SOCIO-ECONOMIC AND ECO-ENVIRONMENTAL ASSESSMENT OF MANGROVE ECOSYSTEM IN MAHI AND DHADHAR RIVER ESTUARIES

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CERTIFICATE

This is to certify that the thesis incorporates the results of original investigation carried out by the candidate himself at the field sites and in the Department of Zoology, The Maharaja Sayajirao University of Baroda, Vadodara. This work has not been submitted by the candidate for any diploma or degree of this or other University.

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CHAPTER 1: INTRODUCTION

1. INTRODUCTION

The word “mangrove” refers to a group of tropical trees and shrubs that grows in the intertidal zone. Mangrove forests are among the world’s most productive ecosystems and thus often called as ‘tidal forests’, ‘coastal woodlands’ or even ‘oceanic rainforests. Mangroves are woody plants that grow in tropical and sub- tropical latitudes along the land-sea interface, bays, estuaries, lagoons, backwaters, and in the rivers, reaching upstream up to the point where the water still remains saline (Qasim, l998). The word “mangrove” dates its origin in 1613 and it is usually considered a compound of the Portuguese word “mangue” and the English word “grove” (Kathirasen, 2001).

As many other plants like Salvadora persica are also capable to grow in semi saline condition at the coastal zone they are often considered as Mangrove. To solve this problem Tomlinson (1986) developed following criteria for a species to be designated as a “true or strict mangrove”:

1. Complete fidelity to the mangrove environment.
2. Plays a major role in the structure of the community and has the ability to form pure stands.
3. Morphological specialization for adaptation to the habitat.
4. Physiological specialization for adaptation to their habitat.
5. Taxonomic isolation from terrestrial relatives.

Thus, mangrove is a non-taxonomy term used to describe a diverse group of plants that are all adapted to a wet, saline habitat. Mangrove may typically refer to an individual species. Terms such as mangrove community, mangrove ecosystem, mangrove forest, mangrove swamps, and mangle are used interchangeably to describe the entire mangrove community. Mangrove forests are extremely important coastal resources, which are vital to our socio-economic development. A vast majority of the human population lives in coastal areas, and most communities depend on local resources for their livelihood. The mangroves are sources of highly valued commercial products and fishery resources and also as sites for developing a burgeoning eco-tourism. The mangrove forests have been shown to sustain more than 70 direct human activities, ranging from fuel-wood collection to fisheries.

Mangrove and other estuarine habitats have been under tremendous human induced stresses due to their immense economic, recreational and transport services. Increase in human population in estuarine areas further increase the pressure on mangroves. Though India had an agriculture based economy in the pre independence era, favoring conditions lead to the growth of industry based economy in post independence era. Consequently, ambient air and water quality are seriously affected. The problem is worse in the case of water pollution. Untreated or allegedly treated effluents have increased the level of toxic heavy metals up to more than 20 times the safe levels in the critically polluted areas of the country. Industrial development is exceedingly expanding in the south Gujarat region and it already has one of the largest chemical industrial areas. The organic chemical based industries dispose effluent through various small and large rivers as well as through effluent channels. The extraordinary capacity of the mangrove habitat sediments to accumulate large amounts of pollutant makes them a favorable ground for the effluent disposal by industries. Various kinds of pollutants, from the industries and sewage, are accumulated in the mangrove swamps changing bio-physical environment of the habitat and consequently the floral and the faunal diversity is changing at the fastest rate. There are several studies on heavy metal contamination in mangrove sediments and their effects on organisms. Besides coastal pollution, mangrove ecosystem suffers from various activities of the dependent local communities.

Thus the socioeconomic and eco-environmental status of mangrove ecosystem is of extreme research significance. In the present studies, I have assessed both the abiotic and biotic components of the mangrove ecosystem, evaluated the influences of the anthropogenic pressure and variable degree of pollution on the mangrove habitats, noted variations in the faunal community structure; particularly with reference to the benthic invertebrate fauna, and compared the better developed and degraded mangrove habitats. As a component of management and conservation I estimated the human dependency on mangrove habitat and carried out educational programs at the school and community levels targeting different age populations.

1.1. Mangrove Ecosystem

1.1.1. Origin and Distribution

Fossils of mangrove pollen suggest that mangroves evolved from terrestrial rather than marine plants and are quite old, possibly arising after the first angiosperms, around 114 million years ago (Duke, 1993). There are two hypotheses that propose the origin of mangroves. The Centre of **Origin Hypothesis** suggests that all mangrove taxa first appeared in the Indo-West Pacific and subsequently dispersed to other regions. The

Vicariance Hypothesis states that all mangroves originated around the Tethys Sea and continental drift then isolated the flora in different regions resulting in diversification and distinct faunas. Ellison et al. (1999) evaluated these two hypotheses using 5 different analyses and supported the Vicariance Hypothesis. Mangroves originated in the Tethys Sea and the high diversity of mangroves in the Indo-West Pacific relates to conditions that favored diversification. Presently 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 (38° 03' S),Australia (38°45' S) and on the east coast of South Africa (32°59' S), according to Spalding (1997). Wide ranging development of mangroves has been found in the estuaries of large rivers flowing over shallow continental shelves, such as the Ganges in Bangladesh, Fly River in Papua New Guinea, and the Mekong Delta in Vietnam. The Amazon and Congo, the two largest rivers in the world, do not have extensive stands of mangroves primarily because of the huge outflow of fresh water (Feller and Sitnik, 1996). The following factors are well thought out to be the major determinants of mangrove distribution:

<u>Climate:</u> Mangroves are tropical species and are not tolerant of freezing temperatures. Their latitudinal limits worldwide vary depending on air and water temperatures (Waisel, 1972; McMillan, 1985; Sherrod and Tomlinson, 1986; Sherrod et al., 1986). The abundance of mangroves is also affected by aridity and development is much greater along coasts that have high inputs of rainfall (Macnae, 1969; Golley et al., 1975).

Salinity: Salt is generally not a requirement for growth, since most mangroves can grow in freshwater (Tomlinson, 1986; Ball, 1988). However, they do not develop in strictly freshwater habitats because of competition from freshwater species. Salinity is thus important in eliminating other vascular plant species that are not adapted for growth in a saline habitat.

Tidal fluctuation: Tidal influence is also not a requirement, but plays an important indirect role:

a. Inundation with salt water helps exclude most other vascular plants and reduces competition.

b. Tides brings saltwater up estuaries against the outflow of fresh water
and extend mangrove development inland.

c. Tides transport sediment, nutrients, and clean water into the mangrove environment and export organic carbon and reduced sulfur compounds.

d. Where evaporation is high, tides help flush soils and decrease salinity.

The effect of this "tidal subsidy" can be seen on two landscape scales:

a. A regional or geographic scale - Mangroves reach their greatest development around the world in low-lying regions with large tidal ranges (Macnae, 1969; Golley et al., 1975; Tomlinson, 1986).

b. A local scale - Trees closest to the edges of land masses, which are subject to the largest fluctuations of the tide, are obviously larger and more productive than trees in the interior (Mendelssohn and McKee, 2000).

c. Sediment and wave energy - Mangroves grow best in a depositional environment with low wave energy (Tomlinson, 1986). High waves prevent propagule establishment, expose the shallow root systems, and prevent accumulation of fine sediments.

1.1.2. Structure of Mangrove Forest

Mangrove forests are characterized by attributes such as species richness, canopy height, basal area, tree density, age/size class distribution, and understory development. Lugo and Snedaker (1974) described six mangrove forest types based on size, productivity, and composition in Florida which were riverine, over wash, fringe, basin, scrub, and hammock. Forest structural characteristics such as canopy height, tree density, and biomass accumulation may be influenced primarily by climatic factors such as rainfall and by nutrient input (Golley et al., 1975; Smith, 1992). Areas characterized by high rainfall typically have tall canopies, high basal areas, and low tree densities. Similarly, larger, more productive trees typify mangrove forests receiving high inputs of nutrients—for example, those areas used as bird rookeries (Feller and Sitnik, 1996). Another structural characteristic of mangrove forests is the frequent absence of understory species, which are usually found in other forest systems (Janzen 1985). Shrubs, grasses, lianas, and other herbaceous plant species do not usually occur under the closed canopy in the mangrove forests. Stand structure in mangrove forests is relatively simple, governed by rainfall and freshwater, when compared to that of other forest types, such as tropical rainforests. The number of strata is often reduced to one: the main canopy. In some forests, a carpet of seedlings may form a second layer, but the abundant lianas and subcanopy trees and shrubs common to most tropical forests are largely absent in mangrove forests.

1.1.3. Zonation in Mangrove Forest

Like any other ecosystem there are zonation patterns in mangrove forests, but unlike other terrestrial ecosystems, zonation in mangrove may also vary on a local scale. Occurrence of species may differ across an estuary, apparently in response to differences in freshwater input (Feller and Sitnik, 1996), for example, species found at the seaward end of the estuary may be absent from the headwaters. Although zonation typically refers to patterns created by segregation of different species, differences in stature and productivity of plants across environmental gradients may also result in readily discernible patterns. Zones may be comprised of different architectural forms that represents variations in height and vigor. Following are the factors that govern the zonation in mangrove forest:

a. Land building and plant succession: The idea is species that grow in the lower intertidal zone successfully trap sediments. Over time, the sediment builds up and new mangroves are able to invade and out compete the colonizers.

b. Geomorphologic influences: It is now widely recognized that mangroves respond to geomorphologic changes rather than cause the changes themselves. Detailed studies have established that mangrove vegetation is directly dependent on the dynamics of sediment topography.

c. Physio-chemical gradients and zonation: A dominant theme in vegetation ecology is the idea that a species adapts physiologically to physico-chemical gradients in the environment.

d. Propagule dispersal and zonation: The mangroves were distributed from low to high intertidal area in a manner inversely related to the size of their propagules. *Avicennia germinans* and *L. racemosa* were restricted to high intertidal zones because they had small propagules that high tides would carry the farthest inland.

e. Propagule predation and forest structure. Predation of seeds has been recognized as an important process in a variety of ecosystems. Watson (1928) commented on the role of crabs as consumers of mangrove propagules, particularly in the managed forests of West Malaysia.

f. Competition and forest structure: Competition was gauged by comparing the reduction in growth of each species in the presence of the other to the growth of that species alone.

1.1.4. Trophic Structure in Mangrove Forest

Trophic structure is the complex interrelationships among the various organisms in an ecosystem connected through the transfer of food energy from one trophic level to another. The traditional view is that mangrove ecosystems are based on the detritus type of food web (Odum and McIvor 1990). Work done by Heald (1969) and Middleton and McKee

(2001) demonstrated that the leaves of the mangroves fall into the water where they are then consumed by various detritivores, which are in turn eaten by fish and other organisms that feed on the detritus consumers. The grazing pathway is well thought out to be unimportant in mangroves, since it has been estimated that only 5% of the leaf material is consumed by grazing insects before leaf degradation. This value may be an underestimate, however, according to Onuf et al. (1977) substantial variation is seen in leaf herbivore among mangrove species and locations. In addition, the contribution of wood-feeding insects to the grazing pathway has not been quantified. Wood-boring beetles may chomp through living wood and in the process kill branches or whole trees (Feller and McKee 1999; Feller, 2002). These activities produce standing dead wood that is then utilized by secondary wood feeders such as termites, which in turn support secondary consumers such as arthropods, lizards, snakes, and birds (Feller and Mathis, 1997).

1.1.5. Socio-Economic Value of Mangroves

The mangrove ecosystem has important direct and indirect economic, ecological and social values to man. Mangrove ecosystems have consistently been undervalued, usually because only their direct goods and services have been included in economic calculations (e.g. Forestry resources), but this represents only a minor part of the total value of mangroves. By undervaluing mangrove ecosystems, "development" has too often favoured their rapid conversion and loss. Mangrove conversion usually leads to short-term economic gain at the expense of greater, but longer-term, ecological benefits and off-site values. The non-market values, for example species biodiversity and off-site functions such as nutrient export are not easily quantified, but have been shown to be significant. The total economic value of mangroves must be calculated in order to provide decision-makers with the real cost of converting mangroves to other apparently more profitable uses. In particular, long-term ecological benefits and off-site values should be included in valuations for mangroves. Mangroves are of prime importance in view of their protective and productive values. They provide numerous tangible and intangible benefits (goods and services) to the coastal communities (Vannucci 2004). The socio- economic importance of natural mangroves has been addressed by many scholars (Ruitenbeek, 1994; Walters, 1997; Barbier, 2006). According to Islam and Gnauck (2009), the Sundarbans mangrove forest is exploited for a range of forest products, including timber, thatching materials and wood for fuel. Transportation and retailing activities are the main sources of income for a large number of people in the southwestern part of the country (Hasan and Rahman, 2001). Wood is an important source of forest revenue and contributes over 80% of the income generated in the Sundarbans. The mangrove forests are an important source of fuel wood for the local population as well as other markets of Bangladesh (Alam, 2001). The total number of people directly employed in the Sundarbans is estimated to be about 500,000 to 600,000 people for about 6 months per year (UN/ESCAP, 1988). Large areas of the inland mangroves of southern Asia have been converted to agriculture (mainly paddy fields) or salt production. The rich fisheries resources in the coast of these countries can be attributed to the presence of mangroves to some extent (Amarasinghe et al., 2002, Islam and Wahab, 2005). Shrimp farming represents a relatively new form of coastal land use, which is a further threat (Mac Intosh and Zisman, 1997).

1.1.6. Threats and Loss of Mangroves

In modern and fast developing world, the mangroves have often been considered as uncreative land and their obliteration and degradation have been done for short-term exploitation for the immediate economic benefit. The fundamental cause of mangrove forest loss is the increase in human population living near the coastal zone. Ong (1995) considers that burgeoning population are possibly the biggest cause of mangrove destruction and degradation. An estimated 60% of the global population lives within roughly 100 km of the shore (WRI). This means that 3.4 billion people rely heavily on marine habitats and resources for food, building materials, building sites and agricultural and recreational areas. They also use coastal areas as a dumping ground for sewage, garbage and toxic wastes. Moreover, many more people in the non-coastal population lives in agricultural and urban communities concentrated along rivers and in the surrounding hills. Pollution and poor land use practices within these watershed areas affect downstream marine habitats because sediments and pollutants are ultimately washed into coastal waters.

1.1.6.1. Causes of Mangrove Degradation and Loss

Over-exploitation by traditional users: Traditional use has historically had little impact upon mangroves, but as populations grew, demand for products increased and this lead to over-harvesting and a decline in the natural resource. In the absence of sustainable management practices this lead to the decline in livelihoods of the mangrove-dependent communities. The main causes of mangrove destruction in Africa stem from traditional uses. The Sunderbans in Bangladesh have been exploited for timber, fuelwood, bark tannin, animal fodder, native medicines and food (fish, shellfish, honey and wild animals) for centuries, but population pressure has greatly increased the rate of exploitation, leading to serious degradation of the mangroves.

a. Commercial utilization: Mangrove wood (especially Rhizophora sp.) is good for charcoal production because it is heavy, dense, hard and with a high calorific value (Aksornkoae, 1993). Mangrove wood is also resistant to decay in salt water, so it has been a favored material for pilings and fishing structures in coastal areas.

b. Conversion to other natural resources use: Increasing populations put pressure on the production for food. Mangroves are often converted/ transformed for salt production, agriculture and aquaculture. Large tracts of coastal mangrove in Asia have been converted to rice farming (FAO, 1982). Thailand lost 51% of its mangroves since 1961, 49% due to conversion to salt pans and aquaculture (Aksornkoae, 1993; Mac Intosh, 1996). The Philippines lost 73% of its mangroves between 1918 and 1994; about 70% due to the construction of aquaculture ponds (Primavera, 2000).

c. Indirect/ Off-site activities: Off-site activities, unrelated to the mangrove ecosystem, but detrimental to it like diversion of upstream freshwater resources for irrigation and offshore dredging also have detrimental effects on the mangrove ecosystem. The interception of fresh water for agriculture has severely affected the mangroves in the

Indus delta of Pakistan (Hogarth, 2001). In Sao Paulo, Brazil the mangroves have been heavily impacted by landfills, solid waste disposal, industrial and domestic effluents, chemical and organic contamination.

d. Management failure: The existing policies for mangrove utilization and conservation are ambiguous and inconsistent. Lack of involvement of communities in policy/ decision (management, development of legislation, enforcement), lack of understanding and awareness of the value of mangrove ecosystems among various groups of people including policy makers, officials, developers and local people have all lead to management bottlenecks.

Underestimation of the total economic value of mangroves and of the impacts of human activities is a major factor contributing to the widespread loss and degradation of mangrove ecosystems (Gilbert and Janssen, 1998). Serious environmental, social and economic impacts are associated with the decline and degradation of mangroves. For example in Vietnam where mangrove loss due to defoliants used during the Vietnam war, logging and aquaculture have led to coastal erosion, salinity intrusion and decline in natural shrimp and mud crab (Scylla species) populations (Hong and San, 1993).

1.1.6.2. Pollution Impacts

Mangrove roots often act as barrier, retain most of the heavy metals and reduce the translocation of heavy metals to other plant parts. It has been suggested that Cu is more mobile in mangrove plants than other metals. In general, very small amounts of heavy metals are found in leaf tissues as most of the absorbed heavy metals are accumulated in the stem and roots (Yim and Tam, 1999). The sheltered and stagnant water environment of mangroves allows extensive sedimentation of the finest clay, silt and detrital particles. This material is bound and stabilized by a tangled mat of root hairs growing horizontally just below the mud surface. Although mangrove ecosystems can act as sinks for heavy metals, they can also become pollution sources for plants and soils. In all the literature that has been reviewed, it seems that lead (Pb) has the most detrimental effect on plants and photosynthetic processes (Karen, 2005). Rainbow (1995) has indicated that heavy metals and many other pollutants are expected to be absorbed more rapidly at higher temperatures. Harbison (1986) reported that tidal mudflats and particularly mangrove substrates contain a much greater load of trace metals than other shoreline sediments. Mangrove mud possesses intrinsic physical and chemical properties and an extraordinary capacity to accumulate materials discharged to the near shore marine environment according to Harbison (1986). Tam and Wong (2000) found that higher concentrations of heavy metals were found in the fine-grained fraction of the sediment rather than the sand-sized fractions. The difference, however, became less significant when the region became more contaminated/ polluted. These results suggest that the source of the pollution is irrelevant as the heavy metals are instantaneously adsorbed into the sediments. Large amounts of heavy metals are bound in the fine grain fraction (< 63 um) of the sediment mainly because of its high surface area to grain size ratio and humic substances content. There are three possible mechanisms by which trace metals may be taken up by sediments and suspended matter:

a. Physicochemical adsorption from the water column
b. Biological uptake by organic matter or organisms
c. Physical accumulation of metal enriched particulate matter by sedimentation or entrainment.

Physicochemical adsorption directly from the water column happens in many different ways. Physical adsorption usually occurs when particulate matter directly adsorbs heavy metals straight from the water. Chemical and biological adsorption are more complicated as they are controlled by many factors such as pH and oxidation.

1.2. Current Scenario of Mangroves of the World

1.2.1. Distribution

According to Spalding (1997) total global mangrove coverage is 18 million hectares and it is just about 0.45% of world forests and woodland. Four countries (Indonesia, Brazil, Australia, and Mexico) account for >40% of the total global mangrove coverage, with Indonesia leads the way with >20%. While we have no accurate means of determining the global cover prior to 1980, it is thought to have been greater than 200,000 km2 (Spalding et al., 1997). Lacerda and Diop (1993) estimated mangroves cover to extend over 15 million hectares worldwide, there are about 6.9 million ha in the Indo-Pacific region, 3.5 million ha in Africa and some 4.1 million ha in the Americas including the Caribbean. In 2006, FAO estimated total mangrove cover to be 39,520,000 km2. The findings of FAO (2007) believed to be most detailed historical records which indicate that in 1980 there was a total of 188,000 km2 of mangroves. Work done by Van Lavieren et. al. (2012) revealed that mangrove forests are found in 123 tropical and subtropical nations and territories. They are globally rare and only cover an area of about 152,000 km^2, which is <1% of all tropical forests worldwide, and <0.4% of the total global forest estate (39,520,000 km2; FAO, 2006). They also identified two main biogeographic flora zones, a diverse Indo-West Pacific flora which is extending from East Africa to Polynesia and a less species in Atlantic East Pacific in the Americas and West and Central Africa. With the exception of the fern, *Acrostichum aureum*, there is virtually no overlap in species distribution between these two realms. In the Indian Ocean region, the mangroves are found in a variety of coastal settings, ranging from arid areas through estuaries, lagoons and deltas to coastal fringes. Kathirasen (2004) estimated total area of mangrove in the Indian Ocean Region to 84,984.56 km2. He also stated that mangrove cover in about 30 countries of the Indian Ocean Region is ranges from 1.08 km2 (in Comors) to 42,500 km2 (in Indonesia). He observed that in a few countries, especially in the arid regions of the Gulf, mangrove occurred only in scattered patches. According to Kathiresan (2003a) mangroves of South and Southeast Asia form the world's most extensive and diverse mangrove system comprising 41.4% of global mangroves.

1.2.2. Mangrove Species Diversity

Tomlinson (1986) estimated Around 34 major and 20 minor mangrove species belonging to about 20 genera in over 11 families have been recorded globally. The species diversity and distribution of mangroves is variable at different spatial scales: global, regional, estuarine and intertidal (Duke et al., 1998). Duke (1993) divided the distribution of mangroves into two global hemispheres the Atlantic East Pacific and the Indo West Pacific. These regions have similar areas of mangrove forests, but the Indo West Pacific region is about five times more diverse with 58 species compared to 12. The Indo-Malaysia region has the most species with 48 (Duke et al., 1998). Macintosh and Zisman (1997) estimate 80 species of true mangrove trees/shrubs are recognized, of which around 50-60 species make a significant contribution to the structure of mangrove forests. Species diversity is much higher in the Southeast Asian region, where approximately two-thirds of all species are found, while approximately 15 species occur in Africa and 10 in the Americas. According to Polidoro et al. (2010) in the world, there are 70 species of true mangroves. The Sundarbans mangroves in West Bengal comprise more than 20 species and represent 50% of India's mainland mangrove resource, whereas at similar latitudes on the arid west coast (Gujarat) only nine species occur and the mangrove forest contributes only about 12% of the total resource (Jagtap et al., 1993). In the Bangladesh Sundarbans, there are 36 mangrove species and 30 mangrove-obligate plant species. Comparatively, there are only 7- 9 obligatory mangrove plant species found in the America´s and Africa, while 20-40 species are typically found in the Indo-western Pacific region (Islam et al., 2009).

1.2.3. Faunal Species Diversity

Crabs of the Grapsidae and Ocypodidae are key components of Indo-Pacific mangroves (Lee, 1998). Ocypodids such as fiddler crabs (Uca) are a characteristic feature of the forest floor and may occur at very high densities (Hartnoll et al., 2002). They can alter both sediment topography (Warren and Underwood, 1986) and the composition of sediment microflora (O´ lafsson and Ndaro, 1997). Sesarmids (Grapsidae: Sesarminae) are likewise of great importance to Indo-Pacific mangrove ecosystems (Lee 1998). Their burrowing and feeding activities may significantly affect mangrove primary productivity (Smith et al., 1991), tree colonization (Dahdouh-Guebas et al., 1997), nutrient cycling and energy flow (Lee, 1997; Skov, 2001; Skov and Hartnoll, 2002). Unfortunately, the trophic importance of such crabs cannot be clearly resolved because satisfactory methods for the estimation of mangrove crab density have been lacking (Lee, 1998). Fiddler crabs are deposit feeders and require water for sediment sorting (Miller, 1961), so surface activity may be reduced and burrow plugging increased during neap periods when the sediment is dry (Zucker, 1978). Macia et al. (2001) and Skov and Hartnoll (2001) found that the relationship between observed counts (visual, burrows) and absolute densities varied between spring and neap periods. Another study by Kethirasan et al. (2005) estimated Brayozoa (5), Crustaceans (229), Insects (500), Mollusca (238), Fish (238), Reptile (22), Amphibians (2), Birds (177) and Mallmals (36) from Indo-Malaysia.

1.2.4. Threats and Loss of Mangroves

The work of many scientists indicates that the original extent of mangrove forests has declined considerably under pressure from human activity. National proportions of the original mangrove cover lost varies from 4 to 84%, with the most rapid losses occurring in recent decades. For example, in Southeast Asia, Malaysia lost 12% from 1980 to 1990 (Ong, 1995); the Philippines originally had 4,300 km2but now has 1,200 km2 (Primavera, 2000); Thailand had 5,500 km2 in 1961 but 2,470 km2 in 1986 (Aksornkoae, 1993); and Vietnam 4,000 km2originally to 2,525 km2today (Spalding et al., 1997). Ong (1995) considers that the loss of 1% mangrove area per year in Malaysia is a conservative estimate of mangrove destruction in the Asia-Pacific region.

1.3. Current Scenario of Mangrove in India

1.3.1. Distribution

India harbors some of the best mangroves in the world. These are located in the alluvial deltas of rivers such as the Ganga, the Mahanadi, the Godavari, the Krishna and the Cauvery as well as on the Andaman and Nicobar groups of Islands (Singh, 2002). Indian mangroves make up 3.1% of the total global cover and are distributed along all the maritime states, except the union territory of Lakshwadeep, covering an area of about 4461 sq. km along the 7,500 km long Indian coastline (Anon. 2005). According to Singh et al. (2012) presently 60% of the mangroves occur on the east coast along the Bay of Bengal, 27% on the west coast bordering the Arabian Sea, and 13% on Andaman and Nicobar Islands.

1.3.2. Mangrove Species Diversity

Kathiresan (2003b) stated that floral diversity of mangroves of India is comprised of 38 core mangrove species. Another study on Mangrove by Kathirasan et al. (2005) indicates 39 principal mangrove species. A more comprehensive study by Singh et al. (2012) revealed that Indian mangroves comprise approximately 59 species in 41 genera and 29 families. Further, the west coast has 34 species belonging to 25 genera and 21 families and east coast has 25 mangrove species. There are 16 mangrove species found in the Gujarat, 20 species in Maharashtra, 14 species in Goa, 10 species in Karnataka and 4 species in Kerala (Singh et al., 2012). Punducherry have seven true mangrove species belonging to three families, 16 mangrove associate plants belonging to 12 families (Sateeshkumar et al., 2012). Excluding the Andaman and Nicobar islands, about 50% of India's mangrove resource is found in the Ganges delta of West Bengal (Sunderbans) and comprises more than 20 species, whereas at similar latitudes on the arid west coast (Gujarat) only about 12% of the total resource and nine species occur (Jagtap, 1993). A study revealed that, 38 species of mangroves belonging to 21 genera and 18 families are found in Andaman and Nicobar (Mall et al., 1985), although Naskar and Mandal (1999) reported 35 true mangrove species from Indian sub-continent. Out of these, 13 species of mangroves are found in the west-coast of India.

Avicennia marina, *A. officinalis*, *A. alba*, *Heritiera* sp., *Rhizophora* sp., *Ceriops tagal*, *Bruguiera* sp., *Aegiceras* sp., *Acanthus* sp. and *Sonneratia apetala* are dominant in mangroves of India (Singh, 2002). James (2006) stated that 50 of the 60 mangrove species are found in India.

1.3.3. Faunal Species Diversity

Kethirasan et al. (2005) noted Carb (138), Prawns (55), Mollusca (308), Insects (711), Other Invertibrates (745), Fish (546), Birds (433), Amphibians (13), Reptile (85) and Mammals (70) in mangrove ecosystems of India. Punducherry mangroves have a total of 76 faunal species recorded. This includes 37 species of mollusks (bivalves 16 and gastropods 21), 22 species of crustaceans, 7 species of amphipods, 6 species of polychaetes, 3 species of barnacles and 1 species of oligochaetes (Sateeshkumar et al., 2012). Kathiresan and Rajendiran (2002) found 102 and 86 species of fin fishes from Pichavaram mangroves and Vellar estuary, respectively. A total of 56 species of birds representing 11 orders, 29 families and 46 genera were recorded from the mangroves of Uran (Raighardh, Maharashtra) coast recorded by Pawar (2011). Recently Singh et al. (2012) claimed that there are 105 species of fishes found in the mangrove ecosystem in India. In the mangroves of Kollam district, (Kerala) 27 species of fishes (17 families) have been found (Singh et al., 2012).

1.3.4. Threats and Loss of Mangroves

India, being a developing country, it's Mangrove are constantly under threats. Kerala along the west coast of India has a coastline of 590 km and presently the mangrove area is estimated to be about 17 km^2, of which 36% is either completely degraded or is degrading (Satheesehkumar et.,al, 2011). In Puducherry the mangroves are increasingly being threat-ened by population pressure, aquaculture operations and mangrove environment conversion to new shrimp ponds, dredging for landfills, and building ports, industrial estates and housing estates for human habitation (Satheesehkumar et.,al, 2011). Top-dying of sundri as well as over-cutting is blamed for this situation, but the die-back problem seems to be associated with increased salinity arising at least partly from large scale diversion of freshwater - an indirect form of human impact on the Sundarbans mangroves. (Macintosh and Zisman,1997). Recent industrialization, development of ports, etc. have again put these ecosystems under stress, as evident from recent satellite data (GEC, 2011).

1.4. Scenario of Mangroves in Gujarat

1.4.1. Distribution

Though Gujarat stood second in total mangrove cover, after West Bengal (46.4%), the state in recent years showed increased growth by 55 km2 (GEC,2011). This makes Gujarat a leading state in terms of increasing of mangrove cover in India. Though such good track record of mangrove cover, the state is considered to be inferior in floristic composition and stem height by many scientists. Gujarat state has about 1,650 km long sea coast and has mangroves spread over an area of 1046 km2 (SFR, 2011). About 90 percent of mangroves in Gujarat are located around the Gulf of Kachchh while the rest of the mangroves are found in the Gulf of Khambhat and on the South Gujarat coast (Hirway, 2004). Out of 1046 km^2 mangrove covers 182 km^2 are moderately dense mangrove and roughly 876 km^2 are open mangrove forest. Very high tidal amplitude and tidal energy in the Gulf of Khambhat are limiting factors for setting of mangroves.

1.4.2. Mangrove Species Diversity

Major work on the mangroves in Gujarat has been carried out by agencies such as the State Forest Department, Space Applications Centre (SAC, Indian Space Research Organization, Ahmedabad), and Gujarat Ecological Education and Research Foundation (Gandhinagar). Eight core mangrove species have been reported by them along the Gujarat coast. However, most of their work is restricted to the Gulf of Kachchh with an emphasis on species diversity and extent (Chavan, 1985; Shah et al., 2005; Singh, 2002; Singh, 2006). Preliminary observations (Singh, 2002) suggest that the estuaries of south Gujarat also harbor a rich diversity of mangroves. However, they have remained largely uninvestigated, except for areas of the Umargaon creek (Kothari and Rao, 1991a, 1991b; Kothari and Singh, 1998) and Valsad (Shah, 1978). Recently

Bhatt et al. (2009) reported seven species of mangrove belonging to five families from Purna estuary. The most addition was done by a study which revealed the presence of 13 different species of mangrove in Southern Gujarat, along the coast of Valsad and Navsari (GEC,2011). A recent all India mangrove survey revealed that the state has total 16 species of mangrove (Singh et al., 2012).

1.4.3. Faunal Species diversity

Sometimes, about a million of water birds can be counted in extensive mudflats in the estuaries of Narmada, Mahi and Sabarmati rivers in winter in the Gulf of Khambhat. This includes a very large colony of lesser and greater flamingo. Estuaries of rivers in south Gujarat have a good patch of mangroves and they support some of the rare species of mangroves and other marine life and hence they require legal protection. Generally the faunal studies are carried out by bird watchers and therefore the non technical reports of bird diversity are available. Along the lower estuarine mud flats of Mahi River 57 species of birds were reported, although their association with the mangrove areas was not specified in the study (Pandya and Vachhrajani, 2010b). Studies from our lab has recently reported few species of crabs and molluscs from various mangrove habitats of Guajrat (Pandya and Vachhrajani, 2010a; 2010b; 2011; 2012; Trivedi et al., 2012; Pathak et al., 2013). By Gulf of Kachchh, 19 species of brachyuran crabs were reported which included both the mangrove and non mangrove open mud flats (Trivedi et al., 2012). Eleven species of gastropod mollusks were reported from lower estuarine mud flats of the Mahi River, which includes sites like Sarod and Kambaoi (Pandya and Vachhrajani, 2012).

1.4.4. Threats and Loss of Mangroves

Gujarat always had good and flourished mangrove cover along the past years, but during the past some decades this extensive and diverse ecosystem had been degraded due to one or other development activities. In reality mangrove were considered as ‘Economically Unproductive Areas’ and suffered from massive loss due to some industrial development until the 1960s (Hirway and Goswami, 2007). After which due to various restorations project state's mangrove cover was on the roll and estimated to be 427 km^2 in 1987 and 1031 km2 in 1999. The second down phase, massive mangrove loss, was observed during 2000-2001 when a study by FSI reveled decrease of 120 km^2 loss (GEC, 2011). But after it mangrove showed its characters to withstand to any possible adverse condition and with numbers of afforestation projects returned back to its normal state.

1.5. Lacuna of Knowledge

Gujarat is a leading state in terms of increasing of mangrove cover in India. About 90 percent of mangroves in Gujarat is located around the Gulf of Kachchh while the rest of the mangroves are found in the Gulf of Khambhat and on the South Gujarat coast. As there is more mangrove cover in the Gulf of Kutch, all the major studies have been carried out there while the mangroves of Gulf of Kambhat are studied very less. Scientist like Shah (1978), Kothari, and Rao (1991a, b), Kothari, and Singh (1998), Singh (2002), Bhatt et al. (2009) etc. have worked on mangrove species diversity of Gulf of Kambhat. Labuska et al. (1999), Nirmal Kumar et al. (2011), Deshkar et al. (2012) have worked on the pollution aspects of the Gulf of Khambhat. Hirvey et al. (2004) and GEC (2011) has worked on socioeconomic aspects of mangrove ecosystems. All of these works are carried out at different locations for various study durations at different time periods over the past two decades and, therefore, a comprehensive status of the mangrove ecosystem of the Gulf of Khambhat cannot be concluded from these studies. Further, the socioeconomic aspect is negligently spared in these studies. The local community has some knowledge on the significance of the mangrove ecosystem and implements conservation measures at smaller/ local levels. Awareness among the people and their sensitization towards important issues are some of the best participatory conservation management approaches. However, the gap of basic information is much wider and hence on the basis of these the holistic conservation management cannot be implemented.

1.6. Initiation of the Research Idea

I was working with the Bombay Natural History Society as a Project Fellow on the aspects of the status of mangrove habitat and its restoration program along the coast of South Gujarat. During my extensive field visits I realized that this area had the extensive anthropogenic pressure and dependency of human population on mangroves was ever increasing. The Forests and Environment Department of Government of Gujarat as well several industries had attempted restoration of mangrove habitat and implemented extensive afforestation programs during the past two decades along the south Gujarat coast. However, the information regarding biodiversity, extent of anthropogenic pressure, dependency estimates were not available at all. None of the studies in Gujarat so far had comprehensively incorporated multifaceted socio- economic and eco-environmental approach to understand the fate of such restoration and agitation programs. Without understanding the root causes of habitat degradation and loss the management and conservation approaches cannot be implemented or sustained.

My interactions with the people of the coastal villages induced me to carry out a comprehensive study which analyzes the status of mangrove habitat through a dual angle of socioeconomic and eco-environmental perspectives. I realized that management and conservation approaches should be primarily based on awareness programs. Therefore, in present study I not only did the basic research, but incorporated extensive awareness and training programs for the coastal community.

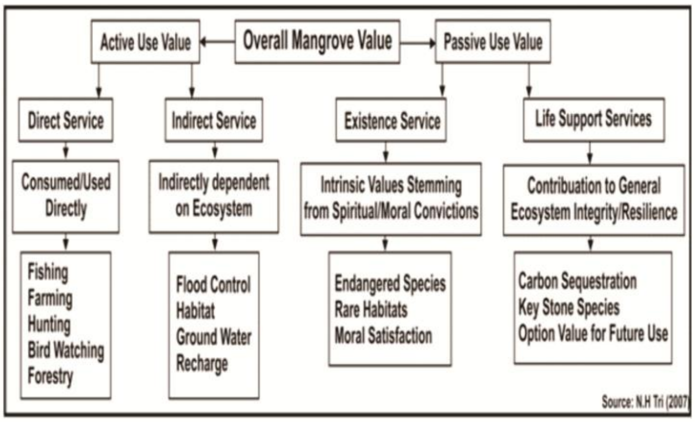


Figure 1.1: Ecological and economic value of mangroves

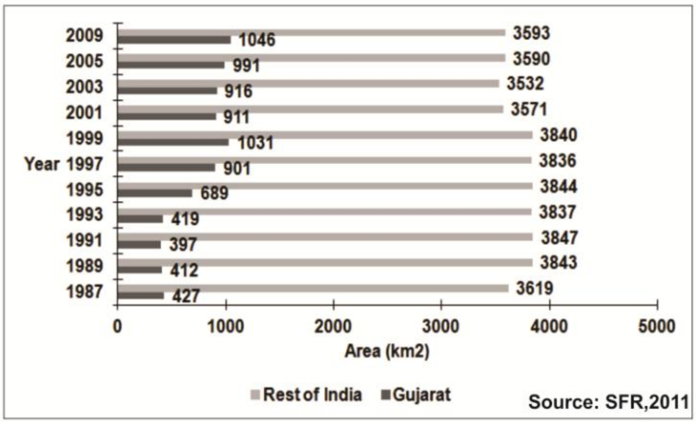


Figure 1.2.: Total mangrove covers in Gujarat

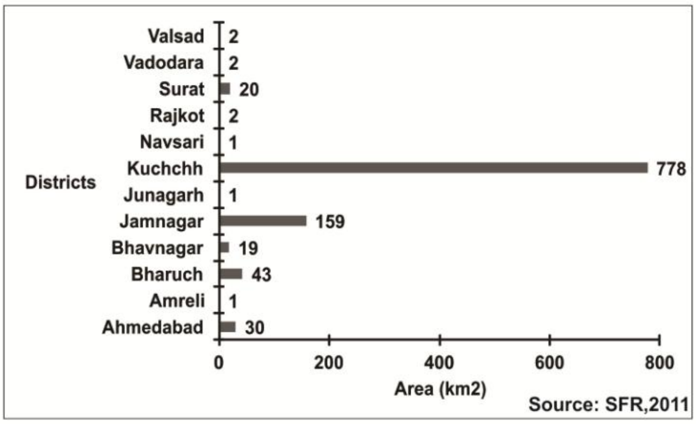


Figure 1.3.: District wise mangrove cover in Gujarat (2011)

1.7. OBJECTIVES

1. Qualitative and quantitative status of mangrove habitat:
   a. Study the extent and status of mangrove ecosystems
   b. Evaluate the abiotic and biotic status of mangrove ecosystems

2. Anthropogenic pressures and dependency on mangroves:
   a. Analyze the types of anthropogenic pressures and their extent in the study area
   b. Evaluate the status of pollution and its impacts on the mangrove ecosystem.

3. Education program implementation
   a. Evaluate status of knowledge on mangroves among the population
   b. Community awareness programs in conservation management of mangrove ecosystem

1.7.1. Justification for Objectives

1. Qualitative and quantitative status of mangrove habitat:

a. Abiotic status of Mangrove ecosystem.

Well being of mangrove ecosystem is dependent upon phytochemical parameters of the sediments and water. Any change in this can have a devastating effect on the ecosystem. So, it is necessary to access the type and variation of these parameters for better assessment of mangrove ecosystem.

b. Biotic status of Mangrove ecosystem.

Mangrove ecosystem is one of the most productive ecosystems of the world. Its sheer existence can protect various other marine ecosystems, like mudflats and coral ecosystem, and its faunal components, like fish, crab, bird, etc. If mangrove ecosystem is under pressure then the diversity and density of these biotic components change and produce an effect on the ecosystem. So, it is necessary to access the associated fauna to understand the status of mangrove ecosystems.

2. Anthropogenic pressures and dependency on mangroves:

   a. Types of anthropogenic pressure and dependency.

   Mangrove ecosystem, not only provide protection from the natural hazards like tsunami, but is a major source of food, in terms of fishing, fodder and seeds, to the local community. Due to this high dependency mangroves are under tremendous pressure. So, it is necessary to access the type and extent of anthropogenic pressure on ecosystems.

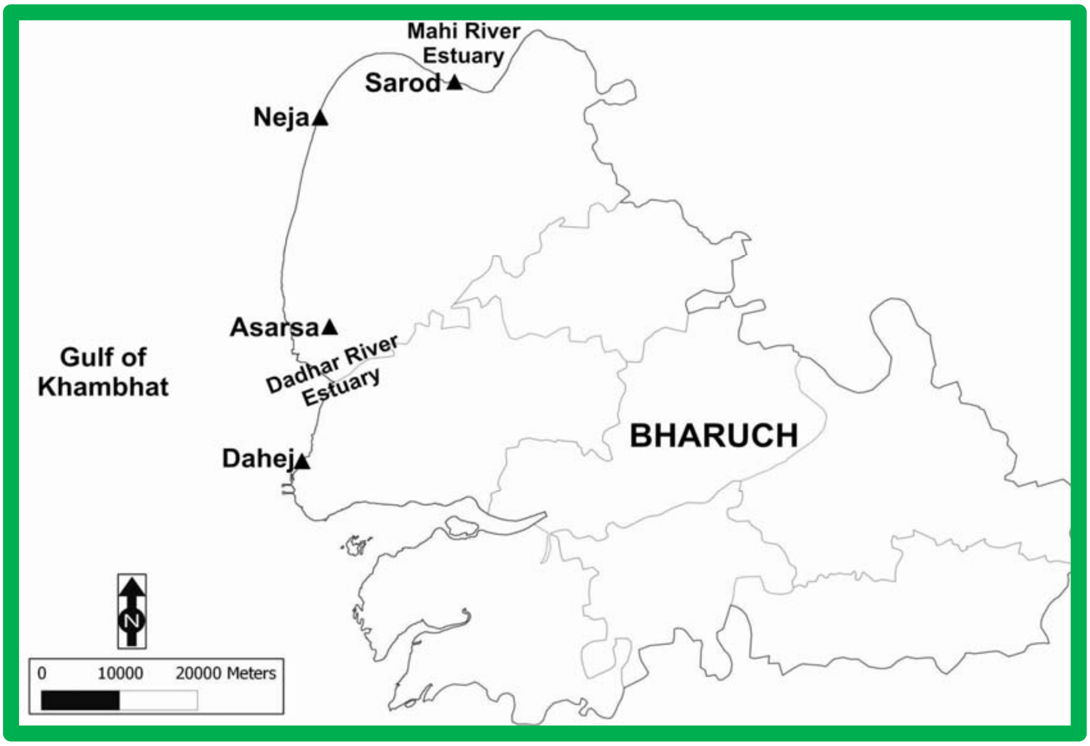
   b. Status of pollution and its impacts on the Mangrove ecosystem.

   Apart from its service to mankind, the mangroves of the world are facing extreme pressure from the industrial and domestic effluent discharges as coastal areas/ mangroves are believed to have a large capacity of absorbing industrial and domestic waste. These can alter the natural balance in the ecosystem resulting in degradation of the habitat.

3. Education program implementation

   After assessment of the various types of pressures on the mangrove ecosystem it is necessary to sustainably manage the habitat. This can be achieved by spreading awareness about mangroves and its importance to local community's livelihoods. This is comprehensively incorporated as community awareness programs in conservation management of mangrove ecosystem.

CHAPTER 2: STUDY SITES



2. STUDY SITES

- 2.1. Gulf of Kambhat
- 2.2. Site Selection Criteria
  - 2.2.1. Site Location
  - 2.2.2. Mangrove Patch
  - 2.2.3. Biodiversity
  - 2.2.4. Pollution
  - 2.2.5. Dependency Pressure
- 2.3. Description of Study Sites
  - 2.3.1. Sarod (22°10'32.12"N and 72°45'18.49"E)
  - 2.3.2. Neja (22° 9'2.00"N and 72°33'3.10"E)
  - 2.3.3. Asarsa (21°53'53.75"N and 72°34'56.43"E)
  - 2.3.4. Dahej (21°43'13.50"N and 72°31'42.90"E)

2.1 Gulf of Kambhat

Gulf of Khambhat is triangle-shaped gulf of the Arabian Sea, projecting northward the coast of Gujarat state, western India, between Mumbai and the Saurashtra Peninsula. It is approximately 190 km wide at its mouth between Diu and Daman, but it promptly narrows to 11 km towards the Mahi River between Kamboi and Khambhat on the two banks/ coasts. The coast of the Gulf of Khambhat is enclosed by a number of estuaries, mud flats, salt marshes, islands, cliffs and mangrove forests. The Gulf is characterized by a number of large and small estuaries appearing as if enclosed within a large one. Many rivers, like Sabarmati, Mahi, Narmada and Tapti, have their river mouth in the Gulf of Kambhat. Its outline and its orientation in relation to the southwest monsoon winds make this Gulf to have a high tidal range 12 m and the high velocity of the entering tides.

On the eastern side of the gulf lies district like Bharuch, one of the oldest Indian ports, and Surat, identified with early European commercial contacts with India. While on northern end districts like Ahmedabad and Vadodara are present. The western side is marked with Bhavnagar, having largest ship recycling yard. The town of Khambhat, from which this gulf was named, is at the head of the gulf in the Anand district. Although the importance of the gulf ports has been only local, the discovery and exploration of oil, particularly at Gandhar near Bharuch, around the head of the gulf, and in the offshore Mumbai High field, has caused a commercial revival in the region.

Extensive mudflats, 6-8 km wide have developed all along the coast except along the coast of Narmada estuary. These mudflats are classified on the basis of their relation with tidal condition into sub tidal, intertidal and the high tidal flats. The sub tidal zone is exposed during very low tide. The intertidal zone lies between high water and mean low water mark while the high tidal flats lie above the mean high water marks. In these zones some extensive forests of mangrove are present. A study done by Charatkar et al. (2005) shows that there is an increase in terms of mangrove cover from 19.78 km^2 (1995) to 28.85 km^2 (2003) in the Gulf of Khambhat.

2.2. Site Selection Criteria

After a preliminary survey of 9 sites, Sarod, Kamboi, Neja, Ishanpur, Nada, Asarsa, Denva, Gandhar and Dahej, in Bharuch district, I selected four sites, Sarod, Neja, Asarsa and Dahej, for this study. The criteria for selecting these four sites, Figure 2.1, are as below:

2.2.1. Site Location

As mangroves are found in the estuarine area, two study sites Neja and Dahej are located on the lower estuarine mud flats of Mahi and Dadhar Rivers, respectively. Sarod and Asarsa are located towards the inner side of Mahi and Dadhar River Estuaries, respectively.

2.2.2. Mangrove Patch

Size and type of Mangrove patch are one of the important criteria to check anthropogenic pressure on it. Two sites, Asarsa and Dahej, have dense and large mangrove patches while Neja has large but open Mangrove Patch. Sarod has a comparatively much sparse patch of mangroves.

2.2.3. Biodiversity

Mangrove provides a feeding and nesting ground to faunal diversity. Even the indirect evidence of the presence or absence of biodiversity can provide a status scenario of mangrove ecosystems and the pressures on it. Sarod, being most polluted site, has very low diversity of mangrove associates while Neja, Asarsa and Dahej have a good diversity of the associate fauna.

2.2.4. Pollution

This is of the important criterion as mangroves are often used as a dumping ground of solid waste and effluent. Sarod, in Mahi Eastury, is used as a discharge point of effluents generated by the Nandesari Industrial Estate and other large/small scale industrial units. Neja, also in Mahi Estuary, have good patch of mangrove and is likely to be affected from the discharged upstream. Asarsa, in Dadhar river estuary, is free from pollution while Dahej, having Oil Jetty and Port, experience different types of pollution.

2.2.5. Dependency Pressure

Traditionally, the mangroves have been exploited for timber and fuel wood, bark tannin, animal fodder, native medicines and food (fish, shellfish, honey, wild animals etc). Every good mangrove patch has anthropogenic pressure of one kind or other. Sarod's small and high contamination mangrove patch provide a lesser ecosystem service and suffers indirect dependency pressure. On the other hand, Neja, Asarsa and Dahej have a lush growth of mangroves that provide a good number of ecosystem services and also face more dependency pressure.

2.3. Description of the Study Sites

2.3.1. Sarod (22°10'32.12"N and 72°45'18.49"E)

Sarod is situated in Jambusar taluka of Bharuch district. It is located on Mahi Estuary (Fig. 2.2). The coastline is marked by steep ravine slopes with *Accasia* Sp. plantation and by huge mudflat towards the sea. Sarod sediment has comparatively low water holding capacity. Sarod is point of industrial effluent release. The effluent from the industrial area of Vadodara is brought here through a 56 km long channel and areleased in the lower estuarine area of Mahi River at Sarod. This site has very less mangrove cover.

2.3.2. Neja (22° 9'2.00"N and 72°33'3.10"E)

Neja is situated in Jambusar Taluka of Bharuch District. It is located beyond Mahi river estuary, towards the gulf (Fig. 2.2). The site is marked by the farms on the landward side with open mangrove cover on the sea ward site. This site has a good growth of mangrove, Avecinnia marina and became more extensive with about 30 hectors of mangrove plantation, *Avecinnia marina*, was carried out by Shir Bhatiji Sanyukt Kheti Sahakari Mandali in 2010 (GEC, 2011).

2.3.3. Asarsa (21°53'53.75"N and 72°34'56.43"E)

Asarsa is situated in Jambusar taluka of Bharuch District. It is located on the Dhadhar estuary (Fig. 2.3). This is marked by a dense mangrove patch on the seaward side and recently created salt pans on the landward side. This site hosts one of the most dense mangrove covers of *Avecinnia marina* in the Gulf of Khambhat. Recent plantation *of Avecinnia marina* to the extent of 150 hector by Jalstrav Gram Vikas Mandal of adjoining village Nada, make this site one of the major mangrove site and the mangrove hot spot of the region.

2.3.4. Dahej (21°43'13.50"N and 72°31'42.90"E)

Dahej is situated in the Vaghra taluka of Bharuch district. It is located on the southern part of Dhadhar estuary (Fig. 2.3). This is a very famous port from ancient time, now serving as major oil terminal of the south Gujarat. The landward side is marked with plantation of Accasia sp. while on the sea ward side it is marked by dense growth of the mangrove *Avecinnia marina*. This site has patchy mangroves towards the low tide line and dense mangrove towards high tide line.

Fig. 2.1: Study Site Location

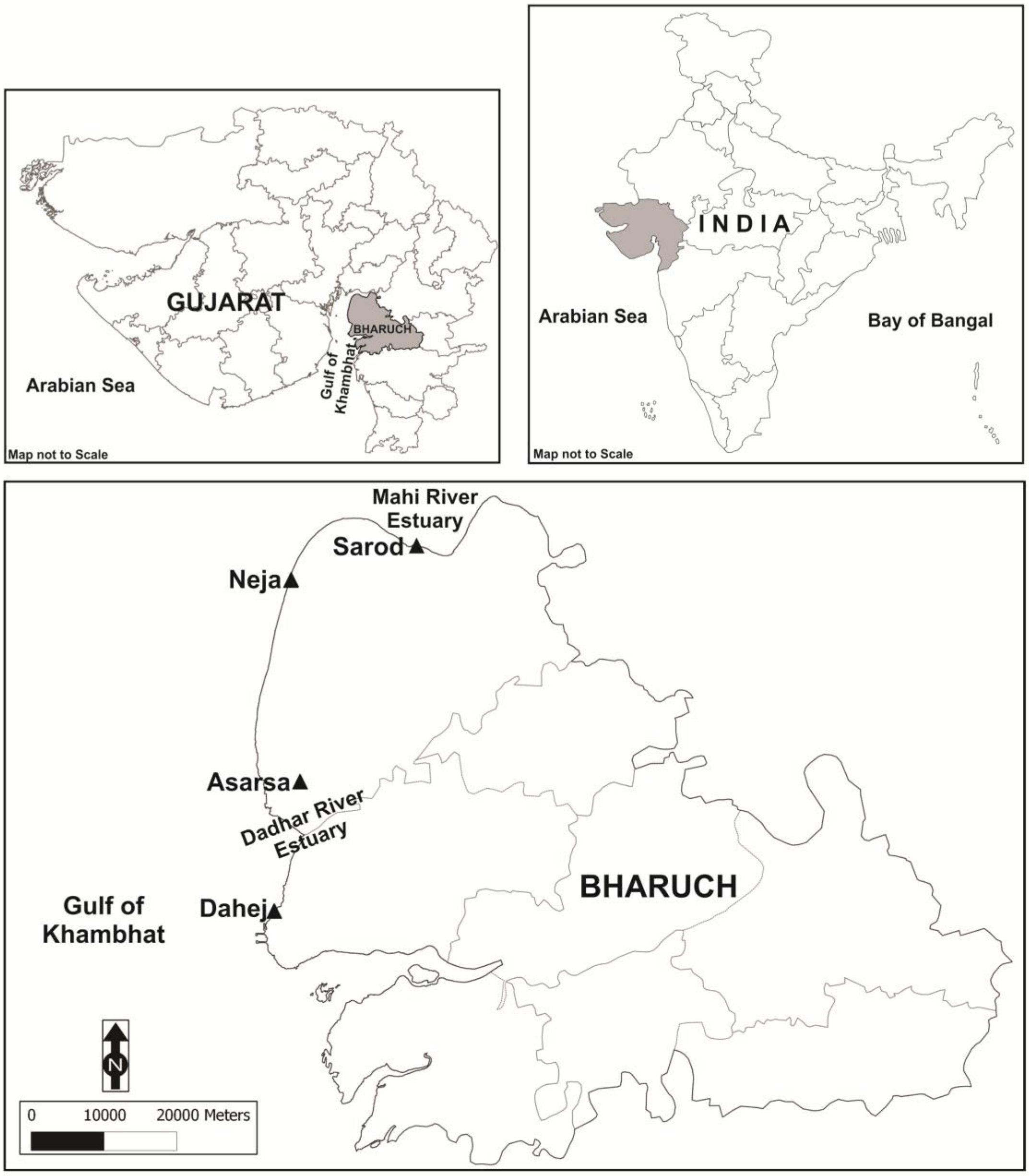


Fig. 2.2: Study Sites of Mahi River Estuary

Sarod

Neja

Fig. 2.3:Study Sites of Dadhar River Estuary

Asarsa

Dahej

CHAPTER 3: METHODOLOGY

3. METHODOLOGY

3.1. Abiotic Status of Mangrove Ecosystem

3.2. Biotic Status of Mangrove Ecosystem

3.3. Types of Anthropogenic Influence in Study Area

3.4. Status of Pollution and its Impacts on the Mangrove Ecosystem

3.5. Community Awareness Programmes in Conservation Management of Mangrove Ecosystem

3.6. Field Survey and Data Collection

3.6.1. Site Station Selection for Data Collection

3.6.2. Socio-Economic Survey

3.6.3. Sediment and Water Survey

3.6.4. Biotic Indicators

3.6.5. Samples for Heavy Metal Analysis

3.6.6. Education Programmes and Materials

3.7. Laboratory Analysis

3.7.1. Sediment Composition

3.7.2. Leachet Preparation

3.7.3. Leachet and Water Sample Analysis

3.7.3.1. pH

3.7.3.2. Alkalinity

3.7.3.3. Salinity

3.7.3.4. Hardness

3.7.3.5. Solids in Water

3.7.3.6. Organic Matter

3.7.3.7. Chemical Oxygen Demand

3.7.3.8. Phenolic Compound

3.7.3.9. Heavy Metals

3.7.3.10. Identification of Associated Fauna

3.8. Analysis of Collected Data

3.8.1. Crab Burrow Count and Mangrove Density

3.9. Statistical Analysis

The methodology selected and the studies carried out is divided into three groups viz., Field Survey, Sampling and Data Collection, Laboratory Analysis of Abiotic Components and Analysis of Collected Data particularly on the biotic community (Fig. 3.1). Selection of methodologies was depended on the following criteria:

3.1. Abiotic Status of Mangrove Ecosystem

For any ecosystem abiotic component is one of the most important factors. These abiotic factors include type and composition of sediment, water quality, light, temperature, oxygen etc. Mangroves grow in the hostile condition and face both salt and fresh water status; balance of all abiotic parameter becomes even more of important.

3.2. Biotic Status of Mangrove Ecosystem

The richness of any ecosystem is determined by its living, i.e. biotic, component which include flora and fauna. Mangrove ecosystem is dominated by various species of Mangrove that play a role of primary producer. Its leaves when shad are decomposed in sediment and provide a good source of food to fiddler crab that are continuously screened out nutrients from mud. This crab, primary consumer, then provides a food source to secondary consumers, to fishes like mudskipper and a diversity of birds. Certain species of fungi then use dead remaining of above mentioned components and releases the nutrient back into the food chain which again are absorbed by mangroves. This simple looking food chain can be a complex one where more than a couple of producers and consumers is involved.

3.3. Types of Anthropogenic Influence in Study Area

Mahi and Dhadhar river estuaries are one of the important estuaries on the upper part of Gulf of Khambhat. Both estuaries are facing a different kind of anthropogenic pressure. On the prior visit each site are checked for various anthropogenic activities by carried out simple checklist method. After it most immediate pressure type screen out and then during each successive visits that pressure is monitor to know its impact on the Mangrove

Ecosystem. Father the anthropogenic influence is divided into two categories, i.e. direct influence and indirect influence.

3.4. Status of Pollution and its Impacts on the Mangrove Ecosystem

One of the anthropogenic effects on mangrove ecosystem is an accumulation of pollutant such as heavy metals, phenol in its root, leaves and other part. These pollutants also make their way to other living fauna such as crab and mudskipper interrupting their lives in many ways. In determining that which pollutant should be studied, mostly secondary data about industries and type of effluence were carried out by literature referencing and use as secondary data. To full fill this objective, I cariied out study on accumulation of selected pollutant and other pollution indicators in sediments, water, mangrove parts, crab and mudskipper.

3.5. Community Awareness Programmes in Management of Mangrove Ecosystem Conservation

The immediate effect of anthropogenic activities on mangrove ecosystem comes from the population settled near to the area. In order to minimize this effect I have carried out community awareness programs in the surrounding area with the help of specially designed presentation which include topics like value of well maintained mangrove forest, ways of its sustainable use, etc. Another presentation included all basic information, like the origin and distribution of mangrove, mangrove plant and its parts, fauna and flora of mangrove ecosystem etc. for school students. Awareness posters and booklets were also made to spread awareness.

3.6. Field Survey and Data Collection

3.6.1. Site Station Selection for Data Collection

After selecting four sites workable area for each site were decided. For it, I took site entry point as a middle point and extend the workable area of 500 meters on both sides. For getting zonal variation two zones were selected, i.e. lower zone (towards seaside or lowest low tide area) and upper zone (towards the landward side or highest high tide area). The placement of this area varies from site to site. For Sarod width of this area is about 100 meters wide while for Dahej this area is about 400 meters wide.

3.6.2. Socio-Economic Survey

For direct influence, which contains effects from direct use of mangrove or mangrove ecosystem as a whole, we selected Questionnaire base method to know the degree of dependency of the local population on the adjoining Mangrove habitat. I developed a questionnaire which contains four major parts like mangrove knowledge, animal husbandry activities, fishing activities and seed collection (Fig. 3.2). The questionnaire includes questions regarding knowledge and sensitivity about mangrove, various uses of mangrove and its parts, income generated from it, the type of activities carried out in the mangrove patch etc. This questionnaire was developed with the help of the sociologist. I selected 20 villages around the Mahi and Dhadhar River basin for survey, these villages belong to three talukas; Jambusar, Amod and Vaghra of Bharuch district. After selecting villages semi-structure interview was carried out with 25 persons from each village. I was able to interview 500 local persons from 20 villages.

3.6.3. Sediment and Water Survey

Sediment characteristics are one of the most important environmental factors directly affecting mangrove productivity and structure. The major physical and chemical properties of the mangrove soils are pH (hydrogen ion concentration), Eh (Redox, potential), salinity and particle size. I followed the methodology described by Kathirasen (2001) in which a composite sample of 1 kg wet sediment from each site was collected. Sediments at 2 depths of 10 cm and 40 cm were collected and measured for temperature using a thermometer with 0.5° accuracy and for pH using a digital pH meter. Then sediment samples were transferred to the laboratory immediately in sterile polyethylene bags and analyzed for moisture as well as sediment composition analysis. Like sediment, water samples were also collected as composite sample, from all over the site. After taking water samples, in 1 liter sterile sample bottles, its temperature and pH were recorded by hand held instruments and then transferred to the laboratory for further analysis. For pollution analysis same method was used for sample collection. The samples were collected during July, December and April for two years to have a complete idea about the status of pollution.

3.6.4. Biotic Indicators

To assess mangrove composition and status I adopted random quadrate survey method, size of 5 X 5 meter. Total 3 such quadrates were laid in the study area thrice a year. In each quadrate total number of individuals counted for density and occurrence. Individual plant recorded in quadrates was checked for its height, girth, flowering or fruiting stage etc. I didn't classify mangroves into seedling, sapling and trees as in this area's mangrove growth is stunted and cannot be checked against parameters set by earlier scientists. For assessment of faunal component I adopted burrow count instated of species as once disturbed, the crabs and mudskipper remain in the burrow for a long time making it difficult to do visually identification up to the species level. The burrow count was done using 1X1 m quadrate. At each site I took 20 quadrates to know density and frequency of burrows of mudskipper and crab. These quadrates were taken at the interval of 100 meters in a line on both the sides in both the zones. Out of theses 20 quadrates, 10 quadrats were laid into the upper intertidal zone and 10 were laid into the lower intertidal zone. Three season survey for two years was carried out to know pattern of burrow count in the study area. Besides, I also laid one 5 X 5 meter fixed quadrate at each site and collected data for mangroves and burrows present in the quadrat area. Idea behind these fixed quadrates was to get more realistic picture of the community structure.

3.6.5. Samples for Heavy Metal Analysis

As heavy metal analysis is more expansive I collected these sample only once during the study period. For abiotic components, sediment and water, composite samples were collected as per the procedure mentioned above. For mangrove, I collected different parts like root, steam and leaf. After collecting the samples were cleaned thoroughly with help of running water to remove mud and then after cleaning with tissue paper. Samples were stored in the sterile polyethylene zip lock bag and transferred to the laboratory. Crabs were collected as entire specimen and after cleaning preserved in the sterile bottles in the deep freezer.

3.6.6. Education Programmes and Materials

Education is an important component of this study. After knowing the impact of direct anthropogenic pressure it becomes more important to include members of local communities under education programs. For this various tools were used. Two separate PowerPoint presentations were made in local, Gujarati language, for two target groups, viz. School students and local community. In the presentation, which runs up to 15 minutes for school students, topics like What are mangroves? How they look like? What are different Adaptations they have? What are their ecological and economic uses? What are associated fauna and flora? Why should we conserve them? How we can conserve them? etc. were included. In presentation for the local community, which runs for 10 minutes, topics like what are Mangroves? What are the financial benefits of sustainable use? What are the consequences of mangrove degradation? What care should be taken when using mangrove? What are economical values of well preserved mangrove? etc. were included. To organize an education program, the first appointment was taken with School Principle or Village Headmen and then after at mutually suitable time programs were conducted. Apart from presentations and Posters, Leaflets on “Mangrove: An Earning Son”, in Gujarati were prepared and distributed to School students and Community people.

3.7. Laboratory Analysis

3.7.1. Sediment Composition

Sediment samples collected at two depths were analyzed for moisture and well as soil composition analysis. Mechanical dry sieving method was employed as described by Folk (1957). At laboratory both depths’ sample mixed and dried at room temperature for 10 days. After it the sample is weight again to know water loss, i.e. water holding capacity. After it sieved it from 8” diameter sieves having sieve size of 2 mm, 1 mm, 0.50 mm, 0.25

mm and 0.125 mm. and the weight of each remaining amount was taken. Then percentages were taken to determine the composition of sediment.

3.7.2. Leachet Preparation

Sediment leachate was prepared as a suspension of water by taking 100 mg of soil and filling up to 1 liter with distilled water, starring for 24 hrs, filtering the solids and analyzing the filtrate.

3.7.3. Leachet and Water Sample Analysis

Analysis of soil leachet and water was carried out by titration methods as per Standard Analytical Procedures for Water Analysis. For Leachet analysis sediment was carried out to find Acidity, Alkaliy, Salinity, Hardness, Organic Matter, Phenolic Compound Chemical Oxygen Demeaned and Heavy Metals while for water sample additional test to find Total Suspended Solid, Total Dissolved Solids, and Total Solids was done. For Heavy metal analysis a Whattmen filter paper was soaked in the water and soil leachet sample and oven dried at 100 ^{0}C till it was completely dry.

3.7.3.1. pH

Determination of pH of water and leachet was carried out by using pH analiser (Hanna and Eutech make model no: PCD 650).

3.7.3.2. Alkalinity

Alkalinities of water and soil leachet samples were carried out as the same titration method used by Satish (2013). Sample's alkalinity can be determined by titrating sample against the standard H2So4. When the solution reaches to pH 8.3, then the de-colonization of phenolphthalein indicator will take place which is indicator of complete neutralization of OH and ½ of CO3 while when pH reached at 4.5 then a sharp colour change from yellow to pink of methyl orange indicator took place. This indicates total alkalinity (complete neutralization of OH, CO3 and HCO3). Total Alkalinity then can be calculated using following formula:

Alkalinity (mg/l as CaCO3) = (A × N × 50 ×1000) / ml sample.

Where, N = Normality of H2SO4 used

3.7.3.3. Salinity

Salinity of water and soil leachet samples were carried out as the same titration method used by Satish (2013) in which Chlorinity of the sample was measured by titrating a sea water sample with AgNo3 (0.15 N). The idea behind this method is to add enough AgNo3 to the sample so all chloride ions will precipitate silver chloride. By measuring exactly what volume of AgNo3 is needed to reach the endpoint, which is marked by formulation of redish- orange ppt, simple proportion to determine the amount of chloride in the sample can be calculated and hence its salinity.

$$\text{Choride (mgL-1)} = \frac{[(A-B) X N X 35.45 X 1000]}{\text{ml of sample}}$$

3.7.3.4. Hardness

Hardness of a sample can be estimated by titrating with a standard EDTA solution. During present study hardness of water and sediment leachet were estimated by following method described by Marvin (1994). In this procedure, a sample is buffered to pH 10.1 and indicator is then added to the buffered sample. The indicator, when added to a solution containing Ca and Mg ions, turns red. The titrant EDTA binds with Mg and Ca cations, removing them from association with the indicator. When all the Mg and Ca are complexed with EDTA, the indicator will turn blue.

Total Hardness (mg/l as CaCO3) = 10 x ml of titrant.

3.7.3.5. Solids in Water

Total solids are the measure of all kinds of solids i.e. suspended and dissolved solids. During the study solids in water were measured by the procedure adopted by Hydrology Project (1994).

i). Total Dissolved Solids: First Wattmen filter paper and evaporating dishes that are going to be use was prepared washing, drying and cooling. Then 50 ml sample took while stirring the sample. Filtered it and washed for three times. Transfer filtrate to evaporating dish and dry it in oven. Then by allowing it to cool and then weight it. After it TDS have been find out by using following formula.

$$\text{Total Dissolve Solids (mg/l)} = \frac{(A-B)X1000}{\text{ml Sample}}$$

Where A= Weigh of dry residue + dish mg

B= Weight of dish, mg

ii) Total Suspended Solids: Wash wattmen filter paper, dry in oven, cool and note the weight. Wash it with distilled water just before pouring 50 ml from stirred sample. Filter it and wash for three times. Transfer filtrate to evaporating dish and dry it in oven. Allow it to cool and then weight it. TSS are calculated using following formula:

$$\text{Total Suspended Solids (mg/l)} = \frac{(A-B)X1000}{\text{ml Sample}}$$

Where A= Weigh of dry residue + dish mg

B= Weight of dish, mg

iii) Total Solids: Evaporating dish has been washed by distilled water and dried in oven. Then, while stirring 50 ml of sample has been taken into it. And then after allowing it to complete dry in oven weight has been taken. Then TS have been calculated by using the following formula.

$$\text{Total Solids (mg/l)} = \frac{(A-B)X1000}{\text{ml Sample}}$$

Where A= Weigh of dry residue + dish mg

B= Weight of dish, mg

3.7.3.6. Organic Matter

The Walkley Black (WB) (1934) method used for determining Soil Organic Matter (OM) utilizes a specified volume of acidic dichromate solution reacting with a determined amount of soil in order to oxidize the OM. The oxidation step is then followed by titration of the excess dichromate solution with ferrous sulfate which gives a volume of ferrous sulfate in ml. The OM is calculated using the difference between the total volume of dichromate added and the volume titrated after reaction.

Organic matter (%) of sample = (1 - S / B) x 10 x 0.68

Where S = Volume of Ferrous Sulfate solution required to titrate the sample, in ml

B = Average Volume of Ferrous Sulfate solution required to titrate the two blanks, in ml, 10 = conversion factor for units.

0.68 = a factor derived from the conversion of % organic carbon to % organic matter

3.7.3.7. Chemical Oxygen Demand

Chemical Oxygen Demand (COD) is a quick, inexpensive means to determine organics in water. The first step is digestion. Concentrated sulfuric acid (H_2SO_4) provides the primary digestion catalyst. The secondary catalyst, Silver Sulfate (AgS_{O4}), assists oxidization of straight-chain hydrocarbons such as diesel fuel and motor oil. Heat from the digestion block (150° C) also acts as a catalyst. During digestion the sample's organic carbon (C) material is oxidized with the hexavalent dichromate ion ($Cr_2O_7$2-) found in potassium dichromate ($K_2Cr_2O_7$). The dichromate readily gives up oxygen (O_2) to bond with the carbon atoms to create carbon dioxide (CO_2). The oxygen transaction from $Cr_2O_7$2- to CO2reduces the hexavalent Cr_2O_7 (2-) ion to the trivalent Cr_3 + ion. In essence a COD test determines the amount of carbon based materials by measuring the amount of oxygen the sample will react with. This oxygen transaction is the source of the test's name, Chemical Oxygen Demand.

$$\text{COD as mg } O_2\text{/l} = \frac{\text{(A-B)XMX8000}}{\text{ml sample}}$$

Where A= mL FAS used for blank,

B= mL FAS used for sample,

M= molarity of FAS,

8000 = milliequivalent weight of oxygen x 1000 ml/l

3.7.3.8. Phenolic Compound

Phenols, categorized as hydroxyl derivative compounds of benzene, occur as natural compounds, like tannin, in the plant. But it also introduced in a natural environment by releasing domestic and industrial waste in water. The analysis method which was used in the study is called 4-aminoantipyrine calorimetric method (APHA, 1999). This has two sub methods. Method C, useful to detect very low concentration of phenol and

Method D, which retains the color in the aqueous solution, is the use of relatively high concentration of phenol. As the concentrations of various phenolic compounds in a sample are unpredictable, it is not feasible to provide a universal standard containing a mixture of phenols. For this reason, phenol (C_6H_5OH) itself has been selected as a standard for calorimetric procedures and any color produced by the reaction of other phenol compounds is reported as phenol.

$$\text{Phenol (mg/l)} = \frac{A}{B} \times 1000$$

3.7.3.9. Heavy Metals

Heavy metals in water, sediments, mangrove and associated fauna were measured by Energy Dispersive X-Ray Florescence Spectrometer (EDXRF Spectrometer) which gives value of heavy metal in percentage. Care has been taken to dry out each sample completely in oven for 48 hours at 120 C^o before introduced into the instrument. This device is working on the principle of the investigation of an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray spectrum. To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains unexcited electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher- energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energy of the X- rays are characteristic of the difference in energy between the two shells, and of the atomic structure of the element from which they were emitted, this allows the elemental composition of the specimen to be measured. This instrument measures heavy metal in two stages, one stage measures lighter heavy metals, from Carbon to Scandium, and in second stage its measures heavier heavy metals, from Titanium to Uranium.

3.7.3.10. Identification of Associated Fauna

Identification of associated fauna was carried out by observed and noted external morphological characters of species. Then that character was compared to getting the species name by referring Jayabhaskaran et al. (2002), Apte (1991), Day (1888), Daniel, (1963) and Ali (1996).

3.8. Analysis of Collected Data

3.8.1. Crab Burrow Count and Mangrove Density

Collected quadrate data for both mangrove and crab burrow was calculated for density by following equation in Microsoft Office Excel program.

$$\text{Density } (m^2) = \frac{\text{Total number of individual}}{\text{Total number of Quadrate}}$$

3.8.2. Statistical Analysis

Correlation of Biotic and Abiotic Components was carried out by following Spearmen correlation in the Microsoft Office Excel program.

One way ANNOVA is carried out to know to find out the significant variation between mean values of different biotic and abiotic components between sites. This was done in the Microsoft Office Excel program.

Bray-Curtis Similarity Analysis: Bray-Curtis Similarity analysis was carried out to find out the similarity of diversity of associated fauna among the sites. This analysis was done in PAST software using following formula:

$$BC_{ij} = \frac{2C_{ij}}{S_i + S_j}$$

Fig. 3.1:Methodology

5X5 meter quadrate for Mangrove

1X1 meter quadrate for Burrow Count

Measurement of Mangrove

Water sample Collection

Socioeconomic Survey

Awareness Pograms

Fig. 3.2: Questioner for Socioeconomic Survey

Name of Village: ____________________ Taluka Name: ____________

GPS Location: N°: __________ E°: __________ Male ☐ Female ☐

Occupation: __________

Do you Use Mangrove: Yes ☐ No ☐

Do you know importance of Mangrove conservation for your Livelihood: Yes ☐ No ☐

Do you detect change in Mangrove Cover in your area: Yes ☐ No ☐

What Change: Increase Mangrove Cover ☐ Decrease Mangrove Cover ☐

Do you use Mangrove as Fodder: Yes ☐ No ☐

What is your fodder preference: Mangrove ☐ Grass ☐ Ready Made ☐

During which month you use Mangrove as Fodder more: ____________

What is your average income form milk sale during that months: ____________

Do you use Fish as Food: Yes ☐ No ☐

Are you a Fishermen: Yes ☐ No ☐

How often you go for Fishing in a Day: 1 ☐ 2 ☐ 3 ☐

Do you use Bait Fish while fishing: Yes ☐ No ☐

Do you prefer Mangrove Patch for Fishing: Yes ☐ No ☐

Do you use Mangrove for Fishnet tying: Yes ☐ No ☐

Do you use Mangrove for Crab Fishing: Yes ☐ No ☐

What are the Major Fish and Crab Species in your Catch: ____________

What is your average monthly income from fishing: ____________

Do you use Mangrove Seeds as Food: Yes ☐ No ☐

What is your average monthly income from seeds sale: ____________

CHAPTER 4: QUALITATIVE AND QUANTITATIVE STATUS OF MANGROVE HABITAT

4. Qualitative and Quantitative Status of Mangrove Habitat

4.1. Observations at Sarod

4.1.1. Physicochemical characteristic of Water at Sarod

4.1.2. Physicochemical characteristic of Sediment at Sarod

4.1.3. Pollution Status at Sarod

4.1.4. Heavy Metal Status at Sarod

4.1.5. Biotic community structure at Sarod

4.2 Observations at Neja

4.2.1. Physicochemical characteristic of Water at Neja

4.2.2. Physicochemical characteristic of Sediment at Neja

4.2.3. Pollution Status at Neja

4.2.4. Heavy Metal Status at Neja

4.2.5. Biotic community structure at Neja

4.3. Observations at Asarsa

4.3.1. Physicochemical characteristic of Water at Asarsa

4.3.2. Physicochemical characteristic of Sediment at Asarsa

4.3.3. Pollution Status at Asarsa

4.3.4. Heavy Metal Status at Asarsa

4.3.5. Biotic community structure at Asarsa

4.14. Observations at Dahej

4.4.1. Physicochemical characteristic of Water at Dahej

4.4.2. Physicochemical characteristic of Sediment at Dahej

4.4.3. Pollution Status at Dahej

4.4.4. Heavy Metal Status at Dahej

4.4.5. Biotic community structure at Dahej

4.1. Observations at Sarod

4.1.1. Physicochemical characteristic of Water at Sarod

4.1.1.1.Water pH

Water at Sarod was slightly acidic (Fig. 4.1a). This is probably due to pollution discharge by various industries. Maximum pH of water recorded was 6.65 during July'10, while minimum pH 6.1 was recorded in April'11. Average water pH at sarod was 6.33.

4.1.1.2. Water Salinity

Sarod is situated at the lower estuarine zone of Mahi River so the tidal influences are seen regularly. However, the salinity was comparatively low. This may be due to the input of effluent discharges at the site. During low tides, the freshwater input further reduces the salinity (Fig. 4.1b). Maximum salinity 7.8 ppt was recorded during April'12, while lowest 6.62 ppt was recorded during July'10. Average salinity of water at Sarod was 7.20 ppt.

4.1.1.3. Water Hardness

Sarod recorded moderately high water hardness (Fig. 4.1c). Maximum hardness 3658 mg/l was recorded in April'12, while minimum 1600 mg/l was recorded in the month of July'10. Average water hardness at Sarod was 2413.7 mg/l.

4.1.1.4. Water Alkalinity

Sarod has maximum alkalinity of water amongst all sites, (Fig. 4.1d). Maximum 778 mg/l alkalinity was recorded in April'12, while lowest 600 mg/l was recorded in the month of July'10. Average water alkalinity at Sarod was 673.67 mg/l.

4.1.1.5. Water Solids

Solids in water at sarod are presented in (Fig. 4.1e). Total solids were maximum 6.8 mg/l. in April'11, while minimum 5.4 mg/l was recorded in month of July'10. The average total solid was 6.4 mg/l In case of dissolved solids in water April'12 recorded highest values of 3.8 mg/l while lowest 2.8 mg/l was recorded in July’10. Average of dissolved solids was 3.2 mg/l. in water at Sarod. December’11 had highest 3.5 mg/l suspended solids, while July’10 had lowest 2.6 mg/l suspended solids. Average of suspended solids at Sarod was 3.13 mg/l.

4.1.2. Physicochemical characteristic of Sediment at Sarod

4.1.2.1. Sediment Composition

Fig. 4.1f, shows that Sarod sediments was dominated by sand, 53% (360 g/kg) in addition to it this site also had a relatively high amount of clay and silt content, 47% (320 g/kg).

4.1.2.2. Sediment pH

As water pH is more towards acidic nature, the sediment pH follows the same trend (Fig. 4.1g). Maximum pH of sediments 6.9 was recorded during April’11 and lowest pH 6.29 was recorded during July’11. The average pH of sediments was 6.54.

4.1.2.3. Sediment Salinity

Sediment salinity at sarod is lowest among all the stations. Fig. 4.1h shows that sarod salinity 0.29 ppt was highest during April’11, while lowest salinity 0.16 ppt was recorded in December’10. Average sediment salinity is 0.20 ppt at Sarod.

4.1.2.4. Sediment Organic Matter

Organic matter at Sarod is lowest among all sites (Fig. 4.2a). Results show that organic matter is highest 1.20 mg/l during April’11, while lowest 0 mg/l during July’10. Average organic matter present in sediment at sarod is 0.65 mg/l.

4.1.2.5. Sediment Hardness

As seen in Figure 4.2b sediment hardness at Sarod is zero.

4.1.3. Pollution Status at Sarod

4.1.3.1. Water Chemical Oxygen Demand

Fig. 4.2c shows that maximum COD 768 mg/l was measured during July’10, while minimum 549 mg/l was measured in April’12. Average COD at this site was 624.74 mg/l.

4.1.3.2. Sediment Chemical Oxygen Demand

Sediment COD was high at sarod (Fig. 4.2d). The maximum COD 233 mg/l was recorded in December’11, while minimum 171 mg/l was recorded in July’10. Average COD of sediment at sarod was 207.66 mg/l.

4.1.3.3. Water Phenolic Compounds

There are a number of chemical industries situated on the upstream of Mahi River. These industries dump their effluent into the Mahi River. Apart from it leachet from various solid wastes also end up in Mahi River. Sarod itself is the effluent discharge point. So, this site has a high concentration of various phenolic compounds in water (Fig. 4.2e). July’10 had the highest concentration, of phenolic compounds 10.26 mg/l in water while December’10 had lowest concentration 4.2 mg/l. The average concentration of phenolic compound in the water at Sarod was 7.37 mg/l.

4.1.3.4. Sediment Phenolic Compounds

Sediment licheate is also having high concentration of Phenolic compound at Sarod (Fig. 4.2f). Highest phenolic compound level 4.7 mg/l was recorded in December’10, while April’11 had lowest concentration 3.2 mg/l of phenolic compounds. Average phenolic compound in the sediment at sarod is 3.78 mg/l.

4.1.4. Heavy Metal Status at Sarod

4.1.4.1. Heavy Metals in Water

Sarod had high levels of heavy metal compared to other study sites in the sampled water (Fig.4.2g). Heavy metals like Hg (0.59 %), Pb (0.67 %) and Cd (0.20%) were found in the water sample analyzed.

4.1.4.2. Heavy Metals in Sediment

Sediment at sarod also had the presence of heavy metals (Fig. 4.2h). Pb (0.31%) and Hg (0.10%) were among the major heavy metals found in the sediment samples.

4.1.4.3. Heavy Metals in Mangroves

Fig. 4.3a shows that heavy metals like Copper (Cu) is high, 1.23%, in the root of sampled mangrove plant. The plant stem had low Cu (0.70%) followed by the leaves which had lowest Cu (0.45%). Presence of Zinc (Zn) in root was 0.32%, in stem 0.21% and in leaves 0.16%. Among the other metals, potassium (K) had highest concentration in root (42.65%) followed by stem (34.93%) and leaves (24.76 %).

4.1.4.4. Heavy Metals in Crab Tissues

As crab depends on the mangrove plant for its food, there is possibility of metal biomagnification. Presence of metals likes Copper (Cu), 0.16 %, and Zinc (Zn), 0.14%, in crab tissue was detected (Fig. 4.3 b). The levels of other metals were comparatively much low.

4.1.5. Biotic community structure at Sarod

4.1.5.1. Mangrove Density

Mangrove density 3.0/ m2was high during December'10, while lowest $0.60/m^2$in April'11 (Fig. 4.3c). Average mangrove density on this site was $0.39/m^2$.

4.1.5.2. Mangrove Height and Diameter

Mangroves of this site have stunted growth (Fig. 4.3d). Maximum height of mangrove 14.2 inch was recorded in July' 10, while lowest 13 inch was recorded in April'11 and April'12. The average height of mangrove at this site is 13.55 inches. Diameter of mangrove stem is also low. Highest diameter 5 inch was recorded in April' 11, while lowest 4.14 inch was recorded in December'11.

4.1.5.3. Brachyuran Crab Burrow Density

Figure 4.3e shows burrow density (m^2) both in the upper zone and lower zone. During July'10 lower zone burrow density was highest, 1.30/m^2, while the lowest was in April'12, 0.50/m^2. Average lower zone burrow density was 0.87/m^2. Upper zone burrow density 1.10 burrow/m^2 was highest in July'10 and July'11, while lowest 0.40/m^2 was observed in April'11. Average upper zone burrow density was 0.82 burrows/ m^2.

4.1.5.4. Associated Fauna

Only two species, *Uca (Austruca) lactea* (De Haan, 1835) and *Casmerodius albus* (Linnaeus, 1758), belonging to two families, were observed during the study period (Fig. 4.3f).

4.1.5.5. Fixed Quadrate Quantification

Sarod also showed a little variation in terms of burrow and mangrove density in fixed quadrate (Fig. 4.3g). Mangrove density ranged from 0.16 to 0.24 mangrove/m^2 and crab burrow density ranged from 0.76 to 2.44 burrow/m^2. Maximum mangrove density 0.24/m^2 was observed in December'10 and December'11, while lowest was 0.16/m^2. Burrow density was recorded in December'11 which was 2.44/m^2 and lowest burrow density observed in April'12 was 0.76/m^2.

4.2. Observations at Neja

4.2.1. Physicochemical characteristic of Water at Sarod

4.2.1.1. Water pH

Water pH at Neja was neutral (Fig. 4.4a). Maximum pH of water 7.88 was recorded during April'12, while minimum pH 7.30 was recorded in July'10. Average water pH at Neja was 7.52.

4.2.1.2. Water Salinity

Neja is situated at the outer most zone of Mahi River estuary so the salinity of water in comparison to Sarod, is high (Fig. 4.4b). Maximum salinity was recorded during April'11, i.e. 26.2 ppt, while the lowest was recorded during July’11, i.e. 21.60 part. Average salinity of water at Neja was 23.18 ppt.

4.2.1.3. Water Hardness

Neja recorded moderately high, Water hardness (Fig. 4.4c). Maximum hardness i.e. 3215 mg/l was recorded in April’12, while minimum 2600 mg/l was recorded in the month of July’10. Average water hardness at Neja was 2942.83 mg/lit.

4.2.1.4. Water Alkalinity

Neja has minimum alkalinity of water amongst all sites (Fig. 4.4d). Maximum 164 mg/l alkalinity was recorded in April’12, while lowest 112 mg/l was recorded in the month of July’10. Average water alkalinity at Neja was 141.66 mg/l.

4.2.1.5. Water Solids

Solids in water at Neja are given in Figure 4.4 (e). Total solids were maximum in April’11, i.e. 23.6 mg/l. while minimum was recorded in month of July’11, i.e. 17.8 mg/l. The average total solid was 19.55 mg/l. In case of dissolved solids in water April’12 recorded the highest dissolve solids, 12.4 mg/l. while the lowest was recorded in July’10, 6.8 mg/l. Average of dissolved solid is 9.38 mg/l. in water at Neja. April’11 had highest suspended solids, 11.2 mg/l. while July’10 had lowest suspended solids, 7.6 mg/l. Average of suspended solids at Neja was 10.16 mg/l.

4.2.2. Physicochemical characteristic of Sediment at Neja

4.2.2.1. Sediment Composition

Figure 4.4f shows that the sand dominated the sediment composition by 67.85% (380 gm/kg). Neja have relatively high amount of clay and silt content, 32.15% (180 gm/kg).

4.2.2.2. Sediment pH

As water pH is more neutral in nature, the sediment pH follows the same trend (Fig. 4.4g). Maximum pH of sediments at Neja was recorded during April'11, Dec'11 and Apr'12, i.e. 7.9 and lowest were recorded during July'10, i.e. 7.40. Average pH of sediments was 7.7.

4.2.2.3. Sediment Salinity

Sediment salinity at Neja is moderate among the all stations. Figure 4.4h shows that sarod salinity was highest during April'11, 1.63 ppt, while lowest salinity was recorded in December'10, 0.98 ppt. Average sediment salinity was 1.20 ppt at Neja.

4.2.2.4. Sediment Organic Matter

Organic matter at Neja is lowest among all sites (Fig. 4.5a). Results shows that organic matter is highest during April'11, 5.13 mg/l. while lowest during July'11, 3.06 mg/l. Average organic matter present in sediment at Neja is 4.18 mg/l.

4.2.2.5. Sediment Hardness

As seen in Figure 4.5b, sediment hardness at Neja is moderate. Highest sediment hardness was recorded during April'12, 38 mg/l. while the lowest was recorded in Dec'11, 30 mg/l. Average sediment hardness at Neja was 34 mg/l.

4.2.3. Pollution Status at Neja

4.2.3.1. Water Chemical Oxygen Demand

Figure 4.5c shows that maximum COD was measured 385 mg/l during July'11, while the minimum was measured in April'11, 217 mg/l. Average COD at this site was 289.43 mg/l.

4.2.3.2. Sediment Chemical Oxygen Demand

Sediment COD was moderate at Neja (Fig.4.5d). The maximum COD

54 mg/l was recorded in December'10, while minimum 26 mg/l was recorded in December'11. Average COD of sediment at sarod was 43.16 mg/l.

4.2.3.3. Water Phenolic Compounds

This site has a moderate concentration of various phenolic compounds in water (Fig. 4.5e). July'10 had the highest concentration, of phenolic compounds, i.e. 2.35 mg/l in water while December'10 had lowest concentration, 0.56 mg/l. The average concentration of phenolic compound in the water at Neja was 1.31 mg/l.

4.2.3.4. Sediment Phenolic Compounds

Sediment lichate was also having low concentration of Phenolic compound at Neja (Fig. 4.5f). The highest phenolic compound was recorded during December'11, 0.50 mg/l while April'12 have lower concentration, 0.10 mg/l, of phenolic compound. An average phenolic compound in the sediment at Neja was 0.22 mg/l.

4.2.4. Heavy Metal Status at Neja

4.2.4.1. Heavy Metals in Water

Neja had second highest presence of heavy metal compared to other study sites in the sampled water (Fig. 4.5g). Heavy metals like Pb (0.10 %) and Cr (0.85%) were found in the water sample analyzed for heavy metals.

4.2.4.2. Heavy Metals in Sediment

Sediment at Neja also had presence of heavy metals (Fig. 4.5h). Pb (0.02%) and Cr (0.10%) were among the harmful heavy metals found in the sediment sample.

4.2.4.3. Heavy Metals in Mangrove

Fig.4.6a. Hazardous Heavy metals like Zinc (Zn) is high, 0.40%, in the root of sampled mangrove pant were recorded. While key harmful heavy metals were absent from samples of stem and leave.

4.2.4.4. Heavy Metals in Crab

The crab depends on the mangrove plant for food and thus biomagnifications of metals is possible (Fig.4.6b). The presence of metals likes Zinc (Zn), 0.10%, in crab tissues was detected. Other metals were in comparatively lesser content in crab tissues.

4.2.5. Biotic community structure at Neja

4.2.5.1. Mangrove Density

Mangrove density was high during December'10, 5.67/ m^2 (Fig. 4.6c), while lowest in April'12, 2.60/m^2. Average mangrove density at this site was 3.97/m^2.

4.2.5.2. Mangrove Height and Diameter

Mangrove of this site has good growth (Fig.4.6d). Maximum height of the mangrove was recorded in July'10; 25.90 inch while the lowest was recorded in December'11, 15.49 inch. The average height of mangrove at this site is 21.51 inches. Diameter of mangrove is highest among all sites. Highest diameter was recorded in July'11; 4.38 inch while the lowest was recorded in December'11, 2.15 inch. Average diameter of mangrove at Neja was 3.51 inches

4.2.5.3. Burrow Density

Figure 4.6e shows burrow density (m2) both in the upper zone and lower zone at Neja. During July'10 Lower zone burrow density was highest, 28.50 /m2, while the lowest was in April'11, 16.10 burrow /m2. Average lower zone burrow density was 22.35 /m^2. Upper zone burrow density was highest in July'11, 39.30 /m^2 while lowest density was observed in April'11, 31.10 burrow/m^2. Average upper zone burrow density was 34.57 /m^2.

4.2.5.4. Associated Fauna

Associated fauna in Mangrove at Neja is presented in Figure 4.6f. Total 30 species, *Uca (Tubuca) dussumieri* (H. Milne Edwards, 1852), *Colotis* *amata amata* (Fabricius, 1775), *Mycteria leucocephala* (Pennant, 1769) etc., belonging to 18 families and 6 classes, were observed during the study period.

4.2.5.5. Fixed Quadrate Quantification

Neja variation in terms of burrow and mangrove density in fixed quadrate is given in (Fig. 4.6g) Mangrove density ranged 1.16 to 1.96/m^2 and burrow density ranged from 9.80 to 5.80 /m^2. Average mangrove density observed was, 1.49 /m^2 while average burrow density was 7.48 /m^2.

4.3. Observations at Asarsa

4.3.1. Physicochemical characteristic of Water at Asarsa

4.3.1.1. Water pH

Water pH at Asarsa was neutral in pH scale i.e.7.0 (Fig.4.7a). Maximum pH of water 8.01 was recorded during April'11, while minimum pH 7.16 was recorded in July'11. Average water pH at Asarsa was 7.52.

4.3.1.2. Water Salinity

Asarsa is situated at the inner zone of Dadhar River estuary so the salinity of water is low as compare to sea water (Fig. 4.7b). Maximum salinity was recorded during April'12, i.e. 22 ppt, while the lowest was recorded during July'10, i.e. 17.70 part. Average salinity of water at Asarsa was 20.05 ppt.

4.3.1.3. Water Hardness

Asarsa recorded moderately high, Water hardness (Fig 4.7c). Maximum hardness i.e. 2712 mg/l was recorded in April'12, while minimum 1800 mg/l was recorded in the month of July'10. Average water hardness at Asarsa was 2315 mg/l.

4.3.1.4. Water Alkalinity

Asarsa has moderate alkalinity of water amongst all sites (Fig. 4.7d). Maximum 236 mg/l alkalinity was recorded in April'11, while lowest 176 mg/l was recorded in the month of July’10. Average water alkalinity at Asarsa was 205 mg/l.

4.3.1.5. Water Solids

Solids in water at Asarsa are presented in Figure 4.7e. Total solids were maximum in April’12, i.e. 21.3 mg/l while the minimum was recorded in month of July’10 i.e. 14.2 mg/l Average total solid was 17.31 mg/l. In case of dissolve solids in water April’12 recorded highest dissolve solids, 11.4 mg/l while lowest was recorded in July’10, 6.5 mg/l. Average of dissolved solid is 8.30 mg/l in water at Asarsa. April’12 had highest suspended solids, 9.9 mg/l while July’10 had lower suspended solids, 7.7 mg/l. Average of suspended solids at Asarsa was 9.0 mg/l

4.3.2. Physicochemical characteristic of Sediment at Asarsa

4.3.2.1. Sediment Composition

Figure 4.7f shows that the sand dominated the sediment composition by 80.64% (500 gm/kg) while amount of clay and silt content is 19.16% (120 gm/kg).

4.3.2.2. Sediment pH

As water pH is more neutral in nature, the sediment pH follows the same trend (Fig. 4.7g). Maximum pH of sediments at Asarsa was recorded during April’11 i.e. 8.20 and lowest were recorded during July’10, i.e. 7.40. The average pH of sediments was 7.76.

4.3.2.3. Sediment Salinity

Sediment salinity at Asarsa is moderate among the all stations. Figure 4.7h shows that Asarsa salinity was highest during April’12, 1.36 ppt, while lowest salinity was recorded in December’10, 0.78 ppt. Average sediment salinity was 1.05 ppt at Asarsa.

4.3.2.4. Sediment Organic Matter

Organic matter at Asarsa is highest among all sites (Fig. 4.8a). Results show that organic matter is highest during April’11, 7.01 mg/l while lowest during July’11, 6.19mg/l. Average organic matter present in sediment at Asarsa was 6.56 mg/l.

4.3.2.5. Sediment Hardness

As seen in (Fig.4.8b) sediment hardness at Asarsa is highest. Highest sediment hardness was recorded during April’12, 91 mg/l while the lowest was recorded in Dec’11, 68 mg/l. Average sediment hardness at Asarsa was 80.33 mg/l

4.3.3. Pollution Status at Asarsa

4.3.3.1. Water Chemical Oxygen Demand

Figure 4.8c, shows that maximum COD was measured 48.26 mg/l during July’11, while minimum was measured in April’12, 18.12 mg/l. Average COD at this site was 28.53 mg/l.

4.3.3.2. Sediment Chemical Oxygen Demand:

Sediment COD was lowest at Asarsa (Fig. 4.8d). The maximum COD 26 mg/l was recorded in April’11, while minimum 15 mg/l was recorded in July’10. Average COD of sediment at sarod was 21.83 mg/l.

4.3.3.3. Water Phenolic Compounds

This site has the lowest concentration of various phenolic compounds in water (Fig. 4.8e). July’11 had the highest concentration, of phenolic compounds, i.e. 0.18 mg/l in water while all other months had zero concentration. Average concentration of phenolic compound in the water at Asarsa was 0.03 mg/l.

4.3.3.4 Sediment Phenolic Compounds

Sediment lichate is also having low concentrations of Phenolic compound at Asarsa (Fig.4.8f). The highest phenolic compound was recorded during July’11, 0.12 mg/l while all other months had a zero concentration of phenolic compound. An average phenolic compound in the sediment at Asarsa was 0.02 mg/l.

4.3.4. Heavy Metal Status at Asarsa

4.3.4.1. Heavy Metals in Water

Asarsa had lowest presence of heavy metal compared to other study sites in the sampled water (Fig. 4.8g). Asarsa had zero presence of hazardous Heavy Metals in the water sample analyzed for heavy metals.

4.3.4.2. Heavy Metals in Sediment

Sediment at Asarsa also had zero presence of hazardous Heavy Metals (Fig. 4.8 h).

4.3.4.3. Heavy Metals in Mangrove

Fig.4.9a shows the concentration of heavy metals in mangrove at Asarsa. All key harmful heavy metals were absent from samples of root, stem and leave in the mangrove at Asarsa.

4.3.4.4. Heavy Metals in Crab

As crab depends on the mangrove plant for its food it (Fig. 4.9b). Heavy metals were not recorded in the crab tissues from Asarsa.

4.3.5. Biotic community structure at Asarsa

4.3.5.1. Mangrove Density

Mangrove density was high during December'10, 6.53/ m^2 (Fig. 4.9c), while lowest in April'11, 3.47/m^2. Average mangrove density at this site was 5.02/m^2.

4.3.5.2. Mangrove Height and Diameter

Mangrove of this site has good growth (Fig.4.9d). Maximum height of the mangrove was recorded in July' 11, 26.53 inch while the lowest was recorded in December'11, 15.63 inch. The average height of mangrove at this site is 22.28 inches. Diameter of mangrove is highest among all sites. Highest diameter was recorded in July'11; 4.16 inch while lowest was recorded in December'11, 2.9 inch. Average diameter of Mangrove at Asarsa was 3.49 inches.

4.3.5.3. Burrow Density

Figure 4.9e shows burrow density (m^2) both in the upper zone and lower zone at Asarsa. During July'11 lower zone burrow density was highest, 44.00/m^2, while the lowest was in April'12, 18.80 /m^2. Average lower zone burrow density was 32.77/m^2. Upper zone burrow density was highest in July'11, 59.10/m^2 while the lowest were observed in April'12, 46.60 /m^2. Average upper zone burrow density was 52.07 /m^2.

4.3.5.4. Associated Fauna

Associated fauna of mangroves at Asarsa is presented in Figure 4.9f. Total 40 species like *Scylla serrata* (Forskål, 1775), *Telescopium telescopium* (Linnaeus, 1758), *Tringa totanus*(Linnaeus, 1758), *Cerberus rynchops* (Schneider, 1799) etc. These 40 species belonging to 24 families and 6 classes were observed during the study period.

4.3.5.5. Fixed Quadrate Quantification

Asarsa variation in terms of the burrow and mangrove density in fixed quadrate is given in (Fig. 4.9g). Mangrove density ranged 1.68 to 2.37/m^2 and burrow density ranged from 8.44 to 11.88/m^2. Average mangrove density observed was, 2.01 /m2 while average burrow density was 10.08/m^2.

4.4. Observations at Dahej

4.4.1. Physicochemical characteristic of Water at Dahej

4.4.1.1. Water pH

Water pH at Dahej was slightly towards acidic in pH scale i.e.8.0 (Fig. 4.10a). Maximum pH of water 8.33 was recorded during April'11, while minimum pH 6.69 was recorded in July'11. Average water pH at dahej was 8.00.

4.4.1.2. Water Salinity

Dahej is situated on the sea front so the salinity of water in comparison to all stations, is high (Fig. 4.10b). Maximum salinity was recorded during April'11,i.e.41 ppt, while the lowest was recorded during July'11,i.e. 36.2 ppt. Average salinity of water at dahej was 38.28 ppt.

4.4.1.3. Water Hardness

Dahej recorded high, Water hardness (Fig. 4.10c). Maximum hardness i.e.6655 mg/l was recorded in Dec'10, while minimum 6000 mg/l was recorded in the month of July'10. Average water hardness at Dahej was 6372.83 mg/l.

4.4.1.4. Water Alkalinity

Dahej has moderate alkalinity of water amongst all sites (Fig. 4.10d). Maximum 363 mg/l alkalinity was recorded in April'11, while lowest 323 mg/l was recorded in the month of July'11. Average water alkalinity at Dahej was 343 mg/l.

4.4.1.5. Water Solids

Solids in water at Dahej are presented in Figure 4.10e. Total solids were maximum in April'11,i.e. 37.3 mg/l while the minimum was recorded in month of July'11, i.e.33.2 mg/l. The average total solid was 34.40 mg/l. In case of dissolve solids in water July'10 recorded highest dissolve solids, 29.40 mg/l while lowest was recorded in Dec'11, 24.20 mg/l. Average of dissolved solid is 26.83 mg/l in water at Dahej. July'11 had highest suspended solids; 8.90 mg/l while Apr'12 had lower suspended solids, 6.10 mg/l. Average of suspended solids at Sarod was 7.50 mg/l.

4.4.2. Physicochemical characteristic of Sediment at Dahej

4.4.2.1. Sediment Composition

Figure 4.10f shows that the clay and silt dominated the sediment composition by 70.58% (480 gm/kg) while amount of sand content is 29.42% (200 gm/kg).

4.4.2.2. Sediment pH

As water pH is slightly towards acidic in nature, the sediment pH follows the same trend (Fig. 4.10g). Maximum pH of sediments at Dahej was recorded during April'11 i.e. 8.40 and lowest were recorded during July'10, i.e. 7.82. The average pH of sediments was 8.06.

4.4.2.3. Sediment Salinity

Sediment salinity at Dahej is highest among the all stations. Figure 4.10h shows that Dahej salinity was highest during April'11, 1.54 ppt, while lowest salinity was recorded in July'10, 1.19 ppt. Average sediment salinity was 1.33 ppt at Dahej.

4.4.2.4. Sediment Organic Matter

Organic matter at Dahej is second highest among all sites (Fig. 4.11a). Results show that organic matter is highest during April'11, 6.01 mg/l while lowest during July'11, 4.25 mg/l. Average organic matter present in sediment at Dahej was 5.13 mg/l.

4.4.2.5. Sediment Hardness

As seen in Figure 4.11b sediment hardness at Dahej is moderate. Highest sediment hardness was recorded during April'11, 37 mg/l while the lowest was recorded in Dec'11, 19 mg/l. Average sediment hardness at Dahej was 28.83 mg/l.

4.4.3. Pollution Status at Dahej

4.4.3.1. Water Chemical Oxygen Demand

Figure 4.11c, shows that maximum COD was measured 156.22 mg/l during July'11, while minimum was measured in April'12, 64.28 mg/l. Average COD at this site was 107.45 mg/l.

4.4.3.2. Sediment Chemical Oxygen Demand

Sediment COD was second highest at Dahej (Fig. 4.11d). The maximum COD 91 mg/l was recorded in December'11, while minimum 77 mg/l was recorded in April’11. Average COD of sediment at Dahej was 84.33 mg/l.

4.4.3.3. Water Phenolic Compounds

This site has second lowest concentration of various phenolic compounds in water (Fig. 4.11e). July’11 had higher concentration; of phenolic compounds, i.e. 1.20 mg/l in water while except July’10 (0.70 mg/l) all other months had zero concentration. The average concentration of phenolic compound in the water at Dahej was 0.31 mg/l.

4.4.3.4. Sediment Phenolic Compounds

Sediment lichate is also having low concentrations of Phenolic compound at Dahej (Fig. 4.11f). The highest phenolic compound was recorded during July’11; 0.56 mg/l while except July’10 (0.40 mg/l) all other months had a zero concentration of phenolic compound. An average phenolic compound in the sediment at Dahej was 0.16 mg/l.

4.4.4. Heavy Metal Status at Dahej

4.4.4.1. Heavy Metals in Water

Dahej had the lowest presence of heavy metal compared to other study sites in the sampled water (Fig. 4.11g). Dahej had zero presence of hazardous heavy metals in the water sample analyzed for heavy metals.

4.4.4.2. Heavy Metals in Sediment

Sediment at Dahej also had zero presence of hazardous heavy metals (Fig. 4.11h).

4.4.4.3. Heavy Metals in Mangrove

Figure 4.12a shows concentration of heavy metals in mangrove at Dahej. All key harmful heavy metals were absent from samples of root, stem and leave in the mangrove at Dahej.

4.4.4.4. Heavy Metals in Crab

As crab depends on the mangrove plant for its food it (Fig. 4.12b). Crab sampled at Dahej hasn't found any trace of hazardous heavy metals.

4.4.5. Biotic community structure at Dahej

4.4.5.1. Mangrove Density

Mangrove density was high during December'10, 5.27 / m^2 (Fig. 4.12c) while lowest in April'11, 13.33 /m^2. Average mangrove density at this site was 3.60/m^2.

4.4.5.2. Mangrove Height and Diameter

Mangrove of this site has good growth (Fig. 4.12d). Maximum height of the mangrove was recorded in July' 11, 29.96 inch while the lowest was recorded in December'11, 13.17 inch. The average height of mangrove at this site is 22.11 inches. Diameter of mangrove is highest among all sites. Highest diameter was recorded in July'10, 4.08 inch while the lowest was recorded in December'11, 1.88 inches. Average diameter of Mangrove at Dahej was 3.22 inches

4.4.5.3. Burrow Density

Figure 4.12 (e), shows burrow density (m^2) both in the upper zone and lower zone at Dahej. During July'10 lower zone burrow density was highest, 21.00/m^2, while the lowest was in April'12, 13.3/m^2. Average lower zone burrow density was 17.20/m^2. Upper zone burrow density was highest in July'11, 34.70/m^2 while lowest was observed in April'11, 29.90/m^2. Average upper zone burrow density was 32.72/m^2.

4.4.5.4. Associated Fauna

Associated fauna in Mangrove at Dahej is presented in Figure 4.12f. Total 36 species like *Grapsus intermedius* (de Man, 1888), *Cerithium echinatum* (Lamarck, 1822), *Gerarda prevostiana* (Eydoux & Gervais, 1822) etc. recorded from this site. These 36 species belonging to 21 families and 6 classes were observed during the study period.

4.4.5.5. Fixed Quadrate Quantification

Dahej variation in terms of the burrow and mangrove density in fixed quadrate is given in (Fig. 4.12g). Mangrove density ranged from 2.67 to 5.27/m^2 and burrow density ranged from 6.52 to 8.84/m^2. Average mangrove density observed was, 3.60/m^2 while average burrow density was 7.70 /m^2.

Fig. 4.1:Observations at Sarod

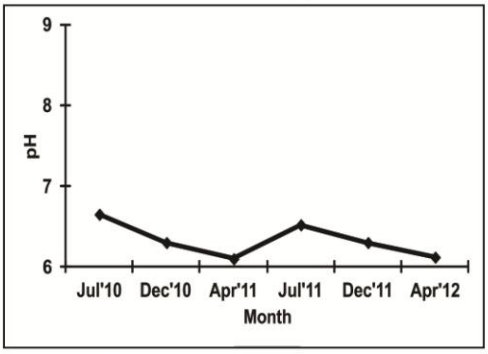


Fig. (a): Water pH at Sarod

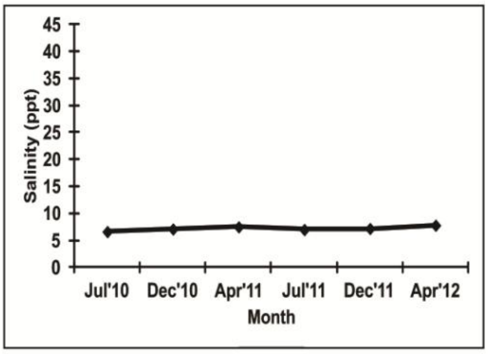


Fig. (b): Water Salinity (ppt) at Sarod

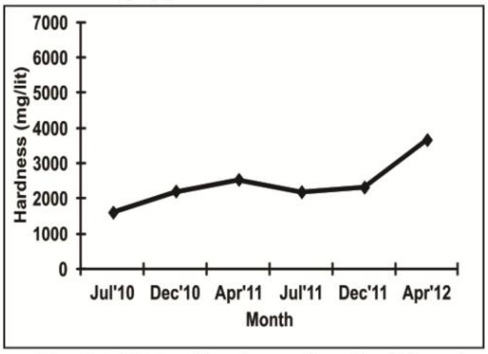


Fig. (c): Water Hardness (mg/l) at Sarod

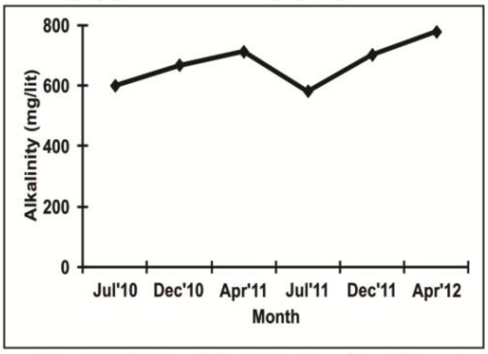


Fig. (d): Water Alkalinity (mg/l) at Sarod

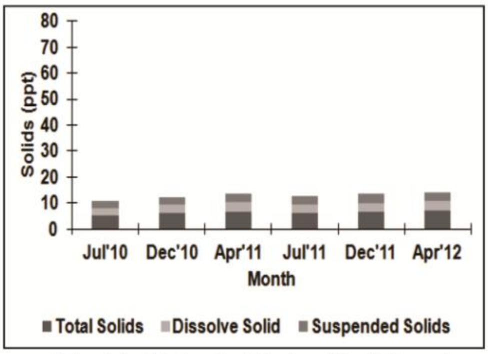


Fig. (e): Water Solids (mg/l) at Sarod

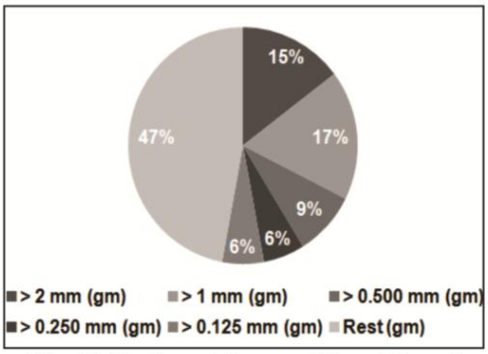


Fig. (f): Sediment Composition at Sarod

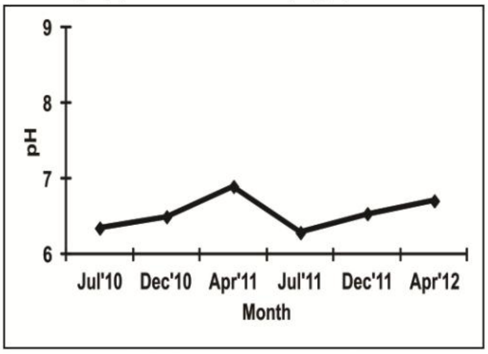


Fig. (g): Sediment pH at Sarod

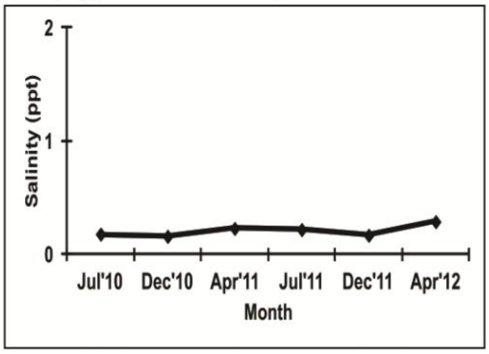


Fig. (h): Sediment Salinity (ppt) at Sarod

Fig. 4.2: Observations at Sarod

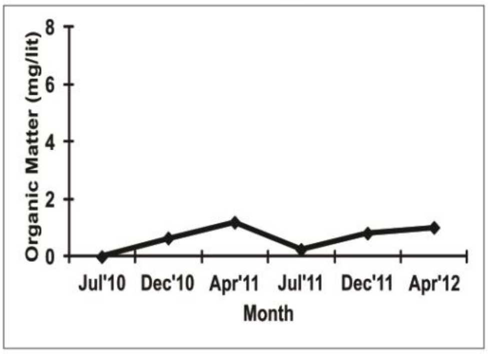


Fig. (a): Sediment Organic Matter (mg/l) at Sarod

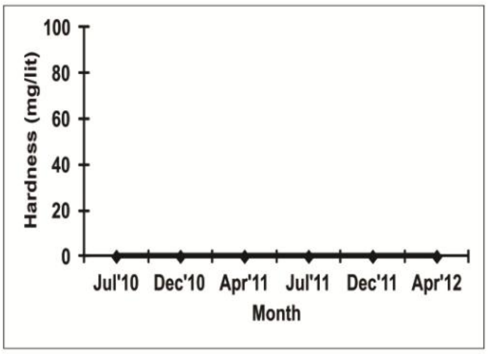


Fig. (b): Sediment Hardness (mg/l) at Sarod

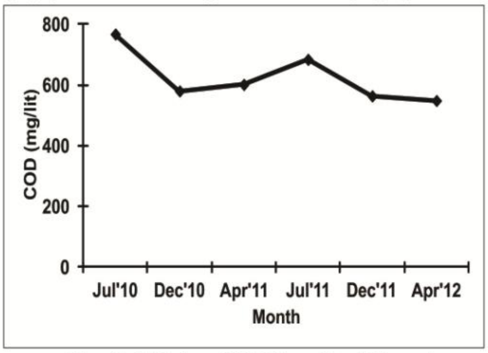


Fig. (c):Water COD (mg/l) at Sarod

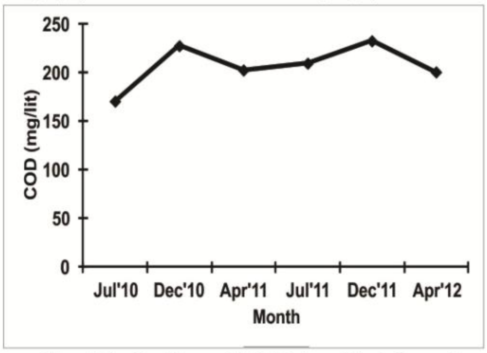


Fig. (d): Sediment COD (mg/l) at Sarod

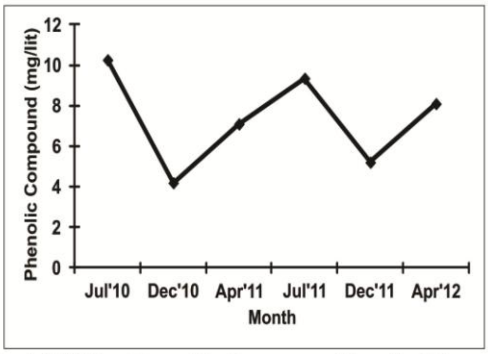


Fig. (e):Water Phenolic Compound (mg/l) at Sarod

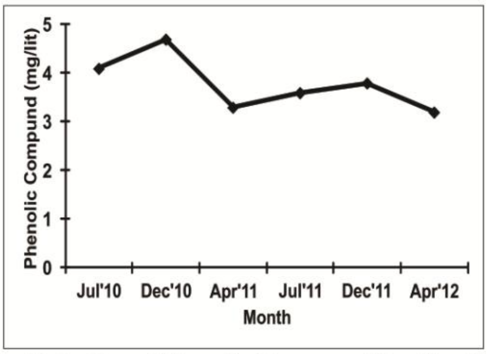


Fig.(f):Sediment Phenolic Compound (mg/l) at Sarod

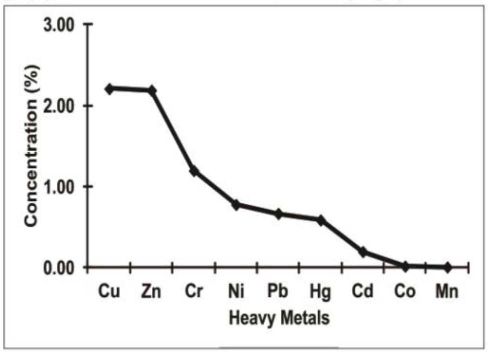


Fig. (g): Heavy Metals in Water at Sarod

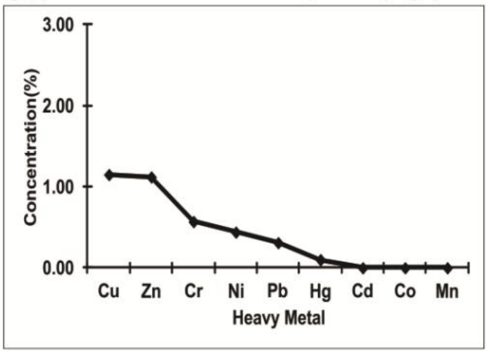


Fig. (h): Heavy Metals in Sediment at Sarod

Fig. 4.3: Observations at Sarod

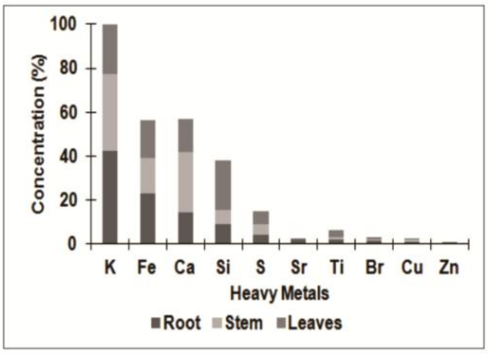


Fig. (a): Heavy Metals in Mangrove at Sarod

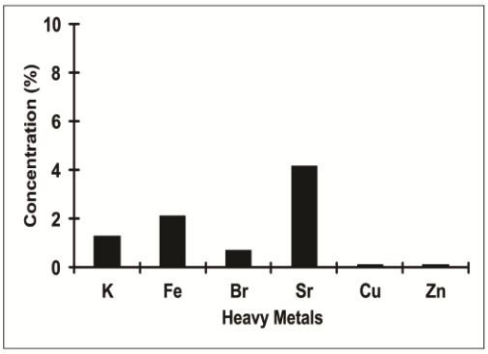


Fig. (b): Heavy Metals in Crab at Sarod

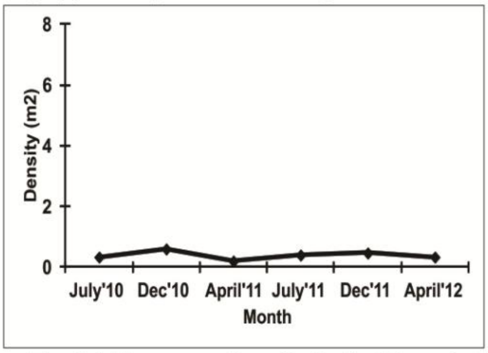


Fig. (c):Mangrove Density (m²) at Sarod

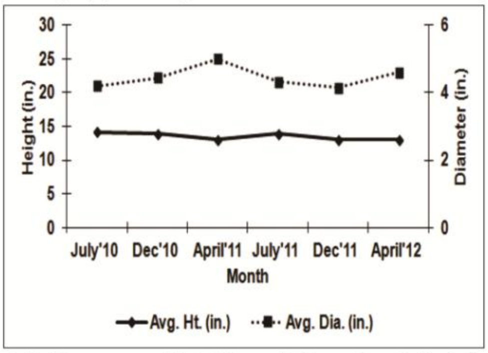


Fig. (d): Mangrove Height and Diameter (in) at Sarod

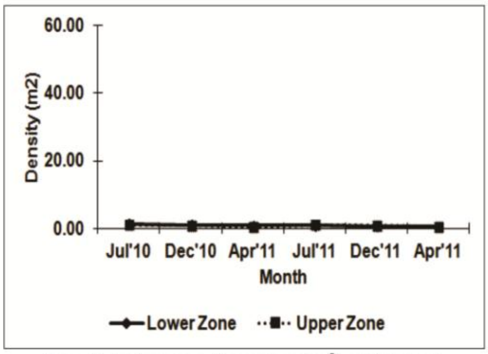


Fig. (e):Burrow Density (m²) at Sarod

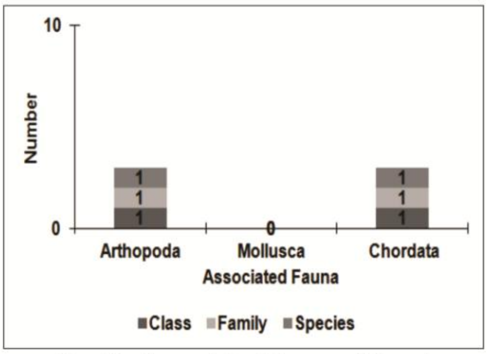


Fig. (f): Associated Fauna at Sarod

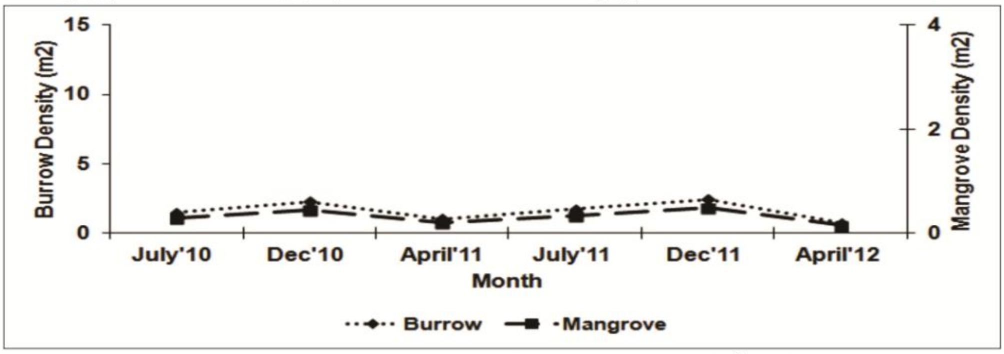


Fig. (g): Fix Quadrate Mangrove & Burrow Density (m²) at Sarod

Fig. 4.4: Observations at Neja

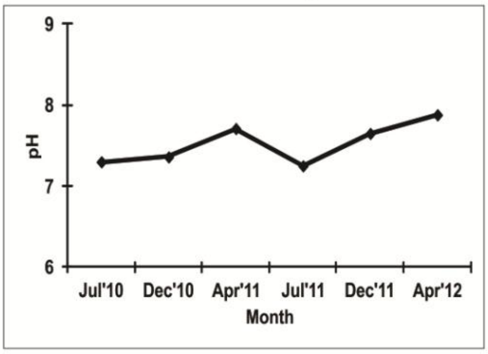


Fig. (a): Water pH at Neja

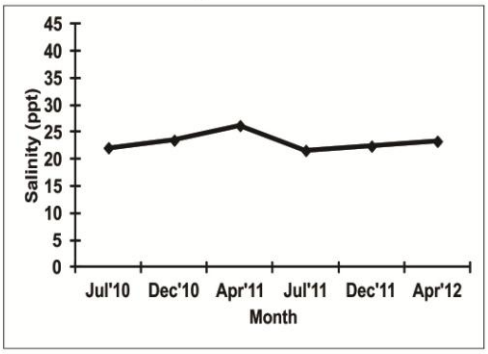


Fig. (b): Water Salinity (ppt) at Neja

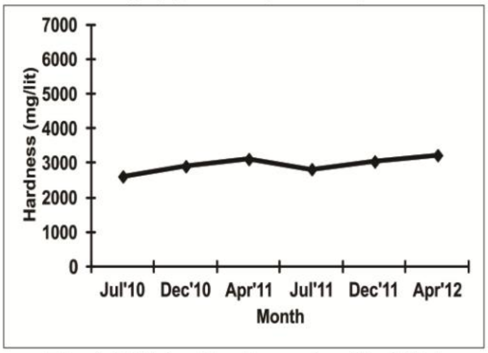


Fig. (c):Water Hardness (mg/l) at Neja

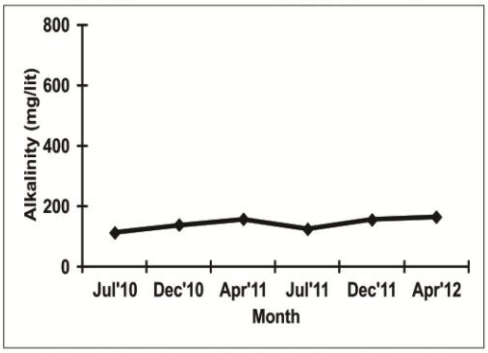


Fig. (d): Water Alkalinity (mg/l) at Neja

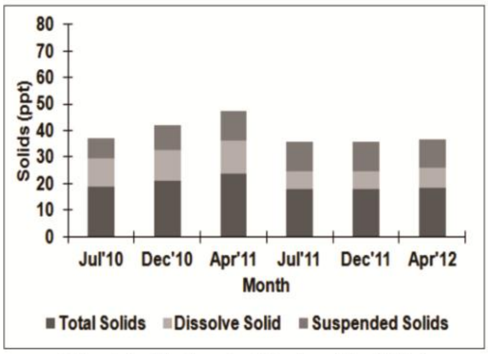


Fig. (e): Water Solids (mg/l) at Neja

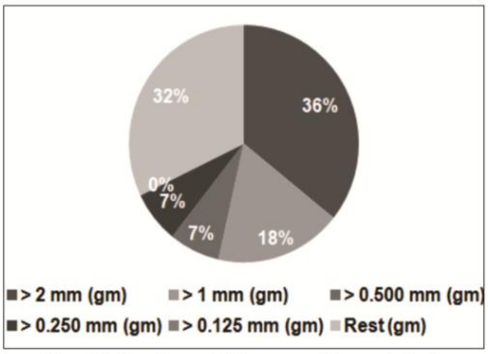


Fig. (f):Sediment Composition at Neja

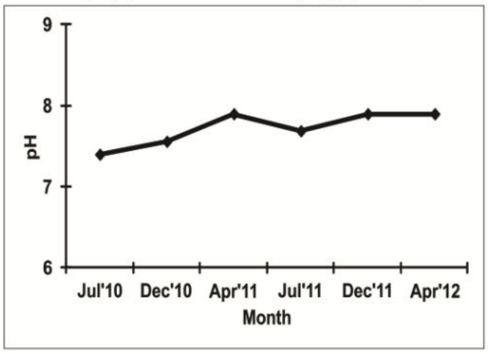


Fig. (g):Sediment pH at Neja

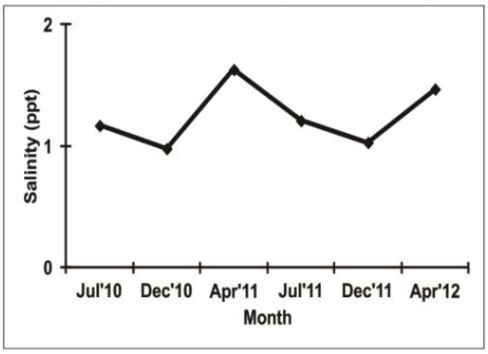


Fig. (h):Sediment Salinity (ppt) at Neja

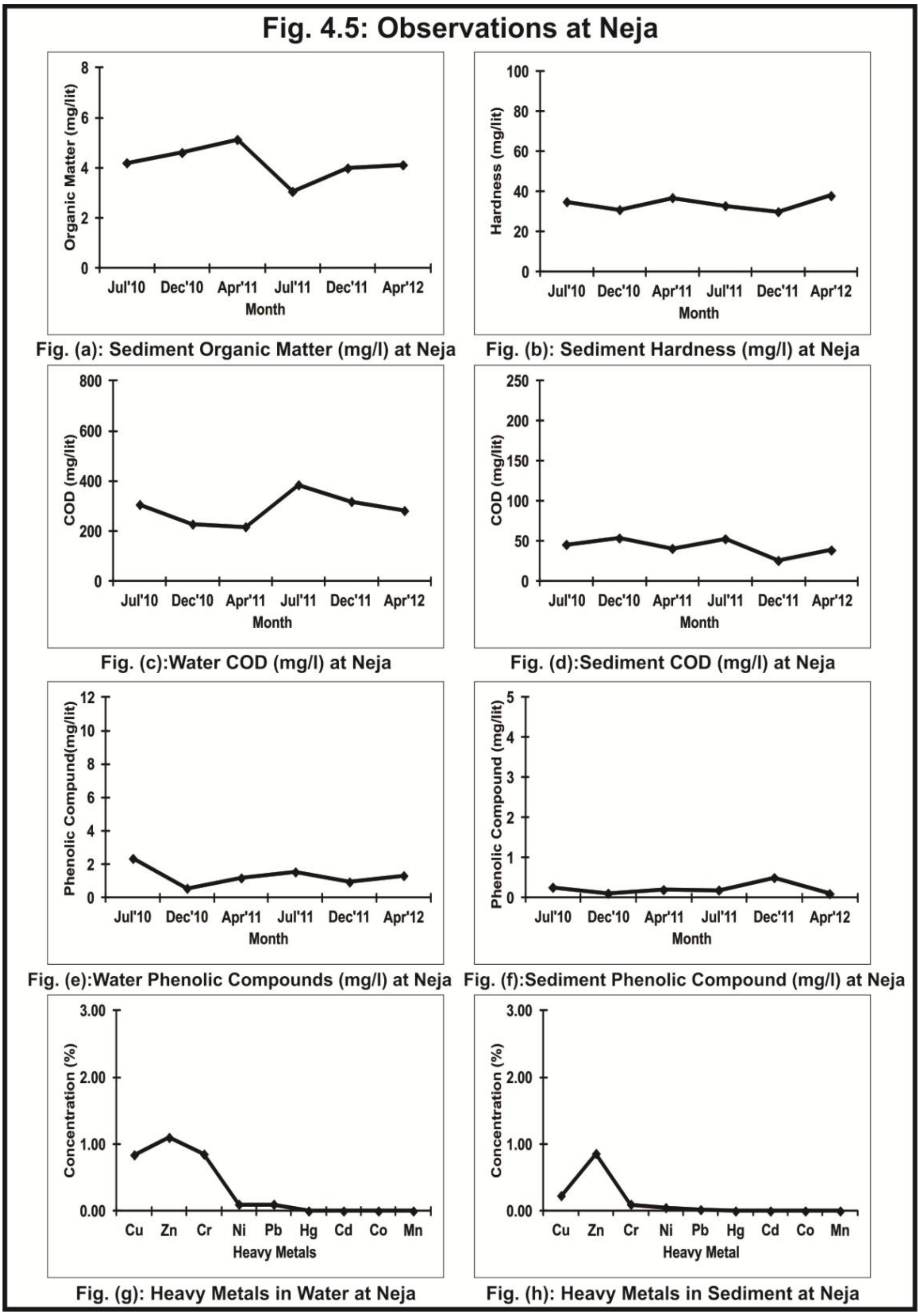


Fig. 4.5: Observations at Neja

Fig. (a): Sediment Organic Matter (mg/l) at Neja

Fig. (b): Sediment Hardness (mg/l) at Neja

Fig. (c):Water COD (mg/l) at Neja

Fig. (d):Sediment COD (mg/l) at Neja

Fig. (e):Water Phenolic Compounds (mg/l) at Neja

Fig. (f):Sediment Phenolic Compound (mg/l) at Neja

Fig. (g): Heavy Metals in Water at Neja

Fig. (h): Heavy Metals in Sediment at Neja

Fig. 4.6: Observations at Neja

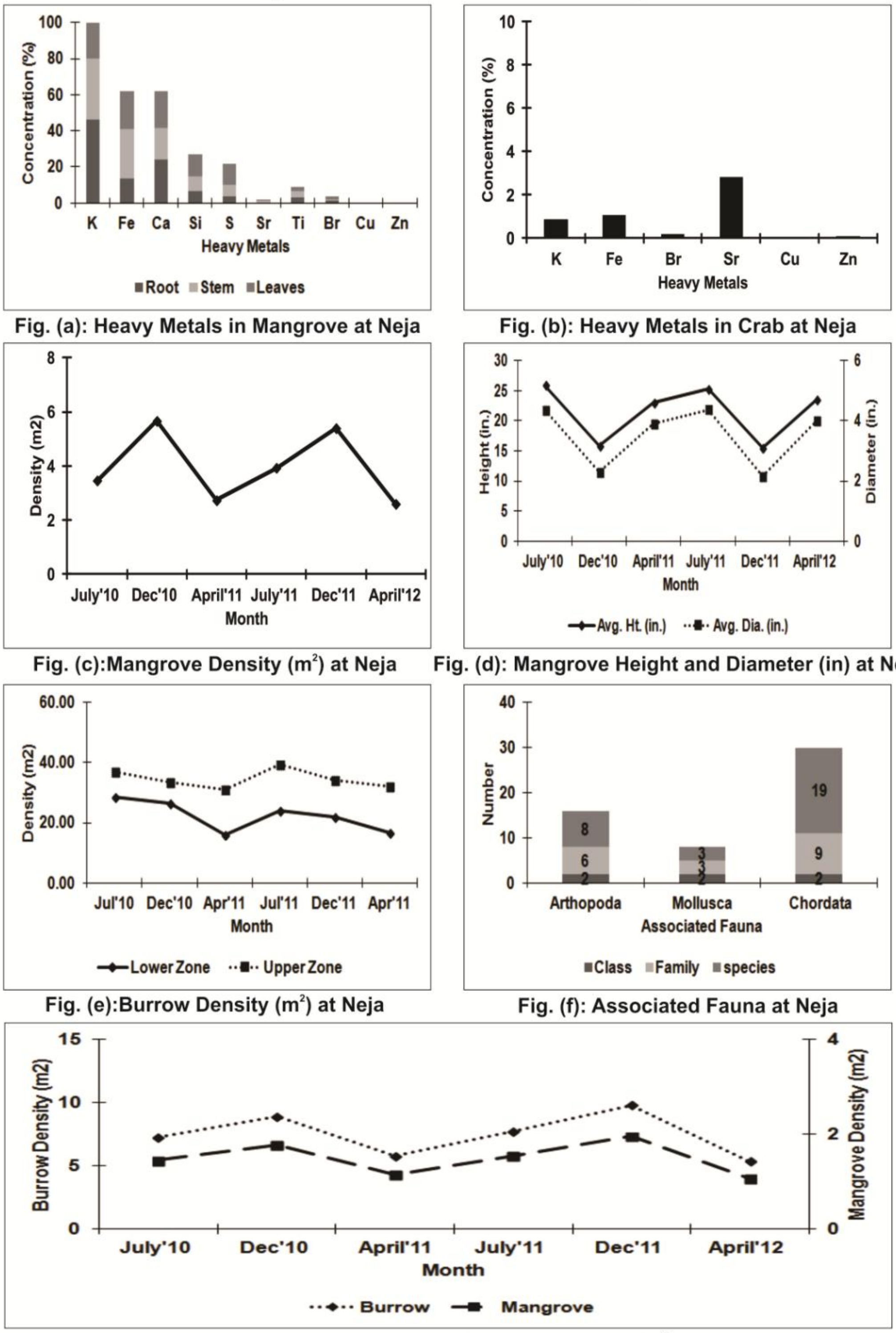


Fig. (a): Heavy Metals in Mangrove at Neja

Fig. (b): Heavy Metals in Crab at Neja

Fig. (c):Mangrove Density (m^2) at Neja

Fig. (d): Mangrove Height and Diameter (in) at Neja

Fig. (e):Burrow Density (m^2) at Neja

Fig. (f): Associated Fauna at Neja

Fig. (g): Fix Quadrate Mangrove & Burrow Density (m^2) at Neja

Fig. 4.7: Observations at Asarsa

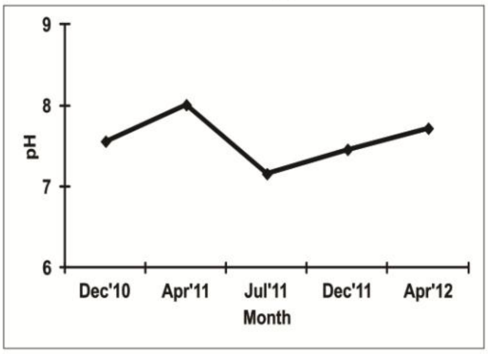


Fig. (a): Water pH at Asarsa

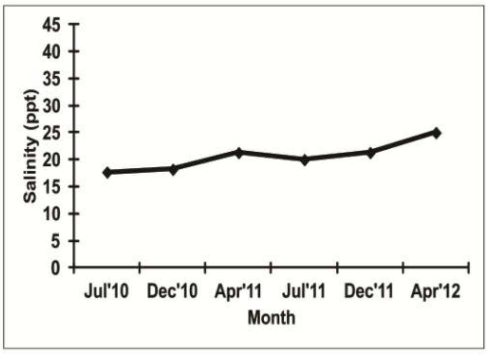


Fig. (b): Water Salinity (ppt) at Asarsa

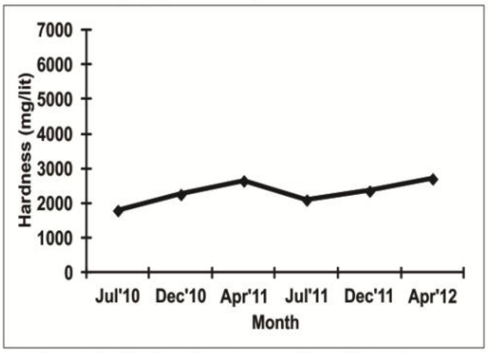


Fig. (c): Water Hardness (mg/l) at Asarsa

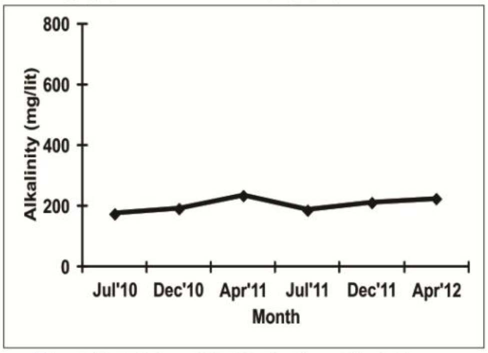


Fig. (d): Water Alkalinity (mg/l) at Asarsa

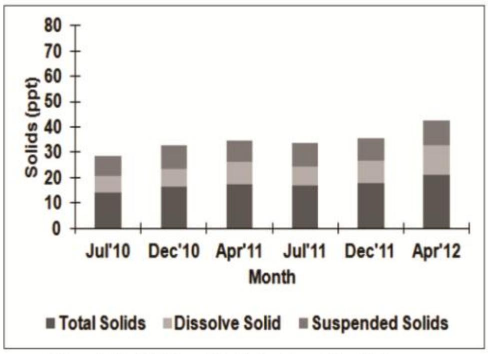


Fig. (e): Water Solids (mg/l) at Asarsa

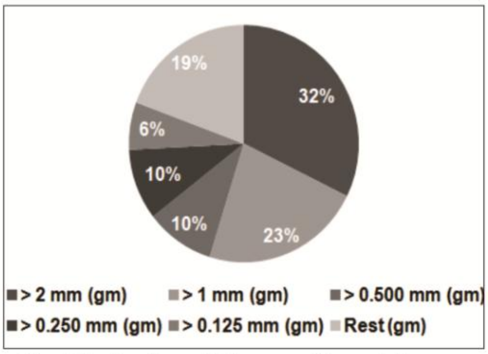


Fig. (f): Sediment Composition at Asarsa

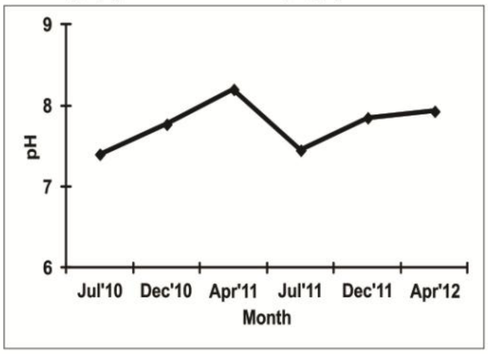


Fig. (g): Sediment pH at Asarsa

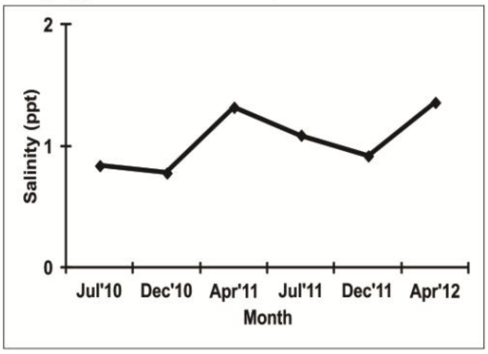


Fig. (h): Sediment Salinity (ppt) at Asarsa

Fig. 4.8: Observations at Asarsa

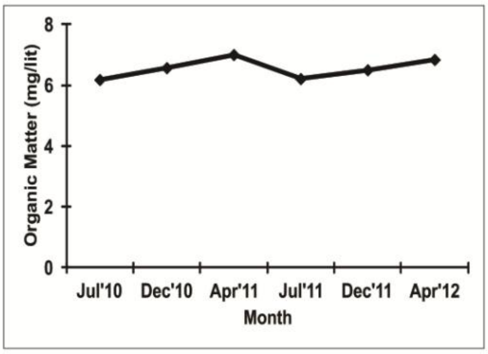


Fig. (a):Sediment Organic Matter(mg/l) at Asarsa

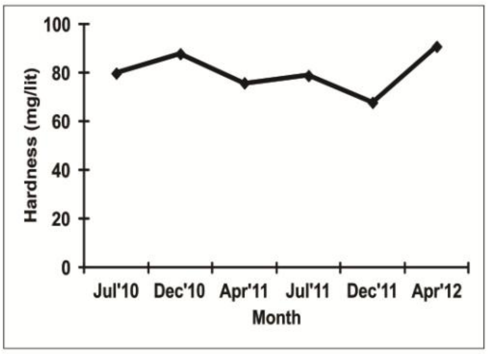


Fig. (b):Sediment Hardness(mg/l) at Asarsa

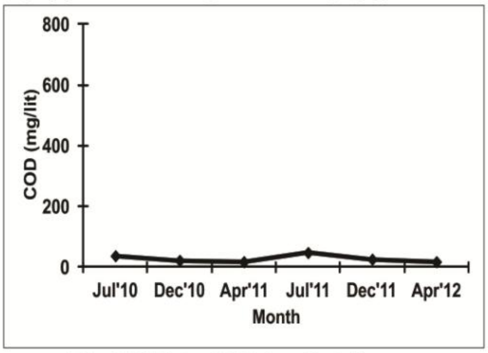


Fig. (c):Water COD (mg/l) at Asarsa

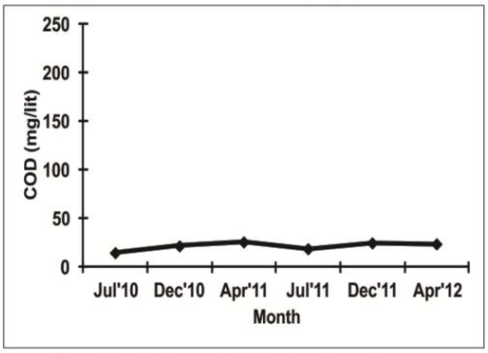


Fig. (d): Sediment COD (mg/l) at Asarsa

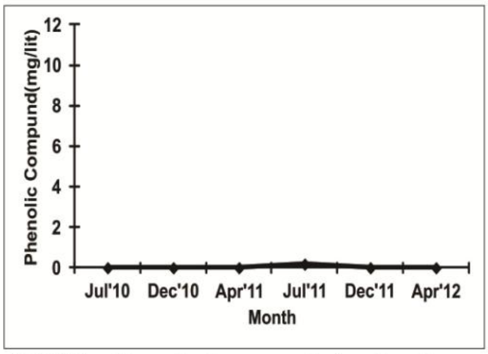


Fig. (e):Water Phenolic Compounds (mg/l) at Asarsa

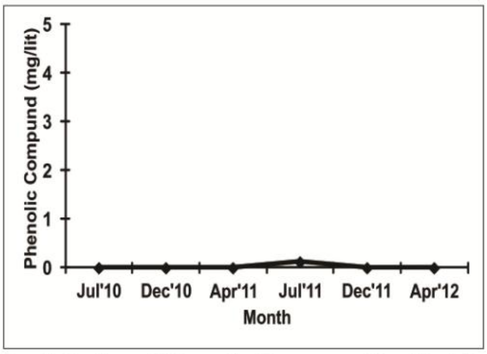


Fig. (f):Sediment Phenolic Compound (mg/l) at Asarsa

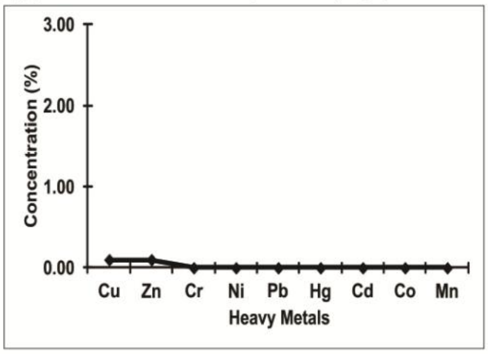


Fig. Heavy Metals in Water at Asarsa

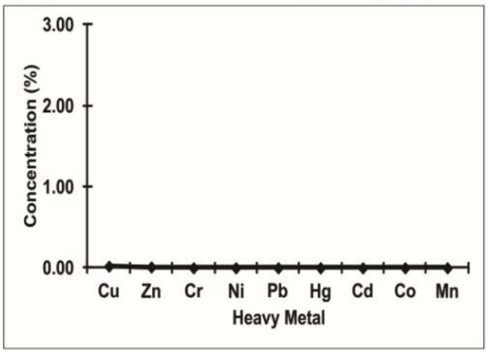


Fig. Heavy Metals in Sediment at Asarsa

Fig. 4.9: Observations at Asarsa

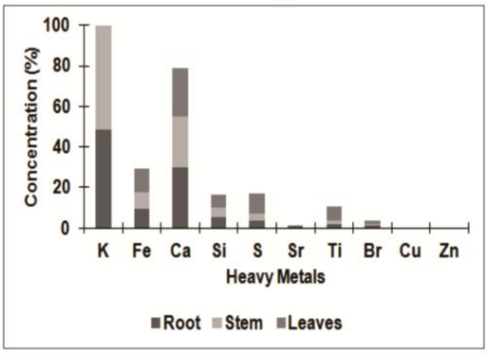


Fig. Heavy Metals in Mangrove at Asarsa

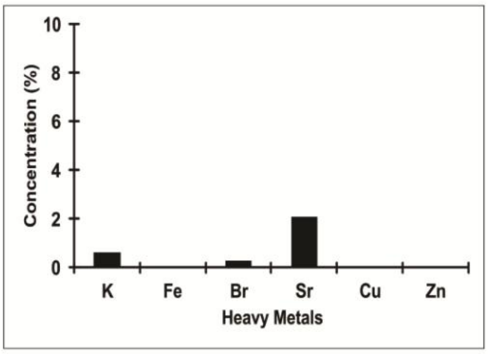


Fig. Heavy Metals in Crab at Asarsa

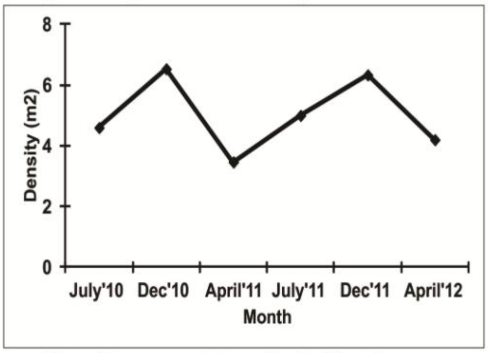


Fig. Mangrove Density (m^2) at Asarsa

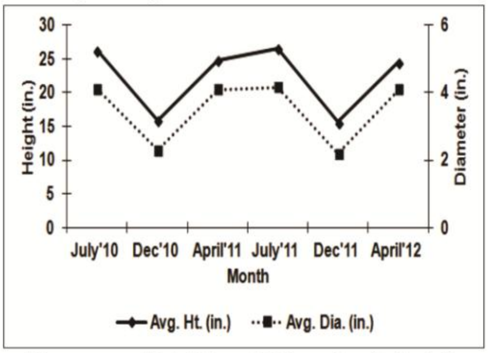


Fig. Mangrove Height and Diameter (in) at Asarsa

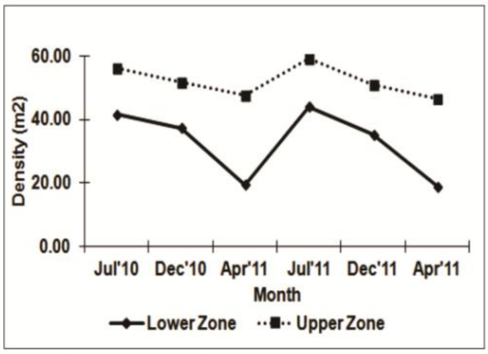


Fig. Burrow Density (m^2) at Asarsa

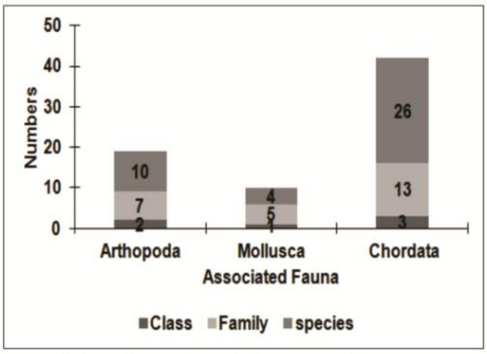


Fig. Associated Fauna at Asarsa

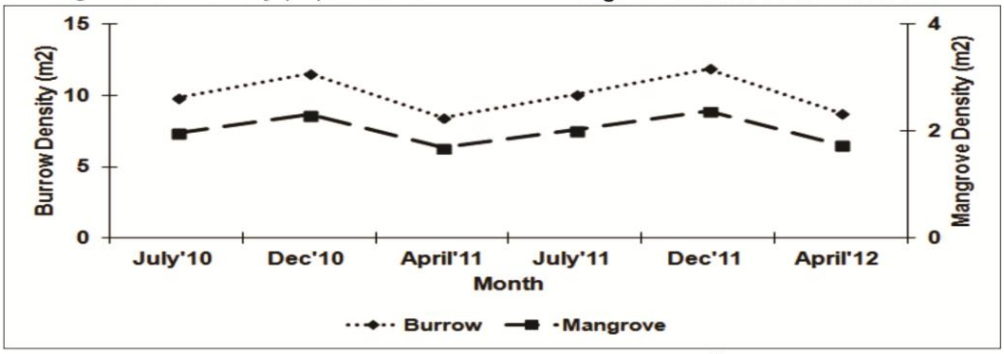


Fig. Fix Quadrate Mangrove & Burrow Density (m^2) at Asarsa

Fig. 4.10: Observations at Dahej

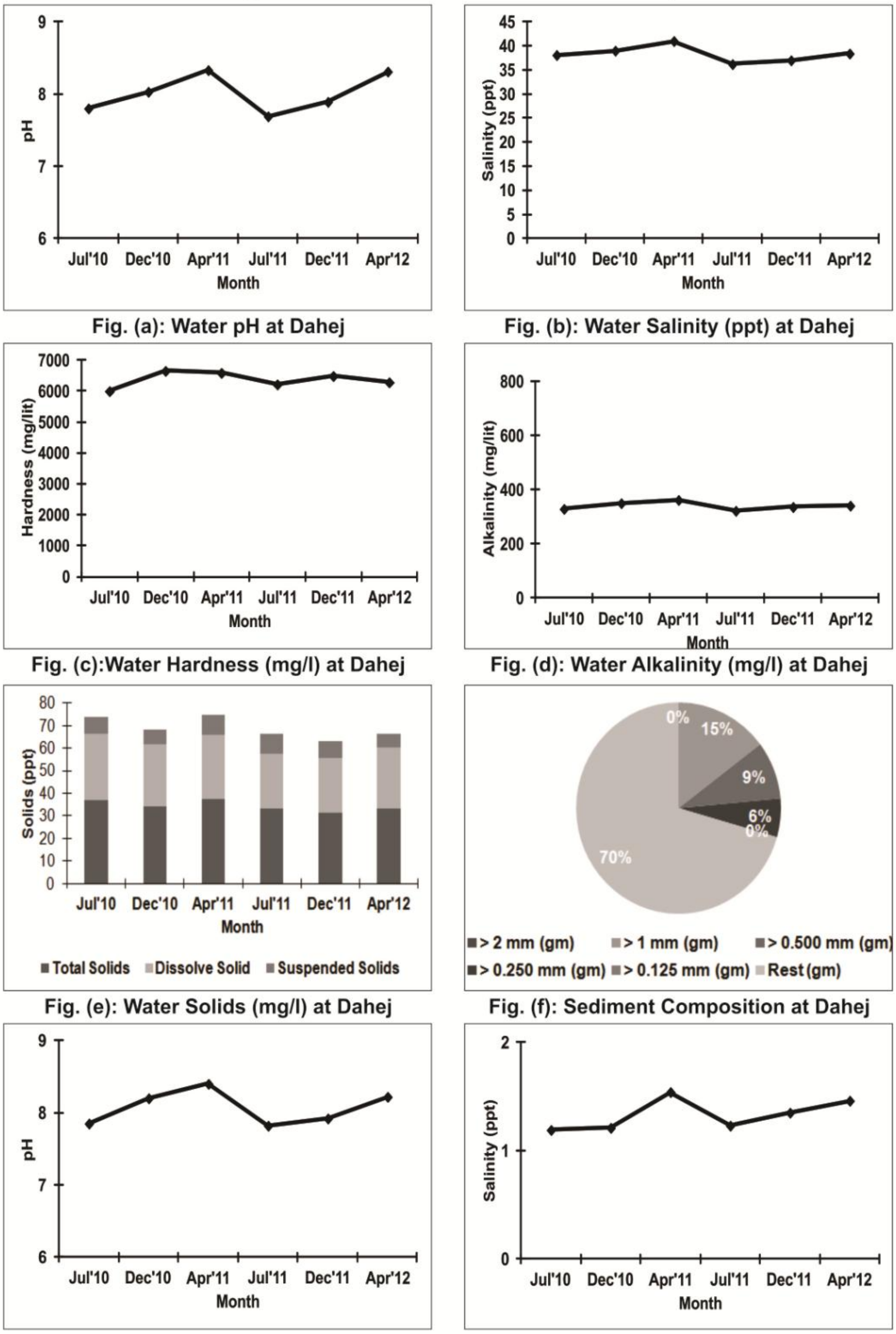


Fig. (a): Water pH at Dahej

Fig. (b): Water Salinity (ppt) at Dahej

Fig. (c): Water Hardness (mg/l) at Dahej

Fig. (d): Water Alkalinity (mg/l) at Dahej

Fig. (e): Water Solids (mg/l) at Dahej

Fig. (f): Sediment Composition at Dahej

Fig. (g): Sediment pH at Dahej

Fig. (h): Sediment Salinity (ppt) at Dahej

Fig. 4.11: Observations at Dahej

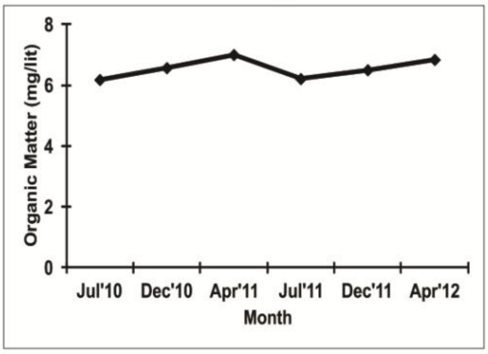


Fig. Sediment Organic Matter (mg/l) at Dahej

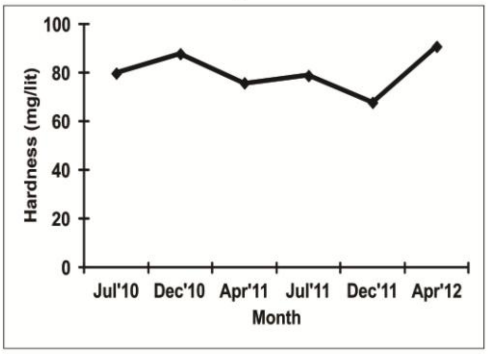


Fig. Sediment Hardness (mg/l) at Dahej

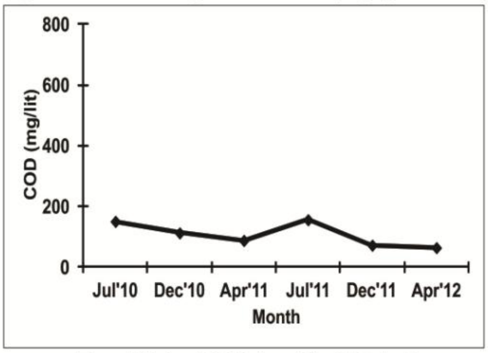


Fig. Water COD (mg/l) at Dahej

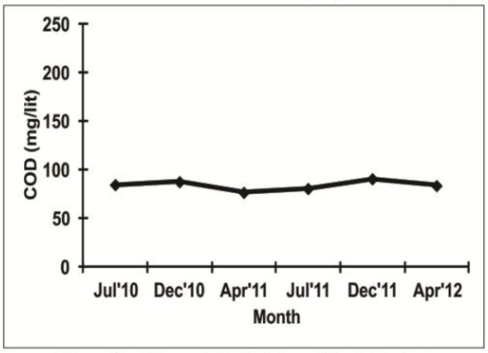


Fig. Sediment COD (mg/l) at Dahej

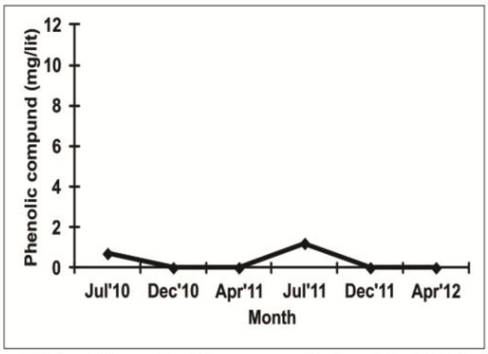


Fig. Water Phenolic Compounds (mg/l) at Dahej

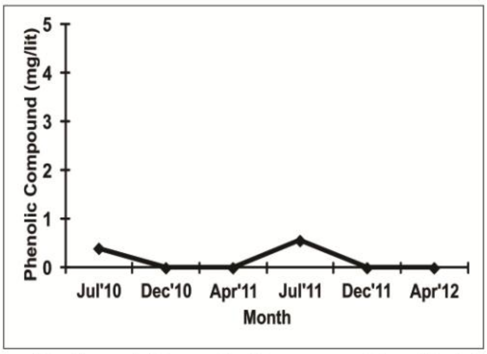


Fig. Sediment Phenolic Compound (mg/l) at Dahej

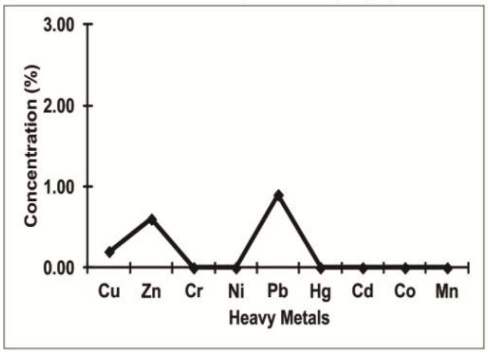


Fig. Heavy Metals in Water at Dahej

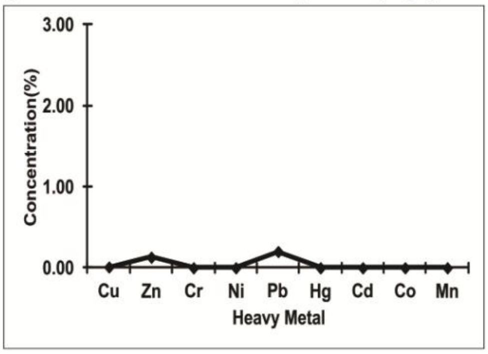


Fig. Heavy Metals in Sediment at Dahej

Fig. 4.12: Observations at Dahej

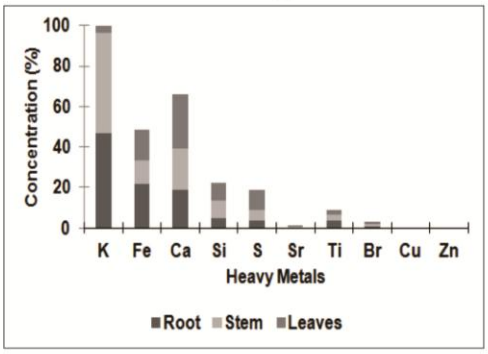


Fig. Heavy Metals in Mangrove at Dahej

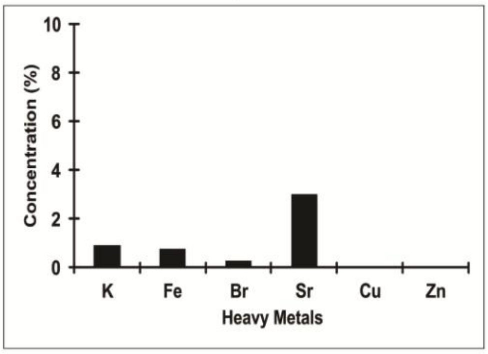


Fig. Heavy Metals in Crab at Dahej

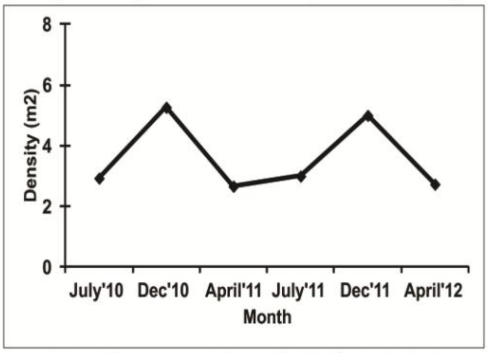


Fig. Mangrove Density (m^2) at Dahej

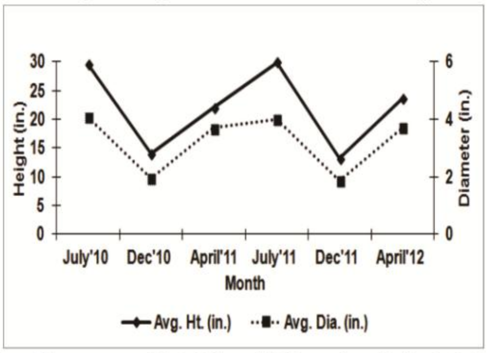


Fig. Mangrove Height and Diameter (in) at Dahej

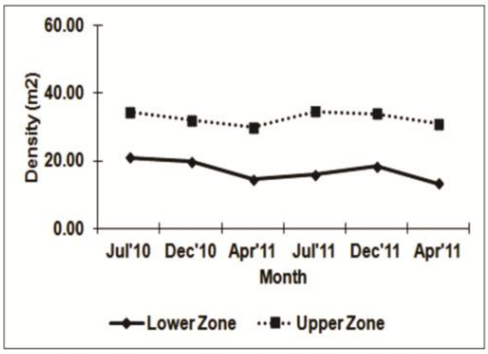


Fig. Burrow Density (m^2) at Dahej

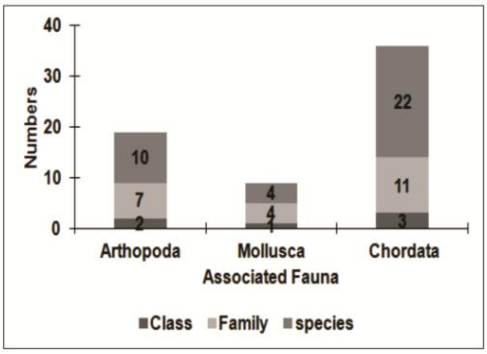


Fig. Associated Fauna at Dahej

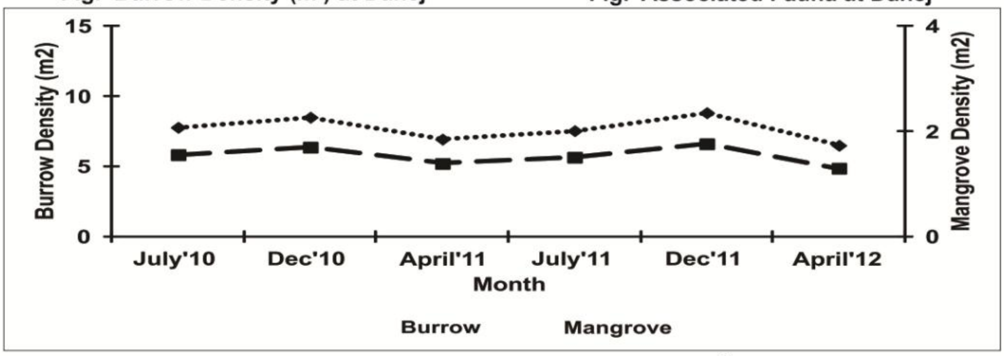


Fig. Fix Quadrate Mangrove & Burrow Density (m^2) at Dahej

DISCUSSION

pH:

pH plays an important role in well being of mangrove ecosystem. The pH of water and soil radically affect plant growth, primarily due to the change in the availability of both essential elements such as phosphorus (P), as well as non-essential elements such as aluminum (Al) that can be toxic to plants at elevated concentrations (Woodruff, 1967; Black, 1993; Slattery et al., 1999; Joshi and Ghose, 2003). Study at Bitarkanika mangrove ecosystem by Mishra et al. (2008) showed that water pH ranged between 7.90 (March) to 6.76 (November). In present study (Fig. 4.13a), water pH ranges from 8.33 (Dahej site, April'11) to 6.10 (Sarod site, April'11). Mean water pH value was observed higher at Dahej, 8.0, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=42.95, Fcrit = 3.09, P > 0.5). During the high water pH value, i.e. 8.33, Dahej's average mangrove density was observed to be 2.65 mangroves/ m^2, while crab burrow density, of both the zones, was observed 22.25 burrow/m^2 while during low pH, i.e. 6.10, at Sarod mangrove density was 0.20 mangrove/m^2 and crab burrow density was 0.60 burrow/m^2. Mangrove density showed non significant negative correlation with pH at Neja (r= 0.41), Asarsa (r= 0.42) and Dahej (r= 0.23) while showing non significant positive correlation at Sarod (r= 0.21). Average Burrow density, both zones, shows significant negative correlation with pH at Neja (r=0.93), Asarsa (r=0.93) and Dahej (r= 0.84) while showing significant positive correlation at Sarod (r= 0.95).

Studies done by Joshi and Ghose (2003) suggested that mangrove can survive in sediment pH, which is even suitable for terrestrial plants. In their study in western Sundarbans they found pH with a range of 7.05 to 7.68. Kathirasen (2002) stated that the average sediment pH of degraded mangrove patch is 7.63 ± 0.4 and that of the dense mangrove patch is 7.45 ± 0.2. During present study (Fig. 4.15a); the pH range was recorded from 8.04 to 6.29. Highest pH was recorded at Dahej, 8.04, during April'12 while lowest pH was recorded at Sarod, 6.29, during July'11. Mean sediment pH value was observed higher at Dahej as compared to the other sites, but the mean variation between the sites was not significant (ANOVA F=44.10, Fcrit = 3.09, P> 0.5). During the high sediment pH value, i.e. 8.04, Dahej's average mangrove density was 3.0 mangrove/m^2 while burrow density, of both zones, were 22.15 burrow/m^2. While during low pH, i.e. 6.10, at Sarod Mangrove density was 0.40 mangroves/m^2 and burrow density was 1 burrow/m^2. Mangrove density shows significant negative correlation with pH at Sarod (r=0. 51) while non significant negative correlation was observed for Neja (r= 0.23), Asarsa (r= 0.29) and Dahej (r= 0.09). Average Burrow density, at both zones, showed significant negative correlation with pH at Sarod (r= 0.87), Neja (r= 0.84), Asarsa (r= 0.90) and Dahej (r= 0.77).

pH acts as a natural controller in the distribution of mangrove and its female associates, thus in Dahej, Asarsa and Neja, negative correlation with the mangrove and burrow was observed where in case of Sarod's positive correlation was mainly due to relatively absent of dense mangrove and burrow presence.

Salinity:

It is well documented that salinity is one of the important factors influencing the vegetation of mangrove swamps. However, information on salinity tolerance of the mangrove species is only available for a few species. Mangroves generally bear higher salinity than non- mangrove plants, but the tolerance level differs from species to species. For example, the growth of *Rhizophora mucronata* seedlings was observed better at 30% salinity, but *R. apiculata* flourish better at 15 % water salinity (Kathiresan and Thangam, 1990; Kathiresan et al., 1996). Similarly *Sonneratia alba* grows better in waters having salinity ranges between 2 % and 18 %, and on the other hand *S. lanceolata* grows in the water having salinity up to 2 % (Ball and Pidsley, 1995). In general, despite common belief, mangrove vegetation is more luxuriant in lower salinities (Kathiresan et al., 1996).

Water salinity acts as a restrictive factor in the scattering of living organisms in mangrove ecosystem (Kathiresan et al., 1996). This variation in salinity caused by dilution during monsoon and evaporation during summer, and it's more likely to control the fauna in the intertidal zone of mangrove (Gibson, 1982). Saravanakumar et al. (2008) studied the seasonal variation in salinity of mangrove in the Gulf of Kachchh and reported that variation in water salinity ranging from 34 to 44% in monsoon and summer seasons respectively. In a study of nutrient profile of Gulf of Kambhat, Sajish (2013) have reported that a variation in water salinity ranging from 26-36% Kavi. In the present study it was reported that water salinity, (Fig. 4.13b) ranges from 41 ppt (Dahej site, April'11) to 6.62 ppt (Sarod site, July'10) with a cumulative average of 22.31 ppt. Mean water salinity value was observed higher at Dahej, 38.28 ppt, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=308.57, Fcrit = 3.09, P>0.5). During the high water salinity (41 ppt) at dahej, the average mangrove density was observed 2.67 mangrove/ m^2 while burrow density, of both the zones, was observed 33.50 burrow/ m^2. During low water salinity (6.62 ppt) at Sarod Mangrove density was observed 0.33 mangroves/ m^2 and burrow density was observed 1.20 burrow/ m^2. Mangrove density showed non significant negative correlation with water salinity at all sites Sarod (r= 0.29), Neja (r= 0.36), Asarsa (r= 0.39) and Dahej (r= 0.19). Average Burrow density, in both zones, also showed negative correlation with water salinity at all sites. (Sarod r= 0.97, Neja r= 0.78, Asarsa r= 0.76 and Dahej r= 0.52).

Soil salinity plays an important role in the distribution of mangrove species. Though mangroves are halophyte plants their tolerance towards the salinity varies species to species. Teas (1979) mentioned that Rahizophora mangle grows at 65% soil salinity while Avecennia marina grows well at 90% salinity (Macnae, 1968). Joshi and Ghose (2003) studied sediment salinity at Sundarban mangroves and reported that distance from the coast has positive correlation with sediment salinity.

Kehrig et al. (2003) reported that sediment salinity with ranged of 3.1 ppt to 11.1 ppt. in mangroves of Jequia (Brazil). In present study, (Fig. 4.15b), recorded soil salinity ranges from 1.63 ppt (Neja site, April'11) to 0.16 ppt (Sarod site, December'10) with a cumulative average of 0.95 ppt. Mean soil salinity value was observed higher at Dahej, 1.33 ppt, as compared to other sites but the mean variation between the sites was not significant (ANOVA F=42.66, Fcrit= 3.09 P>0.5). During the high soil salinity value, (1.93 ppt) at Neja the average mangrove density was observed 2.73 mangroves/m^2 while burrow density, of both the zones, were observed 23.60 burrow/m^2. During low water salinity (0.16 ppt) at Sarod mangrove density was observed 0.60 mangroves/m^2 and burrow density was observed 0.95 burrow/m^2. Mangrove density showed with soil salinity at all sites Sarod (r= 0.61), Neja (r= 0.90) and Asarsa (r= 0.78) while non significant negative correlation was observed Dahej (r= 0.38). Average Burrow density of both zones showed significant negative correlation with soil salinity at all sites. (Sarod r= 0.64, Neja r= 0.75, Asarsa r= 0.74 and Dahej r= 0.89).

It is well documented that salinity is a major factor for determining the diversity and distribution of mangrove and associated fauna and in present study it was observed salinity acts as a controlling factor for mangrove density and burrow density at each site.

Total Solids:

The term Total Solids (TS) are an indication of all of the solid constituents of water that are suspended and dissolved in it. These total solids can be of the organic and inorganic nature. Water flow and tidal current add solid particles in the sea water from shore sediments. In addition to these various anthropogenic activities like dumping domestic sewage and releasing effluents from industries into the water of estuaries and mangroves are act as a man made sources of total solids. These suspended solids, not only control light penetration, but also act as vector of certain pollutants, like heavy metals. Total Solids from the upstream also provide nutrient that has a significant role in well being of mangrove ecosystems, Thus the study of total solids is an important aspect of the mangrove study.

Kathirasen (2002) studied the presence of total dissolve solids in degraded and dense mangroves of Pichavaram and found TDS 33.65±15.6 ppt and 17.85±3.05 ppt respectively. Ramamurthy et al. (2012) studied seasonal variation in total dissolve solid in mangroves of

Vedaranyam and found that there is significant variation in concentration of TDS in water. His results suggested that the coagulation due to evaporation, in summer, and dissolving during precipitation, i.e. monsoon, also have a profound effect on the hydrographic conditions of an estuary. R.R. Mishra et al., (2008) studied TDS in Bitarkanika (Odissa) and found a mean concentration of 8.38 mg/l.

In present study; total solids in water, (Fig 4.13c) ranges from 37.30 ppt (Dahej site, April'11) to 5.4 ppt (Sarod site, Jul'10) with cumulative average of 19.41 ppt. Mean total solids in water value were observed higher at Dahej, 34.40 ppt, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=193.27 Fcrit= 3.09 P>0.5). Average mangrove density and burrow density were observed 2.67 mangroves/m^2 and 22.25 burrows/m^2 at Dahej respectively, with total solids 37.30 ppt in water while average mangrove density and burrow density were observed 0.33 mangroves/m^2 and 1.2 burrows/m^2 respectively with total solids 19.41 ppt at Sarod in water. Mangrove density shows non significant negative correlation with total solids at Sarod (r= 0.24), Neja (r= 0.16) and Asarsa (r= 0.20) while significant negative correlation was observed for Dahej (r= 0.53). Average Burrow density, both zones, showed significant negative correlation with total solids at Sarod (r= 0.96) and Asarsa (r= 0.72) while at Dahej (r= 0.06) and Neja (r= 0.48) non significant correlation was observed.

In present study; total dissolved solids in water (Fig.4.13d) ranges from 24.40 ppt (Dahej site, Jul'10) to 2.8 ppt (Sarod site, Jul'10) with a cumulative average of 11.95 ppt. Mean total dissolved solids in water value was observed higher at Dahej, 26.83 ppt, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=181.3, Fcrit= 3.09 P> 0.5). As the total dissolved solids in water value, i.e. 24.40 part, Dahej's average mangrove density was observed 2.93 mangroves/m^2 while burrow density, of both the zones was observed 27.80 burrows/m^2 while at low total dissolved solids in water value 2.8 ppt Sarod mangrove density was observed 0.33 mangroves/m^2 and burrow density was 1.2 burrows/m^2. Mangrove density shows non significant negative correlation with total solids in water at Sarod (r=0.39), Neja (r=0.15) and Asarsa (r=0.31) and Dahej (r=

0.35). Average Burrow density, both zones, shows significant negative correlation with water hardness at Sarod (r=0.94) while at other sites like Neja (r= 0.12), Asarsa (r=0.18) and Dahej (r= 0.06) non significant correlation was observed.

In present study; total suspended solids in water (Fig. 4.13f), ranges From 11.20 ppt (Neja site,April'11) to 2.6 ppt (Sarod site,Jul'10) with cumulative average of 7.46 ppt. Mean total solids in water value were observed higher at Neja, 10.16 ppt, as compared to other sites but the mean variation between the sites was not significant (ANOVA F=58.61,Fcrit= 3.09 P> 0.5). At the value of total solids in water, 11.20 ppt, average mangrove density and burrow density at Neja was observed 2.73 mangroves/m^2 and 23.06 burrows/m^2 respectively. While at the value of total solids in water 2.6 ppt, average mangrove density and burrow density at Sarod was observed 0.33 mangroves/m^2 and 1.2 burrows/m^2 respectively. Mangrove density showed non significant negative correlation with total solids in water at Neja (r=0.1) and Dahej (r=0.40) while non significant positive correlation was observed at Sarod (r=0.03) and Asasrsa (r=0.08). Average Burrow density, both zones, shows significant negative correlation with total solids at Sarod (r=0.58) and Neja (r=0.60) while non significant negative correlation was observed at Asarsa (r= 0.40) and Dahej (r=0.01).

The above mentioned results revealed that the presence of solids in water has pronounced effect on the density of mangrove and its associated fauna in the study area.

Hardness:

Estuary is an important part of the carbon cycle and hardness is part of inorganic carbon complex. Hardness mainly occurs due the presence of ions like calcium (Ca^{++}) and magnesium (Mg^{++}) in water or sediment. In context of fresh water plant, whose growth can be affects by the hardness of water, but mangroves being halophyte rarely affected by it. Hardness alone or with combination with other abiotic component, can affect the biotic community. Everall et al., (1989) reported that water hardness and pH play crucial role in the acute toxicity of Zinc (Zn) in Salmo trutta.

Study of water hardness in mangrove was carried out by several scientists. Ramamurthy et al. (2012) studied the water quality parameter of Vedaranaym (Tamil Nadu) mangroves and found that water hardness, i.e. presence of Calcium and Magnesium, is depends upon the season and observed highest in monsoon (15.9 mg/gm) and lowest in summer (10 mg/gm). Mishra et al. (2008) studied water hardness in Bitarkanika (Odissa) and reported average hardness 1,769.42 mg/l. Prasanna and Ranjan (2010) studied the water quality of Dharma estuary (Odissa) and reported water hardness as 969.68 to 5655.24mg/l. Kathirasen (2002) studied the water parameters at Pichavaram mangrove and reported Calcium concentration 1.26±0.3 mg/g and 1.13±0.1 mg/g in degrading and dense mangrove respectively.

In present study; water hardness ranges from 6655 mg/l (Dahej site, December'10) to 1600 mg/l (Sarod site, Jul'10) with cumulative average of 3511.08 mg/l. Mean water hardness value (Fig. 4.14a) was observed higher at Dahej, 6372 mg/l, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F>3.13, F=128.24, Fcrit= 3.09) at the value of water hardness value in water, 6655 mg/l average mangrove density and burrow density at Dahej was observed 5.27 mangrove/m^2 and 26 burrow/m^2 respectively. While at the value of total solids in water 1600 mg/l average mangrove density and burrow density at Sarod was observed 0.33 mangroves/m^2 and 1.2 burrows/m^2 respectively. Mangrove density showed significant positive correlation with water hardness at Dahej (r= 0.56) while non significant negative correlation was observed at Sarod (r=0.21), Neja (r=0.23) and Asarsa (r=0.31). Average Burrow density, both zones, shows significant negative correlation with water hardness at Sarod (r=0.85), Neja (r=0.92), Asarsa (r=0.91) and Dahej (r=0.35).

Sediment gains hardness from the water. If water is flowing then the hardness of sediment is being continually washed out and thus resulting in low hardness, but if the water is relatively stagnant, then due to non-transfer of Ca ions sediment tend to have high hardness. In present study sediment hardness ranges from 91 mg/l (Asarsa site, April'12) to 0 mg/l

(Sarod site) with cumulative average of 35.79 mg/l. Mean sediment hardness value (Fig. 4.15c) was observed higher at Asarsa, 80.33 mg/l, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=228.26, Fcrit= 3.09 P> 0.5). At the value of sediment hardness value in water, 91 mg/l average mangrove density and burrow density at Asarsa was observed 4.20 mangroves/m^2 and 32.70 burrows/m^2 respectively. While at the value of total solids in water 0 mg/l average mangrove density and burrow density at Sarod was observed 0.39 mangroves/m^2 and 0.84 burrow/m^2 respectively. Mangrove density shows significant negative correlation with water hardness at Neja (r= 0.97) and Asarsa (r= 0.13) and Dahej (r= 0.42) while showing no correlation with Sarod (0) due to very low density of mangrove as a result of high pollution. Average Burrow density, in both zones, shows significant negative correlation with water hardness at Neja (r=0.54) but at Asarsa (-0.22) and Dahej (-0.42) non significant negative correlation was observed.

Hardness was at higher at all the sites except Sarod. Though Dahej is situated at the mouth of the river the sediment hardness recorded low as compare to Asarsa which situated at the innermost part of the estuary. These high values of hardness can affect heavy metal intake in mangrove and its fauna at Neja, Asarsa and Dahej.

Alkalinity:

The alkalinity or acid power of water is its ability to counterbalance a tough acid to a chosen pH. It is generally imparted by the occurrence of salts of weak acids such as phosphates, carbonates, borates, bicarbonates, etc. together with free hydroxyl ions in solution. It has been well known fact that mangrove water and sediments are generally towards slightly alkaline due to prevailing anaerobic condition so it is necessary to find out alkalinity of sediment and water, which is significant in many of its uses. Alkalinity is used in the understanding presence of waste water that being introduced in the ecosystem.

Alkalinity of water is one of the important phytochemical factors. Water acts as a carrier and brings anthropogenic waste to the healthy mangrove ecosystem. Many scientists have worked on this factor. Ramamurthy et al. (2012) worked on physicochemical analysis of water in the mangroves of Vedaranyam (Tamil Nadu) and reported that there was a seasonal variation in alkalinity level; lower alkalinity of water was reported in monsoon (15.5 mg/l) while highest alkalinity of water was reported in summer (25.6 mg/l). In the present study it is also reported that total average alkalinity (all sites) was low in monsoon (304.25 mg/l) and high in summer (372.25 mg/l).

In present study; water alkalinity, ranges from 778 mg/l (Sarod site, April'12) to 112 (Neja site, Jul'10) with a cumulative average of 340 mg/l. Mean water alkalinity value (Fig. 4.14b), was observed higher at Sarod, 673 mg/l, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=205.09, Fcrit= 3.09 P> 0.5). At the value of water alkalinity in water, 778 mg/l average mangrove density and burrow density at Sarod was observed 0.33 mangroves/m^2 and 0.55 burrow/m^2 respectively. While at the value of total solids in water 112 mg/l, average mangrove density and burrow density at Neja was observed 3.47 mangroves/m^2 and 32.75 burrows/m^2, respectively. Mangrove density showed non significant negative correlation with water alkalinity at Sarod (r= 0.17), Neja (r= 0.15), Asarsa (-r= 0.42) while non significant positive correlation was observed at Dahej (r=0.09). Average Burrow density, both zones, shows significant negative correlation with alkalinity at Sarod (r= 0.90), Neja (r= 0.92), Asarsa (r= 0.92) and Dahej (r= 0.57).

In present study; high alkalinity has been observed at all sites. Sarod has the high alkalinity of water that means the water at zero has high amount of waste water, which resulting in low density of mangrove and crab despite of having good mud flats. Asarsa and Dahej, despite of having good growth of mangrove also suffer from relatively high alkalinity, which means pollution load is getting increased at these sites.

Sediment Composition:

Sediment composition is important to plant life as well as associated faunal diversity. Any drastic change in composition of sediment results in decrease of plant diversity and density that then creates a problem in the whole ecosystem. Plants depend on sediment for essential nutrients and for support while animals, especially the burrowing fauna, depend on the sediment composition for getting saltier. Particle size and its composition are very much important in health of mangrove ecosystems. A mangrove forest is often grown on fine– grained sediment, but scientist like Salomen (1978) suggested that they are able to grow on a wide range of substrate types. Ong et. Al., (2012) stated that mangrove can also grow on intertidal calcareous flats of marine originated sediments.

Many scientists have worked on the sediment composition in mangrove ecosystem. The most comprehensive study was done by Kathirasen (2002) in which he has worked on degraded and dense mangrove forest of Pichavaram. In degraded mangrove he reported sediment composition made up of Coarse sand (0.5 mm) 3.38±2.9%, Medium Sand (0.25 mm) 22.2±8.42 %, Fine Sand (0.125 mm) 41.4± 12.5 %, Very fine sand (0.063 mm) 21.77±7.1 %, Course silt (0.037 mm) 12.39±8.1 %, Silt and Clay (<0.037 mm) 2.14±1.2 %, while in dense mangrove sediment composition were Coarse sand (0.5 mm) 2.46±1.7%, Medium Sand (0.25 mm) 19.49±10.1 %, Fine Sand (0.125 mm) 37.6± 5.1 %, Very fine sand (0.063 mm) 21.67±6.1 %, Course silt (0.037 mm) 13.52±7.9 %, Silt and Clay (<0.037 mm) 3.26±0.8 %). He also reported water holding capacity of 46.26±7.7 % and 60.25±2.6 % in degraded and dense mangrove respectively.

In present study; Asarsa site had the highest amount, (340 GM), of very coarse sand (<0.500 mm) while Sarod had 0 gm of very coarse sand (<0.500 mm) with an average of 185 gm. In case of Course sand (0.500 mm) Sarod, Asarsa and Dahej sites had the highest amount (60 GM) while Neja had 40 gm of course sand (0.500 mm) with an average of 55 gm. Medium sand (0.250 mm) was reported high at Asarsa (60 gm) while Sarod, Neja and Dahej had 40 gm of medium sand with an average of 45 gm. Fine sand (0.125 mm) was found only at Sarod (40 gm) and Asarsa (40 gm) out of four sites with an average of 20 gm. Silt and Clay (>0.125 mm) were observed highest and lowest at Dahej (480 gm) Asarsa (120 gm.) respectively with an average of 275 gm. Water holding capacity was observed highest at Neja (440 gm) and lowest at Sarod (320 gm) with an average of 365 gm.

Sediment composition results have revealed that all sites, accept Sarod, have good and favorable composition for mangrove and its associated fauna and it's also control the density of mangrove and associated fauna.

Organic Matter:

Mangrove ecosystem considered as primary producers in the estuarine environment as they produce large amounts of organic matter in the terms of litter fall. This litter when reached at the sediment produces an organic matter (Cloutier et al., 2005). The hydrological regime controls the accumulation of organic matter in mangrove soils (Tam and Wong, 1997). Le (2008) also stated that sediment organic matter is also controlled by an interaction of site, season, and depth. The build up and decomposition of organic matter in mangrove ecosystem is the function of an anaerobic condition formed by stagnant water and poor soil drainage (Mitsch and Gosselink, 2000). This stagnant water and poor drainage hold soil reduction which leads to low decomposition rate of organic matter.

Le (2008) has reported that due to the low tide intensity, which allows less movement of litter, the organic matter increases. He also reported that organic matter increases in the wet season. Kathirasen (2002) in his study at Parangpatti mangroves reported average organic matter 7.26 ± 2.8 mg/l and 10.16±1.0 mg/l at degraded mangrove sites and dense mangrove sites respectively. In the present study it was also reported that at Sarod, where the pollution was highest, avg. organic matter was observed 0.65 mg/l. Another study done by Ramamurthy et al. (2012) in the mangroves of Vedaranyam (Tamil Nadu) reported seasonal variation in organic matter, during January-March (10.1%), April-June (14.6%) and July-September (13.6%). In the present study seasonal variation in organic matter is also observed Average organic matter values like 4.18 mg/l, 3.67 mg/l, and 4.54 mg/l were observed in December July and April respectively.

In present study; soil organic matter, ranges from 7.01 mg/l (Asarsa site, April'11) to 0 mg/l (Sarod site, July'10) with cumulative average of 4.13mg/l. Mean organic matter value (Fig 4.15d) was observed higher at Asarsa, 6.56 mg/l, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=135.36,Fcrit= 3.09 P> 0.5). At the value of organic matter value 6.56 mg/l average mangrove density and burrow density at Asarsa were observed 3.47 mangroves/m^2 and 33.05 burrows/m^2, respectively. While at the value of total solids in water 0 mg/l, average mangrove density and burrow density at Sarod were observed 0.33 mangroves/m^2 and 1.2 burrows/m^2 respectively. Mangrove density showed non significant negative correlation with organic matter at all sites Sarod (r=0.26), Neja (r= 0.13), Asarsa (r= 0.41) and Dahej (r= 0.05). Significant negative correlation was observed between burrow density and organic matter at Sarod (r= 0.96), Asarsa (r= 0.96) and Neja (r= 0.55) while non significant negative correlation was observed at Dahej (r= 0.31).

The health of any ecosystem is depends upon the primary production. In case of mangrove ecosystem where more secondary consumer found as benthos the organic matter plays commanding role in distribution and diversity of it. In addition to that mangrove, being a plant, also depends on the soil's organic matter for the various nutrients. In the present study at Neja, Asarsa and Dahej where organic matter reported high the density of mangrove and burros were also recorded high, while at the low organic matter stations like Sarod, the density of mangrove and burrows were observed low.

Chemical Oxygen Demand:

The chemical oxygen demand is based on the chemical decomposition of organic and inorganic contaminants, dissolved or suspended in water. For many years mangrove forests have been used as a discharge ground for pollution as believed to have the unique characteristic to absorb pollution. Due to water hydraulics and sediment nature mangrove forest are having high organic load, both suspended and dissolve. This ecosystem is prone to get an additional amount of organic matter from industries which releases pollution in to the mangroves. This results in the presence of high COD and BOD in the mangrove ecosystem. During the decomposition process of organic matter, dissolved oxygen (DO) was consumed largely for mineralization. The degradation of organic matter contributes to the low DO condition and higher loading of organic matter creates anaerobic conditions (Boyd, 1998; Hai et al., 2005). This anaerobic condition leads to significant change in pH, salinity and other important environmental factors and at the end of the chain it will affect the biological community of mangrove.

Many scientists have worked on the aspects of chemical oxygen demand (COD) of water of mangrove ecosystems. Gandaseca et al. (2011) studied water quality in Sibuti Mangrove (Malaysia) and reported COD ranging from 7.5 to 2.5 mg/L. Wang et al., (2010) studied the water quality of mangrove of Zhangjiang Estuary (China) and reported seasonal variation of COD in March (2.0 mg/l), June (1.25 mg/l), September (0.50 mg/l) and December (0.60 mg/l).

In present study; COD of water ranges from 768 mg/l (Sarod site, July'10) to 18.12 mg/l (Asarsa site, April'12) with cumulative average of 265.55 mg/l of all sites. Mean COD value (Fig 4.14c) was observed higher at Sarod, 624.74 mg/l, as compared to other sites but the mean variation between the sites was not significant (ANOVA $F=132.34, F_{crit}=3.09$ $P>0.5$). At the value of COD 768 mg/l average mangrove density and burrow density at Sarod were observed 0.33 mangroves/m^2 and 1.2 burrows/ m^2 respectively. While at the value of COD in water 18.12 mg/l average mangrove density and burrow density at Asarsa were observed 4.20 mangroves/m^2 and 32.70 burrows/m^2 respectively. Mangrove density showed significant negative correlation with COD at Sarod (r= 0.75) while non significant negative correlation was observed at Dahej (-0.18). Mangrove density showed no significant positive correlation with COD at different sites like Neja (r= 0.06) and Asarsa (r= 0.12). Average burrow density showed significant negative correlation with COD at sites Sarod (r= 0.83) and Dahej (r= 0.61) while Average burrow density of Neja(r= 0.56) and Asarsa (r= 0.88) showed positive correlation with COD.

Benthic systems are enriched by the deposition of organic matter and the primary production at the water-sediment interface. So the importance of COD in sediment is more than water for mangrove. In present study COD of sediment, ranges from 233 mg/l (Sarod site, December'11) to 15 mg/l (Asarsa site, July'10) with a cumulative average of 89.25 mg/l of all sites. The mean COD value of sediement (Fig 4.15e) was observed higher at Sarod, 207.70 mg/l, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=257.30,Fcrit= 3.09 P>3.86). At the value of COD of sediment 233 mg/l average mangrove density and burrow density at Sarod were observed 0.47 mangroves/m^2 and 1.2 burrows/m^2 respectively. While the value of COD in water was 15 mg/l, average mangrove density and burrow density at Asarsa were observed 4.60 mangroves/m^2 and 51.55 burrows/m^2 respectively. Mangrove density showed significant negative correlation with COD at Sarod (r= 0.63) while non significant negative correlation was observed at Asarsa (r= 0.04). Mangrove density showed significant positive correlation with COD at Dahej (r= 0.81) while non significant positive correlation was observed at Neja (r= 0.01). Average burrow density showed no significant negative correlation with COD at Sarod (r=0.35) and Asarsa (r= 0.03) while the Average burrow density showed significant positive correlation with COD at Neja (r= 0.63) and Dahej (r= 0.81).

Though Chemical Oxygen Demand is good up to certain level, GPCB limits of COD in water is >4.0 mg/l (Sonal et al., 2012), all the sites showed high COD in the water and sediments. As predicted Sarod had the highest COD of water and very low mangrove and burrow density per meter square.

Phenolic Compounds:

Phenolic compounds comprise a large class of phytochemicals that is endowed with interesting biological properties (Miniati, 2007). Amongst them most important are anthocyanins, flavonoids, catechins, phenolic acids, secoiridoids, stilbenes, coumarins and isoflavones that are widespread in vegetable crops such as fruits, vegetables, herbs, grains and seeds and derived foods such as juices, wines, oils, etc. In recent years there have been many study on the role of phenolic compounds in counteracting the negative effects of oxygen and nitrogen reactive species, maintaining the redox homeostasis of biological fluids and preventing human disease such as cardiovascular diseases, atherosclerosis, and other degenerative pathologies such as cancer, diabetes, alzheimer's and Parkinson's diseases. Phenolics have been considered classic defense compounds for protecting plants from herbivores, ever since plant secondary metabolites were suggested to have evolved for that reason (Banerjee et al., 2008).

Mangrove water, which having low penetration of light, high salinity, high turbidity and high microbial activities, has high concentration of phenolic compound that was leached from mangrove litter. This concentration of natural phenolic compound is good, as scientists suggested but the problem arises when artificial phenolic compound introduced in the water through pollution discharge. Labunska et al. (1999) found Alkyl phenol derivatives in samples collected at Sarod. Deshkar et al. (2012) studied three estuaries in Gujarat and found that in Mahi estuary the level of phenolic compound ranges from 2.61 to 6.21ug/l with an average of 3.63 ug/l. In present study water phenolic compound, ranges from 10.26 mg/l (Sarod site, July'10) to 0 (Asarsa site) with a cumulative average of 2.25 mg/l. Mean water phenolic compound value (Fig. 4.14d), was observed higher at Sarod, 7.37, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=46.43,Fcrit= 3.09 P> 0.5). At the value of phenolic compound in water 7.37 mg/l average mangrove density and burrow density at Sarod were observed 0.33 mangroves/m^2 and 1.2 burrows/m^2 respectively. While the value of COD in water was 0 mg/l, average mangrove density and burrow density at Asarsa were observed 5.02 mangroves/m^2 and 40.59 burrows/m^2 respectively. Mangrove density showed significant negative correlation with concentration of phenolic compound at Sarod (r= 0.60), Neja (r=0.55) while non significant negative correlation was observed at Asarsa (r=0.01) and Dahej (r=0.38). Average Burrow density showed non significant negative correlation with phenolic compound at Sarod (r=0.35) while significant positive correlation observed at Asarsa (r= 0.57) and non significant positive correlation observed at Neja (r= 0.40) and Dahej (r= 0.41).

Sediment of mangrove ecosystem has a high concentration of natural phenolic compounds, like tannin, due to decomposition of fallen leaves and twigs. Sebastian (2002) studied biogenic compounds in mangroves of Kerela and found that there was seasonal, pre-monsoon (4.80 to 1.80 mg/g), monsoon (4.50-2.0 mg/g) and post-monsoon (4.0 to 2.0 mg/g), fluctuation in the concentration of phenolic compound. In present study; sediment phenolic compound, ranges from 4.7 mg/l (Sarod site, December'10) to 0 mg/l (Asarsa site) with a cumulative average of 1.11 mg/l. Mean sediment phenolic compound value (Fig. 4.15f), was observed higher at Sarod, 3.78 mg/l, as compared to other sites but the mean variation between the sites was not significant (ANOVA F=127.76, Fcrit= 3.09 P> 0.5). At the value of phenolic compound in sediment 7.37 mg/l average mangrove density and burrow density at Sarod were observed 0.60 mangroves/m^2 and 1.2 burrows/m^2 respectively. At the value of COD in water 0 mg/l, average mangrove density and burrow density at Asarsa were observed 5.02 mangroves/m^2 and 40.59 burrows/m^2 respectively. Mangrove density showed significant negative correlation with the concentration of phenolic compound at Sarod (r= 0.79) while non significant negative correlation was observed at Neja (r= 0.11), Asarsa (r= 0.01) and Dahej (r=0.40). Average Burrow density showed significant negative correlation with a phenolic compound in sediment at Sarod (r=0. 66). Average Burrow density showed significant positive correlation with a phenolic compound in sediment at Neja (r=0. 81), Asarsa (r=0.57) while it has shown no significant positive correlation at Dahej (0.46).

Although natural occurring phenolic compound is good for mangrove, as they act as an antioxidant, but artificial phenolic compound found in the water and sediments are a cause of worry. As revealed in the results that although they didn't have a significant effect of the associated fauna, still study is needed on the carcinogenic effect of phenolic compound up to species level, phenolic compound controls the density of mangrove along with other factor.

Heavy Metals:

The expression of heavy metal refers to any metallic chemical element that has a relatively high density and is toxic, highly toxic or poisonous even at low concentrations. The presence of heavy metal in mangrove ecosystem is common and well documented. Heavy metal, accumulated in primary producer, i.e. mangrove, finds its way to the human population through the various primary and secondary consumers like crabs and fishes. Heavy metals not only affect the flora or fauna but ecosystems as a whole. Heavy metal level can also act as an indicator of other pollution in the ecosystem (Mateu et al., 1996).

Pollution in water environmental with toxic metals has been attracting significant public attention over the past few years. Though heavy metal pollution in water alone is not that much effective to the mangrove ecosystem; but due to high concentration of solids in mangrove water these heavy metals can settle, percolate and accumulate. Out of the various sources of heavy metal pollution in water major source are mining and smelting of metalliferous ores (Li and Thornton, 2001). Labunska et al. (1999) studied heavy metal, released by the Nandesari Industrial Estate, and its concentration in mahi estuary. This estate has more than 300 units out of which 82% were of dye manufactures and rest 13% are of pharmacy base industries (CPCB, 1996). A sample collected from Sarod (IT9053) showed the presence of Cadmium (Cd), Cromium (Cr) and Cobalt (Co) <10 ug/l, Copper (Cu) 10 ug/l, Lead (Pb) 40ug/l, Mercury (Hg) <2 ug/l, Nickel (Ni) 60 ug/l and Zinc (Zn) 50 ug/l. Another study conducted by Lotfinasabasl et al. (2013) on metal pollution in water at Alibag (Maharashtra) mangrove showed Cu(0.64 mg/l), Cd (0.67 mg/l),Co(1.53 mg/l) and Cr (BDL) in water samples collected from 18 stations.

In present study; heavy metals like Cu, Zn, Cr, Ni, Pb, Hg, Cd, Co and Mn were recorded from the water samples, Copper (Cu), with average of 0.84 %, recorded highest at Sarod, (2.21 %) and lowest at Asarsa (0.10 %). Zinc (Zn), with an average of 1.00%, recorded highest at Sarod, (2.19 %) and lowest at Asarsa (0.10%). Chromium (Cr), with an average of 0.51%, recorded highest at Sarod, (1.20 %) and lowest at Asarsa and Dahej (0 %). Nickel (Ni), with an average of 0.22 %, recorded highest at Sarod, (0.78 %)

and lowest at Asarsa and Dahej (0 %). Lead (Pb), with an average of 0.42 %, recorded highest at Dahej, (0.90%) and lowest at Asarsa (0 %). Mercury (Hg), with an average of 0.15%, recorded highest at Sarod, (0.59%) and lowest at Neja, Asarsa and Dahej (0 %). Cadmium (Cd), with an average of 0.05, recorded highest at Sarod, (0.20 %) and lowest at Neja, Asarsa and Dahej (0 %). Cobalt (Co), with an average of 0.01%, recorded highest at Sarod, (0.02 %) and lowest at Neja, Asarsa and Dahej (0 %). Magnesium (Mn) were absent from the sample. Mean heavy metal value (Fig. 4.14e) was observed higher at Sarod, 0.87 %, as compared to other sites and the mean variation between the sites was significant(ANOVA,F=7.14,Fcrit=2.90,P<0.01). At high concentration site, Sarod, average mangrove and burrow density was observed as 0.39 mangroves/m^2 and 0.84 burrows/m^2 respectively. At the lowest concentration of heavy metal site, Asarsa, average mangrove and burrow density was observed as 5.02 mangroves/m^2 and 42.42 burrows/m^2 respectively. Mean Mangrove density and mean heavy metal concentration show a significant negative correlation (r= 0.97) at all sites. Mean burrows density and mean heavy metal concentration also shows a significant negative correlation (r= 0.93) at all sites.

The presence of heavy metals in sediments is majority due to mineral weathering and natural soil erosion. In past the heavy metal pollution was limited due to the relative absence of industries, but as industrialization took place the metal contamination in sediment has increased. According to Greaney (2005) physical adsorption of heavy metal usually occurs when particulate matter directly adsorbs heavy metals straight from the water and it is controlled by many factors including pH and oxidation. Within the sediment heavy metals can be either transformed to less soluble forms so it can absorb via food to living biota. Kathirasen (2002) has reported heavy metals like Copper (7.85±3.7 ppm), Cobalt (4.84±1.7 ppm), Lead (2.05±0.9ppm) etc. in the degraded mangrove of Pichavaram. Kumar et al. (2008) also studied the seasonal changes in heavy metal concentration in Cochin estuary and found heavy metal like Mn (210.5-315.35 µg/g), Zn (101.3-455.68 µg/g), Cr (53.30- 90.22 µg/g), Ni (30.60–69.35µg/g), Pb(19.5-39.50µg/g),Cu(23.97- 39.12µg/g),Co(12.82-23.08 µg/g) and Cd (0.062-0.223 µg/g). Agoramoorty et al. (2008) studied heavy metal pollution in Pichavaram mangrove and found Pb (8 ug/l).

In present study heavy metals like Cu, Zn, Cr, Ni, Pb, Hg, Cd, Co and Mn were recorded from the sediment samples. Copper (Cu), with average of 0.35%, recorded highest at Sarod, (1.15%) and lowest at Dahej (0.01 %). Zinc (Zn), with average of 0.53 %, recorded highest at Sarod, (1.12 %) and lowest at Asarsa (0.01 %). Cromium (Cr), with average of 0.17 %, recorded highest at Sarod, (0.57 %) and lowest at Asarsa and Dahej (0 %). Nickel (Ni), with average of 0.12 %, recorded highest at Sarod, (0.44 %) and lowest at Asarsa and Dahej (0 %l). Lead (Pb), with average of 0.13 %, recorded highest at Sarod, (0.31 %) and lowest at Asarsa (0 %). Mercury (Hg), with average of 0.03 %, recorded highest at Sarod, (0.10%) and lowest at Neja, Asarsa and Dahej (0 %). Cadmium (Cd), Cobalt (Co) and Magnesium (Mn) were absent from the sample. Mean heavy metal value (Fig.4.15g) was observed higher at Sarod, 0.41 %, as compared to other sites and the mean variation between the sites was significant (ANOVA F=5.98, Fcrit= 2.90 P<0.01). At high concentration site, Sarod, average mangrove and burrow density was observed as 0.39mangroves/m^2 and 0.84 burrows/m^2 respectively. At the lowest concentration of heavy metal site, Asarsa, average mangrove and burrow density was observed as 5.02 mangroves/m^2 and 42.42 burrows/ m^2 respectively. Mean Mangrove density and mean heavy metal concentration, density and mean heavy metal concentration also shows a significant negative correlation (r= 0.93) at all sites.

Mangroves are acknowledged for their tolerance to extreme environmental conditions. Heavy metals are at top list of the pollutants to be present in the natural environment due to their toxicity, persistence and bioaccumulation problems (MacFarlane and Burchett, 2000). As mangroves are facing rapid loss in recent decades, though in some places mangroves are still extensive (Spalding, 1998), the existing mangroves suffer from direct impacts of environmental pollutants such as heavy metals that are released from anthropogenic activities (Cuong et al., 2005). Manufacturing industries, agro-based industries and urbanization are the major sources of heavy metal inputs in mangrove ecosystems (DOE, 1999). The absorption of heavy metals by plants are passive, and its translocation from the roots to other plant organs is generally low (Nirmal Kumar et al., 2008).

There are several studies on heavy metal contamination in the mangrove sediments and their effects on organisms but little is known about heavy metals uptake by mangrove plants (Kurmar et al., 2011). MacFarlane et al., (2003) have reported concentration of Pb (5 ug/g) in the Avicennia marina of Australia. Machado et al., (2002) have reported average concentration of Pb (3.37 ug/g-1) in leaves of Avicennia marina in Guanabara Bay, (Brazil). Kurmar et al., (2011) studied the accumulation of heavy metals in various parts of Avicennia marina, at Valmeshwer mangrove (Gujarat) and found mean accumulation of heavy metal in a pattern of Root>Leaf>Stem. In the present study presence of heavy metals was found in the pattern of Leaf>Stem>Root.

In present study heavy metals like Cu, Zn, S, Si, Sr, Ti and Br were recorded from the root, stem and leaves of Avicennia marina samples. Mean heavy metal value(Fig. 4.16a) in root was observed higher at Sarod, 2.82 %, as compared to other sites and the mean variation between the sites was significant (ANOVA F=0.30, Fcrit = 3.00 P< 0.5). In roots, Copper (Cu), with an average of 0.31 %, was recorded highest at Sarod, (1.23 %) and lowest at Neja, Asarsa and Dahej (0.00 %). In roots, Zinc (Zn), with an average of 0.18 %, was recorded highest at Sarod, (0.32 %) and lowest at Neja, Asarsa and Dahej (0.00 %). Mean heavy metal value (Fig. 4.16b) in stem was observed higher at Dahej, 2.63 %, as compared to other sites and the mean variation between the sites was significant (ANOVA F=0.23, Fcrit= 3.00 P< 0.5). In stem, Copper (Cu), with an average of 0.18 %, was recorded highest at Sarod, (0.70 %) and lowest at Neja, Asarsa and Dahej (0.00 %). In stem, Zinc (Zn), with an average of 0.05 %, was recorded highest at Sarod, (0.21 %) and lowest at Neja, Asarsa and Dahej (0.00 %). Mean heavy metal value (Fig 4.13c) in leaves was observed higher at Dahej, 4.83 %, as compared to other sites and the mean variation between the sites was not significant (ANOVA F=0.09, Fcrit= 3.00 P>0.5). In leaves, Copper (Cu), with average of 0.11 %, was recorded highest at Sarod, (0.45 %) and lowest at Neja, Asarsa and Dahej (0.00 %). In leaves, Zinc (Zn), with an average of 0.04 %, was recorded highest at Sarod, (0.16 %) and lowest at Neja, Asarsa and Dahej (0.00 %).

In a mangrove ecosystem mangrove is primary producer that produces energy with the help of the water and sediment. So if heavy metals are present in any of these components of mangrove ecosystems, associated fauna, primary and secondary consumer are bound to affect from it. The increasing concentration of heavy metal at each tropic level in an ecosystem is known as Bio-magnification. When the top consumer, human, consumes associated fauna like crab and fish, it will also get affected by the heavy metal. Heavy metal contamination may have shocking effects on the ecological balance of the mangrove ecosystem and its fauna (Ashraj, 2005; Kamaruzzaman et al., 2012). Thus, to find out the presence of harmful and toxic substances in associated biota will give direct information about the effect of pollution in the aquatic environment (Hugget et al., 1973).

There have been very few studies done on the bio accumulation of heavy metal in the associate fauna of mangrove. Kamaruzzaman et al., (2012) studied bio-accumulation in Scylla serrata in Malaysia and reported that heavy metal accumulation in Scylla serrata followed Zn > Cu > Pb > Cd order. He also studied the bio-accumulation in different body part of the crab and found the most concentration of heavy metal, Zn (496.31 ug/g) and Cu (57.06 ug/g), in gut. Another study done by Mermi and Machiwa (2002) on the mangrove associated biota (Tanzania) revealed high concentrations of Pb, Zn, Cu, Co, Ni and Cr in the tissue of crab. Palpandi et al (2012) reported heavy metals in tissues of Nerita crepidularia in order of Cd>Cu>Cr>Zn>Ni>Pb. Ahemad et al., (2010) studied heavy metal accumulation in the macro benthic fauna of Sundarban mangrove and found accumulation of heavy metals like Cu (3.66 ± 0.89 to 7.55 ± 1.29 ug/g), Zn (76.8 ± 8.55 to 98.5 ± 6.49 ug/g), Cd (0.46 ± 0.11 to 0.859 ± 0.2 ug/g) and Pb (4.66 ± 1.17 to 6.77 ± 2.1 ug/g).

In present study heavy metals like Cu, Zn, K, Fe, Sr and Br were recorded from tissue of crab samples, Mean heavy metal value (Fig. 4.16d) in crab was observed higher at Sarod, 1.44 %, as compared to other sites and the mean variation between the sites was significant (ANOVA F=0.67, Fcrit =

3.09 P<0.5). Copper (Cu), with an average of 0.04 %, recorded highest at Sarod, (0.16 %) and lowest at Neja, Asarsa and Dahej (0 %). Zinc (Zn), with average of 0.06 %, recorded highest at Sarod, (0.14 %) and lowest at Asarsa and Dahej (0 %).

Heavy Metal recorded for the study showed that anthropogenic activities have considerable pressure on the mangrove ecosystem of the study site. Heavy metal in water and sediment shows negative correlation with mangrove and burrow density. The most surprising results have been observed at Sarod where average mangrove and burrow density were 0.39 mangrove/m^2 and 0.84 burrows/m^2 respectively. This shows that exacting mangrove ecosystem is under tremendous pressure. The presence of heavy metal in mangrove also shows that there are defiantly chances of heavy metals pass for human as mangroves of this area are utilized for fodder and also the consumption seeds in the form of food. Associated fauna also found contaminated with heavy metal which creates high risk of bio-accumulation in human as these fauna is an important part of the diet of the local people.

Mangrove Density:

Mangrove ecosystem flourishing in the intertidal region between sea and land in the warm water of tropical and subtropical latitudes provides valuable services to other ecosystem and mankind. Mangrove is the primary producer in the mangrove ecosystem and by evaluating its density one can have a fair idea about the healthiness of the ecosystem. Mangrove tree is generally considered as standing crops and many other factors affect the density of these standing crops. Mangrove forests are easily identified by their unique characters by having homogeneous species in different zones (Snedaker, 1982, Mendelssohn and McKee, 2000). In the present study site the forest structure is made up of only one species *Avecinnia marina* so such kind of zonation was not observed.

Many scientists have worked on mangrove ecosystem and produced valuable information on the forest structure of mangrove. But there are only few studies focusing on the density of mangrove. Kairo et al (2002) studied mangrove of Watamu Marine National Reserve (Kenya) and reported relative density of *A.marina* 11.59 to11.57 mangroves/m^2. In present study maximum mangrove density was observed 32.67 mangroves/m^2 (Asarsa site, December'10) while lowest density was observed 1.0 mangroves/m^2 (Sarod site, April'11) with an overall average of 16.22 mangrove/m^2. Mean mangrove density (Fig. 4.17a), was observed higher at Asarsa, 25.11 mangrove/m^2, as compared to other sites, but the mean variation between the sites was not significant (ANOVA F=20.69, Fcrit=3.09 P>0.5). Asarsa with highest mangrove density 5.02 mangroves/m^2 showed burrow density of 44.55 burrows while with the lowest density of mangrove of 0.39 mangroves/m^2 Sarod showed burrow density of 0.60 burrow/m^2. Average mangrove density showed no significant positive correlation with burrow density at different sites like Sarod (r= 0.34), Neja (r= 0.46), Asarsa (r= 0.49) and Dahej (r= 0.46).

Height and diameter of mangrove trees are other important factors to assess the health of mangrove ecosystems. Kathirasen (2002) studied the mangrove height at degraded (1.31 ± 1.0 meter) and dense (7.90 ± 2.4 meter) mangrove of Pichavram. In present study average maximum height of the mangrove was recorded at the Dahej site (July'11), 29.96 inches while the lowest was observed at Sarod (April'12) 13 inch. An overall average of mangrove height observed was 19.86 inches. Mean mangrove height (Fig. 4.17b) was observed high at Asarsa (22.28 inch) as compared to other sites and the mean variation between the sites was significant (ANOVA F=4.21 ,Fcrit= 3.09 P<0.01). Maximum average height (29.96 inch) was observed at Dahej with average burrow density of 25.35 burrows/m^2 while the lowest average height of mangrove (13inch) was noted with average burrow density of 0.55 burrows/m^2. Average mangrove height showed correlation with burrow density at Sarod (r= 0.95) while non significant positive correlation was recorded at Neja (r= 0.09), Asarsa (r= 0.09) and Dahej (r= 0.09). Average mangrove height showed non significant positive correlation with mangrove density at Sarod (r= 0.43) while significant negative correlation was reported at Neja (r= 0.82), Asarsa (r=0.84) and Dahej (r= 0.84).

In present study highest average diameter of mangrove recorded was 5 inchs (Sarod Site, April'11) and lowest average diameter of mangrove recorded was 1.88 inchs (Dahej, December'11) with an average diameter of 3.66 inches. Mean mangrove diameter (Fig. 4.17c) was observed higher at Sarod, 4.45 inch, as compared to other sites and the mean variation between the sites was significant (ANOVA F=2.21, Fcrit= 3.09 P<0.5). Highest average diameter (5 inch) was observed at Sarod with an average burrow density of 0.55 burrows/m^2. Lowest average diameter (1.88 inch) was observed at Dahej with an average burrow density of 26.2 burrow/m^2. Average mangrove diameter showed significant negative correlation with burrow density at Sarod (r=0. 64) while non significant negative correlation was observed at Asarsa (r=0.12) and Dahej (r= 0.25). Average mangrove diameter showed non significant positive correlation with burrow density at Neja (r= 0.05). Average mangrove diameter showed significant negative correlation with mangrove density at different sites like Sarod (r= 0.58), Neja (r= 0.84), Asarsa (r= 0.89) and Dahej (r= 0.96). Average mangrove diameter showed significant negative correlation with average mangrove height at Sarod (r= 0.53) while it has shown a significant positive relation at Neja (r= 0.99), Asarsa (r= 0.99) and Dahej (r= 0.95).

Present status of mangrove, density, height and diameter, suggested That there are possibility that Sarod had a relatively good patch of mangrove in the past as Sarod has a highest diameter of mangrove. But due to increasing pressure from the various anthropogenic activities that the patch is now reduced to almost zero in case of mangrove density.

Crab Burrow Density:

Associated macro benthos fauna plays an important role in mangrove ecosystem. They act as primary consumer (crabs), secondary consumer (fish) and decomposer (gastropods) in a healthy mangrove ecosystem. In mangrove density of this macro benthos also indicates the health of the ecosystem. Most of macro benthos lives in burrows in the same sediments on which mangrove grow. So they also get affected if there is any change in environment. For example Fiddler crabs, *Uca* sp., feed on the mangrove's fallen leaves (Miller 1961). So surface activity is significantly reduced and burrow plugging amplified during neap periods when the sediment is dry

(Zucker 1978). Apart from other parameters burrow density also depends on lower zone (land ward side) and upper zone (sea ward side). In lower zone due to shadow of mangrove burrowing activities can be ongoing during the dry period while in upper zone, mud flats, the burrowing activity is affected by dryness.

Prosser (2004) studied burrow density in the mangrove of Moreton Bay (Australia) and reported mean density of 294 ± 29 burrows/m^2. In present study highest average burrow density in lower zone was observed as 44 burrow/m^2 (Asarsa Site, July'11) and lowest average burrow density in lower zone was observed as 0.50 burrows/m^2 (Sarod, April'12) with the overall average burrow density in lower zone of 18.30 burrows/m^2. Mean burrow density (Fig. 4.17d) in lower zone (32.77 burrows/ m^2) was observed higher at Asarsa, as compared to other sites and the mean variation between the sites was not significant (ANOVA F=27.02, Fcrit= 3.09 P>0.5). Highest burrow density (44 burrows/m^2) in the lower zone was observed Asarsa with average mangrove density of 25 mangroves while lowest burrow density (0.55 burrows/m^2) in the lower zone was observed at Sarod with average mangrove density of 1.67 mangroves/m^2. Average burrow density in lower zone showed significant positive correlation with mangrove density at sites like Neja (r= 0.57), Asarsa (r= 0.55) and Dahej (r= 0.58) while non significant positive correlation was observed at Sarod (r= 0.13).

In present study; highest average burrow density in upper zone was observed as 59.10 burrow/m^2(Asarsa Site, July'11) and lowest average burrow density in upper zone was observed as 0.40 burrows/m^2 (Sarod, April'11) with an overall average burrow density in upper zone of 30.04 burrows/m^2. Mean burrow density (Fig. 4.17e) in upper (zone 52.07 burrows/m^2) was observed higher at Asarsa, as compared to other sites and the mean variation between the sites was not significant (ANOVA F=293.36 , Fcrit= 3.09 P>0.5).Maximum burrow density (59.10 burrows/m^2) in upper zone was observed at Asarsa with an average mangrove density was 5.02 mangroves/m^2 while lowest burrow density (0.40 burrows/m^2) in upper zone was observed at Sarod with an average mangrove density was 0.39 mangroves/m^2. Average burrow density in upper zone showed no significant positive correlation with mangrove density at different sites like

Sarod (r= 0.49), Neja (r= 0.19), Asarsa (r= 0.26) and Dahej (r= 0.20). A significant positive correlation was observed between lower zone and upper zone burrow density at different sites like Sarod (r= 0.66), Neja (r= 0.69), Asarsa (r= 0.92) and Dahej (r= 0.60).

As stated earlier burrow density can be an indicator of healthy mangrove ecosystem, Sarod being most polluted site had very low burrow density in both zone as compare to other site.

Associated Fauna:

Health of any ecosystem depends upon its floral and faunal component which is governed by various physical factors. Health of mangrove ecosystem is reflected by the presence of associated fauna that are primary and secondary consumer and decomposers. It has been observed that diversity of associated fauna is more where the mangrove patch is relatively undisturbed than the mangrove patch which is disturbed, either by the local population or by pollution. In mangrove ecosystem, two groups of faunal diversity can be seen. The term “mangrove macrobenthos” is commonly used for species that live in mangrove mud or depend on mangroves for entire life or part of their life- cycle. Different phyla like Porifera (sponges), Mollusca (molluscs), Arthropoda (crabs, lobsters, prawns, etc.), Annelida (segmented worms), Nematoda (roundworms), Sipunculoidea (peanutworms), Platyhelminthes (flatworms) etc. are observed in mangroves. These macrobenthos are primary consumer and decomposers. The second group of fauna which comprises more evolved faunal species of vertebrates, like fishes, aves, reptiles and mammals, act as a primary, secondary and tertiary consumers. As mangrove, particularly the roots, act as a nursery ground for many fishes and birds, mangrove also provides a good livelihood to local human population.

Many scientists studied mangrove associated fauna. Rao (1997) has reported different faunal groups like fishes (397 sp), crab (259 sp.), mollusca (256 sp), insect (450 sp.) and mammals (250 sp.) dwell the in mangrove ecosystem in the world. In the present study, total 51 species belonging different groups like mollusca (7 sp.), arthopoda (13 sp) and cordata (31 sp.) were recorded. The results of Bray-Curtis similarity index

(Fig 4.18) showed that two distinguish groups of faunal diversity are observed that includes in group of Neja-Asarsa-Dahej and group of Sarod. This is probably because of presence of high pollution at Sarod. Sarod has its own kind of diversity and didn't show any kind of similarity with other group. Neja has 60% similarity in species composition with the group of Asarsa and Dahej. Asarsa and Dahej have 80% similarity in species composition. Maximum mangrove associated faunal diversity was observed at Asarsa (40 species) followed by Dahej (36 species) Neja (30 species) and Sarod (2 species). Amongst the mangrove associated species observed in the area, maximum species were reported form class aves (25 species,11 families) followed by class malacostraca (Fig. 4.19) (9 species,7 families),class gastropoda (Fig. 4.20) (6 species, 6 families), class insecta (4 species, 2 families), class pices (3 species, 2 families), class reptile (2 species,1 family) (Fig. 4.21) and Class Bivalve (1 species,1 family).

Uca (Austruca) lactea (De Haan, 1835) is the most common species of associated fauna found in the study site. Species like *Scylla serrata* (Forskål, 1775), *Parasesarma plicatum* (Latreille, 1803),*Colotis amata amata* (Fabricius, 1775), *Periophthalmus waltoni* (Koumans, 1941),*Grus grus* (Linnaeus, 1758), *Tringa tetanus* (Linnaeus,1758), *Circus aeruginosus*(Linnaeus, 1758) etc are found commonly in Neja, Asarsa and Dahej. *Venitus dentipes* (Lucas, in Guérin Méneville, 1836),*Cerithidea obtusa* (Lamarck,1822), *Scartelaos histophorus*(Valenciennes, 1837),*Actitis hypoleucos*(Linnaeus,1758),*Cerberus rynchops*(Schneider,1799) etc. were found commonly in Asarsa and Dahej. *Apis florea* (Fabricius, 1787),*Tringa stagnatilis* (Bechstein, 1803), *Esacus recurvirostris* (Cuvier, 1829) etc. are found commonly at Neja and Asarsa.*Grapsus intermedius* (de Man, 1888), *Cerithium echinatum* (Lamarck, 1822), *Sterna aurantia* (Gray,JE, 1831) etc. are common in Dahej and Neja. Species like *Meretrix meretrix* (Linnaeus, 1758) only found at Neja. Species like *Ashtoret lunaris* (Forskål, 1775), *Cardisoma carnifex* (Herbst, 1796), *Nerita crepidularia* (Linnaeus, 1758) and *Sinum haliotoideum* (Linnaeus, 1758) etc were found only at Asarsa. Species like *Cicindelinae* sp., *Cerithidea cingulata* (Gmelin, 1791), *Gerarda prevostiana* (Eydoux and Gervais, 1822) were recorded only from Dahej.

Composition of associated fauna clearly reflects the fact that the status of physiochemical parameters and the degree of pollutant affects the diversity of associated fauna in the mangrove forest. Sarod being most polluted sites had very less diversity of associated fauna while on other hand Asarsa, relatively free from pollution, had high diversity. But the high diversity of associated fauna at Asarasa, Neja and Dahej is facing pressure anthropogenic activity, i.e. fishing.

Summary of utilization, dependence and anthropogenic pressure on the Mangroves

No	Parameter	Sarod	Neja	Asarsa	Dahej
A	**Location**				
1	N	22°10'32.12"	22° 8'52.57"	21°57'10.28"	21°42'51.39"
2	E	72°45'18.49"	72°33'54.19"	72°35'32.55"	72°34'57.98"
3	Estuary	Mahi	Mahi	Dadhar	Dadhar
4	Taluka	Jambusar	Jambusar	Jambusar	Bharuch
B	**Mangrove Patch**				
5	Type	Sparse	Open	Open/Dense	Dense
C	**Sediment Characteristic**				
6	>2 mm (gm)	100	20	200	0
7	>1 mm (gm)	120	100	140	10
8	>0.500 mm (gm)	60	40	60	60
9	> 0.250 mm (gm)	40	40	60	40
10	>0.125 mm (gm)	40	0	40	0
11	Water Holding (per Kg)	320	440	380	320
12	Avg. pH	6.54	7.73	7.76	8.06
13	Avg. Salinity (ppt)	0.20	1.25	1.05	1.33
14	Avg. Organic Matter (mg/l)	0.65	4.19	6.56	5.13
15	Avg. Hardness (mg/l)	0.00	34.00	80.33	28.83
D	**Water Characteristic**				
16	Avg. pH	6.33	7.52	7.52	8.00
17	Avg. Salinity (ppt)	7.02	23.18	20.58	38.28
18	Avg. Hardness (mg/l)	2413.70	2942.80	2315	6372.80
19	Avg. Dissolved Solid (ppt)	3.20	9.38	8.31	26.83
20	Avg. Suspended Solid(ppt)	3.13	10.16	9.00	6.10
21	Avg. Total Solids(ppt)	6.40	19.55	17.37	34.40
22	Avg. Alkalinity (mg/l)	673.67	141.67	205.33	341.00

E	**Mangrove Status**				
23	Avg. Density (m2)	1.94	19.83	25.11	18.00
24	Avg. Height (Inch)	13.55	21.51	22.28	22.11
25	Avg. Girth (Inch)	4.45	3.51	3.49	3.22
26	Avg. no of Flowering Tree	1	49.50	69.50	43.50
F	**Associated Faunal Status**				
27	Avg. Burrow Density in LZ (m2)	0.87	22.35	32.77	17.20
28	Avg. Burrow Density in UZ (m2)	0.82	34.57	52.07	32.72
29	Total number of Faunal Species	2	30	40	36
G	**Dependency Status**				
30	No. of person using as Fodder	0	9	3	2
31	Avg. Income (Rs./Month)	0	2100	2366	1120
32	No. of person using in Fishing	0	9	6	19
33	Avg. Income (Rs./Month)	0	2922	3083	2484
34	No. of person using Seeds	0	25	18	23
35	Avg. Income (Rs./Month)	0	216	200	214
H	**Sediment Pollution Status**				
36	Chemical Oxygen Demand (mg/l)	207.70	43.20	21.83	84.33
37	Phenolic Compounds (mg/l)	3.78	0.48	0.02	0.16
38	Presence of Heavy Metals (%)	0.41	0.05	0.00	0.04
I	**Water Pollution Status**				
39	Chemical Oxygen	624.74	289.49	28.53	107.45

	Demand (mg/l)				
40	Phenolic Compounds (mg/l)	7.37	1.31	0.03	0.31
41	Presence of Heavy Metals (%)	0.87	0.19	0.02	0.08
J	**Heavy Metal Status in Biotic Component**				
42	Mangrove Root (%)	2.82	2.24	1.72	1.84
43	Mangrove Stem (%)	2.11	2.76	1.64	2.63
44	Mangrove Leaf (%)	4.83	4.08	3.64	3.23
45	Crab (%)	1.44	0.83	0.50	0.83

Fig. 4.13: Physicochemical analysis of Water

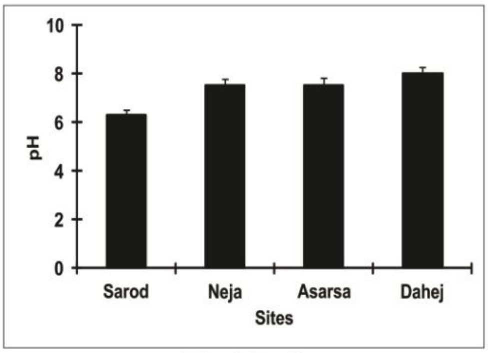


Fig. (a): pH

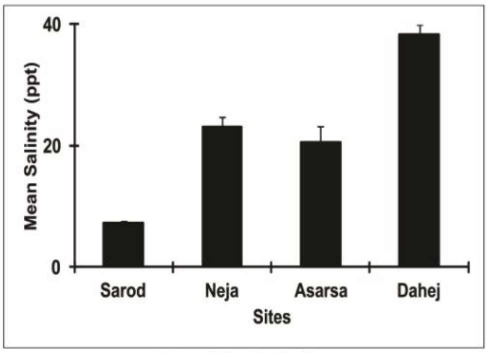


Fig. (b): Salinity

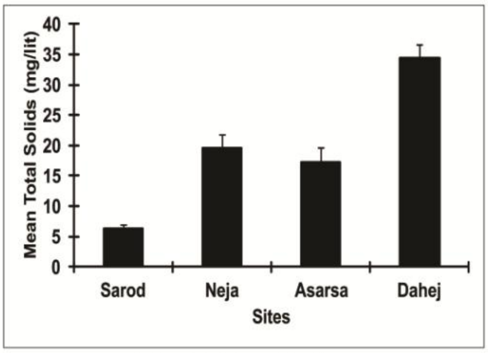


Fig. (c):Total Solids

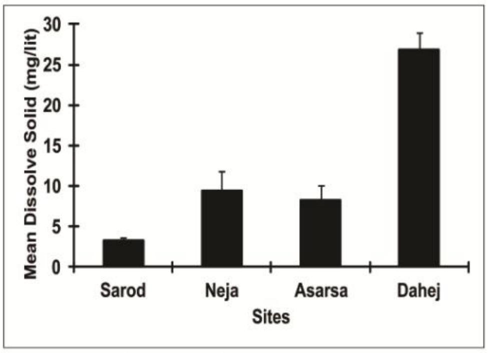


Fig. (d): Total Dissolved Solids

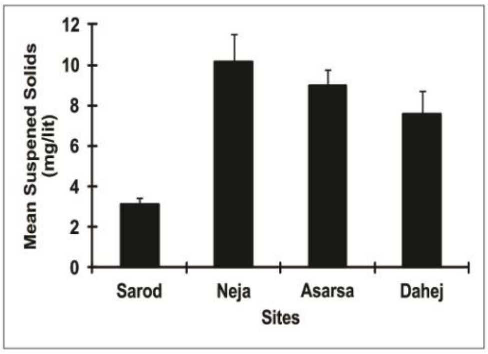


Fig. (e): Total Suspended Solids

Fig. 4.14: Physicochemical analysis of Water

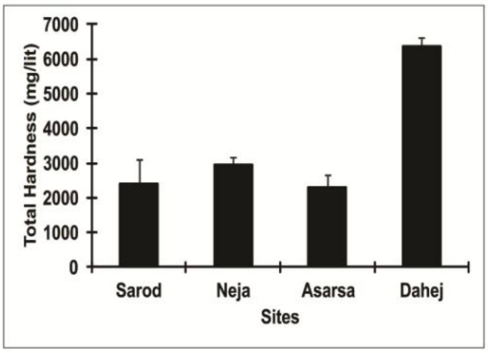


Fig.(a): Hardness

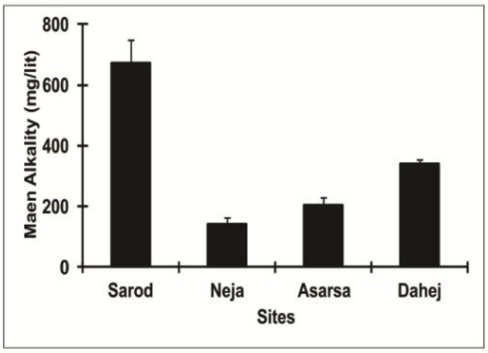


Fig. (b): Alkalinity

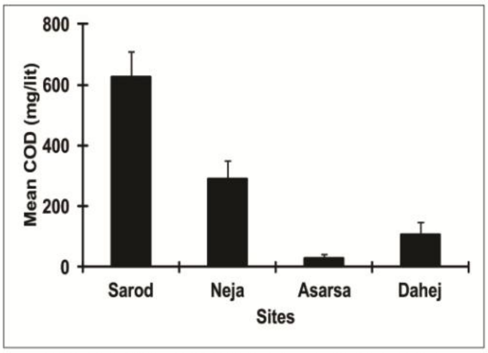


Fig. (c): Chemical Oxygen Demanded

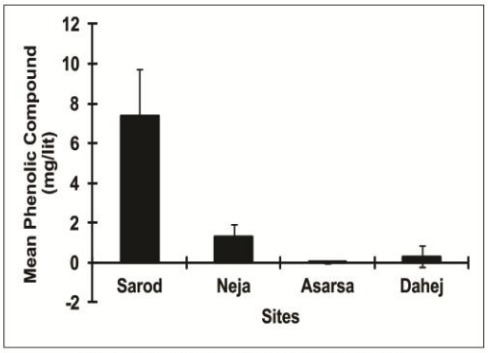


Fig. (d): Phenolic Compounds

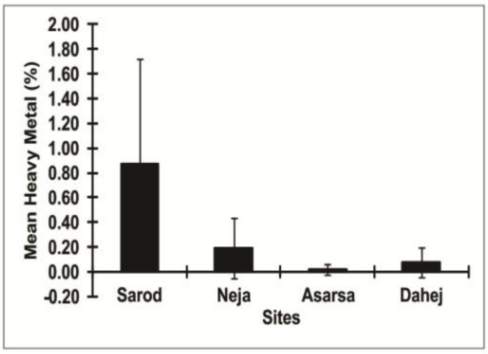


Fig. (e): Heavy Metals

Fig.4.15: Physicochemical analysis of Sediments

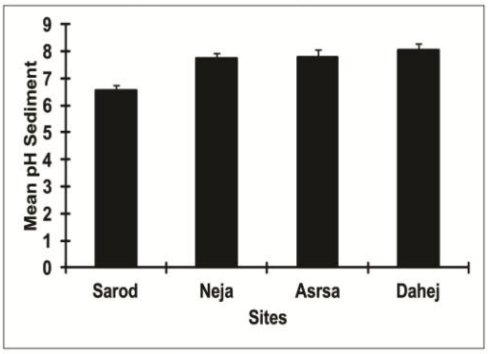


Fig. (a): pH

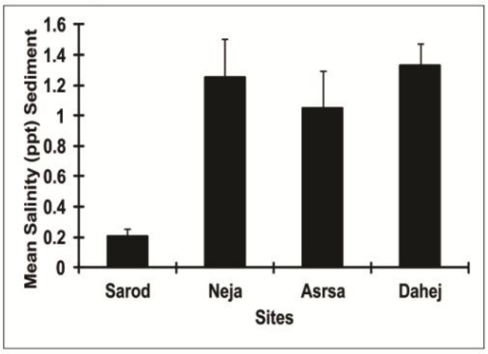


Fig. (b): Salinity

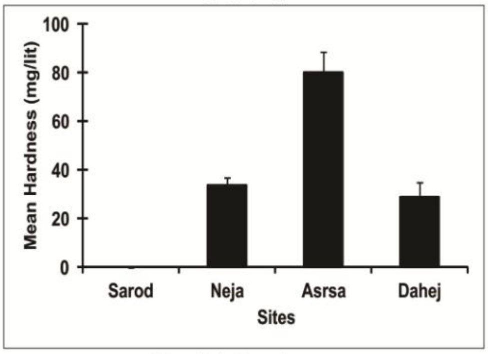


Fig. (c):Hardness

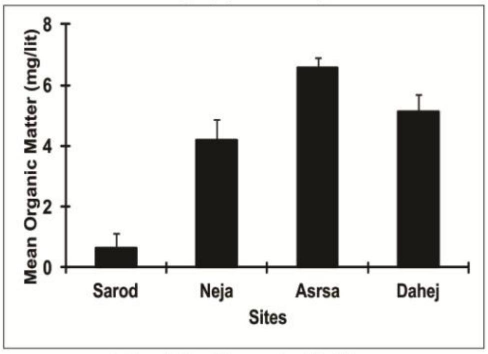


Fig. (d): Organic Matter

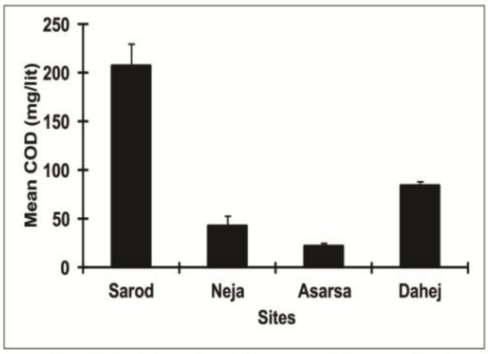


Fig. (e): Chemical Oxygen Demanded

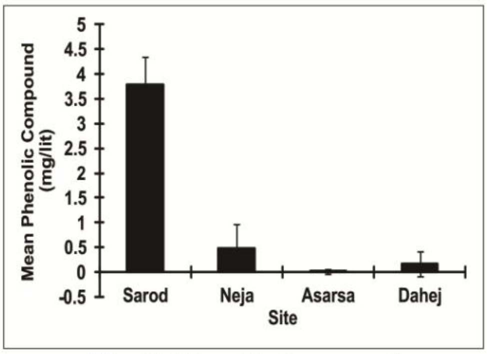


Fig. (f): Phenolic Compound

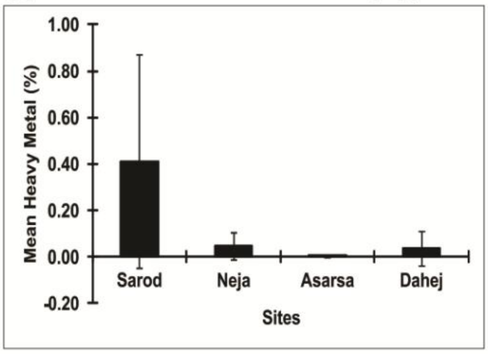


Fig. (g): Heavy Metals

Fig. 4.16: Heavy Metal analysis of Mangrove and Crab

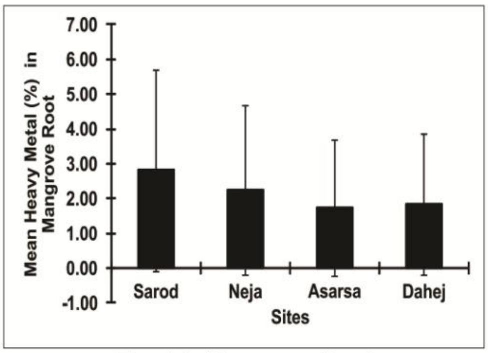


Fig. (a): Mangrove Root

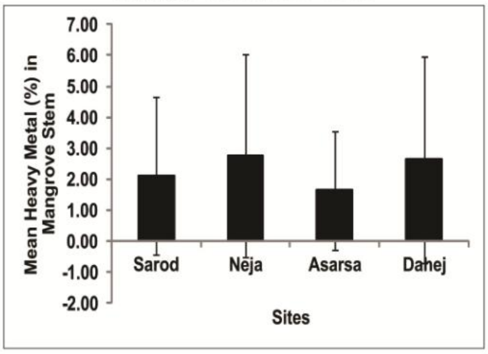


Fig. (b): Mangrove Stem

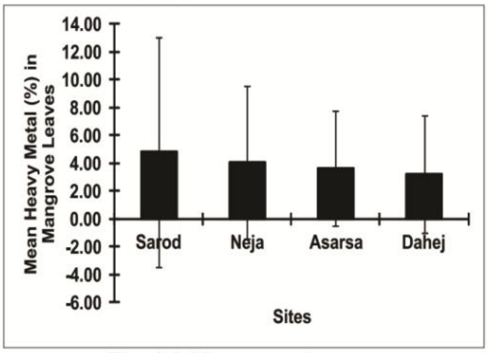


Fig. (c):Mangrove Leaves

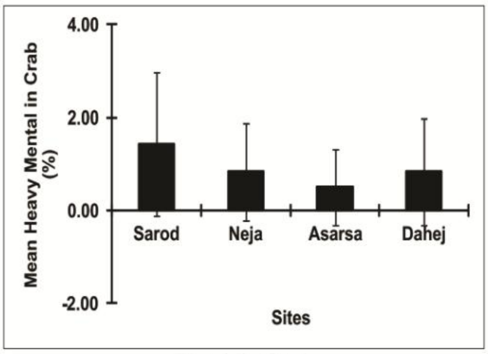


Fig. (d): Crab

Fig. 4.17: Biotic analysis of Mangrove and Burrow

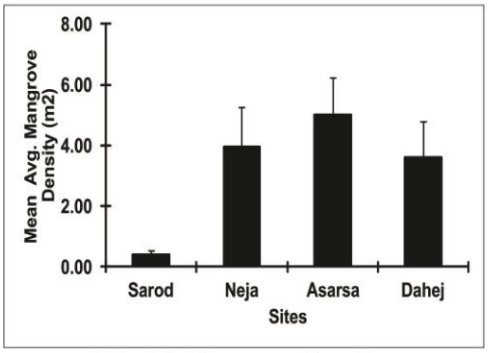


Fig. (a): Mangrove Density

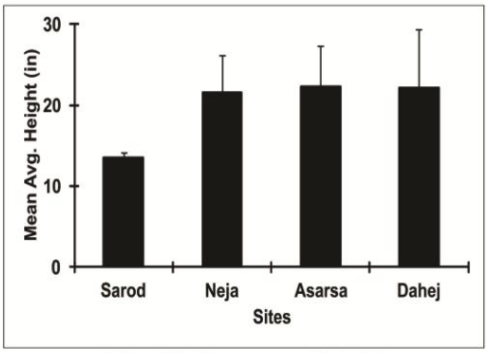


Fig. (b): Mangrove Height

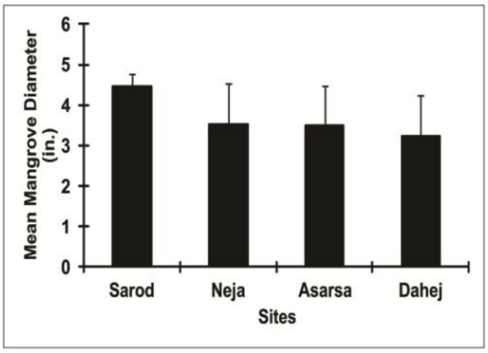


Fig. (c):Mangrove Diameter

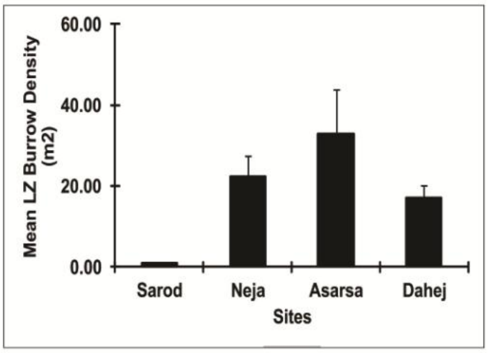


Fig. (d): Lower Zone Burrow Density

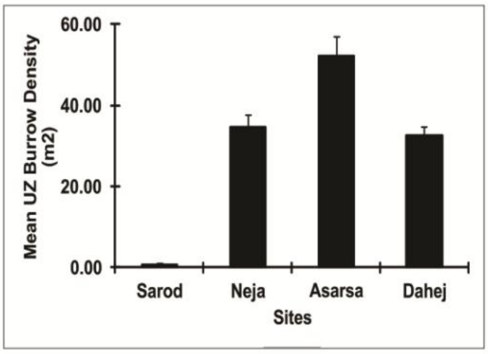


Fig. (e): Upper Zone Burrow Density

Fig. 4.18: Bray-Curtis Similarity of Associated Fauna in Study area

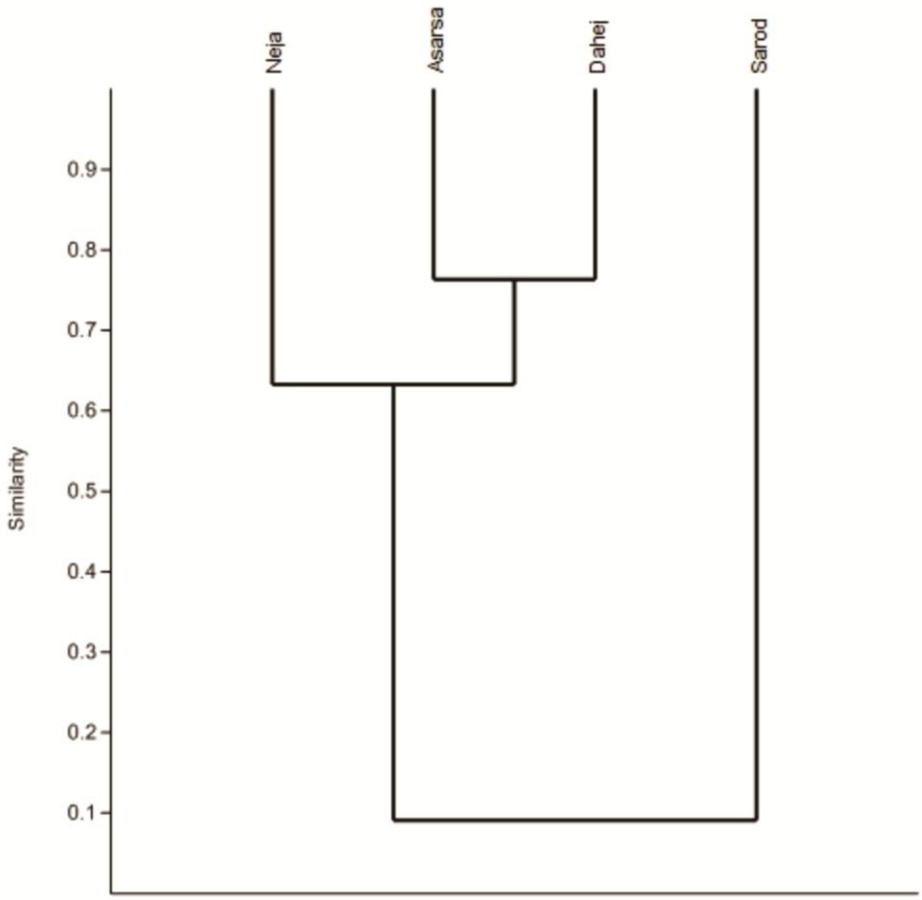
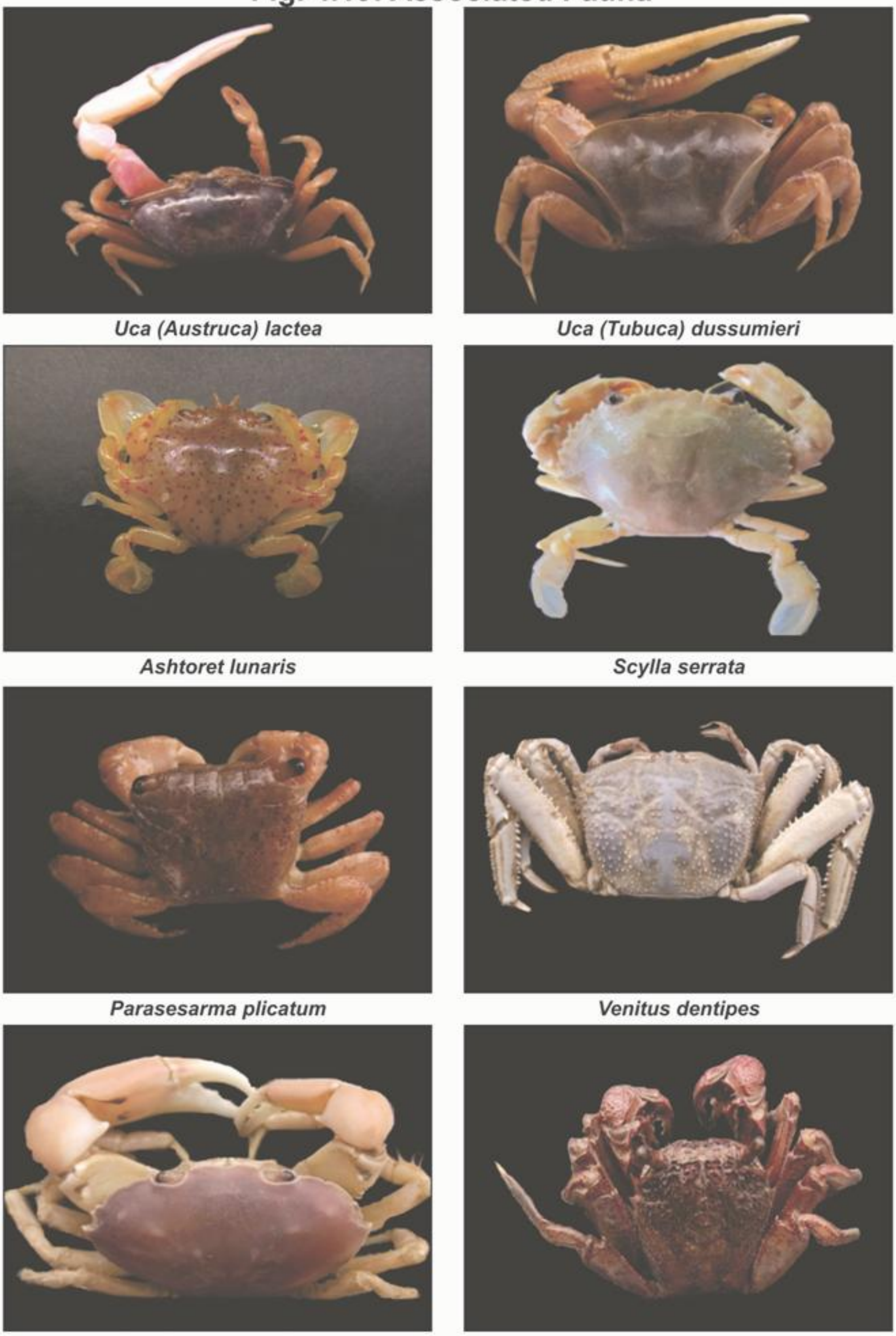


Fig. 4.19: Associated Fauna



Uca (Austruca) lactea | *Uca (Tubuca) dussumieri*

Ashtoret lunaris | *Scylla serrata*

Parasesarma plicatum | *Venitus dentipes*

Cardisoma carnifex | *Grapsus intermedius*

Fig. 4.20: Associated Fauna

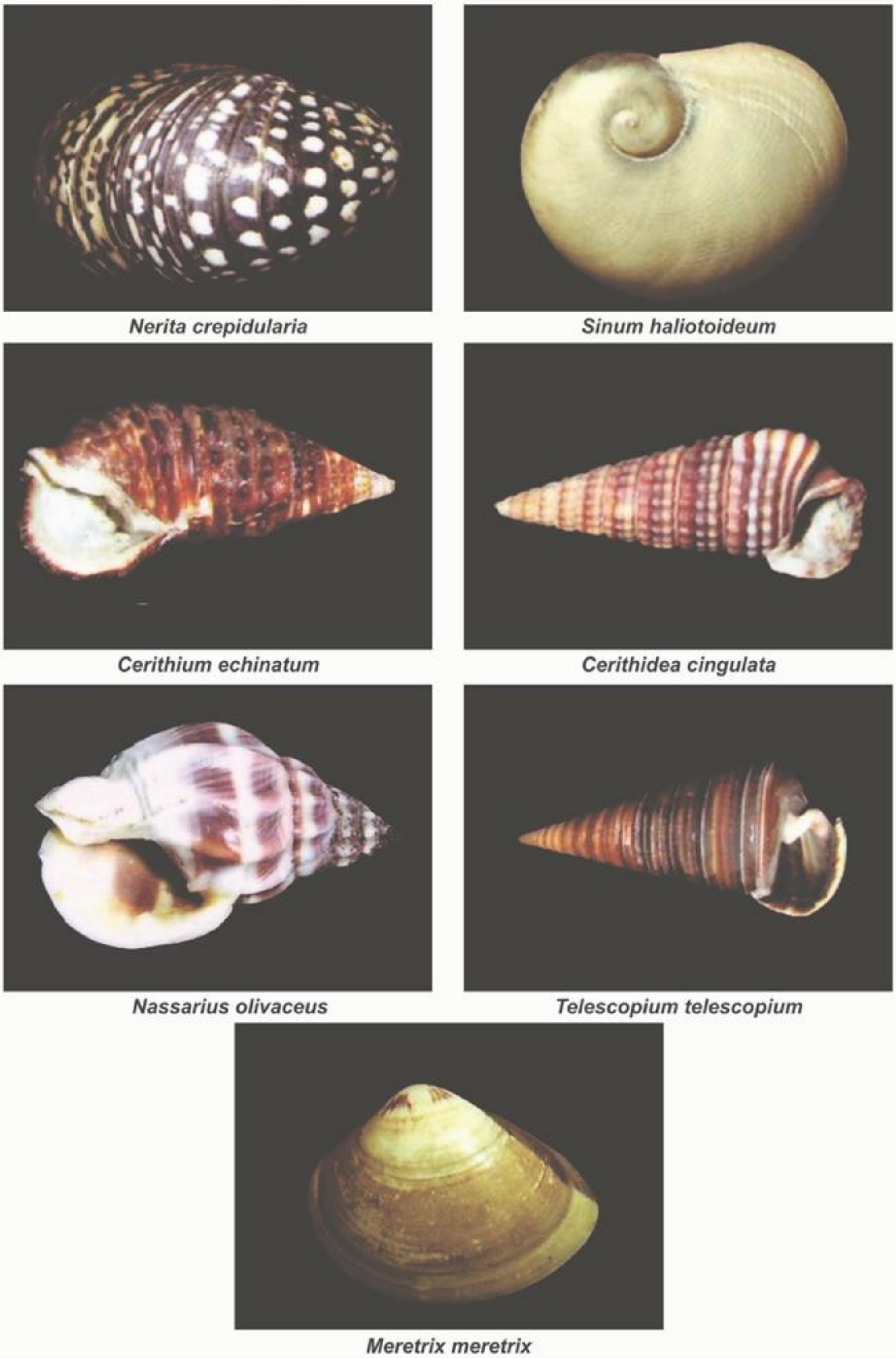


Fig. 4.21: Associated Fauna

Cicindelinae sp.

Colotis amata amata

Periophthalmus waltoni

Scartelaos histophorus

Boleophthalmus dussumieri

Gerarda prevostiana

Cerberus rynchops

Fig. 4.22: Associated Fauna

Tringa nebularia

Charadrius dubius

Larus ridibundus

Ardea cinerea

Casmerodius albus

Phoenicopterus minor

Mycteria leucocephala

Circus aeruginosus

CHAPTER 5: ANTHROPOGENIC PRESSURE AND DEPENDENCY ON MANGROVES

5. Anthropogenic pressures and dependency on mangroves

5.1. Mangrove Utilization Profile: Kamboi
5.2. Mangrove Utilization Profile: Kavi
5.3. Mangrove Utilization Profile: Degam
5.4. Mangrove Utilization Profile: Neja
5.5. Mangrove Utilization Profile: Sigam
5.6. Mangrove Utilization Profile: Ishanpure
5.7. Mangrove Utilization Profile: Zamdi
5.8. Mangrove Utilization Profile: Chindra
5.9. Mangrove Utilization Profile: Jantrana
5.10. Mangrove Utilization Profile: Malpur
5.11. Mangrove Utilization Profile: Devla
5.12. Mangrove Utilization Profile: Nada
5.13. Mangrove Utilization Profile: Asarsa
5.14. Mangrove Utilization Profile: Kapuria
5.15. Mangrove Utilization Profile: Tankaria
5.16. Mangrove Utilization Profile: Achod
5.17. Mangrove Utilization Profile: Denva
5.18. Mangrove Utilization Profile: Chanchvel
5.19. Mangrove Utilization Profile: Gandhar
5.20. Mangrove Utilization Profile: Dahej
5.21. Mangrove Utilization as Fodder
5.22. Mangrove Utilization as Fishing Resources
5.23. Mangrove Utilization as Food

5.1. Kamboi

Kamboi is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spare mangrove cover which is situated about 5.5 km from the village. In this village 20 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 19 male and 6 female mangrove users (Table: 5.1, Fig.5.1 and 5.2). None of the person uses mangrove as fodder. The village has only 6 fishermen out of which only 3 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,066 Rs. /Month. Kamboi village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the shedding season.

5.2. Kavi

Kavi is situated along the mouth of Mahi River Estuary. The main occupation of the villagers is agriculture. Population of this village is also dependent on a spare mangrove cover which is situated about 6 km from the village. In this village 16 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 21 male and 4 female mangrove users (Table: 5.2, Fig. 5.3 and 5.4.). Total 3 persons uses mangrove as fodder. The village has only 6 fishermen out of which only 3 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,033 Rs. /Month. Kavi village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the shedding season.

5.3. Degam

Degam is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spare mangrove cover which is situated about 1.5 km from the village. In this village 11 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 18 male and 7 female mangrove users (Table:5.3, Fig.5.5 and 5.6). Total 14 persons uses mangrove as fodder. The village has only 6 fishermen out of which only 1 fisherman use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 1,200 Rs. /Month. Degam village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village but no one selling it.

5.4. Neja

Neja is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spare mangrove cover which is situated about 1.7 km from the village. In this village 23 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 16 male and 6 female mangrove users (Table:5.4, Fig. 5.7 and 5.8). Total 9 persons uses mangrove as fodder. The village has only 9 fishermen and all of them using a mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,922 Rs. /Month. Neja village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 216 Rs/month on an average during the shedding season.

5.5. Sigam

Sigam is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spare mangrove cover which is situated about 3.6 km from the village. In this village 19 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 17 male and 2 female mangrove users (Table: 5.5, Fig. 5.9 and 5.10). Total 5 persons uses mangrove as fodder. The village has only 7 fishermen out of which only 5 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,720 Rs. /Month. Sigam village has moderate mangrove seed consumption and total 19 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 321 Rs/month on an average during the shedding season.

5.6. Ishanpur

Ishanpur is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is fishing. The population of this village is also dependent on an open mangrove cover which is situated about 0.5 km from the village. In this village 16 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 23 male and 2 female mangrove users (Table:5.6, Fig. 5.11 and 5.12). No one uses mangrove as fodder in this village. All 25 fishermen of this village use mangrove patch for fishing; the Chola and Dodiu being the major or mostly the species captured. The average income of these fishermen is about 4,537 Rs. /Month. Ishanpur village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 230 Rs/month on an average during the shedding season.

5.7. Jhamdi

Jhamdi is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on an open mangrove cover which is situated about 4.4 km from the village. In this village 21 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 16 male and 4 female mangrove users (Table:5.7, Fig. 5.13 and 5.14). Total 4 persons uses mangrove as fodder. The village has only 16 fishermen out of which only 12 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,604 Rs. /Month. Jhamdi village has moderate mangrove seed consumption and total 18 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the shedding season.

5.8. Chidra

Chidra is situated in Jambusar Taluka near to the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on an open mangrove cover which is situated about 6 km from the village. In this village 24 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 21 male and 2 female mangrove users (Table:5.8, figure 5.15 and 5.16). Total 2 persons uses mangrove as fodder. The village has 14 fishermen out of which only 12 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,933 Rs. /Month. Chidra village has highest mangrove seed consumption and total 23 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 263 Rs/month on an average during the shedding season.

5.9. Jantran

Jantrani is situated in Jambusar Taluka near to the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on an open mangrove cover which is situated about 11 km from the village. In this village 12 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 7 male and 0 female mangrove users (Table: 5.9, Fig. 5.17 and 5.18). Only 1 person uses mangrove as fodder. The village has only 10 fishermen out of which only 4 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,550 Rs. /Month. Jantran village has low mangrove seed consumption and total 7 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and no one sale it.

5.10. Malpur

Malpur is situated along the mouth of the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spare mangrove cover which is situated about 3.7 km from the village. In this village 16 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 21 male and 1 female mangrove users (Table: 5.10, Fig. 5.19 and 5.20). Total 10 persons uses mangrove as fodder. The village has only 9 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 1,655 Rs. /Month. Malpur village has highest mangrove seed consumption and total 21 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 220 Rs/month on an average during the shedding season.

5.11. Devla

Devla is situated in Jambusar Taluka along the Mahi River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 6.5 km from the village. In this village 24 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 8 male and 2 female mangrove users (Table: 5.11, Fig. 5.21 and 5.22). Only 1 person uses mangrove as fodder. The village has only 7 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,200 Rs. /Month. Devla village has low mangrove seed consumption and only 8 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 150 Rs/month on an average during the shedding season.

5.12. Nada

Nada is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 6.8 km from the village. In this village all 25 persons sampled are aware about mangrove and its conservation aspects and has 17 male and 8 female mangrove users (Table: 5.12, Fig. 5.23 and 5.24). Total 14 persons uses mangrove as fodder. The village has only 8 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,075 Rs. /Month. Nada village has highest mangrove seed consumption and total 24 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the shedding season.

5.13. Asarsa

Asarsa is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 7 km from the village. In this village 21 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 18 male and 8 female mangrove users (Table: 5.13, Fig. 5.25 and 5.26). Total 3 persons uses mangrove as fodder. The village has only 8 fishermen out of which only 6 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,083 Rs. /Month. Asarsa village has moderate mangrove seed consumption and total 18 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the shedding season.

5.14. Kapuria

Kapuria is situated in Jambusar taluka along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. Population of this village is also dependent on a dense mangrove cover which is situated about 10 km from the village. In this village 18 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 14 male and 0 female mangrove users (Table: 5.14, Fig. 5.27 and 5.28). No person uses mangrove as fodder. The village has only 10 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 4,410 Rs. /Month. Kapuria village has moderate mangrove seed consumption and total 11 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 250 Rs/month on an average during the shedding season.

5.15. Tankaria

Tankaria is situated in Jambusar taluka along the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 12.5 km from the village. In this village 25 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 13 male and 0 female mangrove users (Table: 5.15, Fig. 5.29 and 5.30). No person uses mangrove as fodder in this village. The village has only 8 fishermen out of which only 7 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 1,986 Rs. /Month. Tankaria village has moderate mangrove seed consumption and total 13 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 250 Rs/month on an average during the shedding season.

5.16. Achod

Achod is taluka level head quarter situated near the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spars mangrove cover which is situated about 10 km from the village. In this village 23 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 19 male and 0 female mangrove users (Table: 5.16, Fig. 5.31 and 5.32). No person uses mangrove as fodder in this village. The village has only 6 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 1,368 Rs. /Month. Achod village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and no one is selling seeds.

5.17. Denva

Denva is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a spars mangrove cover which is situated about 1 km from the village. In this village 24 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 15 male and 5 female mangrove users (Table: 5.17, Fig. 5.33 and 5.34). Total 2 persons uses mangrove as fodder. The village has only 11 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,982 Rs. /Month. Denva village has highest mangrove seed consumption and total 19 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 225 Rs/month on an average during the seeding season.

5.18. Chanchvel

Chanchvel is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 7 km from the village. In this village 17 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 21 male and 1 female mangrove users (Table: 5.18, Fig. 5.35 and 5.36). Only 1 person uses mangrove as fodder. The village has only 11 fishermen out of which only 7 fishermen use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 3,240 Rs. /Month. Chanchvel village has highest mangrove seed consumption and total 21 persons were detected to consume seeds as food and couple of them also sale mangrove seed in the village and earn 200 Rs/month on an average during the seeding season.

5.19. Gandhar

Gandhar is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on an open mangrove cover which is situated about 4 km from the village. In this village 25 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 18 male and 7 female mangrove users (Table; 5.19, Fig. 5.37 and 5.38). Total 11 persons uses mangrove as fodder. The village has 10 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,120 Rs. /Month. Gandhar village has highest mangrove seed consumption and total 25 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 275 Rs/month on an average during the seeding season.

5.20. Dahej

Dahej is situated along the mouth of the Dadhar River Estuary. The main occupation of the villagers is agriculture. The population of this village is also dependent on a dense mangrove cover which is situated about 5.5 km from the village. In this village 23 persons out of the 25 sampled are aware about mangrove and its conservation aspects and has 19 male and 4 female mangrove users (Table: 5.20, Fig. 5.39 and 5.40). Total 2 persons uses mangrove as fodder. The village has 19 fishermen and all of them use mangrove patch for fishing; the mudskipper being the major or mostly the only species captured. The average income of these fishermen is about 2,484 Rs. /Month. Dahej village has highest mangrove seed consumption and total 23 persons were detected to consume seeds as food and a couple of them also sale mangrove seed in the village and earn 214 Rs/month on an average during the seeding season.

Table 5.1: Mangrove Utilization Profile of Village Kamboi

A). Basic Information about Village	
Area (Ha)	1,926.80
No. House Holds	128
Total Population	555 (Male: 298, Female: 257)
Major Occupation	Agriculture
N	22°12'48.64"
E	72°37'14.31"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	5.5
Type of Mangrove Cover	Open/Spare
Mangrove Knowledge (Conservation, its Importance)	20
Mangrove User (Male)	19
Mangrove User (Female)	6
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	13
Detection of Change in Mangrove (Decrease in Mangrove Cover)	3

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	0
Avg. Preference of Mangrove as Fodder (out of 4)	0
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	0

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	21
Fishermen (Male)	6
Fishermen (Female)	0
Total Fisher Men	6
Use of Bait	2
Bait Fish	Pura
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	3
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	3
Use of Mangrove as Pole	3
Use of Mangrove for Crab Hunting	3
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3066
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	866

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	200

Table 5.2: Mangrove Utilization Profile of Village Kavi

A). Basic Information about Village	
Area (Ha)	4,140.10
No. House Holds	1824
Total Population	9576 (Male: 4817, Female:4759)
Major Occupation	Agriculture
N	22°11'53.26"
E	72°38'15.46"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	6
Type of Mangrove Cover	Open/Spare
Mangrove Knowledge (Conservation, its Importance)	16
Mangrove User (Male)	21
Mangrove User (Female)	4
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	11
Detection of Change in Mangrove (Decrease in Mangrove Cover)	1

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	3
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1933

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	22
Fishermen (Male)	9
Fishermen (Female)	1
Total Fisher Men	10
Use of Bait	0
Bait Fish	0
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	2
Prefer Mangrove Patch for Fishing (Female)	1
Prefer Mangrove Patch for Fishing (Total)	3
Use of Mangrove as Pole	0
Use of Mangrove for Crab Hunting	2
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3033
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1214

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	200

Table 5.3: Mangrove Utilization Profile of Village

A). Basic Information about Village	
Area (Ha)	5,925.10
No. House Holds	717
Total Population	4380 (Male:2211, Female: 2169)
Major Occupation	Agriculture
N	22°11'12.06
E	72°35'23.67"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	1.5
Type of Mangrove Cover	Open/Sparse
Mangrove Knowledge (Conservation, its Importance)	11
Mangrove User (Male)	18
Mangrove User (Female)	7
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	25
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	14
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1400

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	11
Fishermen (Male)	1
Fishermen (Female)	0
Total Fisher Men	1
Use of Bait	1
Bait Fish	Chola
Frequency of Fishing/Day	1
Prefer Mangrove Patch for Fishing (Male)	1
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	1
Use of Mangrove as Pole	1
Use of Mangrove for Crab Hunting	1
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	1200
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	0

Table 5.4: Mangrove Utilization Profile of Village Neja

A). Basic Information about Village	
Area (Ha)	476.3
No. House Holds	118
Total Population	511 (Male: 261, Female: 250)
Major Occupation	Agriculture
N	22° 8'52.57"
E	72°33'54.19"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	1.7
Type of Mangrove Cover	Open/Spars
Mangrove Knowledge (Conservation, its Importance)	23
Mangrove User (Male)	16
Mangrove User (Female)	6
Total Mangrove User	23
Mangrove Non-user	2
Detection of Change in Mangrove (Increase in Mangrove Cover)	16
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	9
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	2100

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	20
Fishermen (Male)	7
Fishermen (Female)	2
Total Fisher Men	9
Use of Bait	6
Bait Fish	Prawns
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	9
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	9
Use of Mangrove as Pole	9
Use of Mangrove for Crab Hunting	7
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2922
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	216

Table 5.5: Mangrove Utilization Profile of Village Sigam

A). Basic Information about Village	
Area (Ha)	1818.2
No. House Holds	467
Total Population	2055 (Male: 1047, Female: 1008)
Major Occupation	Agriculture
N	22° 8'46.41"
E	72°35'7.60"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	3.6
Type of Mangrove Cover	Open
Mangrove Knowledge (Conservation, its Importance)	19
Mangrove User (Male)	17
Mangrove User (Female)	2
Total Mangrove User	19
Mangrove Non-user	6
Detection of Change in Mangrove (Increase in Mangrove Cover)	12
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	5
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	2860

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	22
Fishermen (Male)	6
Fishermen (Female)	1
Total Fisher Men	7
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	4
Prefer Mangrove Patch for Fishing (Female)	1
Prefer Mangrove Patch for Fishing (Total)	5
Use of Mangrove as Pole	4
Use of Mangrove for Crab Hunting	3
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2720
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1100

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	19
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	321

Table 5.6.:Mangrove Utilization Profile of Village Ishanpur

A). Basic Information about Village	
Area (Ha)	294.2
No. House Holds	50
Total Population	259 (Male: 134, Female: 125
Major Occupation	Fishing
N	22° 7'24.66"
E	72°32'36.11"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	0.5
Type of Mangrove Cover	Open
Mangrove Knowledge (Conservation, its Importance)	25
Mangrove User (Male)	23
Mangrove User (Female)	2
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	25
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	0
Avg. Preference of Mangrove as Fodder (out of 4)	0
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	0

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	25
Fishermen (Male)	23
Fishermen (Female)	2
Total Fisher Men	25
Majority Fish Catch	Chola, Dodiu
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	25
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	25
Use of Mangrove as Pole	25
Use of Mangrove for Crab Hunting	25
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	4537
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	230

Table 5.7: Mangrove Utilization Profile of Village Jhamdi

A). Basic Information about Village	
Area (Ha)	1639.1
No. House Holds	209
Total Population	913 (Male: 482, Female: 431)
Major Occupation	Agriculture
N	22° 6'35.89"
E	72°34'53.59"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	4.4
Type of Mangrove Cover	Open
Mangrove Knowledge (Conservation, its Importance)	21
Mangrove User (Male)	16
Mangrove User (Female)	4
Total Mangrove User	20
Mangrove Non-user	5
Detection of Change in Mangrove (Increase in Mangrove Cover)	16
Detection of Change in Mangrove (Decrease in Mangrove Cover)	1

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	4
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	3250

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	22
Fishermen (Male)	14
Fishermen (Female)	2
Total Fisher Men	16
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	11
Prefer Mangrove Patch for Fishing (Female)	1
Prefer Mangrove Patch for Fishing (Total)	12
Use of Mangrove as Pole	9
Use of Mangrove for Crab Hunting	9
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3604
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1475

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	18
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	239

Table 5.8: Mangrove Utilization Profile of Village

A). Basic Information about Village	
Area (Ha)	1363.7
No. House Holds	413
Total Population	1654 (Male: 861, Female: 793)
Major Occupation	Agriculture
N	22° 60'70.56"
E	72°35'45.84"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	6
Type of Mangrove Cover	Open
Mangrove Knowledge (Conservation, its Importance)	24
Mangrove User (Male)	21
Mangrove User (Female)	2
Total Mangrove User	23
Mangrove Non-user	2
Detection of Change in Mangrove (Increase in Mangrove Cover)	18
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	2
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	2250

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	24
Fishermen (Male)	13
Fishermen (Female)	1
Total Fisher Men	14
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	12
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	12
Use of Mangrove as Pole	9
Use of Mangrove for Crab Hunting	9
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3933
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1750

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	23
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	263

Table 5.9: Mangrove Utilization Profile of Village Jantran

A). Basic Information about Village	
Area (Ha)	2257.5
No. House Holds	492
Total Population	2290 (Male: 1184, Female: 1106)
Major Occupation	Agriculture
N	22° 5'41.77"
E	72°38'38.86"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	11
Type of Mangrove Cover	Open
Mangrove Knowledge (Conservation, its Importance)	12
Mangrove User (Male)	7
Mangrove User (Female)	0
Total Mangrove User	7
Mangrove Non-user	18
Detection of Change in Mangrove (Increase in Mangrove Cover)	6
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	1
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	3500

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	24
Fishermen (Male)	10
Fishermen (Female)	0
Total Fisher Men	10
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	10
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	4
Use of Mangrove as Pole	4
Use of Mangrove for Crab Hunting	1
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3550
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1716

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	7
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	0

Table 5.10: Mangrove Utilization Profile of Village Malpur

A). Basic Information about Village	
Area (Ha)	3088.5
No. House Holds	497
Total Population	2287 (Male: 1138, Female: 1149)
Major Occupation	Agriculture
N	22° 3'28.61"
E	72°35'24.77"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	3.7
Type of Mangrove Cover	Spars
Mangrove Knowledge (Conservation, its Importance)	25
Mangrove User (Male)	21
Mangrove User (Female)	1
Total Mangrove User	22
Mangrove Non-user	3
Detection of Change in Mangrove (Increase in Mangrove Cover)	20
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	10
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1340

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	12
Fishermen (Male)	6
Fishermen (Female)	3
Total Fisher Men	9
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	6
Prefer Mangrove Patch for Fishing (Female)	3
Prefer Mangrove Patch for Fishing (Total)	9
Use of Mangrove as Pole	5
Use of Mangrove for Crab Hunting	8
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	1655
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	21
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	220

Table 5.11: Mangrove Utilization Profile of Village Devla

A). Basic Information about Village	
Area (Ha)	5683.2
No. House Holds	729
Total Population	4090 (Male: 2090, Female: 2000)
Major Occupation	Agriculture
N	21°59'47.63"
E	72°34'34.72"
Estuary	Mahi

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	6.5
Type of Mangrove Cover	Dense/Open
Mangrove Knowledge (Conservation, its Importance)	24
Mangrove User (Male)	8
Mangrove User (Female)	2
Total Mangrove User	10
Mangrove Non-user	15
Detection of Change in Mangrove (Increase in Mangrove Cover)	9
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	1
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	2500

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	10
Fishermen (Male)	6
Fishermen (Female)	1
Total Fisher Men	7
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	6
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	6
Use of Mangrove as Pole	2
Use of Mangrove for Crab Hunting	2
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3200
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1500

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	8
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	150

Table 5.12: Mangrove Utilization Profile of Village Nada

A). Basic Information about Village	
Area (Ha)	3662.9
No. House Holds	547
Total Population	2374 (Male: 1140, Female: 1234)
Major Occupation	Agriculture
N	21°57'4.55"
E	72°33'36.17"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	6.8
Type of Mangrove Cover	Dense
Mangrove Knowledge (Conservation, its Importance)	25
Mangrove User (Male)	17
Mangrove User (Female)	8
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	25
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	14
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1984

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	8
Fishermen (Male)	8
Fishermen (Female)	0
Total Fisher Men	8
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	8
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	8
Use of Mangrove as Pole	6
Use of Mangrove for Crab Hunting	6
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2075
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	24
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	200

Table 5.13: Mangrove Utilization Profile of Village Asarsa

A). Basic Information about Village	
Area (Ha)	865.2
No. House Holds	406
Total Population	2199 (Male: 1097, Female: 1102)
Major Occupation	Agriculture
N	21°57'10.28"
E	72°35'32.55"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	7
Type of Mangrove Cover	Dense
Mangrove Knowledge (Conservation, its Importance)	21
Mangrove User (Male)	18
Mangrove User (Female)	0
Total Mangrove User	18
Mangrove Non-user	7
Detection of Change in Mangrove (Increase in Mangrove Cover)	5
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	3
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	2366

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	20
Fishermen (Male)	7
Fishermen (Female)	1
Total Fisher Men	8
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	5
Prefer Mangrove Patch for Fishing (Female)	1
Prefer Mangrove Patch for Fishing (Total)	6
Use of Mangrove as Pole	4
Use of Mangrove for Crab Hunting	2
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3083
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1140

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	18
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	200

Table 5.14: Mangrove Utilization Profile of Village Kapuria

A). Basic Information about Village	
Area (Ha)	1139
No. House Holds	102
Total Population	481 (Male: 252, Female: 229)
Major Occupation	Agriculture
N	21°58'24.64"
E	72°36'20.53"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	10
Type of Mangrove Cover	Dense
Mangrove Knowledge (Conservation, its Importance)	18
Mangrove User (Male)	14
Mangrove User (Female)	0
Total Mangrove User	14
Mangrove Non-user	11
Detection of Change in Mangrove (Increase in Mangrove Cover)	1
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	0
Avg. Preference of Mangrove as Fodder (out of 4)	0
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	0

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	10
Fishermen (Male)	10
Fishermen (Female)	0
Total Fisher Men	10
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	10
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	10
Use of Mangrove as Pole	10
Use of Mangrove for Crab Hunting	1
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	4410
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	11
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	250

Table 5.15: Mangrove Utilization Profile of Village Tankaria

A). Basic Information about Village	
Area (Ha)	4638
No. House Holds	718
Total Population	5491 (Male: 3660, Female: 1831)
Major Occupation	Agriculture
N	21°59'24.27"
E	72°40'2.00"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	12.5
Type of Mangrove Cover	Dense
Mangrove Knowledge (Conservation, its Importance)	25
Mangrove User (Male)	13
Mangrove User (Female)	0
Total Mangrove User	13
Mangrove Non-user	12
Detection of Change in Mangrove (Increase in Mangrove Cover)	1
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	0
Avg. Preference of Mangrove as Fodder (out of 4)	0
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	0

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	9
Fishermen (Male)	8
Fishermen (Female)	0
Total Fisher Men	8
Majority Fish Catch	Mudskipper
Frequency of Fishing/Day	1
Prefer Mangrove Patch for Fishing (Male)	8
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	7
Use of Mangrove as Pole	6
Use of Mangrove for Crab Hunting	1
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	1986
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1685

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	13
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	250

Table 5.16: Mangrove Utilization Profile of Village Achod

A). Basic Information about Village	
Area (Ha)	2638.9
No. House Holds	1024
Total Population	5844 (Male: 2904, Female: 2940)
Major Occupation	Agriculture
N	21°57'42.53"
E	72°49'55.76"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	10
Type of Mangrove Cover	Spars
Mangrove Knowledge (Conservation, its Importance)	23
Mangrove User (Male)	19
Mangrove User (Female)	0
Total Mangrove User	19
Mangrove Non-user	6
Detection of Change in Mangrove (Increase in Mangrove Cover)	0
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	0
Avg. Preference of Mangrove as Fodder (out of 4)	0
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	0

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	19
Fishermen (Male)	6
Fishermen (Female)	0
Total Fisher Men	6
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	1
Prefer Mangrove Patch for Fishing (Male)	6
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	6
Use of Mangrove as Pole	3
Use of Mangrove for Crab Hunting	1
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	1368
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	19
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	0

Table 5.17: Mangrove Utilization Profile of Village Denva

A). Basic Information about Village	
Area (Ha)	3768.5
No. House Holds	201
Total Population	1012 (Male: 518, Female: 494)
Major Occupation	Agriculture
N	21°56'24.24"
E	72°44'15.69"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	1
Type of Mangrove Cover	Spars
Mangrove Knowledge (Conservation, its Importance)	24
Mangrove User (Male)	15
Mangrove User (Female)	5
Total Mangrove User	20
Mangrove Non-user	5
Detection of Change in Mangrove (Increase in Mangrove Cover)	16
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	2
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1100

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	15
Fishermen (Male)	6
Fishermen (Female)	5
Total Fisher Men	11
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	6
Prefer Mangrove Patch for Fishing (Female)	5
Prefer Mangrove Patch for Fishing (Total)	11
Use of Mangrove as Pole	6
Use of Mangrove for Crab Hunting	3
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2982
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	19
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	225

Table 5.18: Mangrove Utilization Profile of Village Chanchvel

A). Basic Information about Village	
Area (Ha)	3313.7
No. House Holds	506
Total Population	2950 (Male: 1507, Female:1443)
Major Occupation	Agriculture
N	21°54'1.03"
E	72°44'16.67"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	7
Type of Mangrove Cover	Open/Dense
Mangrove Knowledge (Conservation, its Importance)	17
Mangrove User (Male)	21
Mangrove User (Female)	1
Total Mangrove User	22
Mangrove Non-user	3
Detection of Change in Mangrove (Increase in Mangrove Cover)	7
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	1
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	3000

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	19
Fishermen (Male)	9
Fishermen (Female)	2
Total Fisher Men	11
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	7
Prefer Mangrove Patch for Fishing (Female)	0
Prefer Mangrove Patch for Fishing (Total)	7
Use of Mangrove as Pole	6
Use of Mangrove for Crab Hunting	3
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	3240
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	1220

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	21
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	200

Table 5.19: Mangrove Utilization Profile of Village Gandhar

A). Basic Information about Village	
Area (Ha)	6625.8
No. House Holds	311
Total Population	1517 (Male: 783, Female: 734)
Major Occupation	Agriculture
N	21°53'11.99"
E	72°39'29.60"
Estuary	Dadhar

B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	4
Type of Mangrove Cover	Open/Spars
Mangrove Knowledge (Conservation, its Importance)	25
Mangrove User (Male)	18
Mangrove User (Female)	7
Total Mangrove User	25
Mangrove Non-user	0
Detection of Change in Mangrove (Increase in Mangrove Cover)	25
Detection of Change in Mangrove (Decrease in Mangrove Cover)	0

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	11
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1463

D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	19
Fishermen (Male)	7
Fishermen (Female)	3
Total Fisher Men	10
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	7
Prefer Mangrove Patch for Fishing (Female)	3
Prefer Mangrove Patch for Fishing (Total)	10
Use of Mangrove as Pole	5
Use of Mangrove for Crab Hunting	4
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2120
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	25
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	275

Table 5.20: Mangrove Utilization Profile of Village Dahej

A). Basic Information about Village	
Area (Ha)	7630.5
No. House Holds	1551
Total Population	6846 (Male: 3756, Female: 3090)
Major Occupation	Agriculture
N	21°42'51.39"
E	72°34'57.98"
Estuary	Dadhar

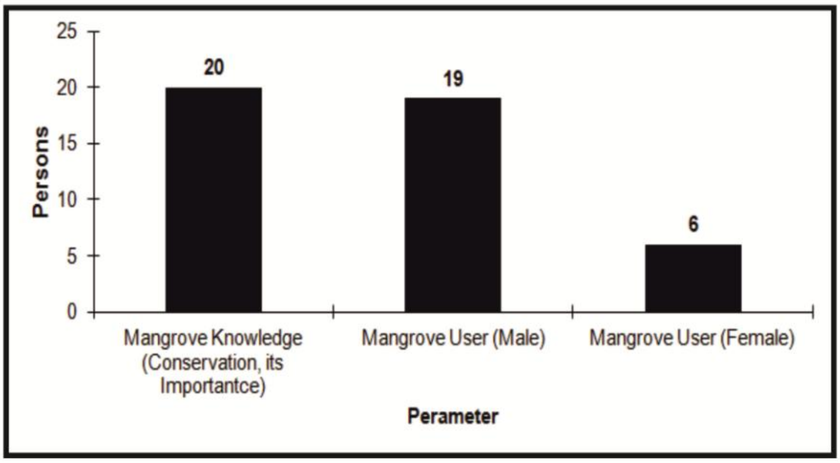
B). Basic Information about Mangrove	
Crow Line Distance from Nearest Mangrove Patch (km)	5.5
Type of Mangrove Cover	Dense
Mangrove Knowledge (Conservation, its Importance)	23
Mangrove User (Male)	19
Mangrove User (Female)	4
Total Mangrove User	23
Mangrove Non-user	2
Detection of Change in Mangrove (Increase in Mangrove Cover)	23
Detection of Change in Mangrove (Decrease in Mangrove Cover)	2

C). Utilization of Mangrove as Fodder	
Use of Mangrove as Fodder	2
Avg. Preference of Mangrove as Fodder (out of 4)	4
Avg. Income from Milk Sale (Rs/Month) [Only for those who use Mangrove as Fodder]	1120

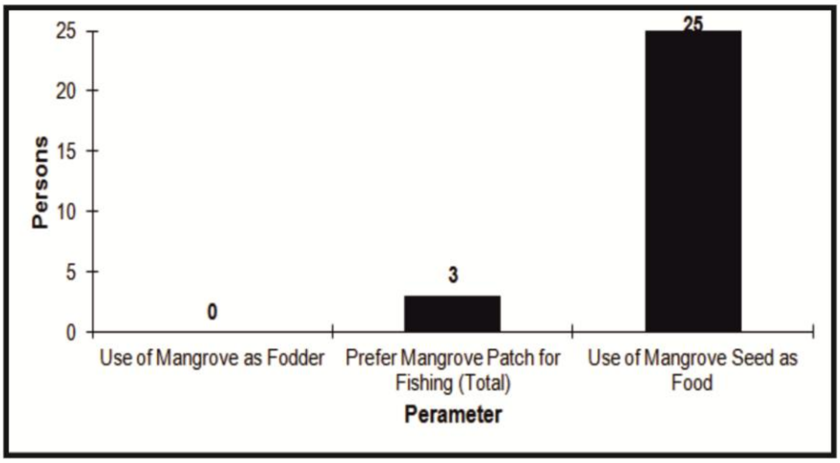
D). Utilization of Mangrove as Fishing Resources	
Use of Fish as Food	25
Fishermen (Male)	14
Fishermen (Female)	5
Total Fisher Men	19
Majority Fish Catch	Mudskkiper
Frequency of Fishing/Day	2
Prefer Mangrove Patch for Fishing (Male)	14
Prefer Mangrove Patch for Fishing (Female)	5
Prefer Mangrove Patch for Fishing (Total)	19
Use of Mangrove as Pole	12
Use of Mangrove for Crab Hunting	16
Avg. Income from Fish sale (Rs/Month)[From Mangrove Users]	2484
Avg. Income from Fish sale (Rs/Month)[From Non-Mangrove Users]	0

E). Utilization of Mangrove as Food Source	
Use of Mangrove Seed as Food	23
Avg. Income from Mangrove Seed Sale (Rs/Month)[Only for Seeding Months]	214

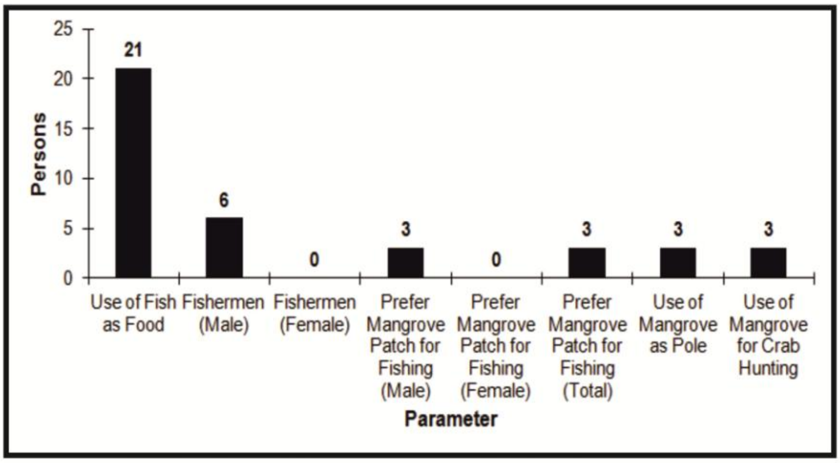
Fig. 5.1: Mangrove Utilization Status of Village: Kamboi



Basic Information on Mangrove and it's Utilization (n=25)

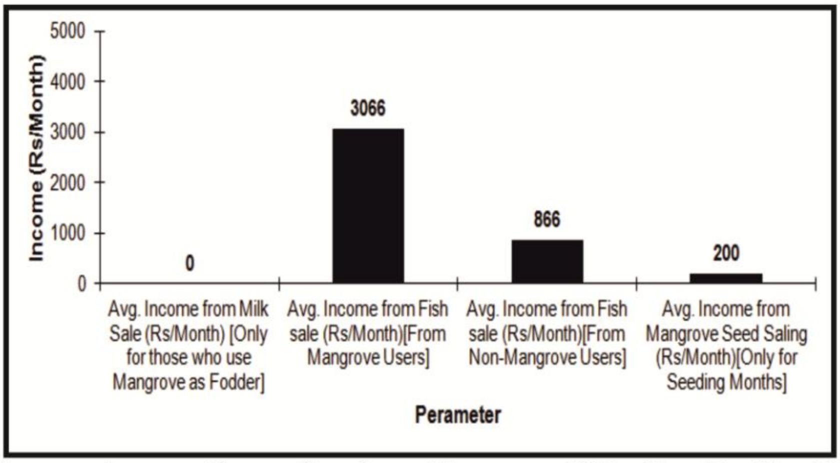


Utilization Status of Mangrove (n=25)

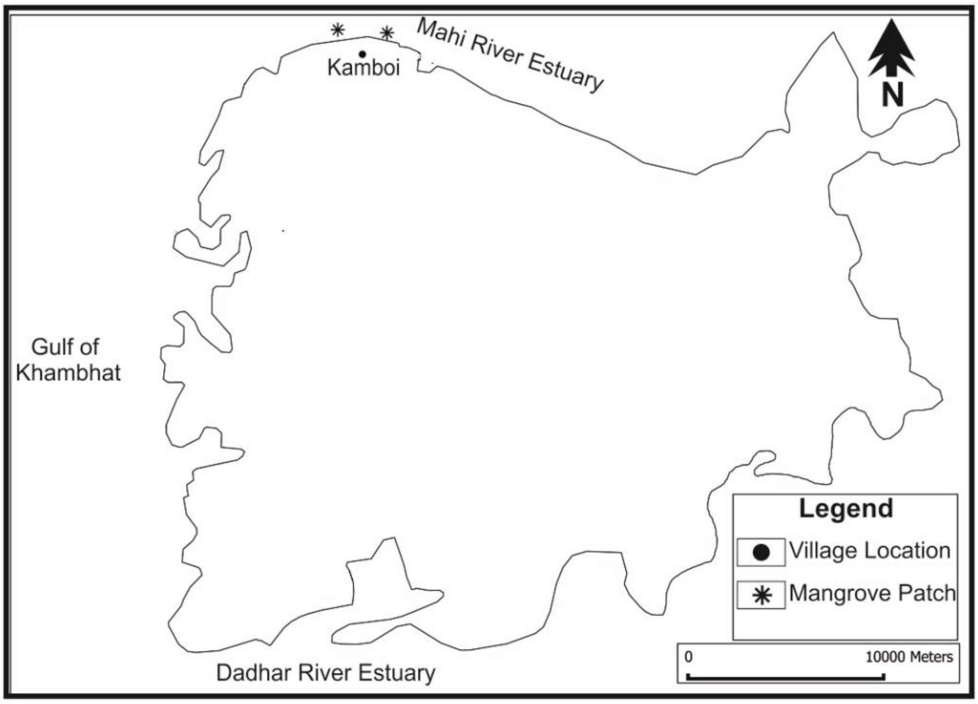


Utilization of Mangrove as Fishing Resources

Fig. 5.2: Mangrove Utilization Status of Village: Kamboi

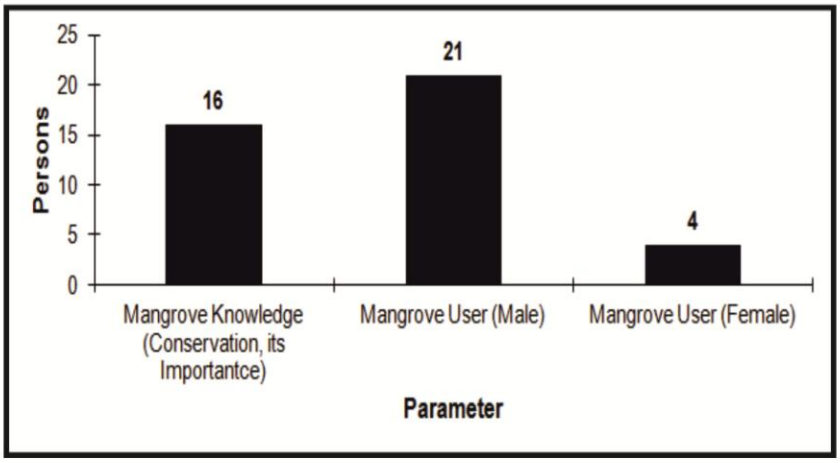


Average Income Generation from Mangrove Utilization (Rs./Month)

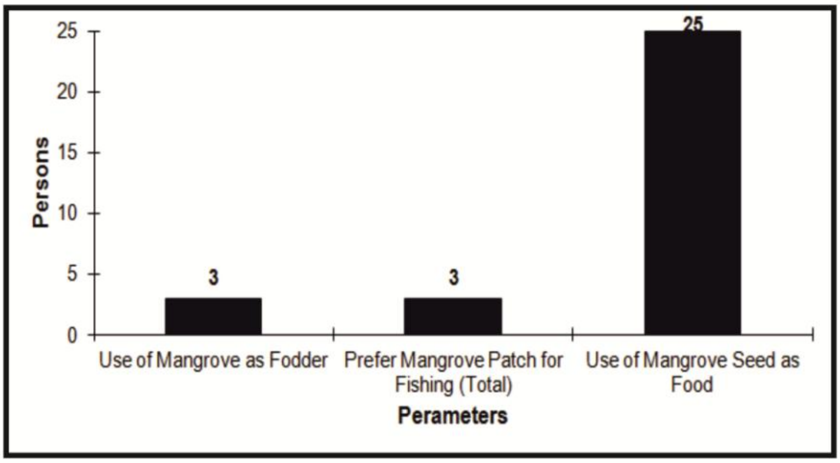


Map. Village Location and Mangrove Utilization Patch

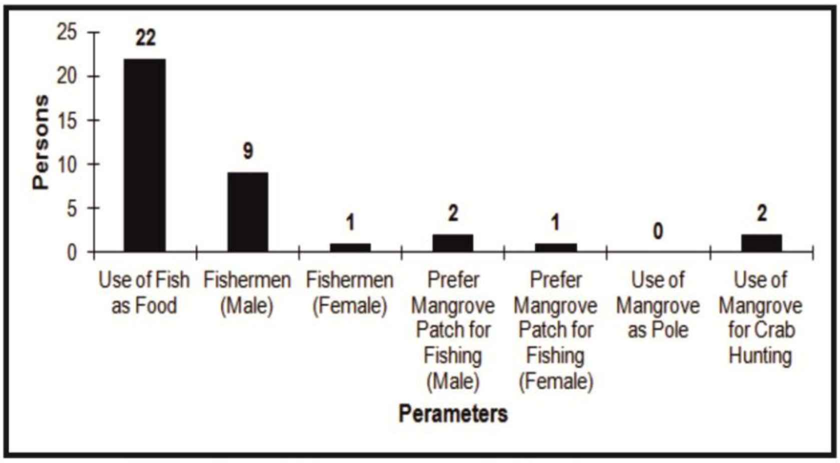
Fig. 5.3.: Mangrove Utilization Status of Village: Kavi



Basic Information on Mangrove and it's Utilization (n=25)

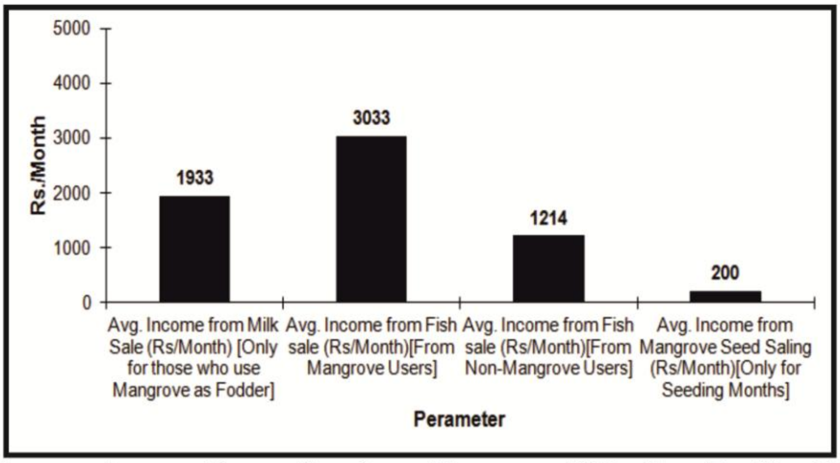


Utilization Status of Mangrove (n=25)

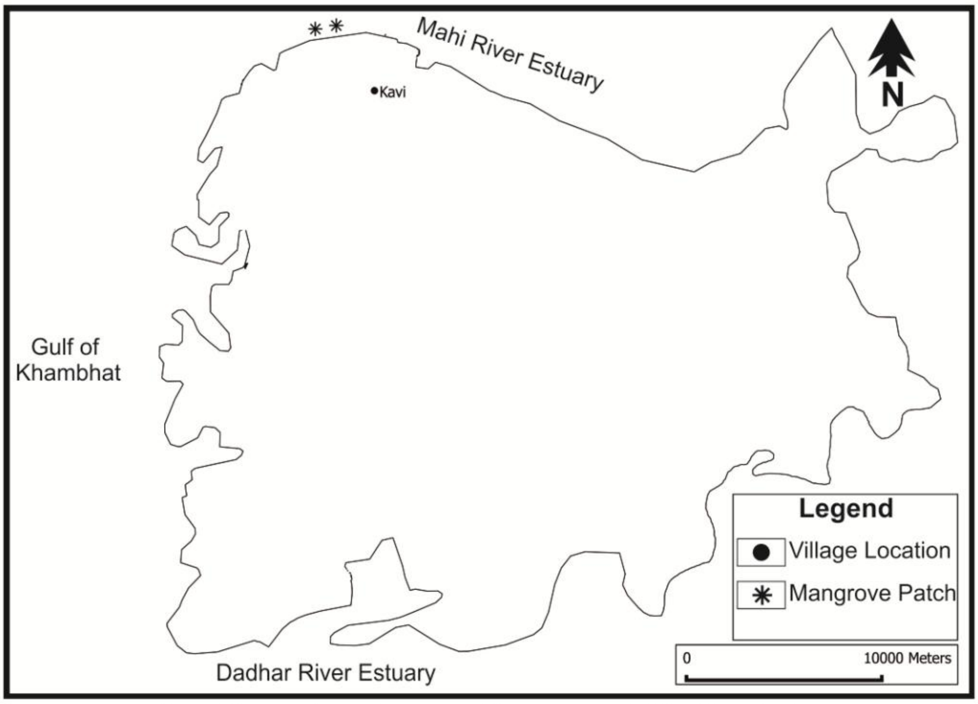


Utilization of Mangrove as Fishing Resources

Fig. 5.4.: Mangrove Utilization Status of Village: Kavi

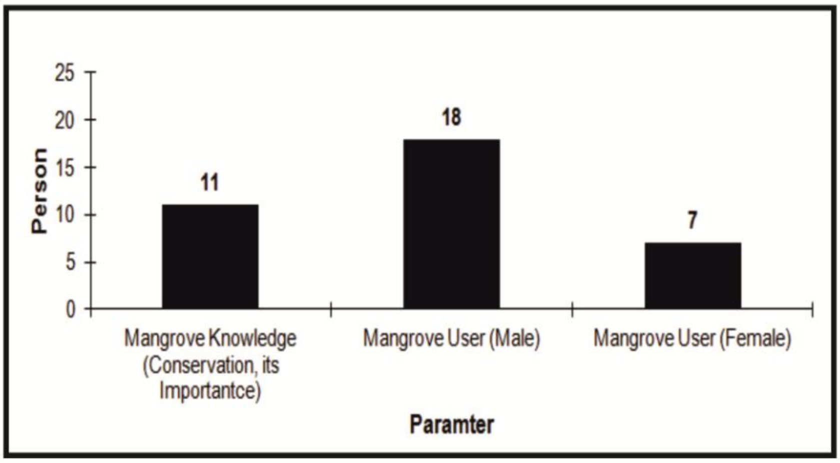


Average Income Generation from Mangrove Utilization (Rs./Month)

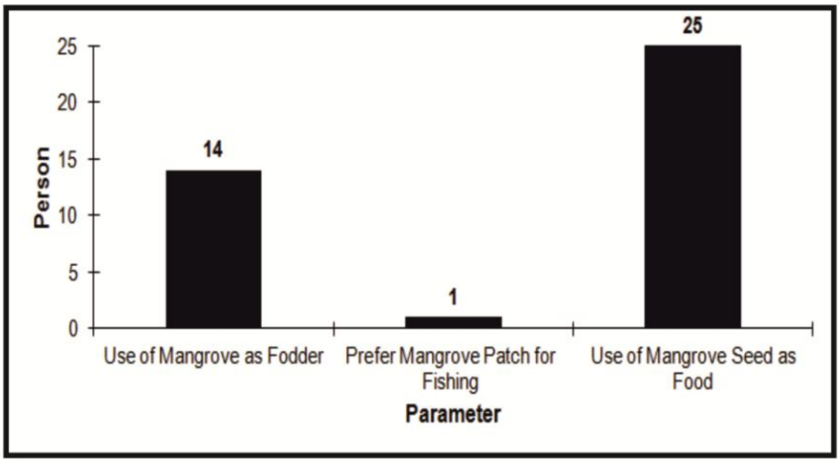


Map. Village Location and Mangrove Utilization Patch

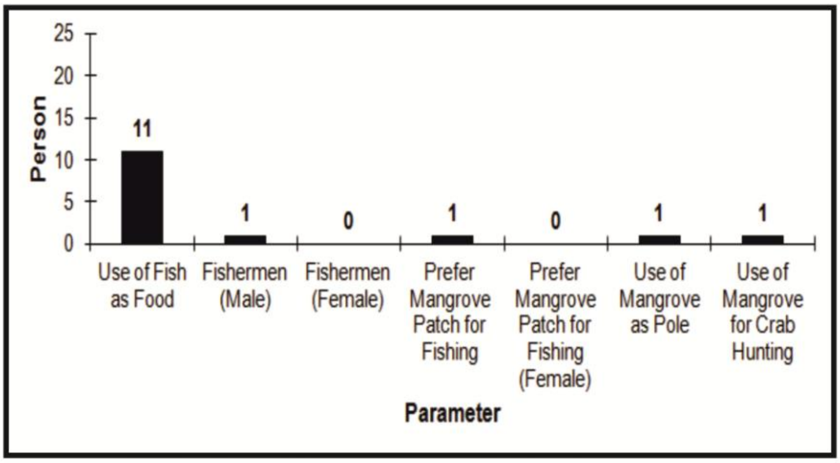
Fig. 5.5.: Mangrove Utilization Status of Village: Degam



Basic Information on Mangrove and it's Utilization (n=25)

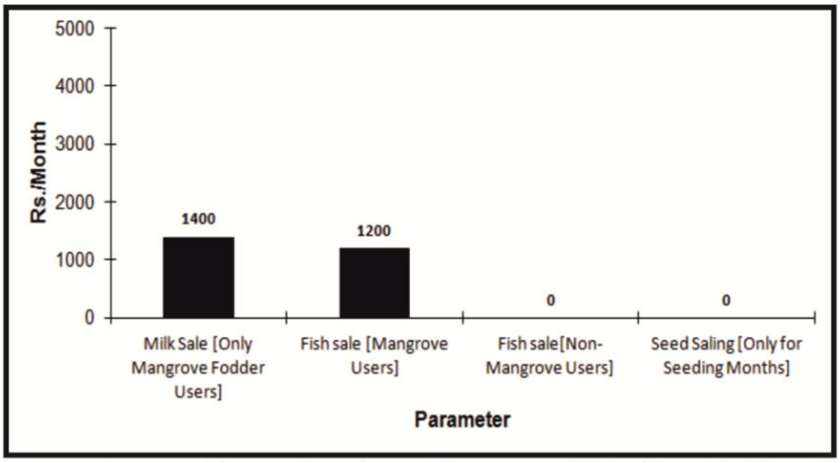


Utilization Status of Mangrove (n=25)

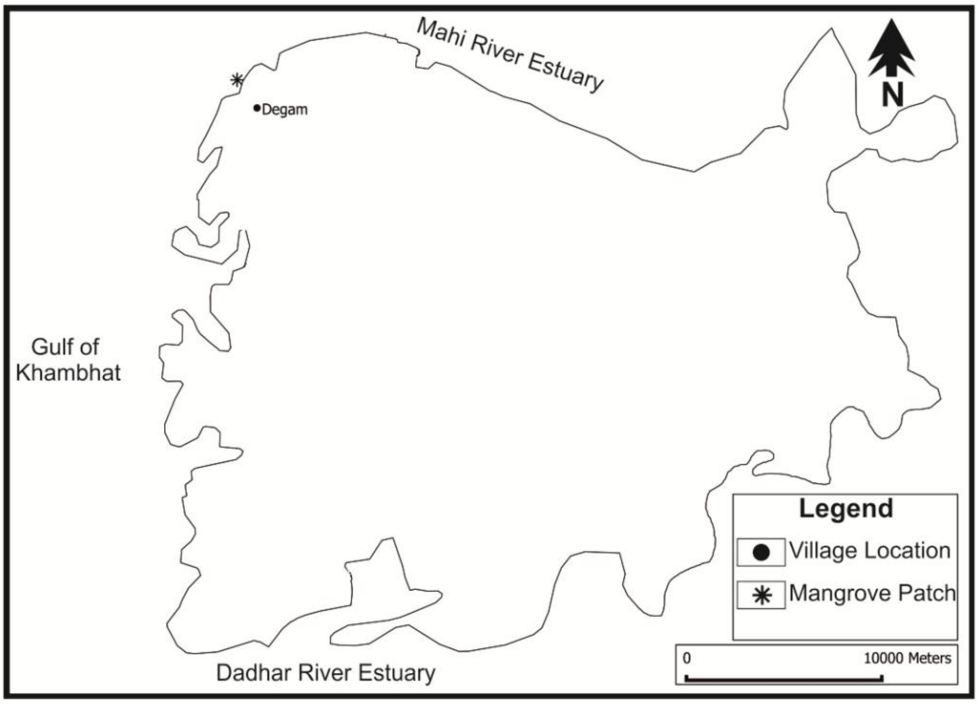


Utilization of Mangrove as Fishing Resources

Fig. 5.6.: Mangrove Utilization Status of Village: Degam

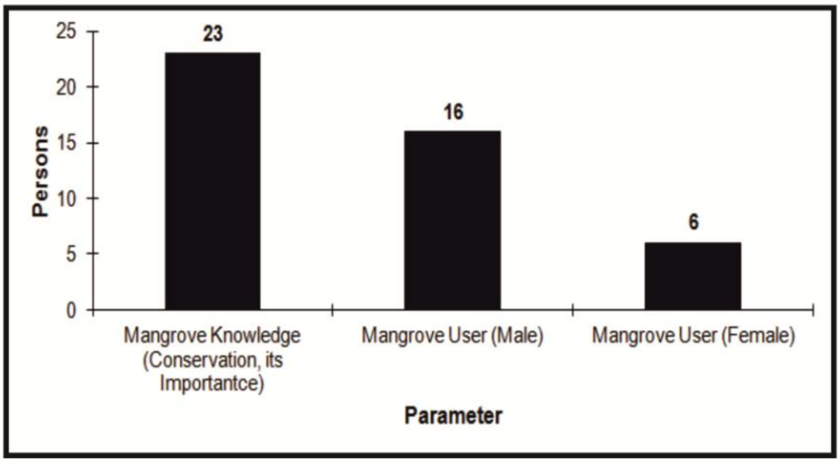


Average Income Generation from Mangrove Utilization (Rs./Month)

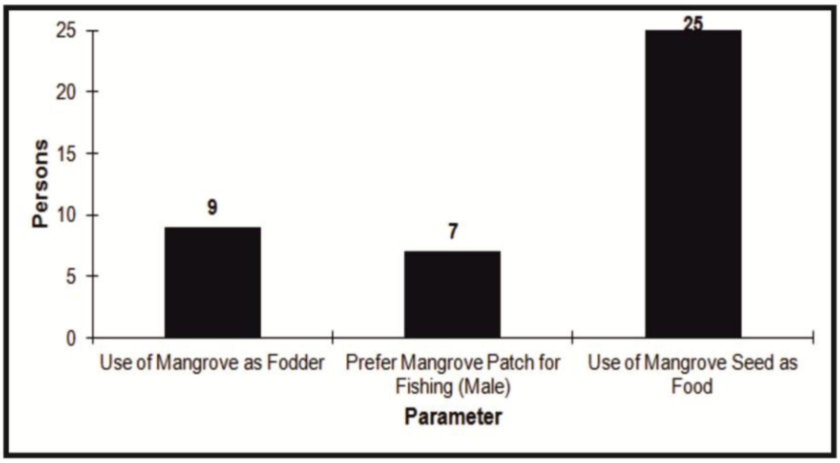


Map. Village Location and Mangrove Utilization Patch

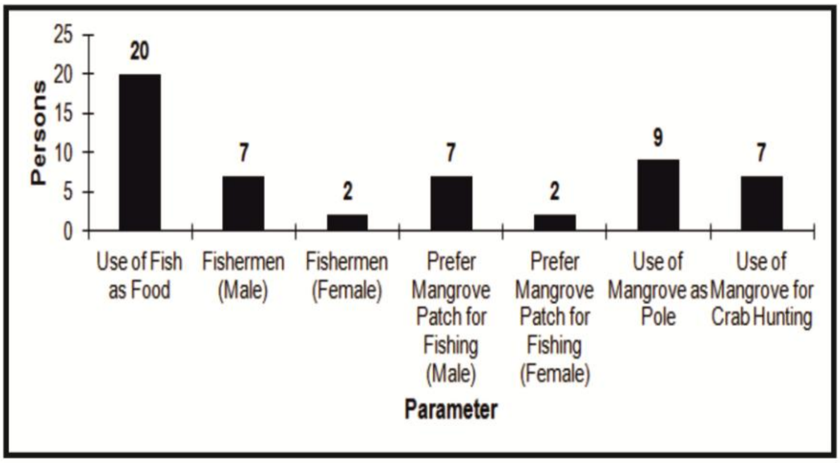
Fig. 5.7.: Mangrove Utilization Status of Village: Neja



Basic Information on Mangrove and it's Utilization (n=25)

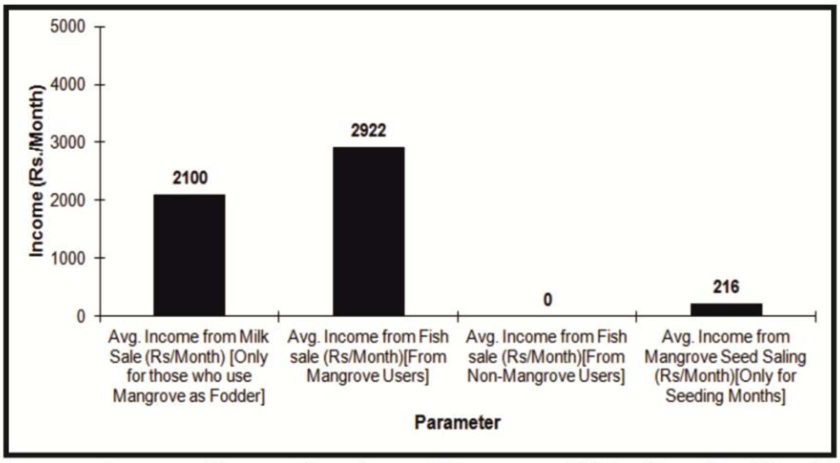


Utilization Status of Mangrove (n=25)

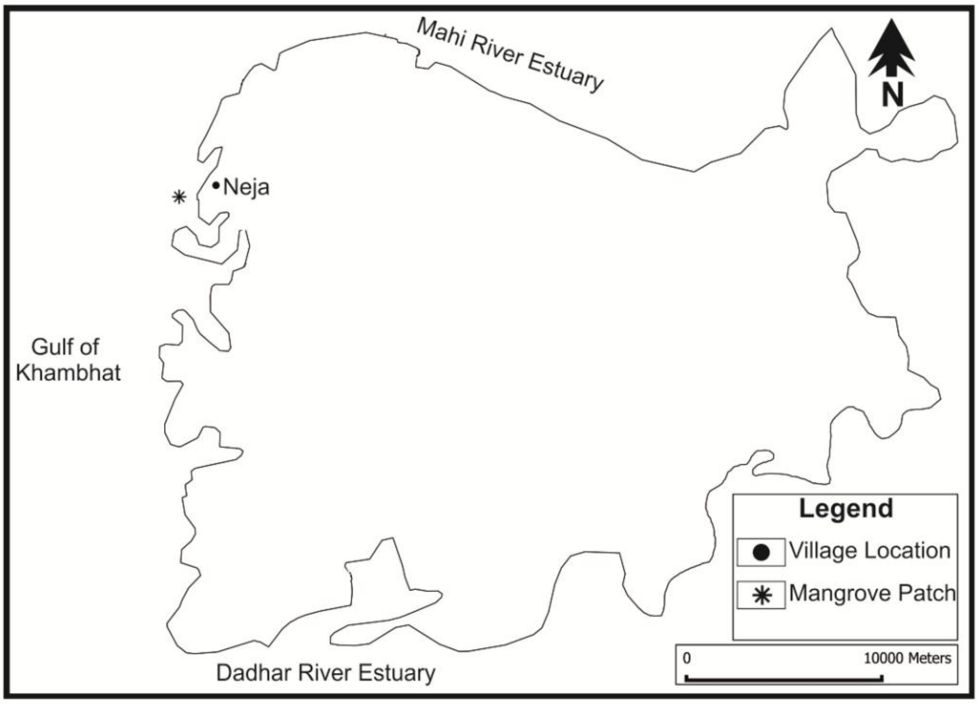


Utilization of Mangrove as Fishing Resources

Fig. 5.8.: Mangrove Utilization Status of Village: Neja

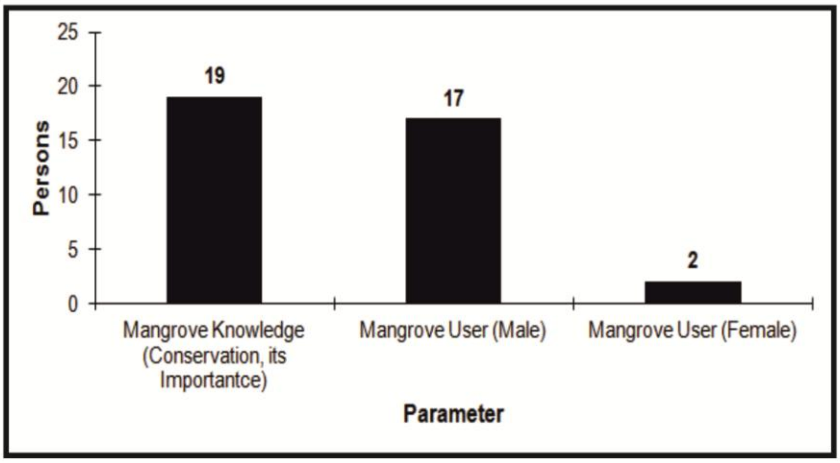


Average Income Generation from Mangrove Utilization (Rs./Month)

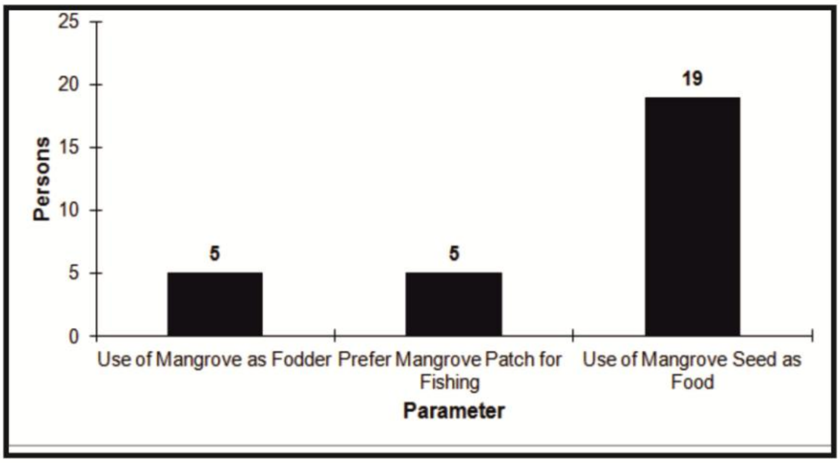


Map. Village Location and Mangrove Utilization Patch

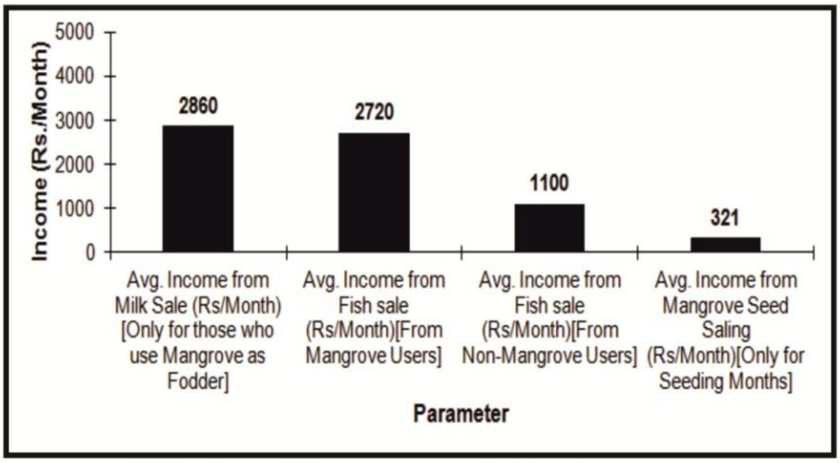
Fig. 5.9.:Mangrove Utilization Status of Village: Sigam



Basic Information on Mangrove and it's Utilization (n=25)

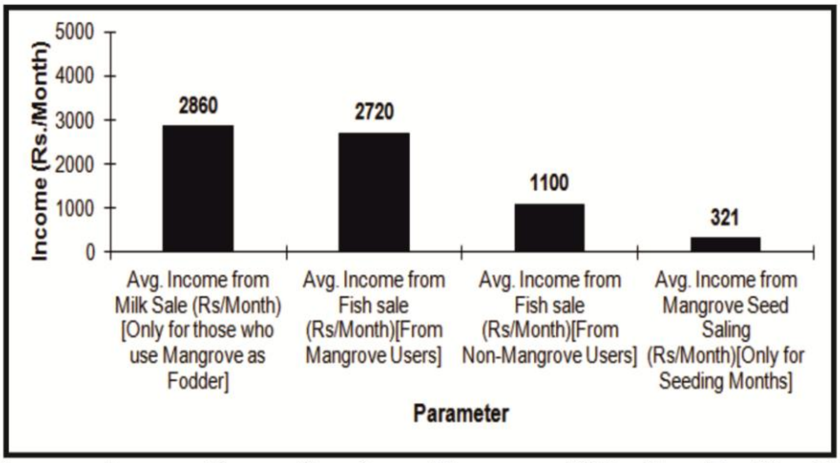


Utilization Status of Mangrove (n=25)

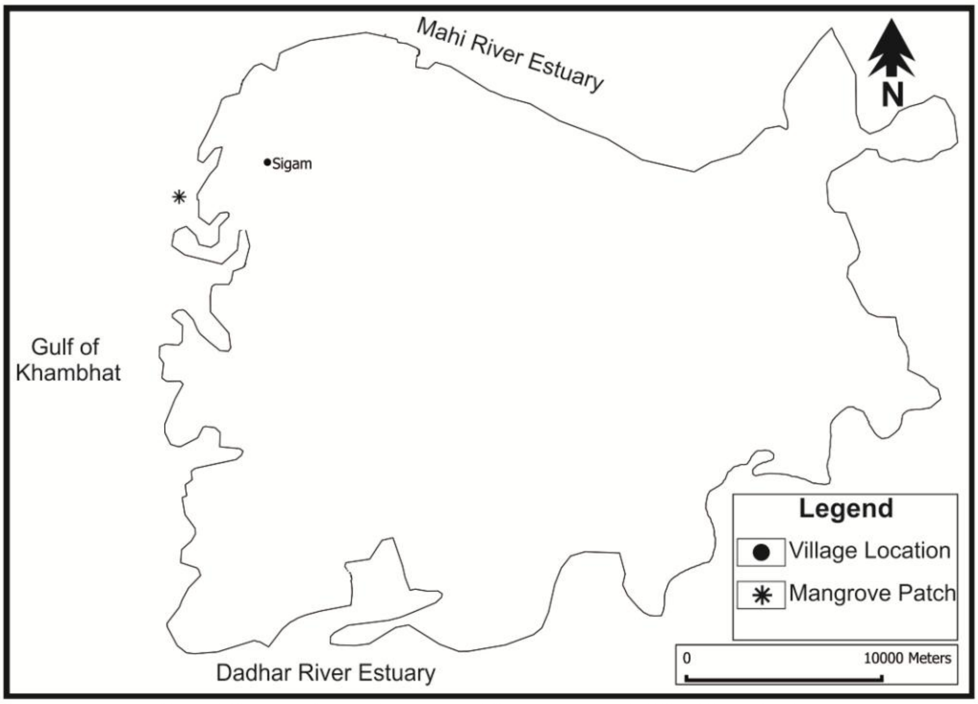


Utilization of Mangrove as Fishing Resources

Fig. 5.10.: Mangrove Utilization Status of Village: Sigam

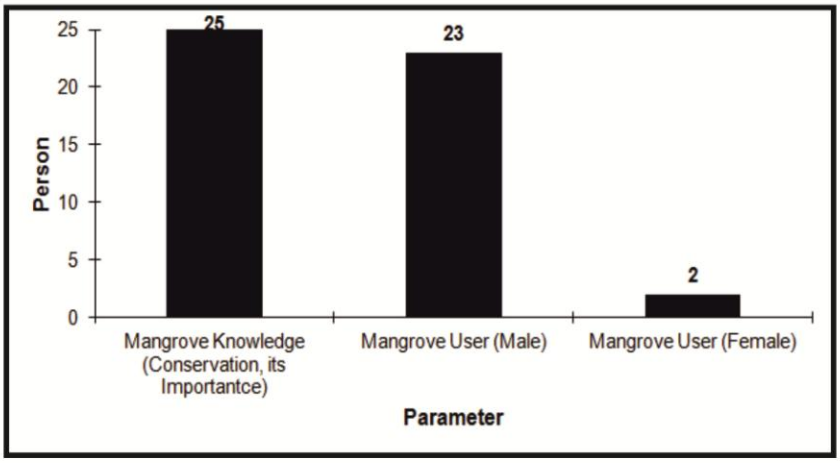


Average Income Generation from Mangrove Utilization (Rs./Month)

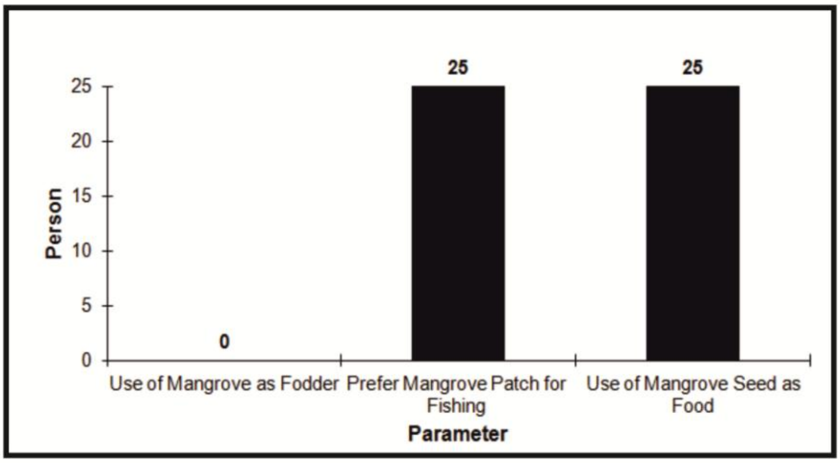


Map. Village Location and Mangrove Utilization Patch

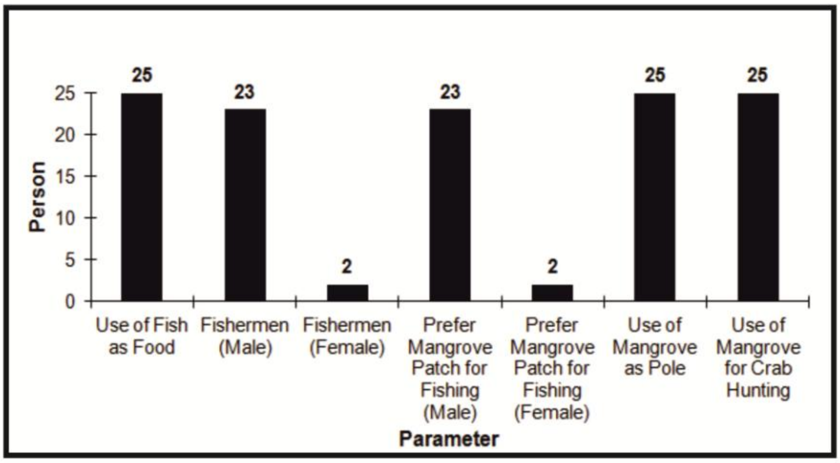
Fig. 5.11.: Mangrove Utilization Status of Village: Ishanpur



Basic Information on Mangrove and it's Utilization (n=25)

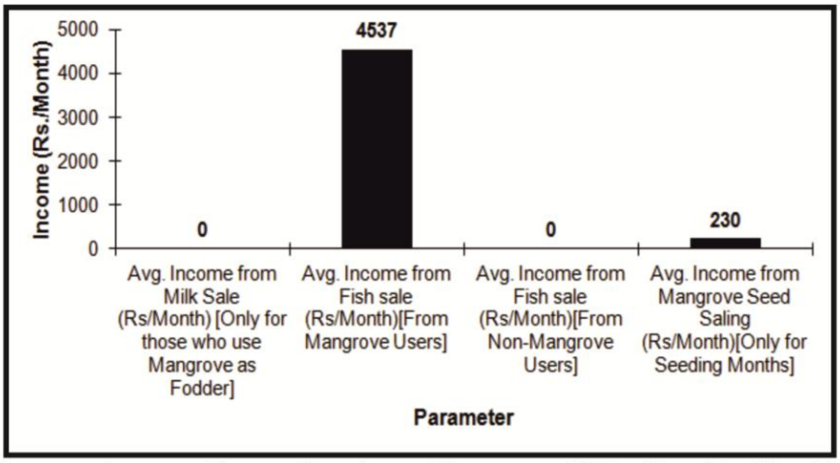


Utilization Status of Mangrove (n=25)

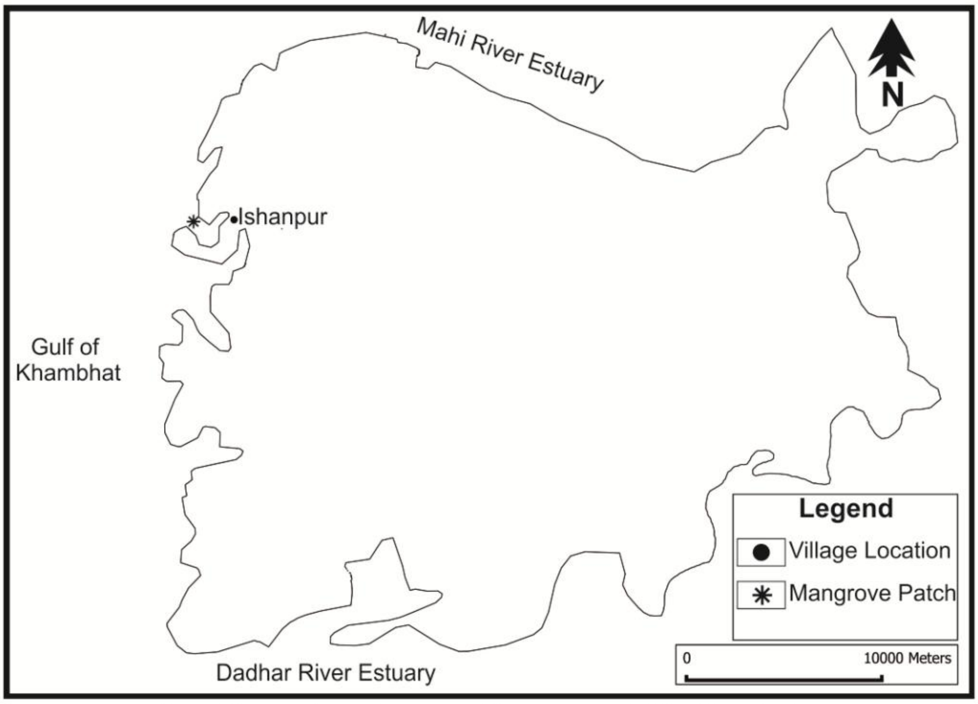


Utilization of Mangrove as Fishing Resources

Fig. 5.12.: Mangrove Utilization Status of Village: Ishanpur

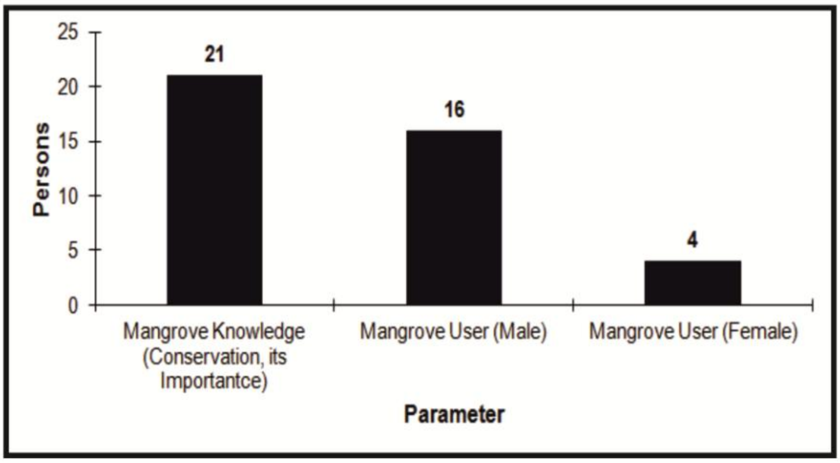


Average Income Generation from Mangrove Utilization (Rs./Month)

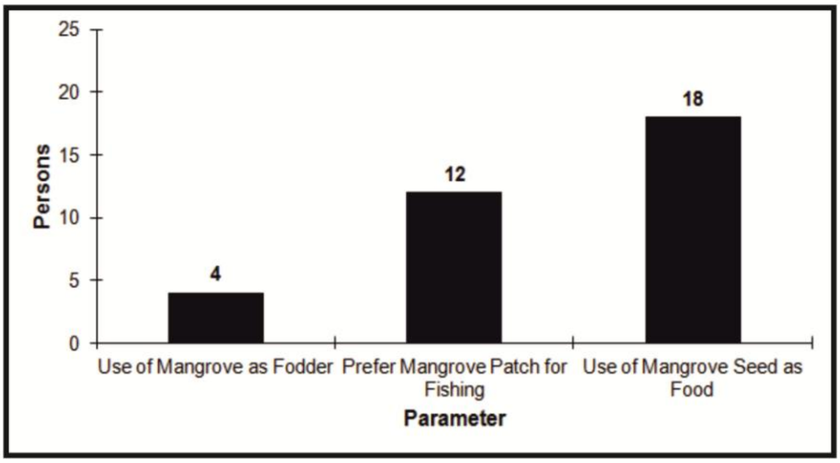


Map. Village Location and Mangrove Utilization Patch

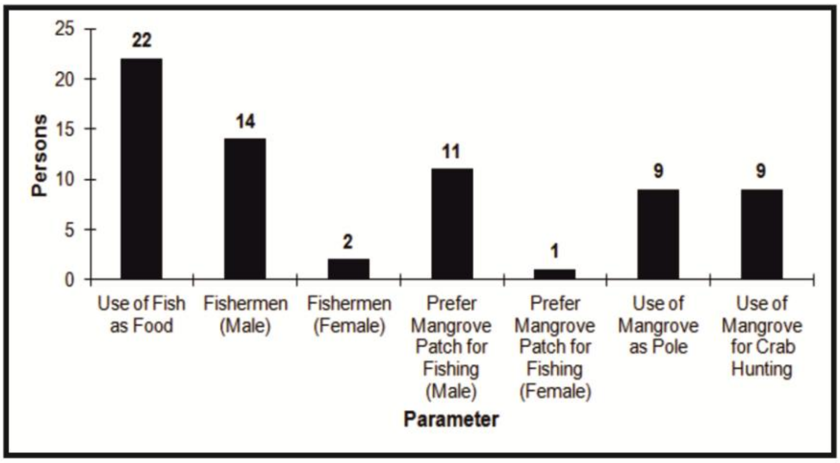
Fig. 5.13.: Mangrove Utilization Status of Village: Jhamdi



Basic Information on Mangrove and it's Utilization (n=25)

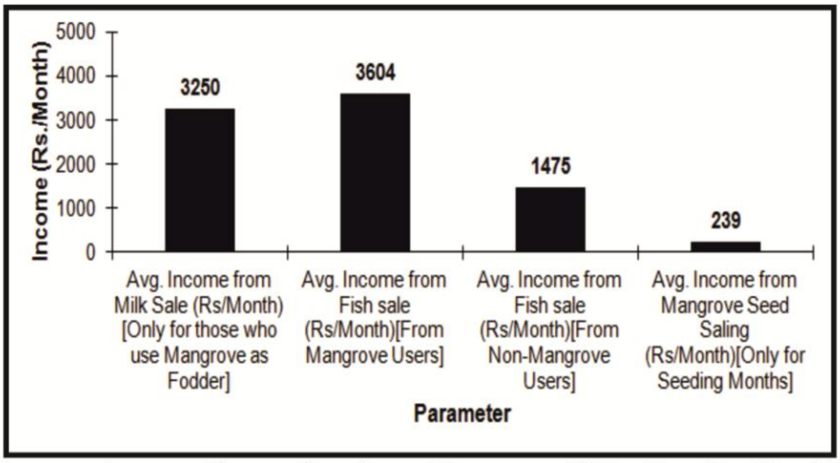


Utilization Status of Mangrove (n=25)

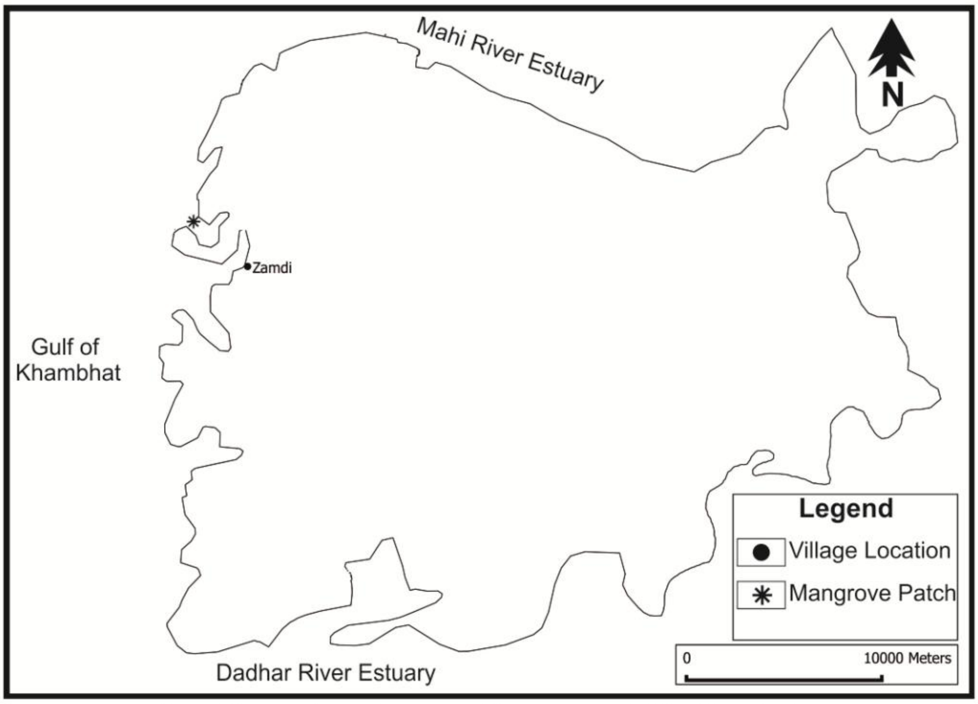


Utilization of Mangrove as Fishing Resources

Fig. 5.14.: Mangrove Utilization Status of Village: Jhamdi

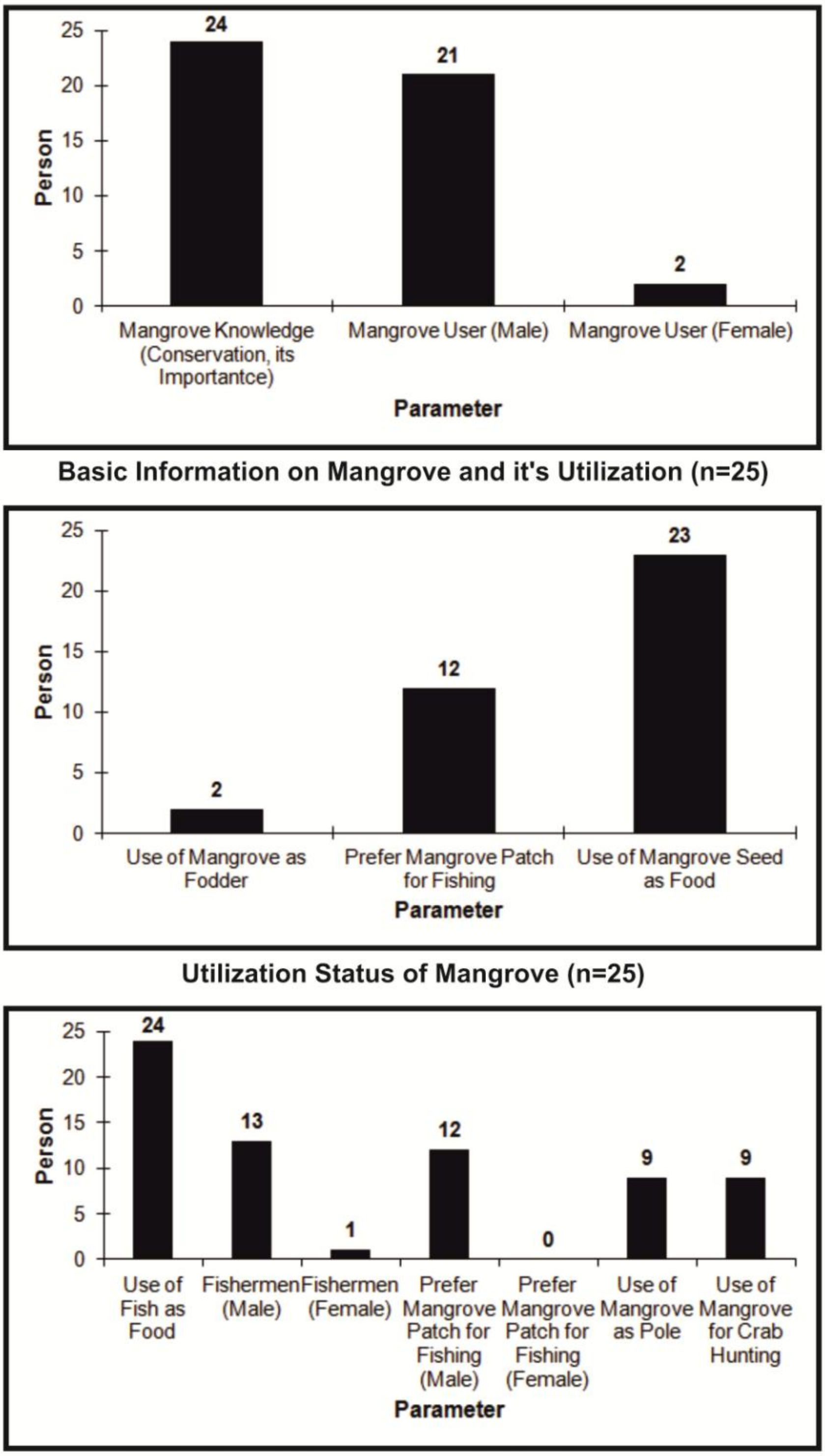


Average Income Generation from Mangrove Utilization (Rs./Month)



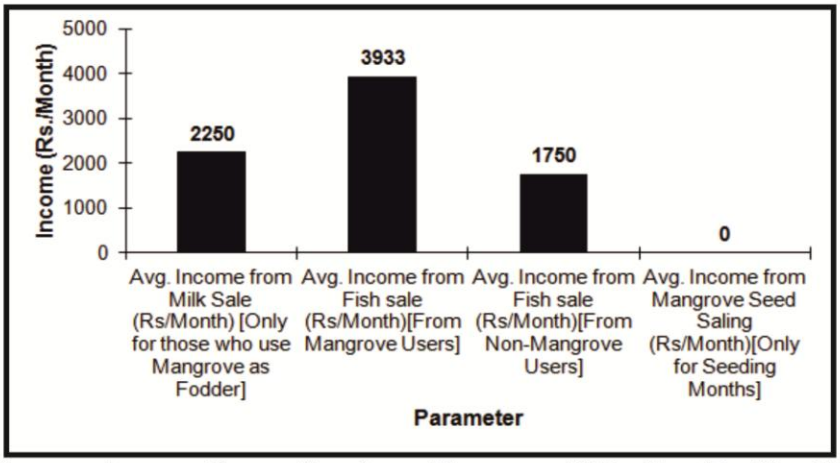
Map. Village Location and Mangrove Utilization Patch

Fig. 5.15.: Mangrove Utilization Status of Village: Chhidra

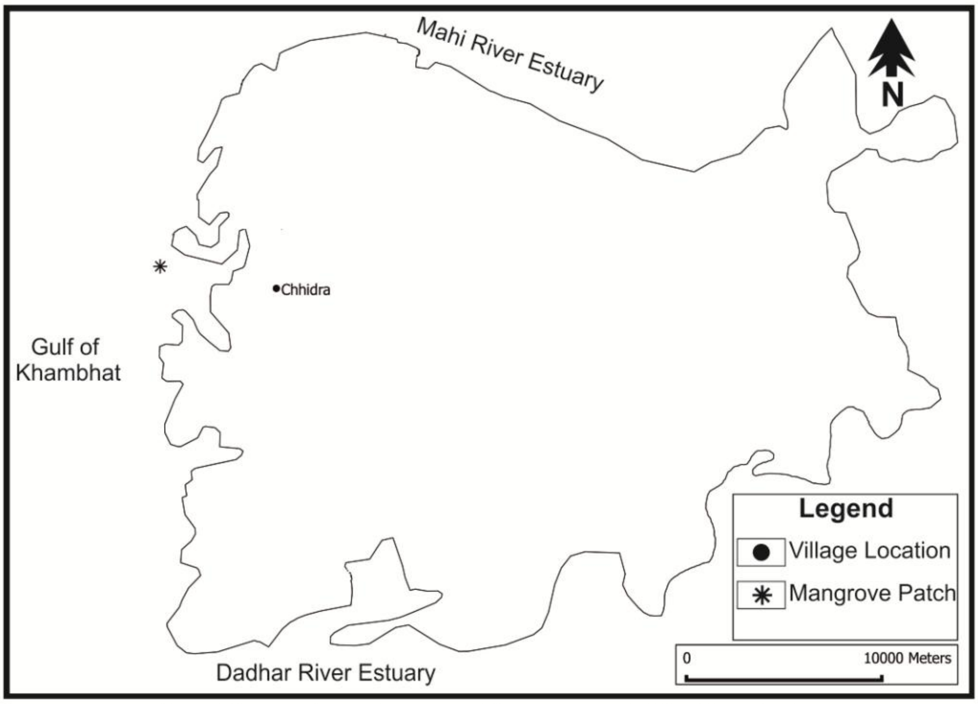


Utilization of Mangrove as Fishing Resources

Fig. 5.16.: Mangrove Utilization Status of Village: Chhidra

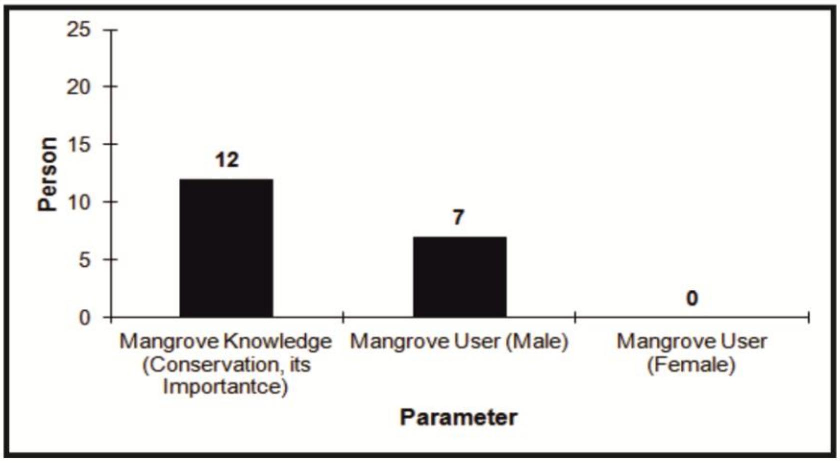


Average Income Generation from Mangrove Utilization (Rs./Month)

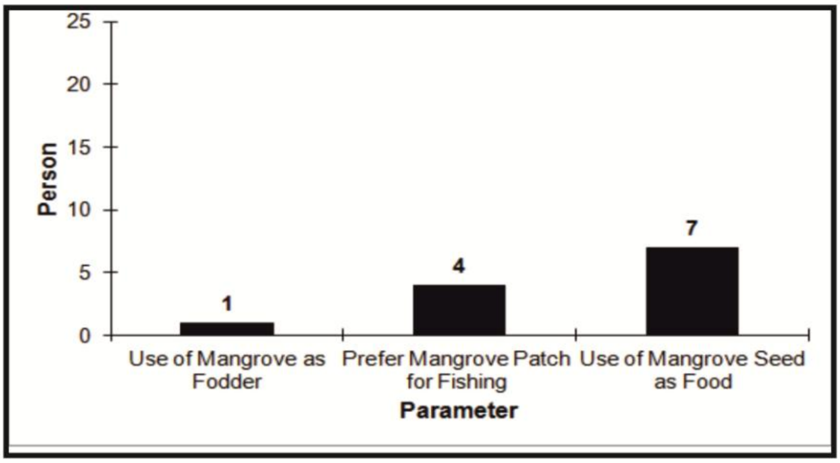


Map. Village Location and Mangrove Utilization Patch

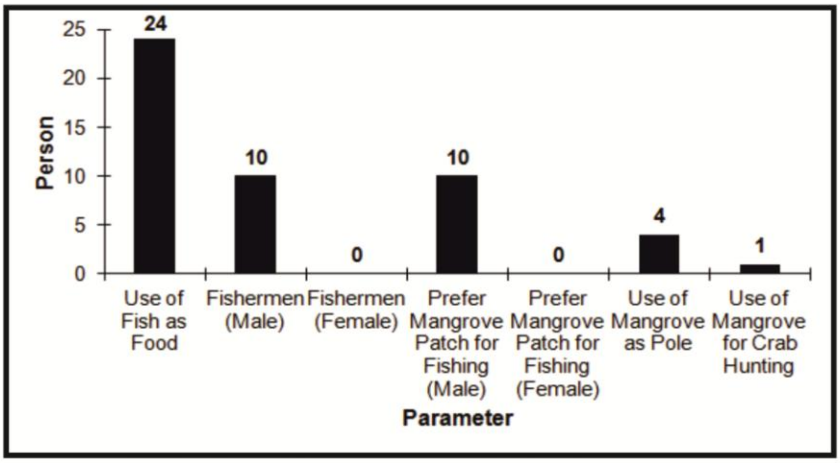
Fig. 5.17.: Mangrove Utilization Status of Village: Jantran



Basic Information on Mangrove and it's Utilization (n=25)

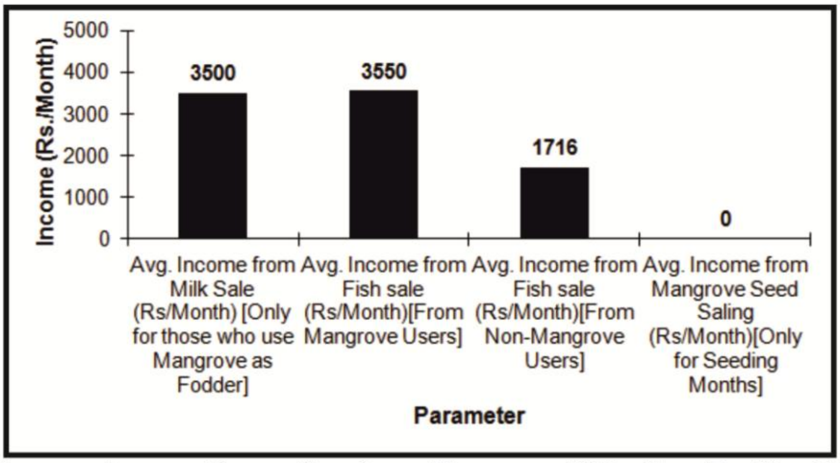


Utilization Status of Mangrove (n=25)

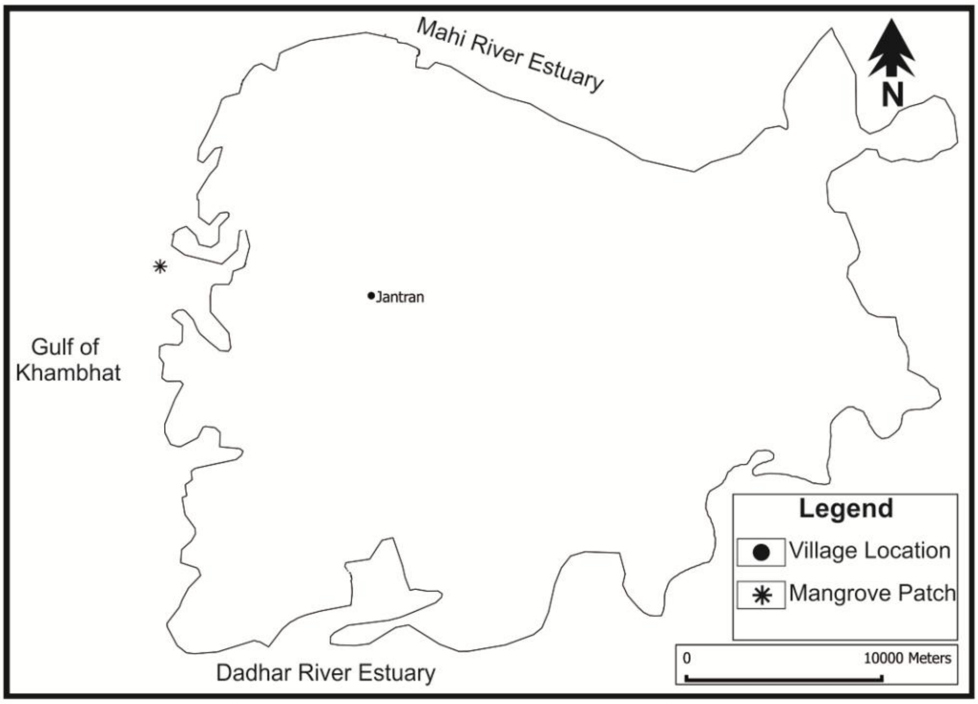


Utilization of Mangrove as Fishing Resources

Fig. 5.18.: Mangrove Utilization Status of Village: Jantran

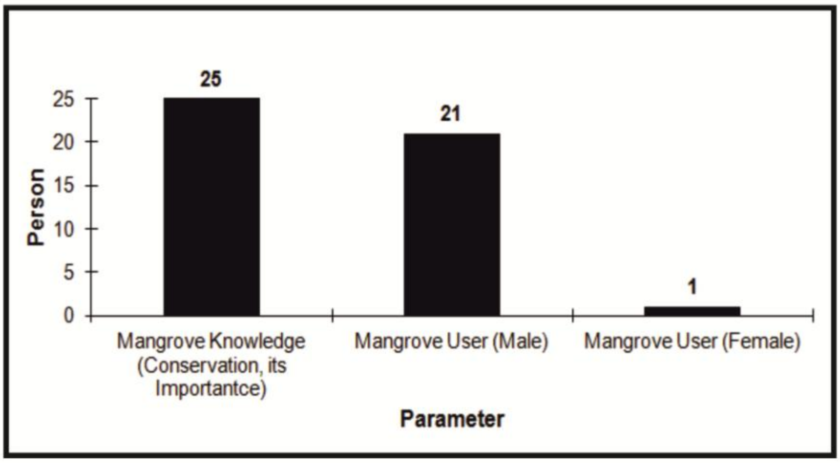


Average Income Generation from Mangrove Utilization (Rs./Month)

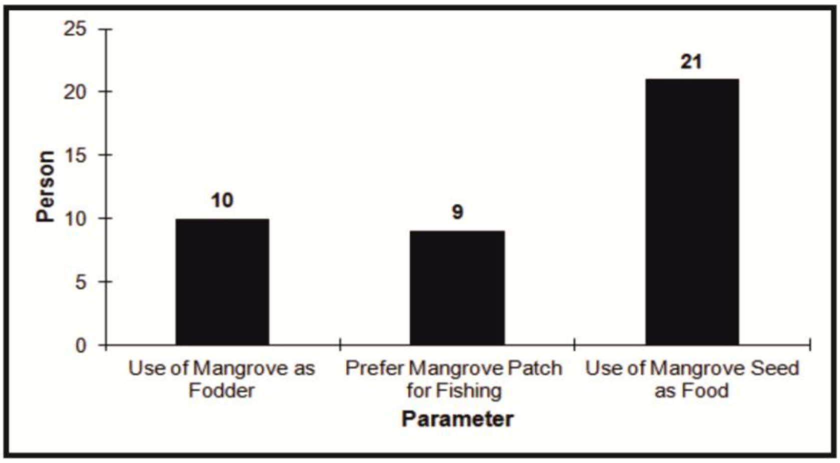


Map. Village Location and Mangrove Utilization Patch

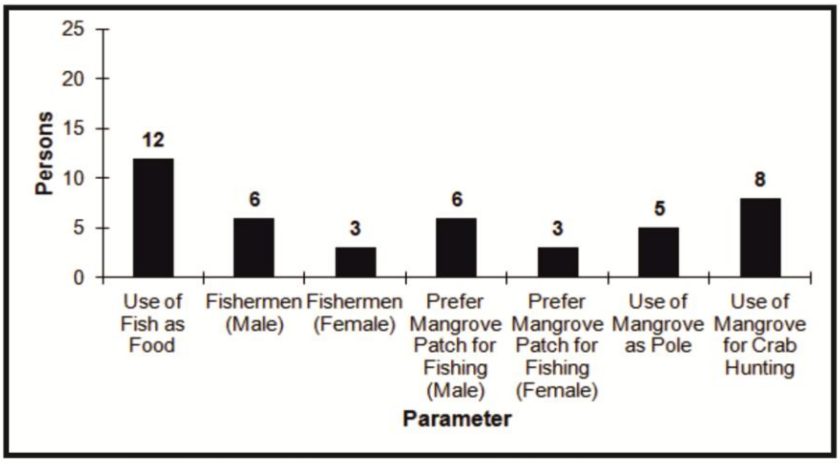
Fig. 5.19.: Mangrove Utilization Status of Village: Malpur



Basic Information on Mangrove and it's Utilization (n=25)

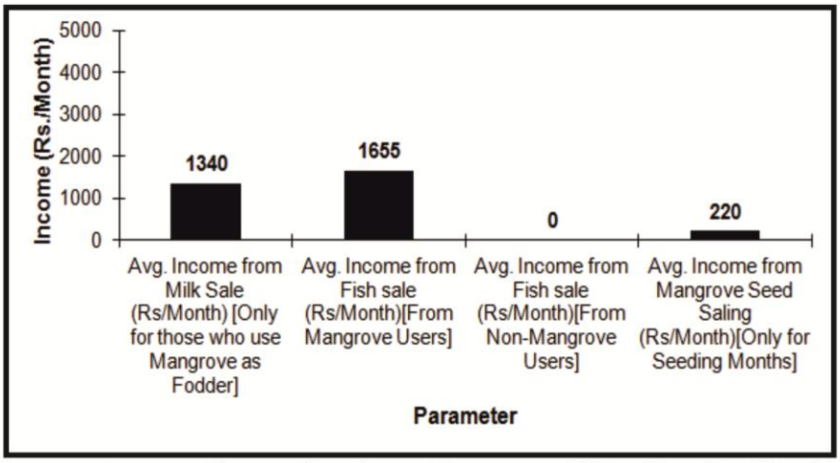


Utilization Status of Mangrove (n=25)

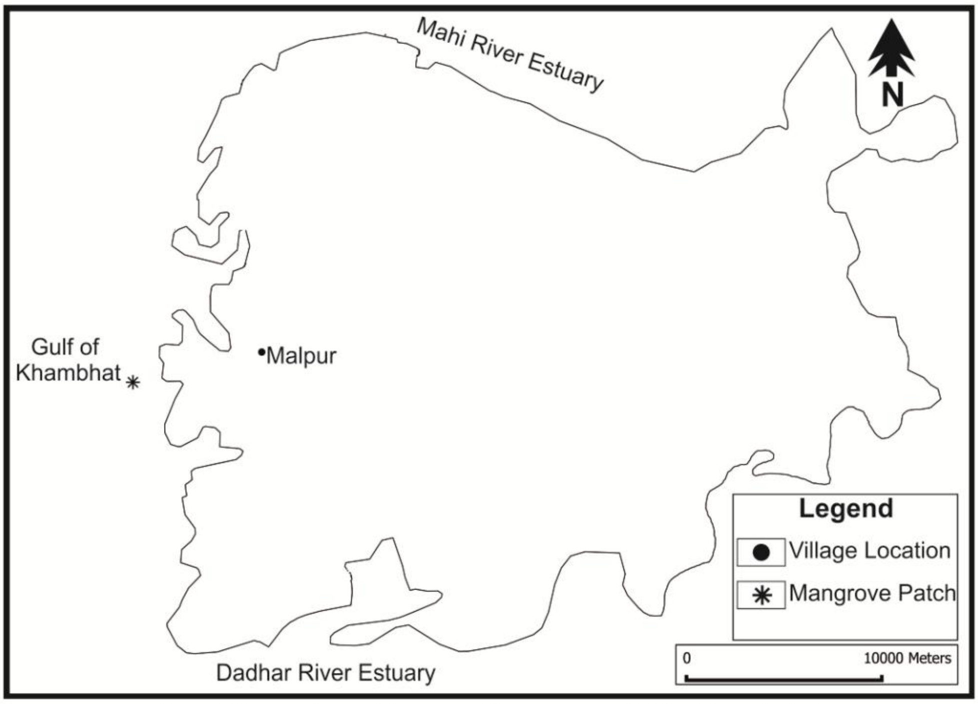


Utilization of Mangrove as Fishing Resources

Fig. 5.20.: Mangrove Utilization Status of Village: Malpur

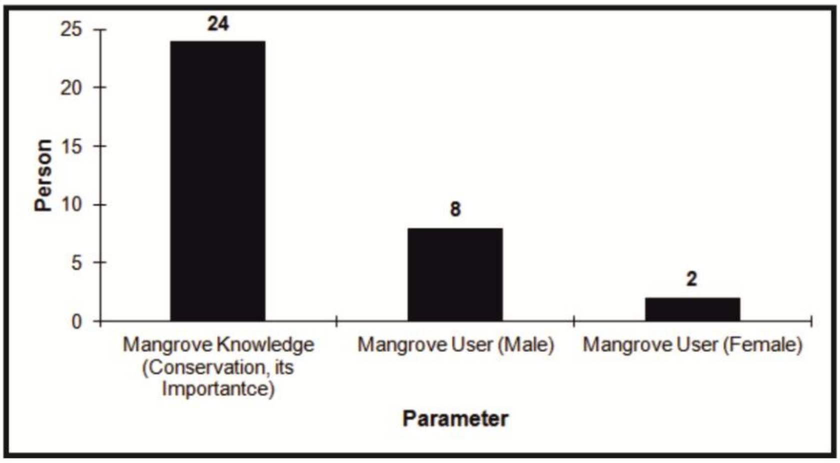


Average Income Generation from Mangrove Utilization (Rs./Month)

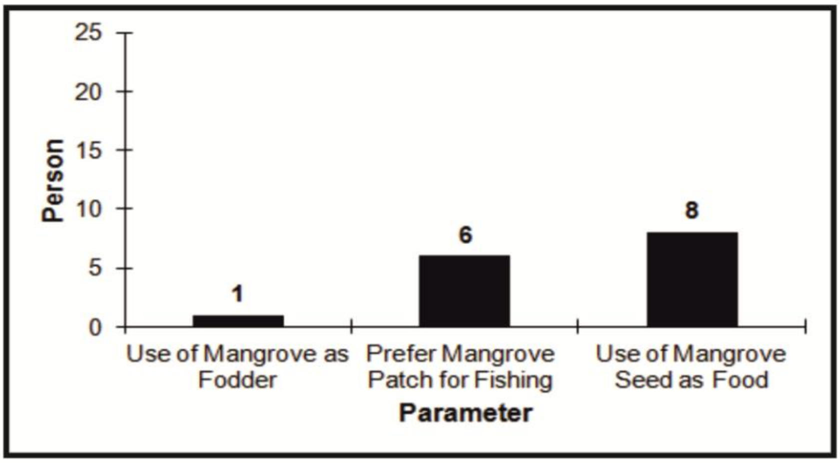


Map. Village Location and Mangrove Utilization Patch

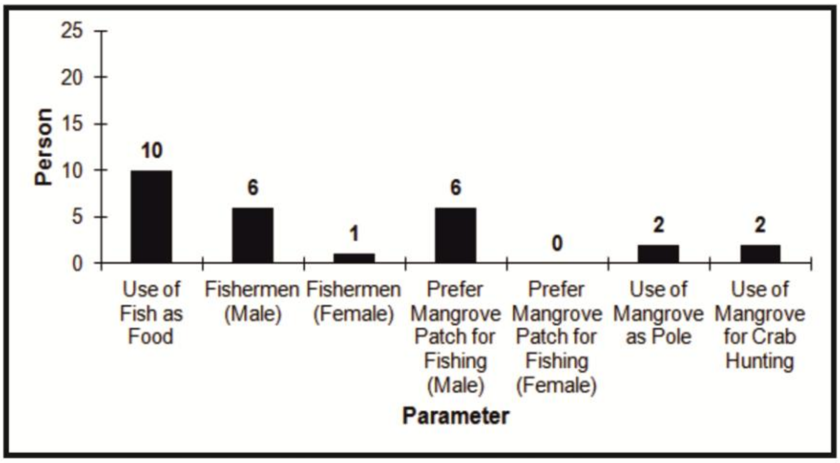
Fig. 5.21.: Mangrove Utilization Status of Village: Devla



Basic Information on Mangrove and it's Utilization (n=25)

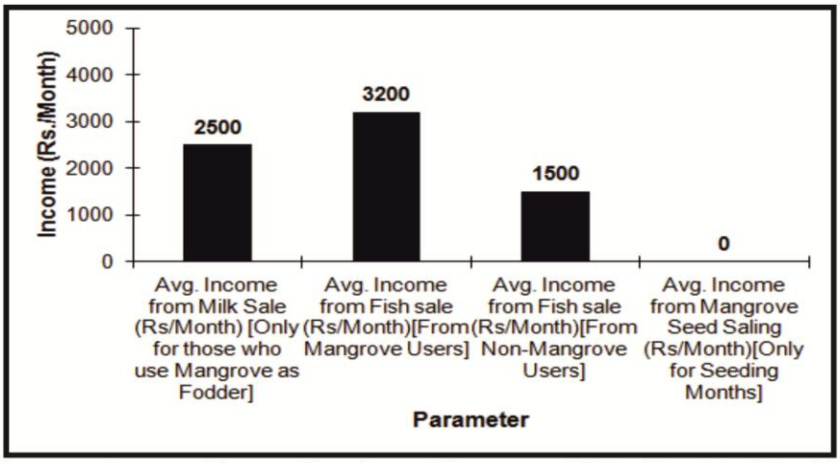


Utilization Status of Mangrove (n=25)

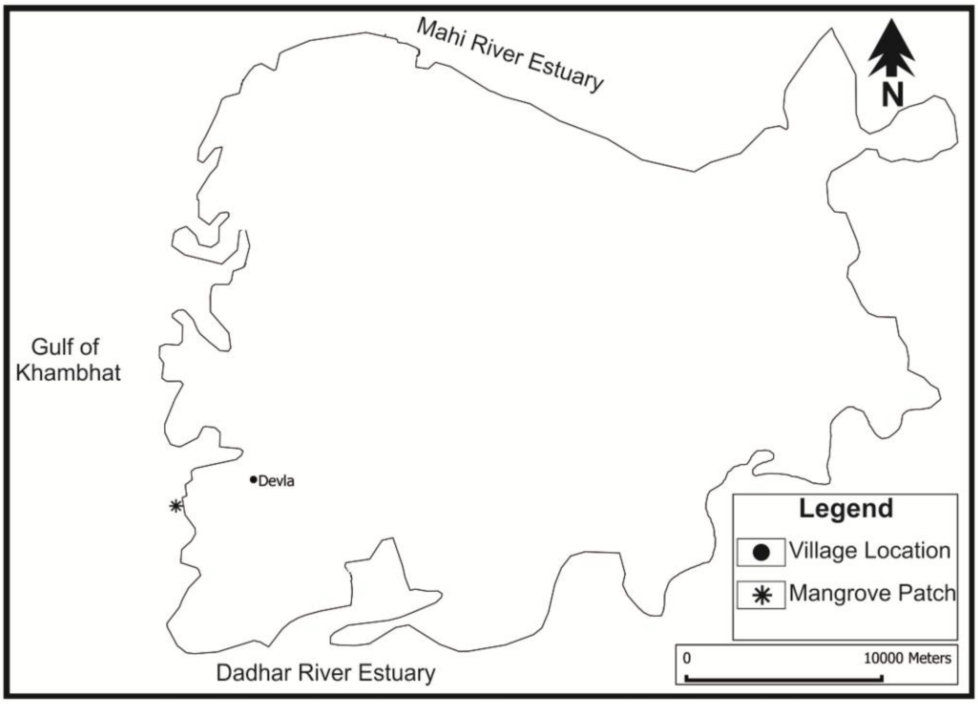


Utilization of Mangrove as Fishing Resources

Fig. 5.22.: Mangrove Utilization Status of Village: Devla

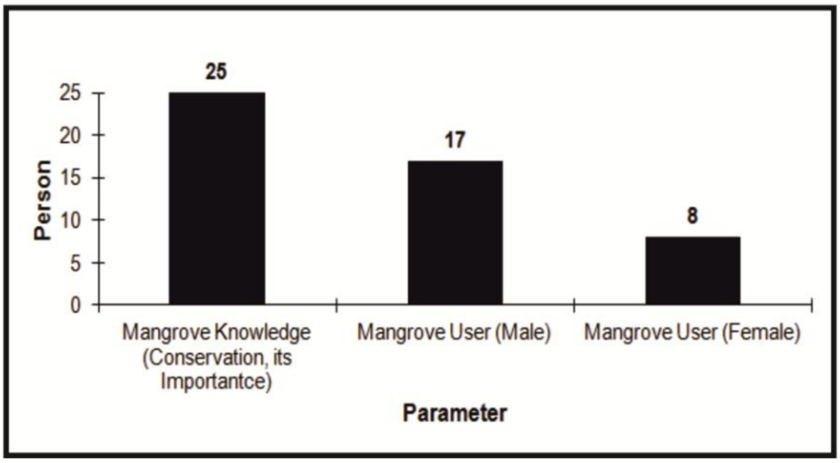


Average Income Generation from Mangrove Utilization (Rs./Month)

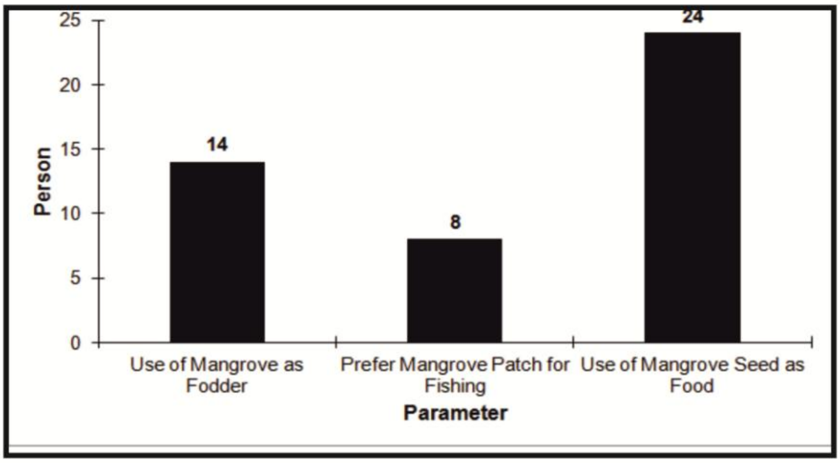


Map. Village Location and Mangrove Utilization Patch

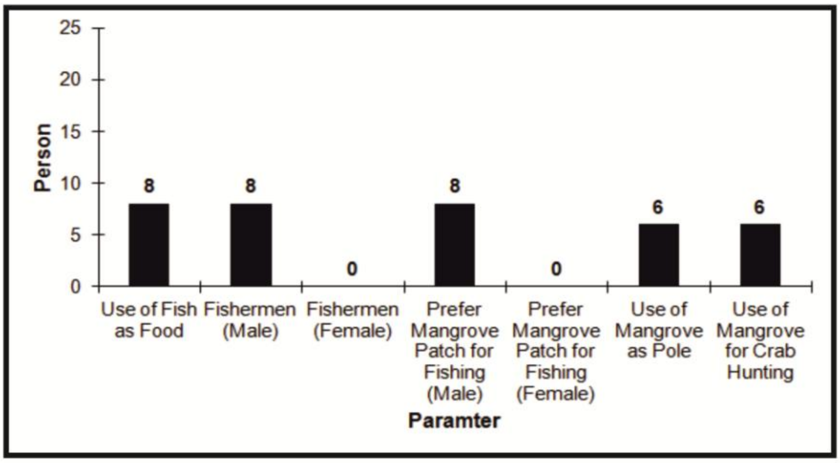
Fig. 5.23.: Mangrove Utilization Status of Village: Nada



Basic Information on Mangrove and it's Utilization (n=25)

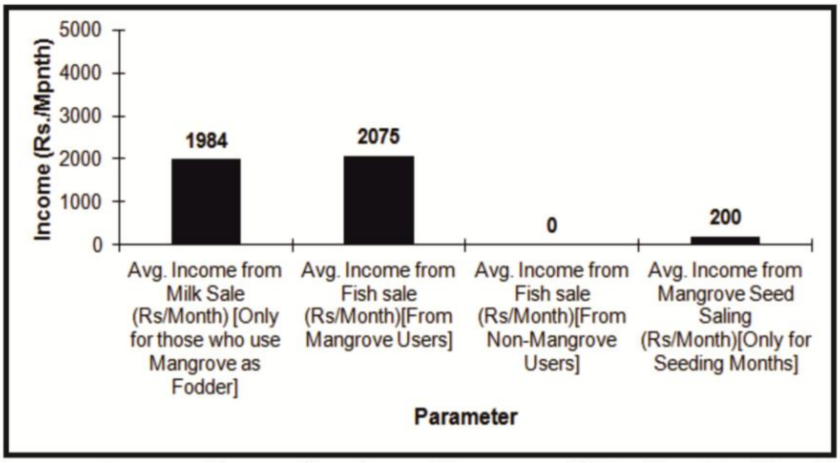


Utilization Status of Mangrove (n=25)

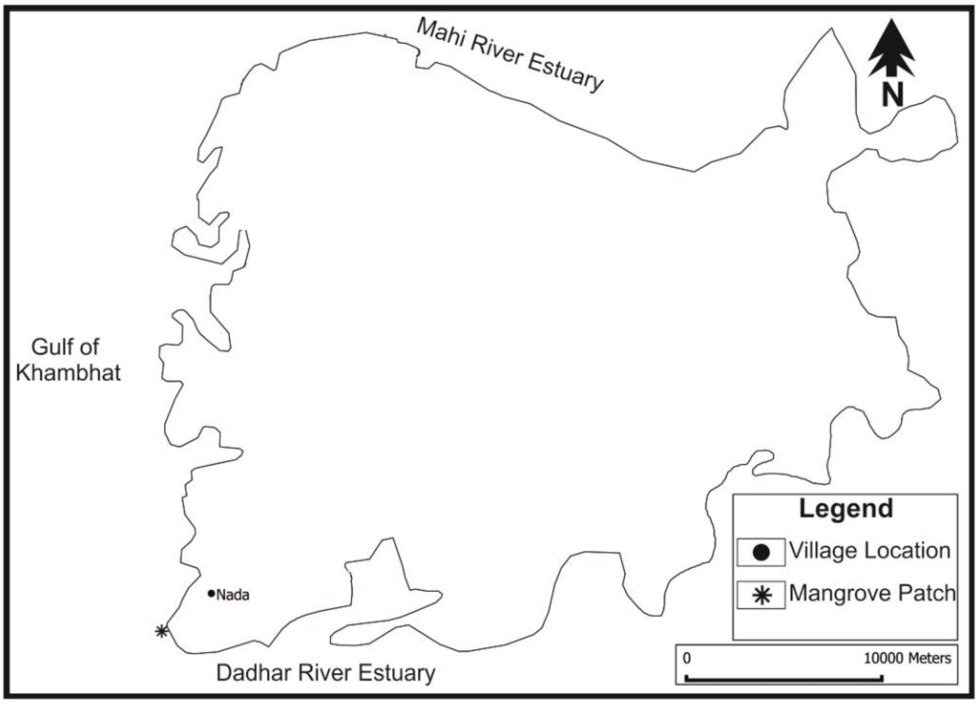


Utilization of Mangrove as Fishing Resources

Fig. 5.24.: Mangrove Utilization Status of Village: Nada

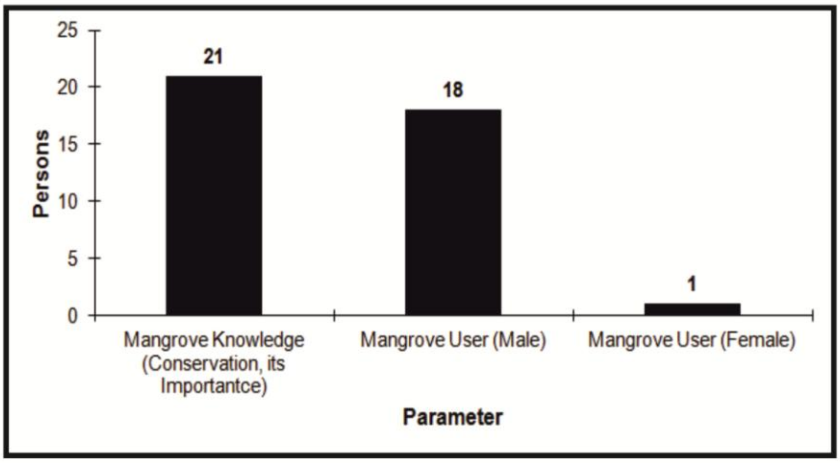


Average Income Generation from Mangrove Utilization (Rs./Month)

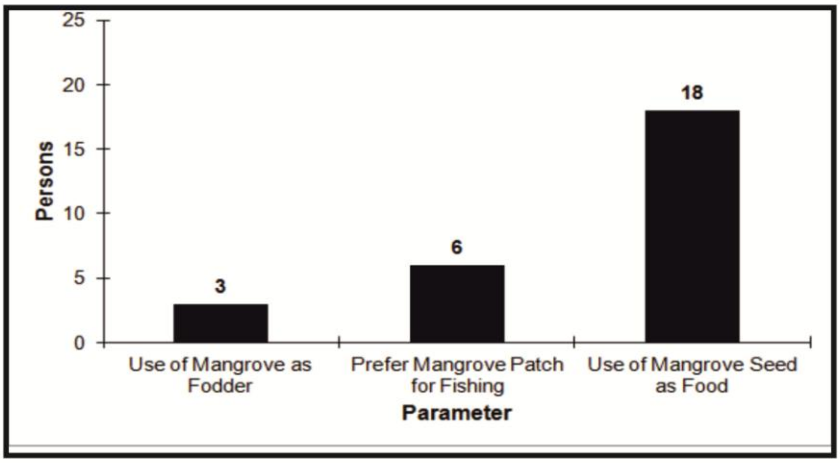


Map. Village Location and Mangrove Utilization Patch

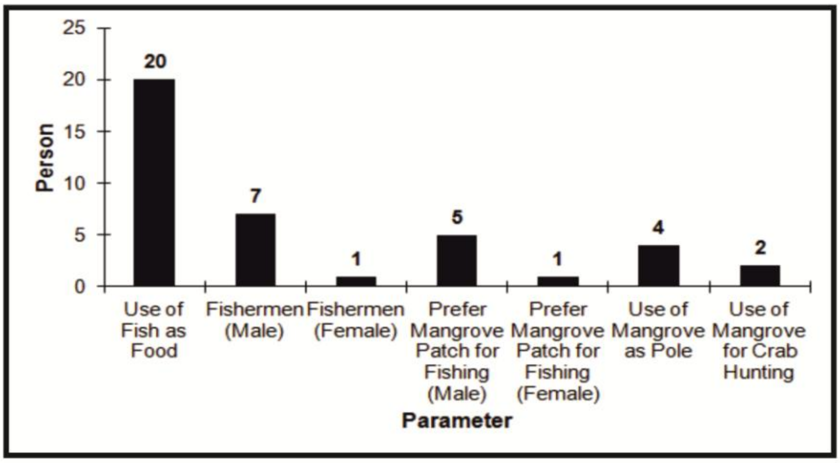
Fig. 5.25.: Mangrove Utilization Status of Village: Asarsa



Basic Information on Mangrove and it's Utilization (n=25)

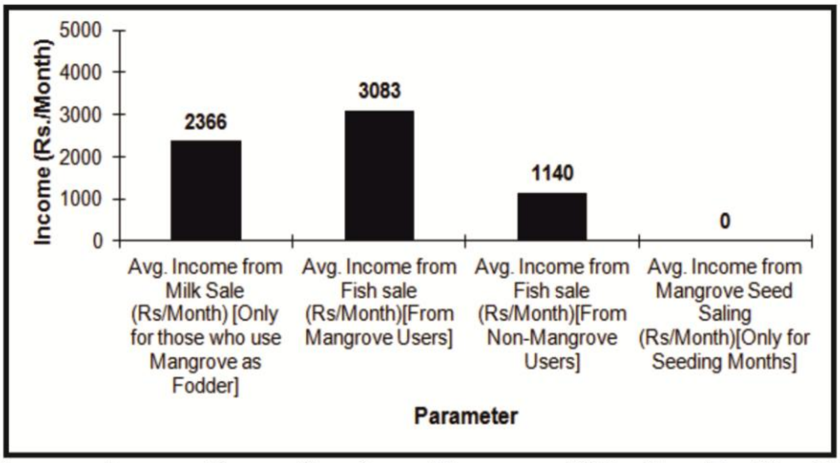


Utilization Status of Mangrove (n=25)

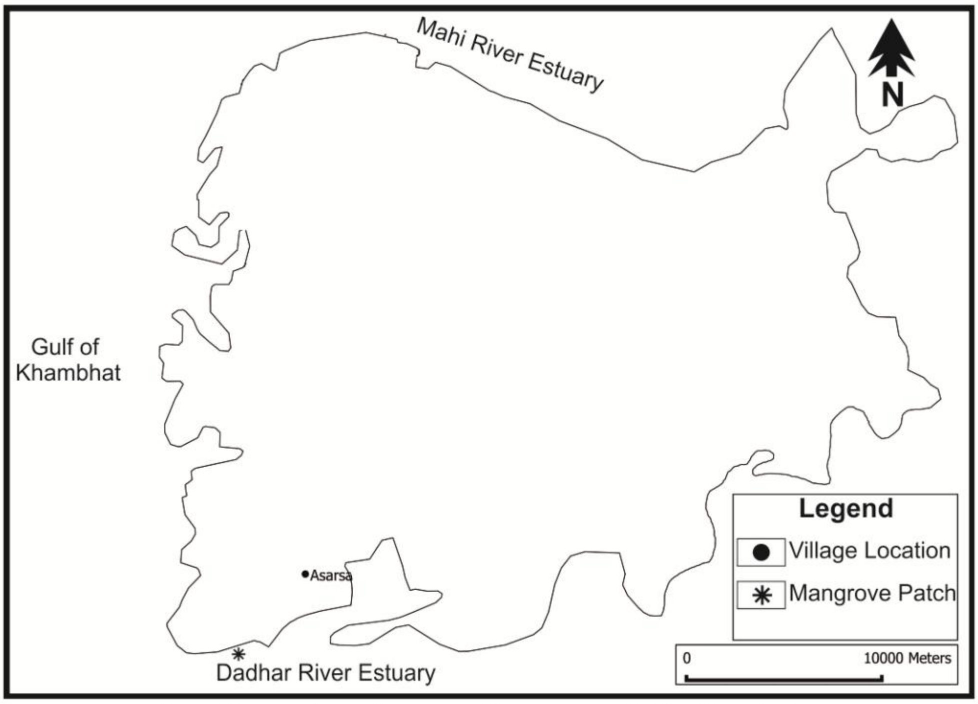


Utilization of Mangrove as Fishing Resources

Fig. 5.26.: Mangrove Utilization Status of Village: Asarsa

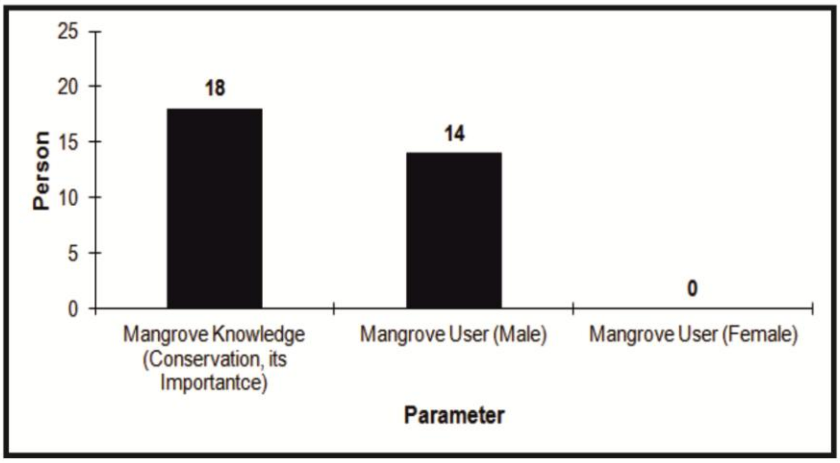


Average Income Generation from Mangrove Utilization (Rs./Month)

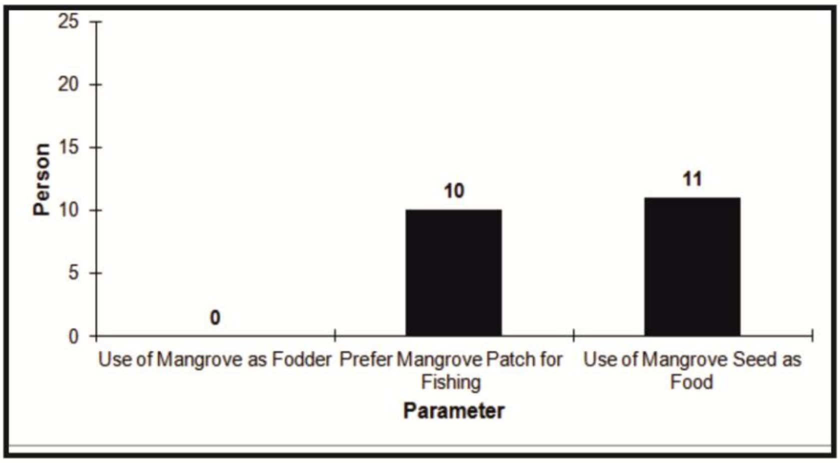


Map. Village Location and Mangrove Utilization Patch

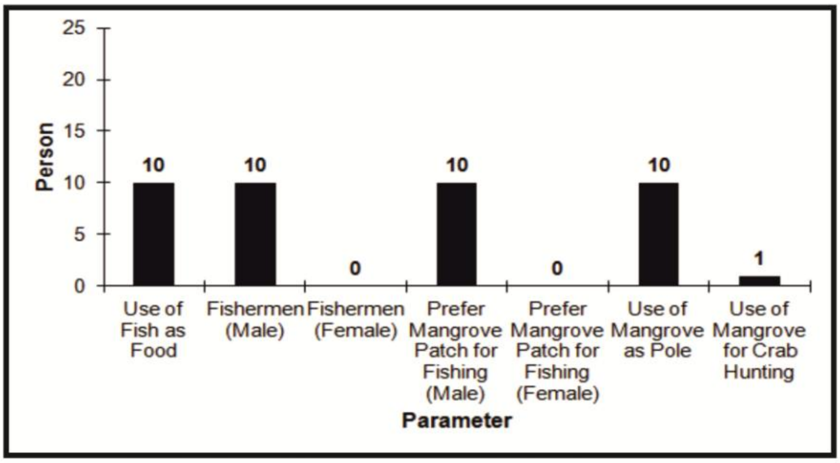
Fig. 5.27.: Mangrove Utilization Status of Village: Kapuria



Basic Information on Mangrove and it's Utilization (n=25)

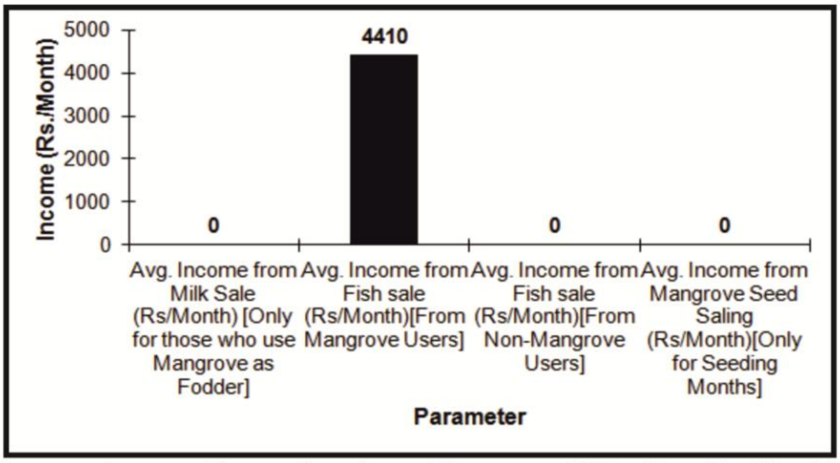


Utilization Status of Mangrove (n=25)

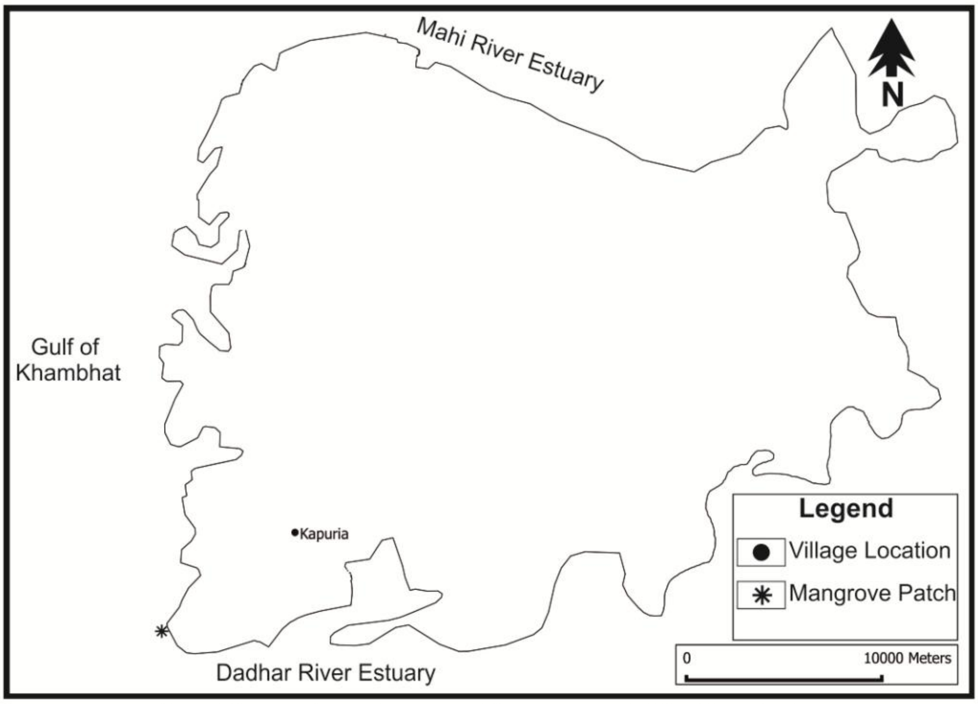


Utilization of Mangrove as Fishing Resources

Fig. 5.28.: Mangrove Utilization Status of Village: Kapuria

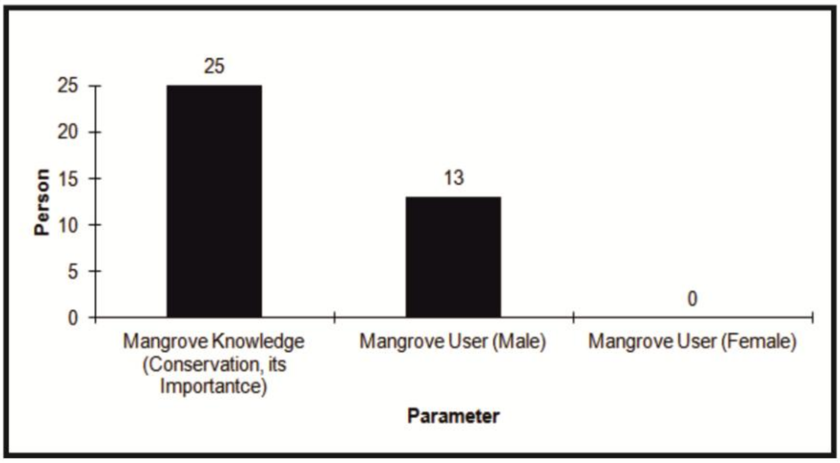


Average Income Generation from Mangrove Utilization (Rs./Month)

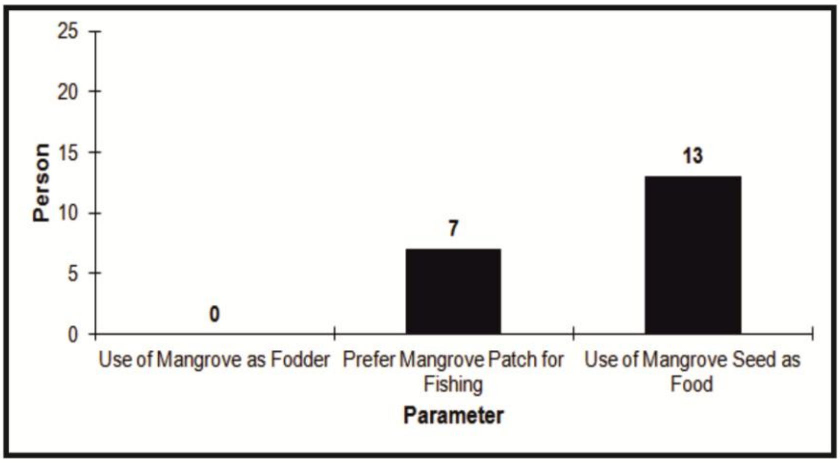


Map. Village Location and Mangrove Utilization Patch

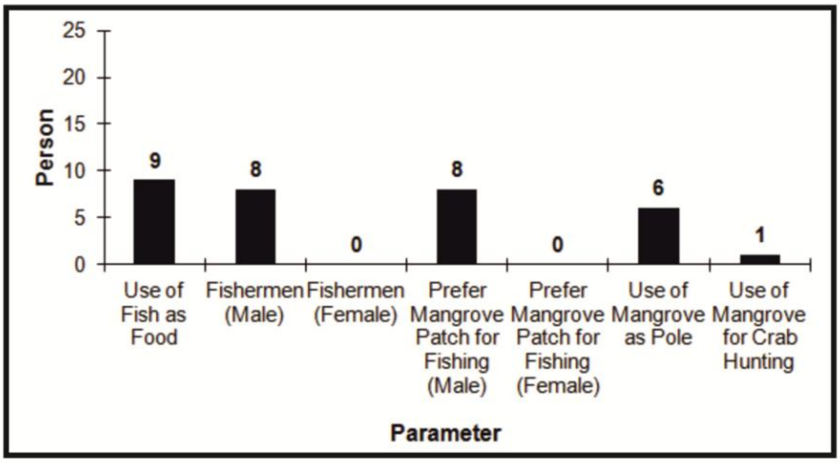
Fig. 5.29.: Mangrove Utilization Status of Village: Tankari



Basic Information on Mangrove and it's Utilization (n=25)

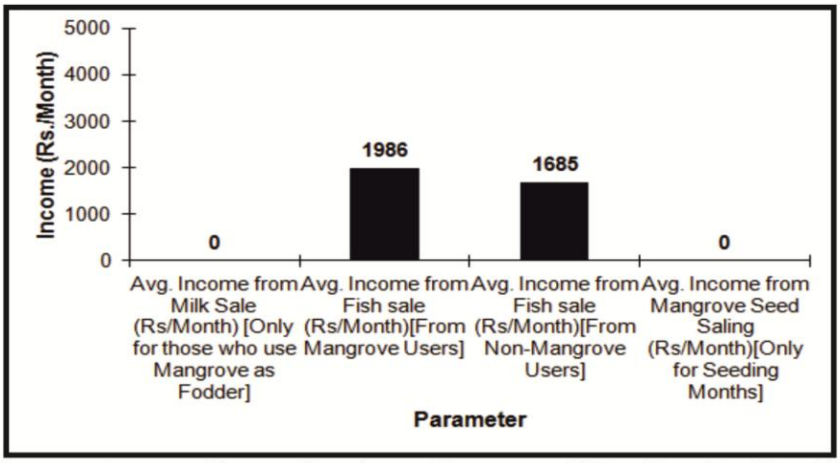


Utilization Status of Mangrove (n=25)

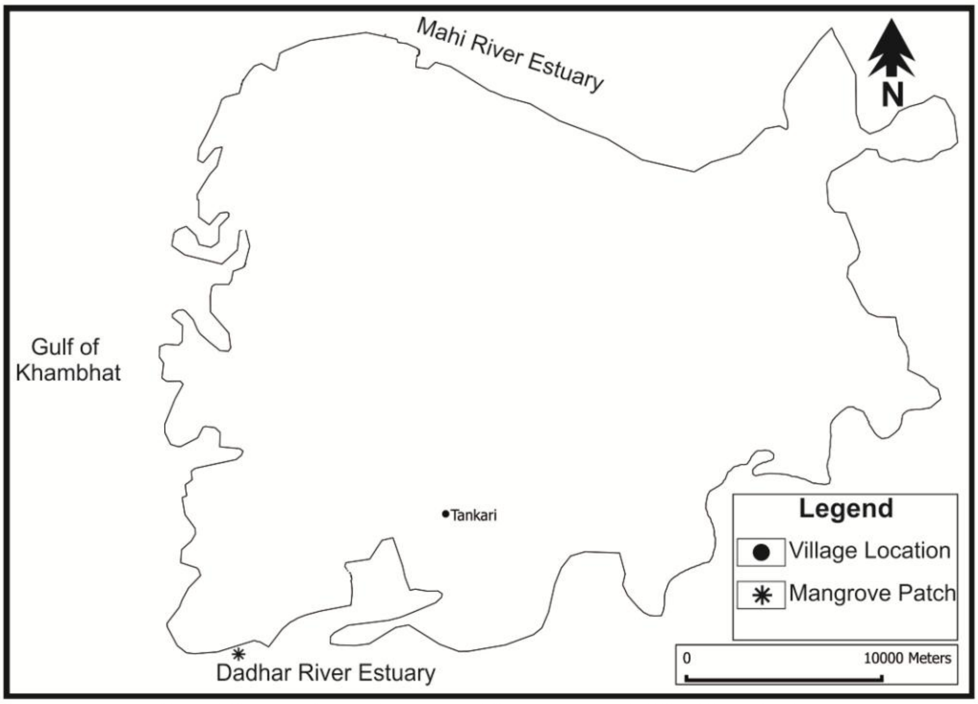


Utilization of Mangrove as Fishing Resources

Fig. 5.30.: Mangrove Utilization Status of Village: Tankari

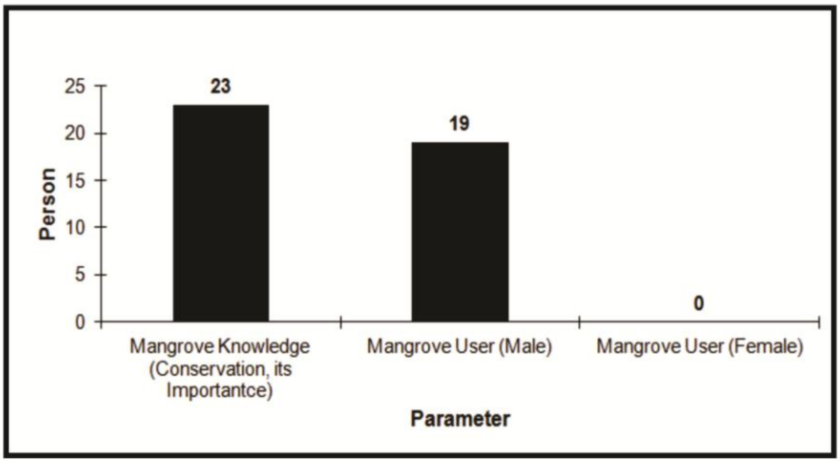


Average Income Generation from Mangrove Utilization (Rs./Month)

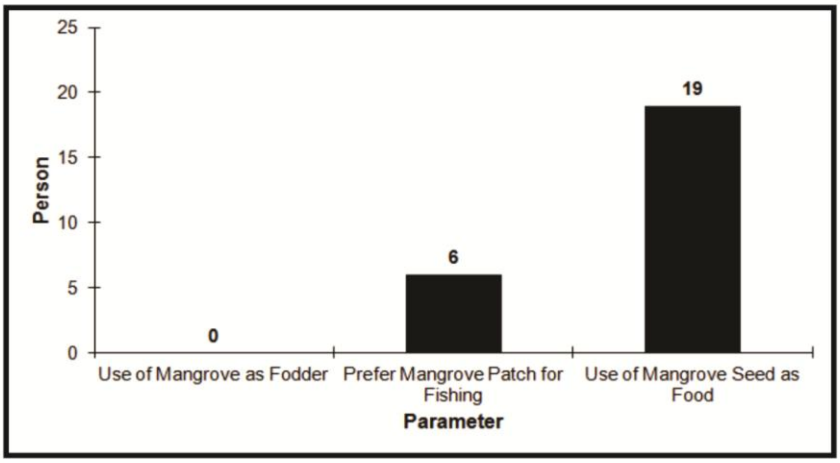


Map. Village Location and Mangrove Utilization Patch

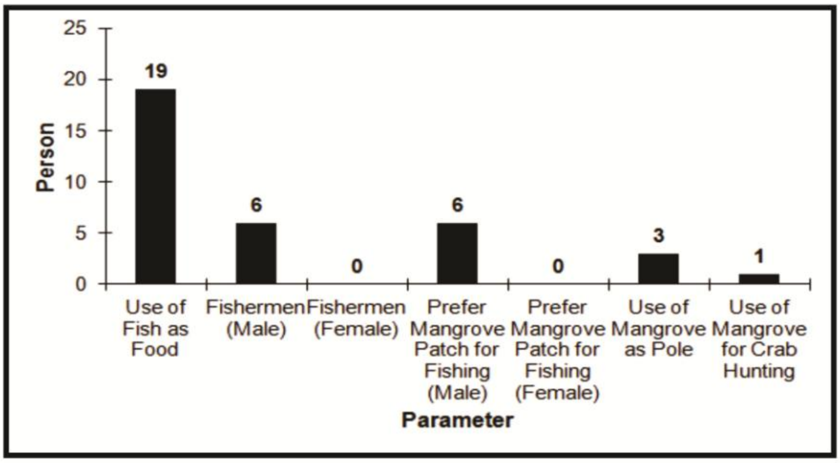
Fig. 5.31.: Mangrove Utilization Status of Village: Achhod



Basic Information on Mangrove and it's Utilization (n=25)

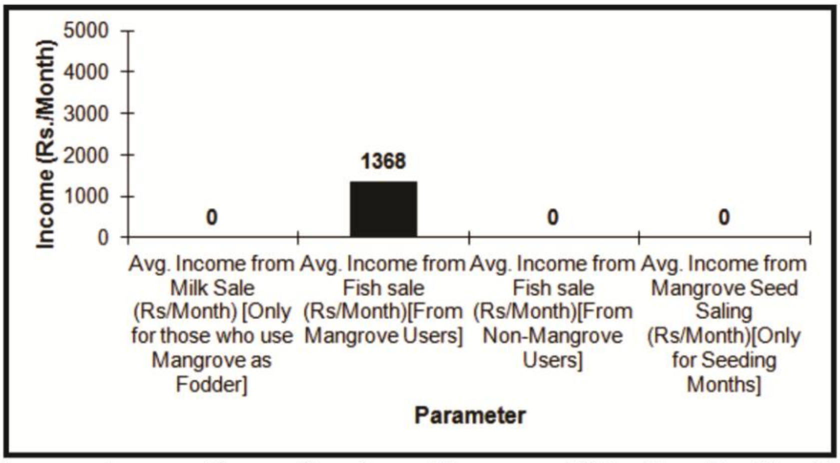


Utilization Status of Mangrove (n=25)

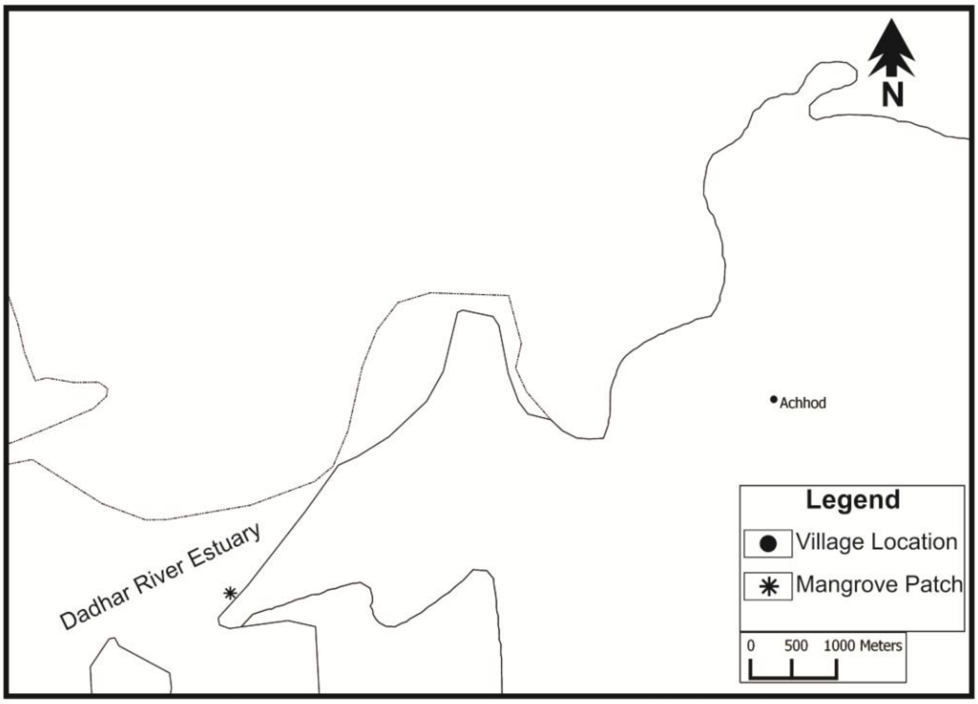


Utilization of Mangrove as Fishing Resources

Fig. 5.32.: Mangrove Utilization Status of Village: Achhod

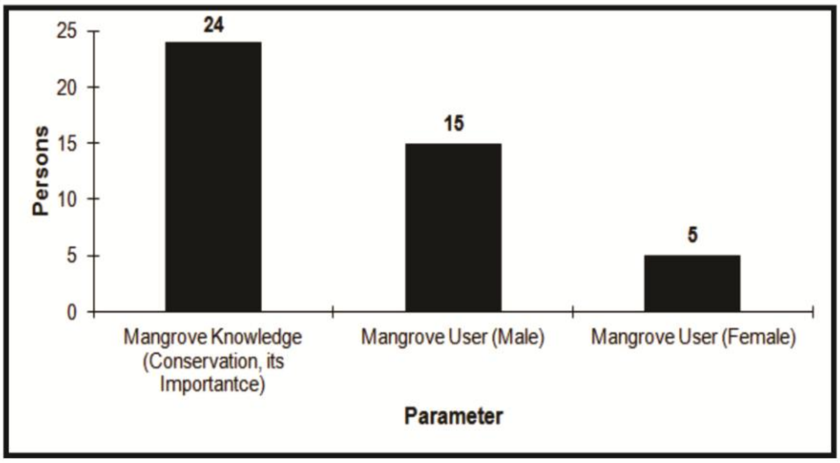


Average Income Generation from Mangrove Utilization (Rs./Month)

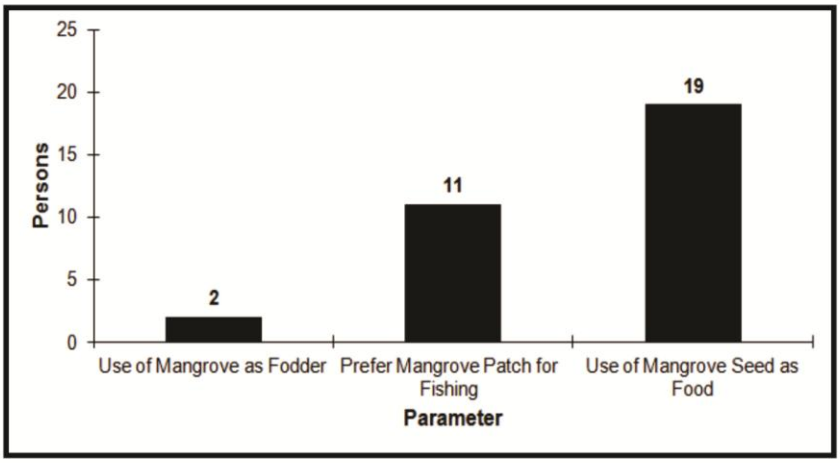


Map. Village Location and Mangrove Utilization Patch

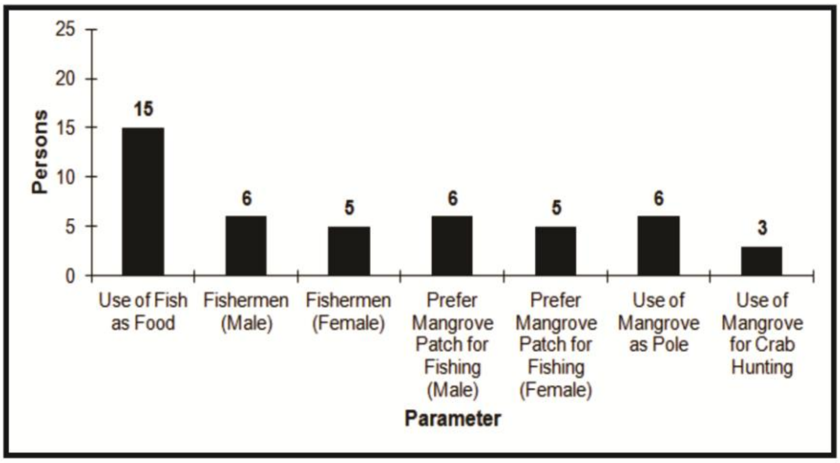
Fig. 5.33.: Mangrove Utilization Status of Village: Denva



Basic Information on Mangrove and it's Utilization (n=25)

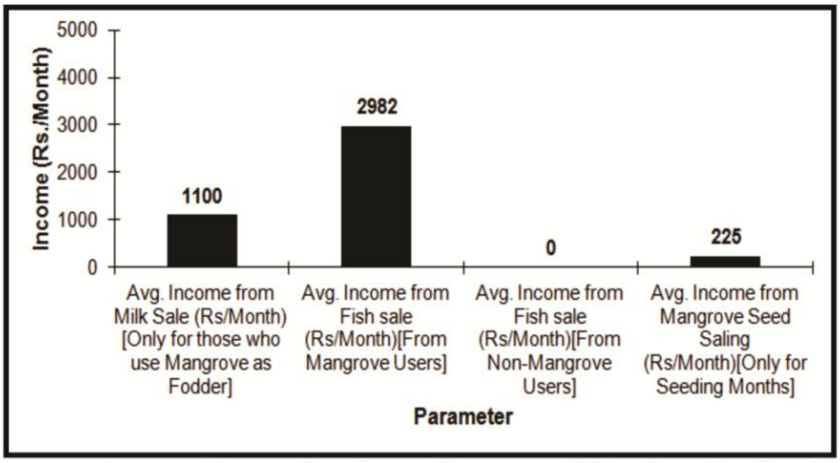


Utilization Status of Mangrove (n=25)

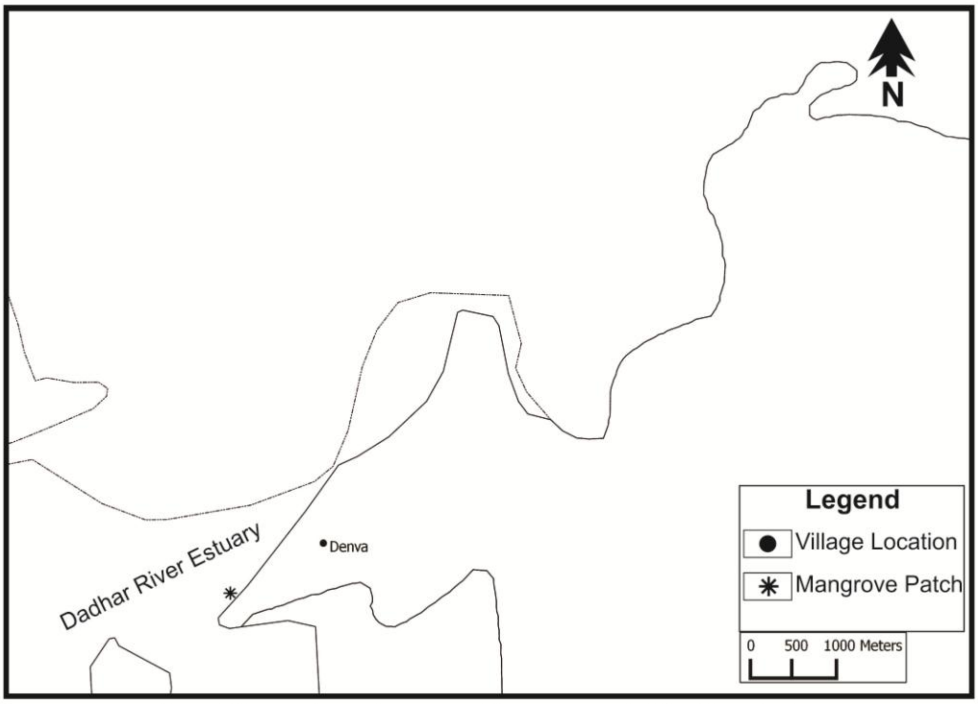


Utilization of Mangrove as Fishing Resources

Fig. 5.34.: Mangrove Utilization Status of Village: Denva

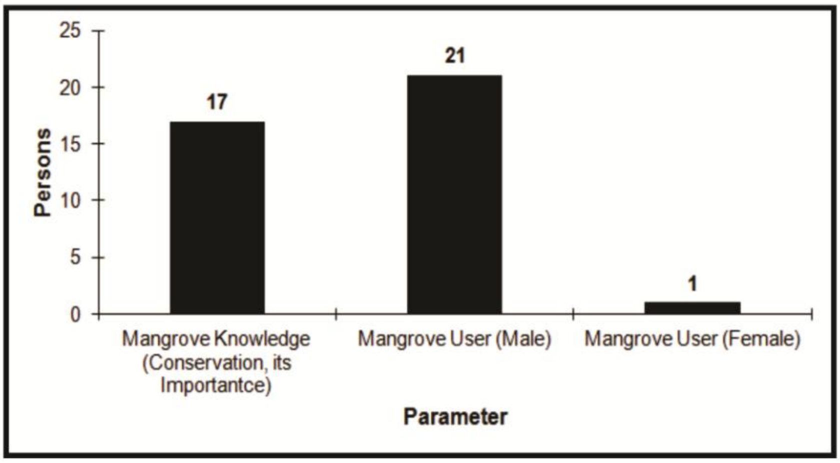


Average Income Generation from Mangrove Utilization (Rs./Month)

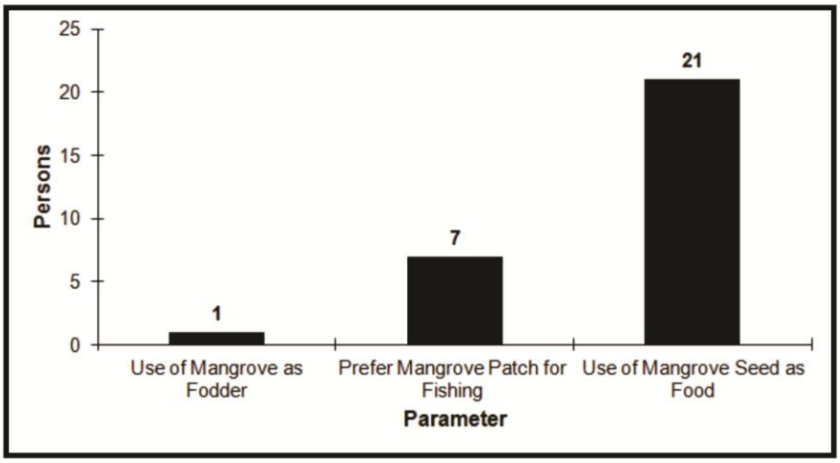


Map. Village Location and Mangrove Utilization Patch

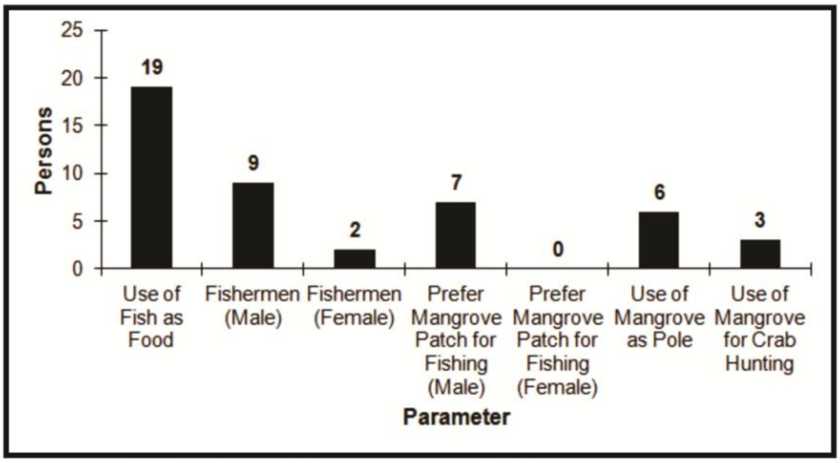
Fig. 5.35.: Mangrove Utilization Status of Village: Chanchvel



Basic Information on Mangrove and it's Utilization (n=25)

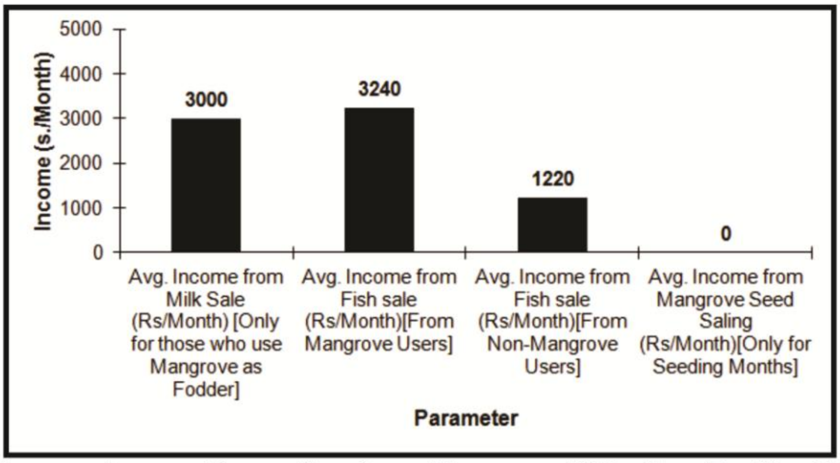


Utilization Status of Mangrove (n=25)

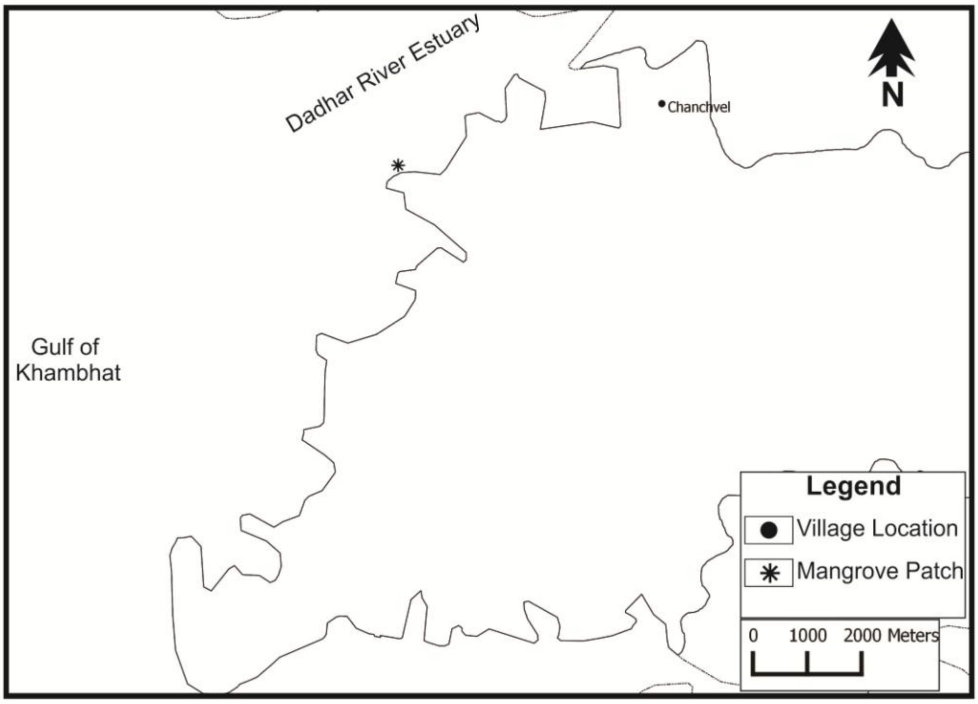


Utilization of Mangrove as Fishing Resources

Fig. 5.36.: Mangrove Utilization Status of Village: Chanchvel

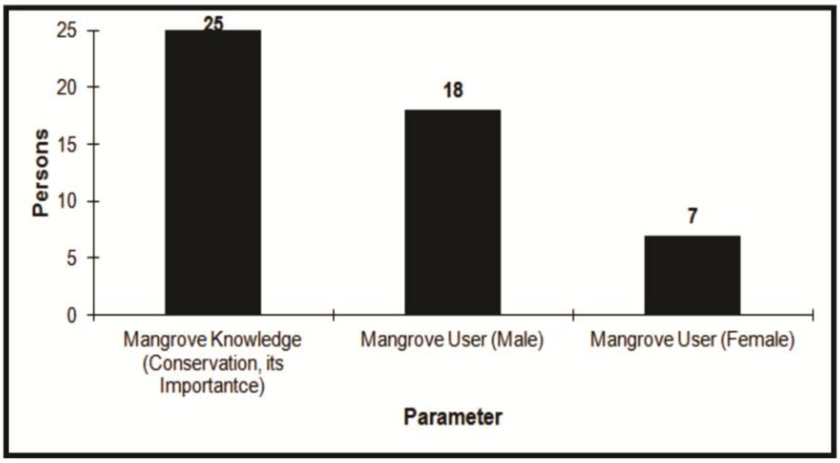


Average Income Generation from Mangrove Utilization (Rs./Month)

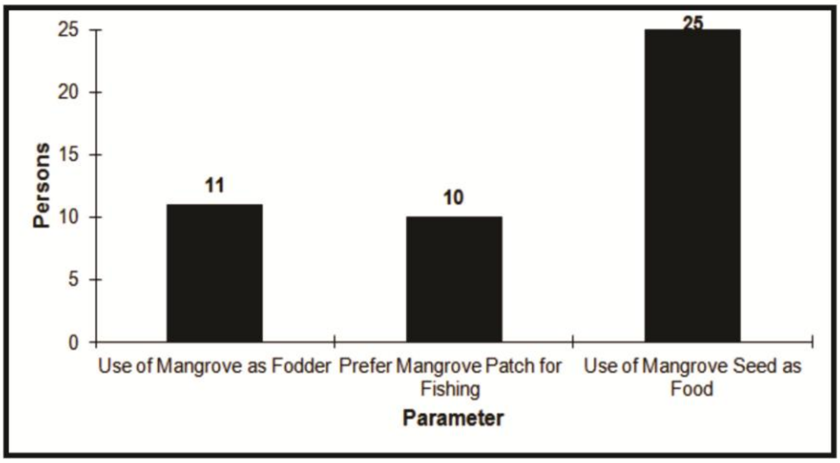


Map. Village Location and Mangrove Utilization Patch

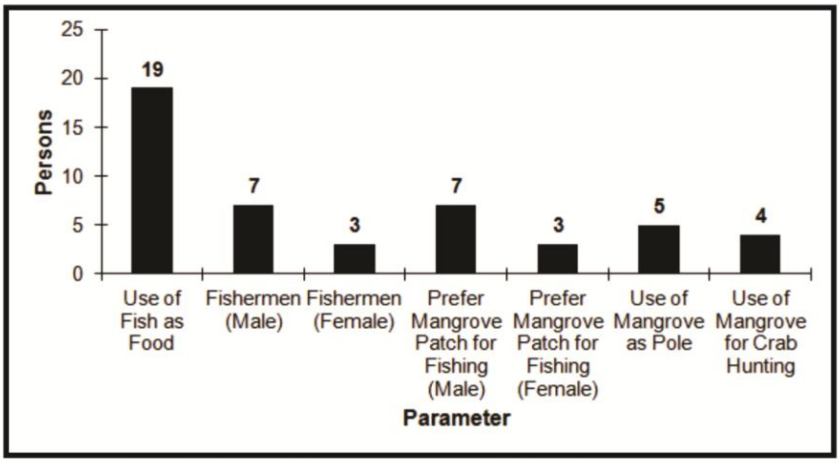
Fig. 5.37.: Mangrove Utilization Status of Village: Gandhar



Basic Information on Mangrove and it's Utilization (n=25)

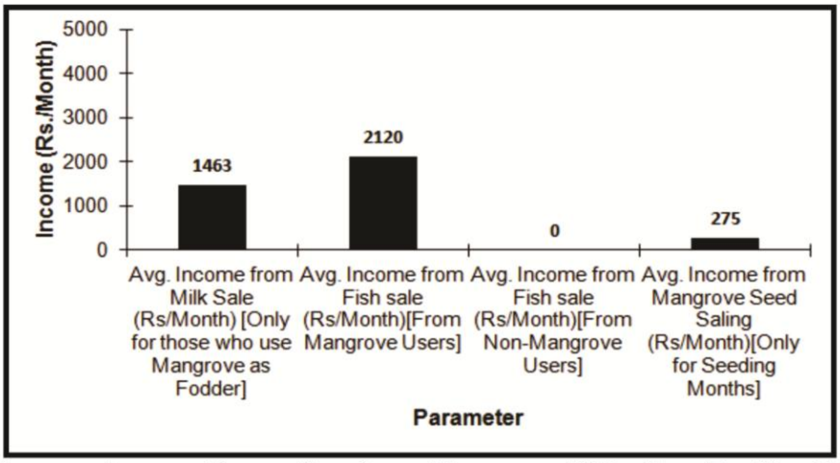


Utilization Status of Mangrove (n=25)

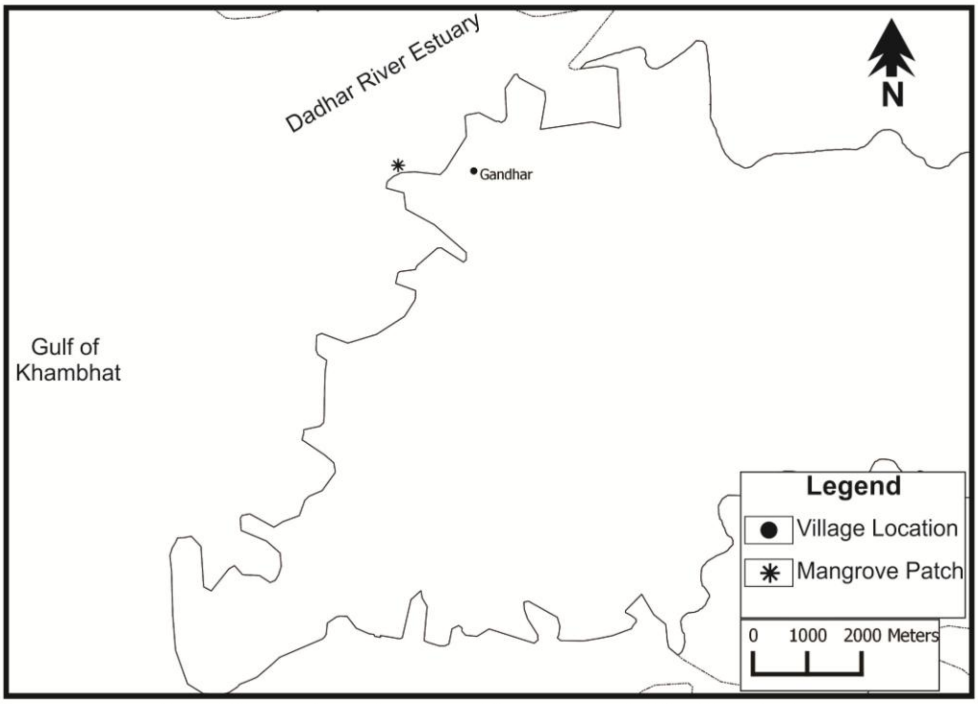


Utilization of Mangrove as Fishing Resources

Fig. 5.38.: Mangrove Utilization Status of Village: Gandhar

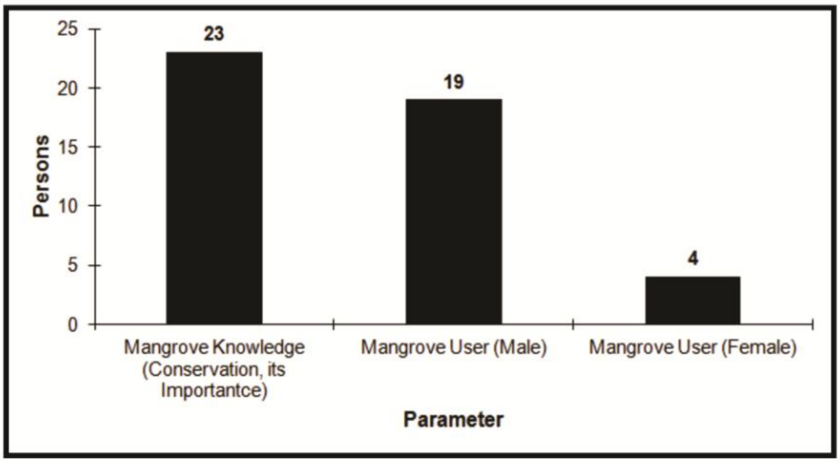


Average Income Generation from Mangrove Utilization (Rs./Month)

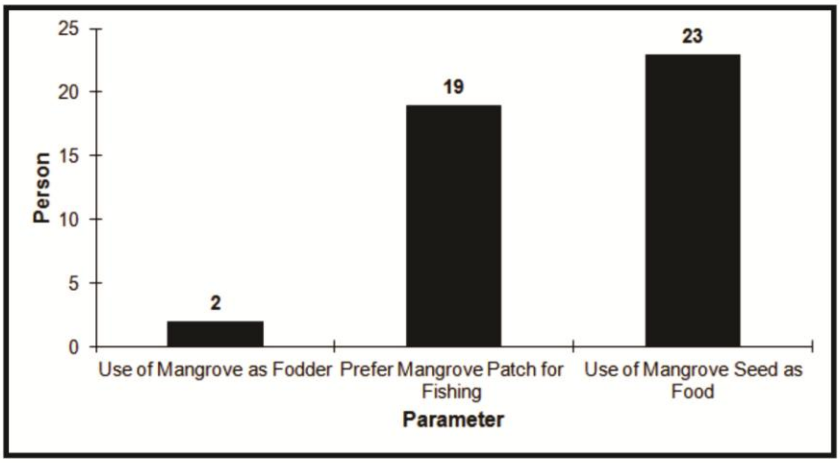


Map. Village Location and Mangrove Utilization Patch

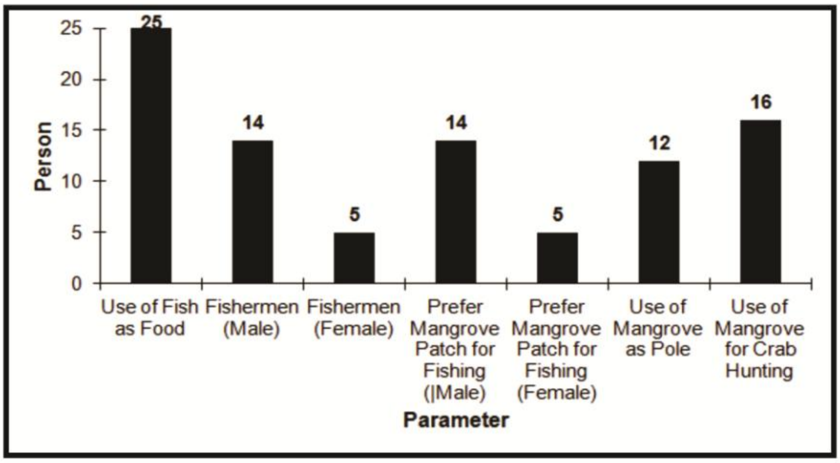
Fig. 5.39.: Mangrove Utilization Status of Village: Dahej



Basic Information on Mangrove and it's Utilization (n=25)

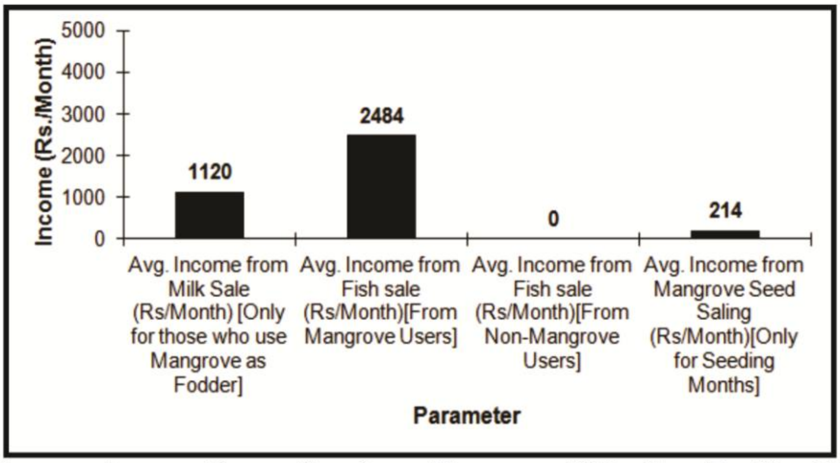


Utilization Status of Mangrove (n=25)

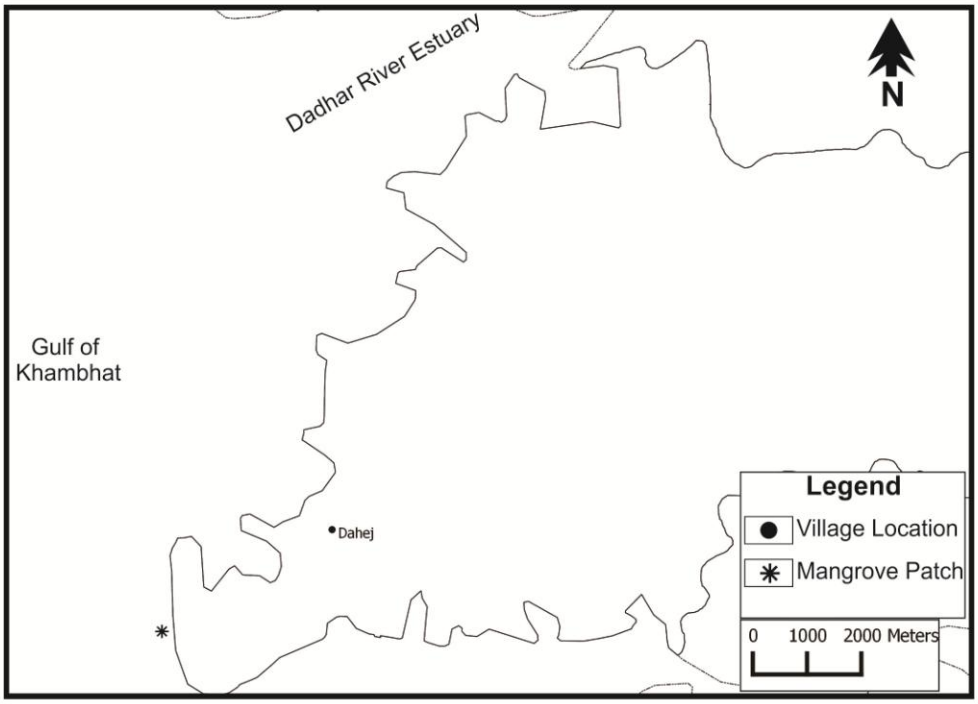


Utilization of Mangrove as Fishing Resources

Fig. 5.40.: Mangrove Utilization Status of Village: Dahej



Average Income Generation from Mangrove Utilization (Rs./Month)



Map. Village Location and Mangrove Utilization Patch

5.21. Utilization as Fodder

Mangrove is a primary producer in the mangrove ecosystem. In natural scenario mangrove leaves and twigs are used by various local fauna. Matsuda et al. (2009) studied Proboscis monkeys (*Nasalis larvatus*) in Mayasia and found that mangrove's young leaves formed 65.9% of its total diet. Steinke et al. (1998) studied feeding behavior of Red mangrove crab (*Sesarma meinerti*) and found that crab prefers mangrove leaves in following order yellow *Bruguiera gymnorrhiza* (L.) Lam. > yellow *Avicennia marina* (Forssk.) Vierh. > green *B. gymnorrhiza* > green *A. marina*. Thus mangrove leaves have an important role to play in the mangrove ecosystem.

In the coastal areas where little fodder grows due to high saline Soil, animal herders tend to utilize mangrove as fodder. Baconguis et al. (1990) studied forage and livestock production in the mangrove forest in the Philippines and found the use of mangrove leaves as fodder. Amer (2000) studied the use of mangrove as fodder in Red Sea (Egypt). Pattanaik et al. (2008) studied the utilization of mangrove forest in the Bitarkanika Wildlife Sanctuary (Orissa) and found that local communities were using leaves of 12 species of mangroves like *A. alba*, *A. marina*, *B. Gymnorrhiza* etc. as fodder. Upadhyay et al. (2002) studied mangrove use in India and found that leaves of *A. marina* are being utilization as fodder for cattle in arid regions of Gujarat, Maharashtra and Goa.

Indira et al. (2004) has done a pioneering survey on mangrove utilization and found that 81.6 % of households are using mangrove as fodder. Most recent work is done by Gujarat Ecological Commission (2011) on the utilization of mangrove as fodder in Gujarat and found that 65.38% of household were using mangrove as fodder.

In present study (Fig. 5.42), it was found that the local population is using mangrove as fodder only during the year or time when rain gets delayed. This finding was also stated by Indira et al. (2004). So, utilization of mangrove as fodder mainly occurs during summer, i.e. April-May. But this utilization can be extending up to June-July if rains get delay. It was found that maximum, 14 persons, fodder usage was in Nada and Degam Villages, while zero mangrove fodder utilization were found in Kamboi, Ishanpur, Kapuria, Tankari and Achod villages. Average of fodder user was 4.32 persons. Indira et al. (2004) found that utilization as fodder in Neja and Nada was 9 and 14 persons, respectively. According to GEC (2011) Nada have fodder consumption of 56.5%. Average income of person, utilizing mangrove as fodder (during those months when use of mangrove as fodder) was 2144 Rs/months with maximum at Jantrana (3500 Rs/month) while minimum at Denva (1100 Rs./month).

5.22. Utilization as Fishing Resource

Mangrove ecosystem, being most productive, harbors a large diversity of associated fauna. One can easily observe a variety of fauna like birds, fish, crab, prawns, molluscs etc. in a healthy mangrove ecosystem. These associated fauna depend upon mangroves for various purposes in different stages of their life cycle. Mangrove can provide an excellent breeding ground for fish and crabs, as there is a low density of predators. Mangrove root and stems, when submerged, provide a defensive structure to juveniles. Verweij et al. (2006) studied the importance of mangrove on juvenile coral fish and found that mangrove structure, availability of food and shade attract them. Nagelkerken (2004) studied mangroves of the Caribbean region and found that mangroves act as feeding ground to fishes.

Fishermen worldwide use mangrove as a fishing ground. Khalil (1999) has done an economic valuation of mangrove along the Karachi coast (Pakistan) and found that fishermen used mangrove as boat building materials and for tying the fishing net. Hasan (1993) studied fish and shrimp harvest in mangrove area of Sindh (Pakistan) and estimated that total shrimp landing was 2945 metric tons and fish landing 1373.84 metric tons in 1992. Pattanaik et al. (2008) studied the utilization of mangrove forest in the Bitarkanika Wildlife Sanctuary (Orissa) and found that local communities were using four mangrove species like *A. corriculatam, B. gymnorrhiza, B. parviflora* etc. for boat building and fishnet tying.

Indira et al. (2004) studied mangrove utilization in Gujarat and found that total 135 households are engaged in fishing. Most recent work done by Gujarat Ecological Commission (2011) on the utilization of mangrove as fishing in Gujarat noted that 30% of households were using mangrove as fishing.

In present study, Fig. 5.43, it was found total 199 persons out of 400 persons have an occupation of fishing with an average of 10.47 persons in a village. Maximum fishermen were recorded by Ishanpure, 25 persons, while the lowest were recorded in Degam, 1 person. Out of these 199 fishermen, 170 were men, with an average of 8.95 men/ village, and 29, with an average of 1.53/ village, were women. Highest number of male fishermen were founded in Ishanpur (25 men) and the lowest number of male fishermen were observed at Degam (1 man). Highest numbers of female fishermen were found in Denva and Dahej, with 5 women each while the lowest number of female fishermen found in villages named Kamboi, Degam, Jantrana etc. Out of 199 persons only 170 persons using mangrove as fishing ground with average of 8.75 persons. Out of these 170 mangrove users, 157 were men, with an average of 8.26, while 20 were female, with an average of 1.05. Highest number of male fishermen that are using mangrove as fishery resources were found at Isahnpur (25 Male) while the lowest number of male fishermen that are using mangrove as fishing were observed at Degam (1 male). In case of female fishermen using mangrove as fishing resources were observed highest at Denva and Dahej with 5 female fishermen each. The lowest number of female fishermen using mangrove as fishing was observed as zero at villages named Kapuria, Tankari, Achod etc. 126 persons were using mangrove as a Pole, for tying fisher net. Out of its highest number of fishermen, that are using mangrove as poles, were observed at Ishanpur (25) while lowest number was observed at Kavi (0 person). Out of 170 persons that are using mangrove as fishing ground total 104 persons were using mangrove for crab fishing. The highest number of fisherfloks using a mangrove patch for crab hunting were observed at Ishanpur (25 person) while the lowest was observed, 1 person, at Degam, Kapuria, Jantrana etc. Indira et al. (2004) shows the total fishermen household was 5 and 52 in Neja and Nada respectively. In present study shows 9 and 8 fishermen in Neja and Nada respectively. GEC (2011) in its study found that Neja have 41.2 % of the fishermen population, while present study shows 35% of the total sample size, i.e. 25 persons, were fishermen.

In the present study it has been observed that the average income of fishermen in the area was 1760.80 Rs/month. The difference between fishermen using mangrove for fishing and non mangrove user can clearly see. From the data it can be revealed that the average income of fishermen using mangrove patch were 2847.47 Rs/month against the non-mangrove user, which have average income of 673.68 Rs/month. Highest average income from the fishing in mangrove area was recorded as 4537 Rs/month at Ishanpur. While the lowest income of fishermen that are using mangrove patch were recorded in Degam, 1200 Rs/month. In a study made by GEC (2011) shows that the average income (both after and before of mangrove plantation) of the fishermen at Nada was 2548 Rs/month while in present study average income of Nada fishermen (both mangrove user and non-user) was recorded as 2075 Rs/month.

5.23. Utilization of Seed

Mangrove seeds are bulky and contain more biomass than leaves or twigs. Thus, many associated fauna like to predate on the mangrove seeds and act as natural control of the mangrove forest. Smith (1987) studied seeds predation with relation to tree dominance and distribution. He observed that crabs belong to Graspidea were heavily predated upon Avecinnia marina. Keith (1997) also studied seed predation in tropical mangrove forest. Robertson et al. (1990) studied seed predation by insect in a tropical mangrove forest in Australia and found Seeds of the species Avicennia marina, *Bruguiera gymnorrhiza*, *B. parviflora* etc showed high (>40%) levels of insect damage.

Human society is also fond of mangrove seeds which they are used as food. Mangrove species like *Aegiceras corniculatum*, *Avicennia alba*, *Avicennia marina*, *Avicennia officinalis* etc. are commonly used for their seeds. Bradley et al. (2008) studied review socio-economy and mangrove forest and found that some countries have establishment hatcheries for seed production of cultured species. In present study, Fig. 5.44, total 369 persons out of 400 persons consume seeds as food. During survey it has been observed that local population makes local delicacy from seeds of Avecinnia marina, called “Kathiyu”, mixed with curd. Highest number of seed consumers were observed in Ishanpur, 25 persons while the lowest were lowest mangrove seed utilization was observed at Jantrana, 7 persons. Average seed consumption among the village was 19.42. Local people also sale these seeds at local market and market of Jambusar, Vaghra and Bharuch. Average income from seed sale was 218.58 Rs/month during seeding months. Higher income from seed sale was observed at Sigam (321 Rs/month) while the lowest was in Degam, 0 Rs/month. According to GEC (2011) 31% of total surveyed, 227 households, population were utilizing seeds as food while in the present study it was observed that 92.52% of surveyed population were using seeds.

This high collection of seed can have a significant effect on recruitment of mangrove. Results of fixed quadrates shows that average, both years, seed to seedling ratio at Neja (1.16:1) where 25 persons use seed. At Neja number of flowering trees observed as 13 (in June'10) and Seedling (<10 in.) were 15 (in December'10). During the second year at Neja number of flowering trees observed as 19 (in June'11) and Seedling (<10 in.) were 13 (in December'11). This ratio was 1.13:1 at Asarsa and seed consumption was 18. On an Asarsa number of flowering trees observed in 20 (in June'10) and Seedling (<10 in.) were 17 (in December'10). During the second year at an Asarsa number of flowering trees observed as 24 (in June'11) and Seedling (<10 in.) were 22 (in December'11). Dahej have seed to seedling ratio of 0.84:1 while having 23 people using seeds. At Dahej number of flowering trees observed as 13 (in June'10) and Seedling (<10 in.) were 16 (in December'10). During the second year at the Dahej number of flowering trees observed as 15 (in June'11) and Seedling (<10 in.) were 17 (in December'11). There was a positive correlation between seed consumption and Seed to seedling ratio during 2010 and 2011, 0.83 and 0.93 respectively.

Fig. 5.41: Anthropogenic Activities observed

Grazing of Mangrove

Collection of Mangrove as Fodder

Use of Mangrove in Fishing

Crab Fishing in Mangrove

Fishermen at Study Site

Effluent discharge at Sarod

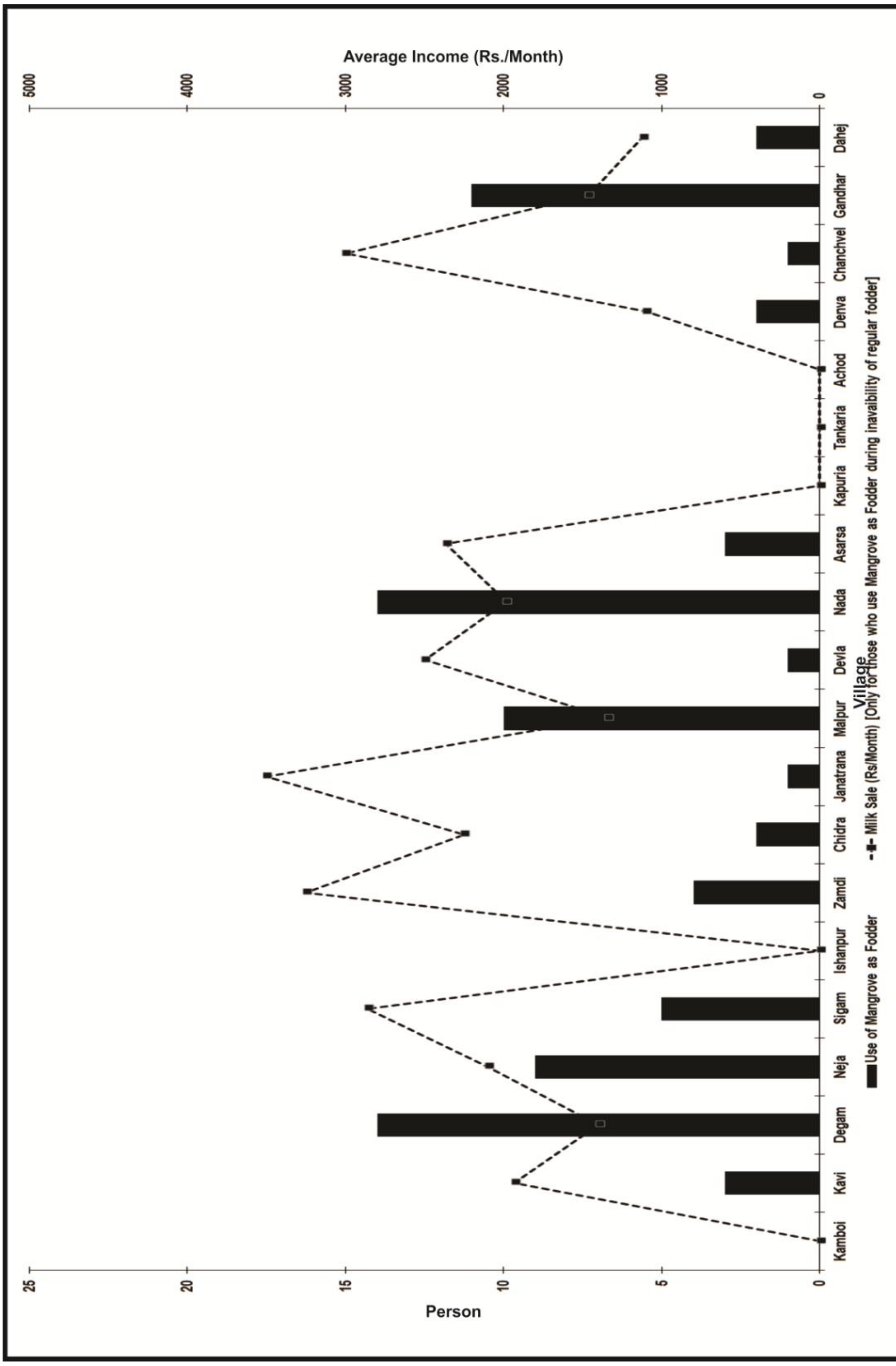


Fig.5.42: Mangrove Use as Fodder

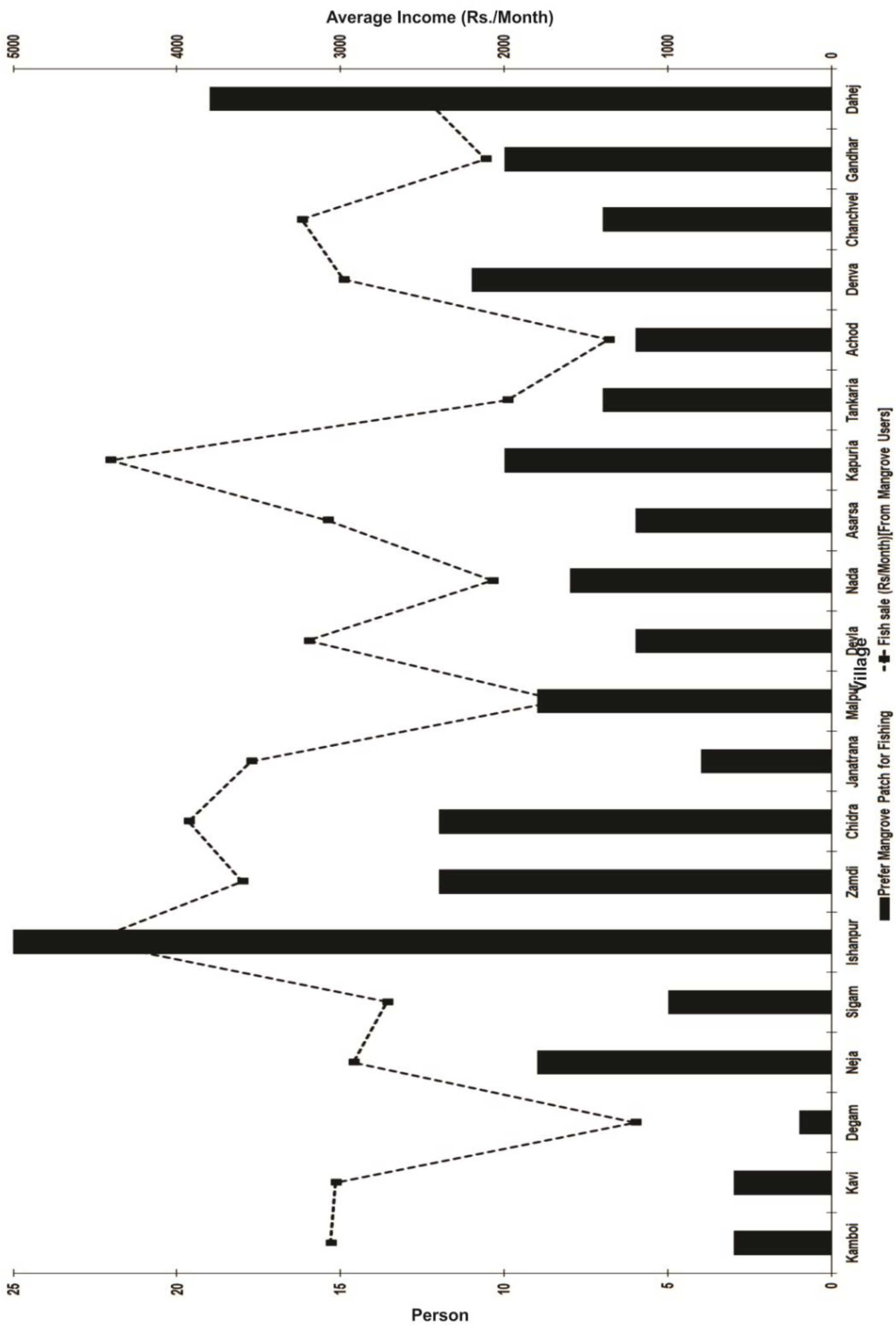


Fig. 5.43: Mangrove Use as Fishing Resource

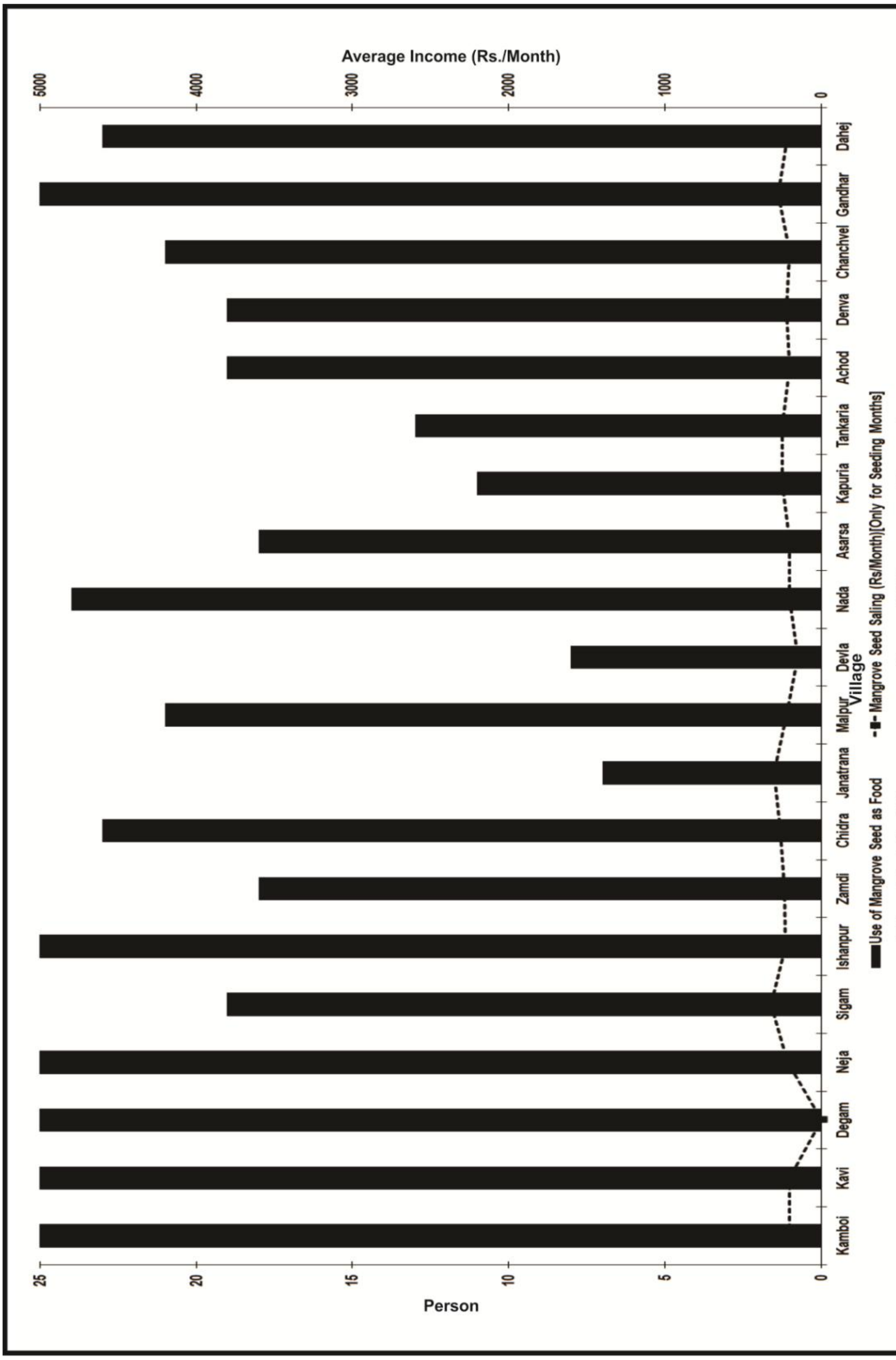


Fig.5.44: Mangrove Seed Use as Food

CHAPTER 6: EDUCATION POGRAMES IMPLIMENTATION

6. Educational Programs

Education or Awareness is the most important part of conservation of natural resources and environment as whole. During the study it has been found that there was a high dependency on local community on mangrove, so this component has become more important. This component is based upon fact that there is greater possibility to conserve environment if its users, i.e. local community, become more sensitive towards its degradation and future problems to their culture or lifestyle.

Many projects and scientist recognized Mangrove awareness as an important component in conservation. Hartnoll (2002) studied mangrove ecosystem in Zanzibar (Africa) and mentioned that mangrove awareness is the key of mangrove conservation. Guyana Mangrove Restoration Project (2010) reported that after the awareness programs of mangroves its role in carbon sequestration was understood better. Ghasemi et al. (2010) reviewed mangrove value and conservation strategy by local communities in Hormozgan (Iran) and stated that such awareness programs should be prepared in local language for better impact.

6.1. School Student Awareness Programs

It has been observed that it is easy to influence tendering minds of children and thus make them a hardcore protector of the environment. Keeping this fact in mind maximum numbers of awareness programs was carried out in the local village schools. By doing this it can be assured that future of mangrove will be in good hands.

In present study, Figs. 6.1, 6.2 and 6.3, total 18 school awareness programs were conducted in 14 coastal villages of three talukas. Total 2,956 students and 96 teachers were made aware during these programs. Highest numbers of students were present in Degam (668) while lowest numbers of students were present at Vaghra (35).

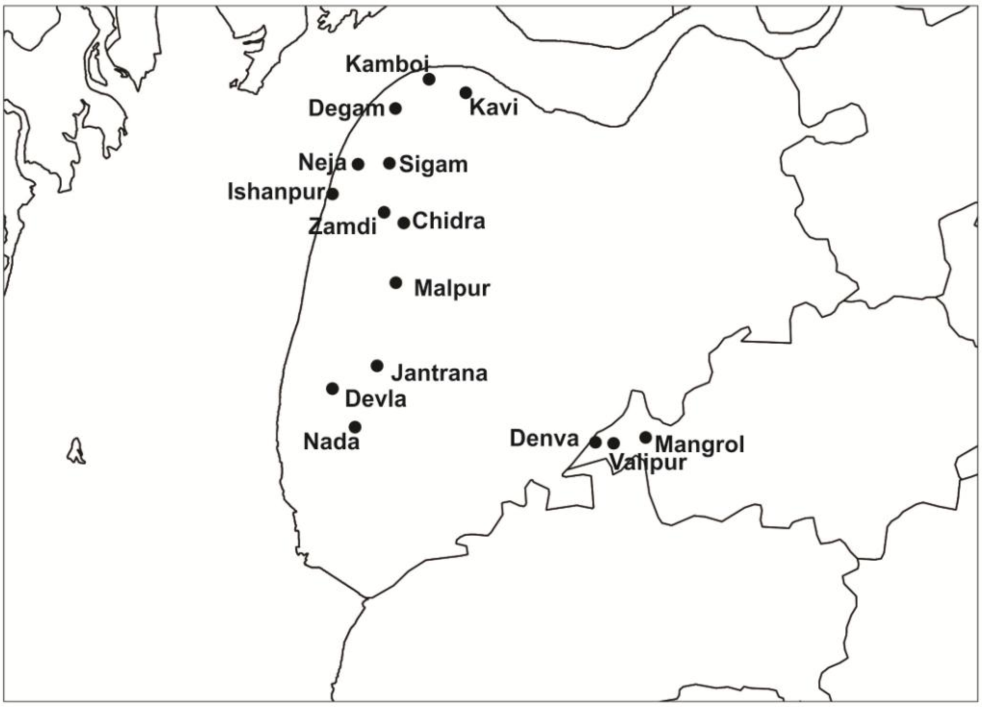
6.2. Community Awareness Programs

Members of the local community are the one who leaves their impact on mangrove ecosystem, during fishing, fodder collection or seed collection. So, this group also has been targeted in the present study. During the discussion with people I emphasized simple methods of conservation management like divide mangrove patch into small compartments and use them in turns, collect only leaves for fodder etc. of sustainable use. By doing this it can be assured that present mangrove can be protected.

In present study total 15 community awareness programs, Fig. 6.1, 6.2 and 6.3, in 15 coastal villages of two talukas were conducted. During these programs total 425 members of the local community were made aware. Highest numbers of members (60) were made aware at Malpur while lowest numbers of members (10) were made aware at Denva.

Fig. 6.1: Locations of Awareness Programs

Map : Villages Covered for School Education Programs



Map : Villages Covered for Community Awareness Programs

Fig. 6.2: Awareness Programs

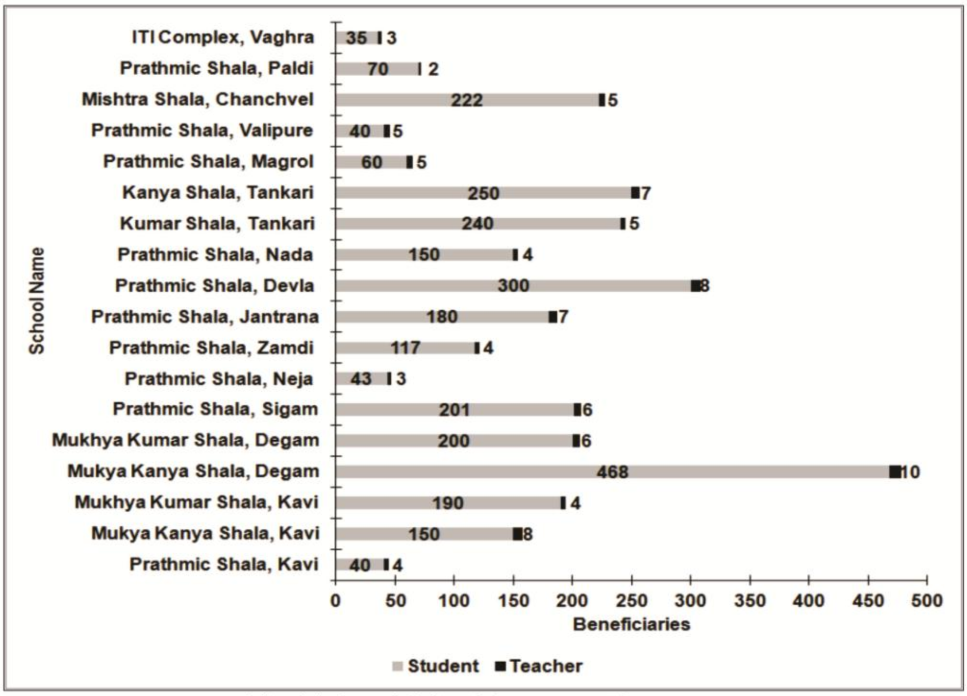


Fig. (a): Local School Awareness Programs

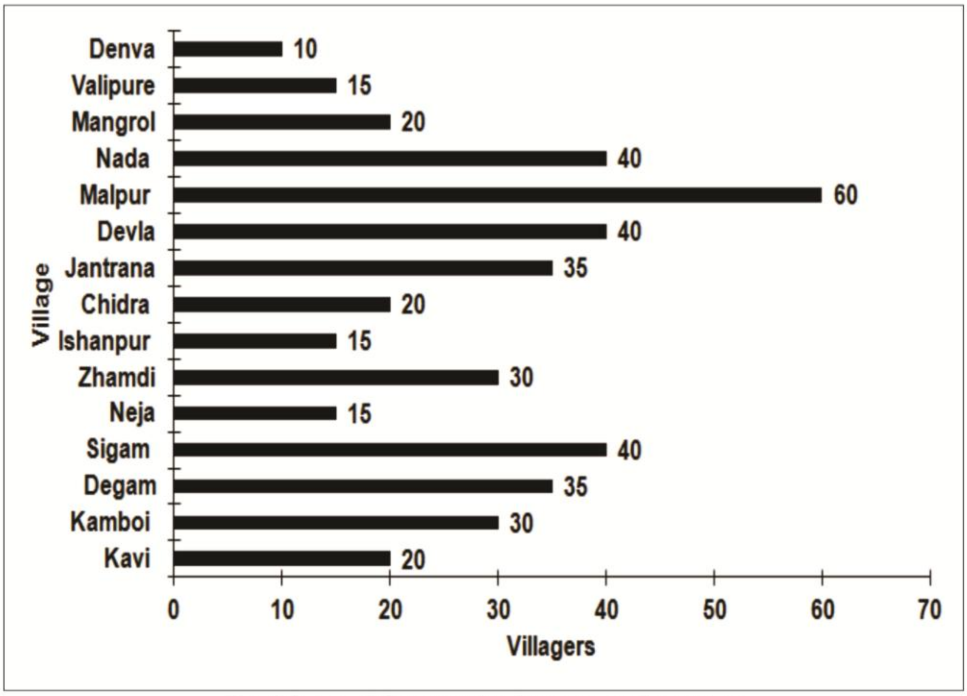


Fig. (b): Local Community Awareness Programs

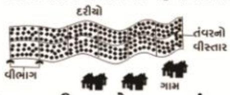
Fig. 6.3: School Awareness Program

Fig. 6.4: Community Awareness Program

Fig. 6.5: Awareness Leaflet on Mangrove (in Gujarati)

તંવરનું સંરક્ષણ અને ગામનો ઉધ્ધાર

- તંવરના લાકડાનેા ઉપયોગ કરવાને બદલે આપણે બાયોગેસનો ઉપયોગ કરી શકીએ. એક ટોપલા છાણ માંથી નીકળતા ગેસથી એક આખા દીવસની રસોચ થઈ શકે છે.
- પશુઓ ના ઘાસચારા માટે ગામની ગોચર જમીન માં જરુરી ઘાસ ઉગાડવવું જોઈએ અને જો તંવરનો ઉપયોગ કરવાનો થાય જ તો તે વીસ્તારને અલગ અલગ વીભાગ માં વહેચી ને તબક્કાવાર ઉપયોગ કરવો જોઈએ.
- માછીમારી કરતી વખતે નાની માછલીઓ અને નાના કરચલાઓ ને ન પકડવવા અને તંવરના વીસ્તારને અલગ અલગ વીભાગ માં વહેચીને તબક્કાવાર ઉપયોગ કરવો જોઈએ.



તંવરનો ઉપયોગ કરતી વખતે ધ્યાનમાં રાખવા જેવી બાબતો

- બરતણ માટે લાકડા કાપતી વખતે હંમેશા નીચેની ડાળીઓ જ કાપો, જેથી ઝાડ ઉપરની તરફ વધે
- પશુઓના ઘાસચારા વખતેપશુઓને ચેરના વીસ્તારમાં લઈ જવાનું ટાળો અને તેમને ચેરના પાન હાથેથી તોડી ને ખવડાવવો
- માછીમારી કરતી વખતે ચાલતી વખતે નાના છોડ તુટી ન જાય તેનું ધ્યાન રાખો અને નાના છોડનો ઉપયોગ જાળ બાંધવા માટે ન કરો

આપણને તંવરને એક કમાઉ દીકરાની જેમ સાચવવો જોઈએ,
જો આપણે આને નહી સાચવવીએ તો તેના માંઠા પરીણામેા આપણને જ ભોગવવા પડશે.
આપણે આપણી માટે અને આપણી આવનારી પેઢીઓ માટે આપણા તંવરને જાળવવા જોઈએ.

તંવર - એક કમાઉ દીકરો

તંવર

તંવર એ ખારા પાણીનું વૃક્ષ છે, જે દરીયાના ભરતી અને ઓટના વીસ્તારમાં કાદવવાળી કાળી જમીનમાં અને ગરમ અને ભેજવાળી આબોહવામા ઉગે છે.તેના ઉદ્ભવ આશરે ૧૧૪ લાખ વર્ષો પુર્વે આજના ઈન્ડો-મલાયા વીસ્તારમાં થયો હતો. હાલમાં વીશ્વમાં તંવરની કુલ ૬૦થી પણ વધુ જાતીઓ મળી આવે છે. જ્યારે ભારતમાં કુલ ૩૮ જાતીના તંવર મળે છે. ગુજરાતમાં કુલ ૮ જાતીના તંવર જોવા મળે છે. આજથી વર્ષોપુર્વે આપણે ત્યાં ૧૦ જાતીના તંવરના વૃક્ષો મળી આવતા હતા, પરંતુ આપણે તંવરની બે જાતોની એવી રીતે કપાત કરી કે તે બે જાતેા હવે ગુજારાતમાં જોવા મળતી નથી. તો આપણી ફરજ બને છે કે આપણે આ ૮ જાતીઓ ને બચાવવી જ જોઈએ.

તંવરની પર્યાવરણ માટેની ઉપયોગીતા

તે પક્ષીઓને રહેવવાનું સ્થળ પુરું પાડે છે. આ પક્ષીઓ બીજાકુંરણની ક્રીયા દ્વારા આપણા કૃષી ઉદપાદનને વધારવામાં મહત્તવનેા ભાગ ભજવે છે.

તે માછલીઓને રહેવવાનું સ્થળ પુરું પાડે છે. આ માછલીઓનો ઉપયોગ આપણે ખોરાક માટે કરીએ છીએ.

તે દરીયાકાઠાંની જમીનું ધેાવાણ અટકાવે છે. આ રીતે આપણા કાંઠાના ખેતરોની જમીનનું ધોવાણ અટકે છે.

તંવરની વીવીધ કક્ષાએ મહત્વ

વીશ્વ કક્ષાએ તંવર અંગારવાયુનું શોષણ કરીને આપણને પ્રાણવાયુ પુરો પાડે છે. તંવર આપણા દેશની જૈવ-વીવીધતાનું રક્ષણ કરવામાં અગત્યનો ભાગ ભજવે છે. ગુજરાત રાજ્યને તંવરથી દરીયાના તોફાનોથી રક્ષણ આપે છે તથા દરીયાની માછીમારી માં ઉપયોગી છે. તંવર આપણા ગામને ઘાસચારો, બરતણનું લાકડું, માછલીએા પુરી પાડે છે. તદઉપરાંત તેઓ આપણી ખેતીલાયક જમીનનું ધોવાણ અટકાવે છે.

તંવરની ઉપયોગીતા

- **સીધી રીતે ઉપયોગીતા:** આપણે તંવરનો સીધી રીતે ઉપયોગ પશુઓના ઘાસચારા,બરતણ ના લાકડા, બાંધકામના લાકડા, માછલીઓ અને ખોરાક માટે કરીચે છીએ.
- **આડકતરી રીતે ઉપયોગીતા:** તંવર આપણને દરીયાચી તોફાનથી રક્ષણ આપીને, આપણી માછીમારીની જગયાનું રક્ષણ કરીને, આપણી કાંઠાની ખેતીલાયક જમીનનું ધોવાણ અટકાવવીને, તથા જમીનની ખારાશ અટકાવવીને આપણને આડકતરી રીતે ઉપયોગી થાય છે.

તંવરનું મુલ્ય

- ગુજરાતના તંવરના વનો, કે જે ૯૬૦ ચો.કી.મી. માં ફેલાચેલા છે તેનું, કુલ મુલ્ય ૪૪૬.૧૧ કરોડ થાય છે.
- સારી રીતે સંરિક્ષચેલા તંવરના જંગલો આપણને ૪૯,૯૩૯.૧૨ રુપીચા પ્રતી હેક્ટર પ્રતી વર્ષ કમાવવી આપે છે.

તંવરની ઉપયોગીતા અને તેનું મુલ્ય

સીધી ઉપયોગીતા	કુલ મુલ્ય (કરોડ રુપીચા)	પ્રતી હેક્ટર/પ્રતી વર્ષ (રુપીચા)
ઘાસચારો	૮૨.૭૬	૯૬૫૨.૮૩
બરતણ	૪.૪૯	૫૪૫.૮૫
માછલીઓ	૭૨.૮૮	૪૭૪૭.૯
આડકતરી ઉપયોગીતા		
દરીયાચી તોફાનથી રક્ષણ	૩૬.૧૪	------
ધોવાણ અટકાવવી	૧૯.૫૯	------

આપણને તંવરનું આ મુલ્ય ત્યારે જ મળી શકે જ્યારે આપણે તંવરને સાચવી ને વાપરીચે.

Fig. 6.6: Awareness Poster on Mangrove (in Gujarati)

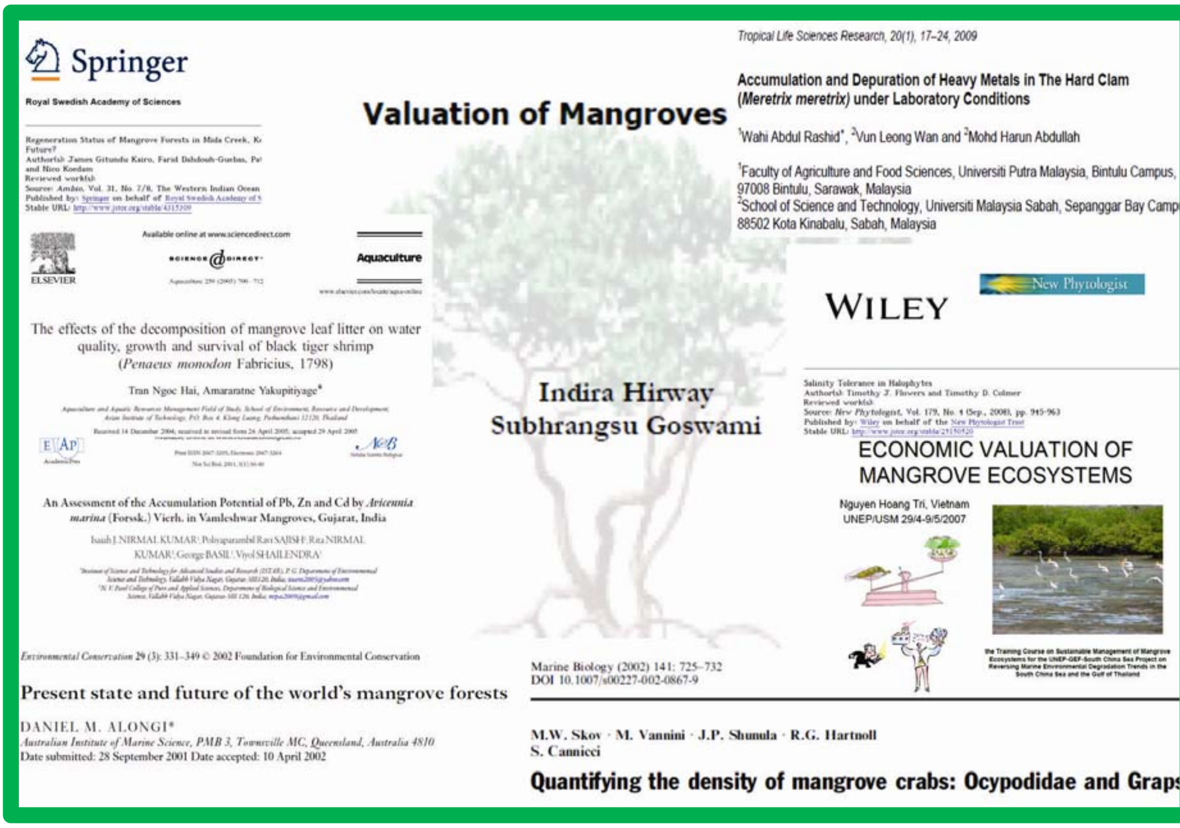
CHAPTER 7: CONCLUSSION

7. CONCLUSIONS

Mangrove ecosystem is one of the most productive ecosystems of the world. Its sheer existence can protect various other marine ecosystems, like mudflats and coral ecosystem, and its faunal components, like birds, fish, crab, molluscs etc. Well being of mangrove ecosystem is dependent upon physiochemical parameters, like pH, salinity, alkalinity, hardness, total solids, and organic matter etc. Any change in this can have a devastating effect on the ecosystems. The presence of mangrove is also important for the well being of human society. Mangrove ecosystem, not only provide protection from the natural hazards like tsunami, but is a major source of food, in terms of fishing, fodder and seeds, to the local community. Due to this high dependency mangrove feels a tremendous pressure. Apart from this mangrove of a world facing extreme pressure from the industrial and domestic effluent discharge as Mangrove is believed to have a large capacity of absorbing industrial and domestic waste. Gujarat a leading state in terms of increasing of mangrove cover in India and about 90 percent of mangroves in Gujarat are located around the Gulf of Kachchh while the rest of the mangroves are found in the Gulf of Khambhat and on the South Gujarat coast. As there is more mangrove cover in the Gulf of Kachchh, all the major study has been carried out there while Gulf of Kambhat mangrove studied very less.

From the results of the present study it has been found that there are many factors, pH, salinity, hardness, alkalinity, sediment composition, organic matter, that affect the natural distribution and density of mangrove in the study area. In addition to these natural factors, other factors like, chemical oxygen demanded, phenolic compounds and heavy metals, which are introduced into the ecosystem as a result of various anthropogenic activities, also control the density and diversity of mangroves and associated fauna. There are two clear types of anthropogenic pressure on the sites of the study area. One is discharges of industrial waste to mangrove ecosystem. As per this factor most polluted and disturbed sites Sarod, situated at the point of effluent discharge, have high impact of pollutants and thus have the lowest density of mangrove and fauna. The other type of pressure is use of mangrove for variety of purposes, suchas use of mangrove as fodder, fishing and seed as food. This type of pressure is more important and has significant impact on mangrove density.

CHAPTER 8: BIBLOGRAPHY



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CHAPTER 9: SUMMARY

No	Parameter	Sarod	Neja	Asarsa	Dahej
A	**Location**				
1	N	22°10'32.12"	22° 8'52.57"	21°57'10.28"	21°42'51.39"
2	E	72°45'18.49"	72°33'54.19"	72°35'32.55"	72°34'57.98"
3	Estuary	Mahi	Mahi	Dadhar	Dadhar
4	Taluka	Jambusar	Jambusar	Jambusar	Bharuch
B	**Mangrove Patch**				
5	Type	Sparse	Open	Open/Dense	Dense
C	**Sediment Characteristic**				
6	>2 mm (gm)	100	20	200	0
7	>1 mm (gm)	120	100	140	10
8	>0.500 mm (gm)	60	40	60	60
9	> 0.250 mm (gm)	40	40	60	40
10	>0.125 mm (gm)	40	0	40	0
11	Water Holding (per Kg)	320	440	380	320
12	Avg. pH	6.54	7.73	7.76	8.06
13	Avg. Salinity (ppt)	0.20	1.25	1.05	1.33

9. Summary

Mangrove forests are among the world's most productive ecosystems and thus often called as 'tidal forests', 'coastal woodlands' or even 'oceanic rainforests'. Mangroves are woody plants that grow in tropical and sub- tropical latitudes along the land-sea interface, bays, estuaries, lagoons, backwaters, and in the rivers, reaching upstream up to the point where the water still remains saline Qasim (l998). The word "mangrove" dates its origin in 1613 and it is usually considered a compound of the Portuguese word "mangue" and the English word "grove" (Kathirasen, 2001).

Mangroves evolved some 14 million years back in the Indo-Malaya region and 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 (38° 03' S), Australia (38°45' S) and on the east coast of South Africa (32°59' S), according to Spalding (1997). Around 34 major and 20 minor mangrove species belonging to about 20 genera in over 11 families have been recorded globally by Tomlinson (1986). Total global mangrove coverage is 18 million hectares and it is just about 0.45% of world forests & woodland, Spalding (1997). According to Kathiresan (2003a) mangroves of South and Southeast Asia form the world's most extensive and diverse mangrove system comprising 41.4% of global mangroves. Indian mangroves make up 3.1% of the total global cover and are distributed along all the maritime states, except the union territory of Lakshwadeep, covering an area of about 4461 sq. km along the 7,500 km long Indian coastline (Anon. 2005). Kathiresan (2003b) stated that floral diversity of mangroves of India is comprised of 38 core mangrove species.

Gujarat state, which has about 1,650 km long sea coast and has mangroves spread over an area of 911 Sq km, which comes to about 20 percent of the national mangrove area. About 90 percent of mangroves in Gujarat are located around the Gulf of Kachchh while the rest of the mangroves are found in the Gulf of Khambhat and on the South Gujarat coast

(Hirway, 2004). Gujarat is represented by 8 species from 5 families of mangroves that grow in the state.

Mangrove forests are extremely important coastal resources, which are vital to our socio-economic development. A vast majority of human population lives in coastal area, and most communities depend on local resources for their livelihood. The mangroves are sources of highly valued commercial products and fishery resources and also as sites for developing a burgeoning eco-tourism, Kathiresan and Bingham (2001). The mangrove forests have been shown to sustain more than 70 direct human activities, ranging from fuel-wood collection to fisheries Dixon (1989) and Lucy (2006). Even thought the full value of mangrove ecosystems is often not recognized, Hamilton et al (1989), many scientists from all over the world carried out many studies on the socio-economic study and Economic Valuation of many mangrove ecosystems. Ruitenbeek, (1992) calculate value of Indonesia's Mangrove around US$ 3,000 /Ha/Year. Christensen (1982) and Sathirathai, (1998) estimated values of Thailand mangrove US$ 230-1200 /Ha/Year. Batagoda (2003) estimate US$ 8,000,00/Ha/Year for the services of the mangrove for strom protection in Sri Lanka. Ong (1982) stresses the socio-economic and environmental value of mangroves and the related fisheries versus forestry. It has been estimated that small scale fisheries in mangrove waters in the world produce nearly one million tons of fisheries, molluscs, crabs and shrimps annually, that is equivalent to about 1.1 percent of the world fishery catch Kapetsky (1985). 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. An interesting study by Badola and Hussain (2003) provides information on the structure of the ecosystem, basic socio-economic patterns, use patterns and rates and their economic costs as well as an extensive survey of the attitudes of the people towards conservation and various proposed and existing alternatives in the Bhitarkanika Protected Area. Analysis by Das (2009) on the storm protection role of mangroves revealed that if the mangrove cover had remained at the level that it had been in the 1950s, the area would not have suffered any fully collapsed houses at all. Survey conducted in India estimate 49939.12 INR/Ha/yr (Hirway, 2004) for Gujarat. The most recent 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.

Because of the above mentioned mangrove use and value, Mangrove and other estuarine habitats have been under tremendous human induced stresses due to their immense economic, recreational and transport services. Increase in human population in estuarine areas will further increase the pressure on mangroves Upadhyay and Mishra. (2008). Though India had agriculture based economy in the pre independence era, favoring conditions like ample supply of the natural resource lead to the growth of industry based economy in post independence era. Consequently, ambient air and water quality is seriously affected which is far lower in comparison to the international standards. The problem is worse in the case of water pollution. It is found that one-third of the total water pollution comes in the form of effluent discharge, solid wastes and other hazardous wastes. Untreated or allegedly treated effluents have increased the level of toxic heavy metals up to more than 20 times the safe level in the critically polluted areas of the country. Industrial development is exceedingly expanding in the south Gujarat region and it already has one of the largest chemical industrial areas. The organic chemical based industries dispose effluent through various small and large rivers as well as through effluent channels. Study carried out by Greenpeace revealed that Nandesari Industrial estate have more than 300 units. Tiwari and Mahapatra (1999) stated that the estate have units that produce a wide range of chemicals, pharmaceuticals, dyes, pesticides and plastics. The main contributors to the total quantity of waste generated by the estate include dyes and dye intermediates manufacture (82%), and the production of drugs and pharmaceuticals (13%), CPCB (1996). The CETP of this estate empties its treated effluent at one of the study sites, Sarod in Mahi River estuary.

The extraordinary capacity of the mangrove habitat sediments to accumulate large amounts of pollutant make them a favorable ground for the effluent disposal by industries. Various kinds of the pollutants, from the industries and sewage, are accumulated in the mangrove swamps changing bio-physical environment of the habitat and consequently the floral and the faunal diversity is changing at the fastest rate. There are several studies on heavy metal contamination in mangrove sediments and their effects on organisms like Lian et al., (1999), Rai et al., (2003) and Ravikumar et al., (2007). There are several studies on heavy metal contamination in mangrove sediments and their effects on organisms, but little is known about heavy metal uptake by mangrove plants Seng et al., (1987); Ismail and Asmah, (1992). One of the pioneering study on heavy metal accumulation carried out by Nirmal Kumar et al (2011) in Narmada Estuary.

Besides coastal pollution, mangrove ecosystem suffers from various activities of the dependent local communities. In Gujarat pionring study on these socioeconomic aspects was carried out by Hirway et al. (2004, 2007). Mangrove leaves and fruits are used as cattle feed; the plants once browsed by the camel struggle for existence and remain dwarf. Reclamation of the land for the agriculture is another act of men that decreases mangrove cover. Mangroves are also used in the boat making, as fire wood, timber, charcoal making etc. by the local communities. The regular activity of local people disturbs the habitat and inhabitants of the ecosystem.

As there were very few studies carried out on mangrove perticularly in southern Gujarat very few data is available, apart from Bhatt (2009) carried out survey in Southern Gujarat on Mangrove diversity in Purna river, Nirmalkumar (2011) carried out heavy metal status in mangrove and Hirway (2004, 2007) focused on Socio Economic factor of Mangrove Ecosystem etc.. But all above scientist carry study on particular aspects rather cover Anthropogenic Pressure and its conservation option as a whole. This study thus important as it covers all aspects of present Mangrove Ecosystem from Abiotic factors to spreading awareness on Mangrove among the local population who are depending on it, as part of conservation.

1). Sarod Site (22°10'32.12"N & 72°45'18.49"E)

Sarod (fig.1[a]) is situated at Mahi Estuary and the point of effluence release of the Effluent Channel Project. This site has very less mangrove cover which could be the result of the high concentration of pollutants released from the channel. We found burrow count and mangrove density very low in this area.

2). Neja Site (22° 9'2.00"N & 72°33'3.10"E)

Neja (fig.1[b]) is situated in between Mahi and Dhdhar river estuaries. This site has a good growth of mangrove and also has good burrow density. But as this site is near to the village and has a good mangrove cover, grazing pressure is high. Huge man made ditches also observed, which result of crab fishing.

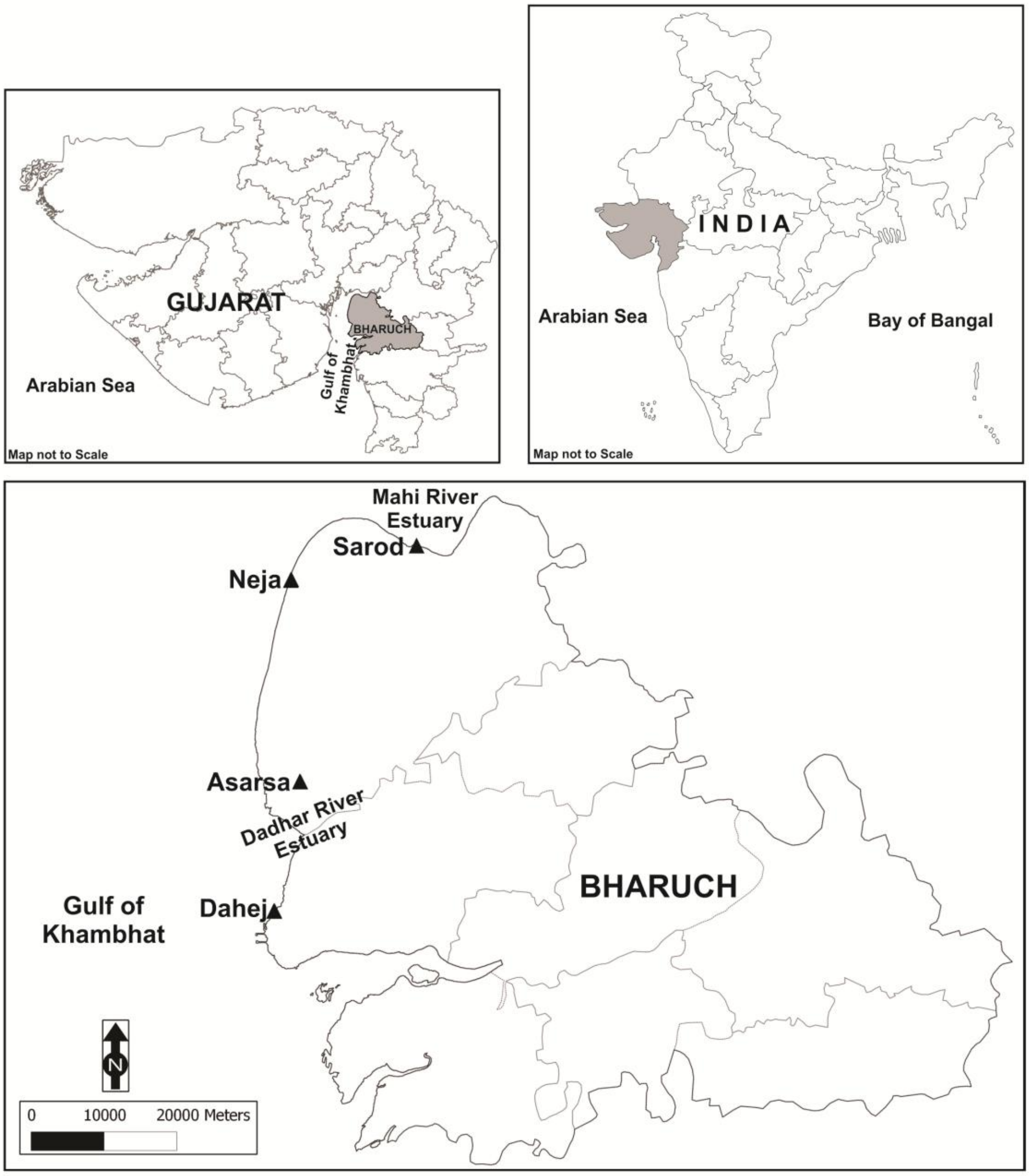
3). Achasara Site (21°53'53.75"N & 72°34'56.43"E)

Achasara (fig.1[c]) is situated in Dhadhar estuary. This site has recently planted mangrove. Nada which has one of the oldest mangrove patches in the upper part of the gulf of Khambhat is just beside this site. This newly planted Mangrove supports a good number of the local population who carried out fishing on the site.

4). Dahej (21°43'13.50"N & 72°31'42.90"E)

Dahej (fig.1[d]) is situated on the southern part of Dhadhar estuary. This is a very famous port from ancient time, now serving as major oil terminal of the southern Gujarat. This site has patchy mangroves towards the low tide line and dense mangrove towards high tide line. The burrow counts are also good.

Fig. 2.1: Study Site Location



Objectives

1. Qualitative and quantitative status of mangrove habitat:
    a. Study the extent and status of mangrove ecosystems
    b. Evaluate the abiotic and biotic status of mangrove ecosystems
2. Anthropogenic pressures and depend on mangroves:
    a. Analyze the types of anthropogenic pressures and their extent in the study area
    b. Evaluate the status of pollution and its impacts on the mangrove Ecosystem.

3. Education program implementation
    a. Evaluate status of knowledge on mangroves among the population
    b. Community awareness programs in conservation management of mangrove ecosystem

Types of anthropogenic influences in the study area

Mahi and Dhadhar river estuaries are one of the important estuaries on the upper part of Gulf of Khambhat. Both estuaries are facing a different kind of anthropogenic pressure. On the prior visit, each site is checked for various anthropogenic activities by carrying out simple checklist method. After its most immediate pressure type screen out and then during each successive visits that pressure is monitor to know its impact on the Mangrove Ecosystem. Further the anthropogenic influence is divided into two categories i.e. direct influence and indirect influence.

Socioeconomic Survey:

For direct influence, which contains effects from direct use of mangrove or mangrove ecosystem as a whole, we selected questionnaire base method to know the degree of dependency of the local population on the adjoining Mangrove habitat. I developed a questionnaire which contains four major parts like mangrove knowledge, animal husbandry activities, fishing activities and seed collection. The questionnaire includes question regarding knowledge and sensitivity about mangrove, various uses of mangrove and its parts, income generated from it, the type of activities carried out in the mangrove patch etc. This questionnaire was developed with the help of the sociologist. I selected 20 villages around the Mahi and Dhadhar River basin for survey, these villages belong to three talukas, Jambusar, Amod and Vaghra of Bharuch district. After selecting villages semi-structure interview was carried out with 25 persons for each village. I was able to interview 500 local persons from 20 villages.

Pollution source Survey:

Most secondary data about industries and type of affluence were carried out by literature referencing and used as secondary data. After that the parameters for pollution study were selected.

Abiotic status of mangrove ecosystem

For any ecosystem abiotic component is one of the most important factors. These abiotic factors include type and composition of sediment, water quality, light, temperature, oxygen etc. Mangrove grow on hostile condition and facing both salt and fresh water, balance of all abiotic parameter become even more of importance.

A). Sediment Survey and Analysis:

Sediment characteristics are one of the most important environmental factors directly affecting mangrove productivity and structure. The major physical and chemical properties of the mangrove soils are pH (hydrogen ion concentration), Eh (Redox, potential), salinity and particle size.

1). Sediment Composition: I adopted methodology described by Kathirasen (2001) in which a composite samples of 1 kg. wet sediment from each site were collected at two different depth of 10 and 40 cm. sediment pH was measured using digital pH meter. Sediment samples were transferred to laboratory immediately in sterile polythene bags and analyzed for moisture and well as soil composition analysis. At laboratory sediment sample were dried at room temperature for 10 days. After that the sample were weighted again to know water loss or water holding capacity. After that the sediment was sieved using 8” diameter sieves having sieve size of 2 mm, 1 mm, 0.50 mm, 0.25 mm and 0.125 mm. and weight of each particle size soil were taken. Then percentages were recorded to determine the composition of sediment.

2). Soil Leachate Analysis: Composite sediment sample were also analyzed for its salinity, hardness, organic materials in laboratory. These test conducted by preparing a suspension of water by taking 100 gm of soil and filling up to 1 liter with distilled water, starring for 24 hrs, filtering the solids and analyzing the filtrate. This data was collected for three seasons.

B). Water Survey and Analysis:

The frequency and duration of tidal flooding is important in determining the zonation, distribution and species composition of mangrove forests. The major physical and chemical properties of mangrove water are pH, hardness, salinity, temperature etc. For water survey I collected 1 liter composite sample in sterilized plastic bottle from each site and measuring temperature on site by using thermometer with 0.5° accuracy. Other parameters were tested in laboratory using standard testing method. This data was collected for three seasons.

C). Biotic Status of Mangrove Ecosystem:

The richness of any ecosystem is determined by its living biotic, component which includes flora and fauna. Mangrove ecosystem is dominated by various species of mangrove that play an important role of primary producer. leaves when shaded, decomposed in sediment and provide good source of food to fiddler crab that are continuously screening out nutrients from mud. crab, a primary consumer, then provides food source to secondary consumers like mudskipper and a diversity of birds. Certain species of fungi use dead remaining of above mentioned component and release the nutrient back into the food chain which again absorbed by mangrove.

1). For Mangroves: I adopted random quadrate method to know ecological parameter like density, abundance and diversity. Individuals that occur in quadrates are also checked for its height, girth, flowering or fruiting stage etc. I didn't classify mangroves in to seedling, sapling and trees as in this area mangrove growth is stunted and cannot be checked against parameters set by earlier scientist.

2). For Crab Burrow counts: I adopted quadrate method for burrow count. At each site 20 quadrates of 1 meter X 1 meter were laid to know density and frequency of burrows of mudkipper and crab. These quadrates were laid at the interval of 100 meter. Out of 20 quadrates, 10 quadrates were taken in to upper intertidal zone and 10 were taken in to lower intertidal zone

D). Status of Pollution and its Impacts on the Mangrove Ecosystem:

One of the anthropogenic effects on mangrove ecosystem is accumulation of pollutant such as heavy metals, phenol in root, leaves and other part. These pollutants also make their way to other living fauna such as crab and mudskipper interrupting their lives in many ways. To full fill this objective I have carried out study on accumulation of selected pollutant and other pollution indicators in sediments, water, mangrove parts, crab and mudskipper.

1). Heavy Metal Analysis: Heavy metals in water, sediments, mangrove and associated fauna were measured by Energy Dispersive X-Ray Florescence Spectrometer (EDXRF Spectrometer) which gives value of heavy metal in percentage. Care has been taken to dry out each sample completely in oven for 48 hours at 120 C^{o} before introducing into the instrument. This device is working on the principle of the investigation of an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray spectrum. To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains unexcited electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was. An electron from an outer, higher- energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X-rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energy of the X- rays are characteristic of the difference in energy between the two shells, and of the atomic structure of the element from which they were emitted, this allows the elemental composition of the specimen to be measured. This instrument measures heavy metal in two stages, one stage measures lighter heavy metals, from Carbon to Scandium, and in second stage its measures heavier heavy metals, from Titanium to Uranium.

2). Pollution Indicator: I have carried out analysis of sediment and water sample to check the presence of pollution in the mangrove ecosystem. A composite sample of sediment and water collected from each site and laboratory analysis was carried out to know chemical oxygen demand, phenol compound, oil residues and organic compound.

E). Community awareness programs in conservation management of Mangrove ecosystem:

The immediate effect of anthropogenic activities on mangrove ecosystem comes from the population settled near to the area. In order to minimize this effect I have carried out community awareness programs in the surrounding areas to help of specially designed power point presentation that includes topics like value of well maintained mangrove forest, ways of sustainable use, etc. Another power point was made that includes all basic information like origin & distribution of mangrove, mangrove plant and its parts, fauna and flora of mangrove ecosystem etc. for school students. awareness posters and booklet were also designed to spreading awareness.

Overall Results:

No	Parameter	Sarod	Neja	Asarsa	Dahej
A	**Location**				
1	N	22°10'32.12"	22° 8'52.57"	21°57'10.28"	21°42'51.39"
2	E	72°45'18.49"	72°33'54.19"	72°35'32.55"	72°34'57.98"
3	Estuary	Mahi	Mahi	Dadhar	Dadhar
4	Taluka	Jambusar	Jambusar	Jambusar	Bharuch
B	**Mangrove Patch**				
5	Type	Sparse	Open	Open/Dense	Dense
C	**Sediment Characteristic**				
6	>2 mm (gm)	100	20	200	0
7	>1 mm (gm)	120	100	140	10
8	>0.500 mm (gm)	60	40	60	60
9	> 0.250 mm (gm)	40	40	60	40
10	>0.125 mm (gm)	40	0	40	0
11	Water Holding (per Kg)	320	440	380	320
12	Avg. pH	6.54	7.73	7.76	8.06
13	Avg. Salinity (ppt)	0.20	1.25	1.05	1.33
14	Avg. Organic Matter (mg/l)	0.65	4.19	6.56	5.13
15	Avg. Hardness (mg/l)	0.00	34.00	80.33	28.83
D	**Water Characteristic**				
16	Avg. pH	6.33	7.52	7.52	8.00
17	Avg. Salinity (ppt)	7.02	23.18	20.58	38.28
18	Avg. Hardness (mg/l)	2413.70	2942.80	2315	6372.80
19	Avg. Dissolved Solid (ppt)	3.20	9.38	8.31	26.83
20	Avg. Suspended Solid(ppt)	3.13	10.16	9.00	6.10
21	Avg. Total Solids(ppt)	6.40	19.55	17.37	34.40
22	Avg. Alkalinity (mg/l)	673.67	141.67	205.33	341.00
E	**Mangrove Status**				

23	Avg. Density (m2)	1.94	19.83	25.11	18.00
24	Avg. Height (Inch)	13.55	21.51	22.28	22.11
25	Avg. Girth (Inch)	4.45	3.51	3.49	3.22
26	Avg. no of Flowering Tree	1	49.50	69.50	43.50
F	**Associated Faunal Status**				
27	Avg. Burrow Density in LZ (m2)	0.87	22.35	32.77	17.20
28	Avg. Burrow Density in UZ (m2)	0.82	34.57	52.07	32.72
29	Total number of Faunal Species	2	30	40	36
G	**Dependency Status**				
30	No. of person using as Fodder	0	9	3	2
31	Avg. Income (Rs./Month)	0	2100	2366	1120
32	No. of person using in Fishing	0	9	6	19
33	Avg. Income (Rs./Month)	0	2922	3083	2484
34	No. of person using Seeds	0	25	18	23
35	Avg. Income (Rs./Month)	0	216	200	214
H	**Sediment Pollution Status**				
36	Chemical Oxygen Demand (mg/l)	207.70	43.20	21.83	84.33
37	Phenolic Compounds (mg/l)	3.78	0.48	0.02	0.16
38	Presence of Heavy Metals (%)	0.41	0.05	0.00	0.04
I	**Water Pollution Status**				
39	Chemical Oxygen Demand	624.74	289.49	28.53	107.45

	(mg/l)				
40	Phenolic Compounds (mg/l)	7.37	1.31	0.03	0.31
41	Presence of Heavy Metals (%)	0.87	0.19	0.02	0.08
J	**Heavy Metal Status in Biotic Component**				
42	Mangrove Root (%)	2.82	2.24	1.72	1.84
43	Mangrove Stem (%)	2.11	2.76	1.64	2.63
44	Mangrove Leaf (%)	4.83	4.08	3.64	3.23
45	Crab (%)	1.44	0.83	0.50	0.83

Conclusions

Mangrove ecosystem is one of the most productive ecosystems of the world. Its sheer existence can protect various other marine ecosystems, like mudflats and coral ecosystem, and its faunal components, like birds, fish, crab, mollusks etc. Well being of mangrove ecosystem depends upon physiochemical parameters, like pH, salinity, alkalinity, hardness, total solids and organic matter etc. Any change in the parameters can have a devastating effect on the ecosystems. The presence of mangrove is also important for well

being of human society. Mangrove ecosystem, not only provides protection from the natural hazards like tsunami, but it also provides a major source of food, in terms of fishing, fodder and seeds, to the local community. Due to high dependency of local people, mangrove feels a tremendous pressure. Apart from this mangroves are facing extreme pressure from the industrial and domestic effluent discharge as mangrove is believed to have a large capacity of absorbing industrial and domestic waste. Gujarat a leading state in terms of increasing of mangrove cover in India and about 90 percent of mangroves in Gujarat are located around the Gulf of Kachchh while the rest of the mangroves are found in the Gulf of Khambhat and on the South Gujarat coast. As there is more mangrove cover in Gulf of Kutch, all the major study has been carried out there while Gulf of Kambhat mangrove studied very less.

From the results of present study it has been found that there are many factors such as, pH, salinity, hardness, alkalinity, sediment composition, organic matter, that affect natural distribution and density of mangrove in the study area. In addition to these natural factors and other factors like, chemical oxygen demanded, phenolic compounds and heavy metals that are introduced in the ecosystem as a result of various anthropogenic activities, also control the density and diversity of mangroves and associated fauna. There are two clear type of anthropogenic pressure on the sites of study area. One is dischsrges of industrial waste to mangrove ecosystem. As per this factor most polluted and disturbed site Sarod, situated at the point of effluent discharge, have high impact of pollutants and thus have the lowest density of mangrove and fauan. The other type of pressure is use of mangrove for a variety of purposes, such as use of mangrove as fodder, fishing and seed as food. This type of pressure is more important and has significant impact on mangrove density.

CHAPTER 10: PUBLICATIONS

Pollution Status in Mangrove Ecosystem of Mahi and Dadhar River Estuaries

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Abstract : Mangrove forests are extremely important coastal resources, which are vital to our socioeconomic development. However, they are often considered as uncreative land and used as discharge ground for pollutants. The Gulf of Khambhat and coast of south Gujarat had reasonably good mangrove cover in the past but the ecosystem has degraded due to development activities. The present study was carried out in four mangrove sites located along the Mahi and Dadhar river estuaries; Sarod, Neja, Asarsa and Dahej. Due to estuarine and gulf hydrodynamics and sediment composition mangrove forests have high organic load, both suspended and dissolved. The organic matter in the form of industrial effluent add to the total organic load of the mangrove ecosystem in this region. In present study COD of water ranges from 768 to 18.12 mg/l while sediment COD ranges from 233 to 15 mg/l. Level of phenolic compound ranges from 10.26 to 0 mg/l in water and sediment from 4.7 to 0 mg/l in sediments. Mangrove litter degradation add to natural phenolics in water and sediments, however, in present studies higher phenolic levels were due to pollution discharges in the gulf. Heavy metals like Cu, Zn, Cr, Ni, Pb, Hg, Cd, Co and Mn were recorded from the water and sediment samples of the studied mangrove ecosystems. Heavy metals like Cu, Zn, S, Si, Sr, Ti and Br were recorded from the root, stem and leaves of *Avicennia marina* samples also while, Cu, Zn, K, Fe, Sr and Br were recorded from samples of crab tissue. The status of over all pollution and its effect on crab population is discussed.

***Key words* :** Metal pollution, Mangrove, Brachyuran Crab, Mahi-Dhadhar Estuary

10. List of Publicaitons

1. Bhavik Patel, Kauresh Vachrajani (2014): **Socioeconomic Dependency of Local Community on Mangrove Ecosystem in Mahi and Dadhar River Estuaries, Gujarat, India** (Selected for 15th Student Conference on Conservation Science, Department of Zoology, Cambridge University, 25-27 March 2014)

2. Bhavik Patel, Dr. Kauresh Vachrajani (2013): **Pollution Status of Mangrove Ecosystem in Mahi and Dadhar River Estuaries**, Proceeding of National Conference on Biodiversity Status and Challenges in Conservation: FAVEO-2013, 29th and 30th November 2013.

3. Bhavik Patel, Kauresh D. Vachrajani, Deepak Apte (2012): **Utilization Status of Mangrove Ecosystem in Mahi and Dadhar River estuaries**, Gujarat. Oral Presentation at Regional Science Congress, M.S. University of Baroda

4. Shukla Manan, Bhavik Patel et al. (2009):**Mangrove Restoration through Community Involvement**. Poster presentation at 20th All India Congress of Zoology, CIFE, Mumbai