Oscillatoria willei* and *O. cortiana*. Their counts vary between 3.1x103 and 4.1x104 colony forming units per gram of soil with the maximum occurrence during summer (May) and the minimum in post monsoon (December) along the east coast of India (Nabeel et al., 2008). Lactobacilli are beneficial bacteria that occur in the root-soil of mangroves. The dominant species of marine lactobacilli are *Lactobacillus delbrueckii, L. lactis, L. casei, L. xylosus, L. plantarum* and *L. curvatus*. Their counts vary from 3x102 to 3.1x104 colony forming units per gram of soil with the maximum occurrence in post monsoon (November) and the

minimum in summer (May) along the east-coast of India (Thiruneelakantan et al., 2008).

There is also a high biodiversity of fungi in mangrove ecosystems. In Kerala, a total of 17 pathogenic fungi, 32 endophytic fungi and 14 wood-degrading fungi (lignicolous fungi) have been recorded (Mohanan, 2008). Cytospora species are associated with the die-back disease of *Sonneratia caseolaris* whereas both Cytospora and Endothia species are responsible for stem infection in *Rhizophora mucronata*. Three lignicolous fungi are widely distributed and they are *Hexagonia apiara, Microporus xanthopus* and species of Phellinus. All the mangrove roots are in association with arbuscular mycorrhizal fungi ranging from 2% in Kandelia candel to 80% in *Aegiceras corniculatum*. The mycorrhizal fungi occur in the root-soil of mangroves in a range from 1.9 to 31.4 per gram of soil. Among the mycorrhizal fungi, Acaulospora, Glomus and Gigaspora are the widely distributed genera. The dominant endophytic fungi are *Cladosporium cladosporioides, Colletotrichum gloeosporioides* and species of Phoma, Phomopsis, Phyllosticta and Nigrospora (Mohanan, 2008).

Yeasts are a group of basidiomycetes and ascomycetous fungi. The dominant species in the root-soil are *Candida tropicalis, C. albicans, Cryptococcus dimennae, Debaryomyces hansenii, Geotrichum sp., Pichia capsulata, P. fermentans, Pichia salicaria, Saccharomyces cerevisiae, Rhodotorula minuta, Trichosporan sp.* and *Yarrowia lipolytica*. Their counts range from 1x102 to 1.4x104 colony forming units per gram of soil with the maximum occurrence during post monsoon (November) and the minimum in Summer (May) (Manivannan and Kathiresan, 2008).

Lichen is a composite organism consisting of a symbiotic association of a fungus and algae (either green or bluegreen). Thirty two species belonging to 13 families are reportedly present in Sundarbans (Santra, 1998). Ramalina species are commonly occurring as epiphytes on *Rhizophora spp*. in Pichavaram and Gulf of Mannar areas of Tamil Nadu.

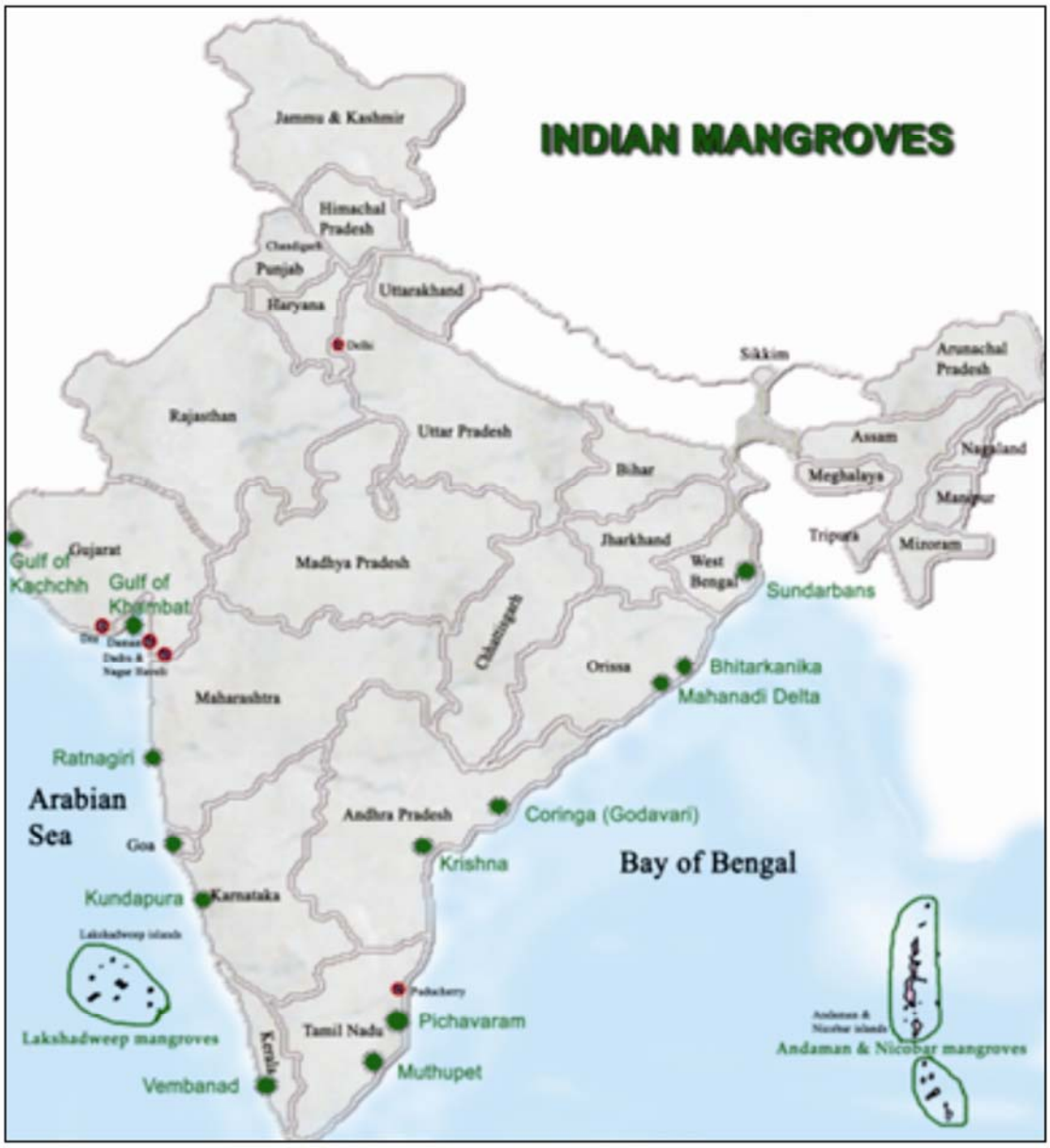


Fig. 1.6. Distribution of Mangrove in India

1.7.2 Current status of research on mangrove fauna

Mangroves are predominantly intertidal habitats that occur worldwide in the (sub) tropics along sheltered and shallow water coastlines. The prop-roots and pneumatophores of mangrove trees extend into the intertidal and subtidal where they become a rare feature: hard substrata in an otherwise soft sediment environment (Ellison and Farnsworth, 1992). As such, mangrove roots become home to terrestrial as well as marine plants, algae, invertebrates and vertebrates. Mangroves form a habitat for a wide variety of species, some occurring in high densities. They are productive habitats and may support coastal fisheries for prawns and fishes (Manson et al., 2005). Mangroves are also important to humans for a variety of reasons, including aquaculture, agriculture,Forestry, protection against shoreline erosion, as a source of fire-wood and building material and other local subsistence use (Hogarth, 1999; Walters et al., 2008). Worldwide, loss of mangroves has been significant in recent decades, although in some regions of the world mangroves still occur as very extensive forests (Spalding, 1998; Alongi, 2002). They suffer from direct impacts such as cutting and pollution, as well as from hidden impacts such as changes in inland freshwater management (Dahdouh-Guebas et al., 2005), and are often regarded as unpleasant environments with little intrinsic value.

Animals found within mangrove environments include a variety of taxa, many of which are vulnerable or threatened as a result of human activities in the coastal zone. Determining the value of mangroves and other estuarine habitats for these animals requires knowledge of their life history, physiology and ecology as they interact across the dynamic mosaic of available habitats. Evidence suggests that mangroves are important to these species, but a lack of research is a major impediment to an evaluation of their mangrove dependency. A challenge for future research is separating the roles of mangroves from those of estuaries and other shallow-water habitats, to help determine the appropriate temporal and spatial scales for habitat protection (Manson et al., 2005). Estuarine habitats have been recognised as important drivers of near shore fish productivity. Worldwide, about 30% of all commercial fish species are mangrove-dependent (Naylor et al., 2000), producing an annual catch of almost 30 million tonnes in 2002 (FAO, 2004). Of all ecosystems, estuaries have the highest value per

hectare (Costanza et al., 1997), making it significant for subsistence in many coastal communities. In Braganca (NBrazil), for example, 68% of the cash income is primarily derived from mangrove crabs and fish (Glaser, 2003). Recent and extensive reviews on mangroves as habitats for terrestrial and marine fauna include Hogarth (1999), Kathiresan and Bingham (2001), and Qasim and Kathiresan (2005). Studies related to the linkages between mangroves and coastal fish populations and fisheries, and new insights relating to the debate on the degree to which mangrove litter fuels the mangrove food web, form an important body of work published since these reviews; hence there is the need for amore up-to-date review. The current review summarises the available data on mangroves as a habitat for terrestrial and marine fauna, with special reference to the interlinkages with adjacent habitats and the importance of litter in the mangrove food web.We focus on the main groups of animals found in the mangrove habitat: sponges, various groups of meiofauna and macrofauna (epifauna and infauna), prawns, insects, fishes (bony fishes and elasmobranchs), amphibians, reptiles, and birds, accepting that a review of the complete fauna would be too far-reaching for this special issue, and that some mangrove fauna are not discussed here. These include less-well studied taxa like zooplankton (e.g., Mohan and Sreenivas, 1998; Ferrari et al., 2003; Krumme and Liang, 2004), tunicates (e.g., Carballo, 2000; Goodbody, 2003; Rocha et al., 2005), and mammals such as bats (Bordignon, 2006), buffalo (Dahdouh- Guebas et al., 2006), deer (Barrett and Stiling, 2006), dolphins (Smith et al., 2006), flying foxes (Moore, 2002), manatees (Spiegelberger and Ganslosser, 2005), marsupials (Fernandes et al., 2006), otters (Angelici et al., 2005), primates (Nijman, 2000), rabbits (Forys and Humphrey, 1996), raccoons (Cuaron et al., 2004), and tigers (Gopal and Chauhan, 2006).

1.7.2.1 Mangroves as habitats for macrofauna

Mangroves are inhabited by a variety of benthic invertebrates, such as brachyuran crabs, gastropods, bivalves, hermit crabs, barnacles, sponges, tunicates, polychaetes and sipunculids. Mangrove invertebrates often show marked zonation patterns, and colonise a variety of specific micro-environments. While some species dwell on the sediment surface or reside in burrows, others live on pneumatophores and lower tree trunks or prop-roots, burrow in decaying

wood, or can even be found in the tree canopies (Sasekumar, 1974; Ashton, 1999). The burrowing activities of certain benthic invertebrates have a pronounced effect on sediment properties and biochemical processes, by enhancing the porosity and water flow through the sediment, assisting in flushing toxic substances. In addition, their feeding on the sediment surface (deposit feeding) and plant matter (detritivory) promotes nutrient recycling (Kristensen et al., 2008). In turn, benthic invertebrates are a source of food for vertebrate predators including shallow-water fishes that enter the mangroves at high tide (Sheaves and Molony, 2000). Macrobenthos may be operationally separated in two groups, i.e., epifauna and infauna. Epifauna refers to those invertebrates that live on various substrates such as lower tree trunks and the sediment surface, but which do not burrow in it. A range of gastropods, crabs, and bivalve species are typical representatives of epifauna. Infauna refers to burrowing invertebrates which live within the sediment, and includes crabs, pistol prawns, polychaetes, and sipunculids. The distinction between infauna and epifauna is not always straightforward, however, and not always related to the organisms' functional role. For example, while many sesarmid crabs create extensive burrow systems, others appear to find refuge in crevices from decaying wood or root structures, or their burrowing status is unknown (see Gillikin and Kamanu, 2005).

1.7.2.2 Diversity and distribution of macrofauna

Macrofaunal communities in high and low intertidal mangroves are often distinctly different, and this relates in part to highly different environmental conditions. They appear to be influenced by hydroperiod, availability of organic matter and sediment characteristics (Lee, 2008). Lower intertidal mangrove sediments (typically silt- or clay-dominated) provide substratum for growth of benthic microalgae and macroalgae (Dor and Levy, 1984; King and Wheeler, 1985; Tanaka and Chihara, 1988; Aikanathan and Sasekumar, 1994; Sarpedonti and Sasekumar, 1996). In high intertidal mangroves, the substratum is often more sandy, and the reduced frequency of tidal inundation results in a drier, more saline environment where more leaf litter accumulates and which is less suitable for growth of micro- and macroalgae. Frequent inundation in the low intertidal zone also favours the presence of filter feeders and deposit feeders, whereas fauna in the high intertidal zone does not have frequent direct access to such

food sources and other trophic groups therefore predominate there. Gastropods are typically one of the dominant and most conspicuous macrofauna in mangrove systems, and occupy a wide range of ecological niches (Cantera et al., 1983; Plaziat, 1984). The distribution of gastropod species within a mangrove forest is influenced by a variety of factors such as light (as a major factor determining algal growth and as a factor influencing humidity), tidal exposure, salinity, and substrate type. The trophic position of gastropods is equally sediment dwellers feed – selectively or not – on sediment organic matter and/or microphytobenthos, Littoraria spp. feed on epibenthic crusts on stems and roots, and some species have been reported to feed on mangrove litter and/or propagules (such as Melampus coffeus and adult Terebralia palustris). Predatory and scavenging species such as Thais spp. and Nassarius spp. are much less abundant. Gastropods can attain very high species diversity in some mangrove ecosystems: Camilleri (1992) mentions 39 species of gastropods in an Australian mangrove, Jiang and Li (1995) found 28 species in a Chinese mangrove, and Wells (1990) reports 23 mollusc species from a mangrove forest in Hong Kong. On the other hand, species diversity differs strongly in different parts of the world, e.g., M. coffeus is the only gastropod present in the mangroves of Guadeloupe (Plaziat, 1984). The numerical abundance and biomass of molluscs can be equally impressive (e.g., Sasekumar, 1974), and they can even reach higher densities and biomass than brachyuran crabs in some cases (e.g.,Wells, 1984), although the number of comparative studies is limited. A number of gastropod genera (e.g., Ellobium, Enigmonia) and species (e.g., Littoraria scabra, T. palustris) appear to occur exclusively in mangrove systems (Plaziat, 1984). The global pattern in species richness of mangrove gastropods closely follows that of mangrove trees (Ellison et al., 1999). Bivalves are often considered to be confined to a narrow seaward zone, due to feeding and larval settlement restrictions (Plaziat, 1984). In Southeast Asia, however, Polymesoda erosa is adapted for a semi-terrestrial existence by living on the high shore where only occasional high tides inundate the habitat (Morton, 1976). A number of bivalves with chemo-symbiotic associations have also been reported from mangroves (e.g., Lebata and Primavera, 2001). Wood-boring bivalves are also common in the mangrove forest, and Singh and Sasekumar (1994), for example, reported 10 species of teredinids and 1 pholadid in several mangroves along the west coast

of Peninsular Malaysia. These wood-boring bivalves are ecologically significant as they stimulate the decomposition of wood and live in symbiosis with nitrogen-fixing bacteria (Waterbury et al., 1983). It has been suggested that the latter process may represent a very significant yet overlooked source of nitrogen fixation in mangrove ecosystems in view of the abundance of dead wood and Teredinidae (Boto and Robertson, 1990). Although mangrove-associated bivalves are only rarely studied, their diversity can be surprisingly high: Alvarez-Leon (1983) reported 29 species of bivalves from the mangrove root systems on the Atlantic coast of Colombia, and Jiang and Li (1995) mention 24 bivalve species from a mangrove system in Hong Kong. Together with molluscs, brachyuran crabs are the dominant macrofauna in most intertidal mangrove ecosystems. Early reports on the species diversity of mangrove-associated crabs in the Indo-Pacific (Jones, 1984) now appear to be outdated (see Lee, 1998), and as taxonomical difficulties are still a major restriction, the diversity and distribution of mangrove associated crabs is likely to be far from understood. Ocypodid crabs (Uca spp. and Macrophthalmus spp., or Ucides cordatus in Central and South American mangroves) and grapsid crabs (Sesarminae, Metopograpsus spp., Metaplax spp.) usually dominate the crab fauna and species often exhibit marked horizontal and vertical zonation patterns (e.g., Frith et al., 1979; Jones, 1984; Frusher et al., 1994; Sivasothi, 2000). Whether these distribution patterns are related to physico-chemical characteristics of the environment (e.g., Frusher et al., 1994), or to the presence of specific tree species or tree diversity, remains to be determined (see Lee, 1997; Dahdouh-Guebas et al., 2002). Similar to what is observed for gastropods (Ellison et al., 1999), species richness of sesarmid crabs appears to follow global patterns in mangrove tree species richness (Lee, 1998), although the number of detailed surveys is relatively limited and taxonomical problems still exist. Sesarmids are most diverse in Southeast Asia and decrease to low numbers in Central America. Only five species of Grapsidae have been found in the mangroves of Florida and Central America (Abele, 1992). However, Alvarez-Leon (1983) recorded an impressive array of Grapsidae (16 species) on the Caribbean coast of Colombia. Other relatively well represented groups of macrofauna such as polychaetes and hermit crabs have been much less frequently studied, and little is known on their overall diversity, abundance and functional role in mangroves. Worms can attain a high diversity in the soft,

unconsolidated substrates on the seaward sides of mangroves, with polychaetes predominating in diversity as well as abundance (Metcalfe and Glasby, 2008).

1.7.2.3 Functional role of macrobenthos

The mangrove macrobenthos is intimately associated with the bottom substratum. Crabs and gastropods ingest sediment and food such as bacteria, microalgae, meiofauna and detritus adhering to it, they burrow in it and move through it, and modify it in many physical and chemical ways (e.g., Warren and Underwood, 1986; Smith et al., 1991). Crab burrows provide an efficient mechanism for exchanging water between the anoxic substrate and the overlying tidal water (Ridd, 1996). This observation was confirmed by Stieglitz et al. (2000) who demonstrated that a burrow inhabited by a sesarmid crab and a pistol prawn was completely flushed within 1 h by the activities of the crustaceans during a single tidal event. Crabs and gastropods are the two major seed predators in mangrove forests, and thus play an important role in determining plant community structure (Smith et al., 1989). An inverse relationship between the dominance of a given tree species in the canopy and the amount of seed predation was found for species of Avicennia, Rhizophora and Bruguiera. It is apparent there is a mutual relationship between sesarmid crabs and mangroves, whereby mangroves provide a suitable habitat for the crabs, and the crabs reduces competition between mangrove plant species through selective predation on seedlings (Bosire et al., 2005). The selective effects of seed predation are not limited to sesarmid crabs, but can include land crabs and hermit crabs (Lindquist and Carroll, 2004). High seed predation by crabs can sometimes have a negative influence on regeneration of mangrove stands (Dahdouh-Guebas et al., 1997, 1998). Grapsid crabs dominate in Australia, Malaysia and Panama, while the gastropods Cerithidea scalariformis and Melampus coeffeus are the most important seed predators in Florida mangroves. Detritus-feeding invertebrates dominate the mangrove fauna. Ucides cordatus, a semi-terrestrial ocypodid crab in Brazilian mangroves, feeds almost exclusively on plant material. Large male crabs consumed 3.3 g dry weight daily corresponding to 6% of their dry body weight (Nordhaus, 2004). Deposit feeders like Uca spp. scoop the surface layers of the sediment and derive nutrition from microalgae, bacteria and detritus. Some large sesarmid crabs are tree climbing and feed on fresh leaves

(Sivasothi, 2000). Competition for mangrove litter has been observed in East African mangroves where many Terebralia palustris (potamidid gastropod) feed on the same leaf to prevent crabs from removing the leaf (Fratini et al., 2001). The dominant role of grapsid crabs in the mangrove community structure and function has been investigated in Australia, Asia and East Africa (Giddens et al., 1986; Robertson and Daniel, 1989; Micheli, 1993; Lee, 1997; Ashton, 2002; Cannicci et al., 2008). The role of grapsid crabs as an agent affecting mangrove litter turnover in the Indo- Pacific is indisputable, but the exact trophic link remains unknown (Lee, 1997;). Numerous studies in Australia and East Africa indicate that grapsid crabs are major consumers of mangrove leaf litter and as a consequence produce large quantities of faecal material rich in nutrients and energy (Leh and Sasekumar, 1985; Micheli et al., 1991; Emmerson and McGwynne, 1992; Lee, 1997). These crabs also spend considerable time grazing and picking organic material off the surface of the substrate (Skov and Hartnoll, 2002), suggesting that they are using microbial resources for their nitrogen needs. Fish predation on mangrove invertebrates occurs at high tide when the mangroves are inundated (Sasekumar et al., 1984; Wilson, 1989; Sheaves and Molony, 2000). For example, the mangrove crabs Chiromantes spp. and Metaplax spp., and the sipuncula Phascolosoma arcuatum were found in the gut of fishes that were netted within the mangroves at high tide (Sasekumar et al., 1984). To what extent this form of feeding contributes to the food of shallow-water fish community and controls the structure of the mangrove benthic community awaits further studies. In summary, benthic invertebrates in mangrove forests play an important ecological role by their activities of burrowing in the sediment where they assist in flushing toxic substances, and modifying the oxidation status of the surrounding sediment. Feeding on plant matter (detritivory) assists in recycling organic matter and produces animal biomass which is a source of food for vertebrate predators (e.g., reptiles, birds, and otters) and inshore fishes that come in with the high tide.

1.7.2.4 Research Status

Animal communities in the mangroves include both resident and visiting or transient fauna. Majority of the visiting terrestrial fauna are insects, birds, mammals and reptiles. Sundarbans is the only mangrove tiger land in the world.

The aquatic visiting fauna are mainly fish and crustaceans with some molluscs and echinoderms. The visitors invade mangroves from the adjacent habitats such as forests, coral reefs, estuaries, creeks and bays. Resident fauna of mangroves are mainly benthic fauna of intertidal habitats, which are grouped under two broad categories viz.: infauna and epifauna. Infauna animals which burrow and penetrate the substratum predominantly comprise polychaetes, brachyuran crabs, wood-boring animals, mud burrowing bivalves and gobiid fishes. Epifauna include the commonly occurring gastropods and some sessile bivalves like oysters, *Modiolus spp*. and barnacle crustaceans. Resident terrestrial fauna include birds such as the Black Capped Kingfisher (*Halcyon pileata*), Brown Winged Kingfisher (*Halcyon amauroptera*) and Mangrove Whistler (*Pachycephala grisola*) and insects like *Polyura schreiber* (Lepidoptera: Nymphalidae) (Ramakrishna, 2008).

Faunal diversity in different sites of mangroves continues to be studied. The Puduvypu mangroves in Cochin of Kerala have recorded 70 bird species, 10 mammals, 12 reptiles, 12 fishes and three amphibians (Gopikumar et al., 2008). The mangroves of North Malabar have 109 bird species in which 34 are migratory (Khaleel, 2008). In Ratnagiri and Sindhudurg districts of Maharashtra, 13 species of crustaceans, 12 gastropods, 11 bivalves, 36 estuarine fishes, 50 birds and three mammals have been registered recently (Bhosale, 2008).

Insect and plant relationships with reference to herbivory in the mangroves of Karnataka state have been studied. A total of 8,638 individual insects belonging to 13 orders and 305 species have been collected. Coleoptera represented the maximum diversity at species level followed by Lepidoptera, Orthoptera and Diptera. The effect of herbivory on the mangrove plants varies with species and the effect of herbivores is significantly site specific for *Avicennia officinalis* and *Sonneratia alba* but not significantly different for *Rhizophora mucronata* (Remadevi et al., 2008a). Latheef et al. (2008) studied seed predation on *Rhizophora mucronata* propagules by a moth borer. About 51.6% of the propagules are attacked by the moth borer. Germination reduces with the propagule damage. The propagules belonging to the damage classes of 1 hole, 2

holes, 3 holes and 4 holes show increasing trend in loss of sprouting. Propagules with more than 3 holes exhibit a total loss of sprouting (Latheef et al., 2008).

Nocturnal insect diversity in Coringa mangroves in Andhra Pradesh has been studied using solar powered light traps. There are 90 species of insects belonging to eight major orders. Hemipterans are dominant followed by Coleoptera, Hymenoptera and Diptera. In Hemiptera, the family Notonectidae is the most dominant with four different species followed by Cydnidae, Fulgoridae and Pentatomidae. Family Staphylinidae belonging to the order Coleoptera is the dominant one comprising 12 species followed by Carabidae, Hydrophillidae and Trogossitidae. In case of the order Hymemoptera, the family Formicidae is the dominant one with respect to the number of species (Remadevi et al., 2008b). A similar study on nocturnal entomo-fauna has been made in Karnataka state. In this study Coleoptera was found the largest order followed by Hemiptera, Diptera, Homoptera and Hymenoptera. However, on the east coast, Hemiptera is the major insect order followed by Coleoptera, Diptera and Hymenoptera (mostly Formicidae) (Remadevi et al., 2008c). Regarding the diversity of oribatid mites in mangroves of Calicut district of Kerala state, there are a total of 11 species belonging to 9 genera and 9 families at mangroves of Beypore while 13 species belonging to 13 genera and 10 families occur at Kottakadavu. Some species such as *Javacarus kuehnelti foliates*, *Tegeocranellus sp., Rostrozetes foveolatus* are abundant in both the mangrove ecosystems (Julie et al., 2008).

Mosquitoes are an important faunal component of mangroves. Mosquitoes breed in tree holes, crab holes and swamp pools of mangroves. In Indian mangroves, 62 species of mosquitoes belonging to 19 genera and 21 sub-genera have so far been recorded (Rajavel and Natarajan, 2008).

Like wise, marine woodborers constitute an important component of mangrove fauna which play a vital role in the biodegradation process. At least 27 species have so far been recorded from the mangroves of India, of which *Bactronophorus thoracites, Dicyathifer manni and Martesia nairi* are almost specific to mangrove habitats (Santhakumaran, 2008). Studies of marine wood borers at the mangroves of Kothakoduru and Bangarammapalem in Visakhapatnam district of Andhra Pradesh recorded the presence of 17 species of Teredinids belonging to six genera. The genus Bankia represented by nine

species was the most dominant. Four species are new records to Indian waters and one new to the mainland of the Peninsula. Despite this fairly rich diversity in the study area, it is interesting to note the absence of *Teredo furcifera* and pholadids that generally showed universal distribution along the Indian coasts. The frequency of another ubiquitous species *Lyrodus pedicellatus* is also meager in the localities explored (Rao et al., 2008).

Crabs play an important ecological role in the productivity of mangroves. Their biodiversity has recently been studied in mangroves of Goa, Maharashtra and Kerala. There are a total of 35 species under 25 genera and 10 families in the study areas. The highest diversity of crab species is in Kerala (27 spp.) followed by Goa (17 spp.) and Maharashtra (12 spp.) and the highest diversity of species is encountered in the family Grapsidae (12 spp.) followed by Portunidae (8 spp.) and Ocypodidae (6 spp.) (Dev Roy and Nandi, 2008). Crabs exhibit significant biomass in pre-monsoon and post-monsoon months in Nalallam and Kadalundi of North Kerala (Sasikumar, 2008). The density of the crab species *Neosarmatium smithi* and *Parasesarma plicatum* increases with mangrove vegetation (Shanij et al., 2008). The predatory effect of *Neosarmatium smithi* has been experimentally studied on *Avicennia officinalis* seedlings. After introducing the crabs into an enclosure set up in the natural habitat the crabs caused more than 50% mortality of seedlings after predation. In the natural environment predation controls the density of the mangrove species (Praveen et al., 2008).

Species belonging to families Portunidae (8 spp.) and Ocypodidae (6 spp.) (Dev Roy and Nandi, 2008) of crabs exhibit significant biomass in pre-monsoon and post-monsoon months in Nalallam and Kadalundi of North Kerala (Sasikumar, 2008). The density of the crab species *Neosarmatium smithi* and *Parasesarma plicatum* increases with mangrove vegetation (Shanij et al., 2008). The predatory effect of *Neosarmatium smithi* has been experimentally studied on *Avicennia officinalis* seedlings. After introducing the crabs into an enclosure set up in the natural habitat the crabs caused more than 50% mortality of seedlings after predation. In the natural environment predation controls the density of the mangrove species (Praveen et al., 2008).

1.7.3 Overall status of biodiversity in India

The floristic as well as faunal diversity of mangroves is under threat to varying degrees. In terms of floristic diversity, 13 species have been associated with lower risk and 26 are threatened. Of the 26 threatened species, 11 belong to the IUCN category (1991 version) of 'endangered' and 15 are 'vulnerable' (Table 3). The 11 endangered species need priority intensive care and immediate attention for their protection and propagation for recovery. *Rhizophora annamalayana* Kathir. is a natural hybrid derived between *R. apiculata* and *R.mucronata* (Kathiresan, 1995, 1999). Novelty of this taxon as a new species is confirmed using DNA markers (Parani et al., 1997). Only 171 individual trees of the species, mostly located among its parental species in Pichavaram, have been recorded. This species requires utmost care for immediate conservation. Xylocarpus species are becoming rare in the Sundarbans due to past over-exploitation (Naskar and Mandal, 1999). *Brownlowia tersa*, reportedly growing abundant near to large creeks of the Middle Andamans and Dhanikhari creek some 80 years ago, is now rarely observed there (Hajra et al., 1999).

Threats are not limited to plant species alone but in varying degrees to animal species also. In the Sundarbans, four reptile, three bird and five mammalian species are extinct and 10 reptile, three bird and two mammalian species are at threat (Table 7-9; Chaudhuri and Choudhury, l994). In Gujarat, three bird and two turtle species are at threat (Table 10; Wesley Sunderraj and Serebiah, l998). Of the 52 species of marine fish assessed, nine are vulnerable and two are endangered (Table 11); of the 41 invertebrates assessed, four species are endangered, four species are vulnerable and one species is critically endangered (Rao et al., l998 ;).

Table7. Threatened and extinct reptile species in the Sundarbans

Name of species	Family
Crocodylus porosus	Crocodilidae
Varanus bengalensis	Varanidae
V. salvator	Varanidae
V. flavescens	Varanidae
*Chelonia mydas**	Chelonidae
*Eretmochelys imbricata**	Chelonidae
Lepidochelys olivacea	Chelonidae
*Caretta caretta**	Chelonidae
*Dermochelys coriacea**	Chelonidae
Lissemys punctata	Trionychidae
Trionyx gangeticus	Trionychidae
T. hurum	Trionychidae
Batagur baska	Emydidae
Python molurus	Boidae

(Source: Chaudhuri and Choudhury, l994. * Extinct species)

Table 8. Threatened and extinct bird species in the Sundarbans

Name of species	**Family**
Pelecanus philippensis	Pelecanidae
Theskiornis melanocephalus	Threskiornithidae
*Leptoptilos javanicus**	*Ardeidae*
Ardea goliath	Ardeidae
*Sarkiodornis melanotus**	Anatidae
*Cairina scutulata**	Anatidae

(Source: Chaudhuri and Choudhury, l994. * Extinct species)

Table 9. Threatened and extinct mammal species in the Sundarbans

Name of species	Family
Panthera tigris	Felidae
*Muntiacus muntjac**	Felidae
*Bubalis bubalis**	Felidae
*Rhinoceros sondaicus**	Felidae
*Cervus deruchea**	Cervidae
*Axis porcinus**	Cervidae
Platanista gangetica	Platinistidae

(Source: Chaudhuri and Choudhury, l994. *Extinct species)

Table 10. Threatened species of animals in mangroves of Gujarat

Name of species	Family
Platalea leucorodia	Threskiornithidae
Pelecanus philippensis crispus	Pelecanidae
Pelecanus philippensis	Pelecanidae
Chelonia mydas	Chelonidae
Lepidochelys olivacea	Chelonidaezz

(Source: Wesley Sunderraj and Serebiah, l998)

Table 11. Threatened species of marine fish in mangrove ecosystems of India

Name of species	Family
*Boleophthalmus dussumieri***	Gobiidae
*Scartelaos viridis***	Gobiidae
Arius subrostratus	Ariidae
Psammaperca waigiensis	Centropomidae
Elopes machnata	Elopidae
Boleophthalmus boddarti	Gobiidae
Periophathalmus koelreuteri	Gobiidae
Leiognathus splendens	Leiognathidae
Secutor ruconius	Leiognathidae
Muraenichthys schultzei	Muraenidae
Desyatis uarnak	Trygonidae

1.8.1 Overall status of biodiversity in Gujarat

Gujarat state has longest coastline (1,650 km i.e. 21% of the total coastline of India) among all the maritime states of the country, which makes it strategically serving as natural gateway to India. The Gujarat coast extends from Western Ghats in Valsad to Kori creek on the coast of Kachchh in north. The area of continental shelf of the state is 1,65,000 sq. km. The Gulf of Kachchh and the Gulf of Khambhat are the two Gulfs in Gujarat out of the three Gulfs in the country. Extent of the inter-tidal and high tidal mudflats in the Gulf of Kachchh, the Gulf of Khambhat, the Bhal region and the Rann of Kachchh is exceptionally large. Mudflats, mangroves, marsh vegetation, coral reefs and saltpans cover a major part of the coastal wetland. Geo-morphological and climatic variation is very high on the Gujarat Coast. Rainfall varies from an average high of 2500 mm in the south to only 300 mm in Kachchh. Tidal amplitude is also very high which sometimes exceeds 10m in the Gulf of Khambhat and varies between 3m to 8m in the Gulf of Kachchh.

The state of Gujarat contains the second largest area of mangroves (1,103 km²) in India (total mangrove area: 4,628 km²). The state's mangrove cover has shown an increasing trend from 1987 to 2013 (Forest Survey of India, 2013). This cover is unevenly distributed across 13 coastal districts forming four mangrove regions: Kachchh (Kori creek), Gulf of Kachchh, Saurashtra and South Gujarat (Table:12). The species diversity of mangroves in Gujarat is relatively low. A total

of 15 mangrove species have been recorded from the state (Pandey and Pandey, 2009). However, a survey of the diversity and regeneration of mangroves in South Gujarat in 2009 by GEER (Gujarat Ecological Education and Research) Foundation found a remarkable floristic diversity and rich growth of mangroves in this area. The study identified a number of new mangrove areas, as well as potential mangrove areas in the southern districts of Navsari and Valsad.

Gujarat, with the second largest mangrove cover (1103 km2) in the country, represents about 83.15% of the total mangrove cover on the west coast of India (FSI, 2013). The state has registered increase in its mangrove cover as compared to the assessment periods of 2007 and 2009. The diversity and distribution of mangrove forests in Gujarat have been studied by many (Untawale, 1980; Singh, 1994; GEC, 1996; GUIDE, 2001; GEER, 2004; Bhatt and Shah, 2008; Pandey and Pandey, 2009). Despite the large mangrove cover, the diversity of mangrove species is found low in the state. This paper deals with the distribution and diversity of mangroves in Gujarat.

Table 12 Distribution of mangroves in Gujarat

Mangrove region	Districts	Mangrove area (km²)	Proportion (%)
Kachchh	Kachchh	789	71.5
Gulf of Kachchh	Jamnagar and Rajkot districts and areas under Marine National Park and Sanctuary	171	15.50
Saurashtra	Amreli, Junagadh,porbandar	4	0.40
South Gujarat	Bhavnagar, Ahmedabad, Anand, Vadodara, Bharuch and Surat, Navsari and Valsad	139	12.60
Total		**1,103**	**100**

Source: Forest Survey of India (2013).

A. Kachchh

The mangrove forests of Kachchh are predominantly concentrated in Kori creek, the northernmost mangrove forests of the country. These forests are represented by a single species, *Avicennia marina* (Forsk.) Vierh. However, plantations of *Ceriops tagal* (Perr.) Robinson, *Rhizophora mucronata* Lamk. and *Aegiceras corniculatum* (L.) Blanco have been raised in the southern portions by Gujarat Forest Department. The average width of intertidal zone in this area is the largest among the four mangrove areas of Gujarat (Table 13). Apart from the mangrove species, *Salicornia brachiata* Roxb. and species of Suaeda are reported from this area. The average number of natural recruits of mangrove species per hectare was found 8641, 8092.5 and 2970.8 in dense, moderately dense and sparse mangrove forests respectively.

Table 13: Intertidal zone in the four mangrove regions

Region	Average length (m)
Kachchh	9300.00
Gulf of Kachchh	4705.36
Gulf of Khambhat	7135.59
South Gujarat	1086.04

Source: Mangrove Cover and Floristic Diversity: R. Pandey and C. N. Pandey 2011

B. Gulf of Kachchh

The mangroves in Gulf of Kachchh have been reported from coastal areas as well as 20 islands (out of the 42 islands). These forests are mostly sparse represented by *Avicennia marina, Aegiceras corniculatum, Rhizophora mucronata* and *Ceriops tagal.* Among them Avicennia is the dominant species. There are 283 species of mangrove associates in the mangrove habitats of the Gulf of Kachchh (GEER, 2004). The average number of natural recruits of mangrove species per hectare was found 15561.9, 9192.6 and 2746 in dense, moderately dense and sparse mangrove forests respectively. The intertidal region is relatively smaller compared to Kachchh. Further, most of the mangrove forests fall under the area of Marine National Park and Sanctuary.

C. Gulf of Khambhat

The natural mangrove forests of Gulf of Khambhat are represented by *Avicennia marina, Avicennia officinalis* L*. Acanthus ilicifolius* L*. and Sonneratia apetala* Buch.-Ham*.* However, *Rhizophora mucronata* and *Ceriops tagal* have been introduced in plantation sites. A number of rivers such as Dhadhar, Tapti, Kim, Mahi and Narmada form several small estuaries in this area. These estuarine areas support dense mangrove forests. *Avicennia alba, A. officinalis, Acanthus ilicifolius* and *Sonneratia apetala* have been reported from these estuarine forests. *Ceriops tagal, Bruguiera cylindrica, B. gymnorhiza* and *R.mucronata* are introduced in mangrove plantations. Several mangrove associates like *Aeluropus lagopoides, Bothriochloa intermedia*, *Caesalpinia crista, Calotropis procera, Carissa congesta, Chloris barbata, Clerodendrum inerme, Cocculus hirsutus, Coldenia procumbens, Cressa cretica, Cyperus rotundus, Ipomoea pes-caprae, Lantana aculeata, Lawsonia inermis, Maytenus senegalensis, Paspalidium geminatum, Portresia coarctata, Prosopis chilensis, Salicornia brachiata, Salvadora persica, Schoenoplectus articulates*, *Sesbania cannabina, Sesuvium portulacastrum, Suaeda monoica, Suaeda nudiflora, Thespesia populnea, Urginea indica, Vernonia anthelmintica, Vernonia cinerea* and *Xanthium strumarium* have also been reported from these areas. The intertidal zone of this area is smaller than that of Kachchh but larger than that of Gulf of Kachchh. The average number of natural recruits of mangrove species per hectare was found 10157.7, 6650 and 4164.3 in dense, moderately dense and sparse mangrove forests respectively.

D. South Gujarat

The extent of mangrove cover decreases significantly as one moves from north to south, Kachchh to Valsad. The conspicuously low extent of mangrove cover in South Gujarat, in fact, hosts the best mangrove forests in terms of diversity. The area harbours 14 species of mangroves, viz.: *Avicennia marina, Avicennia officinalis, Avicennia alba, Ceriops tagal, Ceriops decandra, Aegiceras corniculatum, Excoecaria agallocha, Sonneratia apetala, Rhizophora mucronata, Bruguiera cylindrica, Acanthus ilicifolius, Bruguiera gymnorhiza, Kandelia candel* and *Lumnitzera racemosa.* Of these 14 species, *Kandelia candel* was reported for the first time in Gujarat from Par estuary. *Excoecaria agallocha* was reported

only from Umargam taluka of Valsad district. Similarly, *Lumnitzera racemosa* was reported only from near Kalai river in Valsad district. The two species of Bruguiera have been reported from Ambika and Purna estuaries of Valsad and Navsari districts. *Sonneratia apetala, Acanthus illicifolius* and *Avicennia officinalis* abundantly grow in Purna estuary. In case of *Bruguiera gymnorhiza*, only a few plants were reported. However, *Bruguiera cylindrical* was found more frequently in Purna, Ambika and Waroli estuaries. *Ceriops tagal, Rhizophora mucronata* and *Aegiceras corniculatum* were reported from areas near Waroli river of Valsad district. Apart from the true mangroves, 109 mangrove associates like *Aeluropus lagopoides, Cadaba fruticosa, Caesalpinia crista, Casuarina equisetifolia, Clerodendrum inerme, Cressa cretica, Derris scandens, Derris trifoliata, Grewia abutifolia, Ipomoea fistulosa, Ipomoea pes-caprae, Kyllinga bulbosa, Lantana aculeata, Manilkara hexandra, Pentatropis capensis, Phoenix sylvestris, Portresia coarctata, Sesuvium portulacastrum, Suaeda monoica* and *Thespesia populnea* were reported from these areas. The intertidal zone of this area is the smallest of the four mangrove areas (Table 13).

Kachchh which holds the largest mangrove cover in the state is largely represented by only one mangrove species, *Avicennia marina*. Gulf of Kachchh and Gulf of Khambhat respectively representing 15.2% and 10.1% of Gujarat's mangrove cover have four mangrove species each. However, South Gujarat with only 0.6% of mangrove cover hosts 14 mangrove species. Hence, the extent of mangrove cover does not hold any positive correlation with species diversity in Gujarat. Interestingly, the direct dependence of human population on mangroves is also maximum in South Gujarat. Dependence of humans on mangroves appears to be influenced by the width of the intertidal zone (Pandey and Pandey, 2009). Areas where the intertidal zone is smaller, the human settlements are closer to mangroves and, therefore, the anthropogenic pressure on mangroves is more. In South Gujarat, the human settlements are generally closer to the mangrove areas. This results in reduced mangrove cover. Better climatic conditions in South Gujarat may possibly be facilitating more species diversity.

1.9 Mangrove Plantation techniques used in Gujarat

The Plantation techniques applied in the mangrove afforestation programme are area dependent. Different models of mangrove plantations are direct seed

sowing, propagule plantation and plantation and plantations using nursery raised seedlings. Since the tidal amplitude is high along the entire coastline, plantations are carried out on raised beds. About 20 raised beds (1mX1mX0.3m) are prepared in one hectare area which are then planted by about 80/100 seeds of Avicennia. Propagules of ceriops and Rhizophora are also planted directly on raised beds such propagules are also sown directly on the ground depending upon local conditions. Most of the nurseries have been created near the plantation sites to reduce the plantation cost as well as to help the seeds or propagules acclimatize to the environmental conditions where they would be planted. The sparse mangrove forests are being planted under the model of enrichment plantations under which open areas within existing mangrove forests are filled up with new plantations. Due to high tidal amplitude, human interventions for increasing inundations are generally not required because the tidal mudflats need human interventions to make them suitable for mangrove plantations.

Table 14 List of mangrove species reported from Gujarat

No.	Scientific name	Type	Growth form
1.	*Acanthus ilicifolius* L.	Mangrove	Tree
2	A*egiceras corniculatum* (L.) Blanco	Mangrove	Tree
3	*Avicennia alba* Bl.	Mangrove	Tree
4	*Avicennia marina* (Forsk.) Vierh	Mangrove	Tree
5	*Avicennia officinalis* L.	Mangrove	Tree
6	*Bruguiera cylindrica* (L.) Bl.	Mangrove	Tree
7	*Bruguiera gymnorrhiza*	Mangrove	Tree
8	*Ceriops tagal* (Perr.) Robinson	Mangrove	Tree
9	*Excoecaria agallocha* L.	Mangrove	Tree
10	*Lumnitzera racemosa* Willd.	Mangrove	Shrub
11	*Rhizophora mucronata* Lamk.	Mangrove	Shrub

12	*Sonneratia apetala* Buch.-Ham.	Mangrove	Tree
13	*Xylocarpus* sp	Mangrove (Planted)	Shrub
14	*Ceriops decandra*	Mangrove	Tree

(Source: Pandey, C.N., Pandey, R. and Khokhariya, B., 2012)

Table 15: Plantation models and species planted by the Gujarat Forest Department

Model No	Model	Details	Density of propagules
1	Mangrove Plantation-Poly pot	Open seashore area	2500 Poly pots per hectare
2	Enrichment Plantation (EP)	100 raised beds (1m x 1m x 30cm) per ha. Areas generally have existing vegetation such as with *Avicennia* spp., *Ceriops tagal*, *Suaeda* spp. and *Salicornia* spp.	80-100 seeds of Avicennia per bed or 50-65 hypocotyls of *Ceriops tagal* or *Rhizophora mucronata* per bed
3	Direct Seed Sowing (DSS)	20 raised beds (1m x 1mx 30 cm) per ha. at blank spaces devoid of mangroves, but with *Suaeda* spp., at intertidal zone.	Seeds of *Avicennia* at a rate of 80-100 per bed
4	Fish bone channel method	Being tried where inundation is poor	Tried during 2006-07 in 25 ha.

(GEER,2009)

Since 2001-02, most of the mangrove plantations in Gujarat have been raised directly by sowing seeds or planting propagules (depending upon the species) on raised mounds. The planting techniques involving raised beds have been found to be quite cost effective. Three variations of this planting technique (model 1, 2 and 3) have been used in Gujarat. Model 4 – the Fish Bone Channel method was tried during 2006-07 in areas where inundation was low. This method is relatively

costlier but helps in the drainage of water and, therefore, helps in raising mangrove plantations even where the water is not able to reach naturally on a regular basis.

The overall scenario clearly depicts that a lot of work has been done in other parts of India with reference to mangroves. In case of Gujarat if we notice there is lot of work carried out in Gulf of kachchh but as we refer to the literature in Gulf of khambhat, the data bank for mangroves and its related biodiversity is very limited. Especially recently some work has been done on mangrove floral diversity but there is a great lacunae in terms of studies related to faunal diversity associated with mangroves in this region. The study has been carried out keeping this point in mind and to bring out richness of faunal associates of mangrove ecosystem in the Gulf of khambhat. The study objectives have been selected keeping this factor on fore-front and with view to provide baseline data for further concrete studies on this basis.

In case of dependency of coastal communities on mangroves in Gulf of Khambhat, it has not been highlighted in past studies. In my studies I have collected data in terms of dependency of coastal communities on faunal associates of mangroves for their livelihood.

2. OBJECTIVES OF THE STUDY

2.1 Extent and Distribution of Mangroves at the Study Area.

2.2 Study of Major Macro-Fauna Associated with Mangrove Ecosystem.

2.3 Dependency of Community on Mangrove Ecosystem.

2.4 Identify Potential Areas for Restoration of Mangroves

OBJECTIVES OF THE STUDY

The study was initiated with following objectives:

2.1 Extent and Distribution of Mangroves at the study area

Under this objective the sites were studied to get an idea of the mangrove cover. It is very important to evaluate the key ecological parameters of both structural and functional components while studying mangrove ecosystem. In order to get an idea of the ecological status, the components such as mangrove plant density, sapling/seedling density, pneumatophore density, tree height, tree girth, no. of branches, canopy cover were studied giving better picture of vegetation cover. In addition to have the idea of site conditions the soil and water samples were studied in detail during different period of the year.

2.2 Study of major macro- fauna associated with Mangrove ecosystem

The mangroves are complex and detritus-based ecosystems. Mangrove forests and associated salt flats and salt marsh support a diverse and abundant fauna. The wastes produced by mangroves (leaves, stems, flowers etc.) are rapidly degraded into small particles, known as detritus, which supports many detritus feeding fauna like amphipods, herpacticoids, copepods, molluscs, crustacean larvae, prawn and small fishes (Dam Roy, 1997). This objective was very important as there are very few macro-faunal studies done in the study region which forms a major part of gulf of Khambhat. The faunal components including molluscs, crabs, prawns and shrimps, fishes with special focus on mudskippers, reptiles, birds and mammals were studied.

2.3 Dependency of community on mangrove ecosystem.

This objective was indicative of the relationship and dependency between local communities on mangroves. The faunal catch from mangrove and its nearby area was monitored carefully and based on it a complete picture showing the dependency on mangroves is analysed.

2.4 Identify potential areas for restoration of Mangroves.

This objective was selected keeping in view the present and future need of mangrove restoration required for protection of shoreline. There are certain regions in the Gulf of Khambhat which are experiencing severe erosion. During this study an area of around 200 hectares was identified in between Denva and Gandhar for mangrove restoration in order to stabilize the shore.

3. METHODOLOGY

3.1 Gulf of Khambhat

- 3.1.1 Dhadhar River Basin
- 3.1.2 Mahi River Basin

3.2 Mangroves in Gulf of Khambhat

3.3 Study Sites

3.4 Physico-Chemical Analysis of Soil and Water

3.5 Floral and Faunal Data Collection

- 3.5.1 Mangrove Study
- 3.5.2 Mangrove Associate Study

3.6 Socio-Economic Study

METHODOLOGY

3.1 Gulf of Khambhat

The marine domain of the study region is under the profound influence of the Gulf of Khambhat, the knowledge of which is necessary to understand the ecology of the region.

Gulf of Khambhat is 70 km wide and 131 km long located between Saurashtra peninsula and the mainland Gujarat. The funnel-shaped Gulf which occupies an area of 3120 km^2 is shallow with depths varying between 5 m at the head to 40 m in the channels. Malacca Banks lie in the entrance to the Gulf with deep channels cutting through the shoals. Sands and banks in the inner part of the Gulf are subject to changes due to tidal bores and voluminous freshwater inflows through rivers during monsoon. The Gulf merges into the shallow and wide estuaries of the Mahi Sagar and Sabarmati rivers through the Khambhat Channel. The Gulf is known for its extreme tides, which vary greatly in height and run into it with amazing speed.

Apart from Sabarmati and Mahi Sagar, the other major rivers joining the eastern shore of the Gulf include Dhadhar, Narmada and Tapi all of which have wide and shallow estuaries with intricate channels in-between mud banks and shoals. The western bank of the Gulf is devoid of major rivers though several minor seasonal rivers such as Utavali Nadi, Malesari Nadi, Shetrunji River and Dhantarvadi River join the Gulf.

High tidal influence and nearly flat coastal terrain result in submergence of large areas during flood tide and lead to vast mudflats particularly along the eastern shore. Some of these areas sustain mangrove habitats.

The study location Nada and Gandhar falls under Dhadhar river estuarine region where as Kamboi site falls under Mahi estuarine region. It therefore becomes very much necessary to study these river basins in order to get the origin and flow patterns of these rivers.

3.1.1 Dhadhar river basin

Dhadhar River originates from Pavagadh Hill and meets Gulf of Khambhat. Its length is 142 km and catchment area 4201 sq.km. Two rivers Vishwamitri and Jambuva join Dhadhar at the lower reaches. Though these rivers are shrinking streams in summer, they are liable to sudden flood with impassable currents in their tortuous courses, during rainy season. The Dhadhar River joins the Gulf of Khambhat at Tankari point. There is weir downstream of Achod due to which the estuarine segment is starved of freshwater during the dry season. The 5-8 km wide mouth is full of sand banks and flats that confine the estuary to narrow and shallow criss-crossed channels which are mostly dry during low tide. The outer estuaries are marked by high salinity and high DO accompanied by high SS. On the contrary, the inner segment has low salinity and low DO, indicating some organic load in the upstream segment.

3.1.2 Mahi river basin Mahi River is one of the major west flowing inter-state river of India, draining into the Gulf of Khambhat. The basin is bounded on the North and the North-West by Aravalli hills, on the East by the ridge separating it from the Chambal Basin, on the South by the Vindhyas and on the West by the Gulf of Khambhat. The basin has a maximum width of about 250km. Mahi river originates on the Northern slope of Vindhyas at latitude 22°35' N and longitude 74^{o}58'E near the village of Sardarpur in the Dhar district of Madhya Pradesh. It has a total length of 583 km and it traverses through the states of Madhya Pradesh: 174 km, Rajasthan: 167 km and Gujarat: 242 km. The total drainage area is 15,000-17,000 sq km.

Initially the river flows Northwards through Dhar and Jhabua districts of M.P. and then turns left and passes through the Ratlam district of M.P.; then turning to North-West , it enters the Banswara district of Rajasthan and flows in the South West directions and thereafter enters the Panchmahal district of Gujarat State. Then the river continuously flows in the same direction through Kheda district of Gujarat and finally meets the Gulf of Khambhat near Kavi. Its prominent tributaries are Mahi, Panam, Jarod and Meshri. The river with high banks and deep gullies experiences fierce flood during monsoon making the

banks highly unstable and causing erosion on a large scale. The dams Vanakbori and Kadana in Gujarat are constructed on the river to impound land runoff. The intensity of irrigation is however, poor in the basin; being only 10% of the area.

The river becomes estuarine at Mahammadpura, 50 km upstream where a rocky sill prevents the intrusion of salinity in the upstream. The estuarine mouth is a wide stretch of shallow tidal flats and shoals. During low tide the estuary goes nearly dry except for a few narrow and shallow meandering channels which retain some water.

3.2 Mangroves in Gulf of Khambhat

Avicennia with stunted growth is sparsely distributed along the coast near the Mahi, Dhadhar, Narmada, Kim and Sena rivers. A small patch of mangroves is also observed on the Alia Bet. The dominant areas under mangroves are seen near Bhavnagar, Devla (Bharuch), Mangrol, Pardi, Jankhsi and Dandi in Surat. Ashwini Kumar's (1996) study also shows that the non-Bhal areas of the Gulf of Khambhat mangroves have shown a sharp decline between 1975 -1983.

The study region offers different marine habitats like rocky/ sandy/ muddy intertidal and mangrove for a variety of resident and migratory birds. The birds use these habitats as their active feeding ground especially during low tide. Hectic activities of Gulls, Herons, Terns, Egrets, Kingfisher, Plovers, Avocets, Curlews, Sand pipers, Spoonbills and Bitterns are frequently seen in these coastal habitats. A large number of migratory bird species pass through Nada and a small population of them in the form of juveniles and non-breeding adults take shelter in coastal areas during summer. The intertidal areas also support significant populations of migratory shorebirds, gulls and terns together with large feeding flocks of Pheonicopterus rubber and Phoeniconaias minor. The most abundant shorebirds are *Recurvirostra avosetta*, *Charadrius mongolus*, *C. Leschenaultia*, species of Tringa and Calidris and *Limicola falcinellus*. Population of crab plovers *Dromas ardeola* visits in the winter in the area. Large roosting flocks of *Grus grus* and *Anthropoides virgo* are often sighted.

Fig. 3.1. Dadhar River Basin

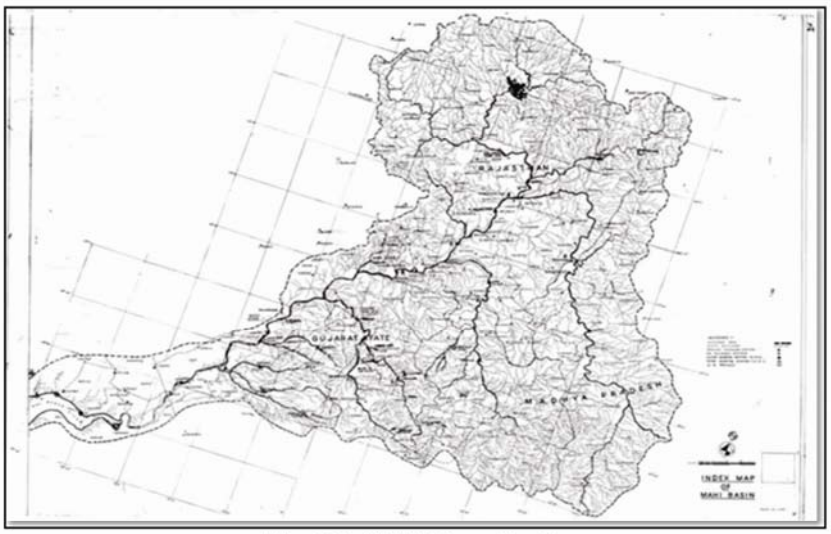


Fig. 3.2. Mahi River Basin

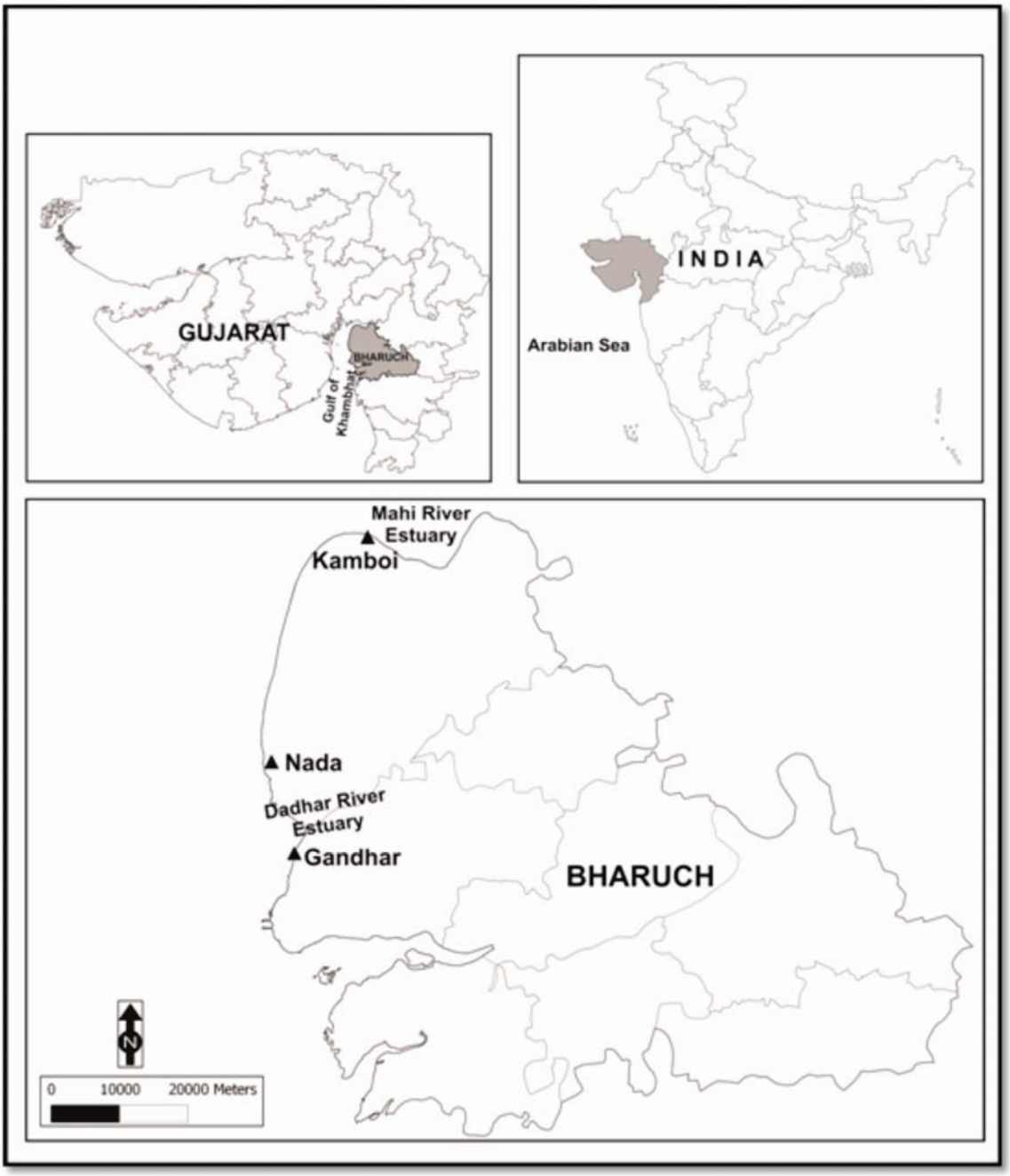


Fig. 3.3. Location of Study Sites

3.3 Study Sites

A) Nada

Location: 21°54’38.60”N & 72°34’43.30”E

In case of Nada it is the coastal village located right on the coast in Jambusar taluka of Bharuch district. Salinity ingress in its land and water resources is quite high. Nada has around 500 households and more than 4500 population. Nada is located on the seacoast with about 1000 ha. coastal area and is about 32 kms away from Jambusar. River Dhadhar flows to the south of the village and merges into the sea. Saltpans and ONGC oil wells and drilling stations are located close to the village. Nada had thick mangroves forest in the past and still has good patches of mangroves for animal husbandry and fishery. About 13% of the household are engaged in fisheries and about 65% households have livestock, with 94% of them depending on mangroves for fodder.

The coast of Nada is muddy composed mostly of clay of recent alluvial deposits. The intertidal expanse varies approximately from 0.8 km to 2.5 km. The open mudflats approximately 800-1000 m width along the coast was totally devoid of natural mangrove vegetation. These also include the mudflats immediate to the north and south of the Nada. *Avicennia marina* in approximately 8.5 km^2 exists along the openshore. Lately large extent of tidal zone particularly supralittoral areas in this region, had been reclaimed, mainly for industrial development and agricultural (salt pans) activities. However, intertidal regions along the rivulets and region along the Nada harbours dense growth of *A. marina*. Obligate halophyte such as *Sesuvium portulacastrum* and *Sueda maritime* are commonly noticed along with *A. marina* in the region just above the mean high tide level.

S. maritima is dominant at the supralittoral zone. *Salvadora persica* appears commonly beyond the supralittoral zone. The mangrove regions are exploited for shell fishes and mud skippers on a large scale by local fishermen.

Nada caters natural mangrove area which exists over 60 years and so has been selected as one of the study site in order to study the mangrove ecology under natural conditions.

B) Gandhar

Location: 21°54’02.9”N & 72°37’35.0”E.

In case of Gandhar it is a coastal village located on the coast in Vagra taluka of Bharuch district. Large oil field of ONGC is located, whereby there are several oil wells around the entire village. Saltpans are also located near the coast and the majority of the population depends a lot on collection of fishery and especially mudskippers to have their earnings. Also regularly the mangrove leaves and branches are collected by womens to feed their livestock. Also they prepare vegetable of *Avicennia marina* seeds and mangrove associate *Sueda maritime*.

Mangrove restoration has been carried out at Gandhar site. It is a young mangrove site with an age of 8-10 years spread over an area of 2.5 sq km. It has been selected as one of the study sites in order to study the mangrove ecology of restored site and also to get a comparative account with natural mangrove site and sparse mangrove site.

C) Kamboi

Location: 22°12’54.0” N & 72°36’36.9” E

In case of Kamboi, the village is located near the coast of Mahi estuary. It is very much famous for Stambeshwar Mahadev Temple of Lord Shiva. It is one of the famous tourist places. There are very sparse mangroves in this region. It has been selected as study site in order to derive a comparative account of this site in terms of composition of faunal and floral diversity with natural mangrove site (Nada) and restored mangrove site (Gandhar).

Fig. 3.4. Nada Site

Fig. 3.5. Gandhar Site

Fig. 3.6. Kamboi

3.4. Physico-chemical analysis of soil and water

At each site, soil samples were collected from 3 different places, randomly from the transect location from a depth of 30-50 cm using a PVC pipe. Sampling was done during low tide. The soil samples were put into labeled, airtight plastic bags and taken to the laboratory to analyze basic physico-chemical properties. Similarly water samples were collected with due care from study site for analysis.

A sampling programme consisting of seasonal physicochemical parameters of water and soil was undertaken. The Physico-chemical characteristics of water were done according to the Standard methods (APHA, 1998). The Physico-chemical characteristics of soil were done according to the standard methods Organic matter (Wlakley and Black, 1934), Available of phosphorus (Olsen et al., 1954), Available Nitrogen and Potassium (Sankaram, 1996). Sodium was recorded by the method of Aitken (1984). Some moles like Ca and Mg were determined by according to the International pipette method describe by Piper (1942) and also Hydrometer method (Bouyoucos, 1962). Ca and Mg are important in the measurement of water hardness. The calcium and magnesium hardness is the concentration of calcium and magnesium ions expressed as equivalent of calcium carbonate. The molar mass of $CaCO_3$, Ca^{2+} and Mg^{2+} are respectively 100,1 g/mol, 40,1 g/mol and 24,3 g/mol. The ratio of Ca and Mg is expressed in moles or molar mass. The temperatures of the water soil were measured at the station itself using digital thermometer. Turbidity and Ph were measured using turbidity meter of Eutech make model no TN 100. All the determinations were replicated thrice and the mean values were used to obtain representation of samples.

3.5. Floral and Faunal Data collection

3.5.1 Mangrove study

The study site was selected using GPS. In order to mark a starting point. Five transect line were drawn perpendicular to the shoreline. The plot dimension was kept 10mx10m ($100m^2$).In each plot, counts were made for tree counts; and in that four (1mx1m) sub-plot counts are made for saplings/seedlings. Second

replicate 100 m^2 quadrate was made on the same transect line at each site at every 100 m distance.Counting the numbers of two class of maturity namely, trees and saplings within the plots were done.

A. Tree

Trees of more than 1.5 m height were considered for measurement of numbers and Girth at a breast height of 1.3 m. Tree height was recorded using an extendable measuring tape cum pole. GBH (Girth Breast Height at 1.3 m height) was measured for each counted tree in particular sample plot.

B. Sapling

Plants with height <1.3 m were counted for Saplings number.

C. Undergrowth Species:

Salinity plays a key role in the growth of the undergrowth species. Therefore, the values of salinity are found influencing the undergrowth vegetation as positively or negatively as well as high or poor diversity. In case of study site it was found that there are many trees with stunted growth and so heights along with girth measurement for such trees was kept in mind and were placed under undergrowth species category.

3.5.2 Study of Mangrove associates

Quadrates of 1x1 meter size were followed. The first sampling point (quadrate) was marked on the Google map of the location and the geo-coordinates were taken to the field to start the sampling. All the subsequent quadrates were taken at the distance 50 meters from the previous in the intertidal zone.

A. Mollusc Study

The molluscs constitute a natural resource of sizable magnitude in many parts of the world. They are an age‐old group represented among the early fossils, a group of great diversity in size, distribution, habitat and utility. The range

of their distribution is as extensive in space as in time for it covers terrestrial, marine and freshwater habitats. They include members from the tiny estuarine gastropod *Bithynia* and small garden snails to the Giant clam *Tridacna* or the Giant squid *Architeuthis*.

(i) Methods of Collection

For the quantitative analysis of the mangrove molluscs, hand picking in quadrates of known area was used. The bivalves were generally collected by digging.

(ii) Identification of Gastropods

The shell characters such as shape, spire length and shape, mouth opening, opercular shape, umbilicus shape and size, colour and ornamentation of the shell were mainly considered for the identification of gastropods apart from the internal characters of which the important one is radula (Apte, 1998).

(iii) Identification of Bivalves

The bivalves were identified mainly based on the shell morphology (Apte, 1998). The shell comprises of two valves. If the valves are similar, the shell is said to be equivalve (clams, mussels); if dissimilar, ineqivalve (scallops). The outer surface is usually covered with a periostracum. The outer surface may be striated or ribbed. The two valves are held together by an elastic ligament, which leaves a scar on the hinge. The hinge may in addition have interlocking ridges called the dentition. The individual ridges (or teeth) may be similar. The two valves are attracted to the soft body by adductor muscles that produce scar on the interior surface. If each valves has a single such scar, the shell is said to be monomyarian. If there are two scars on each valve, the shell is dimyarian. At hinge, the shell has a projection called the umbo; this always points towards the anterior end of the animal (i.e., the end where the mouth is). Thus we can distinguish an anterior adductor scar and a posterior adductor scar in dimyarian shells. A slender scar often touches these two that marks the attachment of the mantle folded into a posterior siphon for conveying water away from the body when the animal is feeding by converted ciliary currents such shells show a pallial sinus in the pallial line.

B. Brachyuran crab study

Brachyuran crabs encountered during study period were collected by hand using a trowel and plastic beaker; burrowing intertidal crabs were collected by digging the substratum. The entire specimens were brought to the lab and preserved in 10% formalin for further study and deposition in the Department of Zoology Museum, The M. S. University of Baroda. The specimens were identified to the species level using different identification keys and monograms (Chhapgar, 1957; Sethuramalingam and Ajmal Khan, 1991; Jeyabaskaran, et al., 2000). For further confirmation of species, all the specimens were examined and compared with the photographs and identification information available on Marine Species Identification Portal website (www. speciesidentification.org) and NIO marine fauna information website (Jeyabaskaran et al., 2002). The classification of brachyuran crabs was adopted from WORMS website (www. marinespecies.org).

C. Prawns and Shrimps study

Prawns and shrimps were collected using different types of nets. After collection, the specimens were preserved in 5% of formaldehyde solution and then the specimens were identified using the standard keys (Holthuis, 1980). In general, the penaeid prawns and non‐penaeid prawns were identified using morphological characters. For *e.g.*, the pleurae are arranged regularly in the penaeid prawns and in the non‐penaeid prawns the pleurae of the second abdominal segment are overlapping those of first and third segments. The third pereopods are not chelated in the non‐penaeid prawns but chelated in the penaeid prawns. Also, abdominal segment has a sharp bend in the non‐penaeid prawns but not in the penaeid prawns.

In penaeid prawns, the distinguished identical characters are the rostral structure, rostral teeth, antenna colouration and body colour with strips. In majority of the penaeid prawns, rostral teeth are important characters to distinguish the different species and also within the groups. For *e.g.*, in *Penaeus* species the rostral teeth are present both in the upper and lower portions of the rostrum, but in case of *Metapenaeus* species the rostral teeth are present only in the dorsal side of the rostrum, but not in the ventral side.

D. Mudskipper study

In order to get the mudskipper density the quadrat were laid in the study area. The mudskipper burrows were counted in each quadrat, as well as mudskippers were collected for identification up to species level. The preservation was carried out using formalin of 10% strength. (Day, 1889)

E. Fish Study

The fish catch done by the locals in the mangroves using net and also the fish captured by small boats in and around area of 500 meters of study sites were considered. The preservation was carried out using formalin of 10% strength. (Day, 1889).

F. Avian Fauna

Birds were observed using binoculars and identified using standard field guides (Ali 1996; Grimmett et al. 1998). Aquatic birds of the Mahi and Dhadhar Estuary as well as the birds found in the mangrove areas were recorded. In case of complications in identification, especially of gulls and terns, photographs were taken when possible and later identified.

3.6 Socio-Economic Study

In case of socio-economic study, the catch of the mudskipper was recorded for three years on daily basis at all the three sites in order to get an idea of the catch. The mudskipper catch methodology was studied in detail in the region.

Fig. 3.7. Quadrate Study for Crab Density

Fig. 3.8. Specimen Preservation for Identification

Fig. 3.9. Mangrove Height Study

4. RESULT & DISCUSSION

4.1 Extent and Distribution of Mangroves at Study Sites

- 4.1.1 Mangrove and its floral associates.
- 4.1.2 Vegetation structure.
- 4.1.3 Physico-chemical analysis.

4.2 Study of major macro fauna associated with mangrove ecosystem

- 4.2.1 Molluscs
- 4.2.2 Brachyuran crabs
- 4.2.3 Prawns and Shrimps
- 4.2.4 Fishes
- 4.2.5 Mudskippers
- 4.2.6 Reptiles
- 4.2.7 Avian fauna found at study sites
- 4.2.8 Mammals

4.3 Dependency of Community on Mangrove Ecosystem

- 4.3.1 Mudskipper catch
- 4.3.2 Prawn and Shrimp catch

4.4 Identify potential areas for restoration of Mangroves

- 4.4.1 Species selection for restoration
- 4.4.2 Habitat selection

4.1 Extent and Distribution of Mangroves at Study Sites

This objective aims at providing a comprehensive assessment of biological mapping of mangrove ecosystems at the study sites for comparative analysis. The objective of the assessment is to understand the a) mangrove and associate species found at study site and their distribution, b) Vegetation structure and c) the ecological process of the mangroves. This study will help to measure indirectly the nutrient availability and the biotic interactions. It will provide the comparative analysis in growth of the natural and restored mangrove sites.

4.1.1 Mangrove and its floral associates

(1) *Arthrocnemum indicum (Willd.) Moq.*

Vernacular name : Pavalappundu/ Kollian (Tamil Nadu), Machur (Gujarat).

Habitat : Growing in saline mud flats and degraded mangrove areas.

Stem : Jointed, outer bark is black.

Leaves : More or less lanceolate in shape with crenulated margins.

Flower : Fine, present in scales of one-like spikes white and yellow cat-kin like structures.

Fruit : A round, green, hard capsular fruit contains many hairy seeds and produces a toxic latex.

Occurrence : Tamil Nadu and Gujarat.

Status : Vulnerable.

Note : The species could be a pioneer in the marginal habitat between inner mangrove and coastal forest.

(2) *Salicornia brachiata Roxb.*

Vernacular name : Batula (Orissa), Kattu umari (Tamil Nadu), Lano(Gujarat)

Habitat : Fleshy jointed branching shrubs or herbs; joints of the branches longer than those of *Arthrocnemum*

Leaves : Absent.

Flower : Very small in cylindrical cone like spikes.

Occurrence: Tamil Nadu,Gujarat, West Bengal, Orissa and Andhra Pradesh.

Status: Lower risk.

Note: The species could be commonly found in the tidal salt marshes of the east and west coasts. Fleshy leafless herbs with jointed stems and tiny flowers present in cavity of stem joints, growing on saline mudflats and degraded mangrove areas.

(3) *Suaeda fruiticosa (L.) Forsk. Ex Gmel.*

Vernacular name : Morad/Luno (Gujarat)

Habitat: Much branched shrub, growing up to 3m tall along salt marshes and tidal blanks.

Leaves : Variable, linear oblong, ellipsoid or obovate, obtuse at apex, narrowed at base.

Flower : Hermaphrodite, axillary in position, 1-3 nate.

Bracteole : Toothed margins.

Occurrence : Gujarat and Andhra Pradesh.

(4) *Suaeda maritime (L.) Dum.*

Common name: Common Indian salt wort.

Vernacular name: Morad (Gujarat), Giria saga (Orissa), Elakura (AP), and Umiri (TN).

Habitat: Ascending or erect annuals growing on tidal mud flats and salt marshes

Stem: Much branched with reddish streaks.

Leaves : Long linear-oblong, sickle shaped when young, base truncate, apex acute, upper leaves reduced, often purple coloured, green when drying.

Flower: Bisexual buds depressed, white in axillary cluster or elongated spikes.

Bracteole: Ovate, entire.

Fruit: Capsule like fish-stomach, length 7-9 cm, occurs in pair, reddish in maturation.

Seed: Brown, shining and horizontal.

Occurrence: Gujarat, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Karnataka, Goa and Maharashtra.

Status: Endangered.

(5) *Suaeda monoica Forsk. Ex Gmel.*

Vernacular name: Morad (Gujarat), Giria saga (Orissa), Karu umiri (Tamil Nadu).

Habitat: Small erect bushy much branched herbs growing on tidal mudflats and salt marshes.

Stem: Marked with tuberculate leaf scars.

Leaves: Alternately crowded, linear-oblong or spathulate, flat or sub terete, obtuse or rounded at tip, narrowed at base, black on drying.

Flower: Unisexual, small, greenish white, axillary, 1-3 nate in clusters leaves often terminating the branchlets.

Bracteole: Ovate, acute, entire.
Fruit: Red when dry.
Seed: Black, horizontal.
Occurrence: Gujarat, West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Goa and Maharashtra
Status: Endangered.

(6) *Suaeda nudiflora (Willd.) Moq.*

Vernacular name: Giria saga (Orissa), Elakura (Andhra Pradesh), Unt Morad (Gujarat).

Habitat: Perennial under shrub, diffusely branched, growing along salt marshes and tidal blanks.

Stem: Woody, diffusely, yellowish, often reddish in colour.

Leaves: Linear-ovate falling off early, fleshy, terete, base acute, apex sub acute, reddish black on drying.

Flower: Globose, clustered in terminal spikes, bisexual in the axils of reduced leaves.

Bracteole: Ovate, acute, pectinate.

Fruit: Reddish.

Occurrence: Gujarat, West Bengal, Orissa, and Andhra Pradesh.

Status: Endangered.

(7) *Salvadora persica L.*

Vernacular name: Miriga (Orissa)

Habitat: Shrub/small tree, growing in degraded mangrove swamps and saline blanks.

Flower: White.

Occurrence: Gujarat, West Bengal, Andhra Pradesh, Orissa and Tamil Nadu.

Status: Not evaluated.

(8) *Sesuvium portulacastrum*

It is commonly known as sea pursulane. In India, it grows along coastal sides of eastern and western regions at inland or seashore. Prostrate succulent glabrous perennial herb, rooting at nodes of thick and smooth stems.

Habitat: In mangrove swamps and on sandy dunes and beaches.

Leaves: opposite, simple, blade glabrous, succulent

Seeds: very small, about 1.2-1.5 mm long black smooth and lustrous on germination

Occurence: Gujarat, Maharastra, Karnataka, Tamilnadu, Andhra Pradesh, Orissa

(9). Avicennia marina

Vernacular name: Gray mangrove, Tavarian, Tivar

Leaves: simple, opposite, decussate, estipulate

Flowers: bisexual, yellow, arranged in dense capitates units

Fruit: like capsule, greenish, more or less rounded. Fruit are dispersed from the parent tree by tidal water movement. Pneumatophores supply oxygen to the root system.

Table 16: List of species of mangrove and its associates found at the study sites

No	Family	Species	Nada	Gandhar	Kamboi
1	Chenopodiaceae	*Arthrocnemum indicum*	✓	✓	
2		*Salicornia brachiata*	✓		
3		*Suaeda fruiticosa*	✓		
4		*Suaeda maritime*	✓	✓	✓
5		*Suaeda monoica*	✓	✓	
6		*Suaeda nudiflora.*	✓		✓
7	Salvadoraceae	*Salvadora persica*	✓	✓	✓
8	Aizoaceae	*Sesuvium portulacastrum*	✓	✓	✓
9	Avicenniaceae	*Avicennia marina*	✓	✓	✓

In case of true mangrove only one species was found at all the three study sites, i.e Avicennia marina. In case of total floral composition found at the study sites, there are 9 species found belonging to 4 families. The maximum species diversity was found at nada with all 9 species present from 4 families. In case of Gandhar 6 species were recorded from 4 families and least was observed at Kamboi with only 5 species recorded from 4 families. As per the information gathered from the locals, the suaeda species leaves are collected and used as vegetable. In total 8 mangroves associate halophytic species were recorded during the study. (Figure: 4.1)

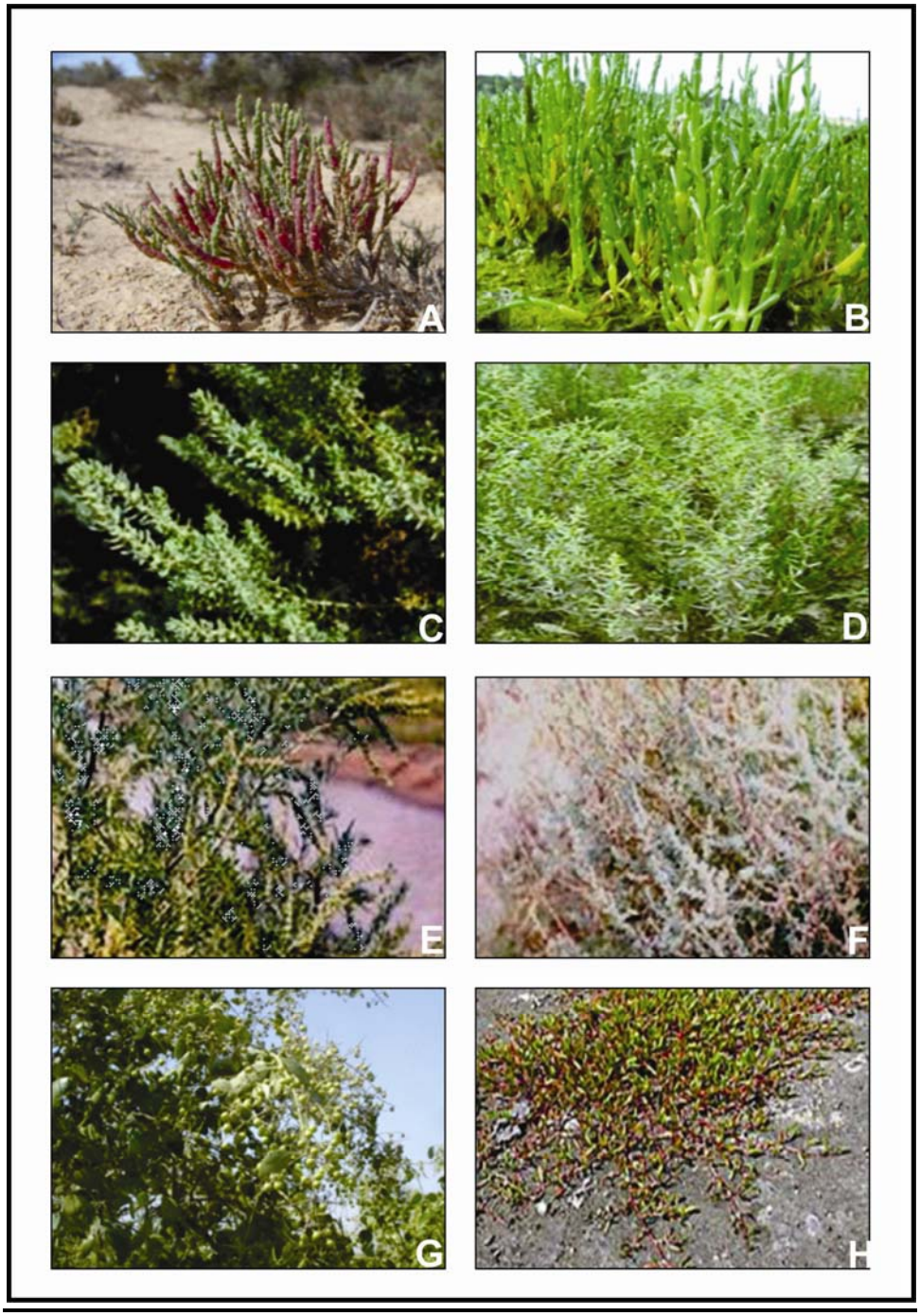


Figure 4.1 List of floral diversity recorded at study sites : **A**- *Arthrocnemum indicum,* **B**- *Salicornia brachiata***, C**- *Suaeda maritime,* **D**- *Suaeda fruiticosa,* **E**- *Suaeda monoica*, **F**- *Suaeda nudiflora* **G**- *Salvadora persica,* **H**- *Sesuvium portulacastrum*

4.1.2 Vegetation Structure

(1) Pneumatophores density

Mangrove roots not only support the plant in unstable soil and to withstand current and tides, but also to breathe air. To avoid suffocation in the oxygen poor mud, mangrove trees snorkel for air. They develop aerial or air-breathing roots.

The results (Fig: 4.2) clearly shows that Nada (24/m^2) has got the highest number of pneumatophores density , followed by Gandhar (13.7/m^2)which is a restored mangrove site and the least was observed at Kamboi(2.05/m^2). This indicates that pneumatophores depend on growth of the mangrove plants. More are the trees, the density of pneumatophores increases which gives a relation that as the trees mature, they need more respiration and survival rate will depend on the number of pneumatophores density.

The other point of discussion was that significant increase in pneumatophores height and density was observed towards seaward side than landward side as tree density significantly increases towards the sea. This increase may be due to an increase in anoxic mud and silts in which the mangroves find it more difficult to grow; each mature tree will need a greater area of substrate to survive and for that it requires an increase in pneumatophores rising above the mud.

(2) Status of Trees and sapling/seedling density

Vegetation survey using biological assessment tools had been undertaken for all the sites in order to understand the status of growth of mangroves, its vegetative cover. This further can be co-related with the presence of the faunal diversity at the study sites.

The maximum numbers of trees were recorded at nada (194/hectare) which is a natural mangrove site. Gandhar which has developed over 8 years recorded 98 trees/ hectare. In case of kamboi there was complete absence of trees. In case of sapling/seedling the same pattern was observed where by the maximum was recorded at nada (2140 sapling/hectare) followed by Gandhar (1660 sapling/hectare) and the least density was observed at kamboi (380

sapling/hectare). The number of sapling density shows the regeneration potential of the site**.** (Fig: 4.3)

(3) Tree height:

In case of the tree height study, Nada and Gandhar sites were taken in to consideration as in case of kamboi; there were no mangrove trees present.

There was an interesting trend which was observed between the sites. The range varied between 1.5 meters to 3.8 meters. In case of Nada and Gandhar the maximum trees falled in the range of 1.5-2 meter range. The trees in this part showed stunted growth. There were very few trees in the height range of 3.5-4 meters. In this range Nada had maximum number of trees falling co-relating directly with the age of the mangrove forest. Gandhar being a restored site with nearly 8 years span showed good growth**.** (Fig 4.4)

(4) Tree Girth at Breast height

Measurements of Girth at Breast height can be used to calculate above ground biomass using allometric relationships between GBH and the biomass of individual plant parts (Ong et al., 1984; Putz and Chan, 1986; Clough and Scott, 1989). Coefficients for these allometric relationships for a number of species are summarised by Clough (1992).

Girth was measured for the trees at Nada and Gandhar site. The results showed an interesting trend at the study sites. The range of the girth size was between 1o.41 to 46.80 considering all the study sites. The maximum girth size for Gandhar was in the range of 10-20 cm which steeply decreased with increase in Girth size. In case of Nada the trees were more or less uniformly distributed in all the range with maximum trees falling in range of 30-40 cm and 40-50 cm. This clearly suggests that even though the girth size is more but the trees are showing stunted growth. (Fig: 4.5). The actual site conditions in terms of mangrove cover are depicted through Fig 4.6 to Fig 4.8.

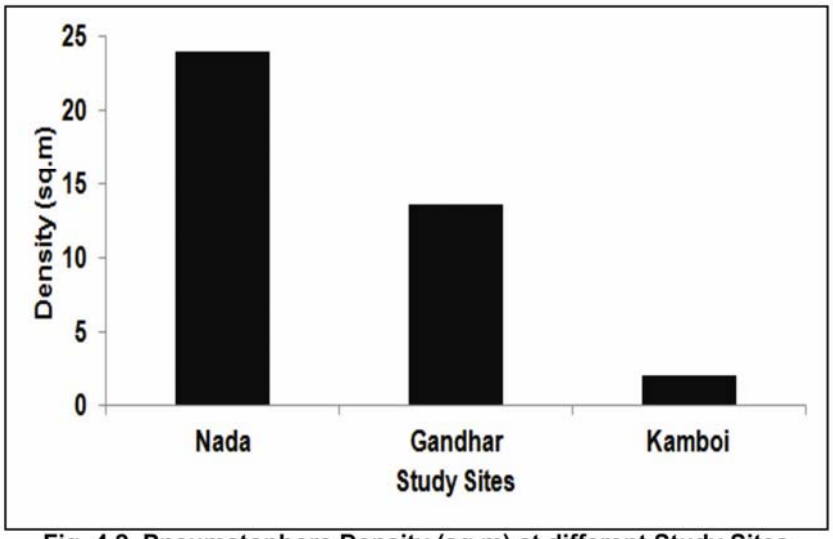


Fig. 4.2. Pneumatophore Density (sq.m) at different Study Sites

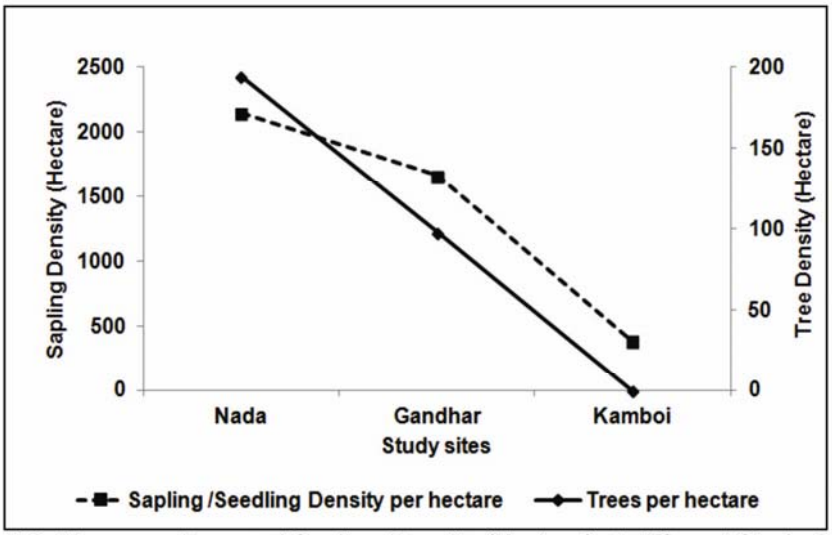


Fig. 4.3. Mangrove Tree and Sapling Density (Hectare) at different Study Sites

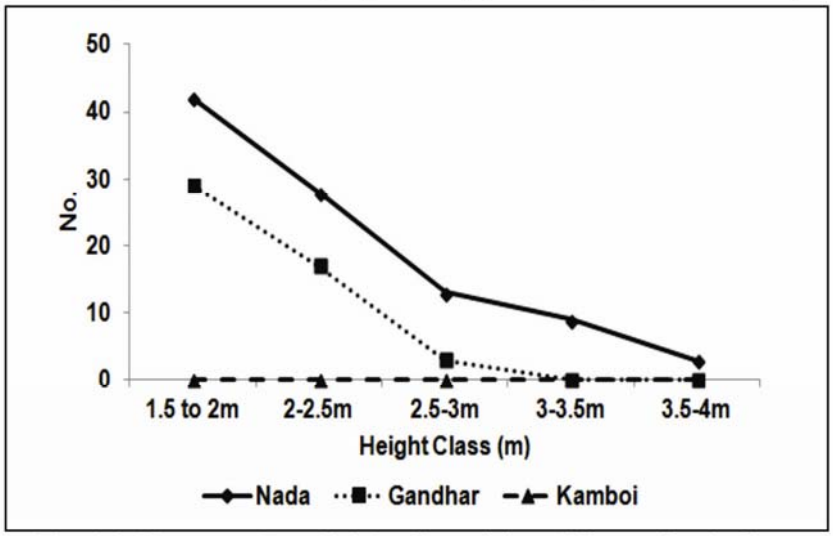


Fig. 4.4. Mangrove Tree Height Class (m) at different Study Sites

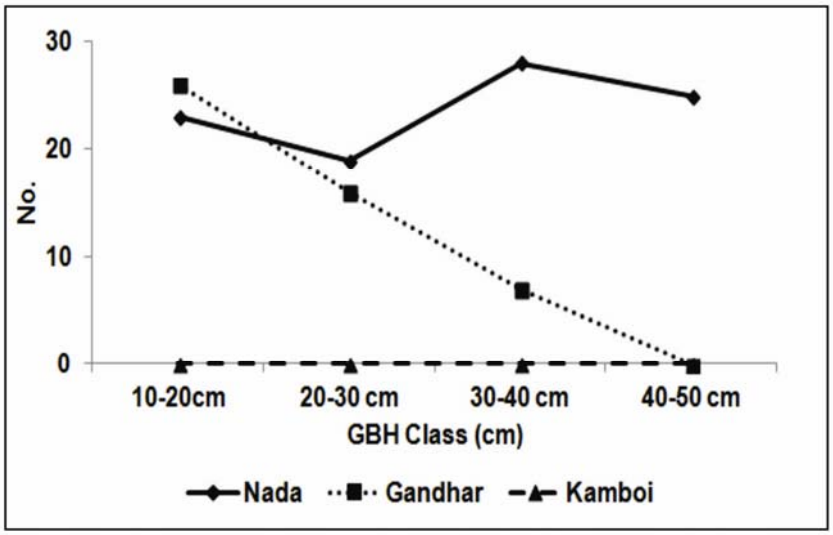


Fig. 4.5. Mangrove Tree GBH Class (cm) at different Study Sites

Fig. 4.6.: Nada

Fig. 4.7.: Gandhar

Fig. 4.8.: Kamboi

4.1.3 Physico-chemical analysis

Physico-chemical analysis of mangrove water and soil samples were carried for the different study sites and the following results were obtained.

The low values of pH noticed during monsoon season may perhaps be due to dilution and mixing of coastal waters by rain floods that leads to reduction in salinity and temperature and decomposition of organic matter.

The low dissolved oxygen concentration observed during summer may be attributed to the higher salinity of the water, higher temperature and less inflow of freshwater coupled with biological processes such as consumption of available oxygen by the organisms for respiration and active decomposition of organic matter during summer

The soil nutrients and physico-chemical characteristics of study sites are given in figures below. Edaphic character sties of samples collected from study areas indicated that the soil were Black to dark brown in colour and in terms of texture it was clayey. pH and Organic matter level were very low during monsoon and high in summer. The chemical properties of the soils varied considerably among samples particularly in nutrient and iron level. The total amount of N, P, K, Na, Ca and Mg were maximum in the monsoon and minimum in summer season.

The mangrove sites was slightly alkaline and contained high amounts of pH, total hardness, calcium, magnesium, chloride, total, inorganic and organic phosphate, ammonia, nitrite and nitrate in all the three seasons examined as compared to non-mangrove site . Most of the parameters tested were slightly higher in summer than the monsoon seasons. Alkalinity and salinity were observed more during the summer.

The pH of the seawater generally varies between 7.5 and 8.5, which is regulated by co_2 ,H_2co_3,HCO_3^- and CO_3^-, salt content and alkalinity due to borates. However, this value may change in the coastal water and estuaries depending upon input of anthropogenic wastes. The change in the pH value is due to the biochemical reactions taking place for the oxidization of organic material. The average values presented **(Fig. 4.9)** reveals range between 7.2 to 8.4. The pH values were higher during summers.

Generally temperature varies in accordance with the air temperature. The data recorded reveal that the temperature was higher during the summer and lower during the winters. It varied in the range between 21°c to 25°c. (Fig: 4.10).The alkalinity results varied over the seasons. The alkalinity values were found higher during summers and less during monsoon season (Fig: 4.11). The range varied between 16-24 mg/l.

The suspended solids of natural origin mostly contain clay, silt, sand of bottom and shore sediment and plankton. Tidal currents influence the level of SS in bottom as well as surface waters. Anthropogenic discharges also add a variety of SS depending upon the source. Most of the chemical constituents which are released to the coastal waters are immediately adsorbed by the SS and settle to the bottom with settling particulate matter. Hence, SS plays major role in removing the pollutants such as metals, PHc and pesticides. The TSS values recorded were higher during monsoon period. (Fig. 4.13)

The ammonia values were found higher during monsoon and lower during summer. (Fig: 4.14)

In case of nitrate and nitirite contents, the results were found higher during monsoon season whereas it was low during summers, expect for result of nitrate in case of nada was found higher during summers.(Fig.4.15 & 4.16) The higher values may be indicative of terrestrial runoff. In case of calcium contents in the water suggests higher values during summer whereas low values during monsoon were recorded. (Fig. 4.17)

In case of magnesium, the values recorded were higher during summers whereas it was low during monsoon (Fig.4.18). Similar pattern was observed in case of dissolved chloride (Fig 4.19).In case of water salinity, it is an important parameter which provides information on the distribution of seawater, which varies with tidal stage and riverine flow. Salinity influences several processes such as dissolution, dispersion, dilution etc.in seawater due to dissolved salt content and higher density. Over the season and sites the salinity range was found between 23-30 ppt (Fig. 4.20). The salinity values were lower during monsoon preferably due to fresh water flow during monsoons.

The values of inorganic and organic phosphorous were recorded high during monsoon at all the three sites (Fig. 4.21 & 4.22). It is also indicative of terrestrial runoff during monsoons. In case of DO which is a critical parameter for marine life and good values of DO (above 5 mg/l) represent the oxidising condition of the water body.when the DO is low, below 3 mg/l the water is called hypoxic. If all the DO is used up, i.e below 0.5 mg/l, the water is called anoxic. Under hypoxic or anoxic conditions no marine fauna and flora survives. There is no agreement on what level of DO are optimum for the health of aquatic biota,it is generally considered that the levels of DO should not fall below 3 mg/l for prolonged periods under tropical conditions.The sources of DO in natural water are photosynthesis and dissolution from the atmosphere across the air-water interface. Influx of anthropogenic discharges containing oxidizable organic matter consume DO more than that the waterbody can replenish leading to threat to the aquatic life.The average value of DO varies from 4.5 to 6.1 (Fig. 4.23). The Values of DO were found higher during monsoon.

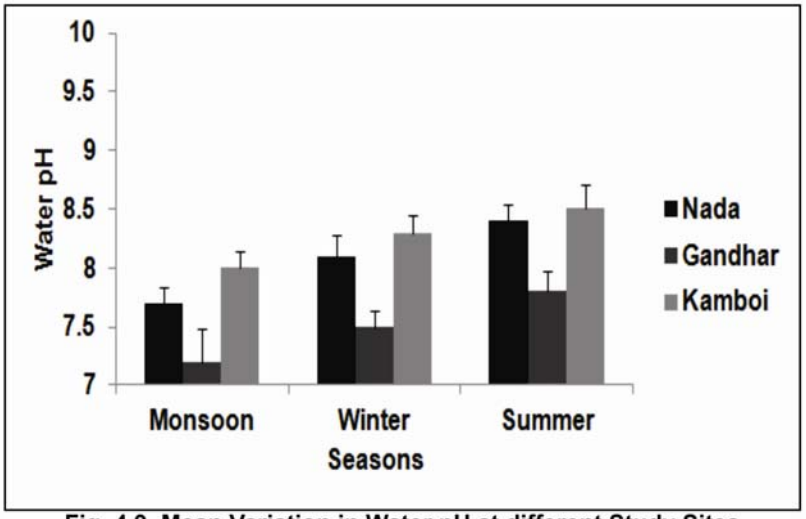


Fig. 4.9. Mean Variation in Water pH at different Study Sites

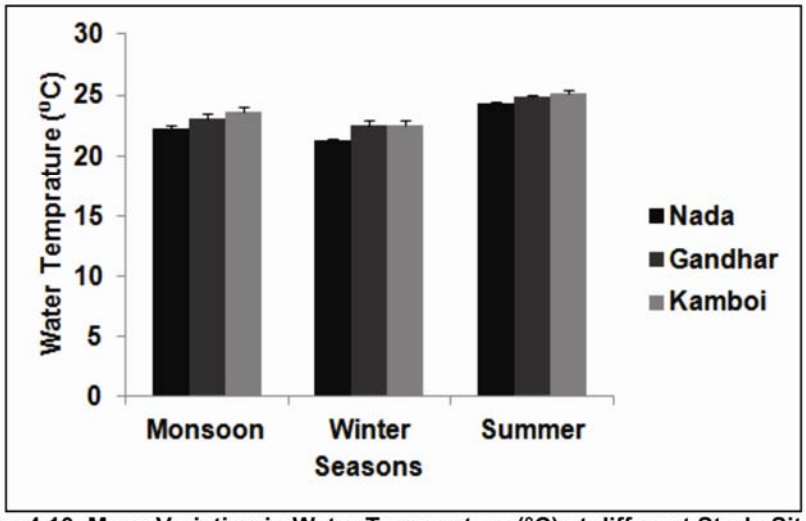


Fig. 4.10. Mean Variation in Water Temperature (°C) at different Study Sites

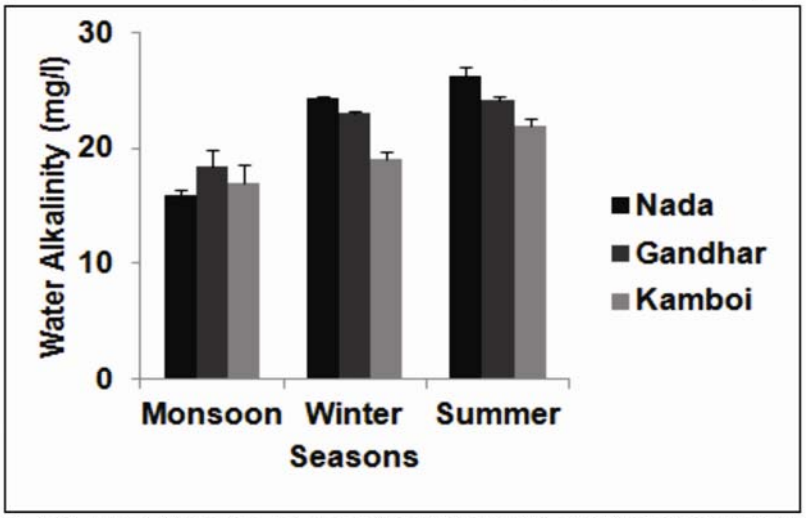


Fig. 4.11. Mean Variation in Water Alkalinity (mg/l) at different Study Sites

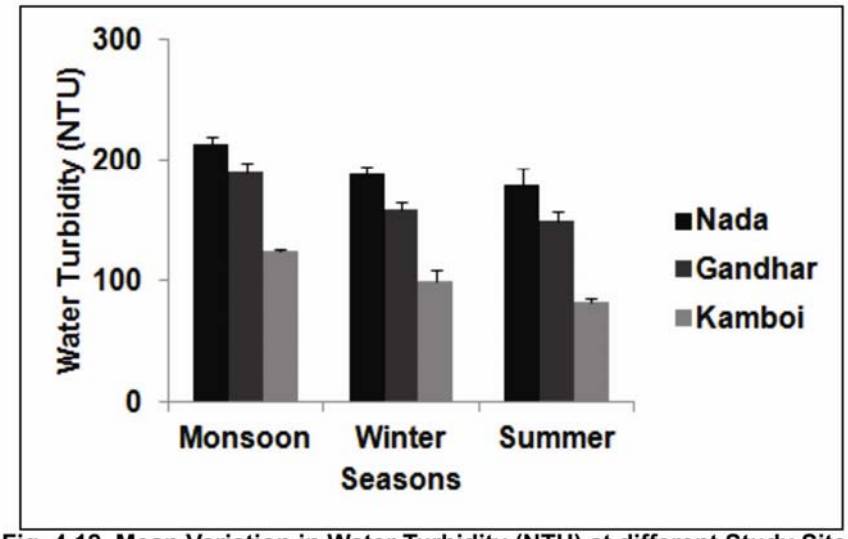


Fig. 4.12. Mean Variation in Water Turbidity (NTU) at different Study Sites

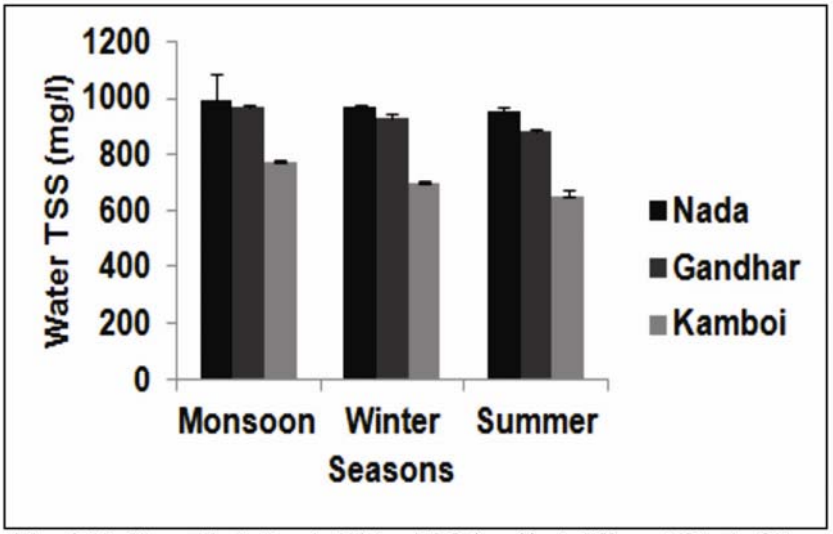


Fig. 4.13. Mean Variation in Water TSS (mg/l) at different Study Sites

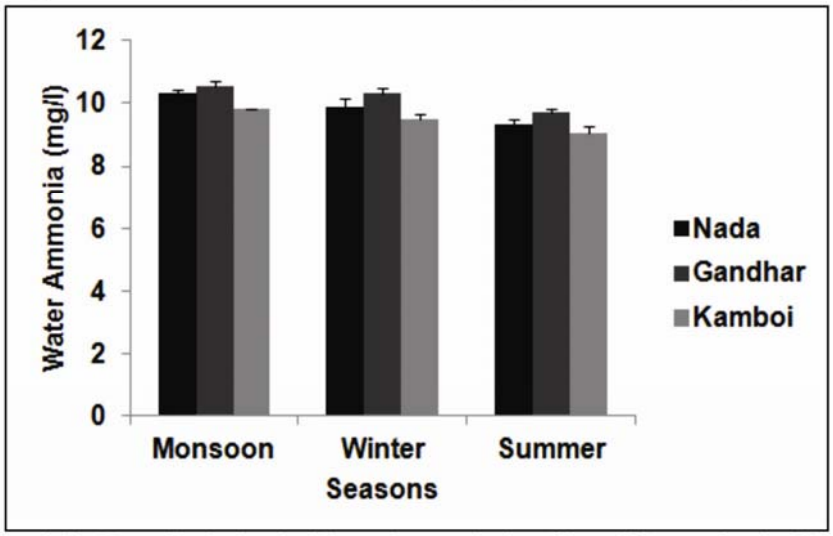


Fig. 4.14. Mean Variation in Water Ammonia (mg/l) at different Study Sites

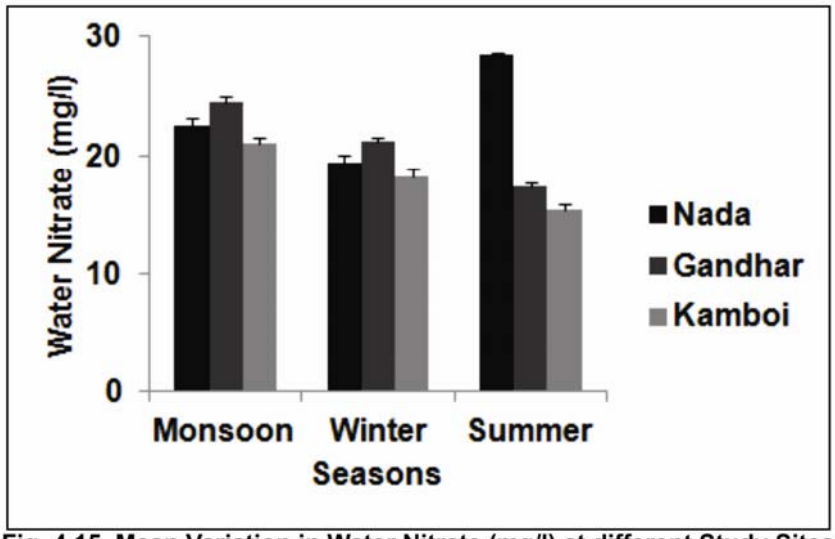


Fig. 4.15. Mean Variation in Water Nitrate (mg/l) at different Study Sites

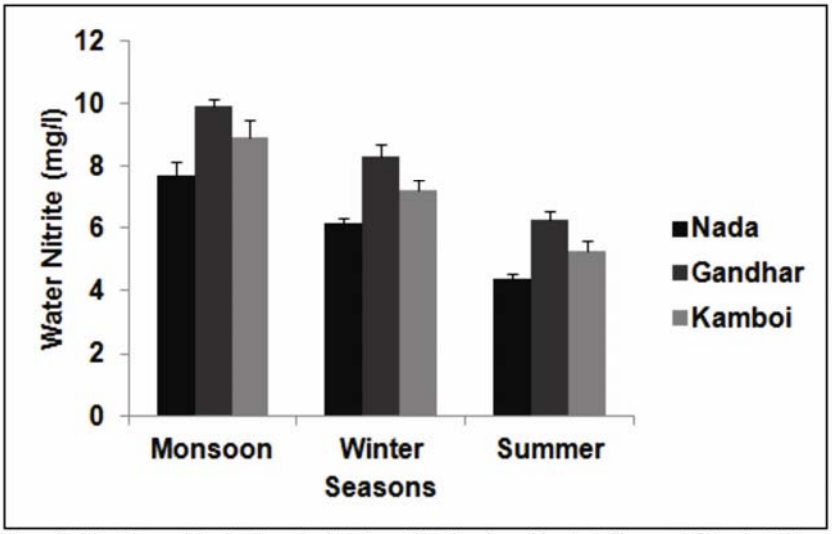


Fig. 4.16. Mean Variation in Water Nitrite (mg/l) at different Study Sites

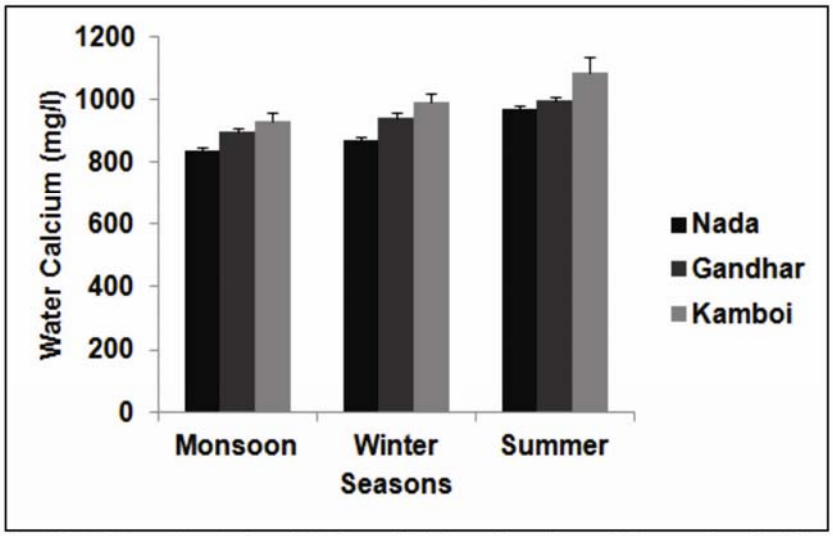


Fig. 4.17. Mean Variation in Water Calcium (mg/l) at different Study Sites

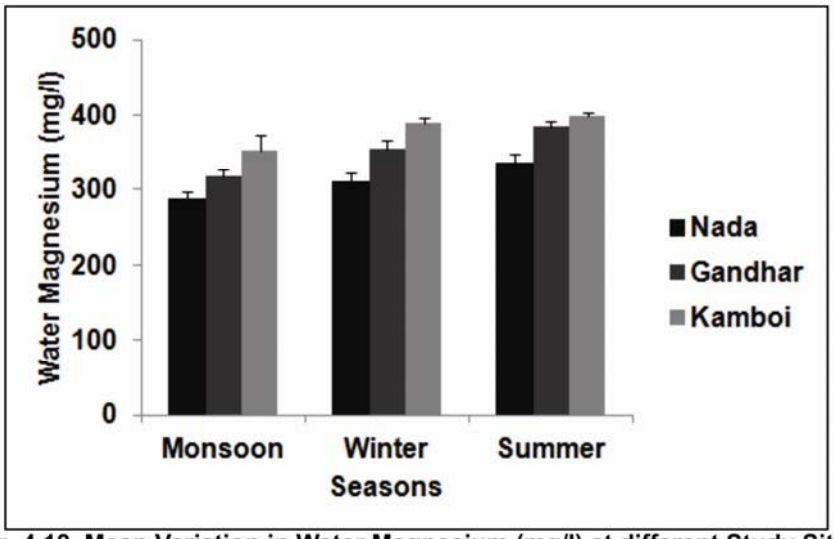


Fig. 4.18. Mean Variation in Water Magnesium (mg/l) at different Study Sites

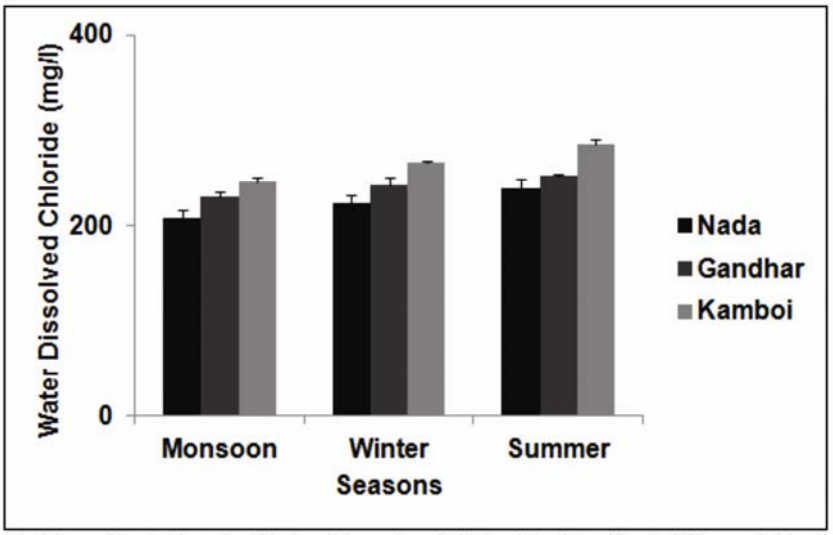


Fig. 4.19. Mean Variation in Water Dissolved Chloride (mg/l) at different Study Sites

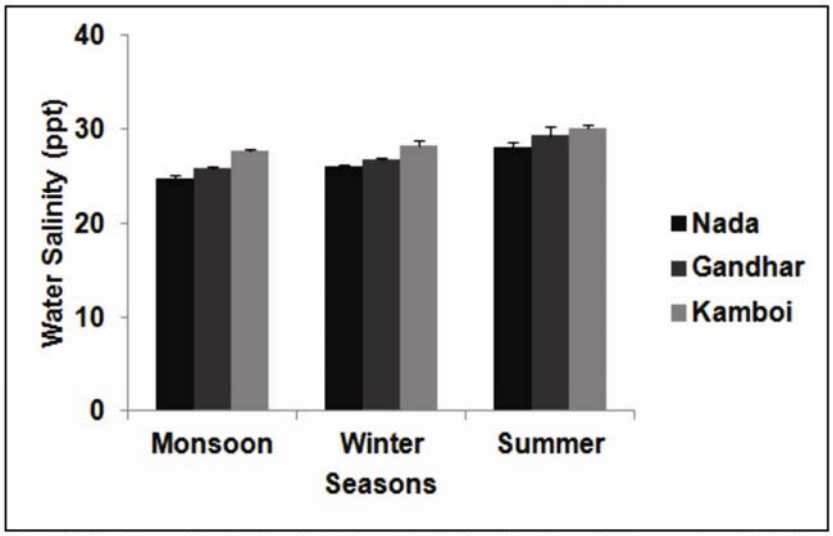


Fig. 4.20. Mean Variation in Water Salinity (ppt) at different Study Sites

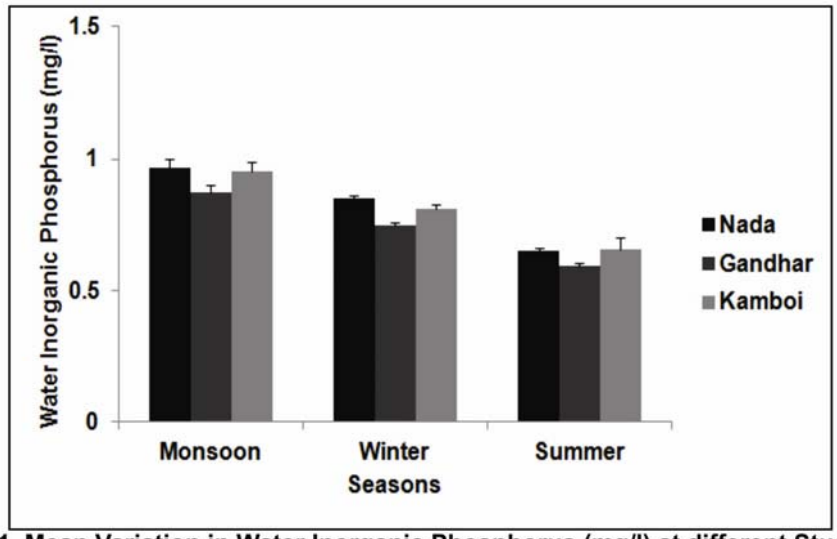


Fig. 4.21. Mean Variation in Water Inorganic Phosphorus (mg/l) at different Study Sites

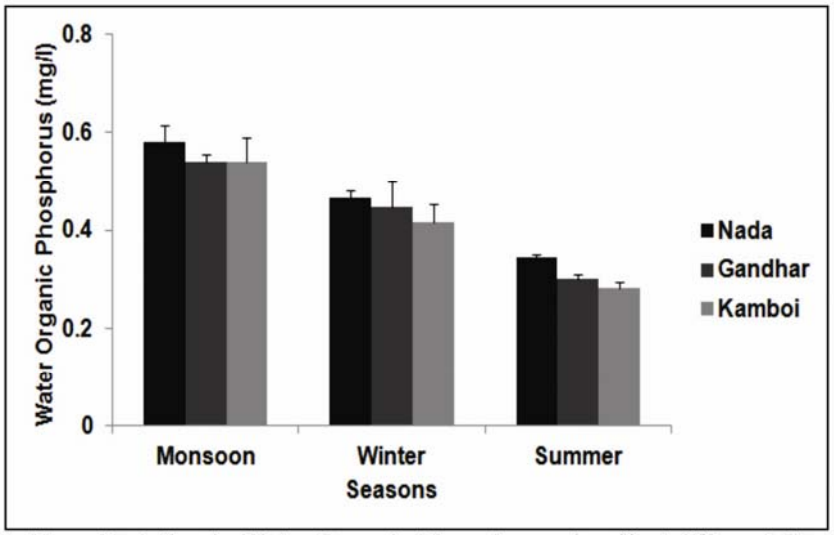


Fig. 4.22. Mean Variation in Water Organic Phosphorus (mg/l) at different Study Sites

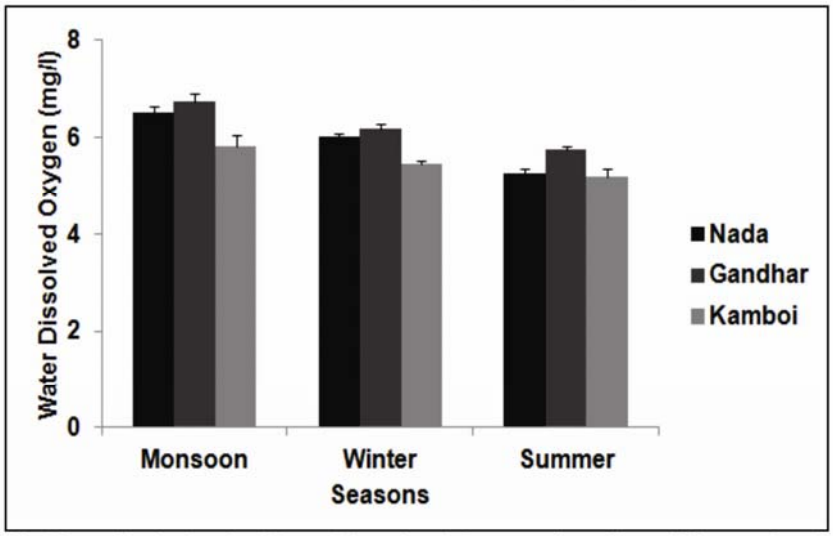


Fig. 4.23. Mean Variation in Water Dissolved Oxygen (mg/l) at different Study Sites

The physico-chemical analysis of the soil carried out for the three sites for the following parameters. In case of soil texture analysis, the soil type found was clay type.

The soil pH values were higher during summer and less during the monsoon. The range varied between 7.8 to 8.9 (Fig. 4.24). In case of Soil electrical conductivity, the readings were quite stable over the season for all the three sites. The maximum values were recorded for Nada and least for the kamboi site (Fig.4.25). In case of organic matter the values were high during summer whereas during monsoon season the values were less. The maximum values was recorded for Nada site, directly co-relating with the litter fall in the area due to presence of mangroves (Fig. 4.26).

The N, P, K analysis of the site soils showed higher values during Monsoon and less during summer. Nada site showed higher values of N, P, K during the study (Fig.4.27, 4.28, 4.29). Lithogenic phosphorous in marine sediment is derived from the geological sources through river flow, while the anthropogenic phosphorous is the result of sewage and industrial discharge, agricultural runoff etc.

In case of sodium, calcium and magnesium the higher values were recorded during monsoon and less values were obtained during summer. For all the three components, Nada showed higher values compared to the other two sites (Fig. 4.30, 4.31, 4.32).

In case of manganese the higher values were recorded during monsoon and low values were recorded during summer. In case of Nada the values are found to be higher as compared to other two sites (Fig. 4.33).

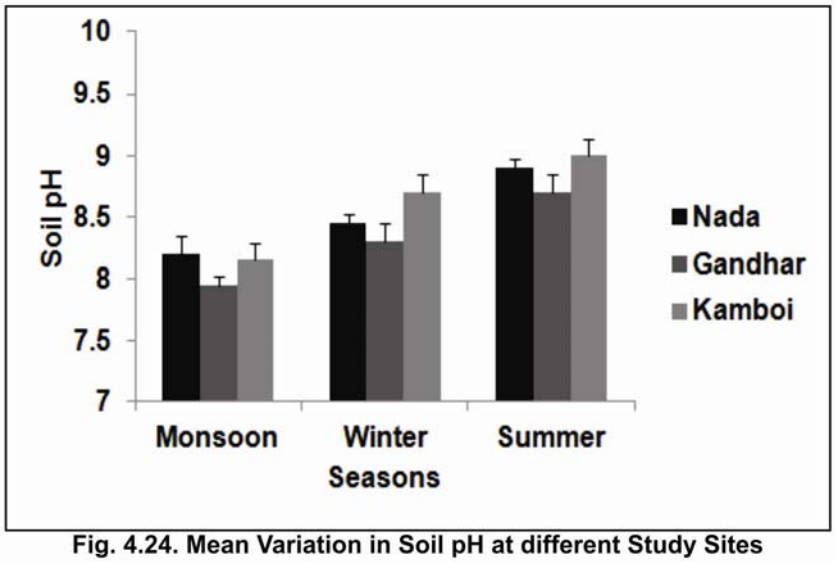


Fig. 4.24. Mean Variation in Soil pH at different Study Sites

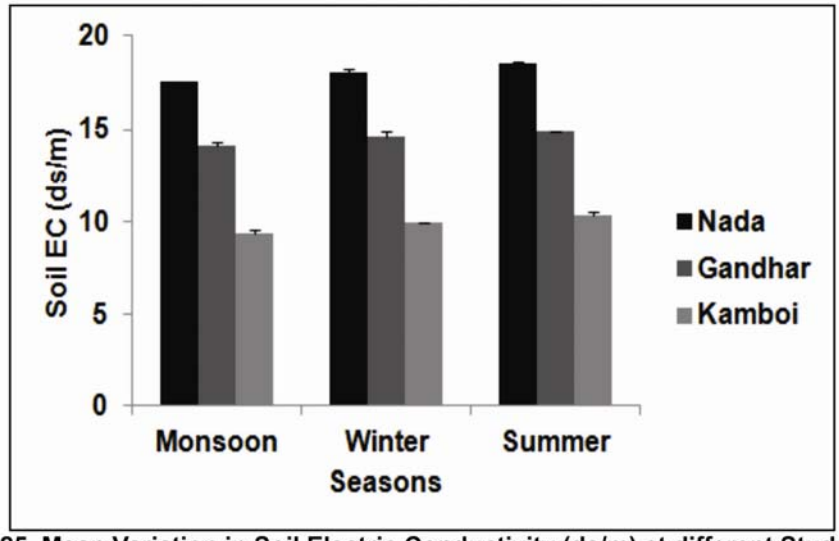


Fig. 4.25. Mean Variation in Soil Electric Conductivity (ds/m) at different Study Sites

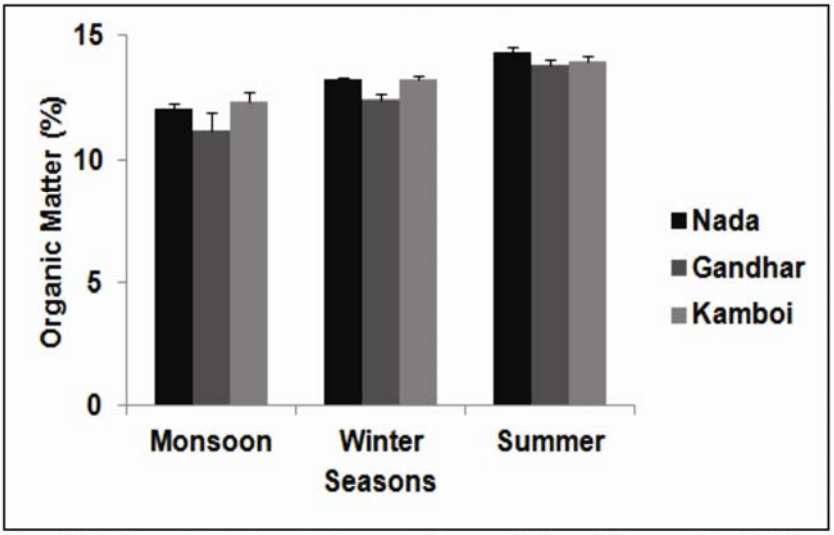


Fig. 4.26. Mean Variation in Organic Matter (%) at different Study Sites

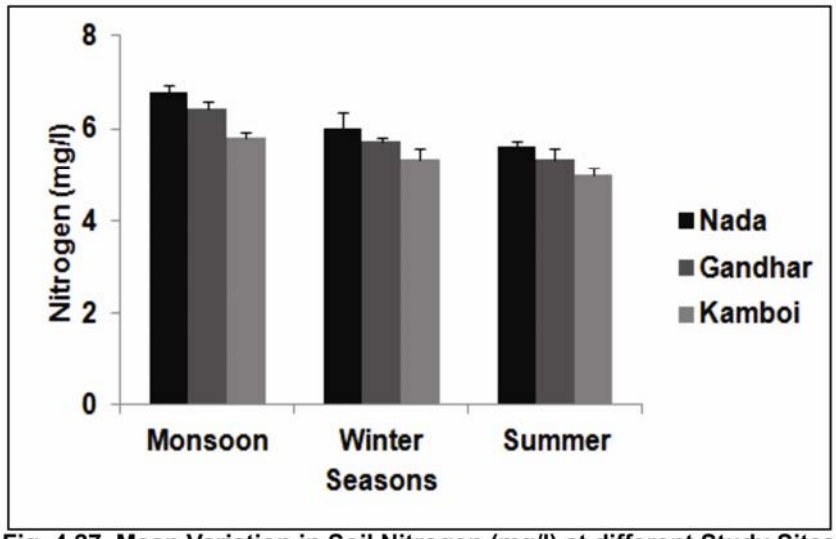


Fig. 4.27. Mean Variation in Soil Nitrogen (mg/l) at different Study Sites

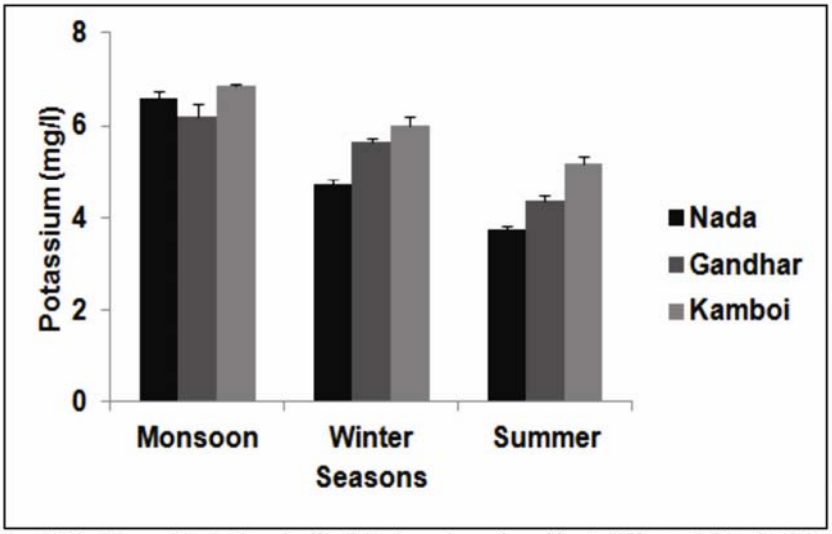


Fig. 4.28. Mean Variation in Soil Potassium (mg/l) at different Study Sites

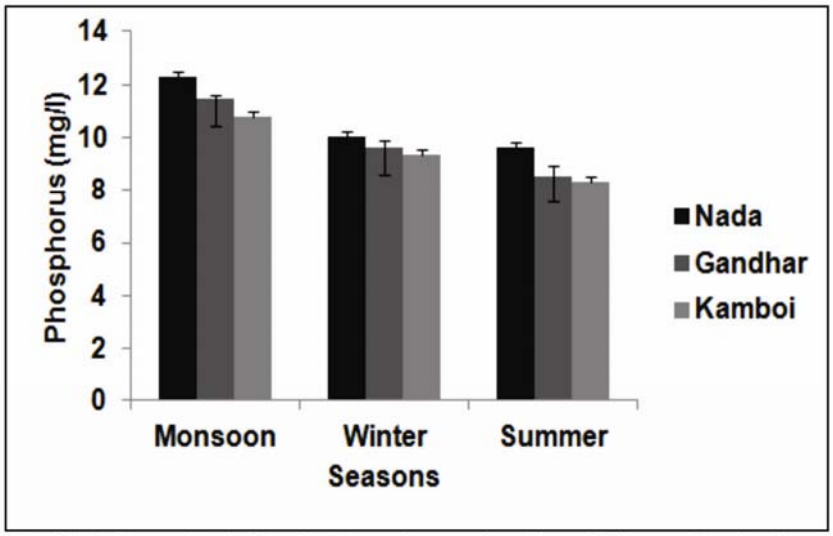


Fig.4.29. Mean Variation in Phosphorus (mg/l) at different Study Sites

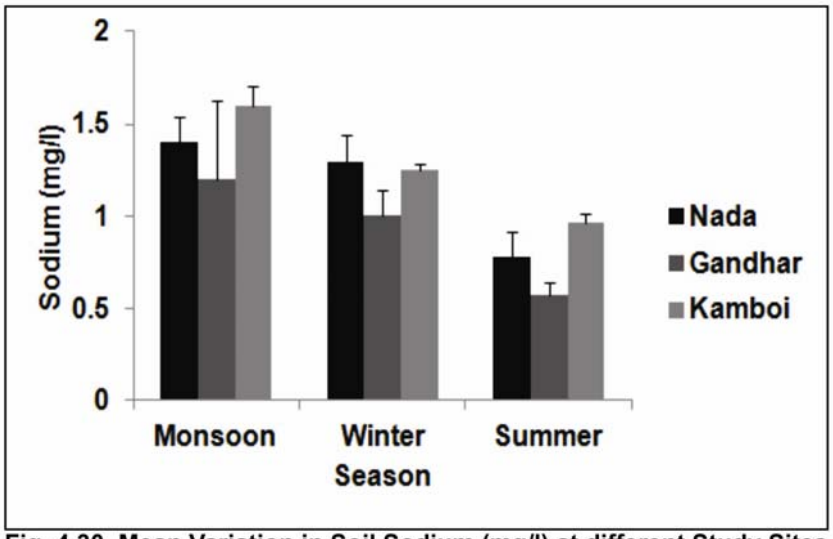


Fig. 4.30. Mean Variation in Soil Sodium (mg/l) at different Study Sites

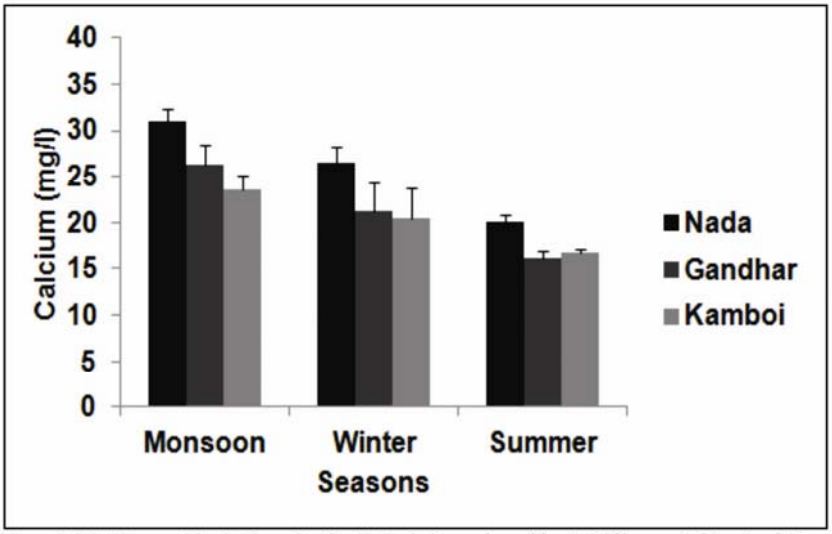


Fig. 4.31. Mean Variation in Soil Calcium (mg/l) at Different Study Sites

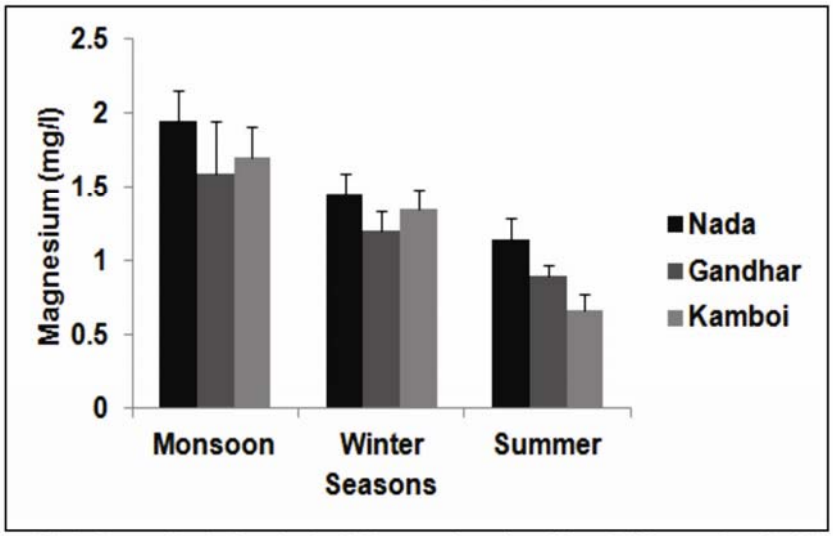


Fig. 4.32. Mean Variation in Soil Magnesium (mg/l) at Different Study Sites

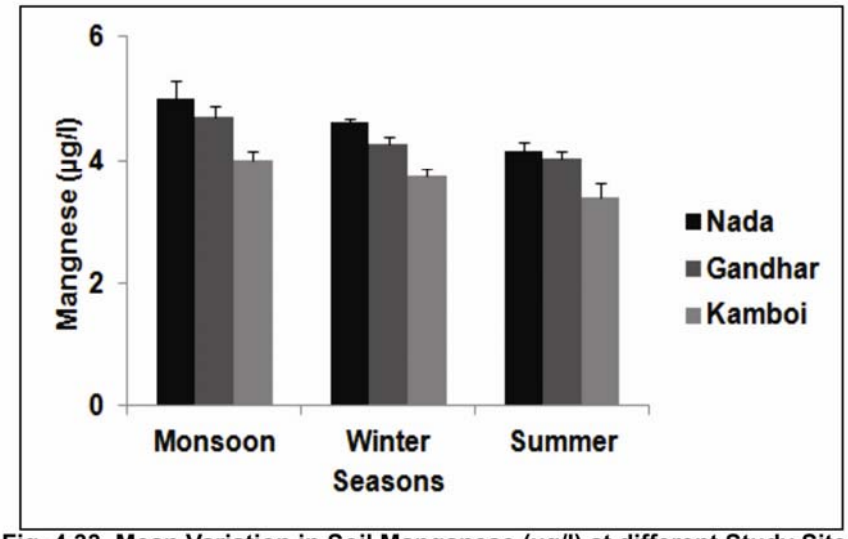


Fig. 4.33. Mean Variation in Soil Manganese (µg/l) at different Study Sites

Discussion:

The environmental parameters showed variations in different seasons in the study region depending on the topography. Salinity showed the highest values in summer nearer to the coastal environment associated with low phosphorus concentrations. The lowest value of salinity was noticed in monsoon seasons, accompanying high phosphorus concentration due to the freshwater zone of this aquatic environment. This in turn enhances the concentrations of ammonia and nitrite at these monsoon periods. High nitrate, Inorganic phosphorus and Organic phosphorus concentration observed in the monsoon periods indicates the impact of terrestrial runoff.

Estuarine mangrove waters in general have relatively low stocks of inorganic phosphorus and nitrogen (Alongi *et al*., 1992). In some cases, the degree of human impact seems to control nutrient profiles (Nedwell, 1975), while in others the degree of upland influence and the hydrology of the system appear to be of greater importance (Boto and Wellington, 1988 and Ovalle *et al*., 1990). The Nada mangrove eco- system was found to be nutrient rich, and the ratios of N:P (10:1) as well as TN:TP (8: 1) were found. The water pH, temperature and salinity fluctuations at all study sites are consistent with seasonal cycles. However, the influence of the Gulf on hydrographic conditions was observed at the sampling stations. The spatial and temporal differences in physicochemical variations indicate the diversity of habitats that exist within this Gulf in reference to the study points. Monsoon season and post monsoon have a lower temperature and salinity than the pre-monsoon.

Total alkalinity values ranged from 15.5 to 25.2 mg/l. The higher total alkalinity values recorded in summer irrespective of the season may have been influenced by the presence of domestic waste and the absence of normal tidal action, which would have had flushing and diluting effect on dissolved constituents as well as bicarbonates, which could increase alkalinity levels. Generally, ammonia concentrations were lower in the dry season months than in the rainy season months. Seasonal influence resulting to lower ammonia values during the summer season, over levels in the monsoon season at all sites. Total Phosphate concentrations ranged from 0.925 to 1.535 mgl-1. Values were also higher in the rainy months and the lowest concentration of summer was recorded.

The soil nutrients and physicochemical characteristics of soil of study sites are given in Fig. 4.24 to 4.33. Edaphic character sties of samples collected from study areas indicated that the soils were dark Brown to black in colour and the texture with clay present in the study sites soil. Given that these mangroves were not located in the geographic areas, the variability in the properties of the soils underlying these mangroves is not unexpected.

The average pH values were determined between 7.1 to 8.7 during the study period.Organic matter concentrations were greatest in the summer in the mangrove sites (14.6%).Five percent organic matter is ideal for the proper composition of soil. Due to more decomposition of plant and animal residues in mangrove area the percentage of organic matter is higher than other soil tract. For this reason the biological activity in mangrove forest area is highly active. Zafar *et al*. (1999) stated that organic matter varied between 0.86 and 1.9% in the intertidal muddy beach. Escourt (1967; Anderson, 1977 and Mayer *et al*. 1985) reported that organic carbon is related to mud percentage in the soil.

The chemical properties of the soils varied considerably among samples particularly in nutrient level of mangrove and non-mangrove sites. Phosphorus concentrations present in the Nada mangrove analyzed in three seasons such as monsoon, winter and summer showed higher values in monsoon as compared to other two seasons. The extractable phosphorus values were in range from the lower and upper profiles was between 20 and 120 mg kg–1. The total amount of potassium was maximum in the monsoon and minimum in summer season. The potassium content is observed in the range of 250 to 750 µg/g in mangroves. Sodium and potassium content in the soil varied considerably between the study sites particularly in nutrient level. The total amount of nutrients was maximum in the monsoon and minimum in summer season.

4.2 Study of major macro- fauna associated with Mangrove ecosystem

A check list of molluscan fauna recorded at the mangrove sites at Gulf of Khambhat

In the geological time scale Molluscs evolved about 600 million years ago during the Cambrian period. The name 'Mollusca" was first used by Linnaeus in the year 1757. Structurally Molluscs are a heterogeneous group of animals with different structural form such as slugs, mussels, octopuses and snails. Majority of the mollusks are known by their shell; but in some forms the shell is absent. Molluscs have been classified based on their morphological, anatomical and biological features. Molluscs are second only to Arthropoda in numerical abundance. The number of species identified under Phylum Mollusca varies between 80,000 to 1, 00,000.

4.2.1 Molluscs

Phylum: Mollusca

Class: Gastropoda

Sub class: Prosobranchia

Order: Archaeogastropoda

(1) *Nerita crepidularia*

Family: Neritidae

Genus: *Nerita* (Dostia)

Species: *Nerita crepidulaia*

Description:

This is one of the common species along West coast. Shell is large, triangular and cap shaped. Shell surface being finely ribbed, the ribs being flattened and close together, colour variable, spire represented by elevated portion of the body whorls, obliquely turned in words; aperture crescent shaped; columelar callous well developed.

(2) *Littorina undulata*

Family: Littorinidae

Genus: *Littorina*

Species: *L. undulate*

Common name: Periwinkle

Description:

Shell non-umblicate, solid, ovately conoid. Columella though appressed by callus, may or may not be violet in general (dark violet in south East coast specimens). Body whorl slightly concavely impressed round the upper part, than convex, evenly rounded without sharp angulation below as in L.s.scabra. Littorina undulate has less elevated spire compared to Littorina scabra.

Lives inter-tidally, invariably at the highest tidal levels on rocky shores commonly clustering in rock crevices during daylight, becoming active at night and crawling on the rocks. These littorines have operacula that completely seal off the aperture of the shell helping to reduce water loss.Grazes on encrusted algae. Due to its variability some form of L. undulata are rather easily confused with L.s.scabra, but could be distinguished by some characters.

(3) *Cerithidea cingulata*

Family: Potamididae

Genus: Cerithidea

Species: *C. cingulata (G melin)*

Common name: Horn shell

Habitat: Inter tidal sand and mud,(coastal and brackish waters)

Size: 40mm.

Description :

Shell is thick and solid with flat-sided whorls. Suture deep. Apex is often eroded. Vertical (axial) ribs are prominent on all whorls, but become obsolete on body whorl. Three rows of nodule ridges per whorl that appear as circular beads.

Outer lips thickened, expanded and arched; white within. Two or three brown or white lines per whorl. The horny operculums have only a few whorls.

The Cerithidium snails of the family Potamididae live in shallow coastal bottoms. Extremely common and occurs by the tens of thousands inter-tidally along estuaries, mangroves and backwaters. They are able to discriminate between different substrata, avoiding fine mud and sand but favouring mixed substrata and are organic detritus feeders.

No correlation has been observed between substrate organic matter and abundance of these snails but size is apparently related to the sediment. Larger animals usually occur in a sandy substrate while those of the muddy sand bottoms are smaller in size. Sexes are separate and attain sexual maturity when they reach 18mm size. Breeding begins in January and extends till June with peak period in any months of these extended periods. Eggs are laid in jelly strings.

(4) *Cerithidea obtusa*

Family: Potamididae

Genus: Cerithidea

Species: C. obtuse

Common name: Obtuse cerith

Description:

Shell elongated and robust; aperture broadly rounded and flared; outer lip thick and flattened. Interior of aperture smooth. Sculptured with spiral threads crossed by prominent axial ridges.

The broken apex has given the specific name ‘obtusa’. A common mud whelk found at a height of half a metre from ground level on mangrove trees and also crawling on mud bottom on upper tidal levels wetted only by spring tides. The attachment to the mangroves is apparently by mucous secretion.

(5) *Telescopium telescopium*

Family: Potamididae

Genus: *Telescopium*

Species: *T. telescopium (Linne)*

Common name: Telescope snail, Top snail, Mud flats of estuaries and mangroves

Description:

Shell telescopic; elevated spire conical. Whorls are spirally grooved; very flat sided; heavy; brown columella ends in a twisted dark brown knot appearing like a corkscrew; labial lip acutely curved; another spiral fold on base of whorls. Operculum round and relatively small. The tall straight sided spire of this heavy shell gives it an appearance of an elongated top shell. Uniformly dark brown with a contrasting ridge of light brown, grey or white, line representing the suture of the whorl. The lower end of the aperture curves sharply towards siphonal canal. It is rare for this shell to have more than a total of 16 whorls.

Telescopium telescopium inhabits mud flats of estuaries and mangrove swamps inundated and exposed by tidal movements. They do not borrow, but plough through the soft mud, feeding on silt and detritus. Breeds during summer (April to July) and during this period the animals are often seen associated in pairs. The egg masses are laid as a compact and continuous ribbon, which is folded upon itself closely.

(6) Erronea caurica

Family: cypraeidae

Genus: *Erronea*

Species*: Erronea caurica* (Linnaeus, 1758)

Description:

These cowries reach 35–55 millimetres (1.4–2.2 in) of length. Their shape is elongated and the basic color is light brown or yellowish, with a pinkish underside and brown spots on the edge. Erronea caurica is a shallow water cowry that prefers quiet lagoon habitats. They are often found paired. Shells are somewhat variable in shape and a number of geographic subspecies have been described. Including the various subspecies, Erronea caurica ranges across most of the Indo-Pacific.

(7) *Sinum haliotoideum*

Family: *Naticidae*

Genus: S*inum*

Species: *Sinum haliotoideum* (Linnaeus, 1758)

Description:

Diameter about equal to the height; shell generally almost globose , consisting mostly of the body whorl(umbilicus either conspicuously open or covered by an obvious callus; height of some species attaining 10 cm).

(8) *Cerithium echinatum*

Family: *Cerithiidae*

Genus: *Cerithium*

Species: *Cerithium echinatum* Lamarck, 1822

Description:

This snail's shell has a short siphonal canal. The shell has spiral rows of bumps as well as reddish-brown dashes. It has been found at 53mm in size.

(9*) Natica vitellus*

Family: *Naticidae*

Genus: *Natica*

Species: *Natica vitellus* (Linnaeus, 1758)

Description:

Shell globular to ovate-conical or somewhat ear-like in shape, outer surface generally smooth and glossy or with reduced sculpture. Spire low, obtuse to conical with few whorls, body whorl large and often inflated. Aperture large, semicircular, with a thin outer lip and a more or less developed callus on the inner lip. Anterior siphonal canal absent. Umbilicus open or closed, sometimes with an internal rib(= funicle).Operculum entirely corneous or externallycalcifiedand sculptured, with an eccentric nucleus and a few spiral coils. Head with moderately small, widely spaced tentacles. Eyes reduced to absent, behind the

tentacles. Foot highly developed, reflecting over the head and much of the shell when expanded.

Class: Bivalvia

Sub-class: Heterodonta

Order: Veneroida

(10) *Mactra antiquata*

Family: Mactridae

Genus: Mactra

Species: *Mactra antiquata* Spengler, 1802

Description:

Shell equivalve, ovate or trigonal to transversely elongated, closed to somewhat gaping posteriorly. Umbones prosogyrate, more or less prominent. Outer surface smooth or mostly concentrically sculptured, often with an obvious periostracum. External ligament short and not prominent, just behind the umbones; internal ligament well developed, set in each valve in a deep trigonal pit of the hinge plate and pointing towards the umbo.Hinge characteristic, each valve with two cardinal teeth and smooth or striated, more or less developed, lateral teeth; cardinal teeth of the left valve forming an inverted V-shaped process; delicate additional cardinal lamellae often present in either valve. Interior of shell porcelaneous. Two, often subequal, adductor muscle scars.Pallial line with a well-developed sinus. Internal margins usually smooth. Gills of eulamellibranchiate type, with generally smooth branchial sheets; outer demibranch expanded above the ctenidial axis. Foot large and compressed, heeled, without a byssus. Siphons united, generally rather short, naked or sheathed with an expansion of the periostracum, papillate on top. Mantle margins smooth more or less cuticularly united or fused ventrally, with a large pedal opening anteriorly and an additional aperture beneath the inhalant siphon.

(11) Meretrix Meretrix (Linne)

Family: *Veneridae*

Genus: *Meretrix*

Species: *Meretrix meretrix* (Linne)

Common name: Backwater clam

Habitat: Estuarine and backwaters

Description:

Shell strong, glossy, triangularly ovate and comparatively more inflated than *M.casta*. periostracum is thin, transparent, delicate and of gray or straw colour. Surface more polished than M.casta in all stages. Umbones large, inflated near the middle but slightly towards the anterior end. Antero-lateral tooth of left valve stout and distinctly notched; pallial sinus is very shallow and feebly developed. Hinge is delicate and weaker when compared to M.casta. transverse wavy bands of grayish blue or reddish brown or pinkish colour invariably on the umbo region. Purple to brownish longitudinal streaks radiating from umbo towards the ventral margin are seen through its transparent periostracum. These colour patterns differentiate M.meretrix from M.casta. Interior ivory.

Molluscan diversity found at study site

In total 11 species belonging to 8 families were found from the study sites (Fig.4.54). In total 9 gastropods and 2 bivalve species were found. The maximum diversity was recorded at Nada site with 9 species of gastropods belonging to 6 families and 2 species of bivalves belonging to 2 families. In case of nada all the 11 species were recorded whereas in case of Gandhar 4 species were only recorded. At Gandhar site 3 species of Gastropods belonging to 3 different families and 1 species of bivalve belonging to 1 family were recorded. The least diversity was recorded at kamboi site where by only 2 species of gastropods were present. There were no bivalve species found from Kamboi site (Table 17).

Table 17: List of molluscan species found at study sites

Sr. No.	Species	Nada	Gandhar	Kamboi
	Gastropods			
1	*Nerita (Dostia) crepidularia*	✓		
2	*Littorina undulata (gray)*	✓	✓	

3	*Cerithidea (cerithidiopsilla) cingulata (gmelin)*	✓	✓	✓
4	*Cerithidea (cerithidea) obtusa (lamark)*	✓		
5	*Telescopium telescopium (linne)*	✓		
6	*Erronea caurica (Linnaeus,1758)*	✓		
7	*Sinum haliotoideum (Linnaeus, 1758)*	✓	✓	✓
8	*Cerithium echinatum Lamarck,1822*	✓		
9	*Natica vitellus (Linnaeus,1758)*	✓		
	Bivalves			
10	*Mactra antiquate Spengler,1802*	✓		
11	*Meretrix meretrix (linne)*	✓	✓	

4.2.2 Brachyuran crabs

Crabs in the Mangrove Environment

Of all benthic macrofauna inhabiting the mangrove forests, grapsid crabs are amongst the most important with regard to both the number of different crab species and the total number of crabs present (Dahdouh‐Guebas, *et al*. 1997). Most grapsid crabs belong to the subfamily Sesarminae and many also belong to the largest genus in Sesarminae, called *Sesarma*. Crabs are good source of food to marine life as well as to man as a good protein source (Khan, 1992 and Siddiqui *et al*., 2002). The nutritional quality of the crab proteins compare very favorable than that of muscle meat of mutton, chicken, duck and fish (Derosier, 1963; Newcombe, 1944; Zaitsev *et al*., 1969).

Diversity for Brachyuran crabs was studied at the three sites. The following crabs were recorded during the study:

Kingdom: Animalia

Phylum: Arthropoda

Class: Malacostraca

Order: Decapoda

(1) *Uca (Austruca) lactea*

Taxonomy

Family: Ocypodidae

Genus: Uca

Synonym:

- *Uca lactea annulipes* (H. Milne Edwards, 1837)
- *Ocypode lactea* (De Haan, 1835)

Description:

Carapace with orbits moderately oblique; front broad, narrowest below eyestalk bases; antero-lateral margins approximately straight, converging, exorbital tooth acute and produced, directed antero-laterally.Palm of major cheliped finely granulate to tuberculate in the center of inner face, oblique ridge high and thin, tubercles largest on highest point of ridge; outer face with extremely minute tubercles, no depression at base of immovable finger; small cheliped in both sexes with merus not flattened posteriorly and not armed with a supraventral row of tubercles, gape throughout about as wide as immovable finger, with weak serrations, which may be absent. Meri of fourth and fifth pereiopodsnarrow, fifth always strikingly slender. Horny terminal endpiece of male first pleopod with strongly developed flanges; palp short.

(2) *Uca (Tubuca) dussumieri*

Taxonomy

Family: Ocypodidae

Genus: Uca

Synonym

- *Gelasimus dussumieri* (H. Milne-Edwards, 1852)

Description:

External orbital angles sharply projecting antero-externally. Posterolateral facets markedly concave. Anterior pleopod of male with its apical process short and broadish, with a short accessory process. The regions of the carapace are strongly defined and the raised lines that bound the dorsal plane of the carapace on each side are more curved, less rapidly convergent

and less distinct in their posterior part. The front, measured between the bases of the eyestalks, is about a fifteenth the greatest breadth of the carapace, and its moulded and bevelled edges together take up more than two-thirds of its breadth. In the large cheliped the arm is longer and more slender, both the oblique granular ridges on the inner surface of the palm are very strongly defined, and the fingers may be fully 3 times the length of the upper border of the palm. These large fingers are broader and thinner, their tips are somewhat hooked and have no enlarged tooth near them. The merus of the last pair of legs though it is compressed and somewhat broadened, is not a short foliaceous joint.

(3) *Ashtoret lunaris*

Taxonomy

Family: Matutidae

Genus: Matuta

Synonym

- *Cancer lunaris* (Forsskal, 1775)
- *Matuta lunaris* (Alcock, 1896)
- *Matuta lunaris* (Sakai, 1976)
- *Matuta victor* (De Haan, 1850)
- *Matuta victrix* (Alcock and Anderson, 1894)

Description:

Carapace sub circular, almost smooth with indistinct tubercles, somewhat depressed and with a prominent horizontal spine at the lateral apibranchial angle, on either side; postero-lateral borders sharply convergent; front wider than the orbit. Longitudinal ridge of dactylus of chelipad strongly milled; palm with spine-like teeth at the base of the lower outer angle near the wrist. Last four pairs of thoracic legs oar-shaped for swimming. The anterior male appendage straight, slender with arowhead-like terminal portion bearing numerous blunt spinules, tubercles and hairs. This species is distinguished by the presence of a distinct spine at the angle of the hand where it comes in contact with the external angle of the arm. The length of the composite segment 3-5 in the male is greater than its breadth at the base, and the length of the terminal segment is considerably more than its posterior

breadth. Differention in the direction of spines was observed, some pointing forward, some laterally and some even backward.

(4) *Scylla serrata*

Taxonomy

Family: Portunidae

Genus: *Scylla*

Synonym:

- *Achelous crassimanus* MacLeay, 1838
- *Cancer serrata* Forskal, 1775
- *Lupa lobifrons* H. Milne Edwards, 1834
- *Scylla tranquebarica* var. *oceanic* Dana, 1852.

Description:

Carapace transverse, broad, moderately convex, perfectly smooth and unbroken except a curved transverse ridge; front four dentate, middle two teeth of equal length; antero-lateral borders cut into nine sharp acuminate teeth of almost equal size. Hands inflated and almost smooth; palm swollen and arm with three spines on the anterior border and two on the posterior border. Legs ambulatory and unarmed, last pair paddle-like and adapted for swimming. Abdomen of male broadly triangular, outer basal of the first pair of abdominal appendages more rounded in male with denser spinules. The anterior male abdominal appendages are elegantly bent and bear hairs along one border and spinules along the other. The tip is shaped like a scapel and bears a patch of spinules.

Solitary, swimmers as well as burrowers. Adapted to salinities ranging from almost freshwater to that of seawater.

(*5) *Metaplax indica

Taxonomy

Family: Varunidae

Genus: Metaplax

Synonym:

- Metaplax indicus (H.Milne Edwards 1852)
- Metaplax indica

Description:

Carapace about two-thirds as long as broad, deepish, a little convex, its surface smooth, the regions and the cervical and epibranchial grooves faint. This species is distinguished by the equal sized male chelipeds, which are less than three times the length of the carapace. The finger has no prominent lobe on its dentary edge. The anterior borders of the carpopodites and propodites of the legs are smooth. The third, fourth and fifth male abdominal segments are fused. There are seven to nine teeth on the male infra-orbital ridge beginning with four or five small teeth, followed by two larger rounded lobules, that are separated by a large inter-space from three very small tubercles in the lateral part of the ridge. The meropodites of all the legs, and the propodites and carpropodites of the middle two are densely hairy only on the anterior border. The third, fourth and fifth male abdominal segments are only partly fused. In the female the chelipeds are very slender, quite smooth, a little longer than the carapace, and the lower border of the orbit is finely and evenly serrulate.

(6)*Grapsus intermedius*

Taxonomy

Family: Grapsidae

Genus: *Grapsus*

Description:

Carapace perfectly quadrangular, the lateral borders feebly divergent backwards, armed with two teeth including the external orbital angle, the vestige of the third tooth can be traced out in some specimens. The frontmedially marked with broad sinus and the postfrontal ridge well marked, four-lobed. The outer surface of palm is covered with depressed tubercles mainly near the middle surface; a patch of larger granules occurs a little below the middle portion of this surface; on the inner surface; a ridge of large tubercles extends from the middle of the superior border toward the

middle poriton, the remainder of the surface also covered with fine granules. The fingers are not much gaping even in full grown male.

(7) *Parasesarma plicatum*

Taxonomy

Family: Sesarmidae

Genus: *Parasersama*

Synonym

Alpheus quadratus Weber, 1795

Cancer quadratus Fabricius, 1798

Ocypode plicatum Latreille, 1803

Description:

Lateral borders of carapace markedly concave in the middle, with an indistinct tooth behind the external orbital angle. The movable finger has a row of 8 to 9 "chiton-like" tubercles. No transverse ridge of granules not crests on the inner surface of palm. The merus of ambulatory legs very broad. Carapace hardly convex, decidedly broader than long, its length being about four-fifths its breadth between the antero-lateral angles, deep. There is no tooth on the lateral borders behind the orbital angle. The front is more than half the greatest breadth of the carapace. The inner border of the arm bears a large tooth at its distal end. On the upper surface of the palm are two oblique pectinated ridges, and the dorsal surface of the male finger is milled with 11 to 19 blunt transverse lamellae. The chelipeds differ in the sexes, being about 1¾ times the length of the carapace in the male and much more massive than the legs, but in the female hardly 11/3 times the length of the carapace and not more massive than the legs. The meropodites of the legs are foliaceous, their greatest breadth in the 2nd and 3rd pairs being more than half their length.

(8) *Venitus dentipes*

Taxonomy

Family: Macrophthalmidae

Genus: Venitus

Synonym

Macrophthalmus (Venitus) dentipes Lucas, in Guérin-Méneville, 1836

Macrophthalmus guerini H. Milne Edwards, 1852

Macrophthalmus pectinipes Guérin-Méneville, 1838

Macrophthalmus rouxii Lucas, in Guérin-Méneville, 1836

Macrophthalmus simplicipes Guérin-Méneville, 1838

Description:

Carapace studded with large conspicuous pearly granules, its length in the adult male is about six-elevenths of its greatest breadth at the level of the second tooth of the lateral border. Orbits sinuous, a little oblique; their upper border elegantly denticulate, the lower broder unevenly crenulate. Eyestalks slender and curved; the eye does not reach to the end of the orbital trench. In the first three pairs of legs, the meropodites, carpopodites, and propodites are scabrous and serrated. The anterior male abdominal appendages bear two lobes at the tip the inner one straight and slender, the outer bent outwards. Both bear hairs, each hair being striped with alternate brown and white bands. There are three types of hairs on the second maxillipeds. The 'spoon' is very long and narrow and consists of irregular lobes. The last lobe is bent at right angles when seen in a side view.

(9) *Macrophthalmus (Mareotis) depressus*

Taxonomy:

Family: Macrophthalmidae

Genus: Macrophthalmus

Synonym:

Macrophthalmus depressus Ruppell, 1830

Macrophthalmus depressus de Man, 1887

Macrophthalmus depressus Rice, 1975

Description**:**

Carapace studded with minute granules not always plainly visible to the naked eye, its length in the male about two-thirds of its breadth. The lateral borders are parallel and the antero-lateral angle is rather a square-cut lobe than a tooth. Front, at its narrowest part, about and eighth the breadth of the carapace, longitudinally grooved, but its free edge is straight and not bilobed.

Orbits little sinuous and little oblique, their upper border microscopically their lower border finely and evenly denticulate. Eyestalks slender, hardly curved, the eyes reach almost to the end of the orbital trenches. The chelipeds and legs are unarmed except for a small sub-terminal denticle on the anterior border of the meropodites of the first three pair of legs. The dactylus is more than two thirds the length of the palm, which is smooth and unsculptured. There is a molariform tooth near the basal end of the dactylus and a similar but less distinct and more oblique tooth on the immobile finger.

(10) *Macrophthalmus dilatatus*

Taxonomy

Family: Macrophthalmidae

Genus: Macrophthalmus

Synonym:

Ocypode (Macrophthalmus) abbreviata de Haan, 1833-1849 (1835)

Ocypode (Macrophthalmus) dilatata de Haan, 1833-1849 (1835)

Macrophthalmus dilatatus de Man, 1890

Macrophthalmus dilatatum Sakai, 1934

Macrophthalmus (Macrophthalmus) dilatatus dilatatus Barnes, 1970

Macrophthalmus (Macrophthalmus) dilatatus Kim, 1973

Macrophthalmus (Macrophthalmus) dilatatum Dai et al., 1986. -- Dai & Yang, 1991

Macrophthalmus (Macrophthalmus) abbreviatus Manning & Holthuis, 1981.

Macrophthalmus abbreviatus Davie, 1992b: 348(key).

Ocypode (Macrophthalmus) dilatatus Yamaguchi, 1993: 582.

Description:

Carapace covered to a variable extent with medium sized granules, sometimes central areas totally devoid of granules, branchial regions with distinct raised clumps of granules; front deflexed, constricted between bases of ocular peduncles, with smooth margins, slightly bilobed or straight distally, median furrow hallow; lateral margins posteriorly convergent, 2 well defined and 1 faint antero-lateral teeth. A large spine is present near to carpus articulation,immovable finger markedly deflexed in adults, cutting edge with a

long crenulate tooth and a few granules; cutting edge of dactylus proximally with a low tooth formed from 4-5 granules.

(11) *Metapograpsus messor*

Taxonomy

Family: Grapsidae

Genus: Metapograpsus

Synonym:

Cancer messor Forskål, 1775

*Eurycarcinus messor (*Forskal)

Grapsus (Pachygrapsus) aethiopicus Hilgendorf, 1869

Grapsus gaimardi Audouin, 1826

Description:

Lateral margins of carapace entire, distinctly converging backwards; free edges of the postfrontal lobes rounded and blunt, postfrontal region with distinct ridges or markings. Suborbital tooth acute strongly keeled from tip to base. Exposed surface of the base of the antenna not densely pubescent. Third and fourth pereiopods without pubescence on lower border; fifth pereiopod without a linear fringe of hairs on the upper margin of the propodus. Male abdomen with sixth segment shorter than fifth. Horny terminal endpiece of first male pleopod short.

(12) *Cardisoma carnifex*

Taxonomy

Family: Gecarcinidae

Genus: Cardisoma

Synonym

Cancer carnifex Herbst, 1796

Cancer urvillei H. Milne Edwards, 1853

Cardisoma obesum Dana, 1851

Perigrapsus excelsus Heller, 1862

Description:

Horny endpiece of male first pleopod asymmetric, external corner dentiform, sperm channel lateral. Female genital duct with strongly protruding lateral

border, median border much less marked; opercle highly elevated, dropping perpendicularly in direction to vulval slit.

Carapace subovate, swollen, surface smooth; setose area on pterygostomial and subbranchial regions small, not extending to branchiostegal region. Third maxilliped with well-developed flagellum on exopod, entirely covered by setae. Adult males with one chela greatly enlarged. Merus of legs not distinctly lined with stiff setae. Color: brown to brownish grey.

(13) *Uca (Gelasimus) vocans*

Taxonomy

Family: Ocypodidae

Genus: Uca

Synonym

Cancer vocans Linnaeus, 1758

Gelasimus cultrimanus White, 1847

Gelasimus marionis Desmarest, 1823

Gelasimus nitidus Dana, 1851

Ocypode citharoedicus Say, 1817

Uca (Thalassuca) vocans

Uca marionis (Desmarest, 1823)

*Uca marionis cultrimana (*Adams & White)

Uca marionis f. excisa Nobili, 1906

Uca vocans excisa (Nobili, 1906)

Uca vocans vocans (Linnaeus, 1758)

Description:

Carapace with orbits moderately oblique; front narrow, narrowest between eyestalk bases, frontal groove moderately wide, with sides diverging rapidly posteriorly; antero-lateral margins short, sometimes absent, converging, exorbital tooth little produced, acute; suborbital crenellations strong, distinct, no tubercles on floor of orbit. Palm of majorcheliped with oblique ridge high, thin and sharp, usually with close set tubercles; outer face near base of immovable finger with a extremely large low triangular depression, reaching from the middle of the palm to the base of dactyl and ending in a longitudinal furrow on immovable finger; dactylus without longitudinal furrows; gape of

female chelae without enlarged teeth. Horny terminal end piece of male first pleopod with anterior flange larger than posterior, inner process well separated from posterior flange; palp of moderate size, subdistal.

(14) *Dotilla intermedia*

Taxonomy

Family: Dotillidae

Genus: Dotilla

Synonym:

Dotilla intermedia de Mann, 1888

Vernacular name: Soldier crab

Description:

No brush of hair between bases of walking legs. Fourth segment of abdomen overlapping 5 with a thick brush of setae at its distal end in both sexes. Gastric and cardiac areas of carapace entire, not divided by a median longitudinal groove; transverse groove near posterior margin incomplete in the middle. No lobules isolated by grooves on gastric region. Adult male with a tooth below orbital angle and a strong compressed tubercles on inner and proximal aspect of cheliped carpus. Tympana on all segments of sternum.

These are related to the so-called bubbler crabs. As they feed, their mouthparts sieve through the sand, filtering out the food particles. When finished, it discards the left-over sand as a ball on the ground. After several minutes of feeding, the ground is littered with dozens of closely packd balls. These are air-breathers and when the tide comes in, they retreat into their burrows, block the opening and ride out the high tide in a small air bubble.

Brachyuran crab diversity found at study site

Total 14 species were recorded in total from 11 genera and 9 families (Fig.4.55&4.56). Crabs belonging to family ocypodidae and macrophthalmidae are most dominant with 6 species out of total 14. The other major outcome of the study was that maximum diversity was found at natural mangrove site with 13 species, followed by restored mangrove site with 10 species and least diversity was recorded at non-mangrove site with 9 species. In addition to this it is also

interesting to note that Grapsidae family species were found at the mangrove sites. The grapsid crabs are mainly herbivorous in nature..The mangroves with quite a lot of litter fall offer them a heaven and therefore grapsid diversity is more in mangroves (Tan and Ng 1994).

Table 18: Checklist of Brachyuran crabs recorded from Gulf of Khambhat

Species	Kamboi	Nada	Gandhar
Ocypodidae			
Uca (Austruca)lactea	+	+	+
Uca (Tubuca) dussumieri	+	+	+
Uca (Gelasimus) vocans		+	+
Matutidae			
Ashtoret lunaris	+	+	+
Portunidae			
Scylla serrata	+	+	+
Varunidae			
Metaplax indica		+	
Grapsidae			
Grapsus intermedius		+	+
Metapograpsus messor		+	
Sesarmidae			
Parasesarma plicatum	+	+	+
Macrophthalmidae			
Venitus dentipes		+	+
Macrophthalmus (Mareotis) depressus	+	+	+
Macrophthalmus dilatatus	+	+	

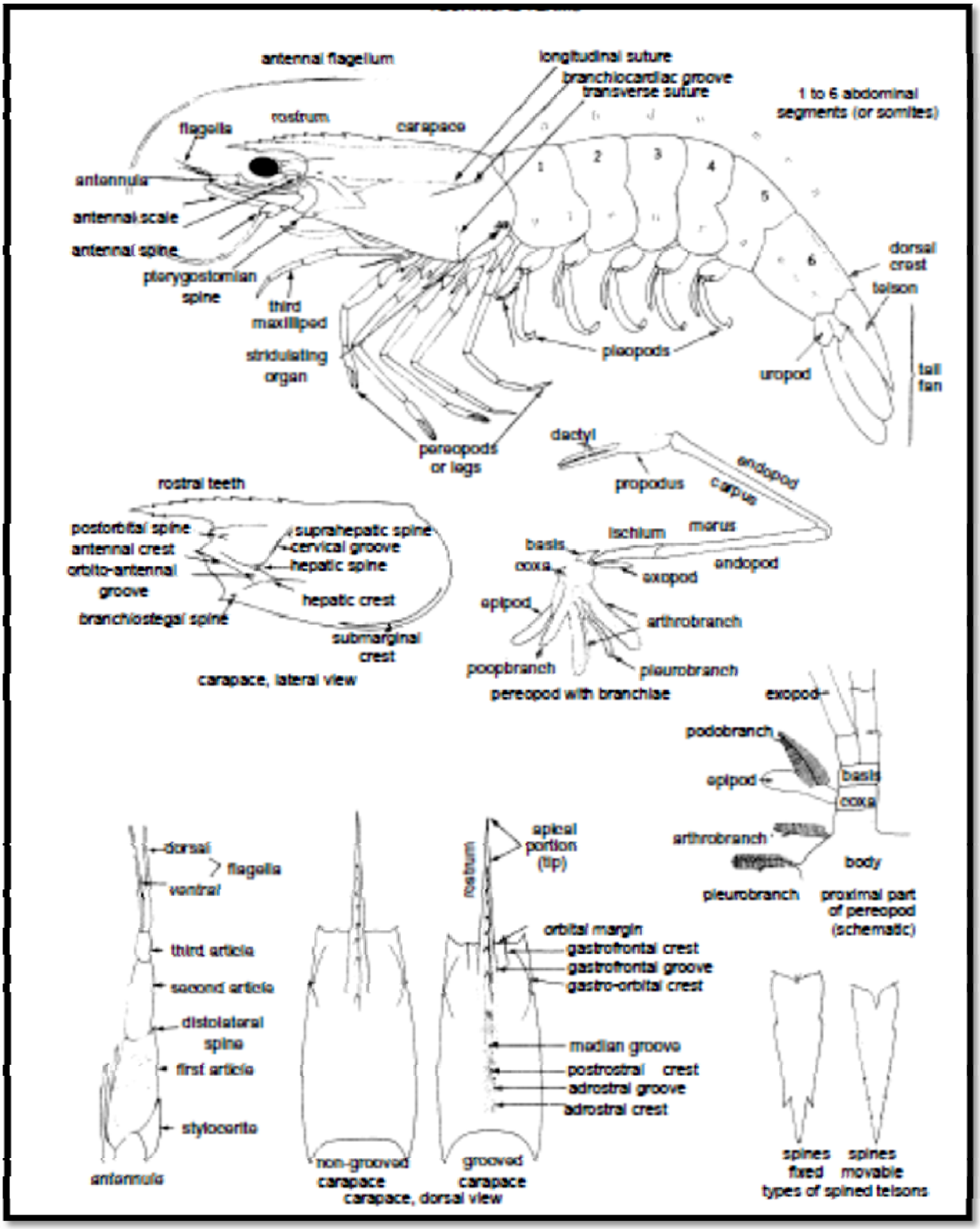
Gecarcinidae			
Cardisoma carnifex	+	+	+
Dotillidae			
Dotilla intermedia	+		

4.2.3 Prawns and Shrimps

Mangrove habitats are rich in shrimp and prawn resources. Commercial prawn fishery yields are greater in the coasts with luxuriant mangrove forests than where mangroves are absent. Mangrove leaf litter provides an important nutrient base for food webs. During the decomposition of mangrove litter, a large amount of nutrients are released, and detritus food is formed. This detritus food contributes to the prawn and shrimp fishery production. Mangrove waters serve as an essential nursery ground for juveniles of many species of prawns and shrimps. The out-welled detritus transported to offshore can also provide food and habitat for juvenile shrimps outside mangrove waterways. Thus the prawns/shrimps are highly associated with the mangrove ecosystems, leading to make a statement by ***Macnae (1968) – "No mangroves, so no prawns".*** The loss of mangrove habitats must have a serious impact on the densities of prawns/shrimps species.

The order – Decapoda comprises of commercially important species of prawns/shrimps, crabs and lobsters. This order comprises of about **1,100 genera** with about **8,321 species**, but the figure has been increasing year by year. According to Holthuis (1980), the prawns/shrimps include about **33** genera with about **2,500** species, of which less than 300 species are of economic interest throughout the world. Among the decapod crustaceans, penaeids constitute a distinct group of commercially important species. Due to their nutritional value, they support a very valuable, trade export market.

Plate 1: Technical terms and principal measurements used for Shrimps and Prawns



Taxonomy

Kingdom: Animalia

Phylum: Arthropoda

Class: Malacostraca

Order: Decapoda

(1) ***Metapenaeus dobsoni*** (Miers, 1878) (Prawn)

Family: Penaeidae

Genus:Metapenaeus

Length recorded: Maximum total length: Male 118 mm; female 130 mm. Color: Reddish brown spots scattered on semi-transparent body; rostrum, carapace and pleural edges deep brown; antennules and antennae dotted red; double rows of reddish spots on telson.

Description:

Body tomentose in patches; rostrum double curved with 8-9 dorsal teeth and no ventral teeth andextending a little beyond the tip of the antennular peduncle; spine on basis of third pair of walking legs in male long; no exopod on the fifth pair of walking legs; petasma is quite symmetrical with two long segments interlocked forming a compressed tube with paired spouts distally; thelycum with concave median tongue and in impregnated female with two conjointed triangular pads; coxa on fifth walking leg of either side articulating with a stump in mature females. The free filament of the distomedian projections of petasma on the dorsal aspect are well in adults. Impregnated females have conjoint white pads on the thelycum. All the legs are ciliated and the chelae weak. Strong spines present on the basis of all 3 pairs of chelipeds.

Spawning appears to take place at the sea bed and the eggs float at different depth levels. Breeding appears to take place almost round the year. Each individual prawn appears tobreed five times during its span of life.

The eggs measure about 0.40 mm. They hatch out as nauplii. The life history involves 3 nauplius stages, 3 protozoea stages, 3 mysis stages and 13

post-larval stages, passed in succession. The post-larvae enter the backwaters and estuaries in enormous numbers. After a period of stay in the estuarine environment the juveniles return back to the sea. They are known to stay but not beyond 80 mm length is attained in the brackish waters. Sexual maturity is attained only in the sea.

Ecology

Habitat: Demersal, Estuarine, Sandy, Muddy, Coastal

Trophic Level: Secondary Consumer

Prey: Diatoms, minute algal and other vegetable matter, copepods, foraminiferans and parts of crustaceans along with detritus

Predator: *Johnius dussumieri*

Common Name (s)

- Chingri (Hindi)
- Kadal Chemmeen (Hindi)
- Flower-tail Prawn
- Kadal shrimp (English)

(2) *Metapenaeus affinis*

Family: Penaeidae

Genus: Metapenaeus

Length recorded- Max size 180 mm

Description:

Body tomentose; rostrum more curved, less uptilted. Generally almost entire body pubescent, rarely partly or completely hairless; rostrum armed with 8 to 11 teeth along entire dorsal margin, slightly sinuous and reaching from proximal to distal margin of third antennular article, or exceeding it; postrostral ridge ending near posterior margin of carapace; adrostral crest ending behind second rostral tooth, and adrostral groove a little behind epigastric tooth; branchiocardiac ridge slightly sinuous and reaching posterior extension of hepatic spine; telson armed only with spinules and without marginal spines and shorter than endopod of uropod; ischial spine on first pereopod present or absent. In adult males, merus of fifth pereopod with a proximal notch, followed by a twisted,

keeled tubercle; distomedian projections of petasma crescent-shaped, leaning on distolateral projections and concealing them partly or completely; distolateral projections directed anterolaterally. In females, anterior plate of thelycum deeply grooved longitudinally and considerably wider posteriorly; posterior transverse ridge with 2 anterolateral rounded projections partly covering lateral plates; impregnated (fertilized).It is a heterosexual species.

Economic Importance: Commercial
(Fisheries, marketed mostly fresh and frozen; also canned, peeled and cooked, sundried or as paste or shrimp meal.)
Ecology
Habitat: Dermersal, Estuarine, Sandy, Muddy, Coastal
Predator: Johnius dussumieri, Otolithes cuvieri
Common Name (s)
Jinga Shrimp (English)
Jinga Prawn (English
Jinga (Hindi)
Indian Prawn (English)

(3) Penaeus monodon

Family: Penaeidae
Genus: Penaeus
Length recorded- Max size 180 mm
Color: Dark blue to almost black with dark bands across carapace and abdomen; pleopods and uropods tipped blue, a pair of broad dark bands on each abdominal somite. Pleopods fringed with bright red setae. Pattern of colour variable.
Description:
Rostrum with 7-8/2-3 teeth, usually 7/3 sigmoid in shape in juveniles and adults, surpassing antennular peduncle in length. Adrostral carina reaching almost to epigastric tooth. Post rostral carina often more or less with feeble indications of a sulcus, carina reaching almost to the posterior edge of carapace. Gastro-orbital carina occupying posterior one-third to half distance between post-orbital margin of carapace and hepatic spine. Hepatic carina prominent, anterior half horizontal, the posterior often diverging very slightly below horizontal axis; distinctly

separated from the base of antennal carina, which ends above middle of hepatic carina. Hepatic sulcus not well defined. Ischial spine on 1st pereopod; no exopod on 5th pereopod.

In petasma, the median anterior lobe small, separated from the laterals by a shallow notch, not projecting as far as lateral lobes. Lateral lobes without distal setae, but with distolateral irregular group of ossicles greatly variable in number. In thelycum, the length of anterior plate twice its breadth, anterior rounded portion concave, posterior bluntly pointed portion inserted between flaps of seminal receptacle for 2/5 of their length. Seminal receptacle circular; flaps forming turgid, reflected lips on mid line; with smooth inner edges in impregnated females.

Economic Importance: Commercial (Fisheries)

Ecology

Habitat: Pelagic,Dermersal,Estuarine,Sandy,Coastal

Prey: Harpacticoid copepods, parts of brachyurans, mulluscs, parts of fish, polychaetes and vegetable matter.

Common Name: Jumbo Tiger Prawn

(4) *Parapenaeopsis sculptilis*

Family: Penaeidae

Genus: Parapenaeopsis

Length recorded: 150-170 mm TL.

Color: Whitish bands edged pink on carapace and abdomen; appendages, pink

Description:

Rostrum with 6-8 teeth, epigastric tooth either feeble or absent; in males reaching upto 2nd segment of antennular peduncle with teeth spreading upto the tip while in females with its edentate tip reaching beyond the antennular peduncle. Antennal spine large, the carina reaching half distance between spine and hepatic spine; hepatic carina distinct only for lower 1/2 sulcus, starting below hepatic spine and running towards sharp pterygostomial angle. Epipodites present on 1st and 2nd pereopods, ischial spines absent. In petasma, the two halves form a compressed tube with paired apical spout-like projections directed anterolaterally and opening ventrally, distance between their apices almost equal to that of distolateral projections, which is 2/5 total length of petasma. Petasma

constricted at 0.7 its length; a pair of very large prominent lateral proximal projections, slightly curved dorsally, ending posteriorly in knob-like processes.

Abdomen Dorsally carinated from middle of 4th somite, carinae of 4th and 5th ending in angular, sometimes very minutely spinuous projections, that of 6th ending in a large spine. The third and anterior 4th somite with feeble dorsal sulcus or flat topped strip indicating its position, often present on 1st and 2nd somites also. Thelycum has its anterior plate slightly concave; with 2 low tubercles on posterior edge separated by shallow median depression and articulating with corresponding pair of tubercles on rectangular posterior sternal plate, latter with tubercle bearing tuft of setae.

It is heterosexual and sexually dimorphic. Sexual maturity at 75 mm in length in both sexes.

Economic Importance: Commercial (Fisheries, marketed fresh, frozen, peeled and cooked or canned; also used as shrimp meal or shrimp paste).

Ecology
Habitat: Demersal, Estuarine, Sandy, Muddy
Trophic Level: Consumer
Prey: Molluscs
Common Name (s)
Shrimps (English)
Rainbow Shrimp (English)
Rangi chingri
Rainbow Prawn

(5) *Exopalaemon styliferus*

Taxonomy

Family: Palaemonidae
Genus: Exopalaemon
Length recorded: 90 mm TL; ovigerous females 68-86 mm.

Color: Whitish translucent, with distal part of rostrum dark reddish brown and some darker spots on tips of uropods and telson. Ovigerous females with large dark spots on first 4 abdominal pleura. Eggs of berried female are yellowish.

Description:

Rostrum armed with 5-7 teeth on basal crest, 1-3 dorsal subterminal teeth, and 6-10 ventral teeth; antennular peduncle with distolateral spine on basal segment barely over reaching adjacent distal margin of segment, free part of shorter branch of dorsolateral flagellum several times as long as fused part; and pereopod with dactylus no more than half as long as propodus. Four posterior abdominal somites not sharply carinate in dorsal mid-line.

Economic Importance: Commercial (Fisheries, marketed mainly fresh, dried or as shrimp paste.

Ecology

Habitat: Pelagic, Estuarine, Coastal

Common Name

Ghora Chingri

Roshna

Prawns and Shrimps diversity found at study site

In total five species of prawns belonging to two families were recorded during the study period (Fig.4.57). It was observed that mangrove rich areas showed more species diversity than non-mangrove area. The natural mangrove site Nada had also higher numbers of prawns and shrimps as compared to other two sites. At Nada site all 5 species were recorded, out of which 4 species belonging to penaeidae family and 1 species from Palaemonidae family. In case of Gandhar site 4 species were recorded belonging to Penaeidae family.The least diversity was recorded at kamboi site with only 3 species belonging to Penaeidae family were recorded (Table 19).

Table 19: List of penaeid and non-penaeid prawns found in study sites

Sr. No.	***Category***	***Genus/Species***	***Nada Site***	***Gandhar Site***	***Kamboi Site***
1	*Penaeidae*	*Metapenaeopsis affinis (Milne Edwards) = M.mutatus (Lanch.)*	✓	✓	✓
2		*Metapenaeopsis dobsoni (Miers)*	✓	✓	✓
3		*Parapenaeopsis sculptilis (Heller)*	✓	✓	
4		*Penaeus monodon (Fabricius)*	✓	✓	✓
5	*Palaemonidae*	*Exopalaemon styliferus (Milne Edwards)*	✓		

4.2.4 Fishes

During the study following are the various species found at the study sites.

Kingdom: Animalia

Class: Actinopterygii

Order: Perciformes

(1) ***Odontamblyopus rubicundus***

Taxonomy
Family: Gobiidae
Genus: odontamblyopus
Common name: Rubicundus eelgoby
Meaning: *Odontamblyopus:* Greek, odous = teeth + Greek, amblys = darkness + Greek, pous = foot
Environment / Climate / Range Ecology
Marine; brackish; benthopelagic; amphidromous, Subtropical; 20°C - 30°C
Maximum length Recorded: 25.0 cm TL male
Distribution: Indo-West Pacific: India, Myanmar and Bangladesh.
Biology: Occurs in coastal waters and estuaries
Short description:

Dorsal Spines (total): 6; Dorsal soft rays (total): 34-41; Anal spines: 1; Anal soft rays: 32 - 39; Vertebrae: 27. Eyes rudimentary but distinct, covered by skin. Mouth oblique. Several short barbels may be present on underside of chin. Pectoral -fin rays free and silk-like. Three anal fin pterygiophores preceding first haemal spine. Cycloid scales embedded on head and body. Caudal fin very long.

(2) ***Taenioides anguillaris***

Taxonomy
Family: Gobiidae
Genus: Taenioides
Common name: Anguilla eelgoby
Meaning: *Taenioides:* Latin, taenia = stripe + Greek, oides = similar to
Environment / Climate / Range Ecology

Marine; freshwater; brackish; demersal; amphidromous.
Maximum length Recorded: 40.0 cm TL male
Distribution: Indo-Pacific: India, China, Malaysia, Indonesia and Papua New Guinea.
Biology: Found in estuaries, shallow coastal waters and rivers
Short description:

Dorsal Spines (total): 6; Dorsal soft rays (total): 40-47; Anal spines: 1; Anal soft rays: 37-44; Vertebrae: 30

(3) *Cynoglossus arel*

Taxonomy
Family: Cynoglossidae
Genus: Cynoglossus
Common name: Large scale tonguesole

Meaning: *Cynoglossus:* Greek, kyon = dog + Greek, odous = teeth + Greek, glossa = tongue

Environment / Climate / Range Ecology:

Marine; freshwater; brackish; demersal; amphidromous; depth range 9 - 125 m.

Length recorded : Max length : 40.0 cm TL male/unsexed;common length : 30.0 cm TL male/unsexed

Short description:

Dorsal spines (total): 0; Dorsal soft rays (total): 116-130; Anal spines: 0; Anal soft rays: 85 - 98; Vertebrae: 50 - 57. Eyed side uniform brown, with a dark patch on gill cover, blind side white. Body elongate, its depth 20 to 26% SL. Eyes with a small scaly interorbital space. Snout obtusely pointed. Rostral hook short. Corner of mouth reaching posteriorly to or beyond lower of eye, about midway between gill opening and tip of snout. Caudal-fin rays usually 10. Midlateral-line scales 56 to 70. Scales large, ctenoid on eyed side of body. Cycloid (smooth) on blind side. Scale rows between lateral lines on eyed side of body 7 to 9.

Distribution: Indo-West Pacific: Persian Gulf to Sri Lanka and Indonesia, north to southern Japan.

Inhabits muddy and sandy bottoms of the continental shelf down to 125 m. Enters estuaries and tidal rivers. Feeds predominantly on bottom-living invertebrates. Marketed mostly fresh and frozen; also dried-salted.

Threat to Humans: Harmless.

Human uses: Fisheries.

(4) *Arius maculatus*

Taxonomy
Family: Arridae
Genus: Arius
Common name: Spotted catfish, sea barbell, sea catfish.

Meaning: *Arius:* Greek, arios, areios = dealing with Mars, warlike, bellicose

Environment / Climate / Range Ecology: Marine; freshwater; brackish; demersal; potamodromous; depth range 50 - 100 m.

Length recorded: Max length: 80.0 cm TL male/unsexed; common length: 30.0 cm TL male/unsexed

Short description : Dorsal spines (total): 1; Dorsal soft rays (total): 7; Anal soft rays: 16 - 30. Head shield somewhat rugose; deep and long median fontanelle groove

Biology: Adults occurs in inshore waters and estuaries. Occasionally form schools. Feed on invertebrates and small fishes. Males incubate eggs in the mouth. Caught mainly with set bag nets and bamboo stake traps. Air bladders are exported as isinglass used by the wine industry. Strong venomous dorsal and pectoral spines provide protection for the fish

Distribution: Indo-West Pacific: off the west and east coast of India, Sri Lanka, Pakistan, Bangladesh, Myanmar to the Arafura Sea and the Indo-Australian Archipelago (excluding Australia).

Threat to Humans: Traumatogenic

Human uses: Fisheries

(5) *Tenualosa ilisha*

Taxonomy
Family: Clupeidae
Genus: Tenualosa
Common name: Hilsa shad, Chakshi, Chaksi, Chaski, Palla (in Guj), Hilsa (in Hindi)
Meaning:
Tenualosa: Latin, tenuis = thin + Latin, alausa = a fish cited by Ausonius and Latin, halec = pickle, dealing with the Greek word hals = salt; it is also the old Saxon name for shad = "alli"
Environment / Climate / Range Ecology: Marine; freshwater; brackish; pelagic-neritic; anadromous.
Length recorded: Max length: 60.0 cm SL male/unsexed; common length: 36.0 cm SL male/unsexed; common length: 42 cm TL (female)
Short description:

Dorsal spines (total): 0, Dorsal Soft rays (total): 18-21, Anal spines: 0, Anal soft rays: 18-23. Belly with 30-33 scutes. Distinct median notch in upper jaw. Gill rakers fine and numerous, about 100 to 250 on lower part of arch. Fins hyaline. A dark blotch behind gill opening, followed by a series of small spots along flank in juveniles. Color in life, silver shot with gold and purple.

Distribution: Indian Ocean: Persian Gulf eastward to Myanmar, including western and eastern coasts of India

Biology: Schooling in coastal waters and ascending rivers for as much as 1200 km (usually 50-100 km). Migration though is sometimes restricted by barrages. *Hilsa* far up the Ganges and other large rivers seem to be permanent river populations. Feeds on plankton, mainly by filtering, but apparently also by grubbing on muddy bottoms. Breeds mainly in rivers during the southwest monsoon (also from January to February to March). Artificial

propagation has been partially successful in India.Known to be a fast swimmer, covering 71 km in one day. Marketed fresh or dried-salted.

Threat to Humans: Harmless.

Human uses: Fisheries, minor commercial; aquaculture, experimental

(6) *Johnius macropterus*

Taxonomy
Family: Sciaenidae
Genus: Johnius
Common name: Largefin croaker
Environment / Climate / Range Ecology: Marine; demersal; depth range - 30 m. Tropical
Length recorded: Max length: 25.0 cm TL male/unsexed; (Ref. 3490); common length: 18.0 cm TL male/unsexed.
Short description : Dorsal spines (total): 11; Dorsal soft rays (total): 29-34; Anal spines: 2; Anal soft rays: 7
Distribution: Indo-West Pacific: India and Sri Lanka eastward to Thailand and Malaysia and south to New Guinea.
Biology: Found in shallow coastal waters. Feeds on benthic worms and small crustaceans. Sold fresh and dried salted in markets.
Threat to Humans: Harmless.
Human uses: Fisheries: commercial

(7) *Herklotsichthys quadrimaculatus*

Taxonomy
Family: Clupeidae
Genus: Herklotsichthys
Common name: Bluestripe herring (in Eng), Kanat (in Marathi)
Meaning: Herklotsichthys – After Janus Adrian Herklots, Australian ichthyologist, 1820-1872
Environment / Climate / Range Ecology: Marine; brackish; reef-associated; depth range 1 - 13 m. Tropical; 39°N - 33°S, 29°E - 178°W

Length recorded: Max length: 25.0 cm SL male/unsexed; common length: 10.0 cm SL male/unsexed.

Short description:

Dorsal spines (total): 0, Dorsal soft rays (total): 13-21, Anal Spines: 0, Anal soft rays: 12-23. Elongate wing-like scales underneath paired pre-dorsal scales separate it from all other species except *H. koningsbergeri* and Herklotsichthys Species A which has prominent black spots on the flank and Herklotsichthys Species B which has dusky tips to dorsal and caudal fins and lower gill rakers. Flank silvery with an electric blue line preceded by two orange spots located on each operculum.

Distribution:

Indo-West Pacific: widespread, East Africa, Madagascar, Mauritius eastward to Japan, eastern Australia, Samoa. Introduced into Hawaii - apparently by accident - where it is now abundant.

Biology:

Adults form schools near mangroves, shallow coastal bays and lagoons during the day and moves further offshore into deeper water by night. Known in mills around in large schools under wharves or along sandy beaches in protected bays. They are pelagic. Feeding occurs mainly at night on zooplankton, chiefly copepods by juveniles, and as adults, on larger prey organisms (chaetognaths, polychaetes, shrimps and small fishes). Breeding occurs on the first year and probably survive only a few months after maturity. Marketed fresh and dried salted. Usually parceled in leaves and baked in a motu oven. Do not recover quite as quickly as other species of baitfish after heavy fishing.

Human uses: Fisheries: minor commercial; bait: usually

Threats to Humans: Potential pest

(8) *Harpadon nehereus*

Taxonomy

Family: Synodontidae

Genus: Harpadon

Common name: Bombay-duck, Bumla, Gulchi (in Guj)

Meaning: *Harpadon:* Greek, arpedon, -es = net, bow, knot

Environment / Climate / Range Ecology: Marine; brackish; benthopelagic; oceanodromous.

Length recorded: Max length: 40.0 cm TL male/unsexed; common length: 25.0 cm TL male/unsexed.

Short description:

Dorsal spines (total): 0, Dorsal soft rays (total): 11-13, Anal spines: 0, Anal soft rays: 13-15. Scales restricted to posterior half of the body. Posterior tip of pectoral fin reaching origin of pelvic fin.

Distribution: Indo-West Pacific: Somalia to Papua New Guinea, north to Japan and south to Indonesia.

Biology:

Inhabit deep water offshore on sandy mud bottom for most of the year, but also gathers in large shoals in deltas of rivers to feed during monsoons. Spawn 6 batches of broods per year. An aggressive predator. Primarily caught along Maharashtra with the bag-net, better known as 'dol' net. Operation of this gear is timed to a strong tidal current. The bag with the mouth set against the current strains the fish which is being retained therein by the strength of the current. The net is thus retrieved before the tide turns. Very phosphorescent. Excellent food fish. Marketed fresh and dried or salted; consumed pan-fried.

Human uses: Fisheries: highly commercial

Threats to Humans: Harmless.

(9) *Coilia dussumieri*

Taxonomy

Family: Engraulidae

Genus: Coilia

Common name: Goldspotted grenadier anchovy (Eng), Mandeli (in Marathi).

Meaning: *Coilia:* Greek, koilia, -as = abdomen, hollow

Environment / Climate / Range Ecology:

Marine; freshwater; brackish; pelagic-neritic; amphidromous; depth range 0 - 50 m.

Length recorded: Max length: 20.0 cm SL male/unsexed; common length: 17.0 cm TL male/unsexed.

Short description: Dorsal spines (total):0, Anal spines: 0, anal soft rays: 80. Body tapering, belly rounded before pelvic fins, with 5 or 6 (rarely 4) +7 to 9= 12 to 15 keeled scutes from just behind pectoral fin base to anus. Maxilla short. Pectoral fin with 6 long filaments and 9 to 11 (rarely 8) branched fin rays. Flanks and belly with golden or pearly spots (light organs) in rows below scales, also along isthmus, edge of lower jaw, on cheek and gill cover.

Distribution: Indian Ocean: India from Bombay to Calcutta, probably also Myanmar, Thailand and Malaysia. Western Central Pacific: Thailand to Java, presumably also Kalimantan).

Biology: A coastal and estuarine species, occurring in fully saline water, but also able to tolerate lowered salinities, perhaps almost fresh water. Feeds on copepods, prawn and fish larvae, various unidentified crustaceans and cypris, also stomatopod larvae, mysids, polychaete larvae, isopods and *Sagitta*. The breeding season is perhaps extended; probably entering estuaries to breed. It is utilized as a food fish.

Human uses: Fisheries: commercial

Threats to Humans: Harmless.

(10) *Thryssa mystax*

Taxonomy

Family: Engraulidae

Genus: Thryssa

Common name: Moustached thryssa (English), Palli (Gujarati)

Meaning: *Thryssa:* Greek, thrissa, -es = shad

Environment / Climate / Range Ecology: Marine; brackish; pelagic-oceanic; oceanodromous; depth range 0 - 50 m.

Length recorded: Max length : 15.5 cm SL male/unsexed.

Short description: Dorsal spines (total): 0, Anal spines:0, Anal soft rays: 29-37. Belly with 24 to 32 keeled scutes from isthmus to anus. Tip of snout on a level with eye center. Maxilla long, reaching to or almost to base of first pectoral fin ray; first supra-maxilla oval, minute. Lower gill rakers with serrae on the inner edge even and not clumped. A dark blotch behind upper part of gill opening.

Distribution: Indo-West Pacific: western coast of India to Myanmar and south to Java, Indonesia.

Biology: Found in coastal pelagic waters and often observed as entering mangroves and adjacent brackish waters. Juveniles and adults may penetrate the upper reaches where mixohaline-mesohaline conditions prevail. Eggs and larvae are found in the lower reaches of the mangroves. A schooling species found mostly inshore. Feed on planktonic organisms in coastal waters. Juveniles in mangroves feed on larvae of shrimps and fish.

Human uses: Fisheries: commercial

Threats to Humans: Harmless.

(11) *Lepturacanthus savala*

Taxonomy

Family: Trichiuridae

Genus: Lepturacanthus

Common name: Savalai hairtail (English), Wagti (Marathi)

Meaning: *Lepturacanthus:* Greek, leptos = thin + Greek, oura = tail + Greek, akantha = thorn

Environment / Climate / Range Ecology: Marine; brackish; benthopelagic; amphidromous; depth range - 100 m.

Length recorded: Max length: 100.0 cm SL male/unsexed; common length: 70.0 cm SL male/unsexed

Short description: Dorsal Spines (total): 3-4, Dorsal soft rays (total): 110-120. Pelvic and caudal fins absent, anal fin reduced to spinules (about 75). Lateral line running nearer the ventral than the dorsal contour of the body.Color is steely blue with metallic reflections; the tapering part white. The margin of the anus pale; usually the margin of the caudal-fin membrane white; tip of both jaws black; the inside of the opercle and the anterior part of the shoulder girdle, pale black.

Distribution: Indo-West Pacific: India and Sri Lanka to Southeast Asia, north to China, and south to New Guinea and northern Australia.

Biology: Inhabits coastal waters and often comes near the surface at night. Feeds on a variety of small fishes and crustaceans. Caught mainly with shore seines, bagnets and coastal bottom trawls in Asian countries. Marketed fresh and iced as well as dried salted.

Human uses: Fisheries: commercial

Threats to Humans: Harmless

Fishes diversity found at study sites

In total 11 species were recorded from the study sites (Fig: 4.58). The highest diversity was recorded from Nada site with all 11 species being recorded whereas from Gandhar site 8 species were recorded and the least were recorded from Kamboi with 6 species. (Table 20)

Table 20: Fish species diversity at study sites

Sr. No.	Species	Nada	Gandhar	Kamboi
1	*Odontamblyopus rubicundus*	✓		
2	*Taenioides anguillaris*	✓		
3	*Tenualosa ilisha*	✓	✓	✓
4	*Herklotsichthys quadrimaculatus*	✓	✓	
5	*Harpadon nehereus*	✓	✓	✓
6	*Thryssa mystax*	✓	✓	✓
7	*Cynoglossus arel*	✓	✓	✓
8	*Arius maculates*	✓	✓	✓
9	*Johnius macropterus*	✓	✓	
10	*Lepturacanthus savala*	✓	✓	
11	*Coilia dussumieri*	✓		✓

4.2.5 Mudskippers

Mudskippers (Gobeedae: Oxudercinae) are the only fishes known to burrow and reside in the intertidal mudflats or mangrove swamps of the Indo-West Pacific region(Murdy,1989) and these fishes are uniquely adapted to a completely amphibious lifestyle (Graham, 1997). They are quiet active when out of water, feeding and interacting with one another, for example to defend their territories.

Compared to the fully aquatic gobies, these fishes have a range of peculiar behavioral and physiological adaptations to an amphibious lifestyle. These include: anatomical and behavioral adaptations that allow them to move effectively on land as well as in the water (Harris, 1961), the ability to breathe through their skin and the linning of their mouth (the mucosa) and throat (the pharynx) by means of cutaneous air breathing (Graham,1997), digging of deep burrows in soft sediments that allow the fish to thermo regulate (Tytler and Vaughan, 1983), avoid marine predators during the high tide when the fish and burrow are submerged (Sasekumar et at., 1984).

Distribution

Mudskippers are found distributed in temperate to tropical mudflats and mangrove forests along the east and the west coasts of India, besides Andaman and Nicobar islands, African coasts (Nigeria, Tanzania, Madagascar) Arabian Gulf, Pakistan, Sri Lanka, Bangladesh, Malaysia, Singapore, Indonesia, the Philippines, Thailand, China, Vietnam, Korea and Australia.

Burrow Dynamics

Habitat selection could play a major role in the maintenance of genetic polymorphism in natural populations (Powell and Taylor, 1979). Soil texture is an important factor determining the distribution of benthic organisms in general and mudskippers in particular.

Mudskippers build burrows the depth of which range from 50 to 150 cm with one or many entrances on the surface of the mudflats (Clayton and Vaughan, 1986; Ravi et al., 2004; Hong and Zhang, 2004). Similarly, Ishimatsu et al. (1998)

observed that these fishes construct burrows in the substrata of the high intertidal zone and transport air for storage in its burrow, which is always filled with water. In general, burrowing animals aerate the soil (Lavelle et al., 1995) and form a labyrinth of interconnected tubes through which water can flow possibly providing an extremely efficient pathway for the transfer of nutrients and oxygen besides many others across the swamp-bed interface (Ridd, 1996). Burrow also serves as an important refuge from piscivorous predators (Milward, 1974). Mudskippers build inside the burrow an egg chamber whose depth range from 20 to 30 cm beneath the surface of mudflats (Hong and Zhang, 2004). After spawning, the females leave the chamber and the male protects the eggs.

The following species of mudskipper were recorded from the study sites.

Kingdom: Animalia

Class: Actinopterygii

Order: Perciformes

(1)Scartelaos histophorus

Taxonomy

Family: Gobiidae

Genus: Scartelaos

Common Name: walking goby (English)

Environment: Marine; brackish; demersal; amphidromous

Maximum length Recorded: 14.0 cm SL male

Distribution: Indo-West Pacific: ranges from Pakistan to Japan and Australia. Known from the freshwater tidal zone of the Mekong

Biology: An intertidal species found on sand and mud flats along bay shores. Also in estuarine areas, swamps, marshy areas and on tidal mud flats. It is also found in the freshwater tidal zone .Actively shuttling back and forth between rock pools and air.

(2) ***Boleophthalmus dussumieri***

Taxonomy
Family: Gobiidae
Sub-family: Oxudercinae
Genus: Boleophthalmus
Common Name: Levti (Gujarat)
Meaning: Boleophthalmus Greek, bole-es= throw, cast + Greek ophthalmos
Environment: Marine, freshwater, brackish, demersal, amphidromous. Tropical
Maximum length Recorded: 18.7 cm TL male
Distribution: Indian Ocean: Iraq, Pakistan and India. Probably occurs in Bangladesh.
Biology: Amphibious air-breather .Lives on mud flats.

(3)***Periophthalmus waltoni Koumans***

Taxonomy
Family: Gobiidae
Sub-family: Oxudercinae
Genus: Periophthalmus
Common Name: Walton's mudskipper (English)
Meaning: *Periophthalmus:* Greek, peri = around + Greek, ophthalmos = eye
Environment: Marine; brackish; demersal
Maximum length Recorded: 15.0 cm TL male
Distribution: Western Indian Ocean: Persian Gulf to Pakistan.
Biology: Found on mud flats. Amphibious air-breather

(4) ***Apocryptes bato***

Taxonomy
Family: Gobiidae
Sub-family: Oxudercinae
Genus: Apocryptes
Common name: Gobi (English)
Meaning*: Apocryptes:* Greek word, apo = outside, far away, kryptos = hidden

Environment / Climate / Range Ecology: Marine; freshwater; brackish; demersal; amphidromous. Tropical; 23°C - 28°C

Maximum length Recorded: 26.0 cm TL male

Distribution: Indian Ocean: India, Bangladesh and Myanmar.

Biology: Found in rivers and estuarine

Table 21: Mudskipper species diversity at different study sites

Sr. No	Species	Nada Site	Gandhar Site	Kamboi Site
1.	***Scartelaos histophorus***	✓	✓	
2.	***Boleophthalmus dussumieri***	✓	✓	✓
3.	***Periophthalmus wa ltoni koumans***	✓	✓	✓
4.	***Aprocryptes bato***	✓		

In case of Mudskippers four different species were recorded during the study belonging to family Gobiidae (Fig.4.58). There have been no previous records of four species of mudskippers being recorded from Gulf of Khambhat. In case of Nada all the four species were recorded whereas in case of gandhar 3 species were recorded and the least 2 species were recorded from Kamboi. (Table: 21)

4.2.6 Reptiles

The biodiversity of reptiles found in mangrove ecosystems has received less attention. Reptiles also play a major role in the food chain of mangrove ecosystem. 25 species of reptiles were reported from the south east Asian countries mangroves, while 39 reptiles were reported by Kathiresan and Rajendran (2000) from east coast of India.

During the present study following species of reptiles were found at the study sites.

(1) Dog faced water snake (Cerebrus rynchops)

Family: Colubridae

It is easily observed in mangrove streams at night when it emerges from hiding to hunt for fish. Being largely aquatic, its eyes are situated on the top of the head such that it is able to see above the water with the rest of the body submerged. Although it has venomous fangs in the rear of the head, the poison is mild and has not caused death. C. rynchops is commonly found in mangrove mudflats, streams, ponds, tidal pools on algae patches, and has even been found burrowing into the mud. C. rynchops is rear-fanged and is mildly venomous. An aquatic and nocturnal snake, it feeds mainly on fish and is known to consume eels.

In captivity, it is observed to move in a sidewinding direction on land. It also has a prehensile tail that would suggest it could climb mangrove trees. It is now known to give birth to live young, numbering from 8 to 30, either in water or on land.

(2) Glossy marsh Snake (*Gerarda prevostiana*)

Family: Homalopsidae

Common names: Cat-eyed fishing snake, cat-eyed water snake, Gerard's water snake.

Distribution - Found in all coastal areas, mangroves and tidal rivers.

Status - Common in its distribution areas.

Glossy Marsh is a nocturnal snake and often seen during day time in coastal areas. It remains hidden in holes situated in mud. Lives in mangroves, estuaries

and coastal parts. It can also be seen a few kilometers away from the sea coast. Feeds on a variety of aquatic animals like freshly moulted Crabs, Fishes, Mud-skippers etc. Often observed catching its prey in their mound or holes. This is one of the few species in the world who feeds on selective parts of its prey. If a Crab is bigger and hard to eat entirely, it breaks the Crab's limbs and chooses the nutritious middle body part only. It is a gentle species and chances of getting bitten are very less. When encountered, it always tries to escape in encounter.

Reptilian diversity found at study site

During the study period, both the snakes were seen at Nada site, whereas from Gandhar site Gerarda prevostiana was only seen. In case of Kamboi both the snakes were not recorded during the entire study period. (Fig.4.57)

4.2.7 Avian fauna found at study sites

- **Family : Ardeidae**

  Species: Herons, Egrets

Long legged, lanky wading birds, with long slender flexible necks, which are retracted into a flat's' during flight. Bill long, sharp-pointed and dagger-like. Tarsi very long. Toes long and slender, the middle and outer toes united by a small web at their base, claw of middle toe pectinate. Most species have curious power-down patches on each side of rump and breast providing a sort of dry shampoo for degreasing soiled feathers. Plumage soft and loose-featured, usually white, grey, purple (or) brown. In many species filamentous ornamental plumes acquired during the breeding season.

- **Family : Charadriidae**

  Species : Lapwings, Plover.

Body compact, stocky,thick-necked shore birds. Bill short, thick, eyes large. Lapwings wings broad, rounded, tail black with a sub-terminal (or) terminal band-crests, facial wattles and wings. Spurns present. Plovers smaller than lapwings, legs shorter, wings longer narrower, more pointed, fly faster.

Crests, facial wattles (or) wing spurns absent. Feeding habits typical; using a "Stop-Run-Peck" method. It's common in intertidal habitats and all types of water bodies.

- **Family : Laridae**

  Species: Gulls, Terns

Gulls: Gregarious, heavy bodied aquatic birds. Plumage a combination of grey white and black. Bill slender to heavy sharply pointed (or) blunt and slightly hooked. Legs short feet webbed hallux small or vestigial. Wings long and pointed, tail square or forked. Sexes alike. Flight strong. Feed on by catching fish and crustaceans, scavenging on various animal and vegetable matters.

Terns: More lightly built than gulls, with longer, narrower wings and a different style of flight. They rest and roost on rocks (or) mud banks and in spite of their webbed feet rarely settle on water. They capture living prey such as fish, crabs by scooping it up from the surface in flight (or) diving vertically from the air and going under water momentarily.

- **Family : Ciconidae**

  Species: Storks

Large than herons, long legged, diurnal birds chiefly terrestrial and marsh haunting. Colour pattern mainly white and black with a metallic shinning. Bill long, massive, pointed, straight (or) nearly so and ungrooved. Wings long and broad. Tail short under tail coverts lax and greatly developed in some species. Stroks are strong filers, flying with neck and legs fully outstretched.

- **Family :Accipitridae**

  Species: Hawks, kites, Eagles.

Bill short with upper mandible longer than lower curved and strongly hooked at the tip. Basal portion covered with a cere, which is usually bright coloured. Wings rounded. Many species have confusingly different adult and juvenile plumage. Feed on the flesh of animals, self-killed or carrion.

- **Family : Alcedinidae**

  Species: Kingfishers

  Usually of green, blue, purple, brown (or) black and white plumage. Body compact neck. Short, bill massive, long, straight and pointed. Wings short and rounded. Sexes generally alike. Flight direct and swift. The aquatic farms feed on fish obtained by diving head long into the water the others live also in large insects and small vertebrates.

Table 22: Checklist of Avian fauna found at study sites

Family	Scientific Name (Common Name)	Nada	Gandhar	Kamboi
Phasianidae	*Francolinus pondicerianus (Grey Francolin)*	√	√	√
Phasianidae	*Pavo cristatus (Indian Peafowl)*	√	√	√
Anatidae	*Dendrocygna javanica (Lesser Whistling Duck)*	√	√	√
Anatidae	*Anser anser (Greylag Goose)*	√	√	√
Anatidae	*Tadorna ferruginea (Brahminy Duck)*	√	√	√
Anatidae	*Anas poecilorhyncha (Spot-billed Duck)*	√	√	√
Anatidae	*Sarkidiornis melanotos (Comb Duck)*	√	√	√
Upupidae	*Upupa epops (Common Hoopoe)*	√	√	√
Alcedinidae	*Halcyon smyrnensis (White-throated Kingfisher)*	√	√	√
Alcedinidae	*Ceryle rudis (Lesser Pied Kingfisher)*	√	√	√
Meropidae	*Merops orientalis (Small Green Bee-eater)*	√	√	√

Meropidae	*Merops phillippinis (Blue-tailed Bee-eater)*	√	√	√
Cuculidae	*Clamator jacobinus (Pied Cuckoo)*	√	√	√
Cuculidae	*Eudynamys scolopacea (Asian Koel)*	√	√	√
Cuculidae	*Centropus sinensis (Greater Coucal)*	√	√	√
Psittacidae	*Psittacula krameri (Rose-ringed Parakeet)*	√	√	√
Apodidae	*Apus affinis (House Swift)*	√	√	√
Strigidae	*Athene brama (Spotted Owlet)*	√	√	√
Columbidae	*Columba livia (Blue Rock Pigeon)*	√	√	√
Columbidae	*Streptopelia orientalis (Oriental Turtle Dove)*	√	√	√
Columbidae	*Streptopelia chinensis (Spotted Dove)*	√	√	√
Columbidae	*Streptopelia decaocto - (Eurasian Collared Dove)*	√	√	√
Columbidae	*Treron phoenicoptera (Yellow-footed Green Pigeon)*	√	√	√
Gruidae	*Grus grus (Common Crane)*	√	√	√
Rallidae	*Amaurornis phoenicurus (White-breasted Waterhen)*	√	√	√
Rallidae	*Porphyrio porphyrio (Purple Swamphen)*	√	√	√
Rallidae	*Fulica atra (Eurasian Coot)*	√	√	√

Rostratulidae	*Gallinago gallinago (Fantail Snipe)*	√	√	√
Scolopacidae	*Limosa limosa (Black-tailed Godwit)*	√	√	√
Scolopacidae	*Numenius arquata (Eurasian Curlew)*	√	√	√
Scolopacidae	*Tringa tetanus (Common Redshank)*	√	√	√
Scolopacidae	*Tringa stagnatilis (Marsh Sandpiper)*	√	√	√
Scolopacidae	*Tringa nebularia (Common Greenshank)*	√	√	√
Scolopacidae	*Tringa ochropus (Green Sandpiper)*	√	√	√
Scolopacidae	*Actitis hypoleucos (Common Sandpiper)*	√	√	√
Scolopacidae	*Calidris alba (Sanderling)*	√	√	√
Scolopacidae	*Calidris minuta (Little Stint)*	√	√	√
Scolopacidae	*Calidris ferruginea (Curlew Sandpiper)*	√	√	√
Burhinidae	*Esacus recurvirostris (Great Thick-knee)*	√	√	√
Recurvirostridae	*Himantopus himantopus (Black-winged Stilt)*	√	√	√
Charadriidae	*Vanellus indicus (Red-wattled Lapwing)*	√	√	√
Charadriidae	*Charadrius dubius (Little-ringed Plover)*	√	√	√
Charadriidae	*Charadrius alexandrines (Kentish Plover)*	√	√	√

Jacanidae	*Hydrophasianus chirurgus (Phesant-tailed Jacana)*	√	√	√
Jacanidae	*Metopidius indicus (Bronze-winged Jacana)*	√	√	√
Dromadidae	*Dromas ardeola (Crab Plover)*	√	√	√
Laridae	*Larus brunnicephalus (Brown-headed Gull)*	√	√	√
Laridae	*Larus ridibundus (Black-headed Gull)*	√	√	√
Laridae	*Larus genei (Slender-billed Gull)*	√	√	√
Laridae	*Larus cachinnans (Yellow-legged Gull)*	√	√	√
Laridae	*Gelochelidon nilotica (Gull-billed Tern)*	√	√	√
Laridae	*Sterna caspia (Caspian Tern)*	√	√	√
Laridae	*Sterna aurantia (River Tern)*	√	√	√
Laridae	*Sterna hirundo (Common Tern)*	√	√	√
Accipitridae	*Elanus caeruleus (Black-shouldered Kite)*	√	√	√
Accipitridae	*Milvus migrans (Black Kite)*	√	√	√
Accipitridae	*Haliastur Indus (Brahminy Kite)*	√	√	√
Accipitridae	*Circus aeruginosus (Eurasian Marsh Harrier)*	√	√	√
Accipitridae	*Circus pygargus (Montagu's Harrier)*	√	√	√

Accipitridae	*Accipiter badius* *(Shikra)*	√	√	√
Podicipedidae	*Tachybaptus ruficollis* *(Little Grebe)*	√	√	√
Phalacrocoracidae	*Phalacrocorax niger* *(Little Cormorant)*	√	√	√
Ardeidae	*Egretta garzetta* *(Little Egret)*	√	√	√
Ardeidae	*Egretta gularis* *(Western Reef Egret)*	√	√	√
Ardeidae	*Grey Heron*	√	√	√
Ardeidae	*Ardea purpurea* *(Purple Heron)*	√	√	√
Ardeidae	*Casmerodius albus* *(Great Egret)*	√	√	√
Ardeidae	*Mesophoyx intermedia* *(Intermediate Egret)*	√	√	√
Ardeidae	*Bubulcus ibis* *(Cattle Egret)*	√	√	√
Ardeidae	*Ardeola grayii* *(Indian Pond Heron)*	√	√	√
Ardeidae	*Nycticorax nycticorax* *(Black-crowned Night-Heron)*	√	√	√
Phoenicopteridae	*Phoenicopterus minor* *(Lesser Flamingo)*	√	√	√
Threskiornithidae	*Plegadis falcinellus* *(Glossy Ibis)*	√	√	√
Threskiornithidae	*Threskiornis melanocephalus* *(Black-headed Ibis)*	√	√	√
Threskiornithidae	*Pseudibis papillosa* *(Black Ibis)*	√	√	√

Threskiornithidae	*Platalea leucorodia (Eurasian Spoonbill)*	√	√	√
Pelecanidae	*Pelecanus onocrotalus (Great White Pelican)*	√	√	√
Ciconiidae	*Mycteria leucocephala (Painted Stork)*	√	√	√
Ciconiidae	*Anastomus oscitans (Asian Openbill)*	√	√	√
Ciconiidae	*Ciconia episcopus (White-necked Stork)*	√	√	√
Laniidae	*Lanius vittatus (Bay-backed Shrike)*	√	√	√
Corvinae	*Dendrocitta vagabunda (Indian Treepie)*	√	√	√
Corvinae	*Corvus splendens (House Crow)*	√	√	√
Corvinae	*Corvus macrorhynchos (Jungle Crow)*	√	√	√
Oriolidae	*Oriolus oriolus (Eurasian Golden Oriole)*	√	√	√
Dicrurinae	*Dicrurus macrocerus (Black Drongo)*	√	√	√
Muscicapidae	*Copsychus saularis (Oriental Magpie Robin)*	√	√	√
Muscicapidae	*Saxicoloides fulicata (Indian Robin)*	√	√	√
Muscicapidae	*Saxicola torquata (Common Stonechat)*	√	√	√
Muscicapidae	*Saxicola caprata (Pied Bushchat)*	√	√	√
Sturnidae	*Sturnus roseus (Rosy Starling)*	√	√	√

Sturnidae	*Acridotheres tristis (Common Myna)*	√	√	√
Sturnidae	*Acridotheres ginginianus (Bank Myna)*	√	√	√
Hirundinidae	*Hirundo concolor - (Dusky Crag Martin)*	√	√	√
Hirundinidae	*Hirundo rustica (Barn Swallow)*	√	√	√
Hirundinidae	*Hirundo smithii (Wire-tailed Swallow)*	√	√	√
Hirundinidae	*Hirundo daurica (Red-rumped Swallow)*	√	√	√
Pycnonotidae	*Pycnonotus leucotis (White-eared Bulbul)*	√	√	√
Pycnonotidae	*Pycnonotus cafer (Red-vented Bulbul)*	√	√	√
Cisticolidae	*Prinia socialis (Ashy Prinia)*	√	√	√
Cisticolidae	*Prinia inornata (Plain Prinia)*	√	√	√
Acrocephalidae	*Acrocephalus aedon (Thick-billed Warbler)*	√	√	√
Acrocephalidae	*Acrocephalus stentoreus (Indian Great Reed Warbler)*	√	√	√
Acrocephalidae	*Hippolais caligata (Booted Warbler)*	√	√	√
Cisticolidae	*Orthotomus sutorius (Common Tailorbird)*	√	√	√
Leiothrichidae	*Turdoides caudatus (Common Babbler)*	√	√	√
Leiothrichidae	*Turdoides malcolmi (Large Grey Babbler)*	√	√	√

Leiothrichidae	*Turdoides striatus (Jungle Babbler)*	√	√	√
Alaudidae	*Eremopterix nigriceps (Black-crowned Sparrow-Lark)*	√	√	√
Nectariniidae	*Nectarinia asiatica (Purple Sunbird)*	√	√	√
Passeridae	*Passer domesticus (House Sparrow)*	√	√	√
Motacillidae	*Motacilla alba (White Wagtail)*	√	√	√
Motacillidae	*Motacilla maderaspatensis (Large Pied Wagtail)*	√	√	√
Motacillidae	*Motacilla flava (Yellow Wagtail)*	√	√	√
Motacillidae	*Motacilla cinerea (Grey Wagtail)*	√	√	√
Motacillidae	*Anthus campestris (Tawny Pipit)*	√	√	√
Ploceidae	*Ploceus philippinus (Baya Weaver)*	√	√	√

Avian diversity found at the study sites

Over the period of 5 years study, nearly 118 avian species were recorded from the study sites. Wide varieties of birds were seen at the study sites (Fig: 4.59 &4.60). The maximum diversity was seen during winter season at all the three sites.

4.2.8 Mammals

Indo-Pacific Humpback Dolphin is the only mammal found during the study period at the study sites.

Kingdom : Animalia.
Class : Mammalia.
Order : Cetartiodactyla.
Family: delphinidae.
Genus : Sousa.
Scientific name : *Sousa chinensis.*

Description

The Indo-Pacific Humpback dolphin gets its name from the elongated dorsal fin and humped back appearance which arises from the accumulation of fatty tissue on their backs as they age. They also differ from other dolphin species in relation to their mounded forehead and long beaks.

Male and female Indo-Pacific Humpback Dolphins grow to a length of between 2.6m and 2.7m reaching physical maturity at around 14 years of age (sexual maturity occurs between the ages of 10 to 13 years). In the wild, these dolphins will live to around 40 years of age. Indo-Pacific Humpback dolphins can weigh up to 260kg but more commonly weigh around 200kg.

Skin colours will vary depending on location and age with calves being born grey and lightening with age (particularly the dorsal fin and forehead). Chinese dolphins turn pink as they age.

Distribution

Indo-Pacific Humpback dolphins are distributed from the coast of Africa, the Arabian Sea, Indian waters and beyond to the South China Sea. In Australia they inhabit the tropical waters of the west and east coasts and are classified as rare by the EPA and ‘near threatened, population decreasing’ by the IUCN red list of threatened species.

Habitat

Indo-Pacific Humpback dolphins prefer coastal and estuarine habitats in tropical and sub-tropical regions where waters are less than 20m deep. They are not known to be migratory.

Diet

The dolphins live on a diet of fish, prawns, molluscs, crabs, squid and octopus according to the location and season.

Behaviour

Indo-Pacific Humpback dolphins are more leisurely swimmers than some other dolphin species and do not as a rule surf bow waves. They swim in small pods of around five or so dolphins. Each pod is lead by an alpha male, or, on occasion, an alpha female. Males will have raking marks on their bodies from fights with other males over territory, and/or female members of its pod.

Observation

Indo-Pacific Humpback dolphins were found at the Nada and Gandhar sites during the high tides. They were seen in a group of 7 – 8. (Fig: 4.57)

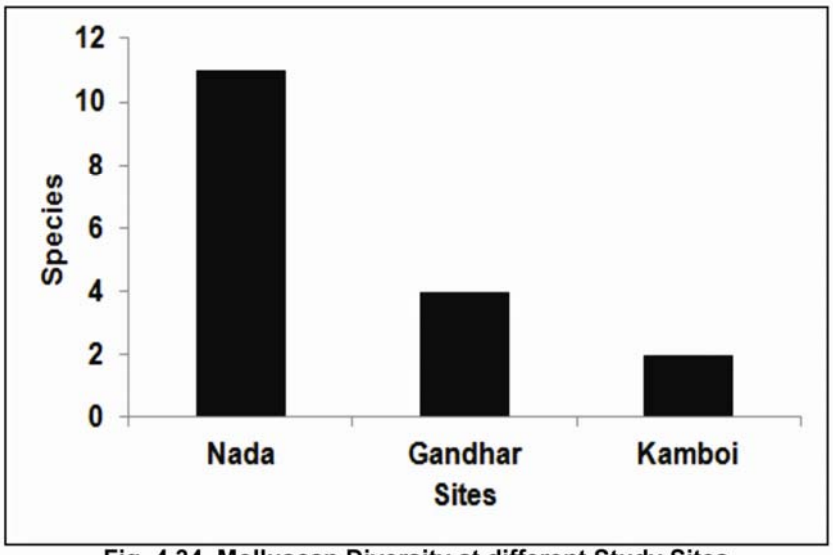


Fig. 4.34. Molluscan Diversity at different Study Sites

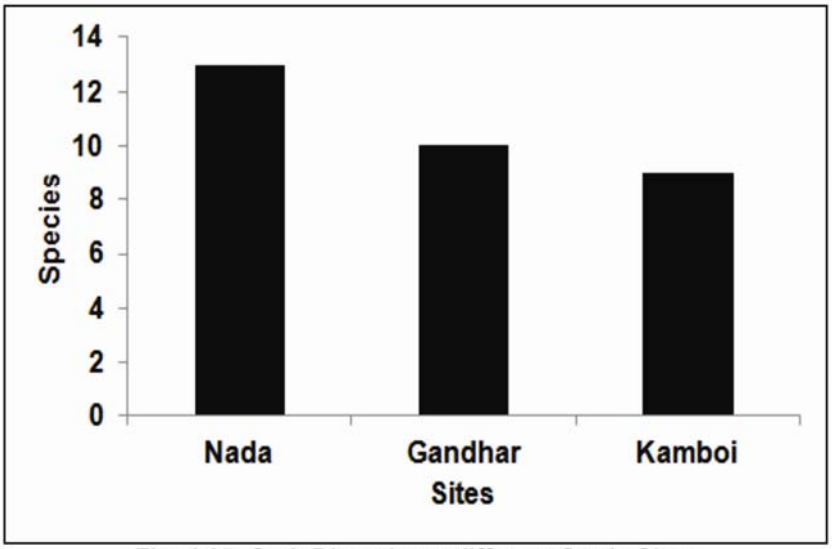


Fig. 4.35. Crab Diversity at different Study Sites

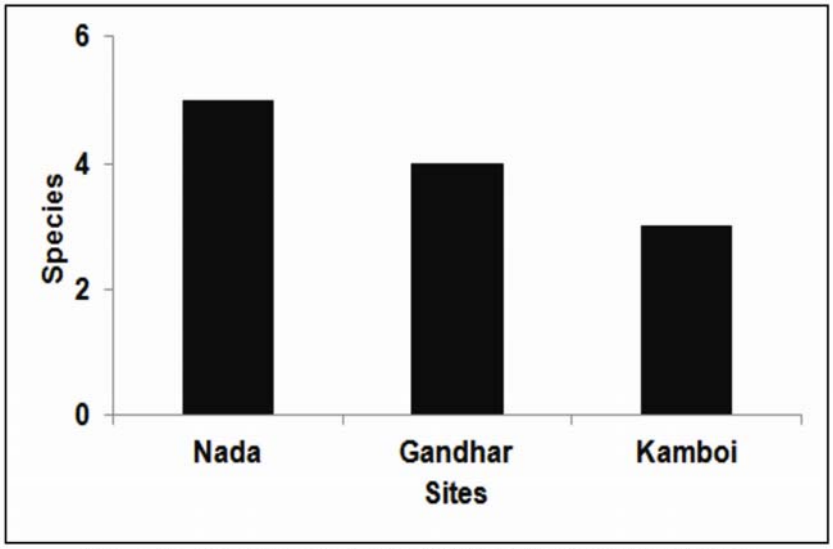


Fig. 4.36. Prawn/Shrimp Diversity at different Study Sites

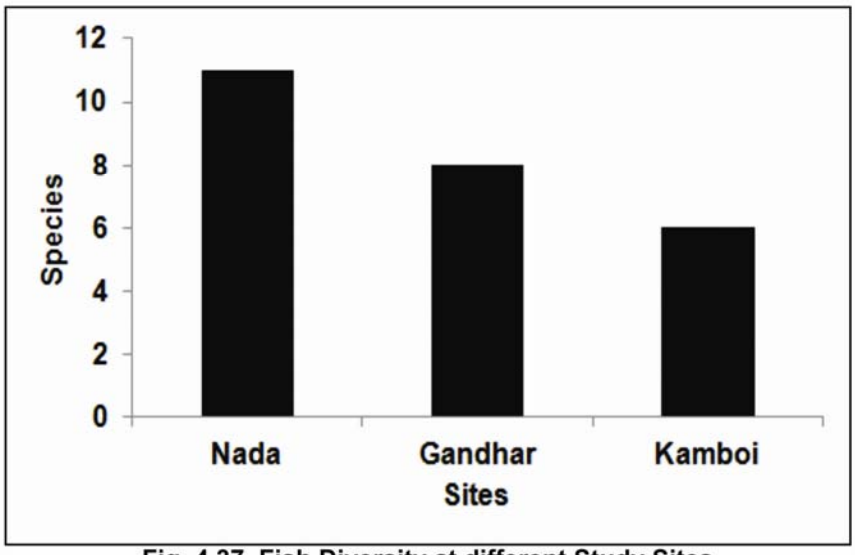


Fig. 4.37. Fish Diversity at different Study Sites

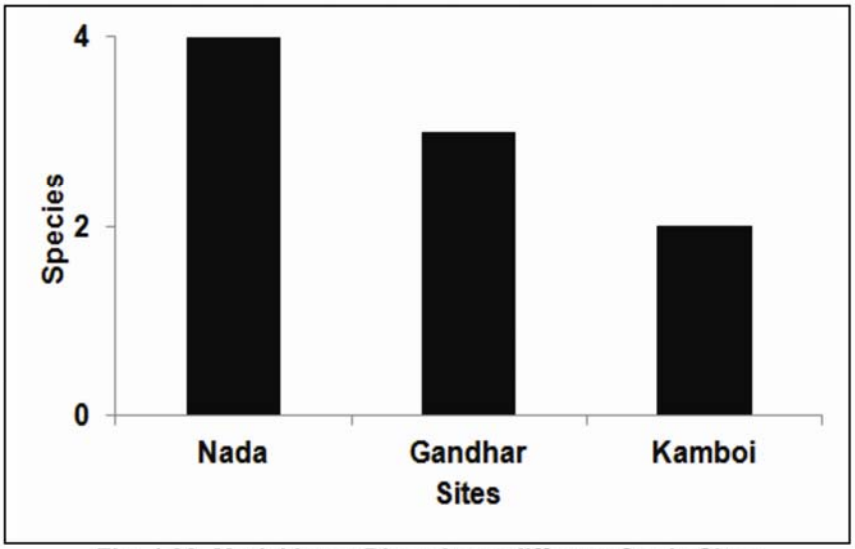


Fig. 4.38. Mudskipper Diversity at different Study Sites

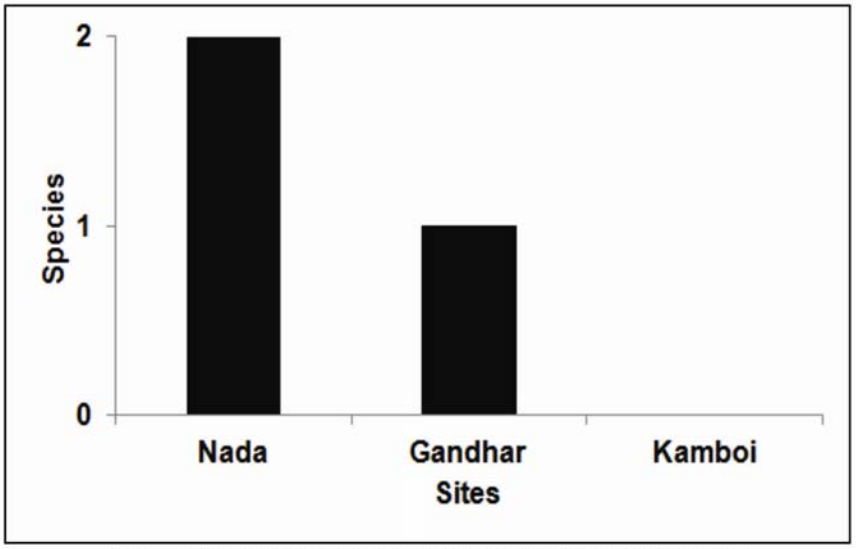


Fig. 4.39. Reptilian Diversity at different Study Sites

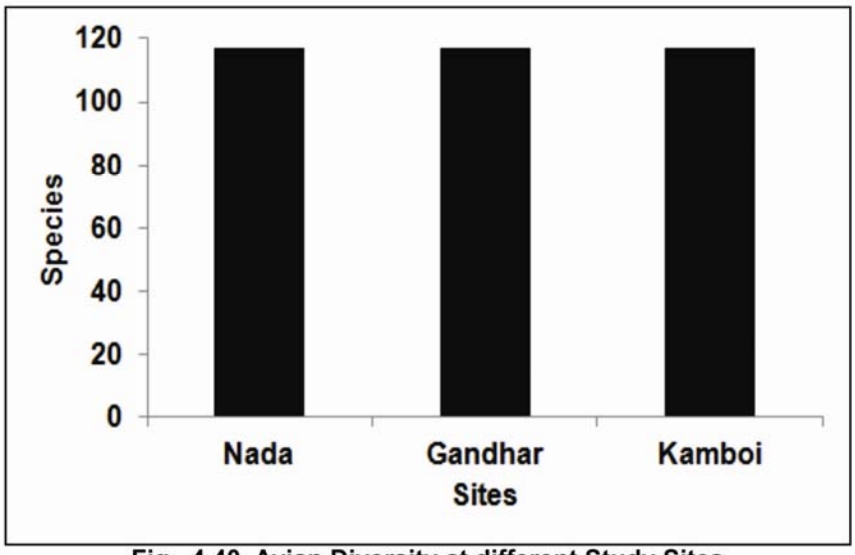


Fig. 4.40. Avian Diversity at different Study Sites

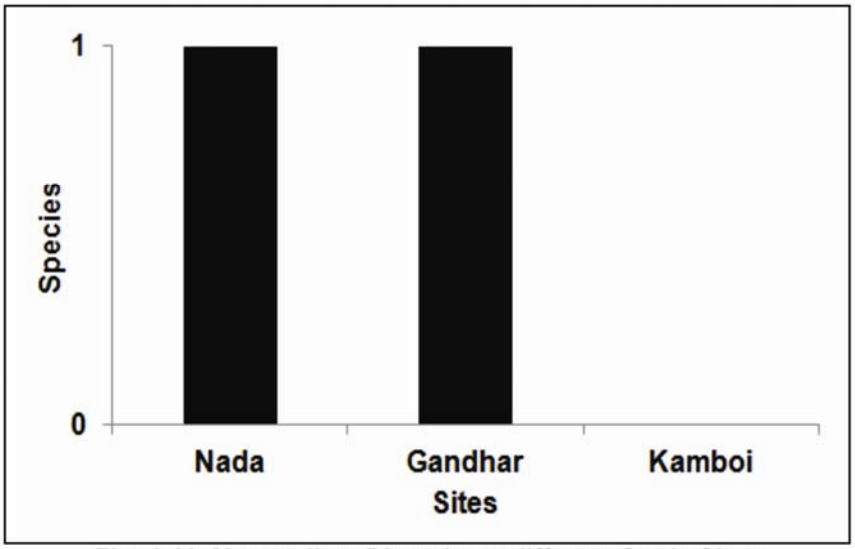


Fig. 4.41. Mammalian Diversity at different Study Sites

The vast majority of the nutrient pool of mangrove is stored in the soil and not in the trees. Mangrove soils of Nada and Gandhar are typically saline, anoxic, acidic compared to Kamboi site. The delivery of nutrients in sediments and water during tidal inundation and sporadically in provides significant sources of nutrients for mangroves. The high level of carbon allocation to roots in conjunction with mangrove litter fall and the low rates of decomposition imposed by anoxic soils results in mangrove ecosystems being rich in organic matter. Despite low rates of decomposition in anoxic soils, decomposition of mangrove vegetative material is also a major source of nutrients in the mangrove ecosystem, as well as for adjacent coastal ecosystems via tidal flushing. Topographic factors such as elevation determine the frequency and duration of tidal inundation, which subsequently affects the salinity, oxidation state and nutrient availability of the soil, resulting in complex patterns of nutrient demand and supply that contribute to the variable structure at Nada and Gandhar site.

The redox state of the soil surrounding the mangrove roots is important for determining the nutrients available for plant uptake. In conjunction with the frequency and intensity of inundation, the redox state of soils is also influenced by the biota, particularly by bioturbation (e.g., crab burrows) and the occurrence and abundance of mangrove roots. Radial oxygen loss from the roots creates an aerobic zone in the area immediately adjacent to the roots, which may vary in extent .Thus; the redox state of the soil can be highly heterogeneous, facilitating a plethora of biogeochemical processes, which influence nutrient availability.

Due to the above major reasons the difference in the faunal diversity seems to have been there between mangrove sites (Nada& Gandhar) and Non-mangrove site (Kamboi).

In the present study, three major groups have been focused for quantification that includes mudskipper, crabs and molluscs. The possible reason behind selecting these groups was the role played by these groups in the maintenance of mangrove ecosystem. All the three groups are benthic in nature and represent burrowing mode of living. The burrowing activity preformed by these three group increase the soil fertility and drives the nutrient cycle. The local community that is

direct dependant of the mangrove ecosystem mostly collects animals belong to these three groups.

The density (Fig. 4.42) and abundance (Fig. 4.43) of the mudskippers was observed high at Nada followed by Gandhar and Kamboi. Nada represent natural mangroves while Gandhar and Kamboi represent restored mangrove and no mangrove site respectively. The results revealed that different habitat types have great influence on the diversity and distribution of the benthic species. The frequency of occurrence (Fig. 4.44) of mudskipper showed great difference between mangrove and non mangrove sites. The results also revealed the density and abundance of the mudskipper species increased during the study period. Maximum density of mudskippers was observed in the year of 2011. The results of the Bray Curtis similarity showed that Gandhar and Nada sites that represents mangrove sites supports maximum and similar kind of mudskippers species diversity while Kamboi that is non mangrove sites supports less and different kind of mudskippers species diversity. (Fig: 4.45)

Brachyuran crabs are the integral part of mangrove ecosystems and play important role in food chain. The density (Fig. 4.46) and abundance (Fig. 4.47) of the brachyuran crab was observed high at Nada followed by Gandhar and Kamboi. The frequency of occurrence (Fig. 4.48) of brachyuran crab also showed great difference between mangrove and non mangrove sites. The result also revealed that the mangrove restoration cause significant effect on the density and abundance of the brachyuran crabs. Significant increases in terms of density and abundance of brachyuran crabs have been observed between the year of 2010 and 2011 at different study sites. The results of the Bray Curtis similarity showed that Gandhar and Nada sites contain similar kind of brachyuran crab diversity while Kamboi forms separated group.(Fig 4.49)

Molluscan species forms significant parts of mangrove benthic fauna. In the present study the results showed significant variations in case of different ecological attributes. The density (Fig. 4.50) and abundance (Fig. 4.51) of the Molluscan species were observed high at Nada followed by Gandhar and Kamboi. The frequency of occurrence (Fig. 4.52) of Molluscan species also showed difference between mangrove and non mangrove sites. The results of

the Bray Curtis similarity showed that Nada with maximum molluscan diversity was separate from the Gandhar and kamboi site which showed very less molluscan presence. (Fig. 4.53)

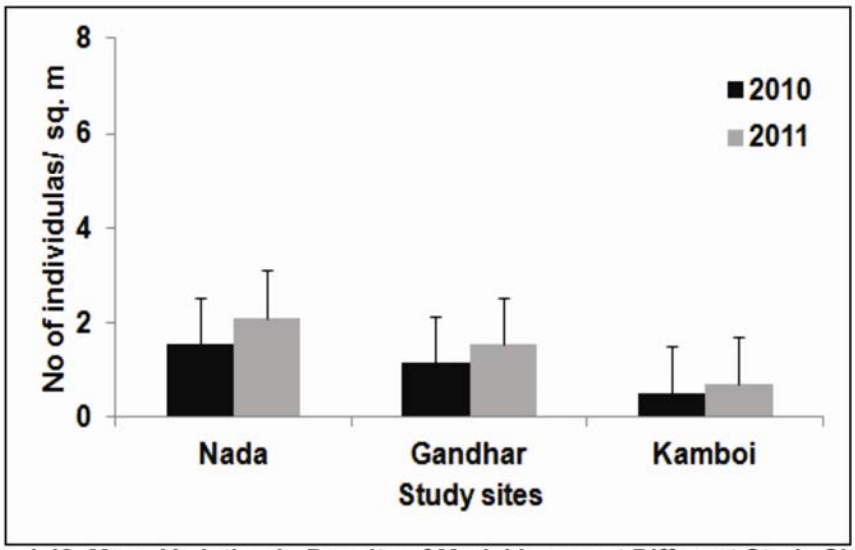


Fig. 4.42. Mean Variation in Density of Mudskippers at Different Study Sites

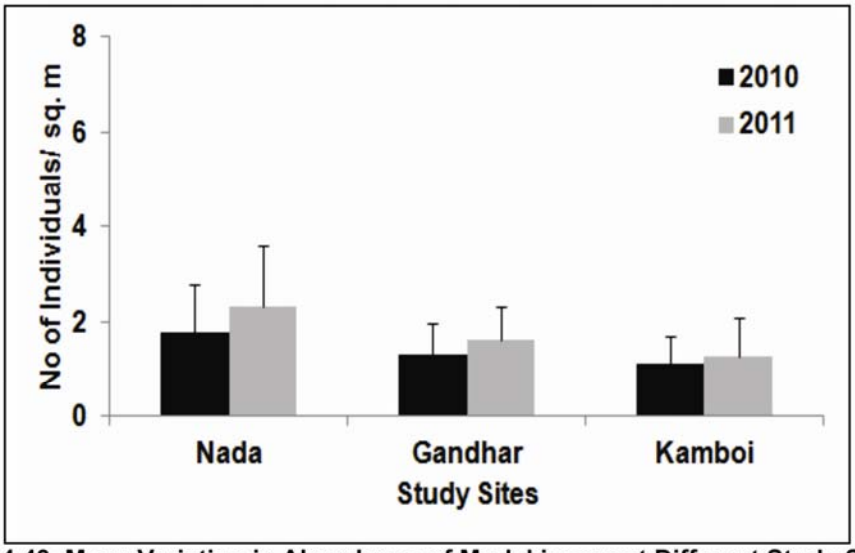


Fig. 4.43. Mean Variation in Abundance of Mudskippers at Different Study Sites

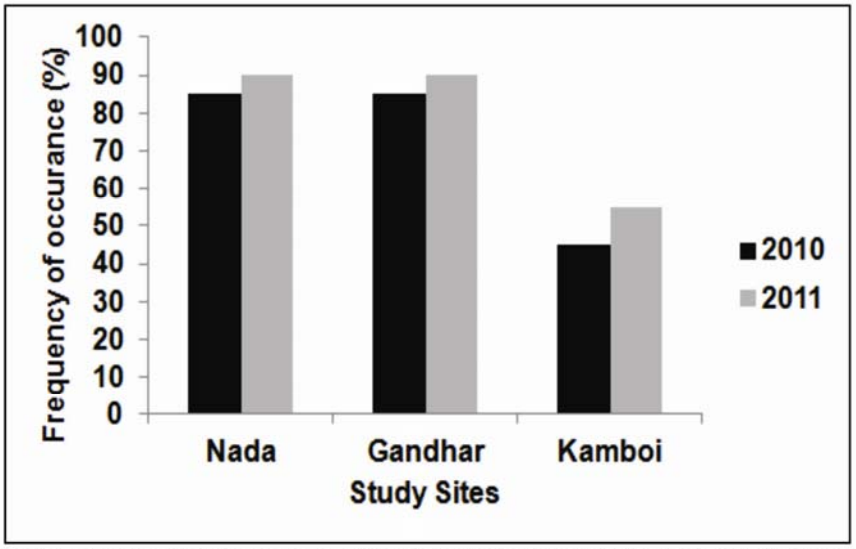


Fig. 4.44. Mean Variation in Frequency of Occurrence of Mudskippers at Different Study Sites

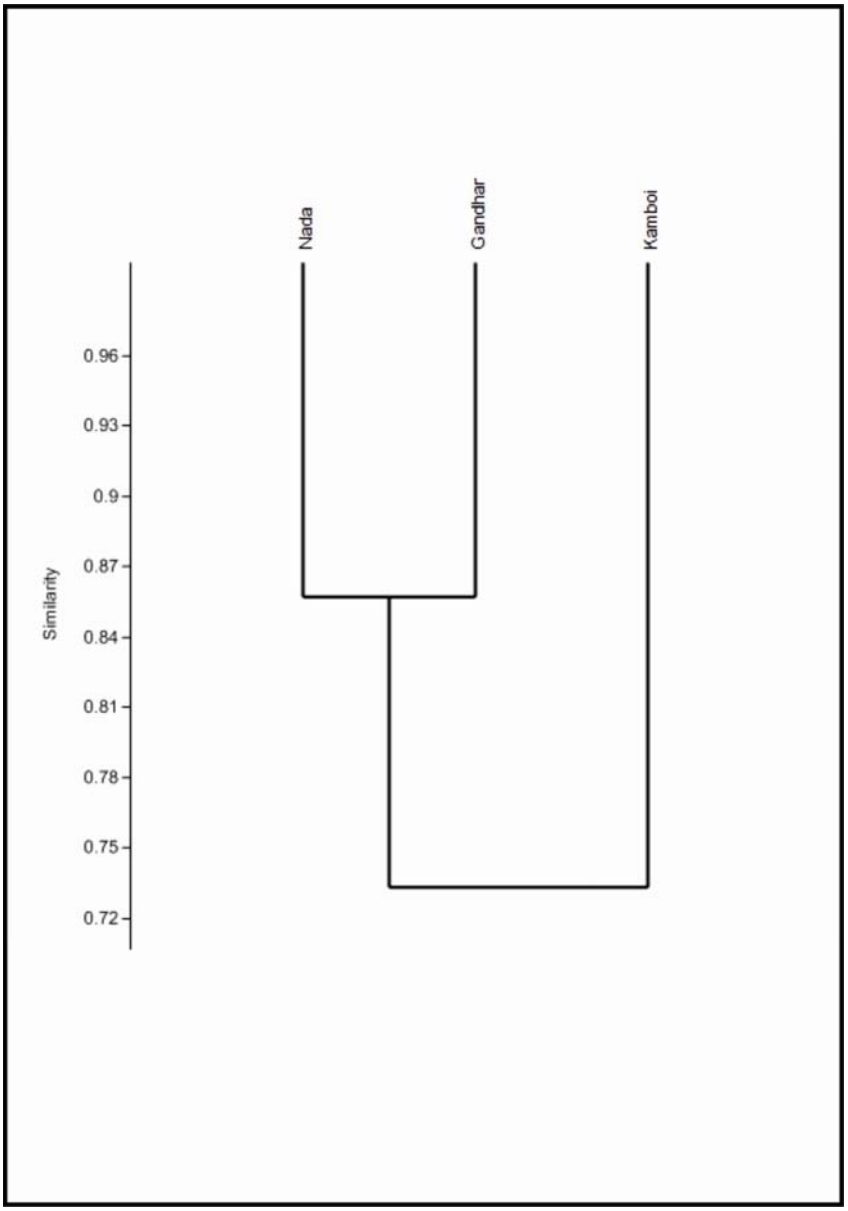


Fig.4.45- Bray- Curtis Similarity Indices for Mudskipper

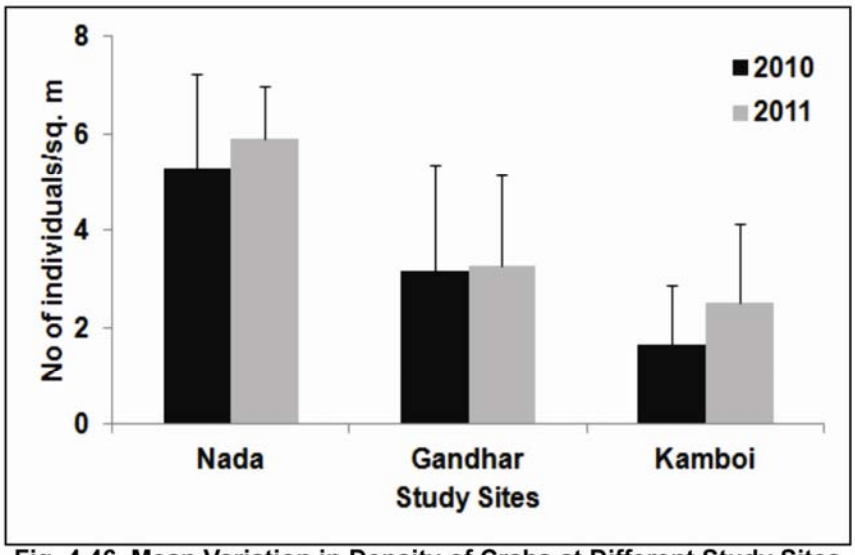


Fig. 4.46. Mean Variation in Density of Crabs at Different Study Sites

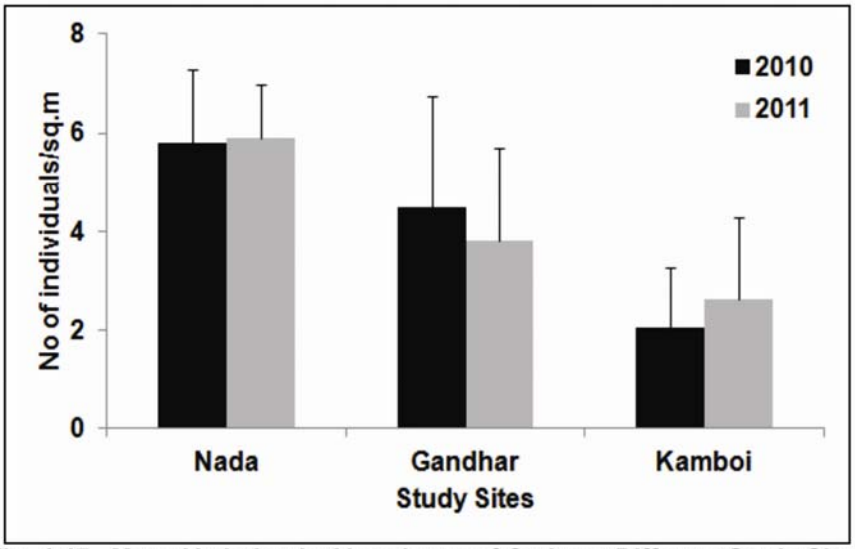


Fig. 4.47. Mean Variation in Abundance of Crabs at Different Study Sites

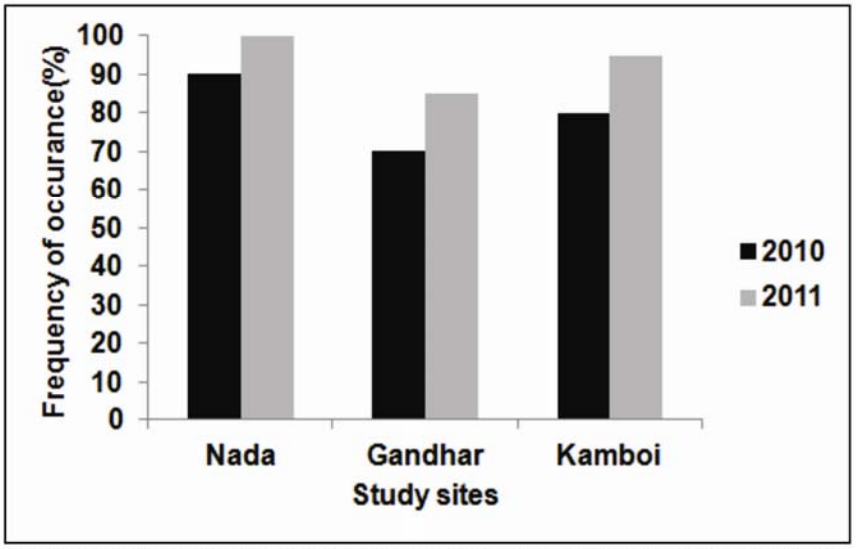


Fig. 4.48. Mean Variation in Frequency of Occurrence of Crabs at Different Study Sites

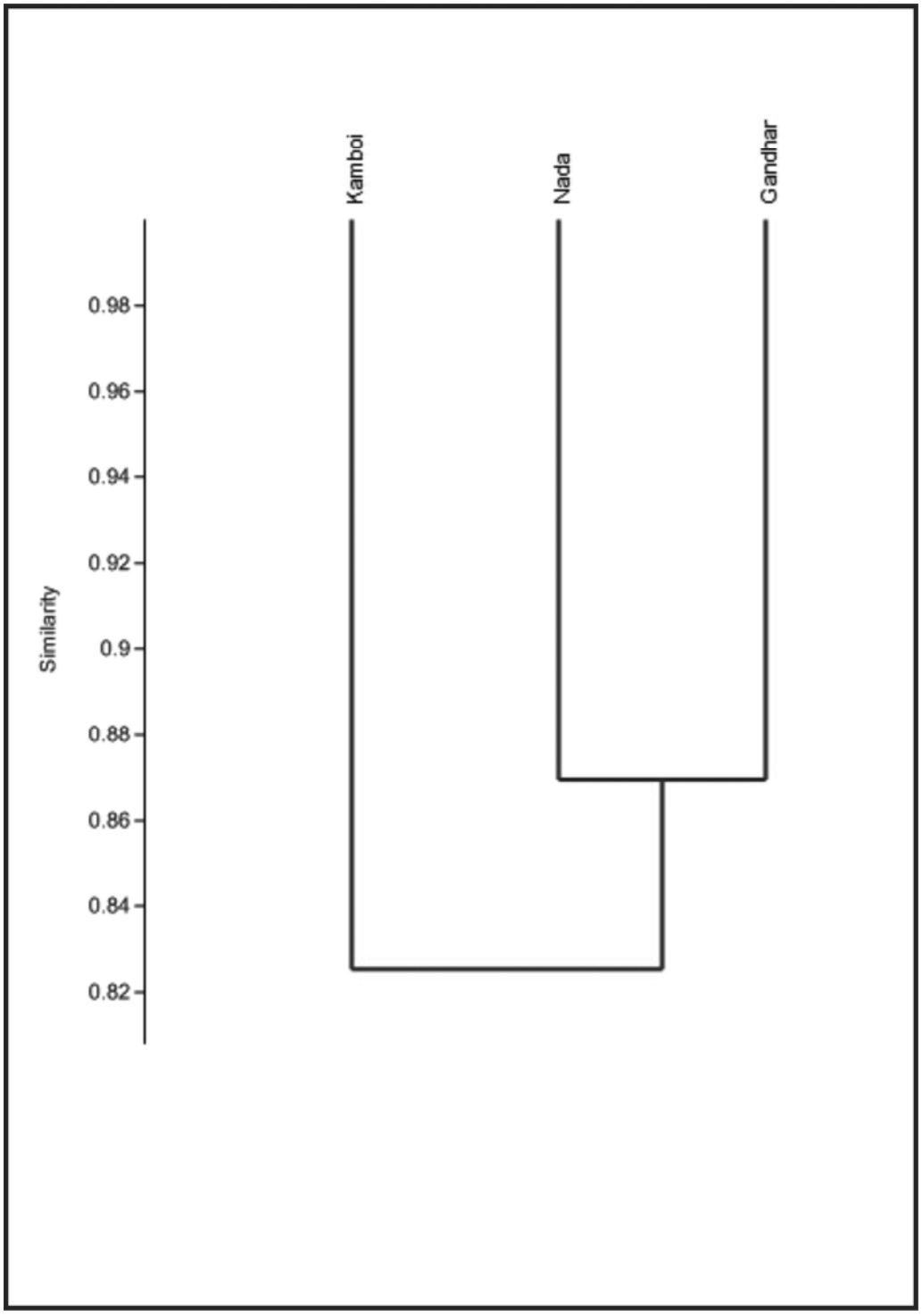


Fig.4.49 Bray- Curtis Similarity Indices for Crabs

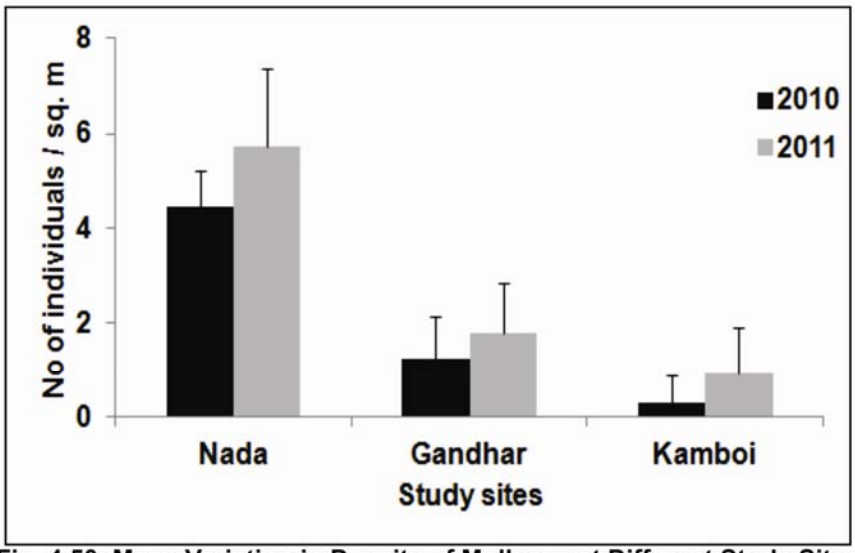


Fig. 4.50. Mean Variation in Density of Molluscs at Different Study Sites

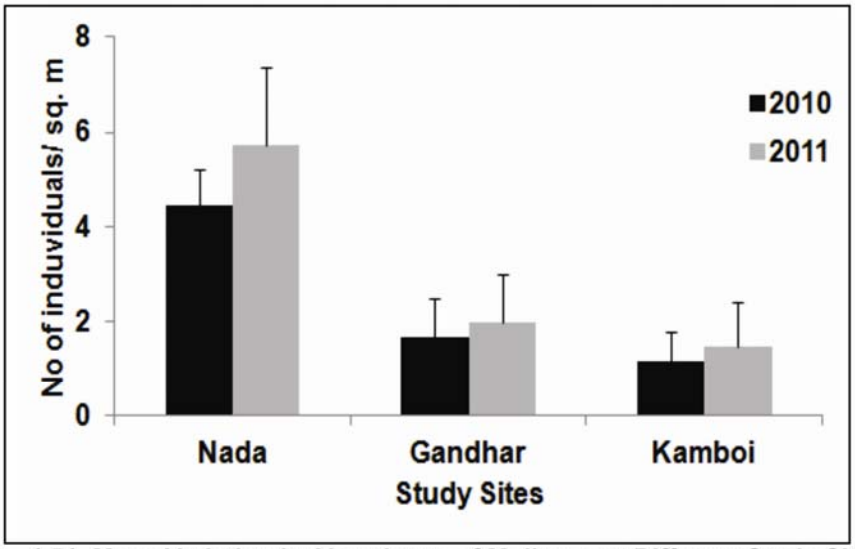


Fig. 4.51. Mean Variation in Abundance of Molluscs at Different Study Sites

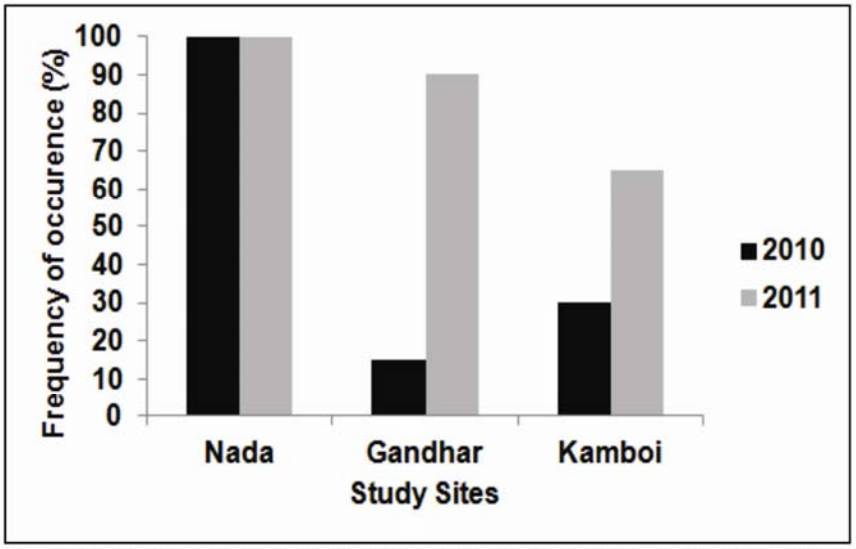


Fig. 4.52. Mean Variation in Frequency of Occurrence of Molluscs at Different Study Sites

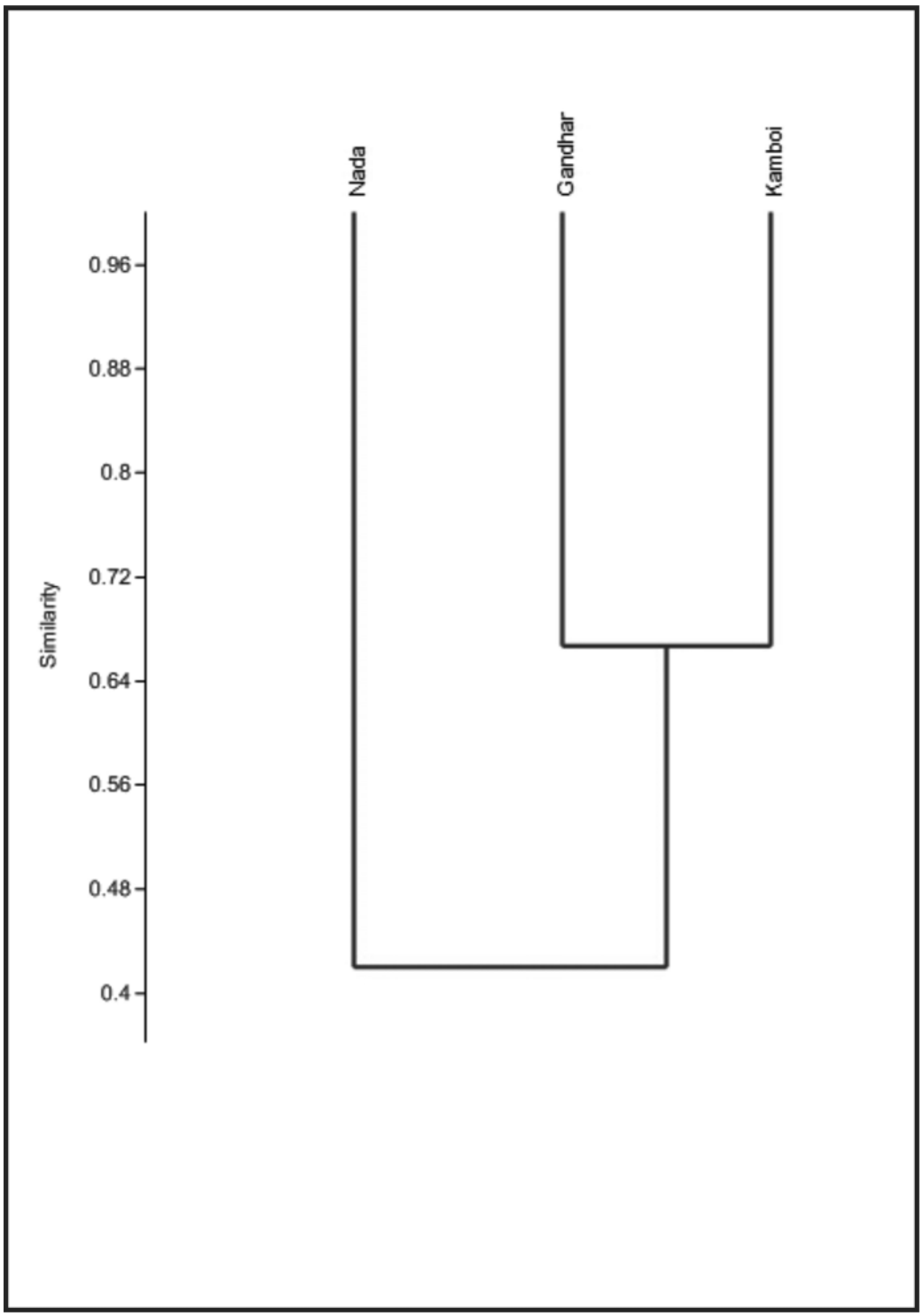


Fig. 4.53 Bray- Curtis Similarity Indices for Molluscs

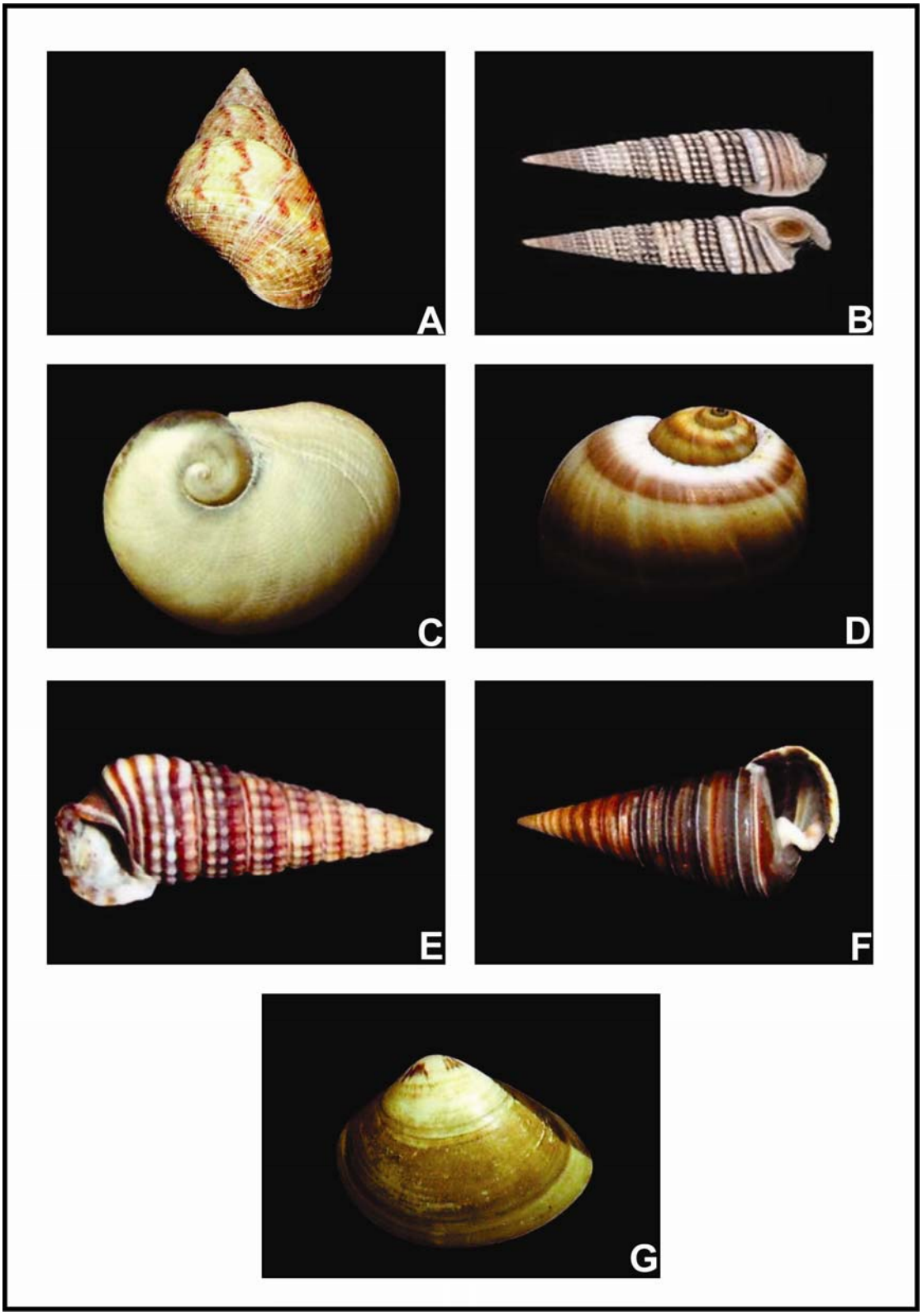


Figure: 4.54 Molluscan diversity found at the study sites

A- *Littorina undulate* **B-** *Cerithidea Cingulata* **C -** *Sinum haliotoideum*

D- *Natica Vitellus* **E-** *Nerita crepidularia* **F-***Telescopium telescopium*

G- *Meretrix meretrix*

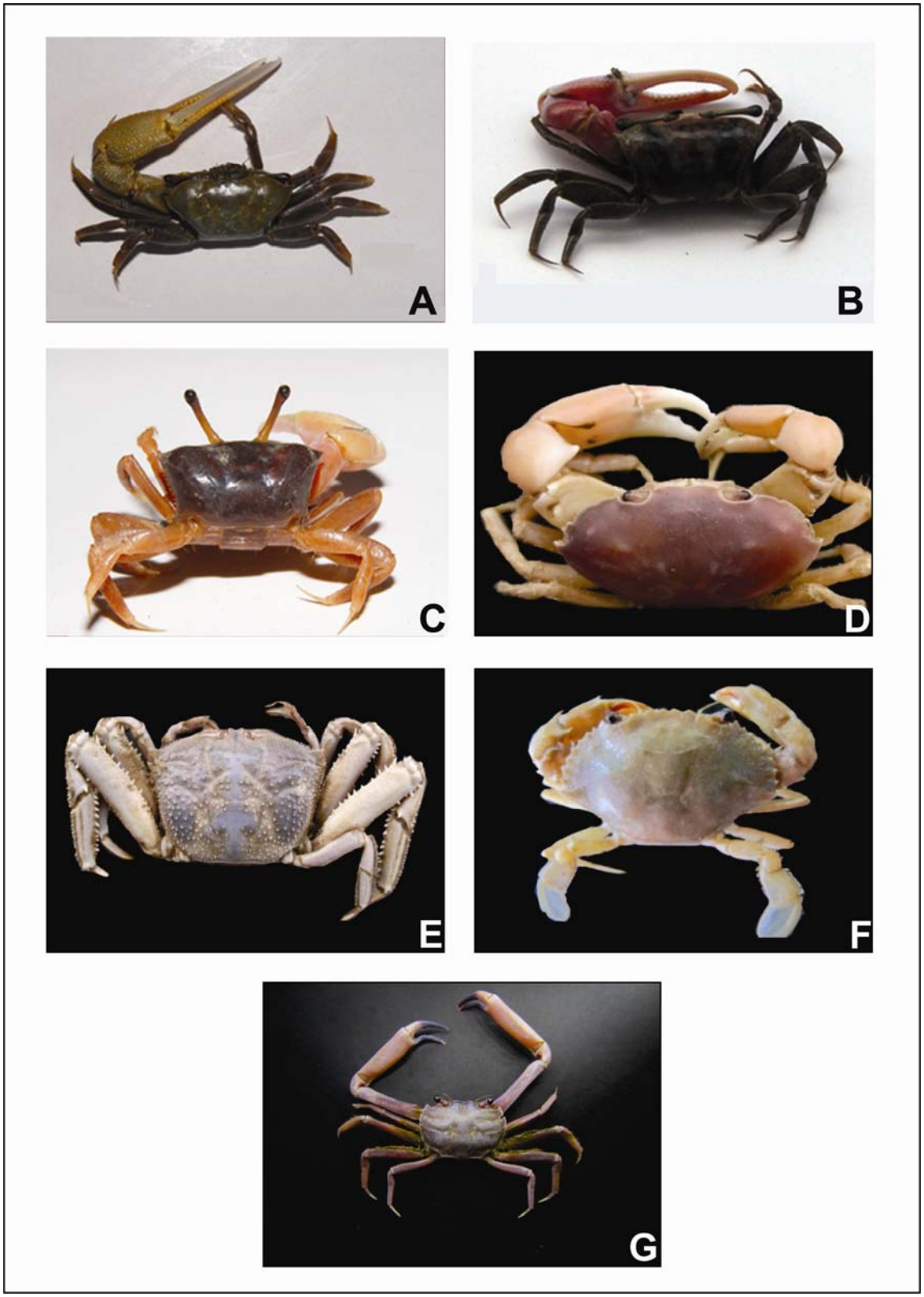


Figure: 4.55 Brachyuran crab diversity found during the study

A- *Uca dussumeiri* **B-***Uca lactuae* **C-** *Uca Vocans* **D-** *Cardisoma carnifex*

E- *Macropthalmus depressus* **F-** *Scylla serrata* **G-** *Metaplax indica*

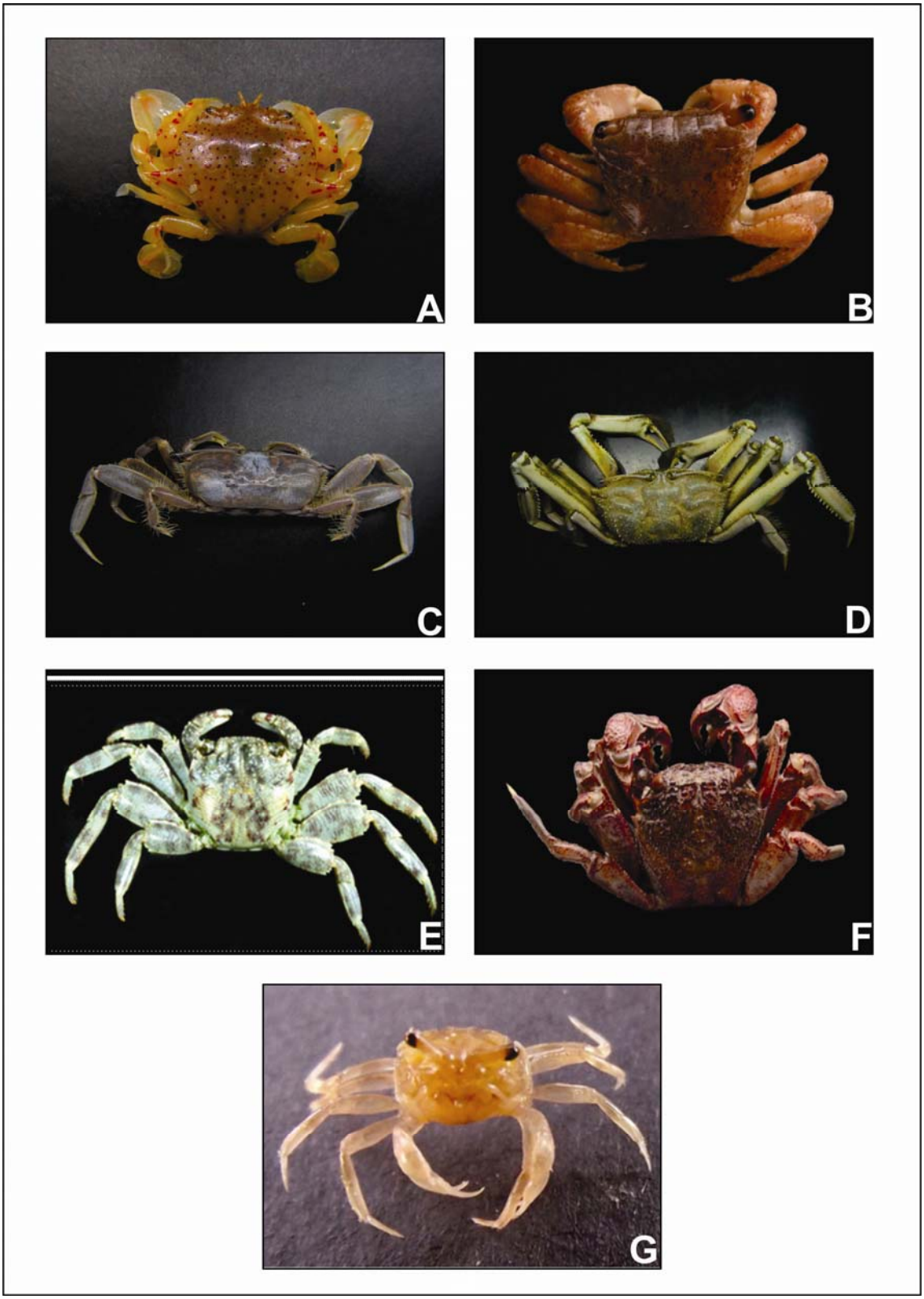


Figure: 4.56 Brachyuran crab diversity recorded during study

A- Ashtoret lunaris **B**- Parasesarma plicatum **C**- Macropthalmus dilatatus **D**- Venitus dentipes **E**- Grapsus intermedius **F**-Metapograpsus messor **G**-*Dotilla intermedia*

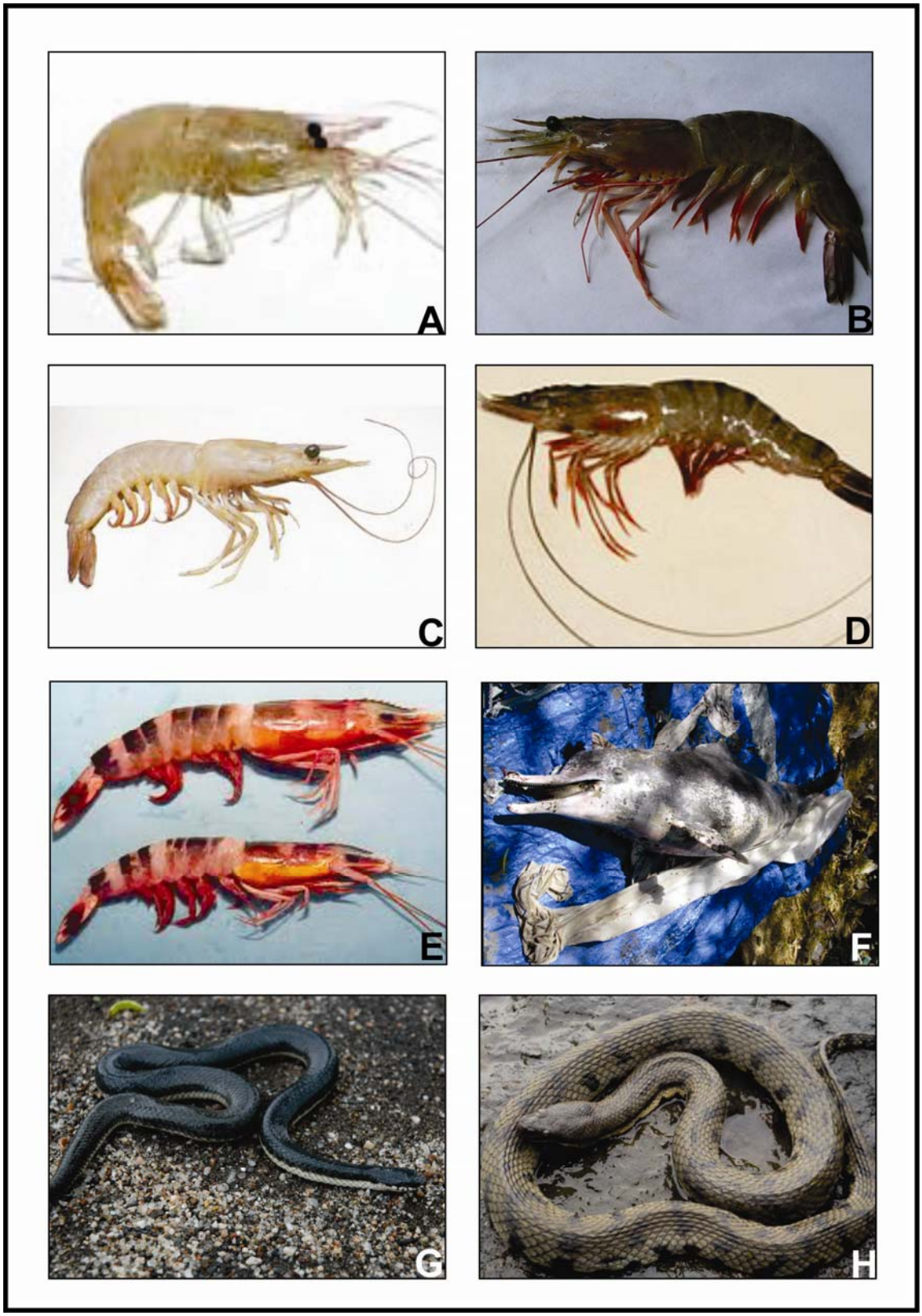


Figure: 4.57 Prawns, Reptiles and mammal found at study site
A: *Exopalaemon styliferus* **B:** *Metapenaeus affinis* **C***: Metapenaeus dobsoni* **D:** *Penaeus monodon* **E:** *Parapenaeopsis sculptilis* **F:** *Sousa chinensis.***G:** Gerarda prevostiana **H:** *Cerebrus rynchops*

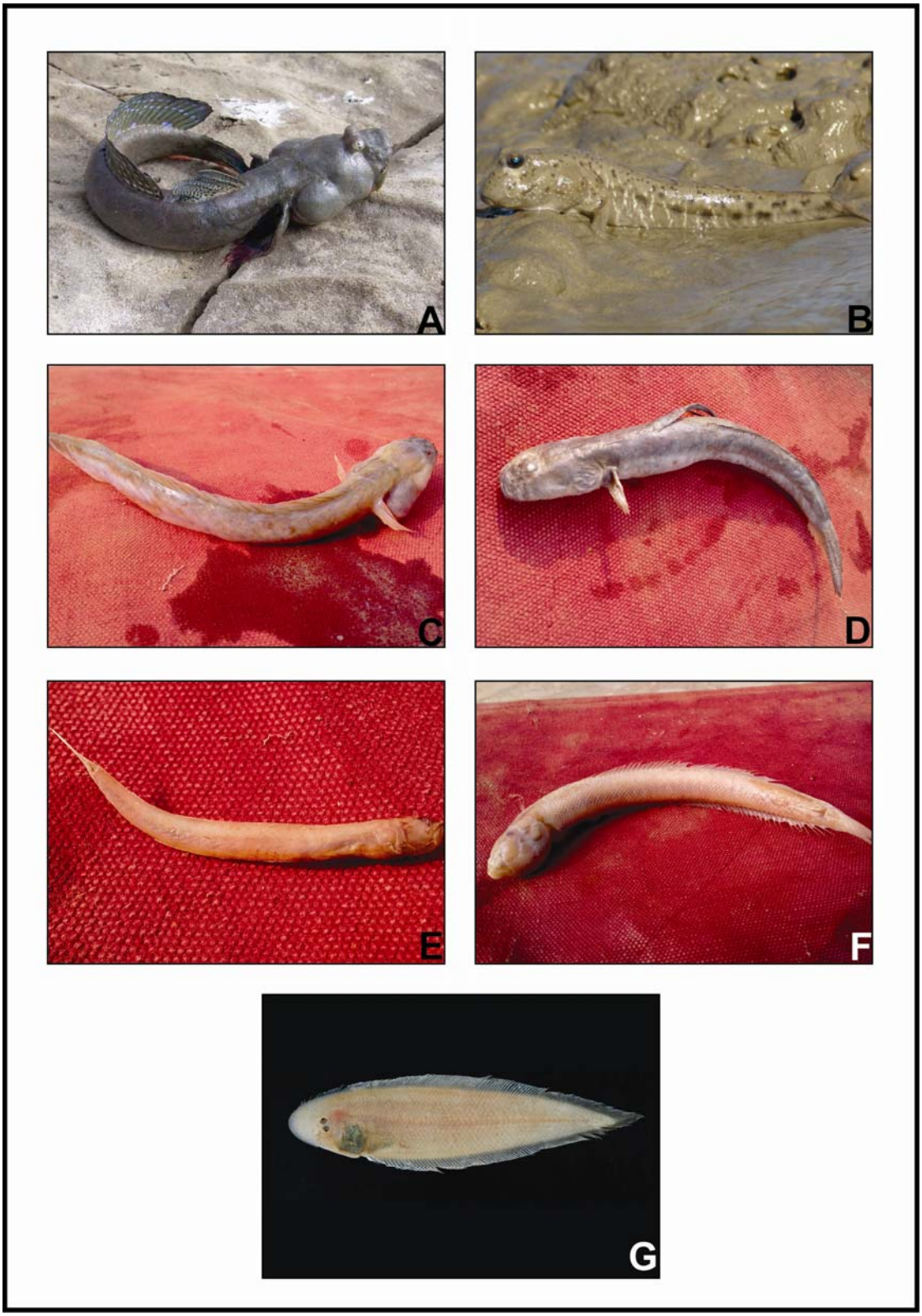


Figure: 4.58 Fish diversity found at the study sites

A- *Boleophthalmus dussumieri* **B-** *Periophthalmus waltoni* **C-** *Apocryptes bato* **D-** *Scartelaos histophorus* **E-** *Taenioides anguillaris* **F-** *Odontamblyopus rubicundus* **G** *Cynoglossus arel*

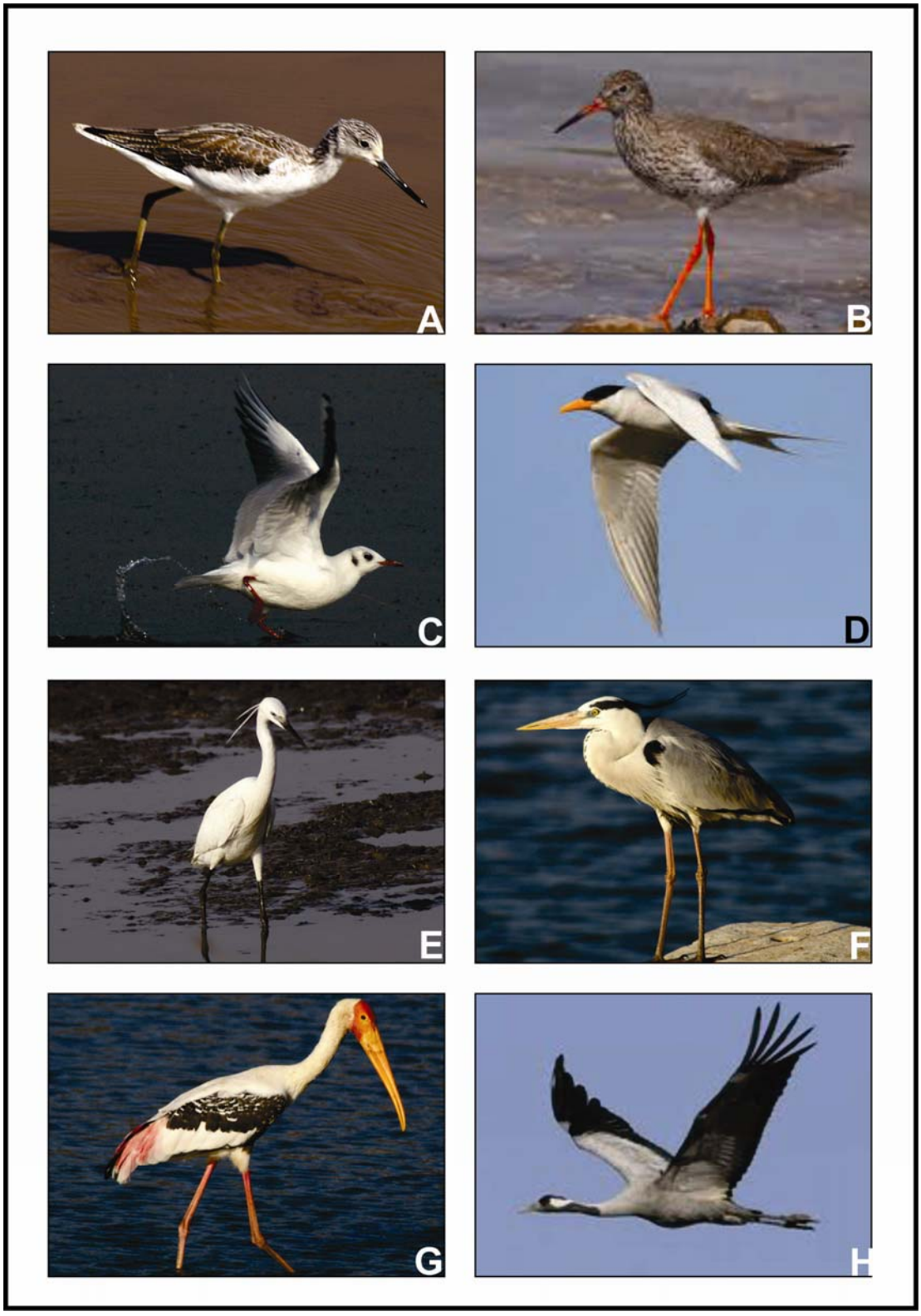


Figure- 4.59 Avian diversity recorded during study

A- *Tringa stagnatilis* **B**- *Tringa totanus* **C**- *Larus ridibundas*

D- *Sterna aurantia* **E-** *Egretta garzetta* **F**- *Ardea cinerea*

G- *Mycteria leucocephala* **H**-*Grus grus*

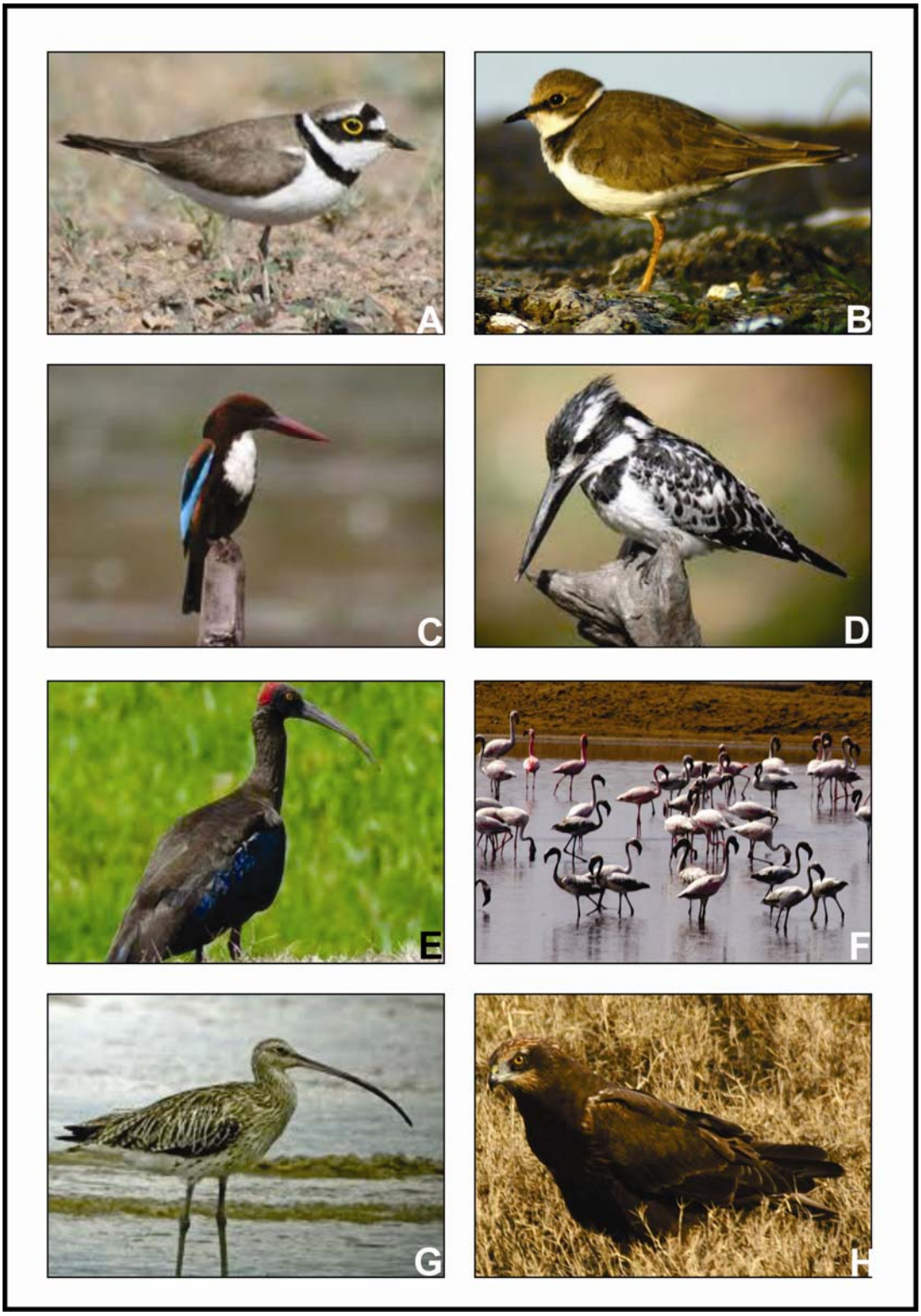


Figure-4.60 Avain diversity recorded during study

A- *Charadrius dubius* **B**- *Charadrius alexandrinus* **C-***Halcyon smymensis*

D-*Ceryle rudis* **E**-*Pseudibis papillosa* **F-***Phoenicopterus minor*

G-*Numenius arquata* **H-** *Circus aeruginosus*

Table 23: Biodiversity found at the study sites

Sr.No	Biodiversity	Nada	Gandhar	Kamboi
1.	Mangrove and its floral associates	9	6	5
2.	Molluscs	11	4	2
3	Brachyuran crabs	13	10	9
4.	Prawns and Shrimps	5	4	3
5.	Fishes	11	8	6
6.	Mudskippers	4	3	2
7.	Reptiles	2	1	0
8.	Mammals	1	1	0
Total Species diversity		**56**	**37**	**27**

The results clearly shows that the maximum diversity was found at nada site, which is a natural mangrove site, followed by Gandhar which is comparatively young mangrove site restored through mangrove plantation and least was seen at Kamboi which is in a way non-mangrove site.In case of Avian diversity, as the sites are very near in terms of crow fly distance and so all the birds diversity have been recorded at all three sites.

4.3 Dependency of community on mangrove ecosystem

There have been several studies examining the beneficial outcomes of mangroves in the Indian context. For instance, the study by Santhakumar *et al* (2005) on the Sundarbans indicate that the direct benefits included abundance of brackish water fish, shrimps, crabs, honey, beeswax and tannin, which provided for requirements of both local and urban consumption. The exports of dried fish, shrimps, crabs and honey brought in substantial gains in foreign exchange. The Sundarbans also acts as a buffer zone between the ocean and the interior lands (Santhakumar, *et al.,* 2005).

An earlier study by Chandrasekaran and Natarajan (1992) estimated the harvest of fish, prawn and crab harvested from the Pichavaram mangroves, between April 1981 and March 1982. As per the estimate, 245 tons of fish, prawn and crabs [85% was accounted for by prawns] was harvested in one year. Prawns are primarily detritivores [detritus eaters] and they thrive in mangrove areas that harbour large quantities of detritus imported from adjacent mangrove forests. In Andhra Pradesh, for example, an estimate by the Centre for Marine Fishery Resource Kakinada showed that prawn catch per boat load from mangrove areas of Godavari and Krishna has been 25 percent more than in non-mangrove areas. The benchmark survey conducted by the MS Swaminathan Research Foundation (MSSRF) in Andhra Pradesh showed that the fishery resources from the Godavari mangrove wetlands supported 32,300 families from 26 hamlets in 1998. The total value of their catch was estimated at Rs. 2.53 crores per annum in 1998, or an average income per family of about Rs. 3500 per annum. The same survey revealed that about 375 tones of fodder grass was obtained from the mangrove area every year (Chatterji, undated).

Highlighting the importance of Gujarat's fishery sector in the country (20%), Saravanakumar, *et al (2009)* observes that 90 percent of Gujarat fish catch is contributed by marine fisheries. The high fishery yield of the state has been attributed to mangroves, as fish recruitment and mangrove cover are directly proportional.

The study by Hirway and Goswami (2007) may be considered as an important case study on the impact of mangroves on the local communities in Gujarat. The study tries to quantify the various benefits in physical terms and monetary terms. The specific objectives of the study were to: a) study the changes in the status of mangroves in Gujarat state during the past two decades or so and to estimate the nature and extent of depletion and degradation of mangroves in physical terms; b) compile monetary value of changing status of mangroves using alternative methods; c) develop a methodology of computing value of a renewable natural resource in the process, and d) infer policy/action implications of the study for improving the status of mangroves in the state. The study was undertaken in 9 villages covering 400 households. The major share of the households surveyed were farmers (63%), followed by agricultural labourers (20%) and fishermen (13%), which together accounted for almost 96 percent of the total mangrove dependent households. The study estimated both direct use value and non-use value accrued by the mangrove dependent communities. While the direct use value (based on 2003 prices) of mangroves has been estimated at Rs. 1603 million, the indirect use value of the current status of mangroves was Rs. 2858 million per year. The total use value (direct and indirect) of mangroves was thus estimated at 7731.3 million per year for the state at 2003 prices (Hirway and Goswami, 2007).

The study was carried out to observe the dependency of the coastal communities in reference to the mangroves. It was observed that the community was largely depended on mudskipper, prawns and shrimps, fishes catch for their livelihood. The following interesting results were observed based on detailed study carried out:

4.3.1 Mudskipper Catch

During the study it was observed that three practices were followed at the study sites in order to catch mudskippers. The three techniques adopted are:

(1) Direct catch through digging the burrow
(2) Stick traps around mudskipper holes
(3) Net catch

(1) **Direct catch through digging the burrow**

In case of direct hand catch method, the locals entered the mangrove and nearby muddy area and enter their hand into mudskippers hole and catch it. This method is quite laborious and time consuming as the person has to move to each hole enter hand and also dug out soil in order to catch mudskippers. Also the catch in terms of quantity is quite less as compared to other two methods. The mortality rate is negligible as the mudskippers are directly caught in the hand and collected in the basket. (Fig: 4.65)

(2) **Stick traps around mudskipper holes**

The other method adopted is through stick traps which are inserted near the holes and then as soon as mudskipper comes out of it hole it gets trapped in the stick trap. This method is known as" Fando" or "Fasi" in vernacular language. In this method trap of nylon string is prepared at the top of the thin sticks which are placed at mouth of the mudskippers hole. When the mudskipper tries to come out of the hole they get stuck in the stick traps. Then the fishermen collect the sticks and remove the mudskippers and collects in the basket. Then they are sold off to the sellers. The quantity of catch is high than manually direct hand catching method but it is less than net catch method. In this method the damage to the mudskipper is less due to only one point catch as compared to the net catch method where the mudskipper gets catch at two three points and damage is high. In this method the mortality rate is around 20% in summers whereas in case of winters it is around 10%. In this method the quantity is less but the quality is good as the placement is done at big size mudskipper holes (Fig-4.65).

(3) **Net Catch**

The local fishermens call this net as "Kandari" in vernacular language. The net is spread over an intertidal area where there are good numbers of mudskipper holes. When the mudskippers come out of their holes they get caught in the net. The fishermens then collect the mudskippers from the net and collect them in a basket. Then they are sold off to the sellers who further sell them off in the market.

The quality of the catch is mix; they are small as well as big size mudskippers which get caught in the net. The mortality is high in this method when the mudskippers are pressed and taken out of the net. In case of summers the mortality is as high as 40% out of the total catch due to high temperature. During winters the mortality is around 10-15% of the total catch and is low due to low temperature. In this method the quality of mudskipper is mix whereas the quantity is high as compared to other two methods. (Fig.4.65)

4.3.2 Prawn and Shrimp catch

In the study area, the local fishermen use net for catch of prawns and shrimps. In the local language the net is known as Golva net. It is fixed on the wooden sticks with the help of the nails. It is fixed near the low tide mark. The catch is done throughout the year. The entire catch is depended on the high tide. The catch is high during summer and monsoon season, whereas in case of winter season the catch is low. The catch is less during low high tides.

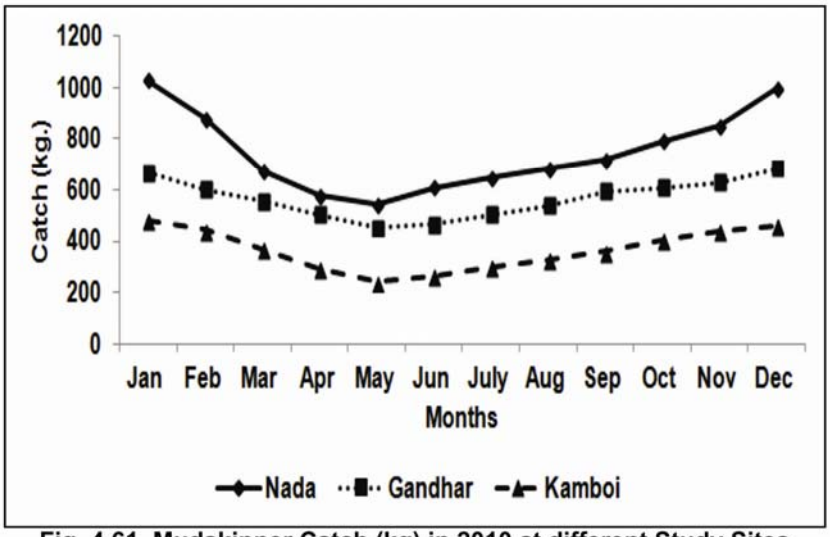


Fig. 4.61. Mudskipper Catch (kg) in 2010 at different Study Sites

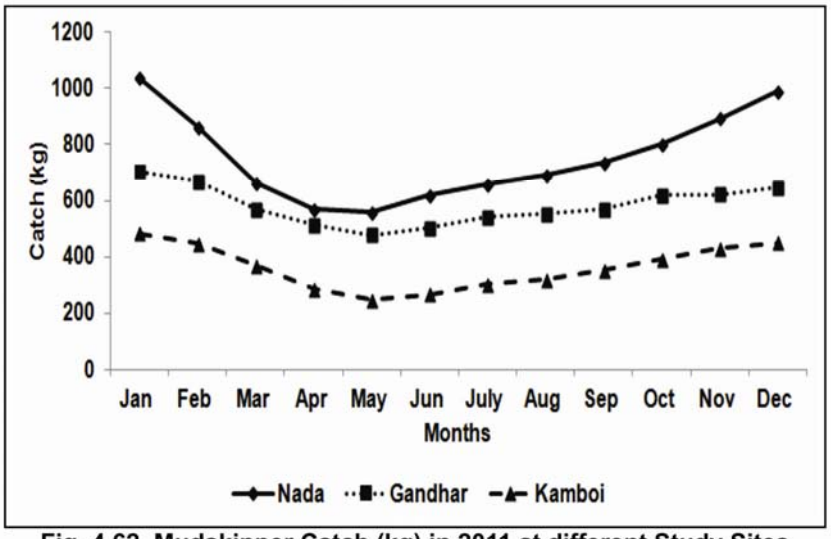


Fig. 4.62. Mudskipper Catch (kg) in 2011 at different Study Sites

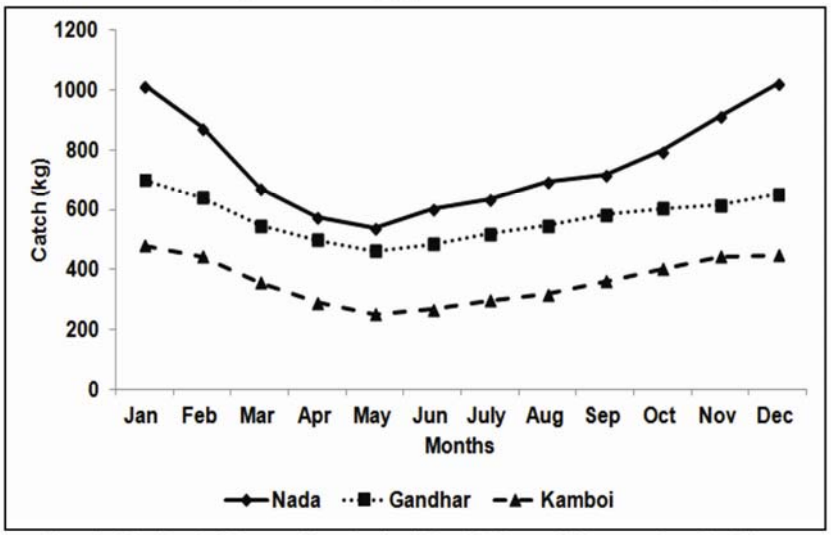


Fig. 4.63. Mudskipper Catch (kg) in 2012 at different Study Sites

Three years data was collected for the mudskipper catch for all the sites (Fig: 4.61 to 4.63). At the end of the analysis of the data, an interesting pattern was observed. At all the study sites the mudskipper catch was high during winter season and it slowly dipped during summer and monsoon season. The daily catch of mudskipper at all the three sites was recorded and based on it monthly catch was totalled up. When all the three years data was put up on graph then it showed a similar outcome related to the season and mudskipper catch. In case of Nada the catch varied from as low as 538.5 kgs/month to as high as 1036 kgs/month considering the three years data. In case of Gandhar the catch varied from as low as 450.5 kgs/month to as high as 703.5 kgs/month. In case of kamboi site though the catch was low in compare to the other two sites but it also showed the same pattern. The variation was between the range of 239.5 kgs/month to 482.5/month. The lowest catch was observed during the month of May and June whereas the highest catch was observed during December and January months. On detailed study it was observed that during summers and monsoon this part showed heavy erosion and during winter it showed heavy siltation so which directly affected the mudskipper catch.

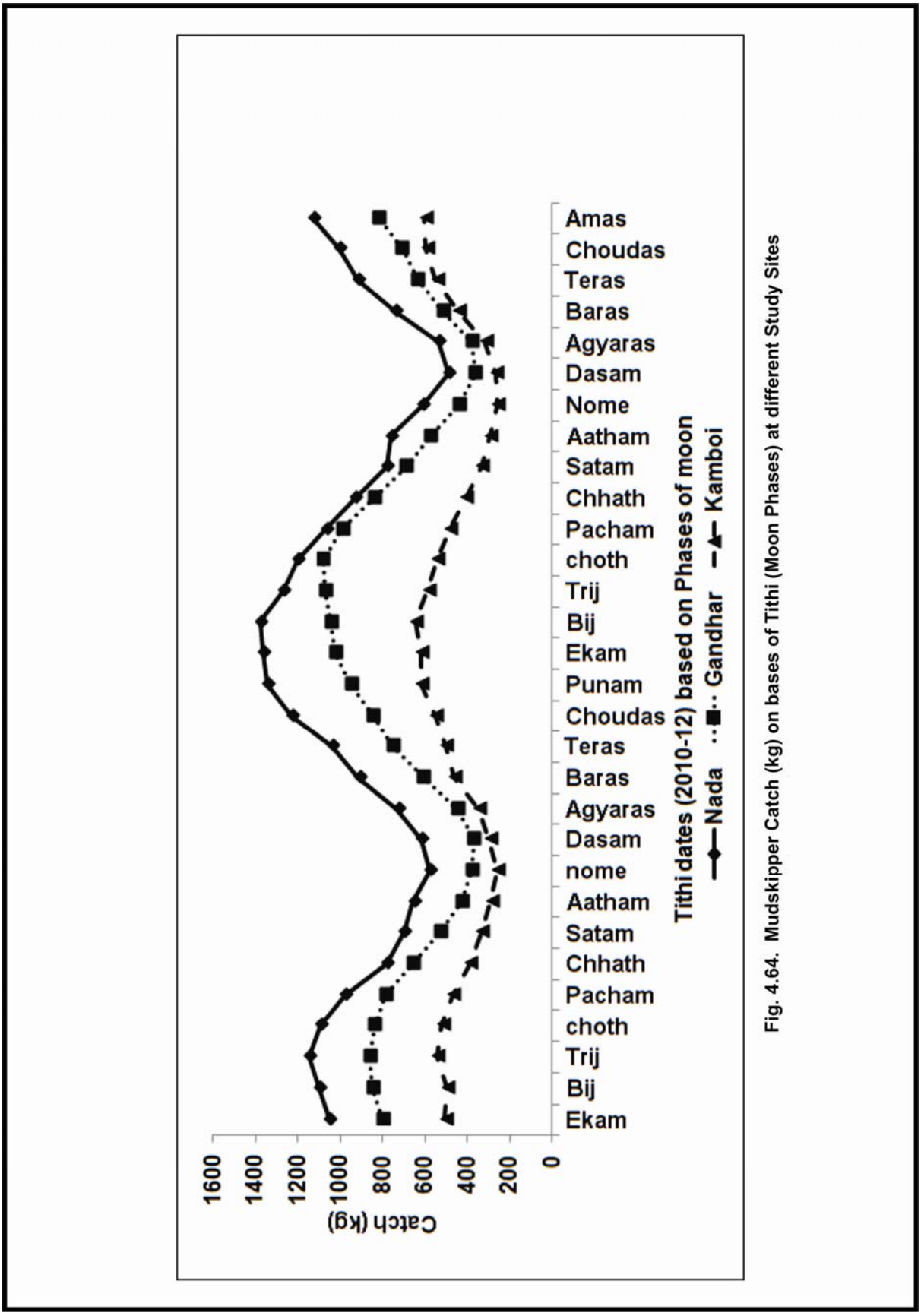


Fig. 4.64. Mudskipper Catch (kg) on bases of Tithi (Moon Phases) at different Study Sites

The data collected for every day mudskipper catch helped to reveal an interesting pattern in co-relating mudskipper catch with the phases of moon based on Hindu calendar(Fig:4.64). The tidal cycle which is very much depended on the phases of moon clearly showed that when the tides were high during Agyaras to trij, there was rise in mudskipper catch. Similarly from chauth onwards there was fall in the mudskipper catch till Dasam. The maximum catch was observed during Punam, ekam and bij at all the three sites Nada (1400 kgs), Gandhar (1100 kgs), Kamboi (610 kgs) whereas the minimum was observed during Naum and Dasam for all the study sites respectively Nada (500kgs), Gandhar (375 kgs) and Kamboi (220 kgs). Based on the above results it is co-related that during high tides between agyaras to trij when the water touches the higher land marks the mudskippers were found in plenty in the area where as during the period from Chauth to dasam when the high tide mark got reduced there was fall in mudskipper as they preferred to enter in to the holes and interesting pattern was observed that during this days they cover up there holes through mud.

Table 24: Rate of Mudskipper catch (per Kg)

Details	Summer (in rupees)	Monsoon (in rupees)	Winter (in rupees)
Fishermen to Carrier person	40	40	50
Carrier person to Market	60	60	70
Market rate	70	70	90

The rates were collected for the mudskipper at all the study sites. The fishermen collect the mudskippers who then sell off to a carrier person who buys the mudskipper from fishermen. The carrier person then sells off the mudskipper to the main market by adding his profit in it. Then the market person sells to the people after adding his profit. Generally the rates are less in summer and

Monsoon and high in winters. The above chart shows the rate of mudskippers per kilogram rates at different stages from fishermen's to end users.

Table 25: Rate of Prawn/Shrimp catch (per kg.)

Details	Summer (in rupees)	Monsoon (in rupees)	Winter (in rupees)
Fishermen to Carrier person	60	70	70
Carrier person to Market	80	90	90
Market rate	100	110	110

Figure: 4.65 A- Hand Catch method, **B**-Trap method, **C**-Mudskipper caught by trap method, **D**-Net Catch method, **E**-Mudskipper catch by locals, **F**- Mudskipper sold by locals to carrier person, **G**&**H**- Carrier person transporting Mudskipper to market.

4.4 Identify potential areas for restoration of Mangroves

In this part of Gulf of khambhat, erosion has been a severe problem. During my study I felt the need to identify potential regions where by mangrove restoration or plantation can be carried out in order to protect coastline. The map below shows the area marked in green which has been identified for restoration of mangroves.

The above areas where identified based on detailed study related to following important factors:

(A) Species selection for restoration.

(B) Habitat selection.

4.4.1 Species selection for restoration

In case of species selection though there is not much choice left in this part of Gulf of Khambhat. However selection was based on criteria of plantation, adaptability, occurrence, availability of mature propagules/seeds, size of propagules and zoning pattern of species.

(1) Purpose of plantation

Species selection was done carefully and tailored to the desired objectives of planting, i.e coastline protection. It has been noticed that largely such objective has been successful with Sonneratia species, Avicennia species and Rhizophora species. *Rhizophora mucronata* was tried on pilot scale but as it requires proper inundation which is not available in the region and so Avicennia was better choice and also the seeds of the same are easily available in the region.

(2) Adaptability of species

The region is quite arid and as well as salinity levels is quite high in this part. The tidal lands are relatively dry with high salinity and so keeping this in mind Avicennia species was selected for plantation.

(3) Natural occurrence of species

Mangrove species selection can be based on species that occur naturally in the locality. It is also necessary to collect data on the historical occurrence of species. It becomes very easy if we plant based on the natural occurrence of species. As long as the study site is concerned it has long history of occurrence of *Avicennia marina* species so the preference was given to it.

(4) Availability and maturity of seeds and seedlings

It is again an important parameter which was kept in mind while selecting Avicennia marina for restoration. It was based on the availability and maturity of seeds from the locality. It further depended on successful flowering and fruiting of the species. The selection was done keeping in mind sufficient quantities of mature seeds produced as it will take by regeneration.

(5) Zoning pattern

Zoning is critical to the success of any restoration. Based on relatively dry intertidal area Avicennia marina proved good and also on backdrop towards land side mangrove associate *salvadora persica* was selected for plantation.

4.4.2 Habitat selection

The plantation sites were identified based on the following important criteria:

(1) Tidal amplitude

Tidal amplitude, measured as the distance between the highest high-tide and lowest low-tide water marks, is an important factor for site selection. The frequency of flooding varies widely depending on intertidal slope, tidal variation and other factors. In this part the dryness is more and on majority of the days the intertidal zone remains dry.

(2) Soil conditions

The salinity is quite high in this region. Also the presence of salt marsh species such as Suaeda indicates hypersalinity of the soil.

(3) Light conditions

Avicennia marina exhibits good resistance to high sunlight intensity with hot and dry conditions. As the site conditions have high sunlight intensity and so it suits A.marina species for selection of plantation.

(4) Sedimentation

Changes in coastal mangroves can often be attributed to changes in hydrology. In this area sediment accretion is high.

(5) Pollution

In this region as the organic load is high due to upstream release of sewage and other waste getting mixed. Avicennia species are known to be tolerant to high organic pollution.

Fig. 4.66. Shoreline map for Study Site

Fig. 4.67. Map showing identified area(in matrix) for plantation near Gandhar village

Fig. 4.68. Area identified for mangrove plantation near Gandhar Village

In fig 4.66: The areas marked in red colour are highly erosion prone areas and requires immediate measures to curb erosion and to stabilise the shoreline.

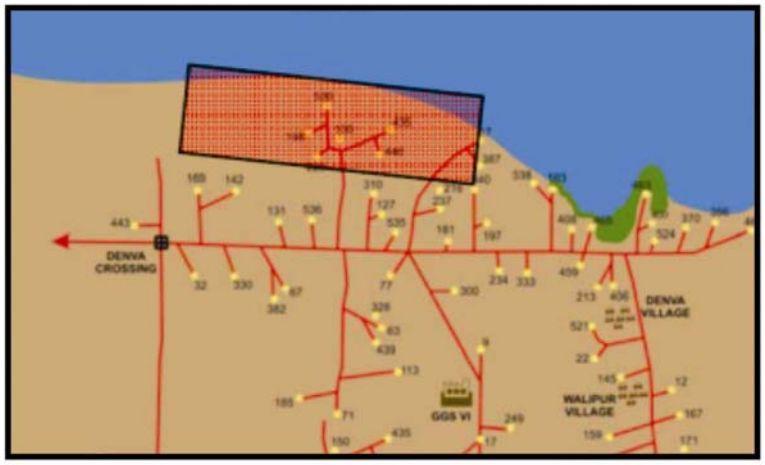


Fig. 4.69. Map showing Identified Plantation site (in matrix) at Denva village

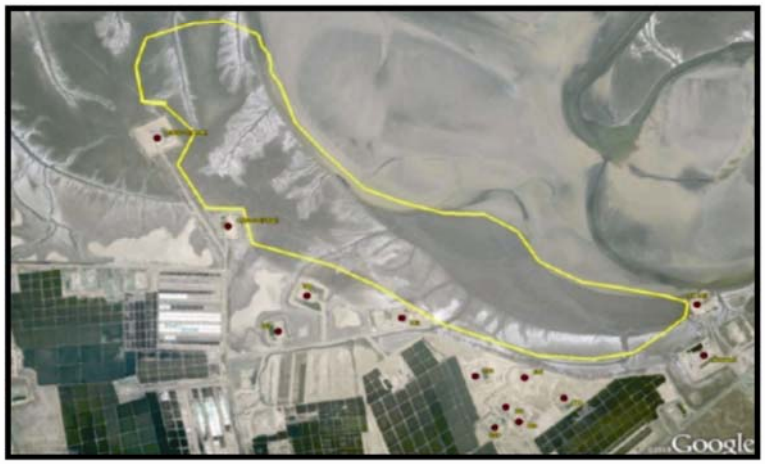


Fig. 4.70. Area identified site for plantation near Denva Village

Based on the above study the identification of the site has been carried out in this region for restoration purpose. The plantation in this region will not only stabilise the shoreline but it will also provide natural protection to the oil wells present in the region which are facing threat of getting eroded in near future. Till date 100 hectare of plantation as been carried out in this region and further 198 hectares which has been identified will also be covered under mangrove plantation. The project has been funded by Oil and Natural Gas Corporation Limited. As the erosion in this part is quite high and so conventional methods of plantation were not adapted. The mangrove saplings were reared in near by nursery for about six months and then transferred to the plantation site as direct seedling and other direct application methods could not withstand the high tidal amplitude so it becomes very necessary that properly grown nursery saplings are planted on such sites in order to avoid wash away and increase the success ratio of plantation.

Figure: 4.71: Plantation activites at identified sites for mangrove plantation

5. CONCLUSION

CONCLUSION

Table 26: List of the bio-diversity found at all the study sites during study period

Family	Species	Nada	Gandhar	Kamboi
Floral Diversity				
Chenopodiaceae	*Arthrocnemum indicum*	□	□	
	Salicornia brachiata	□		
	Suaeda fruiticosa	□		
	Suaeda maritime	□	□	□
	Suaeda monoica	□	□	
	Suaeda nudiflora.	□		□
Salvadoraceae	*Salvadora persica*	□	□	□
Aizoaceae	*Sesuvium portulacastrum*	□	□	□
Avicenniaceae	*Avicennia marina*	□	□	□
Molluscs				
	Gastropods			
Neritidae	*Nerita (Dostia) crepidularia*	□		
Littorinidae	*Littorina undulata (gray)*	□	□	
Potamididae	*Cerithidea (cerithidiopsilla) cingulata*	□	□	□
Potamididae	*Cerithidea (cerithidea) obtusa (lamark)*	□		
Potamididae	*Telescopium telescopium (linne)*	□		
Cypraeidae	*Erronea caurica (Linnaeus,1758)*	□		

Naticidae	*Sinum haliotoideum (Linnaeus, 1758)*	□	□	□
Cerithiidae	*Cerithium echinatum Lamarck,1822*	□		
Naticidae	*Natica vitellus (Linnaeus,1758)*	□		
	Bivalves			
Mactridae	*Mactra antiquate Spengler,1802*	□		
Veneridae	*Meretrix meretrix (linne)*	□	□	
Brachyuran Crabs				
Family	***Species***	**Nada**	**Gandhar**	**Kamboi**
Ocypodidae`	*Uca (Austruca)lactea*	□	□	□
	Uca (Tubuca) dussumieri	□	□	□
	Uca (Gelasimus) vocans	□	□	
Matutidae	*Ashtoret lunaris*	□	□	□
Portunidae	*Scylla serrata*	□	□	□
Varunidae	*Metaplax indica*	□		
Grapsidae	*Grapsus intermedius*	□	□	
	Metapograpsus messor	□		
Sesarmidae	*Parasesarma plicatum*	□	□	□
Macrophthalmidae	*Venitus dentipes*	□	□	□
	Macrophthalmus (Mareotis) depressus	□	□	□
	Macrophthalmus dilatatus	□		
Gecarcinidae	*Cardisoma carnifex*	□	□	□
Dotillidae	*Dotilla intermedia*			□
Prawns & Shrimps				
Penaeidae	*Metapenaeopsis affinis*	□	□	□
Penaeidae	*Metapenaeopsis dobsoni (Miers)*	□	□	□
Penaeidae	*Parapenaeopsis sculptilis (Heller)*	□	□	
Penaeidae	*Penaeus monodon (Fabricius)*	□	□	□
Palaemonidae	*Exopalaemon styliferus (Milne Edwards)*	□		
Mudskipper				
Family	***Species***	**Nada**	**Gandhar**	**Kamboi**
Gobiidae	*Scartelaos histophorus*	□	□	
Gobiidae	*Boleophthalmus dussumieri*	□	□	□
Gobiidae	*Periophthalmus waltoni*	□	□	□

	koumans			
Gobiidae	*Aprocryptes bato*	□		
Fishes				
Family	***Species***	**Nada**	**Gandhar**	**Kamboi**
Gobiidae	*Odontamblyopus rubicundus*	□		
Gobiidae	*Taenioides anguillaris (Linnaeus, 1758)*	□		
Clupeidae	*Tenualosa ilisha (Hamilton, 1822)*	□	□	□
Clupeidae	*Herklotsichthys quadrima culatus (Rüppell, 1837)*	□	□	
Sciaenidae	*Harpadon nehereus*	□	□	□
Engraulidae	*Thryssa mystax*	□	□	□
Cynoglossinae	*Cynoglossus arel*	□	□	□
Ariidae	*Arius maculatus*	□	□	□
Sciaenidae	*Johnius macropterus*	□	□	
Trichiurinae	*Lepturacanthus savala (Cuvier, 1829)*	□	□	
Engraulidae	*Coilia dussumieri Valenc iennes, 1848*	□		□
Seasnake				
Family	***Scientific Name***	**Nada**	**Gandhar**	**Kamboi**
Colubridae	*Cerebrus rynchops*	□		
Colubridae	*Gerarda prevostiana*	□	□	
Birds				
Family	***Scientific Name (Common Name)***	**Nada**	**Gandhar**	**Kamboi**
Phasianidae	*Francolinus pondicerianus (Grey Francolin)*	□	□	□
Phasianidae	*Pavo cristatus (Indian Peafowl)*	□	□	□
Anatidae	*Dendrocygna javanica (Lesser Whistling Duck)*	□	□	□
Anatidae	*Anser anser (Greylag Goose)*	□	□	□
Anatidae	*Tadorna ferruginea (Brahminy Duck)*	□	□	□
Anatidae	*Anas poecilorhyncha*	□	□	□

	(Spot-billed Duck)			
Anatidae	*Sarkidiornis melanotos (Comb Duck)*	□	□	□
Upupidae	*Upupa epops (Common Hoopoe)*	□	□	□
Alcedinidae	*Halcyon smyrnensis (White-throated Kingfisher)*	□	□	□
Alcedinidae	*Ceryle rudis (Lesser Pied Kingfisher)*	□	□	□
Meropidae	*Merops orientalis (Small Green Bee-eater)*	□	□	□
Meropidae	*Merops phillippinis (Blue-tailed Bee-eater)*	□	□	□
Cuculidae	*Clamator jacobinus (Pied Cuckoo)*	□	□	□
Cuculidae	*Eudynamys scolopacea (Asian Koel)*	□	□	□
Cuculidae	*Centropus sinensis (Greater Coucal)*	□	□	□
Psittacidae	*Psittacula krameri (Rose-ringed Parakeet)*	□	□	□
Apodidae	*Apus affinis (House Swift)*	□	□	□
Strigidae	*Athene brama (Spotted Owlet)*	□	□	□
Columbidae	*Columba livia (Blue Rock Pigeon)*	□	□	□
Columbidae	*Streptopelia orientalis (Oriental Turtle Dove)*	□	□	□
Columbidae	*Streptopelia chinensis (Spotted Dove)*	□	□	□
Columbidae	*Streptopelia decaocto - (Eurasian Collared Dove)*	□	□	□
Columbidae	*Treron phoenicoptera (Yellow-footed Green Pigeon)*	□	□	□
Gruidae	*Grus grus (Common Crane)*	□	□	□
Rallidae	*Amaurornis phoenicurus (White-breasted Waterhen)*	□	□	□
Rallidae	*Porphyrio porphyrio (Purple Swamphen)*	□	□	□
Rallidae	*Fulica atra (Eurasian Coot)*	□	□	□
Rostratulidae	*Gallinago gallinago*	□	□	□

	(Fantail Snipe)			
Scolopacidae	*Limosa limosa (Black-tailed Godwit)*	☐	☐	☐
Scolopacidae	*Numenius arquata (Eurasian Curlew)*	☐	☐	☐
Scolopacidae	*Tringa tetanus (Common Redshank)*	☐	☐	☐
Scolopacidae	*Tringa stagnatilis (Marsh Sandpiper)*	☐	☐	☐
Scolopacidae	*Tringa nebularia (Common Greenshank)*	☐	☐	☐
Scolopacidae	*Tringa ochropus (Green Sandpiper)*	☐	☐	☐
Scolopacidae	*Actitis hypoleucos (Common Sandpiper)*	☐	☐	☐
Scolopacidae	*Calidris alba (Sanderling)*	☐	☐	☐
Scolopacidae	*Calidris minuta (Little Stint)*	☐	☐	☐
Scolopacidae	*Calidris ferruginea (Curlew Sandpiper)*	☐	☐	☐
Burhinidae	*Esacus recurvirostris (Great Thick-knee)*	☐	☐	☐
Recurvirostridae	*Himantopus himantopus (Black-winged Stilt)*	☐	☐	☐
Charadriidae	*Vanellus indicus (Red-wattled Lapwing)*	☐	☐	☐
Charadriidae	*Charadrius dubius (Little-ringed Plover)*	☐	☐	☐
Charadriidae	*Charadrius alexandrines (Kentish Plover)*	☐	☐	☐
Jacanidae	*Hydrophasianus chirurgus (Phesant-tailed Jacana)*	☐	☐	☐
Jacanidae	*Metopidius indicus (Bronze-winged Jacana)*	☐	☐	☐
Dromadidae	*Dromas ardeola (Crab Plover)*	☐	☐	☐
Laridae	*Larus brunnicephalus (Brown-headed Gull)*	☐	☐	☐
Laridae	*Larus ridibundus (Black-headed Gull)*	☐	☐	☐
Laridae	*Larus genei (Slender-billed Gull)*	☐	☐	☐
Laridae	*Larus cachinnans (Yellow-legged Gull)*	☐	☐	☐
Laridae	*Gelochelidon nilotica (Gull-billed Tern)*	☐	☐	☐
Laridae	*Sterna caspia*	☐	☐	☐

	(Caspian Tern)			
Laridae	*Sterna aurantia (River Tern)*	□	□	□
Laridae	*Sterna hirundo (Common Tern)*	□	□	□
Accipitridae	*Elanus caeruleus (Black-shouldered Kite)*	□	□	□
Accipitridae	*Milvus migrans (Black Kite)*	□	□	□
Accipitridae	*Haliastur Indus (Brahminy Kite)*	□	□	□
Accipitridae	*Circus aeruginosus (Eurasian Marsh Harrier)*	□	□	□
Accipitridae	*Circus pygargus (Montagu's Harrier)*	□	□	□
Accipitridae	*Accipiter badius (Shikra)*	□	□	□
Podicipedidae	*Tachybaptus ruficollis (Little Grebe)*	□	□	□
Phalacrocoracidae	*Phalacrocorax niger (Little Cormorant)*	□	□	□
Ardeidae	*Egretta garzetta (Little Egret)*	□	□	□
Ardeidae	*Egretta gularis (Western Reef Egret)*	□	□	□
Ardeidae	*Grey Heron*	□	□	□
Ardeidae	*Ardea purpurea (Purple Heron)*	□	□	□
Ardeidae	*Casmerodius albus (Great Egret)*	□	□	□
Ardeidae	*Mesophoyx intermedia (Intermediate Egret)*	□	□	□
Ardeidae	*Bubulcus ibis (Cattle Egret)*	□	□	□
Ardeidae	*Ardeola grayii (Indian Pond Heron)*	□	□	□
Ardeidae	*Nycticorax nycticorax (Black-crowned Night-Heron)*	□	□	□
Phoenicopteridae	*Phoenicopterus minor (Lesser Flamingo)*	□	□	□
Threskiornithidae	*Plegadis falcinellus (Glossy Ibis)*	□	□	□
Threskiornithidae	*Threskiornis melanocephalus (Black-headed Ibis)*	□	□	□
Threskiornithidae	*Pseudibis papillosa (Black Ibis)*	□	□	□

Threskiornithidae	*Platalea leucorodia (Eurasian Spoonbill)*	□	□	□
Pelecanidae	*Pelecanus onocrotalus (Great White Pelican)*	□	□	□
Ciconiidae	*Mycteria leucocephala (Painted Stork)*	□	□	□
Ciconiidae	*Anastomus oscitans (Asian Openbill)*	□	□	□
Ciconiidae	*Ciconia episcopus (White-necked Stork)*	□	□	□
Laniidae	*Lanius vittatus (Bay-backed Shrike)*	□	□	□
Corvinae	*Dendrocitta vagabunda (Indian Treepie)*	□	□	□
Corvinae	*Corvus splendens (House Crow)*	□	□	□
Corvinae	*Corvus macrorhynchos (Jungle Crow)*	□	□	□
Oriolidae	*Oriolus oriolus (Eurasian Golden Oriole)*	□	□	□
Dicrurinae	*Dicrurus macrocerus (Black Drongo)*	□	□	□
Muscicapidae	*Copsychus saularis (Oriental Magpie Robin)*	□	□	□
Muscicapidae	*Saxicoloides fulicata (Indian Robin)*	□	□	□
Muscicapidae	*Saxicola torquata (Common Stonechat)*	□	□	□
Muscicapidae	*Saxicola caprata (Pied Bushchat)*	□	□	□
Sturnidae	*Sturnus roseus (Rosy Starling)*	□	□	□
Sturnidae	*Acridotheres tristis (Common Myna)*	□	□	□
Sturnidae	*Acridotheres ginginianus (Bank Myna)*	□	□	□
Hirundinidae	*Hirundo concolor - (Dusky Crag Martin)*	□	□	□
Hirundinidae	*Hirundo rustica (Barn Swallow)*	□	□	□
Hirundinidae	*Hirundo smithii (Wire-tailed Swallow)*	□	□	□
Hirundinidae	*Hirundo daurica (Red-rumped Swallow)*	□	□	□
Pycnonotidae	*Pycnonotus leucotis*	□	□	□

	(White-eared Bulbul)			
Pycnonotidae	*Pycnonotus cafer (Red-vented Bulbul)*	☐	☐	☐
Cisticolidae	*Prinia socialis (Ashy Prinia)*	☐	☐	☐
Cisticolidae	*Prinia inornata (Plain Prinia)*	☐	☐	☐
Acrocephalidae	*Acrocephalus aedon (Thick-billed Warbler)*	☐	☐	☐
Acrocephalidae	*Acrocephalus stentoreus (Indian Great Reed Warbler)*	☐	☐	☐
Acrocephalidae	*Hippolais caligata (Booted Warbler)*	☐	☐	☐
Cisticolidae	*Orthotomus sutorius (Common Tailorbird)*	☐	☐	☐
Leiothrichidae	*Turdoides caudatus (Common Babbler)*	☐	☐	☐
Leiothrichidae	*Turdoides malcolmi (Large Grey Babbler)*	☐	☐	☐
Leiothrichidae	*Turdoides striatus (Jungle Babbler)*	☐	☐	☐
Alaudidae	*Eremopterix nigriceps (Black-crowned Sparrow-Lark)*	☐	☐	☐
Nectariniidae	*Nectarinia asiatica (Purple Sunbird)*	☐	☐	☐
Passeridae	*Passer domesticus (House Sparrow)*	☐	☐	☐
Motacillidae	*Motacilla alba (White Wagtail)*	☐	☐	☐
Motacillidae	*Motacilla maderaspatensis (Large Pied Wagtail)*	☐	☐	☐
Motacillidae	*Motacilla flava (Yellow Wagtail)*	☐	☐	☐
Motacillidae	*Motacilla cinerea (Grey Wagtail)*	☐	☐	☐
Motacillidae	*Anthus campestris (Tawny Pipit)*	☐	☐	☐
Ploceidae	*Ploceus philippinus (Baya Weaver)*	☐	☐	☐
Mammals				
Delphinidae	*Sousa chinensis*	☐		

At the end of the study, it is clearly visible that mangroves support good biodiversity and as the study suggests that Nada with good mangrove cover has got maximum diversity with highest number of species then is the mangrove restored site Gandhar with moderate number of species and the least was recorded from the kamboi site with minimum number of species. The Nada mangrove forest is in existence over several years (Personal communication with Locals of Nada village). In case of Gandhar, the mangroves have been established only 8 years back. This suggests that mangroves with vast network of roots and trunks offer a very good niche for the faunal diversity. Due to its age and vast extent, the Nada mangrove has higher diversity. In case of Gandhar it will be interesting to know that how long it will take for the remaining species to get established as Nada site in the due course of time. But the question arises how much time it will take? It is an interesting question worth investigating. Continuous monitoring of the diversity checklist may provide the answer.

In case of Socio-economic study carried out, it became relevant that the best practice to catch the mudskipper is net catch; however when ever the catch is target specific then sticks trap method is most suited one. Also the relation based on the different phases of moon and mudskipper catch is related with each other has also been drawn out from the study.

Identification of suitable sites for plantation depends on various factors as discussed earlier under the objective. Accordingly 2-3 sites were identified near the study area based on the future prospect of shoreline stability. The proposal for the same was forwarded to relevant organisation and based on which the plantations were carried out at these sites. Till date good plantation results have been obtained bringing stability to the shoreline and involving local coastal communities for the same has been successful.

6. SUMMARY

6.1 Brachyuran Crabs and Mangroves

6.2 Molluscs in Mangroves

6.2.1 Gastropods in Mangrove Ecosystem

6.2.2 Bivalves in Mangrove Ecosystem

6.3 Birds and Mangroves

6.4 Mudskippers and Mangroves

SUMMARY

The total area of mangroves in India is about 4,461 sq. km, which is about 7% of the world's total area of mangroves. In India, of the total mangroves 80% are present along the east coast, mostly forming the Sunderbans, Bhitarkanika and the Andaman & Nicobar mangroves. Gujarat state has the longest coastline and stands second in mangrove area coverage in the country. Mangrove cover in Gujarat state is about 960 sq. km. In Gujarat, a total of 12 species were recorded in the past but only eight species survive at present. Except *Avicennia marina*, all other species are threatened and have restricted distribution.

The sediments of mangrove mud flats provide wide variety of micro habitats to benthic fauna. Both macro and micro fauna are reported from the mangrove habitat. The bioturbation activities of the benthic animals significantly contribute in changing habitat characteristics e.g. microbial diversity, depth of subsurface aerobic strata and oxidative status, subsurface drain, extent of nutrient distribution etc. Therefore, it is assumed that the variations in the abiotic status along the estuary may determine characteristic features of habitat and subdivide it into the several microhabitats providing survival opportunities for wide variety of animals. This in turn will specify the community structure and distribution pattern of animals.

6.1Brachyuran crabs and Mangroves

Of all the macro fauna inhabiting the mangrove swamps, brachyurans are among the most important taxa with regard to species diversity and total biomass. They make up as much as 80% of the macro faunal biomass in mangroves (Golley *et al*., 1962). The association of brachyurans crabs with mangrove flora, behaviour, feeding and ecology are of great interest to biologists (Macintosh, 1988). The brachyuran crabs are interesting in that they walk on their sides. Another important feature is the much-expanded body in contrast to the elongated one in other decapod crustaceans. Among the brachyuran crabs, grapsids, ocypodids, portunids, xanthids and gecarcinids are dominant in the mangroves. In particular the sesarmids have attained extreme diversity and richness in the Indo-Pacific

mangroves. Crabs also play many important roles in the mangroves. Degradation of mangrove leaf litter by crabs in particular sesarmids plays a key role as a major link between primary and secondary producers. The faeces of the crabs, which contain, nitrogen, carbon, phosphorus and trace metals form a rich food for other consumers (Kuraeuter, 1976). Their burrowing habit aids in aeration and free circulation of water, which promotes the growth of seedlings of mangroves. The burrowing members are of immense use in recycling of nutrients by ploughing. They also help in the breakdown of particulate organic matter by exposing them to microbes. The burrowing habit assists in oxidizing the sulphide that build up due to high rate of organic decomposition in mangrove swamps (Diemont and Van Wijngarden, 1975). They form the food for many birds, snakes and predatory fishes and their larvae are also consumed by many carnivores thereby they play an important role in food chain (Macintosh, 1984). In a way, the saying no mangroves, no prawns is more applicable to the crabs. In the present study, the taxonomic data of brachyuran crabs was processed statistically and compared between the old mangroves in Nada and recently developed mangroves in Gandhar where as a blank site Kamboi was taken to study the difference.

6.2 Molluscs in Mangroves

Molluscs are second only to Arthropoda in numerical abundance. The number of species identified under Phylum Mollusca varies between 80,000 to 1,00,000. Molluscs have colonized all possible habitats from deep sea to high mountains. They are more abundant in the littoral zones of tropical seas. Gastropods and Bivalves constitute 98% of the total population of mollusca and they inhabit land, freshwater and marine environments. The other classes of Mollusca are exclusively marine.

6.2.1Gastropods in Mangrove Ecosystem

The gastropod molluscs, represented by snails, whelks, cowries, limpets, sea hares and their allies, are among the commonest epifaunal species that exist in the mangrove ecosystems. The gastropods are suitably adapted to various macrohabitats of the mangrove ecosystems. Marine species are found in the bottoms as well as in water bodies, the pulmonate snail and several other groups

have conquered mangrove lands with the limination of the gills and conversion of the mantle cavity into lungs. The mangroves provide ideal conditions for higher productivity of gastropods which in turn, serve as food, particularly the veliger larvae for numerous other animals. Because of their predatory nature, the gastropods occupy a central role in maintaining the functioning and productivity of mangroves through “cleaning” root systems from the encrusting fauna like barnacles. The snails also serve as intermediate host for many trematode parasities. Based on the structure of the molluscan assemblages, the pollution damage in mangrove forests can be assessed. Thus gastropods have a significant ecological role to play in the mangrove ecosystems. However very little information is available on the gastropod biodiversity of mangroves. Hence it is necessary to document the biodiversity of the group of threatened ecosystems.

6.2.2Bivalves in Mangrove Ecosystem

Mangroves are highly zoned, typically occupying the upper half of the eulittoral and dominating the supra littoral fringe. They grow best in the soft mud and these two aspects alone partially explain the lack of the data on mangrove bivalves; the bivalves are in general best adopted to lower tidal levels and to firmer deposits. *Lasaea rubra*, for example, is one of the few bivalves capable of colonizing the high inter tidal almost worldwide (Morton, 1960), although, as well as seen, the *Spartina* marsh associate *Geukensia demissa* has similar adaptations to a high zoned life (Lent, 1969), as do deposits by a filter feeder enhance the very real problem of the gill clogging and sediment removal. Thus, little is known of mangrove bivalves, especially those few species which appear to be endemic components of the mangrove forests. As will be seen, large number of bivalves have been recorded from the seaward fringe of the mangroves, and their status as true mangrove associates is dependable apart from the obvious difficulties of working in a mangrove forest, numerous authors (Warner, 1969; Sasekumar, 1974; Murty and Balaparameswara Rao, 1977) ignored the bivalves in favor of the more active and therefore more conspicuous mangrove associates (the gastropod) (Robertson, 1960; Brown, 1971; Vermeiji, 1974). Coomans (1969) has drawn attention to the inherent interest in mangrove molluscs and Bouchet (1977) has provided data on West Africa mangrove molluscs, drawing on the data by Binder (1968) on Ivory coast mangrove and by Coomans (1969) on the

Caribbean fauna to compare the molluscan fauna of various mangrove regions. However, even these authors emphasize the mangrove gastropods, although there are mangrove bivalves of some interest and occasionally, such as the mangrove oysters (especially *Crassostrea rhizophorae* in the Caribbean) of much wider economic potential.

6.3 Birds and Mangroves

Mangrove ecosystems provide an excellent habitat for birds. The most common birds at the mangrove forests are the members of the family **Ardeidae, Charadriidae, Laridae, Ciconidae, Accipitridae** and **Alcedinidae**. Migratory birds visiting the mangroves may fly long distances to find food and nesting places there. This may be particularly true in the neotropics (Parrish and Sherry, 1994; Confer and Holmes, 1995; Lefebvre and Poulin, 1996; Panitz, 1997). Some of the resident bird species are highly dependent on mangroves for their survival. Because of this dependence, disturbances to the mangal may reverberate through the bird populations. This may be particularly true where the bird species show stray site fidelity (Warkentin and Hernandez, 1996). The habitat disturbances may be natural, such as the frequent cyclonic storms that strongly affect myna populations in the Pichavaram mangroves of South India (Nagarajan and Thiyagesan, 1995). More frequently, however, they are caused by human activities. Protection of the mangrove inhabiting birds will require effective management of the entire mangrove habitat. Many of the nest sites are in dead trees suggesting that a comprehensive eagle management plan is required for preservation of both living and dead mangroves (Curnutt and Robertson, 1994). The mangroves are highly important for the survival of many species of birds, but information on birds associated with mangroves in India is scanty (Mukherjee, 1969; Samant, 1985; Rashid and Scott, 1988; Sampath, 1989; Sethuraman and Subramanian, 1997; Subramanian and Sethuraman, 1998; Sethuraman, 2000; Kathiresan, 2000).

6.4 Mudskippers and Mangroves

Oxudercine gobies (Teleostei, Gobiidae, Oxudercinae), also known as ‘mudskippers’, include abundant and typical resident species of mangrove and mudflat ecosystems throughout the Indo-Pacific region and along the Atlantic

African coasts (Murdy 1989). These fishes present different degrees of adaptation to the amphibious lifestyle, and have colonised the entire intertidal gradient, from the subtidal to the supratidal zone (Nursall 1981; Murdy 1989; Takita et al. 1999; King and Udo 1997).

There are few studies related to mangroves and its biodiversity presence in Gulf of Khambhat and as soon as we look towards the reference for this region of Gulf of Khambhat and its mangrove ecosystem, we have very limited source. In order to fulfill these lacunae the study was designed keeping following objectives in mind.

- Extent and Distribution of Mangroves in the study area
- Study of major macro- fauna associated with Mangrove ecosystem
- Dependency of community on mangrove ecosystem.
- Identify potential areas for restoration of Mangroves.

The Gulf of Khambhat is characterized by number of large and small estuaries. The Narmada estuary is live and classified as a salt wedge estuary where fresh water flows predominate.

The other rivers, however, do not have good fresh water flows due to the small and big dams construed on the rivers. Gulf of Khambhat is 70 km wide and 131 km. long located between Saurashtra peninsula and the mainland Gujarat. Extensive mudflats of 6-8 km are distributed all along the coast of the gulf except along the Narmada estuary. Avicennia with stunted growth is sparsely distributed along the coast near the Mahi, the Dhadhar, the Narmada, the Kim and the Sena rivers. A small patch of mangroves is also observed on the Alia Bet. The dominant areas under mangroves are seen near Bhavnagar, Devla (Bharuch), Mangrol, Pardi, Jankhsi and Dandi in Surat.

During the study three sites have been selected namely kamboi located at 22˚12’54.0” N and 72˚36’36.9”E, Nada located at 21˚54’38.60”N and 72˚34’43.30”E and Gandhar located at 21˚54’02.9”N and 72˚37’35.0”. In case of Kamboi there are sparse mangroves where as in case of Gandhar there is a good site with mangrove plantation which is around 8-10 years old and in case of

Nada which has good history of presence of mangroves for about nearly a period of 60 years. The basic idea of the study is to preprare a bio-diversity checklist for the study area keeping the above objectives as the core. As well as to compare the difference found in the diversity among an area with sparse mangroves with a recently developed mangrove site and age old mangrove site.

At the end of the study, the outcome clearly suggests that there is good presence of the floral and faunal diversity in the region. The result also indicates that natural mangrove patch Nada with long existence has got good network of roots and trunks offering good niche to the faunal diversity. Due to its age and extent, the nada mangrove has higher molluscan, brachyuran crab, fishes especially the mudskipper diversity as compared to Gandhar which is relatively a young mangrove site with 8-10 years existence. The least diversity was recorded at Kamboi which was considered as blank site.

Also the soil and water analysis results indicate presence of high nutrient levels and organic matter at nada which is natural mangrove site as compared to the other two sites. In addition to the above, it is clearly indicative of the dependency of coastal community on the mangroves for their existence. The highest catch and dependency was found at Nada as compared to the other two sites. Also the various techniques adopted for mudskipper catch in this part of the Gulf has been studied and all the three methods adopted has been documented in the study with its advantages and disadvantages.

Finally based on various basic parameters, the areas have been identified for mangrove plantation in order to have shoreline stability. The same areas have been suggested to the concerned organisations based on which successful plantations have been carried out in these areas.

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