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Valuation of the Bhitarkanika Mangrove Ecosystem for Ecological Security and Sustainable Resource Use

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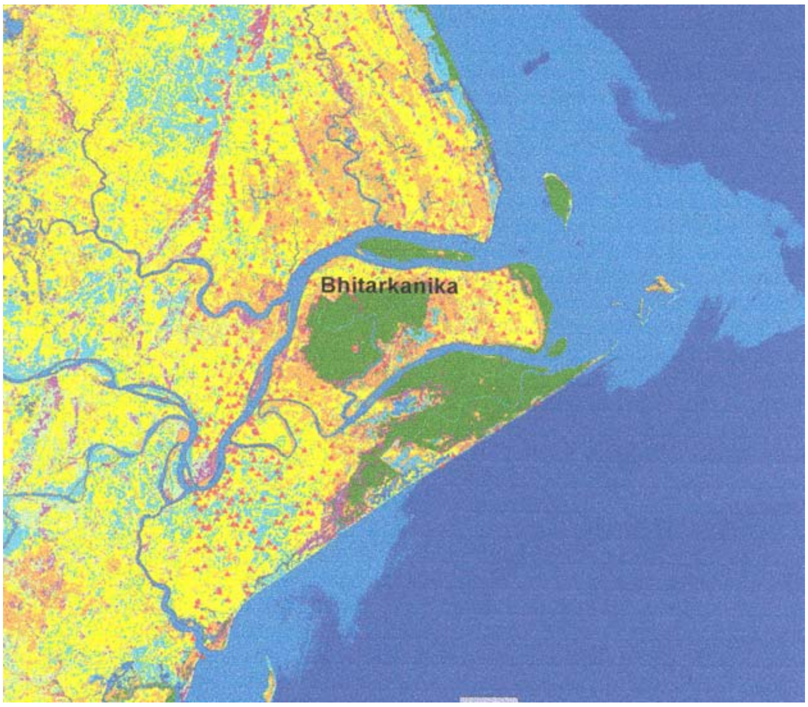
A World Bank Aided India Environmental Management Capacity Building Technical Assistance Project, IGIDR, Mumbai



भारतीय वन्यजीव संस्थान
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Trawling in the coast of Orissa © Bivash Pandav

CONTENTS

CHAPTER 3

Acknowledgements

We thank Prof. Jyoti Parekh and the Indian Environment Management Capacity Buidling Project, Indira Gandhi Institute of Development Research (IGIDR), Mumbai, for granting funding support for this project. We take this opportunity to thank Dr. Raghuram Tata, Project Coordinator, EMCaB Project, IGIDR for his constant help.

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Executive Summary

Ecological systems play a fundamental role in supporting life on earth at all hierarchical scales. They form the life support systems within which all economic development takes place. However, most of the natural ecosystems are rapidly disappearing as a result of the pressure of population growth and economic development. The social inefficiency in natural resource use is not a consequence of multiple use conflicts itself, but results from a combination of information failures, market failures and policy or intervention failures, that are due to the fact that most of goods and services provided by the natural systems do not have economic values attributed to them. In order to formulate sustainable natural resource use policy and measures, valuation of the uses of these ecosystems becomes essential, for it can help resource managers deal with the effects of market failures, by measuring their cost to society, which otherwise are generally hidden from traditional economic accounting. Economic valuation is an attempt to assign quantitative values to the goods and services provided by such natural resources where market prices are not available e.g. in case of ecosystem services or non use values. Studies attempting to quantify the values of tropical wetlands and mangroves are few and are restricted to direct use valuations.

The Bhitarkanika mangrove conservation area comprises of Bhitarkanika National Park and Wildlife Sanctuary and Gahirmatha Marine Sanctuary approximating around 3000 km^2 area of which around 4.8% (145 km^2) area has mangrove cover. This deltaic, estuarine-mangrove wetland system, harbours the highest diversity of Indian mangrove flora, the largest known rookery of the olive ridley sea-turtles in the world, the last of the three remaining population of salt-water crocodiles in India, the largest known population of king cobra, one of the largest heronry along the east coast of India and one of the highest concentration of migratory waterfowls - both ducks and waders. The loss of mangrove of Bhitarkanika is mainly due to human encroachment and reclamation of land for agriculture and unsustainable resources use practices such as aquaculture activities. Around 307 villages having 1.5 lakh people from the Rajnagar Circle and the adjoining areas depend for fuel, fodder and other non-timber forest produce from the Bhitarkanika mangrove ecosystem. Recent development activities such as construction of jetties, roads and the proposal of a major port at Dhamra threaten the existence of this ecosystem. Declaration of the mangrove forests of Bhitarkanika as a Protected Area has affected the local people living around this forest due to lost access of their life support systems. On the other hand the unsustainable resource use in the area is a major threat to continued existence of it. The resulting scenario is one of conflicts between the forest department and the local people, fueled by the man animal conflict.

The present study is an attempt to fill in the gap in information regarding the functions and services performed by mangroves. In addition to this it provides information on the structure of the ecosystem, yields 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. This would assist the planners and PA managers to take informed decisions regarding the management of Bhitarkanika mangrove ecosystem. The major objectives of this study are to:

a) *enumerate ecological functions and the key productive uses of the Bhitarkanika mangrove ecosystem,*
b) *estimate the use values and ecological services provided by the Bhitarkanika*

mangroves ecosystem/Protected Area,

c) quantify the extent of dependency of local communities on Bhitarkanika and identify marginalized stakeholders
d) examine the attitude of local communities towards present management and proposed alternative to mangrove resources,
e) derive a predictive model to assess the extent of impact of sea level rise (at 50 cm, 1 m and 2 m) on the Bhitarkanika mangrove ecosystem.

The Bhitarkanika mangrove ecosystem was characterized in terms of vegetational structure to relate with the major ecological functions performed by this ecosystem. The vegetation map at the landscape level was prepared to identify distinct habitat types. We have used Indian Remote Sensing Satellite (IRS-1D), LISS –III data of November 2000 and hybridized classification and Normalized vegetation Index (NDVI) for Vegetation Mapping. ERDAS Imagine 8.5, ARCINFO 8.03, ARCVIEW 3.1 and IDRISI 4.1, Excel and SPSS 8.0 were used for image processing and data analysis. Digital data was geo rectified with the Survey Of India toposheets (1973-74 survey- Survey Of India, 1979). The vegetation map was classified into 15 classes, of which 8 were natural vegetation, 2 were man modified habitat, 2 barren land - fallow land, sand and mudflats and 3 classes of water bodies. The area calculation for different habitats was done in Bhitarkanika conservation area, which includes Bhitarkanika Wildlife Sanctuary, Bhitarkanika National Park, Protected forest and revenue areas. The vegetation of Bhitarkanika conservation area was divided into 9 major vegetation communities following Champion and Seth (1968). Following are the major communities: Salt Marsh/Wet marshland, Palm/Tamarix Swamp, Brackish Water Mixed Forests, Salt Water Mixed Forests, Mangrove Forest, Mangrove Scrub, Village Woodlot/Agriculture and Agriculture/ Habitation/Prawn culture/Barren areas.

For the micro level assessment the Bhitarkanika National Park was stratified into distinct blocks. Stratified random sampling was employed to collect the field data on mangrove plant species composition and tree species diversity. Square plots of 10 m x 10 m were laid to assess the tree communities. The number of species, number of individuals of each species in the categories of trees (³ 20cm gbh), saplings (³ 15cm and = 20cm gbh) and seedlings (< 15cm gbh) and girth at breast height (gbh) of trees were measured. The grass cover of meadows mangrove was estimated by using 1m x 1m rectangular plots and visually estimating the percentage area covered by grasses, litter, water and bare soil.

A total of 64 species of plants were recorded from Bhitarkanika Mangrove Protected Area, which included 28 true mangroves, 4 mangrove associates and 32 others. The mean canopy cover of Bhitarkanika mangroves was found to be 33.25%. The mean ground grass cover in the meadows of Bhitarkanika was found to be 47%. Grasses were the main contributor to the ground cover. Tree density was found to be 1376.93 trees per hectare. Sapling density was 83.33 saplings per hectare while seedling density was found to be 45.79 seedlings per hectare. The total tree basal area (m^2per hectare) was 220.26. The Mahisamunda block was found to be the most diverse one with respect to seedlings and saplings. But tree species diversity was maximum in Dangamal block. The tree species that is present in highest density was Excoecaria agallocha, which is the dominant species in most of the blocks. The Bhitarknika mangroves differ considerably from the other Indian mangroves because of their dominant trees: Sonneratia apetala and several Avicennia spp. In addition there is a grass, Myriostachia wightiana, which is very common here but practically unknown elsewhere.

The information on ecological functions and the key productive uses of mangrove ecosystems were collected from existing literature. To identify the use values and ecological functions performed by Bhitarkanika mangrove ecosystems and their distribution, discussions were held with the Park management and staff, field biologists, scientists, commercial fishermen and local people. These were also partly identified during the door-to-door socioeconomic/attitude survey. These were compared with those performed by *mangroves elsewhere and it was found that the Bhitarkanika mangroves performed most of the ecological services known to be performed by mangroves. In addition they provided significant goods that contributed to direct use value. Four parameters, viz, nutrient retention, land accretion, storm abatement, and fish and shellfish production were selected for valuation.*

For valuation we considered nutrient retention, fish and shellfish production and storm abatement as the natural income or flow of the ecosystem goods and services. Whereas, land accretion as the stock, as soil, atmospheric structure are the natural capital stock, which uses primary inputs to produce the range of ecosystem services and physical natural resource flow.

By applying the market price method the monetary value of major nutrient present in mangrove and non-mangrove soil was compared. The available NPK in one ha of mangrove soil was found to be 2907kg, 28.1kg and 1564.55kg respectively. The monetary value of nitrogen, phosphorus and potassium in one hectare of mangrove soil was Rs 2,9070 per kg, Rs 433.74 and Rs 11092.66 respectively, while in one hectare of non-mangrove soil it was Rs 20576.70 per kg, 309.83 per kg and Rs 8667.24 per kg respectively. The amount of NPK in one ha of mangrove area exceeded by 849 kg, 8 kg and 342 kg respectively as compared to one ha of non-mangrove area. For 145 km^2 area monetary value of nutrients present was Rs 588 million while for the same area the estimated value for extra nutrient in mangrove area was Rs 160 million.

Through this project we attempted to estimate the contribution made by Bhitarkanika mangrove ecosystems in terms of fish production. To collect information on the fish catch it was decided to monitor fish catch in areas where there are mangroves and areas where mangrove forests have been removed. We selected two fish landing stations Dhamra (Dhamara and Talchua) situated close to Bhitarkanika (site with mangroves) and Paradeep port where most of the mangroves have been removed. Beginning from December we monitored fishing trawlers leaving from and returning to these fish landing stations and collected information on species wise total catch and duration of time spent in fishing. From this we estimated fish catch/unit hour. Few assumptions were made to achieve the desired out come; (i) it was assumed that trawlers from these two fish landing stations restricted their activities within the vicinity of these two stations, (ii) all trawlers from these ports used similar gears. The preliminary data suggested that the number of species caught exclusively at Dhamra, which was nearer to the mangrove, was greater (19) as compared to Paradip (5). The catch per trawler per hour has been found to be greater for Paradip.

However, we suspected secondary data provided by fisherman on their catch was erroneous. Subsequently, we abandoned this method of data collection and to estimate the fish capture in offshore areas with or without mangroves we extensively used data from the ongoing project of Wildlife Institute of India, Dehra Dun, "Experimental trawling along the Orissa coast to estimate the mortality of sea turtles". The valuation of offshore fishery was done using the Market Price method. We found significant difference in total catch/hr between mangrove and non-mangrove area. The Gahirmatha coast (with mangrove) has considerably high fish yield, (123.34 kg/hr) as compared the Paradip coast (without mangrove) where the yield is 17.89 kg/hr. Hence, the earning is also considerably higher in Gahirmatha where the earning is Rs 1784.60 per hour, while, in Paradip it is only Rs 104.83 per hour.

Data on inshore fish productivity was collected from six creeks originating from main Bhitarkanika River and having rich mangrove vegetation cover. Sampling was started in March 2002 and continued till July 2002. A least-damage sampling strategy was used to conserve the fish populations. Gill net was used as the main sampling gear; it was set across the river for thirty minutes, the total catch in thirty minutes was recorded. After sorting the catch to species level, the individual total weights were recorded. Sampling was done at all the sites every fortnight during low tide. If possible, in situ observation and identification of fish species were done and fishes were released back in the water. From *the total sampling done at the six sites 15 species were collected. The major species caught whose catch per hour was highest were Kauntia, Kua, Jalanga and Sulpatia spps. The estimated value of catch per hour for inshore fishery was Rs. 89.91 for 3.77 kg of fish.*

To verify the role of mangroves as nursery ground for fish and shellfish, a circular drag net was used. In order to control, as much as possible, the sampling conditions, fortnightly samplings were done at low tide. Five sampling sites were selected. At each site during each sampling session fishing was done four times to control sample variability. On the basis of sampling done from March 2002 to July 2002, prawn and fish seedling catch per hour was calculated. Total fifteen species were caught of which three were commercially exploited. Per hour catch was found to be highest for Chinguri (Penaeus indicus), other commercially important fishes caught were Kaunkada (Scylla serata) and Bagada (Penaeus monodon). The catch/hr was 65.3 for White prawn, 5.9 for Tiger prawn and 14.8 for Mud crab and earning (Rs/hr) from these species was 6.53 to 32.65, 2.36 to 3.54 and 2.96 to 5.92 respectively.

We used the damage cost avoided approach to value the storm protection function of the Bhitarkanika mangrove ecosystem. In this case since we have the recent incident of super cyclone of 1999 to compare the damages, actual estimates of damage avoided due to mangroves was estimated. Three villages, namely Bankual, Bandhamal and Singidi were identified to represent three situations viz: Mangrove areas with dykes, Non-mangrove areas with dykes, Non-mangrove areas without dykes. Bankual is situated in Rajnagar block whereas the other two are located in Rajkanika block of Kendrapara district which was one of the 7 districts most affected by super cyclone. To keep the intensity of impact as uniform as possible, all the three selected villages were equidistant from the seashore. The two villages outside mangrove covers were located close by, but both were far off from the forest in order to eliminate the effect of mangroves. For the sake of convenience, the intensity of the cyclone was considered to be same for these two blocks that are situated adjacent to each other. Door to door survey was conducted and a 100% sampling of the households was done to assess the socio-economic status of the villages, the actual damage to houses, livestock, fisheries, trees and other assets owned by the people and the rate, level and duration of flooding. Information was gathered by focused public interviews about the direction of entry of water and probable reasons for flooding. The mean household size in the three villages was 4.5 to 8.2. The overall human density in the study villages ranged between 260-340 persons/km^2. The literacy level was highest for Singidi and lowest for Bankual. In Singidi and Bankual majority of the people (70%) were engaged in agriculture, where as in Bandhamal around 61% were labourers. Most of the houses (94%) were made of mud and thatch. The maximum damage to the houses was 10.44 $\pm$ 0.848 for Bandhmal. The lowest 5.34 $\pm$ 0.578 was for Bankual. The flooding in house premise was highest for Bandhamal, the village protected by the dyke but without mangrove cover, while lowest was for Bankual, village protected by mangrove cover. The highest level of flooding in the fields in meters was for Singidi, village outside mangrove area and not protected by dyke, followed by Bandhamal and then by Bankual. The agricultural production was highest in Bankual in 1999 with a value of 6 $\pm$ 0.376 qtl./acre and the lowest for Bandhamal 1.4 $\pm$ 0.956. The highest damage to fish seedlings was in Singidi where Rs 311 $\pm$ 144.975 worth of the seedlings released were washed away and it was the least in Bankual (70 $\pm$ 32.198). The maximum number of livestock casualties occurred in Bandhamal, followed by Bankual and Singidi. The loss incurred per household was found to be greatest in Bandhamal Rs 6918.63 $\pm$ 1136.201 per household followed by Singidi and Bankul. Significant difference was found to exist among the variables used to assess the contribution of mangroves in avoiding damage from cyclones and floods, for the mangrove and non-mangrove areas. No reports of breaches, in the dyke located around the forest area indicate the protection provided by mangroves to the dykes, although this is not conclusive as further data authentication is required. However, in areas far from the forest several breaches in the dyke were reported and this is reflected in higher levels of flooding and greater mean number *of days of flooding in Bandhamal This study therefore reinforces the fact that mangroves form an effective barrier to storms, better than man-made structure such as the dyke in this case.*

Mangroves trap sediments and accelerate land formation in the coast initially as islands or mudflats. Subsequently due to succession these newly created land forms develop into tidal swamps with mangrove species. The Bhitarkanika mangrove ecosystems have significantly contributed in the formation of mudflats and islands along the coast and in the associated riverine ecosystems. We used market value method to estimate the contribution of Bhitarkanika mangrove ecosystem in land accretion. Newly accreted land masses were identified from Survey of India toposheets, and remotely sensed IRS-1D, LISS – III data of November 2000. A total of 4.68 km^2 of land formation has occurred within the Bhitarkanika mangrove area, in a time span of 111 years from 1889 to 2000. The value of 468 ha of land at the current market price is Rs 46 million or 983795.7 US $. However, the land accretion function could be considered reclamation of coastal wetlands for developmental purposes. This means that valuing this function by estimating the current price of land in the area is considerable underestimation of the value of this function. In fact the cost of reclaiming land should be taken as the value of this function. Since we could not get this figure for the study area, a conservative estimate of the value of this function has been given by stating it as the current price of land in the area.

Among the four parameters which we valued the nutrient retention function was US$350 /acre/year, which is quite high as compared to the valuation results of other study. The fish and shell production valuation was done at three levels and the estimated value for offshore fishery, Inshore fishery and fish seedling was determined by using market value method, which came out to be US$ 37.97/hr, US$ 1.9/hr and US$0.2/hr respectively. The storm abatement function was valued using damage cost avoided method. In the village having mangrove cover the damage cost avoided was estimated to be 116.28 US$/household. The value of land accretion function was estimated to be 983795.7 US$ over a period of 111 years.

In this study we could value four major functions of bhitarkanika mangrove forest, the value of which is estimated to be quite high, but to get a clear picture on the overall value of the functions performed by this ecosystem, valuation of other functions performed needs to be undertaken.

The data on socio economic and dependency aspects was collected in three stages. The first stage involved a rapid assessment of the 403 villages located in the impact zone of Bhitarkanika Wildlife Sanctuary. Information on 35 parameters related to socio-economic status, location and distribution of villages with respect to forest and their dependency on forests for fuel wood, timber, fodder etc. was collected. Of the 35 parameters, 28 parameters believed to be characterizing villages were subjected to Factor Analysis. Seven components having eigen values greater than one were identified from the correlation matrix. In the second stage, hierarchical cluster analysis using Ward's method was done to identify relatively homogeneous groups of villages based on selected characteristics. A sample size of 35 villages was identified and the villages were then randomly selected from the clusters in proportion to the size of each cluster. In the selected villages data regarding the socio-economic set up, dependency on mangrove ecosystem and attitude of the people towards conservation were gathered. From each selected village 10% of the housing units were picked up randomly for the household and attitude survey. In the sampled villages the family size obtained is a little over 8 individuals per household. The overall literacy rate was 69.19%, with a male literacy of 79.82 % and female literacy of 59.12%. The villages were basically agriculture based. Majority of the people were involved in the primary sector i.e. agriculture. The percentage of skilled laborer was low (4.01%). 6-9% percent people had fishing as their primary occupation. 2.2% of people were involved in NWFP collection. The mean number of months of employment in the sampled villages was 6.25 $\pm$ 0.212 and the average income per household per annum was Rs.22976.3 ± 1791.486. The agricultural income was Rs.2039.7 ± 297.076. The mean cattle holding per household was 2.3 ± 0.184

The study of socio-demographic characteristics, economic situation and other aspects of life in the mangrove villages reveal a high degree of resource use despite protected status of the Bhitarkanika mangroves. Wood from the Bhitarkanika mangroves is being used, particularly by the communities in the periphery of the forest for firewood purpose. An overall 14.2% of the needs of each of the households was being met by the forests with a mean consumption of 3.1259 ± 0.3216 qtl./annum in the thirty-five sample villages. Highest consumption was obtained for those villages located within 1.5 kms. from BNP, (5.8 ± 0.533 qtl./annum). Highest fish extraction (1.25 ± 0.391 qtl.) has been observed for the villages located in peripheral areas of the mangroves, and the least i.e. 0.60 ± 0.495 for those farthest from it. Thus, highest consumption of NTFP was seen for villages in the adjoining areas of forest while the villages situated at more than 3 kms away from the forest did not use this resource.

Around 90% of the local people in the area were aware that Bhitarkanika forests have protected status and that it is a declared Wildlife Sanctuary. c84% of people feel that they have got a responsibility towards conservation of flora and fauna and another 92.9% are in favour of an ecodevelopment programme for the area. c 43% of people are willing to cooperate with forest department in this regard. Only 18.3% of people feel there has been a violation of their rights with the park's declaration. 52% of the respondents felt that local community should take initiative in ecodevelopment program and consequently be involved or at least be informed regarding the management decision. Very few people (0.7%) are in favor of cutting down the forests and 76.9 % of the people have said more mangrove plantations should be carried out. People living close to the forest seemed to be more willing (80%) to cooperate with forest department in the conservation of flora and fauna, as compared with those living away from it. Majority of the respondents favored Dhamra port extension (87.7%). Very few respondents favoured aquaculture practice (8.6). In case free access to forest resources was stopped, 30.6% respondents said that they would buy alternatives available in the market, 10% opted for stealing the produce from the forest. Only a few respondents (2.6%) opted for growing fodder and a very less percentage (0.4) of them were willing to reduce the number of livestock. Our findings point out that people are able to appreciate the contribution of Bhitarkanika mangroves to their lives and livelihoods directly in form of increased production of fisheries and prospects for better tourism. A high percentage of people (88.6%) recognized the contribution of mangroves in cyclone and flood mitigation. The people have recognized even functions such as biodiversity conservation and ground water recharge. Majority of the local populace i.e. about 89.6% are aware that Bhitarkanika forests have protected status and that it is a declared Wildlife Sanctuary.

Amidst various threats such as development activities, increasing resource demand and development of port and jetties looming Bhitarkanika Conservation Area we derived a predictive model to assess the extent of impact of sea level rise on Bhitrakanika. In recent past the world has already warmed by 0.3 to 0.6 °C since 1860 and the last two decades have been the warmest. The projected global mean sea level because of such increase in atmospheric temperature is .09 to 0.88 m over the same period, as a result of the thermal expansion of the oceans, and the melting of glaciers and polar ice sheets. The physical effects of sea level rise are categorized into five types, inundation of low lying areas, erosion of beaches and bluffs, salt intrusion into aquifers and surface waters, higher water tables and increased flooding and storm damage. The average sea level rise for India has been reported as 2.5 mm/year since 1950's. The change in sea level appears to be higher on eastern coast compared to western coast. If these data are true it is believed that the future sea level rise will affect Bhitarkanika Conservation Area significantly.

Recent assessments indicated that one meter rise in sea level is likely over a period of 200 years, but could occur as soon as the year 2100. Efforts to project *flooding and shoreline change require data on land and water surface elevation and a model of coastal processes. For our study we generated data from different maps in the form of point information of elevation and then the digital elevation model was interpolated. The map is depicted with two levels of inundation, (a) 0-1 m, which indicates the predicted sea level rise of 1 m. (b) 1-2 m, if area inundated up to 1 m due to sea level rise, then 2 m. Elevation will be good approximation of area getting inundated at high tide on the basis of local tide data. The local coastal process and wave pattern are not considered at present due to lack of reliable information that can be extrapolated at large scale. We have used IDRISI 4.1, ArcInfo 8.03, ArcView 3.1, Eras Imagine 8.5, Excel and SPSS 8 for data analysis.*

In our model we considered two levels of uncertainties or errors, (i) Spatial database errors and (ii) Aspatial or Decision based uncertainties. The RMS error for the elevation data was estimated to be 30 percent of the contour data, with assumption that 90 percent of the points fall within half a contour interval. The decision uncertainty was assumed to be 50 percent i.e. there is equal chances of land being flooded or not flooded to one meter height above MSL by the year 2200.

The land between 0-1 meter elevations was estimated to have probability of 73.2 to 63.9 percent to be inundated by year 2200. The possible area of inundation at three level i.e. 0-1, 1-2 and 0-2 m rise are 194.77 km^2 (6.5%), 253.71 km^2 (8.5%) and 448.48 km^2 (15%) respectively. This though seems small will affect the vegetation community of the entire Bhitarkanika Conservation Area.

This empirical study suggests that the value of the estimated goods and services provided by the Bhitarkanika Mangrove Ecosystem is significantly high when compared to other land uses in the area such as aquaculture, paddy cultivation and development options. With short time allocated for the study it was not possible to value the other services performed by this ecosystem. Moreover, the ecosystem services provided by the natural systems cannot be substituted by man-made capital. Despite this fact the Bhitarkanika mangroves are facing threats of extinction due to anthropogenic and developmental pressures. There is a high degree of resource extraction by the local people because of the fact that the local people do not have any other livelihood options other than paddy cultivation and fishing. Consequently more and more mangrove areas are being converted into paddy fields. Moreover developmental activities all around the area also threaten the ecological integrity of the Bhitarkanika Mangrove Ecosystem.

The Bhitarkanika area has had a strong protection policy since 1951. In 1975, the Government of India declared 670 km^2 of the area as a Wildlife Sanctuary under the Indian Wildlife Protection Act, 1972, with a core area of 145 km^{2}that was upgraded to a National Park in 1988. In 1997, 1435 km^{2}area was declared as Gahirmatha Marine Sanctuary, with a core area of 725.5 km^2. All these show that there is no market, information or intervention failure at the primary level in case of the Bhitarkanika area. However, at a higher spatial scale there seems to be ample evidence of all the three types of failures occurring. This is because of two reasons primarily- the inability of the government to implement the Wildlife Protection Act effectively and lack of inter-sectoral coordination. Between 1951-61 there was unprecedented growth of population in the area due to the resettlement of refugees from Bangladesh. Between 1994-95 with scant regard to Wildlife and Forest Conservation Acts, the revenue department legalized a large number of illegal settlements within the Sanctuary area. As per law the creation of villages in the sanctuary limit was illegal and had to be taken into account during the finalization of rights in the Sanctuary leading to loss of Mangroves. Similarly despite the protected status of the Bhitakanika area and the existence of a strong Maritime Act (1982) of the Government of Orissa and Orissa Marine Fishing Regulation Act (1982) and rules (1983) there are unabated development activities such as construction of port and defense structures and inshore fisheries using mechanized vessels in the area. This is the result of information failure on part of the fisheries, waterways, defense and other government *departments. In the absence of valuation studies the forest department has been unable to articulate the importance of conserving this ecosystem in the face of developmental activities that promise higher turnover.*

All these factors are together exerting pressure on the Bhitarkanika Mangrove Ecosystem. However all these can be managed by developing and implementing an Integrated Conservation and Development Plan for the area. But we do not have control over factors resulting from change at the global level such as global warming leading to sea level rise. Our study has revealed that a two-meter rise in sea level by the year 2200, will result in the inundation of 299 km^2 area. This will change the vegetation composition of the entire area affecting productivity of the ecosystem as well as that of the local people. The Government of India is a signatory to various protocols such as Montreal and Kyoto that restrict the use of ozone depleting substances and emissions of greenhouse. At the international level India is also a signatory of the Ramsar Convention, 1971 that requires the contracting parties to identify, formulate and implement conservation plans for wetlands of International importance so as to promote their sustainable use. The wise use concept adopted in1987, proposes sustainable utilization of wetlands for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem. Bhitarkanika is a proposed Ramsar site and in this case its wise use would imply careful planning, management, regulation or even prohibition of certain activities. This can effectively be made possible only through a proper consultation and agreement with the stakeholders. This would also result in better support for its conservation. Higher level of positive attitude of people towards conservation is a positive sign for conservation of the area. However weak participation of the local community in the decisions and management strategies undertaken by the forest department needs to be corrected.

It is crucial to address the dependence of the local communities on the PA resources. Resource extraction from the PA is not permitted under the current law (Wildlife Protection Act, 1972). However, the 324 villages located inside the Sanctuary have no option but to use the resources from the PA. The use in this case is defacto, which is always indiscriminate. Our study suggests that the National Park i.e., the core zone has to be maintained as a sanctum sanctorum and all resource use therein will have to be stopped. The possibility of meeting the needs of the people who are actually dependent on the PA resources for their livelihoods, particularly those living within 1.5 km of forest boundary, has to be explored from the buffer zone. The buffer zone in this case is a Wildlife Sanctuary where resource extraction is not permitted. A policy to permit controlled resource extraction in this zone can be permitted, provided that it does not affect the ecological process of the system. This will also develop stakes of the local people in the conservation of the area. The possibility of changing the status of the buffer zone to other categories of Protected Areas as proposed under the amended Wildlife Protection Act is other option.

Subsistence fishing in rivers like Dhamara, Brahamnai, Baitarani, Hansua and Pathsala should be legalized. It will not have major impact on ecological balance as long as the nursery grounds of the fishes i.e. the small creeks viz. Thanpati, Ganjeikhia, Jalahar, Suajore, Gokhani and main Bhitarkanika River remain undisturbed. There is need to develop and provide alternative fuel to the local people. For this it will be important to develop better approach and communication facilities since the dependence of people particularly on firewood is due to the fact that alternatives to these are not accessible/available to them. Since the income levels of people in this area are relatively high, it can result in shift to other alternate fuel. For the poor people, the Sanctuary still remains the source of wood biomass. Mangrove plantation should also be taken up extensively in and around forest blocks, which are under tremendous pressure and are already degraded due to excessive lopping (e.g. Mahisamunda, Ragdapatia and Kalibhanjdia forest blocks).

The villages located within 0-1.5 km distance from forests have higher number of unemployed population. For these villages income-generating programs should *be initiated. Programs initiated in few villages by forest department and local NGOs, should be extended to more villages. Pisiculture and apiculture can be introduced through these programs as these have tremendous scope in the region. Moreover most of the villages have sufficient number of ponds to sustain fish population and have basic equipment and knowledge to carry out such programs.*

It is imperative to involve local communities in tourism by training them as guides with. It should be made mandatory for visitors to have a trained tourist guide with them, which will not only facilitate these visitors but will also help in monitoring the activities of the visitors. The entry fee to the park is very low, which should be increased so as to generate revenue for the forest department. Funds generated through entry fee should be used to set up ecodevelopment/village development funds as is being done by the states of West Bengal, Madhya Pradesh and Rajasthan. Overnight stay facility for tourists should be developed at other sites beside Dangma, and measures should be taken for up gradation of already existing forest guesthouses at Ekakula and Habalikhati. Villagers can be encouraged to build ethnic huts at places like Khola and Gupti, which will facilitate the stay of tourists and will be an alternate income source to these villagers. Already existing nature trail inside Bhitarkanika forest block and heronry at Bagagahana should be properly maintained.

Maintenance of existing roads and bridges should be done so as to improve transportation facility for local people and tourists. Many important bridges such as at Khola need to be repaired. Regulation of boat movement in the inner creeks should be done so as to reduce the disturbance to birds and crocodiles. Though people support the construction of Dhamara Port, its construction will have detrimental impact on the Bhitarkanika National Park. Increased movement of boats due to construction of Port will be destructive for the nesting sites of turtles, and the social impact will hamper the integrity of the entire ecosystem.

During the extreme situations such as cyclones, water from the sea crosses the dyke and floods the villages and agriculture land. The villagers during the 1999 cyclone faced this situation and suffered damages. Small sluice gates should be made at strategic locations at dyke so that this water is quickly drained out when water starts receding during flooding.

Although prawn farming is banned in the sanctuary area, number of illegal prawn farms is mushrooming in the areas. Frequently the Forest Department has been demolishing these farms or Gherries. *But forceful destruction of these* Gherries *has resulted in conflict of local people with the FD. To mitigate this conflict local people should be taken in confidence and an awareness program should be run to educate the people about the negative impact of these* Gherries *on agriculture production.*

Restriction on mechanized fishing in the coastal zone should be imposed with aid from coast guards and fishery department. The present field staff number is very low to patrol the NP, for effective patrolling of the Park the manpower should be increased. The Forest Department registered many cases of poaching during our study period; hence there is an urgent need of strengthening a network of informers in different areas. Cooperation of the local villagers would be crucial in this. To check the smuggling of timber and wildlife articles sufficient number of enforcement staff with VHF sets and transport facility will have to be deployed at all entry gates for proper checking of incoming and outgoing vehicles at Dangmal, Khola, Gupti and Chandbali.

Environmental awareness is a powerful tool for gaining support for conservation. During our survey we have come across a large section of people who have very poor knowledge about the values of wildlife conservation or about the behavior of wild animals found in the study area such as crocodile, king cobra and python. As a result there is conflict between the communities and wild animals, resulting in a negative attitude towards wildlife conservation. Not only the local communities but also the lower level forest staff has poor knowledge about the behavior of wild animals and various ecological processes. It has also come out *as one of the reasons for the human casualty due to crocodiles in our study. Effective environmental awareness programs for this area need to be developed. A large section of the population particularly those living in and around Bhitarkanika in remote areas are uneducated. Here, role of programs that cater to visual literacy become important. There is a need to develop the skills and expertise of grassroot level NGOs so as to enable them to develop site-specific environmental awareness programs that would target different sections of the local society. There is a need that these NGOs work in close coordination with the forest department and also involve local people in developing awareness programs thereby using their valuable local knowledge and skills.*

Dangmal has an interpretation center, which should be upgraded. Interpretation can be executed through a range of illustrative media i.e., signage, publications, self-guided activities, exhibits (both indoor and outdoor) and audiovisual programmes. The approach should encourage environmentally responsible behavior by fostering awareness, knowledge, attitude, skills and participation.

For effective conservation and management of the Bhitarkanika Conservation Area, it is important to go beyond protection measures for certain areas, habitats or landscape features, and impose binding requirements for coordination of sectoral policies at the scale of an ecological unit, based on the principles of integrated management of coastal zones. It is proposed that a Bhitarkanika Conservation Area Management Authority *be set up.The authority should have adequate representation from the policy makers of central and the state government, local communities and other government departments functioning in the area apart from eminent scientists from reputed institutions.*

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Economics and Ecology

Ecological systems play a fundamental role in supporting life on earth at all hierarchical scales. They form the life support systems within which all economic development takes place. But economic development always remains subject to the ecological limitations, which operate within natural systems. As the scale of human activity continues to increase, environmental damage begins to occur not only in local ecosystems, but also regionally and globally as well. Humanity now faces a novel situation of jointly determined ecological and economic systems (Costanza *et al.,* 1997). This means that as economies grow relative to their life support ecosystems, the dynamics of both become more tightly connected. In the long run a healthy economy can only exist in symbiosis with a healthy ecology (Costanza *et al.,* 1997).

Ecology and economy have been pursued as separate disciplines through most of the 20th century. While each has certainly borrowed theoretical concepts from the other, each had addressed separate issues, utilized different assumptions to reach answers, and supported different interests in the policy process. Ecological economics arose during the 1980s among a group of scholars who realized that improvements in environmental policy and management and protecting the well being of the future generations were dependent on bringing these two domains of thought together. Ecological economics is not a single new paradigm based in shared assumptions and theory. It represents a commitment among economists, ecologists and others to learn from each other, to explore new patterns of thinking together and to facilitate the derivation and implementation of new economic and environmental policies (Costanza *et al.*, 1997). Ecological economics views economics as a subset of ecology and the economy as a subset of the ecosystem (Folke *et al.*, 1994). Ecological economists are rethinking both ecology and economics by for example, extending the materials balance and energetic paradigm of ecology to economic questions (Ayres, 1978; Hall *et al.,* 1986), applying concepts from economics to better understand the nature of biodiversity (Weitzman, 1995), and arguing from biological theory how natural and social systems have coevolved together such that neither can be understood apart from the other (Norgaard, 1981). Practitioners consider ecological economics to be the science and management of sustainability (Costanza, 1991).

The stock of wetlands is a multifunctional resource with very significant economic value (Costanza *et al.,* 1997). Because of the direct use of the structural value provided by (plants, animals, soil and water) wetland (Turner, 1991), they are under heavy utilization pressure. The wetlands are rapidly disappearing as a result of improved access to wetland zones, the pressure of population growth and economic development. Many mangroves are being degraded because of unsustainable levels of grazing and fishing activities, land reclamation, mining and waste disposal (Turner, 1991). According to Turner (1991), the social inefficiency in wetland use is not a consequence of multiple use conflict itself, but results from a combination of information failures, market failures and policy or intervention failures.

Information failures denote the lack of appreciation of the economic value of the conserved wetlands. Market failure is the externality problem whereby wetlands are damaged by economic activities that are not required to meet the direct consequences of such degradation. Market failure also occurs when there is no mechanism to attribute economic values to the public goods provided by the wetlands. Policy or intervention failure occurs where the government policies and programmes directly or indirectly contribute to wetland loss (Shine and de Klemm, 1999). In order to formulate sustainable wetland use policy and measures, valuation of the wetland uses becomes essential, for it can help resource managers deal with the effects of market failures, by measuring their cost to society, which otherwise are generally hidden from traditional economic accounting (Daily *et al.,* 1997). Economic valuation of the services provided by wetlands helps society to make informed choices about the trade-offs (Loomis, 2000). Economic valuation is an attempt to assign quantitative values to the goods and services provided by such natural resources where market prices are not available *e.g.* in case of ecosystem services or non use values. Prices generated for natural resources often do not reflect the true social costs and benefits of resource use, and convey misleading information about resource scarcity and provide inadequate incentives for management, efficient use and conservation of natural resources (Panayotou, 1993). Valuation of non-market ecosystem services, that would be lost due to development, should help in setting full prices of land or impact mitigation fees for development of habitat (Loomis, 2000). Government evaluations of proposals to increase constructed capital at the expense of natural capital such as wildlife are more meaningful when non-market effects are considered. In some situations it may be worthwhile to sacrifice natural resources for the overall development goal. In other cases, support to retain an area as natural may be needed in face of immense pressure from development sector. Whatever maybe the situation, economic valuation provides an important tool to assist with the difficult decisions involved in resource allocation.

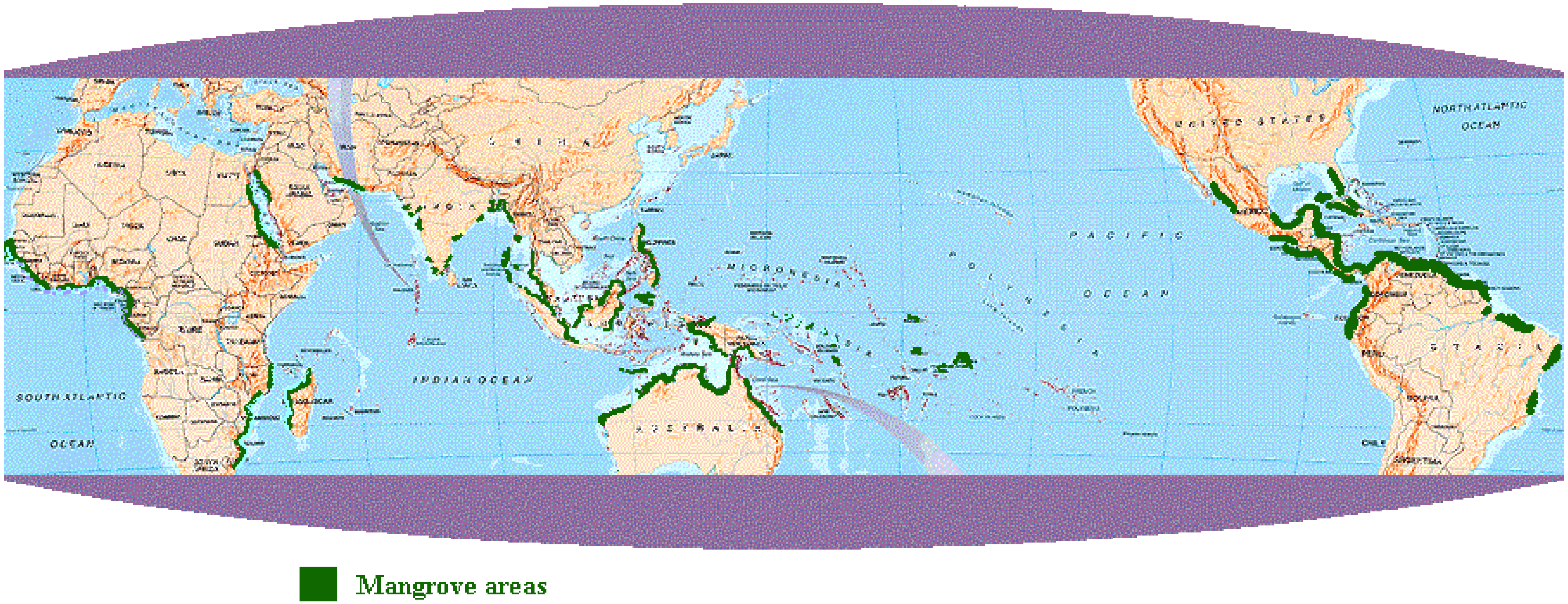
Measurement and valuation of direct use values, expressed in terms of environmental commodities and amenities of direct benefit to humans, has been undertaken at a fairly extensive basis for wetlands (Turner, 1991). The indirect use value for wetlands has remained difficult to quantify. Equally the non-use values of wetlands have not been quantified in more than a small number of cases, though studies of other environmental resources suggest that their existence values are positive and significant (Pearce and Turner, 1990). Studies attempting to quantify tropical wetlands are far less numerous and are restricted to direct use valuations (Turner, 1991).

In the field of Protected Area (PA) management, economic valuation can be extremely useful to indicate the overall economic efficiency of the various competing use of natural resources. This is however only one element for efficient management of a PA, since the underlying assumption is that PA resources should be allocated to those uses that yield an overall net gain to society, as measured through valuation in terms of the economic benefit of each use, less its costs. By this argument, a use showing a substantial net benefit to society would be deemed highly desirable even though the principal beneficiaries may not necessarily be the ones who bear the burden of the cost arising from the use. Decisions regarding the management regimes of PAs where these are based on the principal of 'protection' often are justified in the name of efficient use of natural resources, although in reality the management strategy is defined by considerations having little bearing on economic valuation. Such management strategies particularly in the developing economies, have been often rejected by the primary stakeholders *i.e*. the local communities dependent on the PA resources for their survival, who have responded through non conformation, agitations *etc.* Therefore, to ensure efficient PA management, economic valuation has to be combined with the identification of marginalized stakeholders who may otherwise threaten natural resources because of unsustainable use. It is important to capture the stakeholder's values and attitudes towards various aspects of PA management as well as proposed alternatives and their distributional impacts. Then only it will be able to guide management practices in terms of their efficiency as well as distributional impacts. The present study is an attempt to fill in the gap in information regarding the functions and services performed by tropical wetlands (mangroves in this case). In addition to this it provides information on the structure of the ecosystem, yields, 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. This would assist the planners and PA managers to take informed decisions regarding the management of Bhitarkanika mangrove ecosystem.

1.2 Mangrove Ecosystems, Their Distribution, Uses and Threats

The term mangrove applies to around 68 halophytic species of trees and shrubs found in tropical coastal areas (Chapman, 1975). While not necessarily closely related, all these plants are adapted to flourish in saline water influenced by periodic tidal submergence. Generally speaking, mangroves are distributed in the tropical and sub-tropical zones between the Tropic of Cancer and the Tropic of Capricorn with the Malaysian and Indonesian region supporting the most diverse mangrove communities in the world (Figure 1.1). Occurring along the tropical shores, mangrove forests form a link between land and the sea. They derive many of their physical, chemical and biological characteristics from the sea and the inflowing freshwater from the upland forests. They have the distinctive ability to thrive in salt water as well as fresh

Figure 1.1. Global distribution of Mangroves



water, and their advanced seaward or retreat inland is brought about by water regime and sedimentary processes which prepare shallow water for the growth of seedlings (Adegbehin and Nwaigbo, 1990).

Two zones of mangrove distribution have been identified across the world (Chapman, 1970, 1975)-namely the eastern zone consisting of the East African coast as well as Pakistan, India, Burma, Malaysia, Thailand, the Philippines, southern Japan, Australia, New Zealand, the south eastern Pacific Archipelago, and the western zone comprising the Atlantic coast of Africa and the America including the Galapagos Islands. The greatest number of genera and species occur in the eastern zone (Walsh, 1972). The appearance of mangroves is far from uniform; they vary from closed forests 40-50m high in parts of South America to stunted shrubs less than 1m height, which can be in discrete and widely separated clumps. A wide variety of organisms are associated with the mangrove system, and the habitat is critical to many. Such organisms include a number of epiphytes, parasites and climbers among the flora and large number of crustaceans, mollusks, fishes and birds among the fauna.

Mangrove forests are one of the most productive and bio-diverse wetlands on earth. The mangrove ecosystems are widely recognized as providers of a wide variety of goods and services to people, including storm abatement, sediment trapping, land accretion, nutrient up take and transformation and provision of a variety of plant and animal products. Due to their unique physiology and ecology, mangroves provide optimal breeding, feeding and nursery grounds for many ecologically and economically important fish and shellfish species (MacNae, 1974), as well as feeding habitats for resident and migrant water birds. Furthermore, mangroves protect fresh water resources against salt-water intrusion; they protect the land from eroding waves and winds (Semesi, 1998), and stabilize the coastal land (Carlton, 1974; Wolanski, 1985). The mangroves can be considered as a natural barrier protecting the lives and property of coastal communities from storms and cyclones. The above ground root systems retard water flow that not only encourages the sediment to settle but also inhibits their resuspension. Stabilization of sediments provides protection to shorelines and associated shore based activities, and can even lead to progradation and land gains. Further the resistance, which mangroves offer to water flow, is particularly important during extreme weather events such as cyclones, typhoons and hurricanes (MacNae, 1974). Mangrove ecosystems mitigate against flooding and flood damage by dissipating the energy of floodwaters (Gilbert and Jansen, 1997). They are valuable source of fuel wood, fodder, timber, tannin and other natural products for the local people (Spaninks and van Beukering, 1997; Rosolofo, 1997). Mangrove ecosystems also function as a sink. Sedimentary processes as well as uptake by organisms filter through-flowing waters, incorporating extracted substances in the sediments and/or in the ecosystems biomass (Gilbert and Jansen, 1997).

Despite of centuries of biological research on mangrove structure, productivity and ecosystem dynamics (Rollet, 1981), and in spite of an understanding and recognition of mangrove benefits by scientists, governments and local population (Saenger *et al*, 1983), destruction of these ecosystems continues. Mangrove forests rank among the most threatened of coastal habitats, particularly for developing countries (Field *et al.,* 1998; Saenger *et al.,* 1983). The total mangrove area of the world has been estimated to be approximately 18.15 m ha (Semesi, 1998).

Once occupying around 75% of tropical coasts andinlets, now the mangroves are restricted to few pockets. Today, less than 50% remain, and of this remaining forest, over 50% is degraded and not in good form. A figure of 1% decline per year has been given as the conservative estimate for the Asia-Pacific region (Ong, 1995). While accurate estimates of global deforestation rates of mangroves are as yet unavailable, its well-known environmental and socioeconomic impacts are observed and increasingly documented in coastal communities that depend directly on mangrove ecosystems, and in upland communities with economic links to the coast (Fransworth and Ellison, 1997).

Anthropogenic pressures on mangroves include among others clear cutting and reclamation for agriculture and aquaculture, urban expansion, developmental activities, harvests of mangroves for fuel wood, poles and artesanal material and nonpoint source impacts such as industrial and oil pollution, agricultural run off (Fransworth and Ellison, 1997). In the developing countries pressures for fuel wood, poles, fodder and other NTFPs often exceed sustainable levels. In addition commercial use of wood, for pulp in particular results in some areas being more or less clear felled. Conversion of mangrove areas to aquaculture is a particular threat in the Asian region. The building of ponds for extraction of salt-water can, especially in arid and semi-arid areas, cause extensive damage to mangroves. Another threat to mangroves is diversion or alteration of freshwater flow into them. In arid, semi-arid or seasonally dry regions the mangroves are particularly dependent on periodic inputs of freshwater, but in these regions there is a high demand for freshwater and its flow into the oceans is regarded as wasteful. Consequently rivers are dammed or diverted so that their waters can be used on land. Changes in the land use upstream, such as the logging of a forest, can also affect the freshwater flow into the mangroves. The reduction in freshwater resulted in the gradual replacement of mangrove species with more salt tolerant and possibly less useful species. Mammals within the mangroves are affected by the lack of freshwater while fishery resources may be depleted by the higher or lower salinity and reduced nutrients.

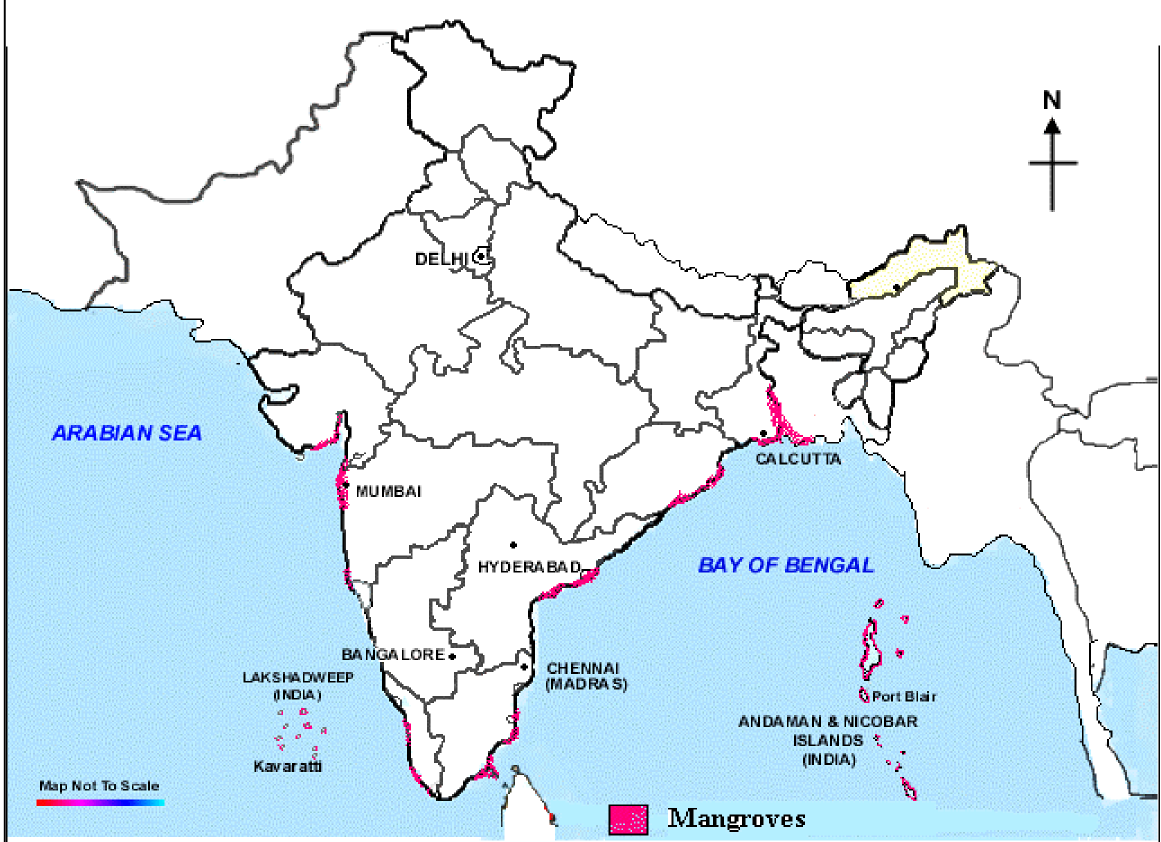
Much of the conversion of mangroves has occurred because this habitat has, traditionally been regarded as unproductive wasteland. The loss of mangrove areas could be attributed to information failure such as a general lack of awareness among people about the values of conserving mangroves ecosystems, or absence of a direct, easily observed relationship between a mangrove forests and the benefits it provides, market failures because of excessive extraction of open-access resources, and intervention failure such a general ineffectiveness or absence of appropriate integrated resource management policies and inter-sectoral policy inconsistencies, leading to mangrove loss and degradation. Besides, these failures could also be attributed to two other factors (Hamilton *et al.,* 1989): (i) many of the goods and services provided by these ecosystems are not traded on markets and thus do not have an observable value; and (ii) some of these goods and services occur off-site and are therefore not readily acknowledged as being related to mangrove ecosystems. As a result it is often concluded that mangroves should be developed for uses that generate directly marketable products, such as aquaculture. However, such decisions ignore the opportunity cost of development. Moreover, such views increase the conflicts in areas that have already been declared as Protected (National Parks/ Sanctuaries).

The supply of the products, functions and attributes of the mangrove ecosystem is directly affected by mangrove conversion. Loss or impairment of mangrove ecosystem values is generally associated with economic cost and in many cases, with a reduction in opportunities for sustainable development. Conversely, maintenance of wetland products, functions and attributes is likely to have economic benefits (Shine and de Klemm, 1999). In India, except for the Gangetic deltas and in the Andaman and Nicobar Islands, the mangroves occupy a very small area and are discontinuous and degraded (Figure 1.2). The total area of the Indian mangroves has been estimated at about 3,56,500 hectare (Blasco 1977). Around 70% of the mangroves along the Indian coast are along the east coast whereas the west coast has 12% and the Andamans have the rest 18% (Krishnamurthy et al., 1987; Karthiresan et al., 1995). The reason for the occurrence of vast extents of mangroves along the East Coast of India is attributed to the nutrient rich alluvial soil formed by the rivers, Ganga - Brahmaputra, Mahanadi, Godavari, Krishna and Cauvery and a perennial supply of freshwater along the deltaic coast (Gopal and Krishnamurthy, 1993). The mangroves of the east coast are more diverse than that of the western part. The important deltas of the East - coast are (i) the Ganga delta (Sundarbans and the West Bengal), (ii) the Mahanadi delta (Bitarkanika, Orissa), (iii) the Krishna delta (Andhra Pradesh), (iv) The Godavari delta (Coringa, Andhra Pradesh), (v) the Cauvery delta (Pichavaram and Muthupet, Tamilnadu state). These deltaic / estuarine east coast mangroves are spread over an area of about 4700 km2. In India the term "mangrove forest" does not necessarily mean a forest cover. It may refer to various formations: arborescent, bushy, herbaceous and also regions which are devoid of any plant cover (Blasco, 1977). Since the estimate of Blasco (1977), it is believed that the Indian mangroves are under severe decline. The Forest Survey of India (Dehradun) assessed the mangrove areas in India using remote sensing technology. Their most recent estimate of 4827 km^2 is now regarded as a reliable estimate. Even though there was lot of ambiguity in the earlier estimates of tidal forests in India, it is now agreed that the extent of mangroves in India has gone down drastically during the 20th century. At this juncture an appropriate policy is needed to arrest such losses, which could only be achieved by educating the people about the values of conserved mangrove ecosystems, and by developing a sound policy based on economic understanding of the benefits derived from this ecosystem that can only flow from sufficient research to document the benefits.

1.3 STUDY AREA

The Bhitarkanika mangrove ecosystem, the second largest mangrove forest of mainland India

Figure 1.2. Distribution of Mangroves in India



Source: Naskar and Mandal

approximating around 672 km^2 is now limited to 145 km^2 area (Chadah and Kar, 1999). The area was declared a wildlife sanctuary to protect the endangered Saltwater crocodile, (*Crocodilus porosus*), in 1975. This deltaic, estuarine-mangrove wetland system, harbours the highest diversity of Indian mangrove flora, the largest known rookery of the olive ridley sea-turtles in the world, the last of the three remaining population of salt-water crocodiles in India, the largest known population of king cobra, water monitor lizard, one of the largest heronry along the east coast of India and one of the highest concentration of migratory waterfowls - both ducks and waders. Along with the largest diversity of estuarine and mangrove obligate fisheries resource, Bhitarkanika also is rich in prawn fisheries. The mangrove and associated forests provide the subsistence requirement of timber, fuel wood, tannin, honey, and thatch roof for the local people and fodder for the local communities (Chadah and Kar, 1999).

1.3.1 Location

The Bhitarkanika-Garhimatha region in the lower reaches of the Dhamra-Pathsala-Maipura river is a microenvironment region of the Rajnagar Block in Kendrapada district of Orissa extending over an area of about 130 sq. km (Figure 1.3). It is located between 86^0 45'E to 87^0 50' E longitude and 20^0 40' to 20^0 48' N latitude (Patnaik *et al.,* 1995). The sanctuary encompasses and area of 175 sq km, with a coastline of 35 km on its eastern side (known as Gahirmatha coast), and is surrounded by the Brahmani and Baitarani rivers and their tributaries on the remaining three sides (Pandav, 1996).

1.3.2 Physiography

The deltaic mangrove swamps of Bhitarkanika Wildlife Sanctuary are extremely low lying and subjected to regular tidal inundation. The general elevation above mean tide level is between 1.5 and 2 meters (Dani and Kar, 1999). Higher ground extends up to 3.4 meters.

Figure 1.3 False Color Composite of Cuttack, Kendarapara and Balasore districts of Orissa showing Bhitarkanika Mangrove Ecosystem

The river flow is influenced twice daily by high and low tides at approximately six hourly intervals. The maximum and minimum tide level varies according to lunar days and seasons. Siltation is a common phenomenon in the river systems. Soil erosion is taking place on the banks of the Baitarani, Bramhani and Dhamra rivers.

1.3.3 Soil

The mangrove soils are fine grain silt or clay formed by the sedimentation in long and wide Mahanadi and Brahamani rivers. Normally the alluvial, silty soil is not much productive until humus or exuviae of organisms, molluscan and crustacean shells are added to it (Chadah and Kar, 1999). Surface soils close to the rivers vary from 2 m to 4 m in depth that decreases gradually from shore to the mainland (Patnaik *et al.,* 1995).

1.3.4 Climate

The climate of the area is tropical characterised by three distinct seasons; summer (March to June), winter (November to February) and monsoons (July to October). Annual rainfall averages 1670mm with the main rainfall occurring during the monsoon months of August and September. In summer the temperature ranges from 30^0 C to 20^0 C (day and night respectively) whereas during the short winter it is 20^0C to 15^0C (Kar and Bustard, 1986). The relative humidity remains between 75% -80% throughout the year. The most important weather phenomenon is the prevalence of tropical cyclones.

1.3.5 Flora

The floral diversity of Bhitarkanika includes more than 300 plant species (Banerjee, 1984). It includes a total of both mangrove and non-mangroves belonging to 80 families. The main mangrove species are *Avicennia alba, Avicennia officinalis, Rhizophora mucronata, Excoecaria agallocha, Acanthus illicifolius, Sonneratia apetala* and *Heritiera minor.* The palm *Phoenix paludosa,* the fern *Acrostichum aureum* and *Hibiscus teliaceus* are widespread throughout the forest (Kar and Bustard, 1986).

1.3.6 Fauna

Mammals of Bhitarkanika are represented by 31 species belonging to 25 genera and 14 families (Patnaik *et al.,* 1995). They include the leopard (*Panthera pardus*), striped hyaena (*Hyaena hyaena*) and the lesser cats, spotted deer (*Cervus axix*), sambar (*Cervus unicolor*) and wild boar (*Sus scrofa*). The reptilian fauna comprises of 29 species out of which there are 4 species of turtles including Olive Ridley sea turtle (*Lepidochelys olivacea*), one species of crocodile (saltwater crocodile, *Crocodilus porosus*), 8 species of lizard and 16 species of snakes including the Indian python (*Python molurus*) and King cobra (*Ophiophagus hannah*). A total of 174 species of birds have been reported from here including 6 species of kingfishers and 57 species of migratory birds (Pandav, 1996).

1.3.7 Management issues

The loss of mangrove of Bhitarkanika is mainly due to human encroachment and reclamation of land for agriculture (Roy, 1989) and unsustainable resources use practices such as aquaculture activities. The growing local population, increasing further by rehabilitation of Bangladeshi/East Pakistani refugees has given a new dimension to the inflated land-encroachments and the present demographic and the socio-political situation in this deltaic island. Around 307 villages having 150,000 people from the Rajnagar Circle and the adjoining areas depend on this ecosystem for fuel, fodder and other non-timber forest produce. Introduction of nylon-nets, trawler fishing and cash-crop generating aquaculture changed the traditional sustainable fisheries resource harvest methods. The socio-economic condition of people around being poor and income restricted to only seasonal agriculture, introduction of a quick income generating activity such as prawn seed collection and aquaculture have become popular, even though these are ecologically unsound. Recent development activities such construction of jetties, roads and the proposal of a major port at Dhamra threaten the existence of this ecosystem. Construction of highways within the Protected Area and fishing jetties within the “area of influence” of the PA are two of the major detrimental development activities taking place in the area. The off-shore islands near the outer wheeler group also happen to be the range of test missiles from the Interim Missile Testing Range, Balasore. These are expected to be detrimental to the highly fragile and fragmented sea-turtle nesting site (Pandav and Choudhury, 1998). Declaration of the mangrove forests of Bhitarkanika Protected Area has affected the local people living around this forest due to lost access of their life support systems. On the other hand the unsustainable resource use in the area is a major threat to continued existence of it. The resulting scenario is one of conflicts between the forest department and the local people, fuelled by the man animal (largely due to crocodile) conflict. Hence, measures devised to conserve biodiversity must provide economic incentives to increase the net local benefits from conservation and sustainable resource use. Despite being declared as a Sanctuary, a large number of villages had been created in Bhitarkanika till 1994-95, with scant regard to the Wildlife Act and Forest (Conservation) Act, 1980 (Chadah and Kar, 1999). This combined with the developmental activities, will have a serious impact on the sanctuary. It is now increasingly recognized as neither politically feasible nor ethically justifiable to deny the poor from the use of natural resources without providing them with alternative means of livelihood, particularly, if we really want their goodwill and co-operation in conservation. In this scenario an economic evaluation study in the area is needed and timely.

Within the constraint of time allotted to us to carry out this study, our aim was to estimate some of the important use and non-use values of the Bhitarkanika mangrove ecosystems, and examine socio-economic status and attitude of the local communities.

1.4 Objectives of the study

The major objectives of this project were to:

a) enumerate ecological functions and the key productive uses of the Bhitarkanika mangrove ecosystem,

b) estimate the use values and ecological services provided by the Bhitarkanika mangroves ecosystem/Protected Area,

c) quantify the extent of dependency of local communities on Bhitarkanika and identify marginalized stakeholders

d) examine the attitude of local communities towards present management and proposed alternative to mangrove resources

e) derive a predictive model to assess the extent of impact of sea level rise on the Bhitarkanika mangrove ecosystem.

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Chapter 2

Understanding Bhitarkanika Mangrove Ecosystem

2.1 Introduction

The ecological function is the outcome of the interaction between physical, chemical and biological components of an ecosystem over a spatial and temporal scale. The mangrove ecosystem of today is the product of anthropogenic modification on decadal time scales, very changeable geomorphology on millennial time scales, as well as vicariant and evolutionary events. It is implicit that the productivity of the ecosystem depends on the quality of the system. As we explore the link between biotic diversity and ecosystem functions using mangrove ecosystem it is essential to define the identity of the system, their edaphic variability, and functional properties such as productivity and turnover rates and delimit clearly and efficiently the spatial scales at which the system operates. Mangroves are the characteristic littoral plant formations of tropical and subtropical sheltered coastlines. They have been variously described as 'coastal woodlands', 'tidal forests' and 'mangrove forests' (FAO, 1994). Growing in the intertidal areas and estuary mouths between land and sea, mangroves provide critical habitat for a diverse marine and terrestrial flora and fauna. Healthy mangrove forests are key to a healthy marine ecology. The diversity of mangrove plant species generally changes consistently across continental or inter-island regions, reflecting important roles of distance from centers of diversification, dispersal availability, the viability of propagules prior to rooting, and the directions of ocean currents (Field *et al.*, 1998). Deltaic environments on India's east coast, support extensive mangrove formation due to a gradual intertidal slope and heavy impact of siltation. The Baitarani and the Brahamani rivers, their distributaries and several tidal creeks provide ideal habitats for the mangroves. Following are the important and dominant species of the Mahanadi-Brahamani-Baitarani deltas (Bhitarkanika) *Avicennia alba*, A. *officinalis, Excoecaria agallocha, Heritiera fomes, Sonneratia apetala, Rhizoiphora apiculata, Ceriops decandara, Bruguiera parviflora, Aegiceras corniculatum, Phoenix paludosa and Porteresia coarctata* (Naskar and Mandal, 1999).

There are significant differences in the characteristics of mangrove habitats, not only between continents and regions but within individual stands of mangroves as well. Using a simple rationale for classifying a given mangrove stand may assist land use managers in determining its likely value to society and subsequently in using more wisely. The purpose of this chapter is to characterize the Bhitarkanika mangrove ecosystems in terms of vegetation structure and to identify the goods and services and the major ecological functions performed by this ecosystem.

2.2 Methodology

2.2.1 Macro level assessment

The vegetation map at the landscape level of the Bhitarkanika Conservation area was prepared to identify distinct habitat types (**Figure 2.1**). We have used Indian Remote Sensing Satellite (IRS-1D), LISS -III data of November 2000. We have used hybridized classification and Normalized vegetation Index (NDVI) for Vegetation Mapping. ERDAS Imagine 8.5, ARCINFO 8.03, ARCVIEW 3.1 and IDRISI 4.1, Excel and SPSS 8.0 were used for image processing and data analysis. Digital data was georectified with the Survey Of India toposheets (1973-74 survey - Survey Of India, 1979).

The total root mean square error of geo-rectification was estimated to be 2 m. The georectified image was classified into 50 classes. The unsupervised classification map, false colour composite and NDVI map were used to ground truth landuse and vegetation type maps. The vegetation sampling was done by laying vegetation plots of 10 m X 10 m plots (see Section on vegetation) and vegetation releve'. In vegetation releve plant species dominance and habitat classification variables were recorded. In total 179 plots and 322 releve's were used for classification and accuracy evaluation. We have used Champion and Seth (1968) classification for vegetation categorization.

The vegetation map was classified into 15 habitat

Figure 2.1 Cuttack, Kendrapara and Balasore districts of Orissa showing Bhitarkanika Conservation Area.

classes, of which 8 were natural vegetation 2 were man modified habitat, 2 barren types of land - fallow land, sand and mudflats and 3 classes of water bodies (Figure 2.2). The area calculation for different habitats (Table 2.1.) was done in Bhitarkanika conservation area, which includes Bhitarkanika Wildlife Sanctuary, Bhitarkanika National Park, Protected forest and revenue areas.

Vegetation characteristics

The vegetation of Bhitarkanika conservation area was divided into 9 major vegetation communities following Champion and Seth's (1968). Following are the major communities:

Salt Marsh/Wet marshland:

Suaeda sps., Family Cyperaceae dominated the saline marshes. *Porteresia coarctata* were the pioneers on the new islands with alluvial soil deposits. *Myriostachya wightiana* was commonly seen along the shorelines.

Palm/Tamarix Swamp

The Sea Dates (*Phoenix paludosa*) were commonly observed as dense pure stands along the edge of the shores. Tamarix is another gregarious species with pure patches. *Casuarina* patches were seen along the coast. Associates: *Heritiera, Excoecaria, Avicennia, Xylocarpus, Thespesia, Acanthus, Salvadora*.

Brackish Water Mixed Forests

Excoecaria and *Heriteria* dominated stands with their associates.

Associates: *Rhizophora, Avicennia, Thespesia, Heritiera, Brownlowia, Cynometra, Bruguiera, Kandelia, Sonneratia, Caesalpinia, Pongamia, Hibiscus, Salvadora, Tamarix, Lummitzera, Acrostichum, Salacia and other Non-Mangrove species.*

Salt Water Mixed Forests

Excoecaria, Cyanometra, Heritiera, Avicennia, Sonneratia and *Phoenix* are commonly associated with

Figure 2.2 Habitat types of Bhitarkanika Conserv

Table 2.1 Vegetation types and their extent in the Bhitarkanika Conservation Area, Orissa

Vegetation Type	**Major community types**	**Area (km^2)**	**Area (%)**
Salt Marsh	*Suaeda*	51.95	1.73
Palm-Tamarix Swamp	*Phoenix paludosa*	98.90	3.30
Brakish Water Mixed Mangrove	*Excoecaria and Heritiera*	524.10	17.47
Salt Water Mixed Mangrove	*Excoecaria, Cyanometra, Heritiera* etc.	50.90	1.70
Mangrove Forest	*Excoecaria, Avicennia, Rhizophora* etc.	167.02	5.57
Mangroove Scrub	*Excoecaria,Salvadora, Avicennia, Rhizophora* etc.	103.94	3.46
Village Woodlot/Agriculture	Coconut, Tamarind, Paddy etc.	321.05	10.70
Agriculture/Habitation		1066.57	35.55
Barren Area/Sand		338.52	9.54
Mixed Mangrove-Non Mangrove	*Avecennia, Excoeceria, Syzygium, Hibiscus* etc.	80.64	2.69
Degraded Mangrove		248.54	8.28
Total		**2999.89**	**100.00**

species like *Kandelia, Acrostichum, Acanthus, Pandanus, Salvadora* and *Caesalpinia*.

Mangrove Forest

Excoecaria, Avicennia, Rhizophora, Sonneratia dominated stands.

Assoicates: *Ceriops, Rhizophora, Thespesia, Heritiera, Xylocarpus, Aegilitis, Aegicerus, Amoora, Salacia, Hibiscus, Kandelia, Brownlowia, Acanthus, Dalbergia, Phoenix, Salvadora, Suaeda sps., Family Cyperaceae, Porteresia coarctata, Myriostachya wightiana.*

Mangrove Scrub

Excoecaria, Salvadora, Avicennia, Ceriops, Cynometra, Lumnitzera, Acanthus dominated areas.

Associates: *Aegiceras, Aegialitis, Rhizophora, Pandanus, Hibiscus, Pongamia, Thespesia, Salacia, Brownlowia, Kendelia.*

Village Woodlot/Agriculture

The woodlots comprised of a variety of avenue and fruiting species to name some: Coconut, Palms Tamarind, Neem, Acacia and Eucalyptus. Main crop cultivated is Paddy.

Agriculture/Habitation/Prawn culture/Barren areas

These have not been delineated separately for classification, hence have been designated as a single class.

Mangrove and Non Mangrove Species:

Avicennia, Excoecaria, Ceriops, Rhizophora, Thespesia, Heritiera, Kandelia, Brownlowia, Acanthus, Phoenix, Salvadora, Suaeda sps., Family Cyperaceae, *Porteresia* were the species commonly associated with non-mangroves. Majority of non-mangrove species occurring in the Bhitarkanika Range namely: *Nux vomica, Syzygium, Bryophyllum, Hibiscus, Dalbergia, Pitanchar, Madhuanchar.*

2.2.2 Micro Level Assessment

The Bhitarkanika Mangrove Protected Area (BMPA) was stratified into distinct blocks based on a reconnaissance field visit and the existing literature with government agencies. Stratified random sampling was employed to collect the field data on mangrove plant species composition and tree species diversity.

Square plots of 10 m x 10 m were laid to assess the tree communities following. The number of species, number of individuals of each species in the categories of trees ($\geq$20 cm gbh), saplings ($\geq$15 cm and $\leq$ 20 cm gbh) and seedlings (<15 cm gbh), girth at breast height (gbh) of trees, the vegetation cover. Tidal inundation period (the period in which the area remain submerged under water in a year) and the signs of wild animals were noted.

The ground cover of meadows was estimated by using 1 m x 1 m rectangular plots and visually estimating the percentage area covered by grasses, litter, water and bare soil. This exercise was replicated in 9 administrative blocks (Table 2.2). Each plot was laid singly and randomly in the various observed vegetation and landform types, so as to represent all the area. The sampling process was carried out during September 2001 and July 2002.

Table 2.2 Distribution of plots for vegetation sampling in various blocks

S. No.	Name of the block	No. of plots taken
1.	Kalibhanjadia	31
2.	Sapuadia	9
3.	Musadia	1
4.	Ekakula	21
5.	Baunsagada	17
6.	Dangamal	15
7.	Bhitarkanika	58
8.	Ragadapatia	11
9.	Mahisamunda	39

2.2.3 Vegetation analysis

a.1 Frequency as introduced by Raunkiaer (1934) indicates the number of sampling units in which a species occurs (Mishra, 1968). It expresses the distribution or dispersion of various species in a community.

Frequency (F) = number of sampling units in which species occur/ Total number of Sampling Units
% Frequency = F x 100

a.2 The abundance and density represents the numerical strength of species in the community (Mishra, 1968). Abundance is described as the number of individuals per sampling unit of occurrence and density as the number of individuals per sampling units. Abundance and density were calculated using following formulae:

Abundance (A) = Total number of individuals/ Numbers of Sampling units of occurrence

Density (D) = Total number of individuals/Numbers of Sampling units studied.

The abundance and density represents the numerical strength of species in the community (Mishra, 1968). Abundance is described as the number of individuals per sampling unit of occurrence and density as the number of individuals per sampling units.

a.3 Importance Value Index (IVI)

The concept of 'Importance Value Index (IVI)' has been developed for expressing the dominance and ecological success of any species, with a single value, (Mishra, 1968). This index utilises three characteristics, viz. relative frequency, relative density and relative dominance. The three characteristics were computed using frequency, density and basal area for all the species falling in all transects using following formulae.

Relative Dominance = Total basal area of the species x 100 / Total basal area of all species

Relative Density = Number of individuals of the species x 100 / Number of individuals of all species

Relative frequency = Number of occurrences of the species x 100 /Number of occurrences of all the species.

IVI = Relative Dominance + Relative Density + Relative Frequency.

a.4 The variation in vegetation cover with respect to various blocks was assessed using multiple comparisons, at different level of significance. The data so obtained were subjected to one-way ANOVA after transforming the percentage values through an ARC-Sin transformation after ensuring that the data follows a normal distribution. The statistical packages SPSS and Bio-diversity pro. were used for all the analysis.

a.5 Shannon's index for diversity was calculated based on the abundance value of plant species in different categories (Ludwig and Reynolds, 1988; Turner *et al.*, 1997).

Shannon's Index $H' = -\sum p_i \log p_i$

As a measure of heterogeneity, Shannon's index takes into account the evenness of the abundances of species. The maximum diversity, which could possibly occur, would be found in a situation where all species were equally abundant.

a.6 Simpson's index gives the probability of any two individuals drawn at random from an infinitely large community belongs to different species

Simpson's Index $D = \sum p_i^2$

b. Analyzing for resemblances in vegetation communities

Resemblance functions quantify the similarity or dissimilarity between two objects based on observations over a set of descriptors (Ludwig and Reynolds, 1988). The more similar the samples are in their species composition, the greater is their resemblance, that is, the closer their ecological distance. Here the objects of interest are 10 m x 10 m plots and the descriptors are the measures of species abundance. Communities were analysed for similarities using Cluster Analysis by taking squared Euclidian distances as the distance measure, which is the sum of the squared differences over all of the variables.

2.3 Results

2.3.1 Overall Vegetation Characters of Bhitarkanika Mangrove Protected Area

A total of 64 species of plants were recorded from Bhitarkanika Mangrove Protected Area, which included 28 true mangroves, 4 mangrove associates and 32 others. Table 2.3 and Table 2.4 summarizes the overall vegetation characters of Bhitarkanika Mangrove Protected Area.

2.3.2 The Vegetation Structure and Diversity

a. Canopy cover

The mean canopy cover of Bhitarkanika mangroves was found to be 33.25% ± 2.8 as calculated from a total of 62 plots of the size 10 m x 10 m spread over seven regions of the study area. The canopy cover could not be measured from all the blocks due to technical constraints. The data presented in Figure 2.3 is summary from six blocks only. The canopy cover varies significantly between some of the blocks of Bhitarkanika (Table.2.5).

Table 2.3 Summary of vegetation characteristics of Bhitarkanika

Tree density (trees per hectare)	1376.93
Sapling density (saplings per hectare)	83.33
Seedling density (seedlings per hectare)	45.79
Total tree basal area (m^2 per hectare)	220.26
Mean basal area per tree (m^2 per tree)	0.16
Total canopy cover	33.25%

Table. 2.4 Dominant species in Bhitarkanika Mangrove Protected Area

Species	Relative dominance	Density	IVI
Excoecaria agallocha	81.71	50525.38	157.11
Pongamia glabra	6.87	18305.58	29.14
Heritiera littoralis	3.49	11656.35	19.11
Avicennia officinalis	2.75	7893.91	16.84
Cyanometra ramiflora	2.54	10067.01	15.88

The Kalibhanjadia block, which is an island formed about less than 200 years ago by an uplift of mudflats, is relatively poor in canopy cover (33%), but the older mangrove areas have more dense canopy cover as in Dangamal (71.25%) and Ekakula (56.66). The Bhitarkanika block also is evidently dense but the low value of canopy cover obtained in this figure is most likely a sampling bias. The number of plots in which the estimations were made was also very low.

b. The ground cover in the meadows of Bhitarkanika mangroves

The mean ground grass cover in the meadows of Bhitarkanika was found to be 47.04% ± 1.7%. (Figure 2.4). Grasses were the main contributor to the ground

Figure 2.3 Mean canopy cover in various blocks of Bhitarkanika

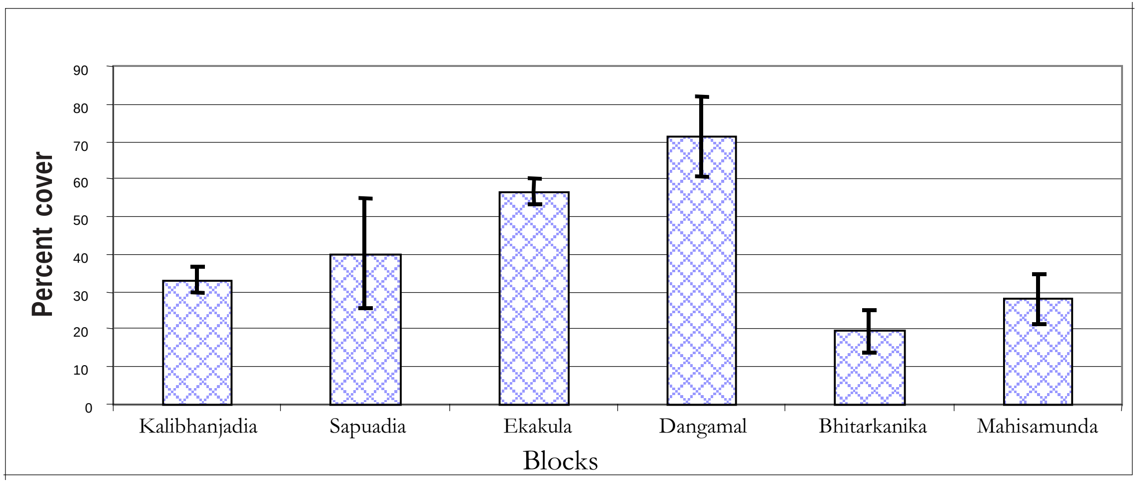


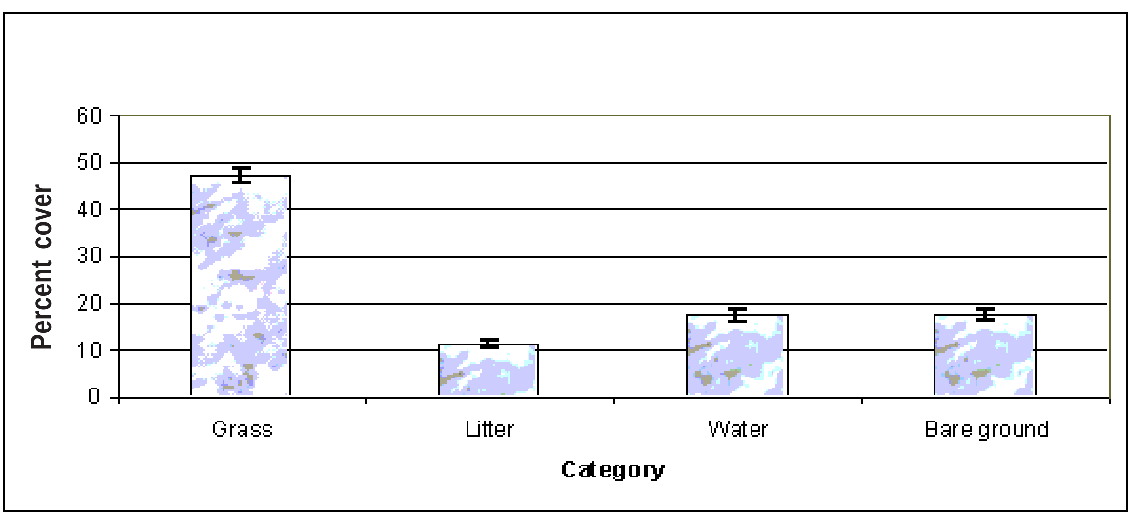
Table 2.5 Significance levels (*p* value) of multiple comparison for canopy cover between various blocks

	Kalibhanjdia	Sapuadia	Ekakula	Dangmal	Bhitarknika	Mahisamunda
Kalibhanjadia	-	0.826	0.652	0.039**	0.638	0.998
Sapuadia	0.826	-	0.987	0.497	0.202	0.818
Ekakula	0.652	0.987	-	0.969	0.222	0.629
Dangmal	0.039**	0.497	0.969	-	0.003***	0.091*
Bhitarkanika	0.638	0.202	0.222	0.003***	-	0.994
Mahisamunda	0.998	0.818	0.629	0.091*	0.994	-

** >90% significance level, ** >95% and *** >99.9%*

cover, whereas litter contributed only 10% to the ground cover and almost equal percent of the ground was bare and had water bodies. The ground cover varies maximum between Bhitarkanika and Kalibhanjadia and Khola blocks. As the tidal inundation period might be the only deciding factor that determines the ground cover composition, this factor should be controlled for a better reliable

Figure 2.4 Ground cover in the meadows of Bhitarkanika



comparison.

c. The plant diversities in different blocks

The evenness of abundances of trees, saplings and seedlings were compared among different blocks using 'Shannon's Index' (Table 2.7). It shows that the Mahisamunda block is the most diverse one with respect to seedlings and saplings. But tree species

Table 2.6 Significance levels of multiple comparisons for ground cover between various administrative blocks

BLOCKS	Bhitarkanika	Dangamal	Kalibhanjadia	Kantikakhai	Khola
Bhitarkanika	-	0.155	0.000***	0.015**	0.000***
Dangamal	0.155	-	0.736	0.997	0.000***
Kalibhanjadia	0.000***	0.736	-	0.851	0.000***
Kantikakhai	0.015	0.997	0.851	-	0.000***
Khola	0.000***	0.000***	0.000***	0.000***	-

** >90% significance level, ** >95% and *** >99.9%*

Table 2.7 Evenness of species abundances of various blocks compared

	Shannon Index		
Blocks	**Seedlings**	**Saplings**	**Trees**
Baunsagada	0.571	0.974	0.963
Bhitarkanika	0.947	0.957	1.071
Dangamal	0.823	0.617	1.218
Ekakula	0.832	1.05	0.957
Kalibhanjadia	0.752	1.024	0.847
Mahisamunda	1.064	1.078	1.159
Ragadapatia	0.857	0.876	1.131
Sapuadia	0.566	0.52	0.885

Table 2.8 Plant species diversities of various blocks compared

Block	Simpsons Index
Baunsagada	0.182
Bhitarkanika	0.236
Dangamal	0.076
Ekakula	0.192
Kalibhanjadia	0.303
Mahisamunda	0.103
Ragadapatia	0.098
Sapuadia	0.177

The Simpson index values (Table.2.8) show that the Bhitarkanika Mangrove is not very diverse. The probability of a random sample of two individuals to belong to different species is very low in most of the blocks.

d. Densities of major tree species in Bhitarkanika

The tree species that is present in highest density is Excoecaria agallocha, which is the dominant species in most of the blocks. The environmental condition befitting each and every species is different as it is evident from the differential densities they show in various blocks, which are separated in space (Table 2.9).

e. Importance Value Indices (IVI) of major tree species

The IVI values of the more dominant species of Bhitarkanika are summarized in the Table 2.10. *Excoecaria agallocha* is far ahead of all the other tree species in its dominance all over the Bhitarkanika mangroves. The representation in the IVI class of 10-30 is only four members and most of the other species fall under this category.

Table 2.9 Density per hectare of major tree species across blocks in Bhitarkanika

Species	Baun-sagada	Bhitar-kanika	Dang-amal	Ekakula	Kalibh-anjadia	Mahis-amunda	Ragad-apatia	Sapu-adia
Acanthus	294.12	35.00	146.67	385.71	112.90	1846.15	3972.73	14877.78
Aegialitis rotundifolia	0.00	0.00	0.00	561.90	0.00	0.00	0.00	0.00
Aegiceras corniculatum	17.65	0.00	180.00	42.86	261.29	25.64	336.36	0.00
Avicennia marina	258.82	0.00	0.00	9.52	0.00	0.00	0.00	0.00
Avicennia officinalis	11.76	0.00	0.00	42.86	0.00	0.00	0.00	0.00
Brownlowia tersa	58.82	15.00	321.67	0.00	306.45	184.62	627.27	0.00
Caesalpinia bonduc	0.00	70.00	0.00	71.43	312.90	2.56	0.00	33.33
Caesalpinia cristata	129.41	350.00	866.67	171.43	648.39	538.46	627.27	522.22
Ceriops	1247.06	0.00	80.00	695.24	1193.55	258.97	0.00	100.00
Cyanometra ramiflora	0.00	0.00	20.00	14.29	45.16	35.90	0.00	200.33
Excoecaria agallocha	1547.06	3955.00	560.00	1257.14	1741.94	479.49	81.82	33.33
Heritiera formes	0.00	705.00	320.00	42.86	0.00	325.64	172.73	0.00
Heritiera littoralis	17.65	865.00	0.00	0.00	803.23	771.79	0.00	313.89
Hibiscus tiliaceus	70.59	0.00	73.33	0.00	135.48	5.13	627.27	72.78
Myriostachya wightiana	41.18	960.00	493.33	0.00	1438.71	607.69	0.00	1288.89
Phoenix paludosa	76.47	0.00	1986.67	209.52	432.26	330.77	0.00	322.22
Pongamia glabara	0.00	0.00	13.33	9.52	12.90	412.82	0.00	600.00
Salacia prinoides	429.41	45.00	153.33	14.29	167.74	79.49	0.00	0.00
Salvadora persica	329.41	25.00	0.00	66.67	0.00	7.69	0.00	0.00

diversity is maximum in Dangamal block.

For convenience these values may be divided into 4 classes as in Table 2.11. From the class values, it can be observed that there are at least 5 leading species from class B-D, which are dominating in the stand with the concept of Importance Value Index. These five have a combined IVI value of 51.83 out of the total 289.63 and the average IVI value is about 17.27. On the other hand, the 19 species in the

Table 2.10 Importance Value Indices (IVI) of major tree species

Species	IVI	Species	IVI
Excoecaria agallocha	157.11	*Avicennia alba*	2.08
Pongamia glabara	29.14	*Strynchnus nuxvomica*	2.00
Heritiera littoralis	19.11	*Kandelia candel*	1.98
Avicennia officnalis	16.84	*Madhuanchar*	1.89
Cynometra ramiflora	15.88	*Diospyrus embryopteri*	1.79
Heritiera formes	8.54	*Rhizophora*	1.73
Hibiscus tiliaceus	6.56	*Xylocarpus granatum*	1.66
Aegiceras corniculatum	5.46	*Saahada*	1.55
Masu	3.83	*Salacia prinoides*	1.51
Sonneratia apetala	3.03	*Sonneratia caseolaris*	1.31
Avicennia marina	2.21	*Gohira*	1.15
Ceriops	2.13	*Salvadora persica*	1.14

class A, have a combined IVI value of 51.55 out of the total 289.63 and the average IVI value of the 19 species is only 2.71. Therefore it is clear that in the class B-D have a maximum Importance Value Index in the Bhitarkanika Mangrove Protected Area.

Table 2.11 The IVIs of major species pooled into classes

IVI Class	Code	No. of species
< 10	A	19
10 – 20	B	3
20 – 30	C	1
> 30	D	1

2.3.3 Resemblances in vegetation communities

a. With respect to trees

The dendrogram (Figure 2.5) is showing the similarities in vegetation types between various blocks. Bhitarkanika separates out as a distinct vegetation type. Ekakula, Sapuadia, Kalibhanjdia and Bansuagada form another distinct group. Mahisamunda, Ragadapatia and Dangamal are found as a group sharing the similar species composition, the closeness in species composition being judged from the relative distance from the base at which the blocks separate on the dendrogram.

b. With respect to saplings

The dendrogram (Figure 2.6) is showing similarities of blocks with respect to sapling diversity as well as abundance. It follows an almost similar pattern as that shown by the tree species. But here, the sapling composition of Kalibhanjadia shows affinities towards Bansaugada, Ekakula and Ragadapatia, which was not the case with tree composition. Also Sapuadia shows similar sapling composition as Dangamal.

c. With respect to seedlings

The seedling composition of Bhitarkanika block seems to be in accordance with the tree composition (Figure 2.7). But the Kalibhanjadia block is not regenerating the same species as its tree composition. Its affinities are towards Mahisamunda and Dangamal. In the same

Figure 2.5 Similarities between blocks in tree species composition

Dendrogram using Ward Method

```
                    Rescaled Distance Cluster Combine

   C A S E      0         5        10        15        20        25
 Label     Num  +---------+---------+---------+---------+---------+
                               +---------------+
 MAHISAMU    6   -+---+                             I               I
 RAGADAPA    7   -+   +-----------------------------+               I
 DANGAMAL    3   -----+                                             I
 BHITARKA    2   ---------------------------------------------------+
```

Figure 2.6 **Similarities between blocks in sapling species composition**

Dendrogram using Ward Method

```
                    Rescaled Distance Cluster Combine
   C A S E      0         5        10        15        20        25
 Label     Num  +---------+---------+---------+---------+---------+

 BAUNSAGA    1   -+-+
 EKAKULA     4   -+ +---+
 RAGADAPA    7   ---+   +-------------+
 KALIBHAN    5   -----+-+             +-----------------------------+
 MAHISAMU    6   -----+               I                             I
 BHITARKA    2   ---------------------+                             I
 DANGAMAL    3   ---+-----------------------------------------------+
 SAPUADIK    8   ---+
```

way Ragadapatia also showed a different seedling composition that the tree community.

2.4 Discussion

Mangroves are relatively well known ecosystems in India (Blasco, 1997). In addition, with the exception of a few endemic species of plants (Heritiera fomes) and vertebrates (Plantanista gangetica), the flora and fauna of modern deltas are not fundamentally different from those recently analyzed or described in Indo-

Figure 2.7. Similarities between blocks in seedling species composition

Dendrogram using Ward Method

Rescaled Distance Cluster Combine

```
  C A S E      0         5        10        15        20        25
Label     Num  +---------+---------+---------+---------+---------+

BAUNSAGA     1   -+
EKAKULA      4   -+-----+
SAPUADIA     8   -+     +---------+
RAGADAPA     7   -------+         +-------------------------------+
KALIBHAN     5   -------+-----+   I                               I
MAHISAMU     6   -------+     +---+                               I
DANGAMAL     3   -------------+                                   I
BHITARKA     2   -------------------------------------------------+
```

Pacific region, Oceania (Australia, New Zealand, New Caledonia).

The 3,000 sq. km woody mangrove of the country are unevenly distributed in seven major mangrove regions, which include: the large deltas of the East-Coast (Ganges, Mahanadi, Godavari, Krishna, Cauvery); the creeks and bays of Andaman and Nicobar Islands.; The small riverine mangroves of the Arabian sea (from Mangalore to Goa and Bombay); The patchy, depleted and vestigial mangroves of the North-West (subdeseartic Gulf of Kutch and Saurashtra) (Blasco, 1997).

The Baitarani and Brahmani rivers, their distributaries and several tidal creeks provide ideal habitats for mangroves and these are popularly known as Bhitarkanika mangroves. This is the third important mangrove habitat among Indian mangals, in terms of species diversity and quality (Naskar and Mandal, 1999). They differ considerably from the other Indian mangroves because of their dominant trees: *Sonneratia apetala* and several *Avicennia* spp. In addition there is a grass, *Myriostachya wightiana*, which is very common here but practically unknown elsewhere (Blasco, 1977).

The riverbanks are low for a considerable distance from the ocean. In these riparian thickets, the initial band towards the landside is usually the tall *Myriostachya wightiana* grass. Beyond this the patch is dominated by *Avicennia officinalis* and *Hibiscus tiliaceus* with some occasional *Sonneratia apetala*. Climbers like *Caesalpinia cristata* and *Dalbergia spinosa* are abundant in the riverine patches making them not easily penetrable. In the small open patches, under-shrubs of *Acanthus* is predominates. The influence of the ocean reflects in the floral composition. *Avicennia marina* along with *Sonneratia apetala* and some rare *Rhizoporaceae* increase in frequency towards the ocean side whereas *Hibiscus tiliaceus*, disappear completely.

The *Aegialitis rotundifolius* and *Avicennia marina* are found only in areas of high salinity. Ekakula and Baunsagada are areas very near to the seacoast and there is high density of this plant in this area. The other two species of *Avicennia* viz. *A. alba* and *A. officinalis* show a wider range of salt tolerance.

Brownlowia tersa is found in small creeks mostly. Ragadapatia, Mahisamunda, Dangamal which are rich in small creeks harbors a high proportion of *Brownlowia*. *Merope angulata*, shows a very narrow distribution range (only in very small creeks like in Khola creek). *Phoenix* comes up in degraded areas and those degraded areas of Dangamal shows a high abundance of *Phoenix*. *Hibiscus tiliaceus* is a species of drier areas, where water level has gone down and the area is not inundated anymore. *Cyanometra* is found in association with *Pongamia*, *Hibiscus*, *Salvadora* and *Dalbergia*. *Heritiera* and *Excoecaria* in firm grounds inside the shoreline. *Sonneratia* found on the shoreline and survive on loose substratum. The loose sandy soil of Mahisamunda shoreline supports a high proportion of *Sonneratia*.

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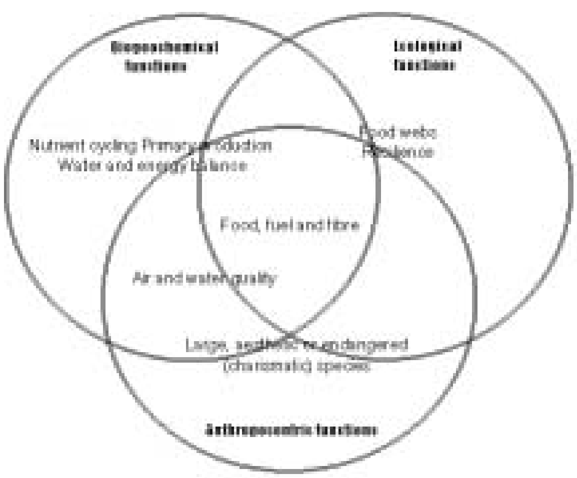
Chapter 3

An Assessment of the Ecosystem Services Provided by Bhitarkanika Mangrove Ecosystem

Natural ecosystems perform fundamental life-support services without which human civilization would cease to thrive (Daily, 1997). Ecosystem functions are often defined in terms of fluxes of matter and energy (Aber *et al*., 1991). According to Field *et al*., (1998) ecosystem function covers three major areas - Biogeographical, ecological and anthropocentric, with overlaps between all three (Figure 3.1). In some cases a single ecosystem service is product of one and more ecosystem functions whereas in other cases a single ecosystem function contributes to two or more ecosystem services (Costanza, 1997a).

Figure 3.1 Ecosystem functions illustrating the concept of overlapping realms of influence among biogeochemical, ecological and anthropogenic functions



Source: Field et al., 1998

The ecological functions or processes ascribed to mangroves are found at the global, ecosystem, and population levels. Ecosystem functions include hydrologic transfers and storage of water (Richardson and McCarthy, 1994), biological productivity (Mitsch and Gosselink, 1986), biogeochemical transformation (Walbridge and Lockaby, 1994). At the population level, mangroves function as wildlife habitats, maintaining unique species and biodiversity. The mangrove ecosystem are widely recognized as the provider of a wide variety of goods and services to people including protection from floods and storm, provision of a variety of plant and animal products, sediment trapping and nutrient uptake and transformation (Table 3.1.). For economists, these functions are also known as indirect-use values (Claridge, 1991). The value of the ecosystem is an estimate of the worth, merit, quality, of a particular ecosystem to human beings that arises from the ecological functions found within the ecosystem.

Natural capital is a stock that yields a flow of valuable goods and services into the future. This sustainable flow of goods and services is natural income and the stock that yields sustainable flow is natural capital i.e. natural capital and natural income are stock and flow components respectively of natural resources (Costanza, 1997b). Ecosystems are renewable natural capital, which can be harvested to yield ecosystem goods and they also yield a flow of ecosystem services when left in place like erosion control and recreation (*Costanza et al*., 1992, 1997b and 1997c). On the basis of above statement in this study, fish and shellfish production, nutrient retention and storm protection are the natural income or flow of the ecosystem goods and services. Whereas, land accretion is the stock, as soil, atmospheric structure, plant and animal biomass are the natural capital stock, which uses primary inputs (sunlight) to produce the range of ecosystem services and physical natural resource flow.

The information on ecological functions and the key productive uses of mangrove ecosystems were collected from existing literature. To identify the use values and ecological functions, which are performed by

Bhitarkanika mangrove ecosystems discussions were held with the Park Management and staff, field biologists, scientists, commercial fishermen and local people. These were partly identified during the door-to-door socioeconomic/attitude survey.

Table 3.1 Ecological functions performed by mangrove ecosystems.

Ecological functions performed by mangrove ecosystems	Intensity	Intensity of ecological functions performed by the BCA	Relative intensity of benefits at three spatial scales		
			High	Medium	Low
Hydrological flux					
Recharge ground water	Low	Low	Regional	Local	Global
Store water as reservoir	High	Low	Regional	Local	Global
Control Regional climate	High	High	Regional	Local	Global
Biological productivity					
Organic matter production: 2.0-3.0 kg / m^2 / yr^{-1}	High	High	Local	Regional	Global
Wood production: 20 -40 c^3 m ha^{-1} $year^{-1}$	High	High	Local	Regional	Global
Fish and shellfish: 60 - 1500 kg ha^{-1} $year^{-1}$	High	High	Local	Regional	Global
Biogeochemical recycling and maintenance of natural processes					
Decomposition and nutrient recycling	High	High	Global	Regional and Local	-
Nutrient retention	High	High	Global	Regional and Local	-
Sediment retention	High	High	Global	Regional and Local	-
Toxicant removal	High	Low	Global	Regional and Local	-
Land accretion	High	High	Local	Regional	Global
Protection from natural forces					
Shoreline protection and flood control	High	Low	Local	Regional	Global
Protection from natural forces - wind break	High	High	Local	Regional	Global
Prevention of saline water intrusion	Low	Low	Local	Regional	Global
Community and wildlife habitat					
Plant and animal diversity	Low	High	Global	Regional and Local	-
Habitats for endangered species	High	High	Global	Regional and Local	-
Genetic reservoir	High	High	Global	Regional and Local	-

The intensity compared here are in relation to fresh water ecosystems.

Table 3.2 Direct use value of the mangrove ecosystems (*Modified from Bann, 1999*)

Direct use value	Intensity of use value of BCA	Relative intensity of benefits		
		High	Medium	Low
Forestry products – Fuel wood, timber, fodder, thatching materials, fibre, honey, medicine	Despite Bhitarkanika being a PA, *de facto* resource extraction for basic livelihood exists	Local	Regional	Global
Contribution to offshore and inshore fish and shell fish production – Fish, crab, shrimp, etc.	Believed to be high as it supports large congregation of fish eating birds, crocodile and nesting turtles	Local	Regional	Global
Aquaculture products – Prawn seedlings	High due to extensive detritus production	Local	Regional	Global
Tourism and recreation	High – a popular tourist destination situated at the junction of Orissa and West Bengal states	Local and Regional	-	Global
Water transport	Connecting links between major villages and fish landing stations	Local	-	-
Genetic resources	High due to large diversity of mangrove species including wild rice	Global and Regional	Local	-
Educational, historic and scientific information	High because of large assemblages of flora and fauna – unique habitat	Global and Regional	Local	-

The following section attempts to quantify some of the use values as well as ecological services provided by the Bhitarkanika mangrove ecosystem. We selected five parameters for the valuation of benefits from the Bhitarkanika mangrove ecosystem. The parameters and the methods adopted for each parameter are given Table 3.3.

Table 3.3 Selected functions and values of Bhitarkanika estimated and methods used for each parameter

S. No.	Parameters to be valued	Methods being used
1	Nutrient retention	Replacement cost approach
2	Fish and shellfish production	Market value
3	Storm abatement	Damage costs avoided
4	Land accretion	Market value

3.1 Nutrient Retention

3.1.1 Introduction

Soils are the physical foundation of every wetland ecosystem. Plants and animals alike are dependent upon the hydric soil for many vital resources. An integration of hydric soils with the plant and animal communities provides the structure for the many functions we associate with wetland ecosystems (Stolt *et al*., 2000).

Soil provides five interrelated services besides moderating the water cycle. First, soil shelters seeds and provides physical support as they sprout and mature into adult plants. Second, soil retains and delivers nutrients to plants. Third, soil plays a central role in the decomposition of dead organic matter and wastes, and this decomposition process also renders harmless many potential human pathogens. The simple inorganic chemicals that result from natural decomposition are eventually returned to plants as nutrients, which forms the fourth service provided. The decomposition of wastes and the recycling of nutrients are two aspects of the same process. Finally, soils are a key factor in regulating the Earth's major element cycles those of carbon, nitrogen and sulphur (Daily *et al*., 1997).

The pool of available nutrients (Nitrogen compounds, Phosphors and Potassium) in mangrove soils is a product of several processes that proceed on different time scales: plant production, decomposition of litter fall, mineralization of organic matter, input by rainfall, sedimentation by tide and runoff, and uptake by plants. In organic phosphorus, nitrogen and potassium are the most significant nutrients, which get deposited in the mangrove systems and in turn, are recycled or dissipated during high flood to the adjacent areas and contribute directly in biomass production. Through this project we are attempting to estimate contribution made by Bhitarkanika mangrove ecosystem in terms of nutrient retention.

Natural mangrove forests are characterized by distinctive tree-height gradients that reflect complex spatial, within-stand differences in nutrient dynamics across narrow environmental gradients that essential nutrients are not uniformly distributed within mangrove ecosystems and that soil fertility can vary across narrow ecotonal gradients. This indicates that the nutrient from the sources (mangrove forests) get transported to nearby areas and enrich the surrounding ecosystems or land areas during high flood, particularly during monsoon.

3.1.2 Methods

Sampling site

The terrain of Bhitarkanika Wildlife Sanctuary is formed by the alluvial filling up of the littoral zone of the Bay of Bengal. It is composed of sandy and muddy beach along the coast including the rivers and networks of creeks and channels (Choudhury *et al*., 1999). For the collection of soil samples, the study area was stratified on the basis of mangrove and non-mangrove areas. The area under forest cover was taken as mangrove area which is about 145 km^2 and the remaining area of sanctuary after excluding forest area from total 672 km^2 sanctuary *i.e.*, 527 km^2, was taken as non-mangrove area. Mangrove areas were further stratified into forest blocks with fairly good mangroves of different species and period of inundation during high flood (Chadha and Kar, 1999). Subsequently, pure stands of different mangrove species were selected for sample collection. Sixty sampling sites were selected from the mangrove and non-mangrove areas each. Sampling sites were selected so as to represent the whole study area uniformly. At each sampling point a 50 m transect was laid perpendicular to the creeks. Assuming that a high degree of spatial variability may exist over quite small areas, the soil samples were collected from five points at an interval of 10 m on each transect. The soil samples were collected from 10-15 cm depth, labeled on site, air-dried and kept in plastic bags for the further analysis.

All samples were brought to the laboratory; pebbles and detritus were removed from each sample. Thereafter, to break up soil lumps, samples were grounded by wooden roller and passed through 2 mm stainless steel sieve. All five samples from each transects were mixed together to form a single sample. In this way a total of 60 samples each were obtained from both mangrove and non-mangrove area. Subsequently, following physical and chemical parameters of soil samples were analyzed using techniques as specified for each parameter:

Physical characters of soil

Soil Texture: Texture was evaluated in the laboratory by Bouyoucos hydrometer method (Allen, 1989).

Chemical characteristics of soil

a) Soil pH: pH value was determined using electrometric method (Jackson, 1967).

b) Organic Carbon: The organic Carbon was determined by Walkley and Black Rapid Titration Method (Jackson, 1967).

c) Total Nitrogen: Micro Kjeldahl method as described by Jackson (1967) was used for estimating total Nitrogen.

d) Available Phosphorus: The available Phosphorus was estimated by using Photoelectric Colorimeter (Allen, 1989).

e) Available Potassium: The available Potassium was estimated by N - Ammonium Acetate Method using digital Flame Photometer (Jackson, 1967).

Valuation of major nutrients

For economic valuation of soil the productivity method, also referred as the net factor income or derived value method is used. The productivity method was selected because by this method the cost of producing a marketed good can be compared to the economic benefits of the ecological function provided (Bann, 1997), in this case the soil nutrients that are essential for plant growth. Thus, the soil nutrients present were related to the cost of equivalent amount of fertilizer to be added.

Productivity method, estimates economic values for ecosystem products or services that contribute to the production of commercially marketed goods. In this method if a natural resource is a factor of production, then changes in the quantity or quality of the resource will result in changes in production costs, and/or productivity of other inputs. This in turn may affect the price and/or quantity supplied of the final good. It may also affect the economic returns to other inputs. Two types of benefits (or costs) may be important. First, if the quality or price to consumers of the final good changes, there will be changes in consumer surplus. Second, if productivity or production cost changes, there will be changes in producer surplus. Thus, the economic benefits from improvements in the resource can be estimated using changes in observable market data (Bann, 1997).

The replacement cost method was used to measure the comprehensive value and provides the estimates of benefits accruing from mangroves on account of nutrient retention process. The replacement cost approach was used to derive the values of mangrove ecosystem in retaining and recycling of nutrients to adjacent terrestrial and aquatic ecosystems. The replacement cost approach looks at how much it would cost to replace productive assets that are damaged by any development. The first step is to conduct an ecological assessment of the services and their level(s) provided by the mangroves. The second step for the replacement or substitute cost method is to identify the least costly alternative means of providing the service(s). The third step is to calculate the cost of the substitute or replacement service(s).

In the case of Bhitarkanika mangroves we valued the nutrients retained in the soil by the mangroves, thereby increasing its fertility. For this soil samples from the mangrove and non-mangrove areas were analyzed. The cost of increasing the soil nutrients in the non-mangrove areas to the level of mangrove areas was calculated by valuing the fertilizers if added to the soil in non-mangrove areas to bring their nutrient level to that of mangrove areas.

3.1.3 Results

Physical properties of soil

After analysis, soil samples were categorized into different texture classes according to presence of silt, clay and sand (Table 3.4 and Figure 3.1). It was found that most of the samples from mangrove (76.67 %) fall under clay and rest fall in silty clay, clayey loam and loamy sand (11.67%, 10% and 1.67%) texture classes, while in non-mangrove area soil is distributed in various classes viz: clay, silty loam, clayey loam and silty clay (36.67%, 23.33%, 15% and 15% respectively).

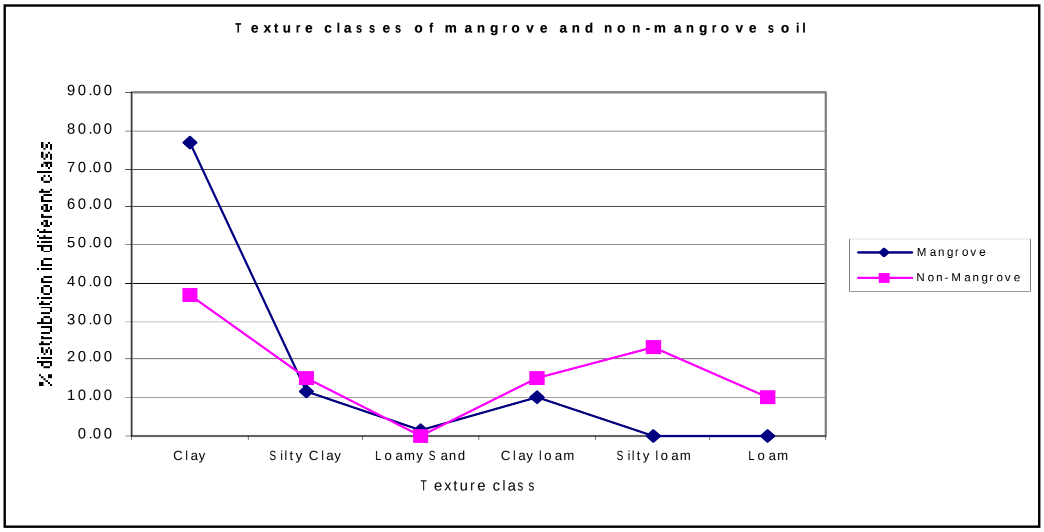
Table 3.4 Distribution of soil in different texture class (%).

Textural class	Mangrove	Non-Mangrove
Clay	76.67	36.67
Silty clay	11.67	15.00
Loamy sand	1.67	0.00
Clayey loam	10.00	15.00
Silty loam	0.00	23.33
Loam	0.00	10.00

Chemical properties of soil

It was found that the soil from mangrove areas showed slightly basic properties (Mean pH 7.58) while soil from non-mangrove areas were found to be almost neutral (Mean pH 7.03). Electrical conductivity of soil from mangrove and non-mangrove was 2.64 and 2.30 respectively. Nutrients present in soil samples, organic carbon, total nitrogen, available phosphorus and available potassium were also estimated. They were found to be present in higher amount in mangrove areas as compared to the non-mangrove areas. Organic carbon was 25326.67 kg/ha and 18323.33 kg/ha; total nitrogen was 2907 kg/ha and 2057 kg/ha; available phosphorus was 28.11 kg/ha and 20.08 kg/ha and available potassium was 1564.55 kg/ha and 1222.46 kg/ha in mangrove and non-mangrove areas respectively (Table 3.5).

Figure 3.2 Texture classes of mangrove and non-mangrove soil.



It was found after the analysis of variance (Table 3.6) that most of the chemical properties of soil viz. pH, organic carbon, total nitrogen, available phosphorus and available potassium of mangrove are significantly different from soil of non-mangrove area (*p = 0.000; df = 59; t = 0.05*). No significant difference was found (*p = 0.263; df = 59; t = 0.05*) in electrical conductivity of mangrove and non-mangrove soil.

Table 3.5 Available nutrient in the soil collected from Mangrove and Non-Mangrove areas of Bhitarkanika Wildlife Sanctuary.

Area / Parameters	Mangrove		Non-Mangrove	
	Mean	**SE**	**Mean**	**SE**
pH	7.58	0.06	7.03	0.09
EC	2.64	0.18	2.30	0.23
Organic C (kg / ha)	25326.67	1429.81	18323.33	982.18
Total N (kg / ha)	2907.00	177.46	2057.67	112.13
P2O5 (kg / ha)	28.11	3.23	20.08	1.92
K2O (kg / ha)	1564.55	100.89	1222.46	67.24

Table 3.6. Analysis of Variance (Mann Whitney U test – Paired sample t test)

Variable	df	t value	p value (2 tailed)
pH	59	4.797	0.000
EC	59	1.130	0.263
Organic C (kg / ha)	59	4.547	0.000
Total N (kg / ha)	59	4.514	0.000
P2O5 (kg / ha)	59	4.797	0.000
K2O (kg / ha)	59	2.660	0.010

Economic valuation of soil nutrients

By applying the market price method the value of all the nutrients present in mangrove and non-mangrove soil was estimated. The values were derived by multiplying the amount of available nutrient (kg/ha) by the market price of the nutrient (Rs/kg). The value of nitrogen, phosphorus and potassium in one hectare of mangrove soil was found to be Rs 29070/kg, Rs 433.74/kg and Rs 11092.66/kg respectively, while it was Rs 20576.70/kg, 309.83/kg and Rs 8667.24/kg respectively (Table 3.7) in one hectare of non-mangrove soil.

Table 3.7 Valuation of available nutrient in the soil collected from Bhitarkanika Wildlife Sanctuary

Nutrients	Nutrient in mangrove (kg/ha)	Nutrient in non-Mangrove (kg/ha)	Market Value (Rs/kg*)	Estimated value for a ha of mangrove (Rs/kg)	Estimated value for a ha for non-mangrove (Rs/kg)
	(1)	(2)	(3)	(4) = (1 x 3)	(5) = (2 x 3)
Available N	2907.00	2057.67	10.00	29070.00	20576.70
Available P2O5	28.11	20.08	15.43	433.74	309.83
Available K2O	1564.55	1222.46	7.09	11092.66	8667.24
Total value of N+P+K				**40596.40**	**29553.78**

** Source: Fertilizer Association of India, Statistics 2000*

The total amount of nutrient provided by mangrove forests of Bhitarkanika Conservation Area was estimated by the replacement cost method (Kumar, 2001). The area under mangrove forest is 145 km^2 or 14500 ha. The amount of nutrients (N+P+K) provided by total area under mangrove forest was estimated. The nutrients provided thus estimated were valued and this gave the value of nutrient retention function of mangroves, which is Rs 588 million for the total mangrove forest of Bhitarkanka Wildlife Sanctuary (Table. 3.8.).

Table 3.8 Valuation of nutrient in the total area under mangrove forest in Bhitarkanika Wildlife Sanctuary

Nutrients	Amount of nutrient in mangrove (kg/ha)	Area under Mangrove forest (ha)	Nutrient in total area under Mangrove (kg/ha)	Market Value (Rs/kg *)	Estimated value for Nutrients in total mangrove area (Rs)
	(1)	(2)	(3) = (1 x 2)	(4)	(5) = (3 x 4)
Available N	2907	14500	42151500	10	4,21,515,000
Available P_2O_5	28.11		407595	15.43	6,289,190.85
Available K_2O	1564.55		22685975	7.09	1,60,843,562.75
Total value of N+P+K					**588 million**

**Source: Fertilizer Association of India, Statistics 2000*

Table 3.9 Estimation of economic value of the extra nutrient present in total mangrove area as compared to the non-mangrove area of Bhitarkanika mangrove ecosystem

Nutrients	Amount of nutrient in mangrove (kg / ha)	Amount of nutrient in Non-Mangrove (kg / ha)	Amount of extra nutrient in mangrove (kg / ha)	Total Area under Mangrove forest	Amount of extra nutrient in total Mangrove area (kg / ha)	Market Value (Rs/ kg*)	Estimated value for extra nutrients in total mangrove area (Rs)
	(1)	(2)	(3) = (1 - 2)	(4)	(5) = (3x4)	(6)	(7)
Available N	2907	2057.67	849.33	14500 ha	12315285	10	1,23,153,850
Available P_2O_5	28.11	20.08	8.03		116435	15.43	1,796,592.05
Available K_2O	1564.55	1222.46	342.09		4960305	7.09	35,168,562.45
Total value of N+P+K							**160 million**

** Source: Fertilizer Association of India, Statistics 2000*

3.1.4 Discussion

Soil properties, such as texture and organic matter content affect the hydrology. The physical properties of soils - texture, structure, density, porosity, water content, consistency, temperature, and colour - are dominant factors, affecting the use of soil. It was impossible to examine all the factors, like temperature, consistency and colour in the normal way because the water table was often high, sometimes at or above the surface. Soil texture signifies the water holding capacity and nutrient retention capacity of soil. One of the objectives of this analysis was to find if mangrove soil is helping in nutrient retention therefore only soil texture was taken in to consideration. Natural soil is comprised of soil particles of varying sizes. The soil particle-size groups, called soil separates are sands (the coarsest), silts and clays (the smallest). Soil particles are categorized into groups according to size - clay (less than 0.002 mm), silt (0.002 to 0.06 mm) and sand (0.06 to 2.0 mm). The amount of sand, silt, and clay ultimately makes up the class of the soil. To determine the class type of an unknown soil we will have to determine the ratio of sand, silt and clay particles in a specific volume of soil. Soil particles that are less than 2 microns diameter (*i.e.*, clay) carry a surface electrical charge that is generally negative, this property holds positively charged nutrient cations near the surface, in proximity to plant roots, allowing them to be taken up gradually (USDA, 1954). Otherwise, these nutrients would quickly leach away. The soil composition of mangrove shows that it primarily falls under textural class - clay (76.67%) compared to non-mangrove soil (36.67%), therefore it can be safely assumed that mangrove soil acts as nutrient sink and helps in nutrient retention.

The chemical analysis of soil included estimation of soil pH, organic carbon, total nitrogen, available phosphorus and total potassium. The soil pH greatly affects the solubility of minerals. Amount of organic carbon in the soil is important in soil classification and chemical characterization. Many soil bacteria require organic carbon as an energy source. Nitrogen is most often the limiting element in plant growth; it is a constituent of chlorophyll, plant proteins, and nucleic acids. Nitrogen can be utilized by plants as the ammonium cation or as the nitrate anion. Phosphorus is contained in plant cell nuclei and is part of energy storage and transfer chemicals in the plant. Soils have low total and low plant-available phosphate supplies because mineral phosphate forms are not readily soluble. Phosphorus used by the plant is taken up as the HPO_4^{2-} and $H_2PO_4^-$ anions. Potassium, though soluble in the plant, apparently facilitates many plant actions and enzyme transformations. It is in great total supply as a component of common minerals (Donahue *et al*., 1983). On analysis it was found that the pH is slightly basic in mangrove and almost neutral in non-mangrove soil that is slightly different from the pH of Sunderbans where soil was found to be highly alkaline. Although organic carbon content is higher in mangrove than in non-mangrove. However, organic carbon contents were not in good state in mangrove soil in Bhitarkanika also as in Sundarbans. The amount of all the other nutrients were found to be considerably higher in mangrove soil than in non mangrove soil, which proves the greater nutrient retention capacity of mangrove soil in comparison to non-mangrove soil. In Sundarbans also the nutrient status of mangrove status of mangrove soil showed that soil was inherently fertile.

For economic valuation of the nutrient available in the soil, the individual nutrients such as nitrogen, phosphorus and potassium were estimated in terms of Rs/kg/ha and the total value of nutrients was estimated both for mangrove and non-mangrove areas as Rs 40596.40/ha and Rs 29553.78/ha respectively.

The total amount of nutrient provided by mangrove forest of Bhitarkanika Wildlife Sanctuary was estimated by replacement cost method. The nutrients (NPK) provided the total mangrove forest of Bhitarkanka Wildlife Sanctuary, *i.e.*, 14500 ha, was replaced with the cost of chemical fertilizers and thus nutrients value estimated was estimated. This finally gave the value of nutrient retention function of mangroves, which is Rs 588 million for the Bhitarkanika Wildlife Sanctuary and 350 US $ for an acre of mangrove forest in a year.

It can be summarized on the basis of these results that as the soil of mangrove area act as nutrient sink and help in nutrient retention, therefore they have significantly high amount of nutrient available. And in monetary terms also they contribute significantly by nutrient retention.

3.1.5 Conclusions

The physical properties of mangroves (*e.g.,* vegetation, size, water depth) tend to slow down the flow of water. This facilitates sediment deposition. This deposition is closely linked to the beneficial removal of toxicants and nutrients since these substances are often bound to sediment particles. Nutrients are often associated with sediments and therefore can be deposited at the same time (Bann, 1997). To understand the nutrient retention function of the mangroves the soil samples from both mangrove and non-mangrove areas were analyzed. The nutrient content of mangroves was found to be significantly high. On the basis of the comparative study of mangrove and non-mangrove areas of Bhitarkanika, it is possible to say that mangroves are able to retain nutrient rich sediments. We have estimated the major three nutrients in terms of N, P and K in mangrove and non-mangrove areas. The cost in order to replace the same amount of N, P and K with the help of chemical fertilizers have been estimated. This approach, known as replacement cost method, measures the comprehensive value and provides the estimates of benefits accruing from mangroves on account of nutrient retention process. The difference in the nutrient content in mangrove and non-mangrove gave the amount of nutrient provided by mangroves, which is Rs 160 million for the 145 km^2 that comes under mangrove forests in Bhitarkanika Wildlife Sanctuary.

3.2 Fish and Shellfish Production

3.2.1 Introduction

Coastal areas are vital to the prosperity of the country and are usually, biologically most productive areas, supporting a wealth of living marine resources. Marine capture fishery of India is very important sector being a source of valuable food, employment and foreign exchange earnings (Sudarshana *et al*., 2000). Mangrove ecosystem is generally considered important for supporting the population of certain species of fish, which are caught off-site. Therefore any disturbance to the mangrove ecosystem, such as cutting down for fishpond development, will result in smaller population sizes and hence smaller catches in the off-site fisheries.

Mangroves are very important as coastal habitats for commercially important fishes and invertebrates. Fish provide a large percent of animal protein consumed by the world population. In tropical developing countries, 60 percent of the people depend on fish for 40 percent or more of their protein demand. The majority of the world's landed fish catch (87 percent) comes from marine areas.

Since the early 80s, Orissa made significant strides in marine fisheries with rapid motorization of the gears. The state has a continental shelf of about 24,000 km^2 up to 200 m-depth zone. The fishing potential (exploitable fish stock) of Orissa coast is estimated at about 2,08,000 t. Out of this, 1,80,000 t is in the 0-50 m depth zone and the rest in 50-200 m zone. The maximum landing till 1993 were 1,19,376 t leaving an additional ca. 68,000 t in the 0-50 m zone and 28,000 t beyond to be exploited (Sudarshana *et al.,* 2000).

The 480 km coastline of Orissa along northwest Bay of Bengal represents a prograding and depositional environment, endowed with a vast estuarine system, the second largest mangrove zone in India. In India, the largest fish production comes from the coastal capture fisheries of inshore waters (< 50 m depth), which contributed about 82 percent to the total marine capture fish production of 2.7 million tonnes (mt) in 1997 (Sudarshana *et al*., 2000).

India's annual marine fish production is about 2.4 million tones of the estimated fishery potential of 3.92 tones (Rao *et. al,* 2000). The biggest number of Indian fishing fleet comes from the non-mechanized traditional sector and mostly operating at the near shore within 50 m depth zone.

The success of near shore fisheries in many tropical regions depends as much on the mangrove habitats themselves rather than the detrital foods for recruitment success. There is positive correlation between mangrove area and prawn/shrimp landings and in many areas commercial shrimp fisheries production related directly to area of mangroves.

Inshore fisheries play vital role in the lives of communities living in and around Bhitarkanika National Park. Yet as they are difficult to quantify, they are frequently underrated or absent from national statistics.

The estuarine and mangrove systems are widely recognized as good nursery grounds for young fishes of exploited populations (Miller *et al*., 1983; Little *et al*., 1988). In most of the cases when mangrove is present, it is associated with 'true' physico-chemical estuarine condition that is to say under conditions where fresh water is provided in such amount that the environment is brackish most of the time (Sasekumar *et al*., 1992; Tzeng and Wang, 1992). Mangrove ecosystems serve as vital nursery grounds for the economically important near shore fish and shellfish species. Snedaker (1984) estimated that more than 90% of near shore marine species were found in the mangroves during one or more parts of their life cycles.

For estimating the function of mangrove in fish productivity the sampling was undertaken in this study with three objectives. Firstly, the survey of the fishing in offshore fishing port was done. Secondly, the sampling was carried out to determine the contribution of inshore fishery resources in the socio-economic life of people in Bhitarkanika. Thirdly, a survey of the juvenile fish community was undertaken with the aim of verifying whether or not this environment is suitable as a nursery area for exploited prawn and fish community.

3.2.2 Offshore Fishery

3.2.2.1 Site selection and sampling

Through this project we are attempting to estimate contribution made by Bhitarkanika mangrove ecosystems in terms of fish production. To collect information on the fish catch it was decided to monitor fish catch in areas where there is mangrove and areas where mangrove forests have been removed. We selected two fish landing stations Dhamra (Dhamara and Talchua) situated close to Bhitarkanika (site with mangroves) and Paradeep port where most of the mangroves have been removed. Beginning from December we monitored fishing trawlers leaving from and returning to these fish landing stations and collected information on species wise total catch and duration of time spent in fishing. From this we estimated fish catch/unit hour.

Few assumptions were made to achieve the desired out come; (i) it was assumed that trawlers from these two fish landing stations restricted their activities within the vicinity of these two stations, (ii) all trawlers from these ports used similar gears.

A limited set of data available restricted us from predicting an accurate model for the off shore fisheries. At the same time our data suggests that the number of species caught exclusively at Dhamra, which is nearer to the mangrove, are greater (19) as compared to Paradip (5). At both the places 25 species were caught. The catch per trawler per hour has been found to be greater for Paradip.

It has been proved by many studies that the mangrove ecosystem contributes substantially to offshore fisheries as they are breeding and nursery ground for varied marine fish species, from our preliminary studies we suspected secondary data provided by fisherman on their catch was erroneous. Subsequently, we abandoned this method of data collection and to estimate the fish capture in offshore areas with or without mangroves we extensively used data from the ongoing project of Wildlife Institute of India, Dehra Dun, “Experimental trawling along the Orissa coast to estimate the mortality of sea turtles” (Gopi *et al.,* 2002), in this study the Orissa coast was divided into three zones. The characters of each zone are as follows:

Zone I: The Gahirmatha coast (zone with mangroves). The length of this zone is 35 km extending between Dhamra river mouth to Barunei, the mouth of river Hansua and forms the eastern boundary of the Bhitarkanika Wildlife Sanctuary. In this zone 12 experimental trawling was carried out. The depth in which trawling was carried out varied from 6 to 10 fathoms (mean 7.72 ± 0.208). Average duration of the trawls varied from 1 to 2 hr (mean 1.24 ± 0.109). Average trawl distance in Zone I varied from 3.39 km to 14.36 km with mean value 6.68 ± 0.934 and the average distance from nearest shore line 0.77 to 23.48 km with a mean of 5.85 ± 1.985.

Zone II: The Paradip coast (zone without mangroves) (55 km) stretches from Barunei to the mouth of Jatadhara. Near Paradip, the only natural harbor along the Orissa coast, Mahanadi river enters the Bay of Bengal. This zone was taken as zone without mangroves. In Zone II, 29 experimental trawls were carried out. Depth in which trawls were carried out varied from 5 to 20 fathoms with mean value 10.13 ± 0.47. Average duration of the trawls varied from 1 to 2.15 hr with mean value of 1.21 ± 0.065. Average trawl distance in Zone II varied from 1.7 to 8.8 Km with mean value 4.4 ± 0.29 and the average distance from nearest shoreline 0.43 to 14.07 Km with a mean of 4.9 ± 1.08.

Zone III: The Devi coast including the Kujang coast of 30 Km stretches from Jatadara river mouth to Kadua river mouth, making it 60 km long zone. We have not taken data from this zone as this zone was too far from Bhitarkanika.

3.2.2.2 Methods

The valuation of offshore fishery was done using the Market Price method, the market price method estimates the economic value of ecosystem products services that are bought and sold in commercial markets (Bann, 1997). All fishes have some commercial value. On the basis of their market prices these fishes are classified in three classes, A-class, B-class and C-class. The marginal productivity of these commercial fish species (*i.e.* the yield per trawling) can therefore be valued in terms of market or shadow prices.

Contribution to fishery benefits (cbf) = value of fish catch per hour in mangrove areas (x) – value of fish catch per hour in areas where no mangrove is present (y).

3.2.2.3 Results

By applying market price the earning/hr was calculated (Table 3.10). There is a significant difference in total catch/hr between both the sampling sites. The zone I, Gahirmatha site (with mangrove) have considerably high fish yield, 123.34 kg/hr then the zone II, Paradip site (without mangrove) where the yield is 17.89 kg/hr. Hence, the earning is also considerably higher in Gahirmatha where by trawling the earning is Rs 1784.60 per hour, while, in Paradip it is only Rs 104.83.

Table 3.10 Comparison of off shore fishery productions at Gahirmatha and Paradip

	Gahirmatha coast (Zone 1)			Paradip coast (Zone 2)		
Fish class	**Rate (Rs/kg)**	**Catch (kg/hr)**	**Earning (Rs/hr)**	**Rate (Rs/kg)**	**Catch (kg/hr)**	**Earning (Rs/hr)**
A-Class	51.17	15.78	807.50	55.92	0.24	13.27
B-Class	15.00	43.93	658.94	15.48	0.31	4.83
C-Class	5.00	63.63	318.16	5.00	17.35	86.73
Total		**123.34**	**1784.60**		**17.89**	**104.83**

3.2.2.4 Discussion

Mangrove areas of Bhitarkanika support a range of inter-connected food webs, which directly sustain shrimps and provide a food source for fishes. Some of the commercially important fishes are *Ilisha* (*Hilsha illisha), Khainga (Mullet sp.), Bhekti (Lates calcifer), Kantia (Mystus gulio)* and *Kokili* (*Anchovella sp.*). Prawns such as *Penaeus indicus*, *Penaeus monodon, Metapenaeus affinis* and crabs, mainly the mud crab (*Scylla serrata*) and fiddler crab (*Uca* sp.) are seen in large numbers. Edible crabs are exploited in large numbers by the fisherman both in the breeding and non-breeding seasons (Dani, 1999).

Many of the fish species that contribute to domestic and foreign consumption are directly harbored by the mangroves during a part of their life cycle, and they remain dependent on the mangrove food web throughout their life cycle. This is particularly the case with prawn, which is the most valuable commercial species in offshore fishery.

To estimate the influence of mangrove in the offshore fishery, the fish catch by trawling in two sites was recorded. The first site was Gahirmatha, which is very near to mangroves and other site is Paradip port, which is far from the mangroves and was considered as the non-mangrove area. The fish catch per hour calculated from these both site showed that the Fish catch is considerably higher in Gahirmatha than Paradip (123.34 kg/hr and 17.89 kg/hr). The per hour earning in both site was calculated using the market price method, which showed the earning by per hour trawling is considerably higher in Gahirmatha. By trawling in one hour in Gahirmatha fisherman can earn Rs 1784.60 while for the same duration earning in Paradip is Rs 104.83 (Table 3.10).

It was observed that the area in the mangrove influence zone gave higher yield of fish than the areas far away from the mangroves, thus, it can be safely assumed that mangrove have positive influence on offshore fishery.

3.2.3 Inshore Fishery

3.2.3.1 Site Selection and Sampling

Six sampling sites were selected; these sampling sites were six creeks namely, Balijore, Ganjeikhia, Jalahar, Mahisamunda, Suajore and Thanpati. All these creeks originate from main Bhitarkanika River. All these creeks have rich mangrove vegetation cover. Sampling was started at all sites in March 2002 and continued till July 2002. A least-damage sampling strategy was used to conserve the fish populations. If possible, in situ observation and identification of fish species were done and fishes were released back in the water (Zakaria *et al*., 1999). Gill net was used as the main sampling gear; it was set across the river for thirty minutes, the total catch in thirty minutes was recorded. After sorting the catch to species level, the individual total weights were recorded (Koranteng *et al*., 2000). Sampling was done at all the sites every fortnight during low tide.

3.2.3.2 Methodology

The estimation of the value of the fish productivity involved following steps:

- An estimate of total fish catch per hour was estimated, by extrapolating the results of the sampling done.
- Estimate different species caught per hour.
- Determine the price of various fish species in local market, the price was determined by surveying the local market at 3-4 places.
- Value different species based on the price of different species obtained from market survey.
- The results obtained thus gave an estimate of the value of effort put in an hour of fishing.

The valuation of fisheries was done using market price method and estimated as follows (Bann, 2000):

Total Value = Unit market * Quantity

The species diversity in all the sampling sites was calculated using the Shannon Index.

Shannon's index for diversity was calculated based on the abundance value of different species in different creeks.

Shannon's Index $\quad H' = -\sum p_i \log p_i$

As a measure of heterogeneity, Shannon's index takes into account the evenness of the abundances of species. The maximum diversity, which could possibly occur, would be found in a situation where all species were equally abundant.

3.2.3.3 Results

For the complete study period, the calculated mean catch in kg/hour is given in Table 3.11. It was evident from the table that although the catch per hour is greater for Kauntia and Kua but it fetch less price than Jalanga, which fetches the highest price in market. Although Hilsha is commercially the most important species but its catch per hour is very low. The estimated value for catch per hour is Rs 89.91 for 3.77 kg of fish.

Table 3.11 Biomass of various species of fish from six sampling sites

Local Name	English Name	Scientific Name	Market value (Rs/ kg)	Catch (kg / hr)	Earning (Rs/ hr)
Kua	--	--	25	0.90	22.43
Khasal	Flat head gray mullet	*Mugil cephalus*	--	0.05	--
Hilsa	Hilsa	*Hilsa ilisa*	58	0.01	0.54
Sulpatia	Gaint catfish	*Arius thalassinus*	22	0.16	3.49
Kauntia	--	*Mystus gulio*	18	1.40	25.26
Jalanga	--	*Pangasius pangasius*	45	0.70	31.72
Sahal	Golden six-thread threadfin	*Polynemus sexfilis*	--	0.17	--
Kaunkada	Mud crab	*Scylla serata*	20	0.11	2.21
Khainga	Gray mullet	*Liza tade*	38	0.04	1.48
Phasi	--	--	24	0.05	1.10
Kutibengo	Pufferfish	*Tetrdon hispidus*	--	0.10	--
Pittatali	--	--	25	0.07	1.69
Sal	--	--	--	0.01	--
Ruli	Gold spotted anchovy	*Coilia dussumieri*	--	0.00	--
Borei	--	--	--	0.01	--
Total				**3.77**	**89.91**

From the total sampling done at the six sites 15 species were collected. The major species caught whose catch per hour was highest were *Kauntia, Kua, Jalanga* and *Sulpatia* (Figure 3.3). Of these species *Kauntia, Kua* and *Jalanga* were present in all the sampling species. While *Sulpatia* although present in Thanpati, Balijore, Jalahar and Mahisamunda was not found in Suajore and Ganjeikhia.

Table 3.12 gives the values of Shannon Index, Ish for each sampling sites. The species diversity is highest in Mahisamunda (Ish = 0.745), followed by Thanpati (Ish = 0.696) and Suajore (Ish = 0.599) had the least species diversity. While species richness was found to be highest in Thanpati followed by Suajore and least in Ganjeikhia.

Fig 3.3 Per hour catch of different species in Bhitarkanika Wildlife Sanctuary

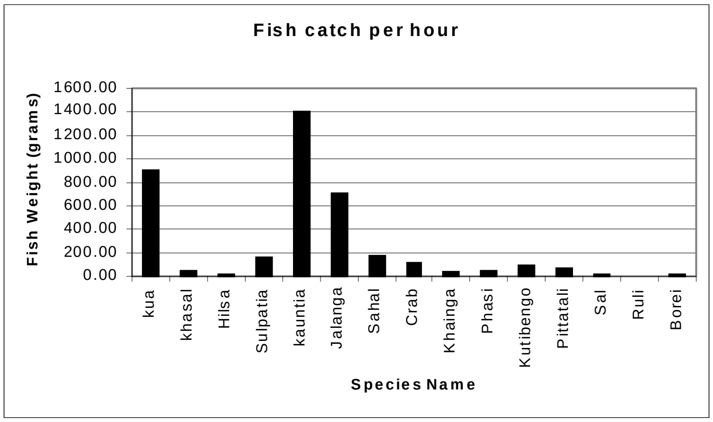


Table 3.12 Species richness and Shannon diversity index by sampling site for the overall period of sampling.

Sampling site	Shannon Index
Balijore	0.675
Ganjeikhia	0.664
Jalahar	0.659
Mahisamunda	0.745
Suajore	0.599
Thanpati	0.696

3.2.3.4 Discussion

Inside the Bhitarkanika National Park, fishing is usually not practiced, but many families carry it out mainly for local consumption. But outside the National Park fishing is carried out in an intensive way. In fact, usually, fish markets are very well developed and self-consumption rate is rather high, which satisfies the protein need of the villagers. According to the gear used, it is possible to define three types of fishing. The cheapest type is by hand lines or harpoons. The second one is fishing by traps: they consist of a "fence" of small sticks hammered in the ground of the coastline, in the area between the limits of the tides. They are put during the low tide and they trap the fishes that arrive with the new high tide and are left behind in the fence as the water recedes. The third and most profitable fishing is the one carried out with boats and nets; usually gill nets, cast nets and dragnets are used for this purpose. Inshore fishing plays an important role in the economy of the inhabitants of Bhitarkanika, especially during the off-season of marine fishing. As a complete annual data was not collected, it is difficult to fully describe the total annual production of fish, as absence of year round data can lead to over or under estimation of total annual production. On the basis of results obtained from sampling done from March 2002 till July 2002, the catch per hour was calculated and from it earning per hour from inshore fishery was calculated, which was Rs 89.91.

3.2.4 Function of Mangroves as Nursery Ground for Prawn and Fishes

3.2.4.1 Site selection and sampling

In Bhitarkanika mangrove system many large and small creeks penetrate through the inner mangrove forest. Initially a survey was undertaken for methodological and sampling gear adaptation. After testing it was decided to sample only the mangrove area as the areas outside the mangroves had fast water current which made it difficult for sampling. The main gear used was a circular drag net, a circular frame was made of steel rod and net was fitted around it. In order to control, as much as possible, the sampling conditions, fortnightly samplings were done at low tide. Five sampling sites were selected. At each site during each sampling session fishing was done four times to control sample variability.

3.2.4.2 Method

For environmental products that have a market price, their monetary value may be estimated as follows:

Total Value = Unit Market Price * Quantity

Where, in Market Price, account is taken of seasonal changes in market prices Quantity harvested are based on maximum sustainable yield (MSY) (Bann, 1997). Market prices were derived by surveying three local markets.

Shannon's index was used to calculate the diversity of fish and shellfish seedlings for each station (Vidy, 2000). The data from the entire list of species were used for calculating the diversity.

Shannon's Index H' = $-\sum$ pi log pi

As a measure of heterogeneity, Shannon's index takes into account the evenness of the abundances of species. The maximum diversity, which could possibly occur, would be found in a situation where all species were equally abundant.

3.2.4.3 Results

On the basis of sampling done from March 2002 to July 2002, every fortnight, the prawn and fish seedling catch per hour was calculated. Total fifteen species were caught (Table 3.13). Per hour catch was found to be highest for *Chinguri (Penaeus indicus*), other commercially important fishes caught were Kaunkada (*Scylla serata*) and *Bagada* (*Penaeus monodon*).

Table 3.14 gives the values of Shannon Index, I_{sh} for each sampling site. Thanpati shows the highest diversity (I_{sh} = 0.743) followed by Suajore (I_{sh} = 0.710) and Mahisamunda shows the least diversity (I_{sh} = 0.637)

Table 3.13 Prawn and Fish seedling yield per hour from Bhitarkanika National Park.

Local Name	English Name	Scientific Name	Catch (no./ hr)
Chinguri	White prawn	*Penaeus indicus*	65.30
Bagda	Tiger prawn	*Penaeus monodon*	5.90
Pittatali	--	--	1.30
Jellyfish	Jelly fish	*Mnemiopsis leidyi*	4.30
Kaunkada	Mud Crab	*Scylla serata*	14.80
Manohari	--	--	32.30
Chandi	Silver pomfret	*Pampus chinensis*	27.50
Kua	--	--	4.97
Tuari	Flat head gray mullet	*Mugil cephalus*	1.27
Kutibengo	Pufferfish	*Tetrdon hispidus*	0.63
Baligira	Blunt nose lizard fish	*Trachinocephalus myops*	*0.20*
Khurant	Tiger perch/ Jarbua	*Therapon jarbua*	0.10
Magrol	--	--	0.10
Khainga	Gray mullet	*Liza tade*	0.07
Kagja	--	--	1.30

Table 3.14 Species richness and Shannon diversity index by sampling site for the overall period of sampling.

Sampling site	Shannon Index
Balijore	0.705
Jalahar	0.649
Mahisamunda	0.637
Suajore	0.710
Thanpati	0.743

Of the fifteen species of fish and shell fish seedling caught only three species are commercially exploitated they are, *Chinguri* (*Penaeus indicus*), Kaunkada (*Scylla serata*) and Bagada (*Penaeus monodon*). The price of these species varies according to demand. The rate of these species varies for *Chinguri* (*Penaeus indicus*) Rs 0.10 to 0.50 per seedling, for *Kaunkada* (*Scylla serata*) Rs 0.20 to 0.40 per seedling and for Bagada (*Penaeus monodon*) Rs 0.40 to 0.60 per seedling (Table 3.15). From these prices the earning per hour was calculated.

Table 3.15 Commercially exploited seedling and their rate in local market.

Local Name	English Name	Scientific Name	Catch (no./hr)	Rate (Rs/piece)	Earning (Rs/hr)
Dhaula Chinguri	White Prawn	*Penaeus indicus*	65.30	0.10-0.50	6.53-32.65
Bagda	Tiger Prawn	*Peneaus monodon*	5.90	0.40-0.60	2.36-3.54
Kaunkra	Mud Crab	*Scylla serata*	14.80	0.20-0.40	2.96-5.92

3.2.4.4 Discussion

The consequences on the diversity of fish populations in the inner mangrove creeks and especially the diversity of the young fish community are here described and discussed in the scope of the question: "What are the respective importance of the estuarine or the mangrove conditions in the nursery?" Data gathered from all the sampling sites was used to answer this question and to do valuation of this function of mangrove. This study was undertaken to verify whether mangrove is suitable as a nursery area for exploited fish and shellfish community. For this the data was collected from six sites and the fish and shellfish seedling per hour catch was estimated, the catch per hour consisted fifteen species, of which are some commercially exploited species such as *Penaeus indicus, Penaeus monodon* and *Scylla serata*. Seedlings of these species are collected by children and women folk in Bhitarkanika and are sold to aquaculture pond. Seedling of many species, which are not collected as seedling but are commercially exploited for fishing like, *Scylla serata, Pampus chinensis* and *Mugil cephalus* are also found as seedling. The number of seedlings caught was highest (65.30 per hour) for *Penaeus indicus*. The observations thus made highlight the relative importance of estuaries and mangroves as the nursery ground for fish and shellfish.

3.2.5 Conclusions

The case study presented was done with the objective to do the valuation of ecological functions of mangrove ecosystems. The importance of mangroves in fish production has been widely recognized. Many commercially important fishes, crabs, prawns and various kinds of molluscs use mangroves as nursery grounds and also for shelter during their juvenile stages. The mangrove forests have vital economic importance in sustaining the productivity of inshore and offshore fisheries. They provide shelter and nurseries for commercial fishery species and some coastal species such as prawns.

Aquaculture is widely practiced in Bhitarkanika mangrove area. Coastal communities benefit from a host of products and services of the mangrove ecosystem. Fishing is the primary source of income for the majority of the fishermen residing in villages along the coast line and these fisheries depend upon mangroves for regeneration.

For valuation of fishery products, data was collected on three levels. Firstly data was collected for offshore fishery from two sites: one near the mangroves - Gahirmatha and the other far from mangrove influence zone - Paradip. The data collected from these two sites showed that the catch per hour is considerably higher in Gahirmatha. At second level, data on inshore fish productivity was collected from six sites where sampling was done fortnightly from which catch per hour was calculated. By using the market price method the earning from inshore fishery was calculated. At third level, to verify the role of mangroves as nursery ground for fish and shellfish, fortnightly sampling from five sites was done and number of seedlings caught per hour was estimated.

These indicative results from the valuation of fish productivity of the Bhitarkanika mangrove ecosystem suggest that this resource is of significant economic importance to this region and to the country as a whole. While our calculations are rough, they highlight the need for more research both on the fish productivity of the mangrove-dependent systems and on their contribution to the local economy. This must be complemented with further study of the impact of incremental changes in the ecosystems and their productivity due to decreased river flow, overuse, pollution, and other pressures. This information could lead to much better estimates of the values of the goods and services provided by the mangroves and their contribution to the regional and national economy.

3.3 Indirect Use Value: Storm Protection

3.3.1 Introduction

It has been estimated that some six million people are exposed to storm surge damage along the US Gulf and Atlantic coasts, and millions more in Australia, Bangladesh, China, India, Japan and Mexico are similarly prone. While property damage from hurricanes is highest in the developed Northern nations prone to such storms, deaths and injury are usually highest in the poor tropical and sub-tropical nations, where larger numbers of people are exposed to the storms (Maltby, 1986).

The Indian Ocean is one of the six major cyclone–prone regions of the world. Such cyclones occur every year often with wind speeds of about 200 km/h accompanied by storm surges of about 4 m to 5 m high. They cause considerable damage to crops, different types of buildings/dwellings and other structures, power transmission, communication systems resulting in heavy loss of life and property (Shanmugasundaram *et al.*, 1989). The annual average cost of damage estimated to be around Rs 200 crores, which at times has exceeded even Rs 400 crores (Rakshit, 1989).

The undisturbed and natural mangrove forests or ecosystems act as seaward barrier and check the coastal erosion and minimize the tidal thrust or storm hit arising from the sea considerably (McNae, 1968). The degree of protection varies with the width of mangroves. Mangrove root systems retard water flow. Resistance to water flow serves to dissipate the energy of floodwaters, of particular service during cyclone (e.g. Gilbert *et al*., 1998). A super cyclone in the month of October in 1999 hit the Orissa coast near Saharabedi, a village lying about 1.5 km away from the seacoast in Ersama Block of Jagatsinghpur district had a wind speed of around 260 km/h and a storm surge of about 10 m. This super storm traveled more than 250 km inland and within a period of 36 hrs ravaged more than 200 lakh hectares of land, devouring trees and vegetation, leaving behind a huge trail of destruction. This cyclone affected around 15 million people in 12 districts and caused the deaths of about 20,000 people and over 4 lakh cattle. The loss to property, crops and plantations, communication and transportation networks was colossal, the value of which is estimated to be over Rs 10,000 crores. The most severely affected districts were Balasore, Bhadrak, Cuttack, Ganjam, Jagatsinghapur, Jajpur and Kendrapara affecting around population a population of around 11 million people.

Following this cyclone, various agencies quantified the extent of damage in almost all the districts. However, because of lack of experienced surveyor, the damaged data were grossly erroneous and do not give exact loss. In fact in most cases data were erroneous leading to uneven allocation of resources for rehabilitation programs. The preliminary report however suggested that those villages that were in the shadow of mangroves suffered the least. In a situation where data is erroneous estimation of contribution of mangrove in protecting villages situated in the shadow of mangroves, using secondary data will be misleading. In this background we wanted to evaluate the extent of damage caused by super cyclone in three representative villages situated closer to and away from Bhitarkanika mangrove ecosystem. Our assumption was that those villages situated in the shadow of mangroves suffered least damage from the cyclone.

3.3.2 Methods

We used the damage cost avoided approach to value the storm protection function of the Bhitarkanika mangrove ecosystem. The damage caused approach involves in specifying the relevant service(s), how they are provided, to whom they are provided, and the level(s) provided. The second step is to estimate the potential physical damage to property, either annually or over some discrete time period. The final step for the damage cost avoided method is to calculate either the monetary value of potential property damage, or the amount that people spend to avoid such damage**.**

In this case since we have the recent incident of super cyclone of 1999 to compare the damages, actual estimates of damage avoided due to mangroves was estimated. Initially we planned to compare the damage caused by the super cyclone in the districts of Balasore and Kendrapara districts - the former having very less area under mangroves and the later having considerable area under mangrove cover. However, on examining the area of influence of the super-cyclone we found that the intensity of cyclone in these two areas was different. Hence, the results from these two districts cannot be compared. Subsequently we decided to compare the intensity of damage caused by cyclone in the three tehsils - Rajnagar, Rajkanika and Chandbali falling under Kendrapada and Balasore districts. While collecting secondary information in these tehsils, we came across the fact that the data collected by the government agencies were erroneous and accordingly the compensation paid to the people had no relation to the damages suffered by them. Thereafter, during the preliminary door-to-door survey we collected information randomly by asking people regarding the losses incurred by them due to the cyclone. On this basis we tried to demarcate villages protected by mangrove cover and those that were not protected by mangrove, and compared the damages in the two areas. But since, saline embankments have already been constructed in and around the area almost in the entire coastal belt to prevent the intrusion of seawater, it was imperative, that the effects of dyke and mangroves be separated. Hence, the following four situations were identified,

1) Mangrove areas with dykes
2) Mangrove areas without dykes
3) Non-mangrove areas with dykes
4) Non-mangrove areas without dykes

Three villages, namely Bankual, Bandhamal and Singidi were identified to represent the first, third and fourth situations respectively, but the second situation was dropped because of the fact that the dyke covers the entire mangrove area, and therefore there was no village representing this situation. Bankual is situated in Rajnagar block whereas the other two are located in Rajkanika block of Kendrapara district which was one of the 7 districts most affected by super cyclone. To keep the intensity of impact as uniform as possible, the geographic locations of the villages thus selected, are such that all the three villages are equidistant from the seashore. Another criteria, for village selection was the fact that there were very few villages that were without dykes as well as mangroves *i.e.* third situation. The two villages outside mangrove area are located close by, and are far off from the mangrove area in order to eliminate the effect of mangroves. For the sake of convenience, the intensity of the cyclone has been considered to be same for these two blocks that are situated adjacent to each other.

Door to door survey was conducted and 100% sampling of the households was done to assess the socio-economic status of the villages as well as the actual damage in these villages. Those households having common house and shared property and resources were treated as a single household. Data on the following parameters were obtained from each of the households.

1) Demography,
2) Literacy and occupational pattern,
3) Difference in agricultural productivities in normal and cyclone year,
4) Type of house and the damage suffered,
5) Livestock and poultry casualties,
6) Loss to fisheries, other movable-immovable assets,
7) The level of flooding inside house, in the premises and in the fields,
8) Rate and duration of flooding.

The extent of damage caused by cyclone depends on many factors. For trees this could be age, size, health and species. Data for all the trees owned by the interviewees were recorded and the following information was obtained during the survey:

1) number of trees presently owned
2) number of trees damaged during 1999 cyclone

3) type of damage suffered, *i.e.* uprooted or broken, branches broken
4) state *i.e.* fruiting, healthy, diseased and age of the trees past and present.

Besides information was gathered from local sources by focused public interviews about:

1) the direction of entry of water
2) reasons for flooding
3) damage to nearby villages
4) difference in the intensity of floods and cyclones which had earlier hit the area, in the year 1971, 1982 and the one under study, *i.e.* 1999
5) the height of dykes in different areas.

SPSS 8.0 software was used for data processing and One-Way Anova tests were performed to compare the means of various variables for the three villages.

3.3.3 Results

During a preliminary study done to quantify the extent of damage in the villages a few respondents were questioned in 10 of the villages covered during the household survey about human, livestock casualties and the type of damage to the houses, the results of which are given in Table 3.16.

Table 3.16 Preliminary estimation of value of property lost during the super cyclone 1999

Village	Distance from forest (km)	Type of damage	Mean (Rs.)	S.E.
Talchua	1.00	Houses partially damaged	86.67	13.33
		Money value of partially damaged houses	51,666.67	1666.67
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	66.67	16.67
		Houses fully damaged	10.33	0.33
		Money value of partially damaged houses	1,57,666.67	65844.09
Daleisahi	2.00	Houses partially damaged	55.00	16.07
		Money value of partially damaged houses	78,333.33	11666.67
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	33.33	17.64
		Houses fully damaged	15.67	2.33
		Money value of partially damaged houses	55,000	16072.75
Righagarh	0.50	Houses partially damaged	92.33	22.52
		Money value of partially damaged houses	1,33,333.33	22047.93
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	0.00	0.00
		Houses fully damaged	26.67	4.41
		Money value of partially damaged houses	96,666.67	26822.46

Satavaya	0.00	Houses partially damaged	130.00	0.00
		Money value of fully damaged houses	27,500.00	2500.00
		Money value of washed out houses	1,35,000.00	15000.00
		Human casualty	0.00	0.00
		Cattle casualty	65.00	5.00
		Houses fully damaged	5.50	0.50
		Money value of partially damaged houses	1,30,000	0.00
Junusnagar	3.00	Houses partially damaged	58.75	7.74
		Money value of fully damaged houses	1,50,000.00	10206.21
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	325.00	228.67
		Houses fully damaged	30.00	2.04
		Money value of partially damaged houses	58,750.00	7739.24
Rajrajeshwaripur	0.50	Houses partially damaged	57.50	9.46
		Money value of fully damaged houses	1,06,250.00	21347.81
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	61.25	4.27
		Houses fully damaged	21.25	4.27
		Money value of partially damaged houses	57,500	9464.85
Dangmal	0.00	Houses partially damaged	0.00	0.00
		Money value of fully damaged houses	0.00	0.00
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	0.00	0.00
		Houses fully damaged	0.00	0.00
		Money value of partially damaged houses	0.00	0.00
Bankual	0.00	Houses partially damaged	0.00	0.00
		Money value of fully damaged houses	0.00	0.00
		Money value of washed out houses	0.00	0.00
		Human casualty	0.00	0.00
		Cattle casualty	0.00	0.00
		Houses fully damaged	0.00	0.00
		Money value of partially damaged houses	0.00	0.00

- The geographic location of Satavaya is such that no protection is offered by the forest though it is in vicinity of forests
- The values have been calculated using a rough estimate of cost of construction of houses in the locality
- For partially damaged houses Rs 1000/
- For fully damaged houses Rs 5000/
- For washed out houses Rs 10000/

This preliminary data (Table 3.16) shows an inverse relationship between the extent of mangrove cover and damage due to cyclone. However we found the results to be highly erroneous and a detailed study was to be taken up during the later phase, the methodology of which has been described in the previous section.

Table 3.17 General economic and demographic characteristics of the three villages selected for intensive study

Demographic characteristics	Singidi	Bankual	Bandhamal
Distance from forest (km)	4.7	0	4.2
Total area (acre)	278.22	137.65	363.73
Number of households	58	42	56
Mean household size	8.21	4.5	6.84
Total population	353	189	383
Human Density (persons/ km^2)	314	340	260
Literacy (%)	56.66	31.22	38.64
People involved in agriculture (%)	70.62	70.60	14.44
People involved in fishing, animal husbandry and allied activities (%)	0	14.70	0
People involved in labour (%)	22.35	2.95	61.28
People involved in other activities (%)	7.03	11.76	24.38

The three villages are medium sized with respect to other villages in the sanctuary area. The mean household size for Bankual is 4.5, which is low in comparison to the household size for the sanctuary, 8.2407 + 0.2799 as per 1991 census. Literacy level for Singidi is highest (56.66%), while it is lowest for Bankual (31.22). In Bankual and Singidi highest number of people are involved in agriculture (70.62% and 70.60% respectively) and in Bandhamal, 61.28 % are engaged in labour activities (Table 3.17).

3.3.3.1 Construction details and damage to houses

93.5% of the households in the surveyed area are mud dwellings with thatched roofs, the maximum percent of such houses being in Bankual. In all the three villages only 1.9 % of the houses are Pucca. The maximum number of Pucca houses are in Singidi (Table 3.18).

Table 3.18 Type of house in the three study villages

Type	Singidi	Bankual	Bandhamal	Total
Total no. of houses (n)	37	38	32	107
Pucca (%)	5.4	0	0	1.9
Pucca with thatched roof (%)	0	2.6	9.4	3.7
Partially pucca (%)	2.7	0	0	0.9
Fully kutcha (%)	91.89	97.4	90.6	93.5

However, only 17.5 % of the houses have been constructed within last three years *i.e.* in the post cyclone period. 31.1 % of kuccha constructions are even more than 25 years old (Table: 3.19). Not many cases of damage to basic roof frames were reported. This is in accordance with the fact that there were not many reports/cases of a total wash out or a full collapse of houses (Table 3.20).

Table 3.19. Age of houses in the three study villages (n = 103)

Age of house	Singidi	Bankual	Bandhamal	Total
< 3years*	21.6	19.4	10.0	17.5
4-15	24.3	50	26.7	34.0
16-25	5.4	27.8	26.7	17.5
>26	48.6	2.8	43.3	31.1
Total	37	36	30	103

**Post cyclone*

However, in most of the houses roof thatch were blown away, accompanied by either cracking of walls, or their partial collapse on some sides, and the breaking or fall of roof beams and supports. In majority of (49.53%) the cases thatch was blown away along with some damage to walls followed by both thatch blown and collapse of beams (45.79%). (Table 3.20.)

Table 3.20 Type of damage to the houses in the three study villages

Type of damage	% of cases
Thatch blown exclusively	21.49
Wall collapse or cracking	0.93
Both thatch blown and wall damage	49.53
Both thatch blown and collapse of beams	45.79
Total collapse	3.73

3.3.3.2 Scores as indicator of the type and extent of damage

On the basis of the type of damage to the houses, a composite score, the variable DMR was developed for each of the household surveyed in all the three villages. The scores increased in scale with the intensity of damage. This was in a range of 0-19.The households getting a maximum value of 19 for total collapse which was taken as sum of damage to all the structures, *i.e.* thatch, poles, roof and beams and walls, as given in Table 3.21.

Table 3.21 Scores for type and extent of damage

Type of damage	Score
Thatch blown exclusively	1
Damage to poles	2
Wall cracking	3
Damage to roof and collapse of beams	4
Wall collapse on one side	7
Wall collapse on two or more sides	9
Total collapse	19

Wall collapse on one side (7) = Wall cracking (3) + Damage to roof and beams (4)

Total collapse (19) = (1+2+3+4+9)

The maximum value of the scores *i.e.* maximum damage to the houses was 10.44 ± 0.848 for Bandhmal village i.e. the village located in non mangrove area, outside the dyke. The lowest 5.34 ± 0.578 was for Bankual *i.e.* the village in mangrove cover (Table 3.23; Figure 3.4). A significant difference was found between the means of the scores for the three villages (*F = 14.633; df = 2; p = 0.0000*) (Table 3.24). The difference between Bankual and Singidi; Bankual and Bandhamal was – 4.063 and –5.095 respectively, which were significant at 0.05 level (Table 3.25).

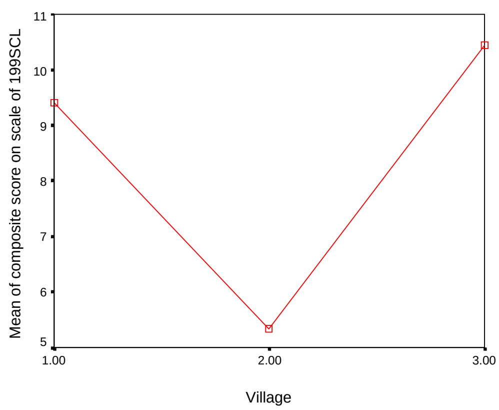
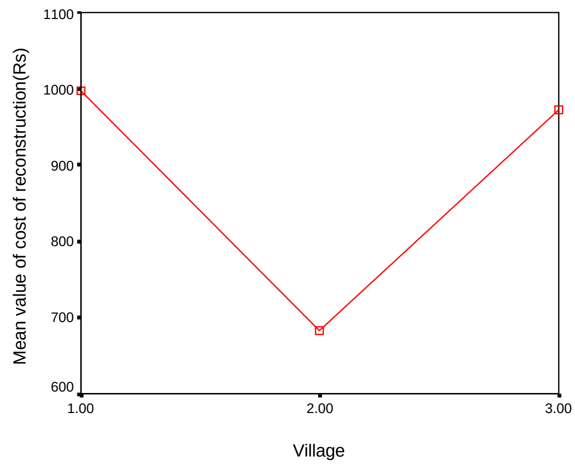


Figure 3.4 Plot of scores for extent of damage

3.3.3.3 Reconstruction costs for houses damaged during the cyclone

A mean sum of Rs 1582.38 ± 320.178 was incurred for reconstruction work per household. This data was however found to be skewed and after removing 9 of the outliers (>3000), the highest was found to be Rs 996.97 + 182.184 for Singidi village, which is located outside the dyke area and has no protection due to mangrove cover. The lowest was found to be 682.86 ± 144.055 for Bankual village, which is surrounded by mangroves on three sides (Table 3.23, Figure 3.5). However, no significant difference in the means of reconstruction cost was revealed after performing the post-hoc tests at 95% confidence limit (*F = 0.286; df = 2; p = 0.286*) (Table 3.24).

Figure 3.5 Cost of reconstruction and repair works



The following variables were used as indicators of the damage.

Table 3.22 Variables used for quantification of extent of damage

Variable	Definition
DMR	Damage rating on a scale of 0-19 as indicator of extent of damage to houses
PREMMTR	Flooding in premises (m)
FLDMTR	Flooding in fields (m)
Wtr field	Water logging in fields (days)
RECONS	Cost of repair-works and reconstruction (Rs)
TREECENT	%of tree damage
YIELD99	Yield in qtl. / acre for the year 1999
FISH	Loss to fish seedlings in money terms released prior to cyclone (Rs)
DAMOTH	Damage to other personal property (Rs)
LVSSTK	Damage to livestock in money terms (Rs)
TOTMONEY	Total money worth of quantifiable variables

The means and S.E. for the variables have been summarized in Table 3.23

Table 3.23 Basic description of the variables (per household) examined for comparing the damage due to the cyclone.

Variable	Singidi		Bankual		Bandhamal	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
DMR	9.41	0.713	5.34	0.579	10.44	0.848
PREMMTR	0.35	0.060	0.29	0.045	0.58	0.054
FLDMTR	1.99	0.115	1.09	0.044	1.39	0.046
Wtr field	9.46	0.939	5.63	0.485	12.87	0.963
RECONS	996.97	182.184	682.86	144.055	973.21	142.875
TREECENT	0.21	0.044	0.03	0.007	0.15	0.029
YIELD99	0.61	0.257	5.99	0.376	1.36	0.956
FISH	310.81	144.975	69.74	32.199	260.94	111.006
DAMOTH	108.11	59.701	0.00	0.000	2375.00	962.764
LVSSTK	54.05	54.054	127.63	93.545	1044.37	427.197
TOTMONEY	1983.36	437.296	1454.13	391.705	6918.62	1136.201

One-way Anova tests at 95% confidence limit were performed to test the difference between means of these variables. The sample size (n), degrees of freedom (df), value of F statistic, and the p value showing significance values are reported in (Table 3.24) The difference among the means of village is highly significant for all the variables except for cost of repair works and reconstruction (RECONS, $p = 0.286$) and that for damage to fish seedlings (FISH, $p = 0.227$) at 0.05 level.

Table 3.24 Variables and significance of their means

Variable	n	df	F	Significance (p value)
DMR	107	2	14.633	0.000
PREMMTR	103	2	7.670	0.001
FLDMTR	100	2	35.102	0.000
Wtr field	102	2	18.654	0.000
RECONS	96	2	1.270	0.286
TREECENT	93	2	9.891	0.000
YIELD99	59	2	99.029	0.000
FISH	107	2	1.506	0.227
DAMOTH	107	2	6.814	0.002
LVSSTK	107	2	5.398	0.006
TOTMONEY	98	2	17.936	0.000

Results of post-hoc Bonferroni test which gives the difference for each pair of means in order to identify the pair for which the mean differ significantly are given in Table 3.25. Difference has been calculated as (I – J), where both I and J are villages. For the variable DMR, difference between Bankual (I = 2) and Singidi (J) is - 4.0633, indicating the score of damage to houses for Bankual is less than that for Singidi by units of 4.0633 and which is highly signifiacant (*p = 0.000*).

Table 3.25 Results of post-hoc test showing difference of means for pairs of means

Variable	(I)	Singidi(J)		Bankual (J)		Bandhamal(J)	
		P value	Difference (I- J)	P value	Difference (I- J)	P value	Difference (I - J)
DMR	2	0.000	-4.063*	-	-	0.000	-5.0954*
	3	0.944	1.0321	0.000	5.095*	-	-
PREMMTR	2	1.000	-5.473	-		0.001	-0.2941*
	3	0.009	0.239*	0.001	0.294*	-	
FLDMTR	2	0.000	0.904*	-	-	0.033	-0.298*
	3	0.000	-0.606*	0.033	0.298*	-	-
Wtr field	2	0.003	-3.830*	-	-	0.001	-7.238*
	3	0.14	3.407*	0.00	7.238*	-	-
RECONS	2	0.460	-314.11	-	-	0.618	-290.357
	3	1.0	-23.755	0.618	290.357	-	-
TREECENT	2	0.000	-0.180*	-	-	0.016	-0.122*
	3	0.56	-5.790	0.016	0.122*	-	-
YIELD	2	0.000	5.374*	-	-	0.000	4.633*
	3	0.139	0.741	0.000	-4.632*	-	-
FISH	2	0.307	-241.074	-	-	0.633	-191.201
	3	1.000	-49.873	0.633	191.200	-	-
DAMOTH	2	1.000	-108.108	-	-	0.004	-2375.00*
	3	0.011	990.320*	0.020	916.743*	-	-
LVSTK	2	0.000	6.1692*	-	-	0.004	1.924*
	3	0.000	4.245*	0.004	-1.9242*	-	-
TOTMONEY	2	1.000	-529.235*	-	-	0.000	5464.498*
	3	0.000	4935.263*	0.000	5464.49*	-	-

** Significant at 0.05 level*

3.3.3.4 Flooding in the villages

The flooding in house premises (in meters) was highest for Bandhamal, the village protected by the dyke but without mangrove cover (0.58 ± 0.054), while lowest was for Bankual, village protected by mangrove cover (0.29 ± 0.045) (Table 3.23, Figure 3.6).

The highest level of flooding in the fields in meters was for Singidi, village outside mangrove area and not protected by dyke (1.99 ± 0.115), followed by Bandhamal (1.39 ± 0.046) and then by Bankual (1.09 ± 0.044) (Table 3.23, Figure 3.7). Difference between flooding levels in fields, was found to be significant for all the villages at 95% confidence level (*$F = 35.102$; $df = 2$; $p = 0.000$*) and the same was true for the level flooding in house premises (Table 3.24).

Flood waters remained in the fields for a maximum number of days in Bandhamal, the village protected by the dyke but without mangrove cover (12.87 ± 0.963), followed by Singidi (9.46 ± 0.938) and Bankual (5.63 ± 0.485) (Figure 3.8).

Figure 3.6 Level of flooding in premises

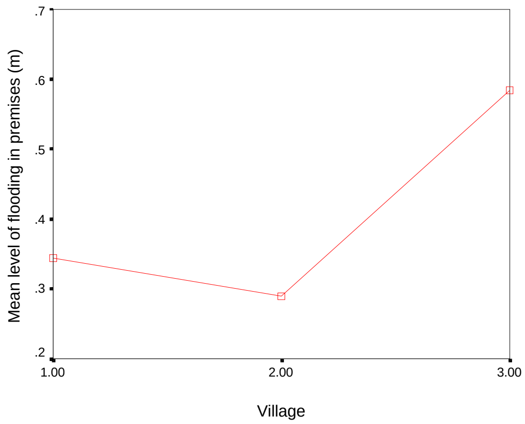


Figure 3.7 Level of flooding in fields

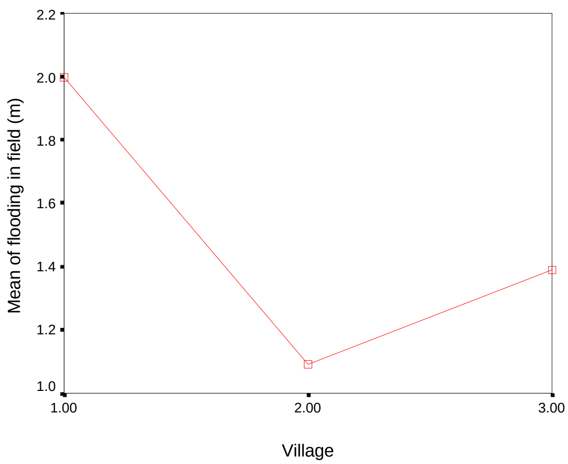
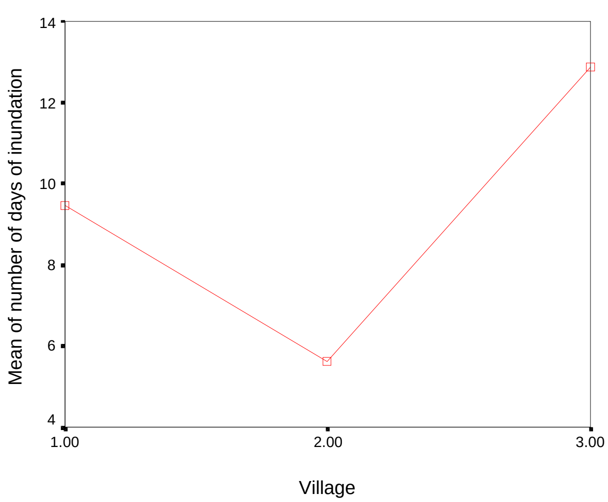


Figure 3.8 Period of inundation in the villages



3.3.3.5 Damage to crops

In general the agricultural production for 1999 was low as vast areas got submerged and the fields remained inundated for a period 9.14 + 5.55 of days. The standing crop of paddy was severely affected and a significant difference between means of the crop production for the three study villages was seen at 0.05 level (*$F = 7.239$; $df = 1$; $p = 0.008$*), (Table 3.26). The yield/acre for year 1999 in all the villages combined together was 2.25 $\pm$ 0.328 and that for 2001 was 4.13 $\pm$ 0.378 (Table 3.26). The year 2001 was itself not considered a good year for the paddy crop 71.64% of the people (n = 67), who undertook cultivation having complained of a bad harvest. The agricultural production was highest in Bankual in 1999 with a value of 5.99 $\pm$ 0.376 qtl./acre and the lowest for Bandhamal 1.36 + 0.956 (Table 3.23, Figure 3.9). A significant difference was revealed among the villages when one way Anova test was performed, (*$F = 99.029$; $df = 2$; $p = 0.000$*) (Table 3.24). However, the agricultural productivity is revealed to be high, for Bankual and it's nearby areas even in normal years *i.e.* 2001.

Figure 3.9 Paddy production during 1999

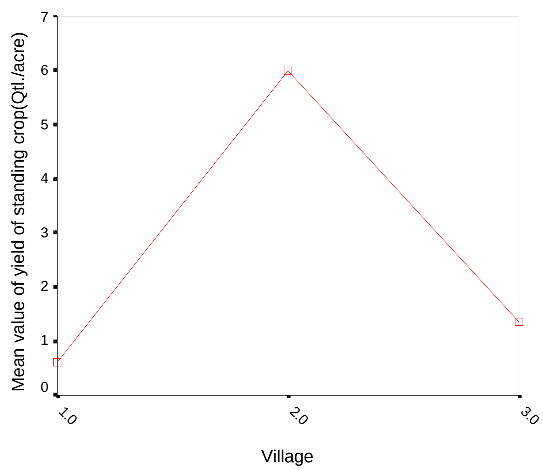


Table 3.26 Difference in agricultural productivity in 1999, with 2001 as base year

Year	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1999	59	2.25	2.524	0.328	1.59	2.90	00	8
2001	75	4.13	3.276	0.378	3.37	4.88	00	10
Total	134	3.30	3.102	0.268	2.77	3.83	00	10

Table 3.27 Test of significance for difference in agricultural productivities of 1999 and 2001

	Sum of squares	df	Mean Square	F	Significance level
Between groups	116.552	1	116.552	13.221	0.000
Within groups	1163.640	132	8.815		
Total	1280.192	133			

3.3.3.6 Loss to fisheries, livestock and other assets

The highest damage to fish seedlings was in Singidi where Rs 310.81 ± 144.975 worth of the seedlings released were washed away and it was the least in Bankual (69.74 ± 32.199) (Table 3.23). Loss to private property was highest in Bandhamal at Rs 2375.00 ± 962.764 (Table 3.23, Figure 3.10). The maximum number of livestock casualties occurred in Bandhamal, followed by Bankual and Singidi (Figure 3.11).

Figure 3.10 Money loss to other assets

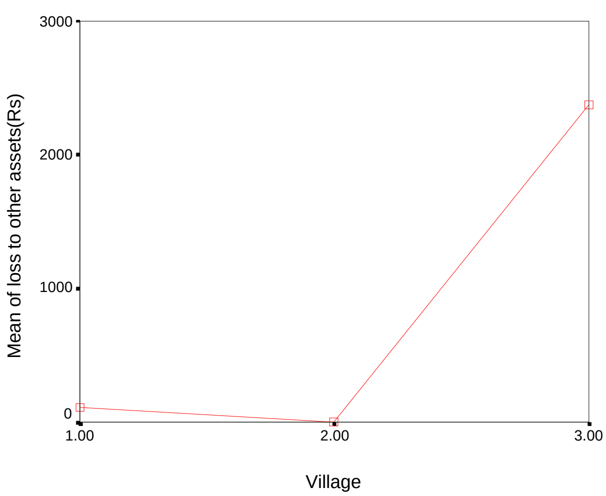
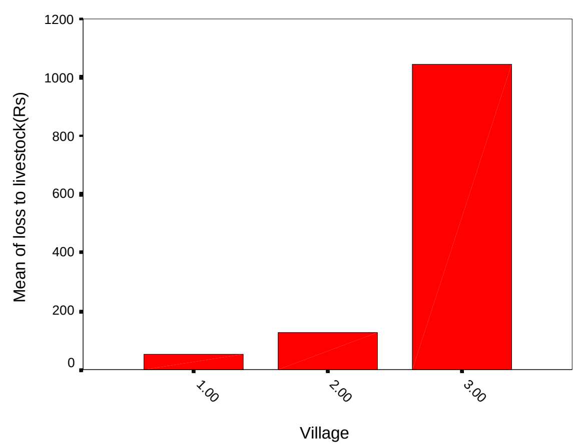


Figure 3.11 Loss of livestock in money terms



3.3.3.7 Damage to Trees

The percentage of trees dying due to cyclone was the highest in Singidi with about 21.3% of the trees having either uprooted or broken from the trunk. Only 3.3% were damaged in Bankual abutting the forest area, which had the highest number of trees (Table 3.23, Figure 3.12). The mean percentage of trees damaged in Singidi exceed that damaged in Bankual by a value of 0.185 and between Bankual and Bandjamal by 0.103, which is significant at 0.05 level with adjusted p values 0.000 and 0.092 (Table 3.25).

Figure 3.12 Trees damaged in cyclone in the three villages

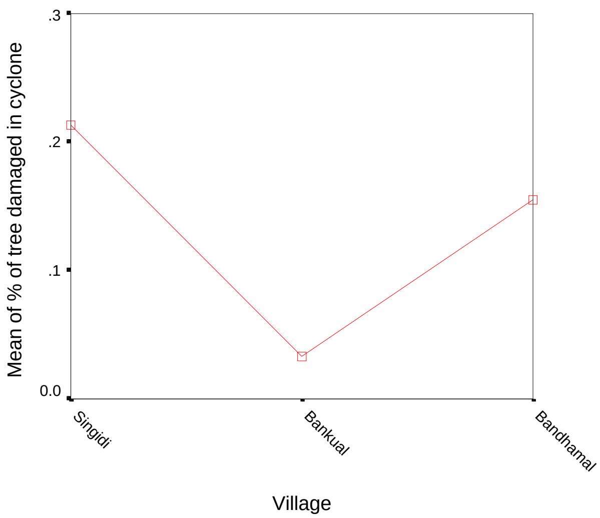
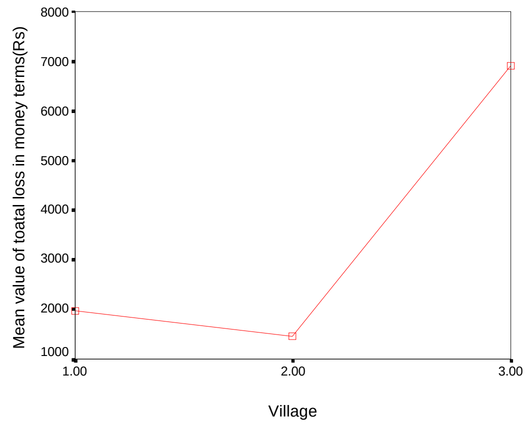


Figure 3.13 Total money loss



3.3.3.8 Total Loss in Money Terms

Finally a total loss was obtained for each of the households in all the three villages by combining the money values of the following quantifiable variables:

- RECONS
- DAMOTH
- LVSTK
- Market value of loss of agriculture income with a target production of year 2001 *i.e.* the difference in total paddy production (2001-1999) taking the area cultivated in 1999 as a common factor.

This calculation was made in order to arrive at an indicative value for the money loss suffered in three different areas. For the sake of convenience, various other factors on which these variables otherwise depend have been ignored.

The loss incurred per household was found to be greatest in Bandhamal, *i.e.* Rs 6918.63 $\pm$ 1136.201 per household (Table 3.23).

3.3.4 Discussions

The vulnerability of many coastal communities is heightened by the removal of coastal wetlands for crops and habitation. These wetlands are natural buffers against storm surges (Maltby, 1986). Mangroves protect tropical shores from erosion by tides and currents and a mangrove strip at least 100 m wide should be left as a buffer zone on the more exposed shores. An environmental preservation project, undertaken by the Thai Binh branch of the Vietnam Red Cross, involved creating 2,000 hectares of mangrove plantations, which served two important purposes. Firstly, the trees acted as a buffer zone in front of the sea dyke system, reducing the water velocity, wave strength and wind energy. This helped to protect the coastal land, human life and assets invested in development. The project area was struck by the worst typhoon in a decade two months before the project evaluation. Lack of any significant damage to the sea dyke and aqua culture pond systems in Thai Thuy provided the best possible indicator of the effectiveness of the mangroves (http://www.ifrc.org/what/dp/ vietnam.asp.). The mangrove forest of the uncleared Sundarbans forest of Bangladesh and India acts as a coastal buffer, dampening the effects of storm waves (Maltby, 1986).

The degree of protection provided, however is not much clear, because if the impact is direct, it may kill a vast patch of mangrove vegetation itself though for the time being they may sustain the high water in surge and strong winds and protect the neighborhood because of their natural resilience to uprooting. For example during August and September 1992, Category 4 hurricane, Hurricane Andrew caused extensive damage in south Florida, Louisiana, Guam, and Hawaii in USA and completely stripped vegetation from the northernmost Florida Keys. In the case of mangrove trees, defoliation and wood damage killed large old stands along the shoreline (http://marine.usgs.gov/fact-sheets/hurricane/hurricane-txt.html).

In this case study, it was revealed that the extent of damage, particularly in and around the villages undertaken for intensive examination was hyped and exaggerated. Most of the housing structures remained intact after the cyclone. Even the mean of compensation granted in the three villages (in Rupees) was 650.48 $\pm$ 26.261, almost sufficient to cover for the repair works, i.e. 875.52 $\pm$ 92.023.The combined monetary loss to agricultural income and property for the three villages (in Rupees) is also not very high (3305.14 $\pm$ 467.426).

3.3.4.1 Levels of Flooding and Damage to Local Structures

Embankments, constructed in 1971, by the Saline Irrigation Division suffered a number of breaches and this resulted in the flooding of villages such as Bandhamal, surrounded on all sides by the embankment. But the same acted as an obstruction when the water was receding. This was also due to delay of several days in the opening sluice gates after the initial flooding. This is reflected by higher flooding levels and greater mean number of days of flooding in case of Bandhamal. This was significantly low, at 0.05 significance level, for Bankual when compared to the other two situations. Singidi with no mangrove cover suffered the highest level of flooding in the fields and a medium one in the house premises. This is because the fields are located directly on the bank of Kharsuan River but 1 m high village road offers some protection to the houses. The mean number of days of flooding was higher for Singidi as compared to Bankual because no mangrove cover was available to reduce the bulk of flooding. Through the height of embankments are sufficient as there were no incidents of river flowing over the dykes, these soil dykes are however liable to breaches and hence don't provide effective protection against flooding and storm surges.

Our findings indicate that mangroves help in reducing the influx of water as evident from lower levels of flooding in Bankual. Further they do not impede the slow recede of water from the houses and the fields. Flooding in Bankual area was from the forest side when Patsala and other creeks overflowed the banks during the high tide. Incessant rains lashing the sides of the wall accompanied by wind, washed off the soil from houses but the crumbling of walls was caused due to water logging in the house premises and against the walls. Costs incurred thereafter for repair works was also lowest for Bankual. Weak structures such as cattle sheds and kitchens, which are either separate from the house or included in it, were more affected. The mean cost of damage incurred is almost same for Singidi and Bandhamal and quite low for Bankual and this could be correlated to the low values of other variables for Bankual.

Though, the rate of flooding would have been a better indicator of the detrimental affect of mangroves on the surge of water, the figures obtained during the survey had to be discarded as they were based solely on individualistic assumptions and hence varied a lot.

3.3.4.2 Damage to Kharif crop

Mostly there is only one crop season in the sanctuary area due to lack of irrigation facilities, and hence the kharif season paddy production has an important role in the economy of the area. In areas such as Singidi located near riverbanks and far from the saline influence of seawater, some varieties of paddy as Trichin and pulses are sown as Rabi crops. The yield of paddy was found to be highest for Bankual and it may be inferred that it was easier to salvage the crop in the area and not much damage was caused besides the productivity is revealed to be high even in the base year 2001 for the village indicating that it is a more productive area even as such. To remove the difference in productivities due to other factors such as soil type and geographic conditions the fraction of yield in 1999 was taken against 2001. The lowest level of paddy production in Singidi could be related to the highest level of flooding in fields.

3.3.4.3 Damage to Trees and Dykes

It was revealed during the study that mangrove act as a natural barrier against strong gales. A large number of trees were located in area adjoining the forest, i.e. in Bankual and it showed the lowest tree casualty ratios due to the cyclone.

No reports of breaches, in the dyke located around the forest area is indicative of the buffer protection provided by mangroves to the dykes, although this is not conclusive as data authentication is required from reliable sources and needs to be correlated with many other factors.

3.3.4.4 Loss to Life and Property

Human Casualty

One human casualty was reported among the three villages, in Bandhamal where it occurred due to a wall collapse. Again loss in monetary terms was highest for Bandhamal for livestock and poultry. These two factors point to the ineffectiveness of dykes in protecting human lives and property from storms.

There was least loss in money terms in Bankual, which was however significantly less than that in Singidi that is located outside dyke area, though quite low as compared to Bandhamal. This could be explained by the fact that the loss of agricultural income is an important contributor to the total money loss. The fact that the area cultivated in Singidi happens to be low and also the yield/acre is low in comparison to highly productive areas around Bankual. This is indicated by the fact that the production in Singidi was 0.408 fraction of the total production in Bankual.

3.3.5 Conclusions

Costanza *et al.*, 1989 have concluded ecological functions such as storm protection may be very important components in the total economic value of a wetland area and may constitute almost 80% of the estimated value. Significant difference was found to exist among the variables used to assess the contribution of mangroves in avoiding damage from cyclones and floods, for the mangrove and non- mangrove areas. The descriptives in almost all the cases have either the lowest values for adverse parameters, or highest values for positive parameters, such as for crop yield, for Bankual village that was totally protected by mangroves. The total money loss is also found to be least for the same mangrove area and hence, it can be concluded that Bhitarkanika mangroves help in avoiding a considerable damage to life and property. Because artificial sea defenses and river levees are expensive to build and repair (in Britain, coastal defense constructions cost well over 1 million pounds, per km.), no-cost natural alternatives begin to look very appealing. There is a growing awareness that trees adapted to water logged conditions are effective in controlling bank erosion and that conserving or even replanting wetland vegetation may be the most cost-effective solution to erosion problems in both freshwater and marine environments. This study therefore reinforces the fact that mangroves form an effective barrier to storms, better than man-made structure such as the dyke in this case.

3.4 Indirect Use Value: Land Accretion

Wetland ecosystems frequently contribute to ecological, geomorphological or geological systems or processes. The ecological processes may be short-term for example breakdown of vegetative matter, breeding or migration of fish and shellfish or they may be long-term as in succession. Geomorphological processes lead to the development of landforms such as flood plains and coastal mudflats. Mangroves trap sediments and accelerate land formation in the coast initially as islands or mudflats. Subsequently due to succession these newly created land forms develop into tidal swamps with mangrove species. The Bhitarkanika mangrove ecosystems have significantly contributed in the formation of mudflats and islands along the coast and in the associated riverine ecosystems.

3.4.1 Methods

Since land is a traded commodity in the area, the current price of land in the area is being used to value this function of the Bhitarkanika mangroves. We procured time series maps of Bhitarkanika area for the year 1887-1889, 1939-1941, 1975-76 and satellite imageries for the year 2000 for comparison of landforms in the area. Also we collected information on the newly created islands in the area from various literatures. An estimate of the land accreted, based on literature survey and ground truthing of remotely sensed imageries is presented here.

3.4.2 Results

Table 3.28 gives area wise land formation in the region between the years 1889-2000. In last one hundred eleven years a total of 4.68 km^2 of land formation has occurred within the Bhitarkanika mangrove area.

Table 3.28 Age and area of newly accreted landmasses in and around Bhitarkanika Wildlife Sanctuary

S.No.	Name	Nearest land mark	Age (years)	Area (km ^{2})
1	Sapuadiha (Big)	South of Kalibhanjdia	150	0.28
2	Musa diha	South west of Kalibhanjdia	50	0.056
3	Adabhutia	In Patsala river, west of Gupti, North of Habaliganda	12	0.54
4	Laxmiprasaddia	West of Iswarpur in river Brahmani	200	0.84
5	Laxmiprasaddia small 1	West of Iswarpur in river Brahmani	Not known	0.004
6	Laxmiprasaddia small 2	West of Iswarpur in river Brahamani	Not known	0.015
7	Madhubandia	West of Righagarh inside river Brahmani	150	0.59
8	Unnamed island	West of Iswarpur	Not known	0.20
9	Mangaladia	Western side of Confluence of Kharsuan and Brahmani rivers	65	0.06
10	Chandanpur dia	North of Bajarpur	40	1.05
11	Naliadia	North of Bajarpur	100	0.99
12	Jagannathprasaddia	North of Bajarpur	40	0.052
TOTAL AREA				**4.68**

The market price of land in the area is = Rs 98,800/ ha

The market value of 468 ha of land is = Rs 46 million or 983795.7 $

3.4.3 Discussions

The land accretion function could be considered reclamation of coastal wetlands for developmental purposes. This means that valuing this function by estimating the current price of land in the area is considerable underestimation of the value of this function. In fact the cost of reclaiming land should be taken as the value of this function. Since we could not get this figure for the study area, a conservative estimate of the value of this function has been given by stating it as the current price of land in the area.

3.5 Conclusions

Comparison with studies conducted elsewhere

We valued four functions performed by Bhitarkanika mangrove ecosystem. The method used and the details of results have been described in the previous sections of this chapter and summarised in Table 3.29. The value of Nutrient retention function for this study came out to be 350 $/acre/year, which is quite high as compared to the valuation results of other study (Table 3.32). The fish and shell production valuation was done at three levels and the estimated value for offshore fishery, Inshore fishery and fish seedling was determined by using market value method. The results of the other studies on fish valuation are stated in $ per acre, but we have determined the value of fish and shellfish production of mangroves in earning per hour. The study design does not allow extrapolation of the estimated values to the total mangrove area or cover. The storm abatement function was valued using damage cost avoided method. In the village having mangrove cover the damage cost avoided was estimated to be 116.28 $/household. The land accretion function gave value of 983795.7 $ over a period of 111 years.

Table 3.29 Estimated value of Bhitarkanika Mangrove Ecosystem functions

Mangrove function		Method used	Estimated value
Nutrient retention		Replacement cost approach	349.69 $/acre/year
Land accretion		Market value	983795.7 $
Fish and shell fish production	Offshore fishery	Market value	37.97 $/hr
	Inshore fishery	Market value	1.9 $/hr
	Fish seedling	Market value	0.2 $/hr
Storm abatement		Damage cost avoided	116.28 $/household

We reviewed thirteen studies on coastal ecosystem valuation, out of which seven were taken up from Heimlich *et al*., (1998), three were taken from Spaninks *et al.* (1997) and the remaining three were reviewed from the original study. This was done to get an idea of the coastal ecosystem services' valuation methods and estimated value. The authors have used a varied range of valuation techniques, like market price, adjusted market price, shadow price, value of annual marginal product, change in surplus, willingness to pay for valuation of sustainable production services such as fish/shellfish, fowl hunting, forestry products, agriculture and aquaculture (Table 3.30). For valuation of cultural services 'willingness to pay' was used (Table 3.31). Value of ecological services, like storm protection, nutrient retention, property buffering and erosion control, provided by mangroves the most followed method are damage avoided and replacement value, besides these methods reduced service flows, benefit to agricultural productivity and international transfers to rain forests have been used (Table 3.32). The studies of coastal ecosystem valuation are found to be diverse in terms of value obtained and their characteristics.

Heimlich *et al.* (1998), reviewed thirty-three wetland valuation studies, with per acre values ranging from US$ 0.06 to US$ 22050. The value of the ecosystem services or goods stated are based on 6% discount rate and 50 years accounting period of the actual stated estimates by individual studies. The ecosystem services valuation has been regrouped under three categories of mangrove services and functions, for sake of convenience.

Table 3.30 Summary of the estimated value of sustainable production services provided by mangrove

Ecosystem services	Area	Method used	Estimated value ($ per acre)	Reference
Fish/shellfish	Florida, Gulf coastal wetlands	VAMP[1]	$7	Lynne *et al.*, 1981[a]
Fish/shellfish	Florida, Gulf coastal wetlands	Change in surplus	$ 22	Fischer *et al.*, 1986[a]
Fish/shellfish	Louisiana, coastal wetlands	VAMP[1]	$ 547	Farber and Costanza, 1987[a]
Fish/shellfish	Louisiana, coastal wetlands	VAMP[1]	$ 702	Farber, 1996[a]
Fish/shellfish	Virginia, coastal wetlands	VAMP[1]	$ 1,205	Batie and Wilson, 1979[a]
Fish/shellfish	Florida, Gulf coastal wetlands	VAMP[2]	$ 1,259	Bell, 1989[a]
Non-marketed fish (freshwater)	Louisiana, coastal wetlands	WTP[2]	$ 95	Farber, 1996[a]
Fishing	Florida, coastal wetlands	WTP[2]	$ 15,126	Bell, 1989[a]
Non-marketed fish (Saltwater)	Louisiana, coastal wetlands	WTP[2]	$ 356	Farber, 1996[a]
Fisheries	Chanthaburi, Thailand	Market price	$ 52.61	Christensen, 1982[b]

Fisheries	Fiji	Market price and shadow price	$ 40.5	Lal, 1990 [b]
Fisheries	Sarawak	Market price	$ 978.5	Bennet and Reynolds, 1993 [b]
Fisheries	Indonesia	Market price and shadow price	$ 47.35	Riutenbeek, 1994
Fisheries	Pagbilao	Adjusted Market price	$ 24.3	Janssen and Padilla, 1996
Water fowl hunting	Louisiana, coastal wetlands	WTP	$ 156	Farber, 1996 [a]
Forestry	Fiji	Market price and surrogate price	$ 2.43	Lal, 1990 [b]
Forestry	Chanthaburi, Thailand	Market price	$ 12.14	Christensen, 1982 [b]
Forestry	Indonesia	Market price and shadow price	$ -27.11	Riutenbeek, 1994
Forestry	Pagbilao	Adjusted Market price	$ 61 (151/ ha/ year)	Janssen and Padilla, 1996
Forestry	Sarawak	Market price	$ 5.66	Bennet and Reynolds, 1993 [b]
Local uses	Chanthaburi, Thailand	Market price	$ 93.1	Christensen, 1982 [b]
Local uses	Indonesia	Market price and shadow price	$ 13.35	Riutenbeek, 1994
Agriculture	Fiji	Market price	$ -21	Lal, 1990 [b]
Aquaculture	Chanthaburi, Thailand	Market price	$ -874.14	Christensen, 1982 [b]
Aquaculture	Pagbilao	Adjusted Market price	$ -2883.04	Janssen and Padilla, 1996
Furs	Louisiana, coastal wetlands	VAMP[1]	$ 261	Farber and Costanza, 1987 [a]

[a] Source: Heimlich et al., 1998; [b] Source: Spaninks et al., 1997
[1] VAMP: Value of annual marginal product; [2] WTP: Willingness to pay

Table 3.31 Summary of the estimated value of cultural services provided by mangrove

Ecosystem services	Area	Method used	Estimated value ($ per acre)	Reference
Recreation	Louisiana, coastal wetlands	WTP[2], TC[3]	$ 91	Farber and Costanza, 1987 [a]
Recreation	Louisiana, coastal wetlands	WTP[2]	$ 160	Farber and Costanza, 1987 [a]
Recreation	Louisiana, coastal wetlands	WTP[2]	$ 607	Farber, 1996 [a]

[a] Source: Heimlich et al., 1998; [b] Source: Spaninks et al., 1997
[1] VAMP: Value of annual marginal product; [2] WTP: Willingness to pay; [3]TC: Travel cost

Table 3.32 Summary of the estimated value of ecological services provided by mangrove

Ecosystem services	Area	Method used	Estimated value ($ per acre)	Reference
Storm protection	Louisiana, coastal wetland	Damage avoided	$ 17	Farber, 1987 [a]
Storm protection	Louisiana, coastal wetland	Replacement value	$ 74	Farber, 1996 [a]
Storm protection	Louisiana, coastal wetland	Damage avoided	$ 1915	Costanza, Farber, Maxwell, 1989
Nutrient filtering / retention	Louisiana, coastal wetland	Replacement cost	$ 1	Farber, 1996 [a]
Nutrient filtering / retention			$ 331.85	Lal, 1990 [b]
Property buffering	Louisiana, coastal wetland	Reduced service flows	$ 8435	Farber, 1996 [a]
Erosion control	Indonesia	Benefit to agricultural production	$ 1.21	Riutenbeek, 1994
Biodiversity	Indonesia	International transfers for rain forests	$ 6.07	Riutenbeek, 1994

[a] Source: Heimlich et al., 1998 ; [b] Source: Spaninks et al., 1997

Spaninks and Beukering (1997) reviewed and analyzed the scope and limitations of different valuation methods for assessing management alternatives for mangrove ecosystems. The paper compares range of studies on mangroves with regard to the methodologies employed and the range of products and services valued. Some of the valuation studies reviewed by them, relevant to the present study context are as following: Christensen, 1982, valued production services at market price, ignoring costs. This study ignores future developments and assumes that removal of mangrove results in total disappearance of mangrove dependent fish species. In a case study undertaken by Lal (1990), value of commercial forest product and fish is based on Market price, which is corrected for actual cost incurred, while the value of subsistence fishery is based on shadow price. 5% discount rate and time horizon of 50 years is taken as assumptions, marginal value of labour and capital is assumed to be zero, rotation cycle is taken to be 40 years, 20 to 100% decline in fish harvest is assumed due to various ecological linkages. Bennet and Reynolds, 1993, ignored future development in valuation and they considered that removal of mangrove results in total disappearance of fish.

Janssen and Padilla (1996), valued the traded forest products using market price, which were adjusted by transportation and gathering costs, whereas non-traded forest products were valued using market price. For fisheries sustainable harvest is estimated using Gulland's exponent rate. Fishery productivity is linked to nutrient productivity. The value of aquaculture was listed as negative, for this value represents the foregone benefits of not converting the forests to fishponds and therefore can be considered as an opportunity cost of conservation.

Riutenbeek (1994), considered transportation cost for valuation of livestock, fish and firewood, but he did not correct local farming products for transportation cost. Biodiversity benefits were valued using contingent valuation approach. CBA was also used and cost and benefits were extended over a period of 90 years to allow three full rotations, rotation cycle being 30 years. Riutenbeek linked various ecosystems.

Costanza *et al*. (1989) in valuation of a coastal wetland, Louisiana, tried to estimate storm protection value of wetlands. They used the estimates by USACE, of property damage resulting from Gulf Coast hurricanes. These damage estimates included both wind and flooding damage. With data on property damage, distance of center of county from coast, distance from path of hurricane, population size, hurricane strength, probability of hurricane, they estimated increase in expected property damages resulting from being closer to the landfall of hurricane. At annual population growth rate of 1.3%, present value of 207-ft wide strip for storm protection was found to be $ 1915 per acre.

We valued four major functions of Bhitarkanika mangrove forest, the value of which is estimated to be quite high, but to get a clear picture on the overall value of the functions performed by this ecosystem, valuation of other parameters need to be done. From the available literature on coastal ecosystem valuation, it has become clear that these ecosystems provide a range of renewable marketed and non-marketed goods and services at three spatial scales – local, regional and global. The ecosystem are diverse in their structure and composition, especially the coastal ecosystem, there is need to carry out similar study in other coastal ecosystems, so as to reflect their environmental value in the decision making process and achieve sustainability in long run.

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Chapter 4

Dependency Pattern

Degradation of natural resources all over the world and especially in the third world countries in the last few decades has been mainly attributed to population explosion, industrial revolution and thereby induced changes in land use patterns (Tidsell, 1994). These man made activities have been responsible for the loss of species in particular and biodiversity in general (Enrlich, 1988). It is a recognition of the fact that where the loss of biodiversity is predominantly because of anthropogenic pressure, the objectives of conservation cannot be achieved in isolation i.e., without a clear understanding of social and economic forces and their interaction with the environmental factors (Gadgil, 1992), especially in a country like India where more than 80% of the wildlife reserves have human presence and some level of natural resource use (Kothari et al., 1989). India's forests have generally speaking not been uninhabited wilderness. Even in the remote forests, people have either been living traditionally or were brought by the forest department and settled there to ensure the availability of labour.

Imposing National Parks on rural communities has had a number of negative consequences, including the restriction of access to traditionally used resources. These situations arise largely due to lack of clear cut understanding of the needs, resource use patterns and aspirations of the local people as also due to lack of dialogue and trust between local people and forest department. At a superficial level there are only two stakeholders involved in National Park - the administration and the local resident population. The local people have divergent interests. On one side there may be rural subsistence farmers concerned about supplies of firewood and building poles for domestic consumption, while the urban communities may be more interested in the commercial possibilities of firewood and charcoal. Even within the same area there will be divisions based on socio-economic status and occupation (Hough, 1988).

Keeping these things in mind the approach and the concept of species oriented conservation is being seen in a broader perspective i.e., ecosystem level conservation. This approach therefore essentially involves the study of social forces, economic status and environmental quality that is being affected due to human activities and has been applied to the studies of PAs in the recent decades (Machlis and Tinchell, 1985; Lele, 1993; Saberwal and Kothari, 1996; Badola, 1997). The importance of such interdisciplinary studies lies in finding out the solution of real problems of local people as well as park management and also to find the mechanism of involving other stakeholders in the management of the concerned PA. Such interdisciplinary approach of merging social, economic and environmental forces to achieve the goal of conservation has more importance in a country like India where the use of natural resources has been the part of traditions and culture of the majority of the rural population (Panwar, 1990). The wise use and sound management of the forest resources aim at the balance between the utilization and the development of resources. The success in reaching this balance depends on the economic and environmental policies, the application of appropriate technologies and rational economic and ecological consideration, the presence of skilled manpower and the socio-economic environment, therefore it becomes imperative to undertake socio-economic studies.

In order to evaluate the use of natural resources in a qualitative and quantitative manner it is crucial to understand the relative use of various energy resources and extent of dependency of local people on these resources (Badola, 1997), further use of energy resources and dependency of people is governed by combination of various social and economic factors. Evaluating management alternatives for forest resources alone would yield an incomplete reflection of priorities when trying to eliminate understanding and dependency of dwellers of the forests. Thus it is imperative to identify different resource use groups of a community with varied requirements and dependency. Their dependency may be due to lack of alternatives, lack of education and awareness or just due to habit. This process may help in identification of other alternate sources of energy, predict the availability and consumption pattern and project rate of exploitation of natural resources (Badola, 1997).

One major constraint on development of a mangrove management plan for improving the quality of life of mangrove dwellers is lack of basic knowledge about community structure, resource utilization, and economic conditions of people living in mangrove communities. It is therefore necessary to make intensive studies of mangrove settlements, which depend mainly on the productivity of mangrove organisms. Decisions on the inadequate knowledge of these people may result in unanticipated hardship for mangrove dwellers, and irrevocable loss of valuable mangrove resources (Aksornkoae *et al*., 1984). In this chapter, critical analysis of socio-economics of the residents of the study area and their dependency has been done to find out viable and sustainable management alternatives.

Assessment of the socio-economic aspects of human settlements in the mangroves are difficult for several reasons. Mangrove forest ecosystem and the socio-economic systems of the mangrove settlers are not coterminous and as compared with the natural ecosystem, information on the socio- economic systems of mangrove dwellers is sparse (Kunstadter *et al*., 1986).

Long-term residents of mangrove areas are generally similar ethnically to the inland populations (Aksornkoea *et al*., 1984), but their way of life often involves adaptation to mangrove environmental conditions, and economic exploitation of several distinct ecological zones. Thus mangrove dwellers have many different socio economic systems, some of which are primarily focused on subsistence activities both agriculture and fishing and some are primarily commercial, including agriculture, fishing and forestry.

Often local coastal communities are dependent on the natural resources that mangroves provide in form of food, firewood, construction materials and medicine and on their ecological services and functions for their livelihood. The impact on local livelihoods of activities of activities that damage mangrove areas are therefore of fundamental consideration in the design of management plans (Bann, 1997).

4.1 Methods

The data on socio economic and dependency aspects was collected in three stages. A sampling frame or survey area was initially identified and this was broadly taken to comprise of the 403 villages located in the impact zone of Bhitarkanika Wildlife Sanctuary. These villages fall in the Rajanagar, Rajakanika and Chandbali Tehsils of Kendrapada, and Bhadrak districts. The first stage involved a rapid assessment of the study area in order to obtain an overall perspective of the villages that were located inside the sanctuary area. The data collected mainly was of secondary nature and involved information regarding access to facilities such as PHC's, schools, bus-boat services, kerosene-coal distribution centers, type of roads, livestock information, land utilization, demographic profile of the villages, location and distribution of villages with respect to forest and their dependency on forests for fuel wood, timber, fodder etc.

The first stage of data collection was carried out in the months of October and November 2001 and they were obtained from the District Statistical Office, Collector's office, District Animal husbandry departments, Panchayat offices, Block's VS, BDO'S, DFO's and State electricity boards offices. For gaining further information visits to many of the main panchayat villages and other major and easily accessible villages were made and information regarding facilities and living standards like number of Kutcha-Pucca houses, community and occupational pattern gathered. In total data on 35 parameters was collected. A public encounter setting while conducting the rapid survey helped in a general discussion of the issues in these villages.

Of the 35 parameters 28 parameters believed to be characterizing villages were subjected to Factor Analysis using software tools like SPSS 8.0. Only 336 villages were taken up for the analysis. The rest 67 of the total 403 villages were dropped as these were uninhabited and hence had no direct impact on the park area. Factor analysis attempts to identify underlying variables, or factors, that explain the pattern of correlation within a set of observed variables. It is often used in data reduction, by identifying a small number of factors, which explain most of the variance observed in a much larger number of manifest variables. Following seven components having eigen values greater than one were identified from the correlation matrix. Together they explained 66.099% of the variation in the system.

Principal component 1: (28.72% of the total variance) is interpreted mainly as the demographic component separating the villages on the basis of population structure, literacy, number of residential houses, agriculture.

Principal component 2: (10.96% of total variance) is the occupational pattern component and includes people involved in animal husbandry, business, services, cottage industries and SC community, number of electrified houses and can be referred as the living standard component.

Principal component 3: (6.75% of total variance) is the livestock component.

Principal component 4: (5.85% of total variance) is the land use pattern comprising of land put to non-agricultural uses, wasteland and total area of the village.

Principal component 5: (4.8% of total variance) has positive loading for people involved in labour and ST community whereas distance from forest has negative loadings on the component.

Principal component 6: (4.21% of total variance) shows a positive relationship between forest and male buffaloes.

Principal component 7: (3.78% of total variance) is the barren land component having a negative association with non-irrigated net area sown.

In the second stage, hierarchical cluster analysis using Ward's method was done to identify relatively homogeneous groups of cases (villages) based on selected characteristics (seven PCA scores), using an algorithm that starts with each case (or variable) in a separate cluster. During the process seven clusters were identified. A sample size of 35 villages was initially identified and the villages were then distributed in each cluster in proportion to the size of each cluster. These villages were then randomly selected from the clusters. In the selected villages data regarding the socio-economic set up, dependency on mangrove ecosystem and attitude of the people towards conservation were gathered.

All the villages of Rajanagar block, which is a total of 310 villages, have been notified within the sanctuary limits. Out of these 65 villages are uninhabited but their land area is being used for the agricultural and aquaculture purposes. These 310 villages fall under 18 Gram Panchayats. In Rajkanika three villages namely Jagannathprasad dia, Gangadhar Prasad dia and Upulai dia are accreted lands and hence were excluded while identifying the clusters, which have an impact on the park resources.

Table 4.1 Selection of villages for intensive sampling

Cluster number	No. of villages in cluster	Proportion	No. of villages covered for intensive survey
1	129	0.383	14
2	79	0.235	8
3	16	0.047	2
4	17	0.05	2
5	39	0.116	4
6	41	0.122	4
7	15	0.044	2
Total	**336**		**36**

For each selected village 10% of the housing units were picked up randomly for the household and attitude survey. A structured questionnaire was used for intensive household surveys, as it constitutes a mean of obtaining a large number of quantitative data relatively quickly, in a form amenable to rapid analysis. The intensive survey interviews were conducted from December 2001 to June 2002 as the dry season facilitates better mobility. It was not very difficult finding the people, as the farm plots are not very dispersed in the areas so far covered, although some of the harvesting was already underway. A point was made to evenly distribute the households over the total area of the villages in order to get a full representation of all caste and communities. Since working entirely without help was not feasible, field assistants were used as interpreters or the main communicators for proper comprehension of the local language. Besides the interviewing responsibilities was also delegated to them in order to strike the right balance between comprehensiveness and manageability, as the time available was quite less. Working with an interpreter not only gave fairly direct contact with the respondents but also provided some flexibility (to write and think) during interviews. A fairly good understanding of the language by the researcher helped to pick up obvious mistranslations and to detect when words were being put into the respondents mouth.

In our fieldwork, we have also used participant observation to inform our understanding of processes rather than a principal method of data collection. The advantage of a quantitative approach is that it's possible to measure the reactions of a great many people to a limited set of questions, thus facilitating comparison and statistical aggregation of the data. This gives a broad, generalized set of findings presented succinctly and parsimoniously. At the same time in a qualitative inquiry the researcher is the instrument. Validity in qualitative methods, therefore hinges to a great extent on the skill, competence and rigor of the person doing fieldwork. As Guba and Lincoln, (1981; 1994), comment on this aspect of qualitative research, "Inquirer is himself the instrument, changes resulting from fatigue, shifts in knowledge and cooptation, as well as variations resulting from differences in training, skill". Because qualitative and quantitative methods involve differing strengths and weakness, they constitute alternative, but not mutually exclusive, strategies for research. Recent developments in the evaluation profession have led to an increase in the use of multiple methods, including combinations of qualitative and quantitative data and the same has been applied in this study with quantitative approach undertaken for the rapid village survey and household surveys to assess the dependency level and a qualitative one for determining the attitudes of local people towards conservation issues (Patton, 1990).

4.2 Results

Table 4.2 gives the land utilization pattern of all the villages in sanctuary area. It is evident that more than 50% of total land area is being utilized for agricultural purpose of which 92.18% of land remains unirrigated. The average household size is 7.59 ± 0.114. More males (62%) are educated as compared to females (48%). Total literacy rate is (48%).

Table 4.2 Land utilization pattern of villages in the study area

Land utilization	Mean (acres)
Village area	279.78 ± 9.83
Mean forest area	3.44 ± 1.43
Land used for non-agricultural purposes	41.06 ± 3.93
Barren land	2.79 ± 0.72
Wasteland	11.34 ± 1.01
Net area sown irrigated	11.97 ± 1.46
Net area sown non irrigated	143.17 ± 6.44

Table 4.3 Demographic characteristics of the villages in the sanctuary area (n = 323)

Demographic parameter	Mean
Avg. household size	7.59 ± 0.114
Sex ratio	1.00 ± 0.033
Male literacy (%) *(n = 322)*	62 ± 0.020
Female literacy (%) *(n = 320)*	36 ± 0.011
Total literacy (%)	48 ± 0.009
Mean cattle population	0.61 ± 0.14

Table 4.4 Occupational pattern of the villages in the sanctuary area

Occupation	%people engaged
Agriculture	60.30
Fishing, animal husbandry and allied activities	1.96
Labour	25.47
Cottage industries	1.57
Private services	5.03
Government services	5.67

The villages are basically agriculture based. c 60% of the people are engaged in agricultural activities. A single crop is sown during the Kharif season due to lack of irrigation facilities and salinity of soil baring small tracts of land along riverbanks in some areas. However this is also an important contributor to the income of the villagers (10.37%). Not many people are engaged in animal husbandry and allied activities and the livestock owned are of local, inferior breed. The average months of employment are also low (7.3) (Table 4.4.).

4.2.1 Detailed information on intensive study villages

4.2.1.1 Distribution of villages

To assess the effect of distance on resource use the villages were divided in three categories based on a rough estimation of their difference from the park (forest) boundary (Table 4.5). Villages in 0-1.5 kms. distance category has forests lying within a range of 1.5 km from their outer boundaries. They mainly fall in Rajnagar block and Dangamal, Rangini, Iswarpur and other Panchayats. All the villages in the Rajkanika block fall in third category *i.e.* more than 3 km from the forest.

Table 4.5 Distribution of intensive study villages in three distance classes

Distance class (kms)	No. of villages	No. of households sampled
0-1.50	16	150
1.50-3.00	11	84
>3.00	8	90

4.2.1.2 Demographic status of the sample villages

Table 4.6 gives the demographic profile of the sampled villages. A total of 324 households were surveyed for socioeconomic study for all the three villages.

Table 4.6 Demographic profiles of the sample villages (n = 324)

Parameters	Total
No. of households	324
Total population	2974
Years of education	5.89 ± 0.233
Mean family size	8.24 ± 0.279
Total Males	1526
Total Females	1448
Female/1000 male	949/1000

In the sampled villages the family size obtained is a little over 8 individuals per household being 8.24 + 0.279, which is nearly same as that obtained for all the villages in the sanctuary area, 7.59 + 0.114. Sex ratio for the sampled villages is 949/1000 (Table 4.6). This is quite low when compared to the sex ratio for rest of the villages in the sanctuary area, which is above 1.00 (Table 4.3).

4.2.1.3 Age distribution of the sampled population

About 50% of the 2949 people for whom data was collected were under 20 years of age. Only 5.7% of the population was 60 years and older. The third and fourth age classes which are important constituent of the working population, includes 44.7% of population (Table 4.7).

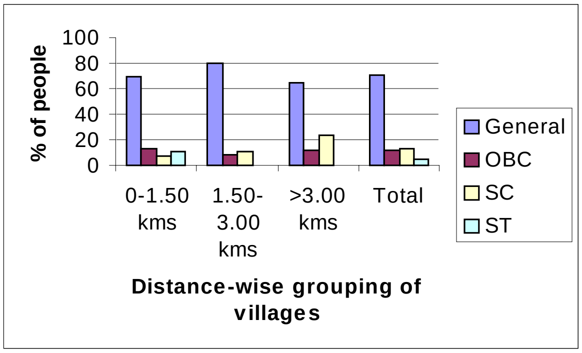
Table 4.7 Distribution of sample population in different age classes

Age class(Years)	% of population	Cumulative %
0-6	16.6	16.6
6-20	33	49.5
20-45	35.9	85.5
45-60	8.8	94.3
>60	5.7	100.0

4.2.1.4 Caste composition

Figure 4.1. gives the distance wise caste composition. Percent of people belonging to upper castes is highest and dominates the human population, (70.43%). The ST population, (10.79%) is reported only in villages located in the periphery of the forest i.e. in the 0-1.50 km class. A significant difference was found in caste composition within the villages (c2 = 31.164; df = 6; p = 0.0005). This implies that there is a significant association between caste and the distance from forest.

Figure 4.1 Caste wise distribution of people in different categories



4.2.1.5 Educational status of sample villages

The literacy level was calculated after eliminating the < 6 age group category. The highest percentage 31.92 % was found to be of people having primary level (0-5) of education. People with secondary education are almost in equal numbers. Those with higher secondary and above (>10) are only 5.58 % (Table 4.8.). Also, a surprisingly high level of literacy was observed with a male literacy of 79.82 % and female literacy of 59.12%. The overall literacy rate was 69.19%. A significant difference in the mean number of years of education was seen among the villages (*F = 12.605; df = 2; p = 0.000*), which was highest, i.e. 7.2 for villages situated farthest from the mangroves (Table 4.14).

Table 4.8 Educational levels of the study villages (n = 2976)

Years of education	Male %	Female %	Total %	Frequency
0	21.18	40.88	30.81	917
1-5	32.13	31.77	31.92	950
6-10	38.69	24.31	31.69	943
>10	8.00	3.04	5.58	166

4.2.1.6 Occupational pattern

Of the 324 respondents interviewed majority of the people were involved in the primary sector i.e. agriculture. In all the 35 villages covered 25% of population either was engaged purely in agricultural activities. Another 20.99% of people also work as unskilled labourers in these sectors. The percentage of skilled labourer is also low (4.01%). The percentage of people with fishing, as their primary occupation is 6% in the first category of villages and is 8.9% for the third category. 2.2% of people are involved in NWFP (largely Nalia grass extraction in the villages farthest from the National Park as compared to 1.3% of those nearest to the Park (Table 4.9).

Table 4.9 Occupational pattern of the respondents of the sampled villages in three distance categories (%) (n = 323)

Occupation	0-1.50 kms (n = 150)	1.50-3.00 kms (n = 84)	>3.00 kms (n = 89)	Total
Not engaged	16.00	14.29	10.0	13.89
Service	4.00	4.76	4.44	4.32
Business	7.33	10.71	8.89	8.64
Agriculture only	20.00	22.62	35.56	25.00
Agriculture and agriculture labour	20.67	29.76	13.33	20.99
Skilled labour	4.00	2.38	5.56	4.01
Unskilled labour	12.67	5.95	3.33	8.33
Fishing	6.00	1.19	8.88	5.56
NWFP extraction	1.33	1.19	2.22	1.54
Agriculture and others	8.00	7.15	7.79	7.72

4.2.2 General economic characteristics of the intensive study villages in the three distance categories

The mean number of months of employment in the sampled villages is 6.25 $\pm$ 0.212 and the average income per household per annum is 22976.3 $\pm$ 1791.486. The agricultural income is Rs 2039.7 $\pm$ 297.076 and the mean cattle holding per household 2.3 $\pm$ 0.184 (Table 4.10.).

Table 4.10 Overall economic characteristics of all the households covered during the intensive survey (n = 324)

Parameters	Mean	Standard Error
No. of months of employment	6.25	0.219
Income of the family (Rs/ annum)	22976.33	1791.486
Income of the interviewee (Rs/ annum)	8196.02	557.983
No. of family members engaged	2.20	0.078
Owned agricultural land (acres)	2.88	0.296
Agricultural income	2039.75	297.076
Income from dairy, animal husbandry, poultry (Rs)	577.07	225.422
Cow	0.85	0.062
Calf	0.77	0.064
Buffalo	0.31	0.138
Ox	1.19	0.077
Poultry	1.54	0.213
Goat	0.45	0.101
Others	0.71	0.349
Cattle	2.35	0.184
Net	0.08	0.017
Boat	3.43	0.369

4.2.2.1 Workers per household and dependency ratio

On overall basis for all the villages, 2.2 ± 0.078 persons/household were engaged in some sort of income generating activity. The percentage of people so engaged was found to be highest for the households in the peripheral villages with about 30.37% of the persons in each household being a paid worker, either earning from wages or income derived from productive activities. For the second and third category of villages these percentages are 27.5 and 27.9 respectively (Table 4.11). The dependency ratio thus calculated for all the villages, i.e. the ratio of dependents to working family members was about 3.7 and it was highest for the villages in the second category.

Table 4.11 Distance wise workers per household and dependency ratio in the study villages

Distance Categories	Family size (approx.)		No. of family members engaged		Dependency ratio
	Mean	S.E.	Mean	S.E.	
0-1.50	7.96	0.395	2.20	0.117	3.60
1.50-3.00	8.95	0.653	2.23	0.157	4.02
>3.00	8.04	0.457	2.18	0.140	3.69
Total	8.24	0.279	2.20	0.078	3.74

4.2.2.2 Work participation rates

As evident from Table 4.12 the mean number of months of employment for the respondents was 6.25 ± 0.219. This is highest for the third category villages, 6.71 ± 0.417. A total of 13.58 % of the surveyed respondents were unemployed. 44.75% of the respondents have <6 months of employment. The mean number of months of employment for the total sample area is 6.25 ± 0.219 months that falls just above the minimum 183 days of employment for the marginal workers.

Table 4.12 Work participation rates of the respondents in the sampled villages (n = 324)

No. of months of employment	0-1.5 kms (n=150)		1.5-3.0 kms (n=84)		>3.0 kms (n=90)		Total	
	N	Valid %	N	Valid %	N	Valid %	N	Valid %
0	24	16	11	13.1	9	10	44	13.58
1-6	64	42.67	41	48.81	40	44.44	145	44.75
6-12	62	41.33	32	38.1	41	45.56	135	41.67

4.2.2.3 Family income

The villages, which are, located near the park the maximum number i.e. 36% of people have income levels in the 0-7500 category. The income increases with increasing distance from park. For the villages at moderate distance (1.5 to 3.0 km), 41.11% and for those located far off from Bhitarkanika National Park, the maximum number of people, 37.04% have income in the 7500 -15000 Rs/annum classes (Table 4.13). Among the three classes of villages the mean family income in Rs/annum, for the households happen to be highest for the villages in the second category with a mean value of 28710 ± 3689.177 and the lowest for the villages located near the forests, 18414.7 ± 1795.508 (Table 4.14).

Table 4.13 Distribution of income levels (%)

Income levels (Rs/annum)	0-1.5 kms (n = 150)	1.5-3.0 kms (n = 84)	>3.0 kms (n = 90)	Total (n = 324)
0-7500	36.00	3.57	16.67	22.22
7500-15000	27.33	50.00	41.11	37.04
15000-25000	18.00	15.48	20.00	17.90
15000-50000	12.00	17.86	7.78	12.35
>50000	6.66	13.10	14.44	10.49

Table 4.14 Comparative statistics of socio-economic characteristics for the three distance categories

Village Characteristics	0-1.5 kms (n = 150)		1.5-3.0 kms (n = 84)		>3.0 kms (n = 90)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
No. of years of education	4.7	0.297	6.643	0.475	7.2	0.464
No. of months of employment	5.97	0.327	6.25	0.413	6.71	0.417
%of family members engaged	30.37	1.402	27.494	1.35	27.9	1.334
Mean family income (Rs/year)	18414.73	1795.51	28710	3689.177	25227.56	4505.396
Mean cattle population	2.42	0.281	3.036	0.469	1.59	0.138
Average land holding (acres)	2.31	0.344	4.503	0.864	2.33	0.356
Agricultural income	1677.73	471.915	3173.33	685.643	1580	315.091
%of boat owners	8		7.14		4.44	
%of net owners	65.33		52.38		25.36	

4.2.2.4 Livestock

The mean cattle holding (sum of cow, bull and buffalo population) per household has been found to be 2.35 ± 0.184 (n = 324). The breeds are mostly local and 69.85 % of the population have kept them basically for agricultural and domestic purposes. A significant difference is seen between the mean cattle holdings in the three classes (*F = 4.278; df = 2; p = 0.015*), the value being highest for the villages falling in second category, 3.036 ± 0.469 followed by the first 2.42 ± 0.282 and the third 1.59 ± 0.138 (Table 4.14).

Table 4.15 Livestock holdings among the households (n = 324)

Cattle holding	No. of households	Percent	Cumulative Percent
0	78	24.1	24.1
1-5	226	69.8	93.8
>5	20	6.2	100.0

4.2.2.5 Agricultural landholdings and land utilization

It is a predominantly agriculture based community with about 49.4% of the population with 1 acre to more than 1 acre of agricultural land. A single crop is sown during the Kharif season due to lack of irrigation facilities and salinity of soil. About 26.2% of the population was landless and another 24.45 % had less than one acre of land (Table 4.16).

The mean agricultural land per household was found to be 2.88 ± 0.296 acre (Table 4.18). A significant difference is seen among the mean land holdings (*F = 5.388; df = 2; p = 0.005*). The value again being highest for the villages falling in second category, with a mean of 4.5 ± 0.864 acre (Table 4.14).

Table 4.16 Pattern of landholdings in the surveyed villages (n = 324).

Land holding class (acre)	Frequency	Percent	Cumulative percent
0.00	85	26.2	26.2
0.1-1.0	79	24.4	50.6
1.0-5.0	119	36.7	87.3
>5	41	12.7	100

Area (acre) sown on contract basis is 1.57 ± 0.179. The average production (qtl.) of paddy per household is 16.88 ± 1.77 and 4.93 ± 0.521 from own land and land taken on contract respectively (Table 4.18). Agricultural income accounts for about 26.99% of the total income in all the villages (Table 4.17).

Table 4.17 Contribution of various sectors to total income

Occupational sectors	Contribution to total income (%)
Govt. / Private service	14.59
Business	18.25
Agriculture	26.99
Skilled labour/ Manufacturing industries	16.17
Unskilled labour	12.83
Fisheries	9.96
NWFP collection	0.92
Aquaculture	0.29

Table 4.18 Agricultural characteristics of the households in the villages (n = 324)

Characteristic	Mean
Total agricultural land (acres)	2.88 ± 0.2961
Area sown (acres)	2.85 ± 0.2959
Produce from own land (qtl.)	16.88 ± 1.7703
Area sown on contract basis (acres)	1.57 ± 0.1792
Produce from land on contract (qtl.)	4.93 ± 0.5217
Agricultural income (Rs.) (n=323)	2039.75 ± 297.07

A difference was seen in caste-wise land ownership pattern (*F = 4.294; df = 3; p = 0.006*) with the upper caste having a land holding of 3.49 ± 0.416 acres. The SC community people have the lowest landholding of only 0.57 ± 0.115 acres per household (Table 4.19).

Table 4.19 Caste-wise land ownership

Caste	Mean	S.E.
General	3.49	0.416
OBC	2.39	0.586
SC	0.57	0.115
ST	0.91	0.305

4.2.2.6 Net and boat ownership

The percent of boat and net owners decreases with increasing distance from the parks. The maximum value 8 % of people having boats and 65.33% of people having nets was observed for the villages nearest to park (Table 4.14).

4.2.3 Traditional uses of mangrove resources

The uses of the mangrove forests by the local people ranges from timber, poles and posts to firewood and fiber. Non-wood forest products include thatch, honey, wildlife, fish, fodder and medicine. Though the area has protected status and legally no extraction is allowed, the villagers living in mangrove areas use mangrove trees mainly for fuel wood, construction of houses and agricultural implements. Table 4.20 enumerates the various use values derived from Bhitarkanika mangrove forest, as reported by the villagers during the survey and represents the species that are most frequently used. They do not necessarily represent the quality of timber and their suitability.

Table 4.20 Specific use values of various mangrove species of Bhitarkanika

Specific Use	Poles (*Khunta*)	Rafters & supports Beams (*Ruo & Ghudiya*)	Beams/Bars (*Mathan*)	Connectors (*Bata*)
Timber	*Heritiera spp.*	*Phoenix paludosa*	*Avicennia* spp.	Garani (*Ceriops tagal*)
	Singada			Hental(*Phoenix paludosa*)
	Bani (*Avicennia* spp.)			Sundari (*Heritiera spp.*)
Firewood	Garani (*Ceriops tagal*)			
	Sundari (*Heritiera spp.*)			
	Jagula(*Tamarix dioca*)			
	Bania (*Hibiscus spp.*)			
	Bani (*Avicennia spp.*)			

Thatching	*Hental (Phoenix paludosa)*	
Fodder	Bani (*Avicennia* spp.)	
NWFP	*Myriostachya wighitiana*	
Medicinal species		***Medicinal values***
	Sundari *(Heritiera spp.)*	Cuts/ Bruises
	Pattarkuriya (*Xylocarpus mekongensis*)	Oil
	Karanja	Oil
	Panurigada	Toxic insect bites
	Muchkundi	Stomach ailments
	Chonchina	Rheumatic pain
	Jajajhanga	Rheumatic pain
	Jagula (*Tamarix dioca*)	For treatment of poisonous latex of *Excoecaria agallocha*
	Strychnos nux-vomica	Multiple uses
Honey	Garani (*Ceriops tagal)*	
	Keruan (*Sonneratia spp.)*	
	Kharsi (*Aegiceras coniculatum)*	
	Ooanr (*Amoora cucullata*)	

4.2.3.1 Firewood

Total requirement of firewood and other similar resources for cooking purposes per household in the 35 villages came out to be 22.05 ± 1.042 qtl. /annum. The major sources being non-mangrove firewood purchased from market or from the trees in the backyard. A heavy dependence (88.43 %) (Figure 4.2) was on cow dung cakes and farm refuse as no other sources such as LPG or kerosene or coal are easily available.

Table 4.21 Dependency on various forest and non-forest resources (n = 324)

Uses		**Mean**	**S.E.**
Fuel	Total consumption of fuel (qtl.)	22.05	1.042
	National Park firewood (qtl.)	3.12	0.322
	Other firewood (qtl.)	2.1	0.235
	Cow dung, farm refuse, others (qtl.)	19.49	3.75
Fishes	Fish caught from sanctuary rivers and roadside creeks (qtl. / year.)	0.98	0.283
	Income from sales of National Park fishes (Rs.)	770.03	214.792
Timber	Used as rafters (qtl. / annum)	3.43	0.369
	As roof supports (qtl. / annum)	0.27	0.043
Non wood forest produce	Honey (qtl. / annum)	5.247E-04	2.397E-04
	For thatching (qtl. / annum)	0.4886	0.087

Wood from the Bhitarkanika mangroves is being used, particularly by the communities in the periphery of the forest for firewood purpose. An overall 14.18% of the needs of each of the households was being met by the forests (Figure 4.2.) with a mean consumption of 3.12 + 0.322 qtl./annum in the sampled villages (Table 4.21). When the same data was segregated distance class-wise highest value was obtained for those villages located within 1.5 kms. from BNP, which was 5.80 + 0.533 qtl./annum in terms of quantity (Figure 4.3. and Table 4.22.). A significant difference was found between the mangrove firewood consumption in the three distance categories (*F = 36.179, df = 2, p = 0.000*).

Figure 4.2 Fuel consumption pattern in the sampled villages

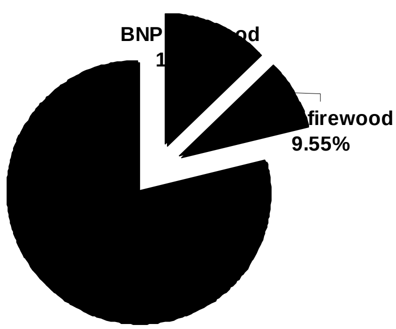
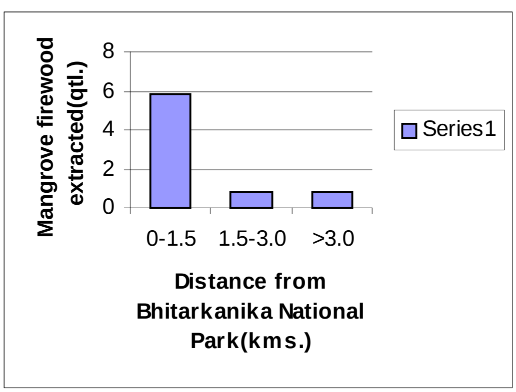


Figure 4.3 Distance wise firewood consumed from the National Park



4.2.3.2 Fishing

Fishing is an important occupation in the area, it accounts for 5.56% of the village people with reported occupation (Table 4.9). Fishing is prohibited inside the park but not in the sanctuary area. Fishing leases are being granted to traditional fisherman to operate in the sanctuary area by the Orissa revenue department. Quite a significant amount of fishing activities were observed in the major rivers like Baitarni and Brahmani. The river Dhamra is in the vicinity of forest and hence no leases are granted but more cases of fishing offences are committed because of the presence of marine fishing trawlers that frequently violate the provisions. Also, shrimp seedling collection, also called pin is a profitable business and is mainly carried out by the female members in the villages located on bank of river Dhamra. However even the mangrove area, estuaries and tidal creeks in mangrove areas in the dry seasons i.e. February to June are used by local fisherman particularly women folk, for mud crabs, prawn and other fishes. But majority of the populace do the fishing in the tidal waters on the side of dykes and roads along the rivers.

Many of the small time farmers also, are involved in fishing using cast nets and various types of fish traps such as mundali jal, Andhuni, Launja in their leisure time, mainly for subsistence purposes. Each fisherman normally operates two or more types of gear that can be use in different localities and weather conditions. Most of the people who are involved in large scale harvesting of fish products own powerboats and big nets, locally called Bhasa, Bengapatia (types gill nets). The ownership of these boats and fishing nets is either private or joint ownership of three people provided by the Care-India group to the members of marginalized communities in the villages. The best fishing period is between August to December, when the tidal range is more pronounced (spring tides). The same is however not true for the people involved in fishing in the high seas.

As seen from Table 4.21 there is an annual catch of 0.98 + 0.283 qtl. of fish and crabs per household, which is quite high viewing the protected status of the park. The highest 1.25 + 0.391 qtl. has been observed for the villages located in peripheral areas of the mangroves, and the least i.e. 0.60 + 0.495 for those farthest from it (Table 4.22).

Similarly there is distance wise variation in income from fishing with the highest of Rs. 1043.84 + 231.891 per annum for the villages in 0 - 1.50 km. distance category which decreases to 667.47 + 604.637 for the second and then to 412.50 + 356.291 in the third category (Table 4.22). Though no significant difference was seen in the quantity of fish harvested between the villages in the three categories (*F = 0.470; df = 2; p = 0.625*) but a significant difference was seen for the incomes derived from the same (*F = 0.788; df = 2; p = 0.456*).

Table 4.22 Distance–wise comparative resource use and dependency of villages(n = 324)

Resource use (per annum)	0.00 - 1.50 (n = 150)		1.50 - 3.00 (n = 84)		> 3.00 (n = 90)	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Firewood from BNP (qtl.)	5.80	0.533	0.83	0.254	0.82	0.504
Fish catch / annum from the sanctuary (qtl.)	1.25	0.391	0.94	0.652	0.60	0.495
Income from fishing (Rs)	1043.84	231.891	667.47	604.637	412.50	356.291
BNP wood used as rafters (qtl./ household)	4.56	0.504	2.49	0.527	2.42	0.885
BNP NTFP used for thatching (qtl/ household)	0.90	0.161	0.27	0.152	0.00	0.000
BNP wood used as supports (qtl./ household)	0.43	0.079	0.21	0.067	0.05	0.032
Honey (qtl.)	0.011	0.0005	0.00	0.00	0.00	0.00

4.2.3.3 Construction materials

In the past wood was being used for construction purposes. Presently also, it is used for making furniture and for as beams and supports for the interior of the houses (Table 4.20). *Avicennia, Bruguiera, Phoenix, Heritiera* species are commonly used for columns, bracing members, beams, and roof frames.

Various species of mangrove wood are used for construction works. Overall approximately 0.27 ± 0.043 qtl./household wood was consumed for roof supports, which is a conservative estimate (Table 4.21). Mangrove timber is extracted on a small scale in many areas for jetty construction, forest pathways, and small gap bridges. It is also used for boat building, fish traps, and mooring poles. *Phoenix paludosa* rafters are used in many of the households. In the villages located in the proximity of BCA 4.56 ± 0.504 qtl./household of wood was used as rafters, whereas this was 2.42 ± 0.527 qtl./household for the villages falling in second category (Table 4.22).

4.2.3.4 Non Wood Forest Products

Permits were granted by the Forest Department till last year for the collection of honey to ST community people, in two of the sampled villages, *i.e.* Dangmal and Satavaya. One of the mangrove associates *Myriostachya wighitiana* locally called Nalia is used for weaving baskets, mats and other articles which are long lasting. A number of people are still involved in the Nalia extraction and weaving business though the permits that were earlier given for their collection have long been stopped. Besides, quite a few species of other grasses growing on the banks of rivers in the sanctuary area are used for making such articles.

The leaves of *Phoenix paludosa* stacked together in bundles of 13-20 served as shingles for thatching purpose. Weight of each of these was calculated after taking measurements of different samples in different areas and was found to be 0.00418 qtl per piece. Highest consumption of 0.90 ± 0.161 qtl. /household was seen for villages in the adjoining areas of forest while the villages situated at more than 3 kms away from the forest did not use this resource. A significant association between distance and consumption of thatch was revealed ($F = 10.942; df = 2; p = 0.000$) (Table 4.22).

4.2.4.5 Livestock and grazing

There is a huge livestock population dependent on the forests in absence of any worthwhile pasturelands. Nutritive fodder is available from trees like *Avicennia* and this prompts the villagers to rear cattle. There is no gathering of forest fodder. However grasses such as, *Ragad* and *Duba* are gathered from the fields especially in the rainy season, but not by many households. The cattle are left to graze in the fields in the fallow season. During the cropping season *i.e.* July-December, they are either stall-fed or are left to graze in the forest, particularly in the areas around the forest. An estimation of the amount of fodder consumed posed a problem, because of these varied factors.

4.3 Discussion

India's forests have generally speaking not been uninhabited wilderness. Even in the remote forests, people have either been living traditionally or were brought by the forest department and settled there to ensure the availability of labour. There are about 100 million forest dwellers in the country living in and around forest lands for whom forests have continued to be an important source of their livelihoods and means of survival (Lynch, 1992).

As pointed out by Wells and Brandon (1992), forest conservation is critically dependent on government policies, land tenure legislation and institutional relationships. These send out a range of incentives to different stakeholders, causing them to conserve or degrade the forest (Richards, 1995). For, forest use is the function of village socio-economic activities (Moench, 1991). The number of cattle in a village determines fodder needs. The village agricultural system and the amount of fodder produced on agricultural land determine the non-forest component of fodder supply. The occupational pattern of the village influences the number of people actually living in the village and access to external sources of income. These in turn influence agricultural and animal husbandry patterns and thereby forest use. Therefore to understand, predict and plan for ecological change it is also important to study the interactions between social and economic processes and the environment (Clarke, 1986). According to Singh *et al.,* 1989, population variables are taken into consideration as they influence attainment of specific developmental objectives. The population variables considered in planning relate not only to size but also its distribution by residence, age, socio-economic groups, income/ expenditure and poverty levels.

4.3.1 Family size and age distribution

The area has a comparatively larger household size as compared to that of households in other mangrove areas of the world, a study in Ko Lao and Had Sai Khao village in Thailand gave the household size for the two villages as 5.8 and 4.6 persons respectively (Aksornkoae *et al.,* 1984). But household size is also a function of many other socio-economic parameters and is more representative of the country's demographic profile rather than that of similar areas.

The comparatively larger size of the households, which is almost same as that of the whole sanctuary area could be attributed to the greater tendency for joint families. 49.5% of the population are in the age group of 0-20 years suggesting a higher birth rate (Aksornkoae *et al.*, 1984). Also, with comparative studies, the population age structure of the villages could be called young (Mantra, 1982).

4.3.2 Sex ratio

The sex ratio observed was high as compared to that of India (2001: 933/1000) and lower than that of rural Orissa (1991: 988/1000). The higher sex ratio may be linked to higher educational levels in the villages as well as the fact the women generally occupy a respectable place in society.

4.3.3 Education and literacy

Literacy in the area is quite high with 69.19% of people being literate in comparison to 65.38% for India as 2001 census and 49.1% for Orissa as per 1991 census. The number of people formally educated is high because of easy access to primary schools, only 37.27 % of the population have >6 years of education. The value being a minimal 5.58% for more than 10 years of education, the comparative statistics for Orissa being 16.7% as per 1991 census. This is because of the fact that the secondary, higher secondary schools and colleges are very few in number and quite far away. Thus many children particularly girls, do not continue their formal education beyond elementary school, and stay in the village to assist their parents. The male and female literacy rates for the study area were found to 79.82% and 59.12% respectively. The corresponding figures for Orissa, as per 1991 census were 63.1% and 34.7% for male and female literacy respectively.

4.3.4 Caste composition and land Holdings

People from the general category dominated in the villages falling in the second distance category. People from this category of villages were found to have larger landholdings. A significant difference was found between the land holdings by different communities, with the ST and SC households having smaller landholdings. The average land holding is higher when compared with a study conducted in south west Bengal giving an average land holding of 0.32 acre/household and also, somewhat greater than that revealed by a study in the foot hills of Himalayas in the lower Shivaliks, giving range of land holding as 1.1 to 3.4 acres per land holding family (Badola, 1997).

4.3.5 Income levels, occupation and economic condition

The villages have higher levels of income considering their nearness to the forest area. This is accounted for by the higher levels of paddy production. Besides fishing and water transportation is also profitable business for the people. Many people are working as skilled and unskilled labourers in other states and this reflects on their income levels. 59.26% of the people have income levels between Rs 0-15000 per annum. The highest income was observed for the villages at 1.50-3.00 km distance. The agricultural income, the mean cattle holding and the land holdings were also found to be highest for this category of villages. They also have high values for all other economic parameters. This can be correlated with the occupational pattern of the villagers. Among the three categories of villages the second class has the highest percentage of people engaged in either business sector, *i.e.* 10.71% or in government and state services, *i.e.* 4.76%. As, these two occupations have highest returns in terms of money, this accounts for the comparatively, better status of category two villages. These villages have better access to markets and also, many of the households are involved in ferry transportation and high seas fishing, engagement in this activity also contributes to their income and thus it explains relatively higher mean income of people in 1.5 to 3.0 km distance category from the National Park. Mean family income of people in third distance category *i.e.,* > 3 km from National Park, is more than that of people from first distance category, as the percent of unemployed people is less in this category and more percent of people are involved in business, agriculture and more percent of people work as skilled labour. Moreover the mean number of months of employment is also high for people from third distance category, which means relatively higher income.

4.3.6 Livestock holdings

The average cattle holding for the households in the sanctuary villages was found to be quite high, but the majority of the cattle and other livestock are local breeds and despite the higher levels of income, quite undernourished and weak. This is because of the absence of any grazing pastures. Because of the salinity in soil, most areas remain without any significant grass cover during major part of the year. Mainly oxen have been kept for drought purposes.

4.3.7 Resource use and dependency

To the extent that material alternatives of the forest resources are unavailable or people are unable to buy substitutes they are dependent. Dependence on forests could be primary or secondary. Villages situated close to the forest having primary subsistence or economic forest dependence are primarily dependent as they have no easy access to other sources. Villages situated at a greater distance from the forest may claim no formal or informal rights, but nonetheless use the forest periodically for the collection of subsistence goods such as firewood or fodder - these are secondary dependent villages. The second and third category villages show a lesser degree of dependence on the mangroves. However they also enjoy the benefits of fishing and other uses. The pattern of consumption of fuel wood, construction materials and fish products decreased with increasing distance from the park's boundary.

4.3.8 Firewood consumption

All the houses use of fuel wood, farm refuse and cow dung for cooking purposes. Only a few households made use of electric heaters, mostly in the villages farthest from the sanctuary but this was also occasional owing to the erratic supply of electricity in the villages. Some houses in Prassannapur village falling in the first category have biogas plants which are also quite new, established in 2002 itself and these households were also earlier dependent on the traditional resources. Kerosene is hardly used for cooking purposes and LPG is not available. The only distributing centres are at Pattamundai and at Chandbali that are at least 40 km away and difficult to access.

In India too, between 80 and 90 per cent of the total domestic fuel consumed in rural areas is made up of fuel wood, agricultural wastes and animal dung (Saxena, 1995). The national average of per capita firewood consumption has been reported to be 0.6 tons per year (Bartwal, 1987). In comparison to these figures the per capita firewood consumption in the Bhitarkanika area came out to be quite less. The lifestyle of the residents may be one of the factors responsible for the lower rate of consumption of firewood, as the cooking is done mostly once or twice in the day.

4.3.9 Fishery products

Capture fishery

The annual catch of fish products is quite high in the villages. In a study on mangroves in Had Sai Khao village in Thailand the average catch per household per year was, 452 kg of shrimp, 662 kg of crabs, and 4 kg of molluscs (Aksornkoae *et al.,* 1984). The catch in the villages located near the forests can be assumed to be the direct benefit accruing from the mangroves, as the harvest is made entirely from the areas adjoining the mangroves. The maximum level of catch in the peripheral villages is also indicative of the high productivity of the mangrove ecosystem. The comparatively higher level of income from fishing in these villages is because of ability of these people to harvest commercially important fishes such as shrimps, Vekti, Cat fish and others.

Culture fishery

Aquaculture, especially shrimp and fish farming, is widely practised in the mangrove area. Many shrimp and fish-ponds have been built by clear-cutting the mangrove forest. However, in the household survey it was revealed that though there was a boom in the business in the past, in the present times viral attacks and diseases have led to significant losses.

4.3.10 Housing and timber use

Many of the kutcha houses, earlier used to use mangrove timbers. The rafters, poles, supports used in the house construction were extracted in the past. Some timbers such as *Phoenix, Avicennia, Xylocarpus* spp. are noted for their longevity and many *Phoenix* rafters last as long as 80-90 years.

However, only the Shingles or the *Phoenix* leaf thatch that have to be replaced every second or third year and only a small percentage of timber form part of the present day extraction. A shift towards the use of Bamboo for construction purposes is noted because of the increased restriction on mangrove timber and easy availability of Bamboo, which is also comparatively a better construction material.

4.4 Conclusions

The study of socio-demographic characteristics, economic situation, and other aspects of life in these mangrove villages reveal a high degree of resource use despite the protected status of the Bhitarkanika mangroves. This also brings forth the problems that should be alleviated and overcome by the government in order to assist the people living right near the forest and having a high dependency on the mangroves to improve their living standards before the situation becomes worse. Important steps need to be taken immediately to reduce the biotic pressure on these forests. Appropriate legal models for benefit sharing and usufruct rights should be worked out with the communities.

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Chapter 5

Attitudes of People

5.1 Introduction

Perception and attitude studies are becoming useful in environmental management decisions because they can provide information about public support and about the current and future behaviour of relevant parties. The term attitude has been used in relation to and in favor or against response (agreement or disagreement) towards one or more stimuli (an object, person, a psychological object or an affective domain), but can also be related with possible conduct and behaviour (Murphy and Watson 1991, Bruvold 1973). Attitudes are formed in part by communities' and individuals' perceptions and experiences of the park (Infield and Namara 2001). Studies on attitudes and perception of local people have contributed in the understanding of people's needs and aspirations and also in the identification of their ideas, opinions and suggestions regarding conservation issues. The paradigm of conservation with development has attracted increasing support from conservation organizations and international development agencies in recent years. Surveys of attitudes of local people can provide guidance for the policy and management decisions involved in the design, implementation and evaluation of the conservation with development projects (Hill 1991; Parry and Campbell, 1992; IIED, 1994).When decisions affecting wetlands are made with inadequate knowledge of attitudes about and practices of resource use by the local people, conservation programs are unlikely to be successful (Sah and Heinen, 2001), since the conservation and sustainable use of wetland resources rely mainly on farmers, fishermen and other users living in settlements close to wetlands (Pyrovetsi and Daoutopoulos, 1991). Therefore, it is of great importance for conservation policy makers and officials to know the attitudes and awareness of environmental issues, affecting the wetlands. It is generally presumed that conservation related benefits could positively influence attitudes. However, if benefits are perceived to be small in relation to losses or are inequitable distributed, they may not achieve this required effect. Through attitude surveys it may be possible to predict how people's attitudes will be influenced by conservation policies, which may in turn allow more effective planning (Badola, 1998). Attitude surveys can offer guidance for management decisions, as well as provide baseline data to assess the efficiency of new policies (Fiallo and Jacobson, 1995). In this chapter, we examined the attitude of local communities residing in and around the Bhitarkanika Wildlife Sanctuary.

5.2 Methodology

Household survey was conducted between October 2001 and July 2002, during which data on socio-economics, resource use and attitudes were gathered through a questionnaire survey, which targeted 10% of the households. Selection of the sample villages for the survey has been discussed in length in the previous chapter on dependency.

Mostly a set of semi structured along with a few open type questions were put up to know the perception and attitude of local people towards conservation issues. The questionnaire for attitude was divided into three general parts: (1) personal information (gender, age, education, community); (2) economic activities such as land and occupation, family income; (3) awareness and attitudes of local people towards conservation and developmental issues. Respondents answered each question according to their knowledge regarding related issues and hence we got responses in terms of yes, no and don't know. Data were analysed using the Statistical Package for Social Sciences (SPSS) Version 8.0. (Norussis, 1994). Descriptive statistics (frequency, percentages) were used to summarize the data. Preliminary bivariate tests (cross-tabulations) were carried out as part of two-stage analysis, using SPSS, to identify the factors that were associated with various responses at various significance levels ($p = 0.001$; $p = 0.01$ and $p = 0.01$). Kruskal-Wallis tests were used if chi-sq. results had expected frequencies of less then 5.

5.3 Results

5.3.1 Awareness, attitudes and views on conservation options

Awareness and attitude in the present context means awareness among the respondents regarding park's existence, conservation issues and initiatives. Table 5.1 summarizes the attitude of local populace towards Bhitarkanika Wildlife Sanctuary and related conservation issues. Majority of the local populace *i.e.* about 89.6% (*n = 268*) are aware that Bhitarkanika forests have protected status and that it is a declared Wildlife Sanctuary. The main source of awareness about the park, being media *i.e*. radio (43.7%) and word of mouth (35.8%). A staggeringly high percentage (84.3 %) of people feel that they have a responsibility towards conservation of flora and fauna and another 92.9% are in favour of an ecodevelopment programme for the area. Out of 268 responses 43.3% of people are willing to cooperate with forest department in this regard, whereas all most one-third (36.6%) population was found to be indifferent in this regard. Only 18.3% of people feel there has been a violation of their rights with the park's declaration, the main reason behind such a feeling being the denied easy access to firewood. Around 85% respondents felt that they do not face any problem due to legally protected status of the area 72.4% respondents do not want their future generations to shift to promising places (Table 5.1).

When a question regarding ecodevelopment initiative and its implementation was directed to respondents, following views emerged: 52% of the respondents felt that local community should take initiative in ecodevelopment program and consequently be involved or at lest be informed regarding the management decision. 28% felt that NGOs should take the lead in ecodevelopment and the rest 26% felt that government should take up ecodevelopment programme by itself (Table 5.2).

The importance of existence of forests is emphasized by the fact that very few people (0.7%) are in favour of cutting down the forests and 76.9 % of the people have said more mangrove plantations should be carried out (Table 5.3.). 18.3% of the population believes that the present management situation is good. A significant difference was found in the management alternatives opted by respondents ($\chi^2 = 755.179$; *df = 5 and p= 0.000*).

Table 5.1 Attitude of local people towards Bhitarkanika Mangrove Wildlife Sanctuary and conservation initiatives (n = 268)

Questions	Yes (%)	No (%)	Don't know
Are you aware that Bhitarkanika is declared National Park and Sanctuary?	89.6	10.4	0
Do you feel any sense of responsibility for the protection of diverse flora and fauna?	84.3	13.4	2.2
Do you think your rights have been violated after declaration of park?	18.3	72.8	9
Do you face any problem because of park?	5.6	84.7	9
Are you in favour of ecodevelopment project?	92.9	2.2	4.9
Would you like to co-operate with forest department in regard to ecodevelopment project?	43.3	23.1	36.6
Will you like your future generations to move to more promising places?	25	72.4	2.6

Table 5.2 View of local populace towards ecodevelopment initiatives (n = 106)

Views	Frequency	Percent
Want through govt. initiative	26	24.5
Want through community initiative	52	49.05
Want through NGO initiative	28	26.41

Table 5. 3 View of local people towards various management alternatives (n = 268)

Management alternatives	Response (%)
Forests should be cut and land used for agricultural and other purposes	0.7
Crocodiles should be removed and forests should remain	2.2
Present situation of protecting the forests is good	18.3
More mangrove plantations be carried out	76.9
Others	0.4

Majority of the respondents (84.7%) reported that they do not face any problem due to the park and among those who face problem, 4.9% cited crocodile nuisance to be the major problem (Table 5.4.). Respondents differ significantly in their views regarding problems due to protected area status of Bhitarkanika (χ^2= *903.477; df = 5 and p = 0.000*).

Table 5.4 Responses of the population to various problems due to existence of Bhitarkanika Wildlife Sanctuary (n = 268)

Problems	Response (%)
No problems	84.7
Crocodiles create havoc	4.9
Restriction imposed by the forest department on extraction of forest resources	0.4
Damage to crops due to wild animals	0.4

Table 5.5 Influence of distance of village from forest on willingness to cooperate (*p = 0.035)* (n = 172).

Distance class (Km)	Willingness (%)	
	Yes	***No***
0	80	20
0.5 to 1	60	40
1.1 to 3	61.5	38.5
3.1 and above	53.4	46.6

People living close to the forest seemed to be more willing (80%) to cooperate with forest department in the conservation of flora and fauna, as compared with those living away from it ($\chi 2 = 8.36$; *df = 3 and p = 0.035*) (Table 5.5).

Results of the Kruskal-wallis test (Table 5.6.) revealed that males and females differ in their perception towards issues pertaining to conservation *(p = 0.015)*. More males (91%) are found to be aware of the protected status of Bhitarkanika as compared to females (75%); more males are reported to believe that their rights have been violated, as compared to their female counterparts (19.7% and 4.16% respectively).

Education plays significant role in influencing attitude of people. Awareness percent regarding existence of protected area increases with increase in education level *(p = 0.001)*. Only 77.5% illiterate are aware, whereas 85.54% of primary educated, 94.73% of secondary educated 92.7% of intermediate passed and 100% of the graduates are aware of the park's existence. Almost all respondents (100%) from higher education level favour ecodevelopment *(p = 0.032)* and 47.05% of the literate respondents are willing to cooperate with forest department *(p = 0.000)* in this regard. In the case of view regarding violation of rights, due to creation of Wildlife Sanctuary, more educated people (29.4%), feel that their rights have been violated *(p = 0.02)*.

Out of total respondents owning more than 1.1 acre of land, 21% believe that their rights have been violated due to creation of Wildlife Sanctuary. Whereas 15.2% of the respondents owning less than 1.1 acre land, believe that their rights have been violated (*p = 0.009*).

Around 47.7% of the population engaged in farm work is willing to cooperate with forest department as compared to population engaged in other activities *(p = 0.033)*. More respondent in the fishing community were found to be indifferent (75%), the rest 25% foster a positive attitude towards cooperation with forest department (Table 5.7).

Table 5.6 Results of Kruskal-wallis tests *(p = 0.001; 0.05 and 0.01)*, of relationships between socio-economic variables and attitude of local people towards Bhitarkanika Wildlife Sanctuary and conservation initiatives

Issues	Gender	Education	Landholding	Occupation
Aware of the protected status of Bhitarkanika	0.015	0.001	NS	NS
Positive attitude for ecodevelopment	0.014	0.032	NS	NS
Willing to cooperate with forest department	0.019	0.000	NS	0.033
View on violation of rights	0.024	0.020	0.009	NS
Problem due to protected status of the forest	NS	NS	NS	NS

Table 5.7 View of people regarding willingness to cooperate with forest department (n = 267)

Occupation class	Yes (%)	No (%)	Don't know (%)
Agriculture	47.7	26.2	26.2
Fishing	25	0	75
Others	39.1	20	40.9

5.3.2 Developmental options

Recently, various developmental activities have been carried out in and around Bhitarkanika Wildlife Sanctuary. When enquired about various developmental options, majority of respondents favoured Dhamra port extension (87.7%). Very few of respondents favoured aquaculture practice (8.6%). A small population (5.5%) owns aquaculture plant and even from these only 33.3% of these people found aquaculture to be useful for them (Table 5.8).

Table 5.8 View of local people towards various developmental options (n = 268)

Queries	Yes (%)	No (%)	Indifferent (%)
Are you in favor of extension of port at Dhamra	87.7	7.1	5.3
Whether you have an aquaculture plant	5.5	94.4	0
Are you in favor of aquaculture if you don't own a plant	8.6	72.4	19.1
Has aquaculture been useful to you *(n = 15)*	33.3	66.7	0

Table 5.9, represents the percent of respondents who do not prefer aquaculture due to various reasons, like pollution, deterioration of soil properties. Increased salinity, which is detrimental to crop production and pollution caused by aquaculture practice, were cited to be the main cause for not preferring aquaculture practice (24.6%). Other reasons included lack of money and infrastructure required for set up and maintenance of the aquaculture plant.

Table 5.9 Reasons for not preferring aquaculture practice (n = 268)

Reasons	Percent
Destroys agriculture	19.4
Causes pollution	19.4
Causes diseases	1.5
Other reasons	4.9
Detrimental to agriculture and causes pollution	24.6
Don't know	30.2

5.3.3 Ecological functions and values identified by the local community

A list of ecological functions was given to the respondents and they were asked to rank these. This was done in order to find out how much people knew about functions of Bhitarkanika forests and their direct and indirect importance to their livelihoods and lives. For the convenience of respondents the functions and values were enumerated just once. Respondents recognized fishing and fish as separate functions; fishing was used in context of direct use of fish, whereas fish was used as indirect use.

Table 5.10 reveals that, in the case of use values, 22% respondents feel that gave highest ranking to contribution of mangroves to agriculture, 81.2% respondents stated tourism as their second preference and 60% people stated fishing as second preference. In case of ranking, for ecological functions performed by Bhitarkanika wetland, first preference was clearly given to cyclone mitigation, with significant number of respondent (88.6%) stating it as the first preference. 96.2% people gave second preference or ranking to fish productivity, last ranking was given to other functions like biodiversity, rains, ground water recharge, wildlife, education, by10.8% of the respondents (Table 5.11).

Table 5.10 Percentage ranking of various use values (n = 268)

Use values	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)
Fishing	15	60	25
Agriculture	22	73.2	4.9
Tourism	17.2	81.8	1.0
NWFP	20.6	73.5	5.9

Table 5.11 Percentage ranking of various functions (n = 268)

Ecological functions	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)
Aesthetic	38	61.2	0.8
Nutrient	8	92	0
Historical	8.8	88.9	2.3
Cyclone mitigation	88.6	11	0.4
Land erosion prevention	50	50	0
Fish	1.9	96.2	1.9
Others	18.9	70.3	10.8

5.3.4 Views on Crocodiles and Olive Ridley turtles

The fact that crocodile population has reached a nuisance status is proved by our study. 64.9% of population wants that their number should be decreased (*n = 268*), whereas 24.6% respondents prefer that the number of crocodiles should be controlled (Table 5.12). 14.2% respondents think that the crocodile population should be kept at the present number. Only 3.7% want that they should at least be confined to the park area and to prevent them from entering village ponds and habited areas some wire fencing or any other measure to restrict their movement should be used. Another 8.2% of the respondents want that the population of crocodiles should be totally exterminated.

45.1% of people are in favor of some kind of protection to the Olive Ridley sea turtles especially in the nesting season and another 50.4% want strong measures to be taken for their conservation (Table 5.12).

Since the figure of percentage of people favoring decrease in the number of crocodiles was relatively low and there was no logical explanation for this, we classified the villages into two categories-villages in Rajnagar area away from forests and crocodiles, and villages near the rivers and forested areas.

Significant difference (*p = 0.000*) was found in the attitude of local people, from two different groups of the villages, towards conservation of crocodiles (Table 5.13). From the first group of villages (village situated away from rivers and forested areas), 50% respondents felt that crocodile population should be decreased, whereas in second group (villages situated near rivers and forested area), 68.5% respondents wanted their number to be decreased and another 28.3% wanted their number to be controlled (Table 5.13). 12.6% people from second group of villages felt that the population of crocodiles should be totally exterminated, whereas from first group of villages only 4.4% respondents felt that crocodile population should be totally exterminated.

Table 5.12 Views regarding the conservation of salt water crocodiles and Olive Ridley turtles (n = 268)

Options		Responses (%)
The situation before the start of the crocodile breeding project was good		1.9
The numbers of crocodiles should be controlled		24.6
They should be kept at present numbers		14.2
They should be kept within an enclosure		3.7
Their numbers should be decreased		64.9
They should be totally exterminated		8.2
Their number should be controlled and they should be kept within enclosure		1.9
They should be kept at present number and within enclosure		3
Their number should be increased but they should be kept within enclosure		5.2
Can't say		1.9
Olive Ridley sea turtles should be protected	Strongly in favour	50.4
	In favour	45.1
	Indifferent	1.1
	Not in favour	1.1
	Strongly not in favour	0.4
	Can't say	1.9

Table 5.13 View of respondents, from two different group of villages, towards conservation of crocodiles (χ^2 = *23.011; df = 5 and p = 0.000*)

Response categories	Group 1 villages (%)	Group 2 villages (%)
Crocodile population should be maintained at level prior to start of conservation program	3.7	0
Crocodiles population should be kept at present number	13.2	15.7
Population of crocodiles should be controlled	25.7	28.3
Crocodile should be kept in enclosure	2.9	11.8
Crocodile population should be decreased	50	68.5
Crocodile population should be totally exterminated	4.4	12.6
Total respondents	127	136

5.3.5 Alternatives if free access to fodder and fuel wood are denied

To find the extent of actual dependency, a question regarding alternatives to forest produce in case free access to forest resources is stopped, was asked. In its response, 30.6% respondents said that they would buy the alternatives available in the market, 10.1% opted for stealing the produce from the forest. 39.6% reported that they are not dependent on forest and therefore denial to easy access to these resources will not affect them. Only a few respondents (2.6%) opted for growing fodder and a very less percentage (0.4) of them were willing to reduce the number of livestock (Table 5.14).

5.4 Discussion

It is important to take into account the socio-cultural acceptability and viability of the suggested alternatives in designing effective alternatives to forest resources for local people (Leach and Mearns, 1991; Wells and Brandon, 1992; Fairhead and Leach, 1994; Pimbert and Pretty, 1995). Effective conservation of wetlands cannot depend merely on prohibition but instead it is necessary to investigate user's attitude towards these

Table 5.14 Response towards alternatives for reducing dependence on forest resources (n = 268)

Choices	%
Grow fodder	2.6
Buy from market	30.6
Reduce number of livestock	0.4
Steal from forest	10.1
Agitate	0.7
Switch to other substitutes	3.4
Buy from market and grow fodder	2.6
Buy from market and switch to other things	4.1
Not dependent on forest	39.6

vulnerable resources and then inform and encourage sustainable use (Pyrovetsi and Daoutopaulos, 1999) and hence it becomes imperative to survey rural people's conservation attitudes to provide guidance for the policy and management decisions involved in the design, implementation and evaluation of conservation with development projects (Hill, 1991; Parry and Campbell, 1992; IIED, 1994).

5.4.1 Attitudes towards conservation

Findings from this study are in sharp contrast with the findings by Infield (1988), from which he inferred that third world populations are almost entirely antagonistic to conservation and ignorant of conservation issues. In the study area, of the present study, people are well aware of their responsibility towards conservation and protection of flora and fauna, these results are in accordance with the findings by Badola (1998), that local people assumed their responsibility in the conservation of the forest. Majority of the respondents stated that they do not face any problem due to protected status of the wetland. As people inhabit this region rely on agriculture, they are not directly influenced by restrictions imposed on extraction of resources from forest.

A relatively high level of don't know or indifferent response have been encountered by the researchers, the reason for this could be because of the fact that communities that are impoverished do not have the leeway to support the practice conservation even if they support the concept (Badola, 1998). According to Rodgers (1989), real values of conservation *i.e.* water, soil, environmental buffering are appreciated but often elicit a "not in my backyard" response, which in present study indicates that people are willing to conserve the forest resources and cooperate with forest department in conservation initiatives but not at the expense of their livelihood.

Attitude and awareness are supposed to be related with respondent's education, wealth and other demographic variables. Most residents living in the villages around the study area were aware of the fact that the forest adjoining to their village has been given protected status legally. The present study prove the fact that education is one of the major variables, which can affect conservation attitudes and awareness (*e.g*. Infield, 1988; Mordi 1987; Fiallo and Jacobson 1995), more educated people were found to be aware of the protected status of Bhitarkanika. More males were aware of conservation issues, this could be due to the reason that males interact more with forest department and outside agencies as compared to females, but then due to the same reason males think that their rights have been violated.

Distance from the forested area also pays significant role in influencing attitude of people towards conservation initiatives. The less positive response of the respondents, residing in the villages away from the forest, towards willingness to cooperate with forest department, is unawareness of the respondents as well as due to the fact they have less dealing with the forest department in their day to day lives as compared to the villages lying adjacent or close to forests.

The average fishermen expressed positive attitude towards conservation related issues, whereas, the study undertaken by Pyrovetsi and Daoutopoulos (1989), found that antagonistic attitudes towards the wetland environment were expressed by professional fishers making their living from the wetland. The farmers, from the present study area also expressed positive attitude towards conservation and this finding is in sharp contrast with the findings by Pyrovetsi and Daoutopoulos (1999), where they found that wetland farmers seemed to be more ignorant of conservation issues. The general positive attitude exhibited by farmers and fishermen are likely to be the result of awareness and appreciation of the direct and indirect services provided by the mangrove forests to agriculture and fisheries.

Few people believe that their rights have been violated and that too due to denial of easy access to fuel wood. Landholding affected people's view regarding violation of rights, as few landless people believe that their rights have not been violated, where as more percent of landowing people feel that their rights have been violated. Similar antagonistic attitudes were found to be associated with large landholdings in Ghodaghodi Lake area, Nepal (Sah *et al.*, 2001). However, Infield and Namara (2001) found that people who owned land had more positive attitude than those who did not have land. Larger landholdings, in the present study, were found to be associated with large families, which have an implication that larger families have more fuel wood consumption and hence they feel that their rights have been violated.

Widespread local support for concept of protection of flora and fauna was demonstrated from the survey data. Almost half of the population living in and around the Sanctuary was found to be willing to cooperate with forest department in matters pertaining to conservation initiatives, like ecodevelopment. But still they prefer involvement of local community and NGOs, as the workers in these organizations are basically from their area and therefore the people trust these organizations more than the government organizations. Similar results were obtained by Trakolis 2001, in Greece where 69% of respondents wanted participation of local communities in decision making process and hence showing will of local people to be equally represented in a possible future administrative scheme.

5.4.2 Developmental options

As the concerned area is very remote and does not have very good transportation facilities, its residents favour extension of Dhamra port, which is contributing to their individual income and economy in several ways. They foresee additional employment and income generating activities by this extension. People do not favour aquaculture plant for they are aware of its drawbacks, such as pollution and its detrimental effects on crop production.

5.4.3 Ecological functions and values identified by the local community

Human societies derive many essential goods from natural ecosystem, including sea food, game animals, fodder, fuelwood, timber, pharmaceutical products in addition to fundamental life support services without which human civilization would cease to thrive (Daily *et al.,* 1997). Wetlands are multifunctional resources, which provide many direct and indirect benefits to the local population and the rest of the world. Respondents from the study area were aware of few of these functions or benefits. People valued those uses (agriculture and tourism) and function (cyclone mitigation), as their preference, which are directly linked to them. In a study undertaken by Verma (2001), people valued drinking water to be the most important service provided by the Bhoj wetland. Hence, it is evident from both the results that people value the uses and functions according to their needs/ problems and understanding of these uses and functions. Among wetland functions, cyclone mitigation is one such function, which the local populace is highly aware of. Besides the stated ecological functions and values in the questionnaire, people identified other functions such as rainfall, water table recharge, maintenance of biodiversity and wildlife education.

5.4.4 Views on Crocodiles and Olive Ridley turtles

Bhitarkanika has the highest population of salt-water crocodiles and now after formation of task force for protection of olive ridley turtles, population of Olive ridley turtles has also gone up. Despite large number of casualty in the study area the people are in favour of increasing their population and one of the main cause is that the frequency of casualties due to crocodiles is high in villages or areas near water bodies like river, creek. But villages, which are, situated at safer distances, have less frequency of encounter with crocodiles. These villagers foresee the tourism potential of crocodiles which is the major attraction of Bhitarkanika, besides the media publicity received by the area because of the crocodiles, and their own sense pride in being a part of the entire conservation gambit of Bhitarkanika Wildlife Sanctuary. In addition to these it could also be the existence value of crocodiles and turtles derived by these people. The positive view of local people regarding Olive ridley turtle is mostly based on the fact that these turtles do no harm to the local populace. This could also be the extension of the general tolerance towards wildlife and nature - a part of the religion and culture of the local people.

5.4.5 Attitude towards alternatives to forest resources

A relatively large proportion of people were reported to be not dependent on forest resources, this could be due to relatively less number of livestock holding per family. In cease of non-availability of biomass resources from the Bhitarkanika Wildlife Sanctuary a large proportion (30.6%) of respondents was ready to buy the alternatives available in market. These findings are contrary to that of Badola (1998), where only 11.4% people opted for this alternative. In the same study, 7% respondents said that they would agitate if the supply of resources to them were stopped, whereas in the present study only 0.7% respondents opted for this choice. According to Badola, dependence of people on the forest is due to lack of alternatives to the forest resources, either due to inability of the people to produce alternatives from market, or in some cases it is ‘habitual’ or ‘traditional’. In Bhitarkanika area income level of individuals is high as compared to the income level of people from study area of Badola and therefore people are relatively willing to buy alternative from market and therefore we can conclude that actual dependency of people living in the present study area is less and is largely a result of easy access to resources and the lack of effective conservation programs.

5.5 Conclusions

While summarizing the results, we found that people in general have positive attitudes towards conservation and the demographic and socio-economic conditions influence people’s attitude towards conservation and related issues. The potential, of the fact that local population is highly aware of conservation issues and their responsibility towards protection of flora and fauna and are in favour of ecodevelopment program, can be harnessed to formulate sustainable management policies for the concerned wetland. The indifferent response of the individuals should be harvested to positive attitude at the earliest. In this case N.G.Os and media, *i.e.*, radio can play very significant role in mobilizing people for common cause of conservation. Villagers see tourism as one of the major use of the wetland and hence such programs that enhance eco-tourism and local economy should be formulated and implemented, with involvement of local people. The findings of the study reveal local people’s willingness to be represented in decision-making process and bodies for management of the Bhitarkanika forests.

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Chapter 6

Impacts of Sea Level Rise on Bhitarkanika : A Predictive Model

The earth's climate has been evolving continuously over millennia but the last two centuries have witnessed the development of the enhanced greenhouse problem caused by human induced changes in physical characteristics of the earth's atmosphere, which threatens to change climate in an unprecedented manner (Brown, 1996). The enhanced greenhouse problem is created due to excessive accumulation of greenhouse gases in the atmosphere. The main greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs) (Firth and Fisher, 1992). Except for CFCs the rest of the gases occur naturally, together making up less than 1% of the atmosphere (Dickinson and Cicerone, 1986). The naturally occurring greenhouse gases allow incoming ultraviolet solar radiation to pass through relatively unimpeded, but partially absorb and re-emit outgoing infrared terrestrial radiation. This natural process raises the earth's average temperature from -20 °C to $\pm$ 15 °C, and is hence, vital for life on earth (Ramanathan *et al.,* 1989).

Measurement records suggest that the world has already warmed by 0.3 to 0.6 °C since 1860 and the last two decades have been the warmest (Watson *et al.,* 1996, 2001). Evidences are getting stronger that the warming being experienced at present is anthropogenically induced (Brown, 1996). The IPCC (Intergovernmental Panel on Climate Change) Third Assessment Report (2001) has incorporated new results from the last 5 years of climate change research, which shows that global average surface temperature is projected to increase by 1.4 to 5.8° C over the period 1990 to 2100. This projected warming will be greater than that experienced over the last 10,000 years. It is also higher than the projected increase in the IPCC Second Assessment Report (1996), which was 1.0 to 3.5° C. Moreover, the global mean sea level is projected to rise by 0.09 to 0.88 m over the same period, as a result of the thermal expansion of the oceans, and the melting of glaciers and polar ice sheets. The physical effects of sea level rise are categorized into five types, inundation of low lying areas, erosion of beaches and bluffs, salt intrusion into aquifers and surface waters, higher water tables and increased flooding and storm damage (Nichols and Leatherman, 1994).

The sea level rise mapping requires high-resolution data. Preparation of sea level rise maps requires a combination of elevation information and models of shoreline erosion, land accretion and other coastal processes (Titus and Richman, 2000). In many cases the sea level rise results are as sensitive to uncertainty regarding geological process as to the rate of sea level rise. The global temperature has been rising (Keeling *et al.,* 1995, IPCC 1996) which leads to acceleration in sea level rise (IPCC, 1996). Recent assessments indicated that one meter rise in sea level is likely over a period of 200 years, but could occur as soon as the year 2100 (EPA-Titus and Narayanan, 1995). Efforts to project flooding and shoreline change require (i) data on land and water surface elevation and (ii) a model of coastal processes (Titus and Richman, 2000).

Most of the sea level rise studies suffer from data limitations. Two types of unpleasant realities, which render data inaccurate, are (a) Vertical resolutions and (b) Bench marks (Titus and Richman, 2002).

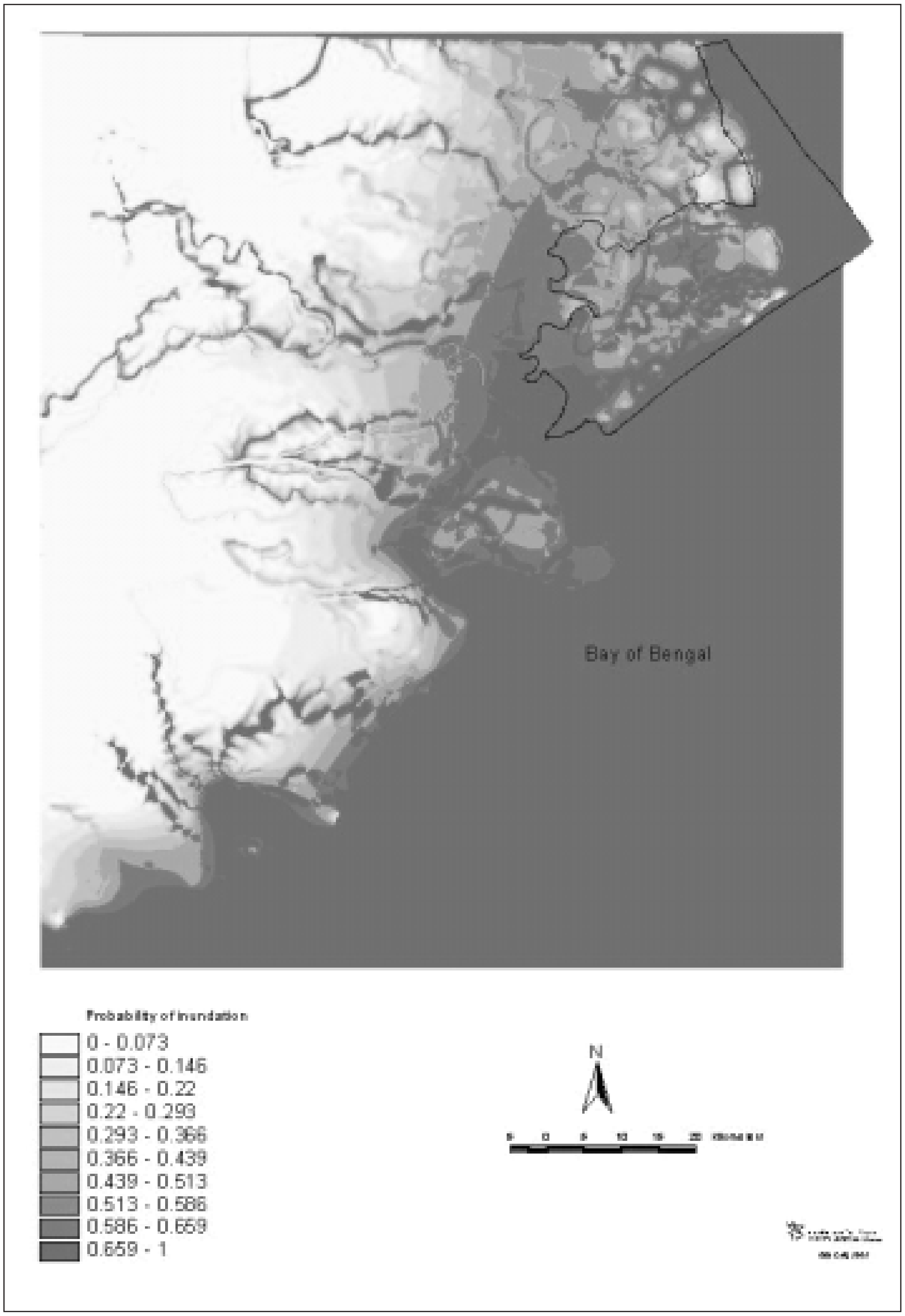
Vertical resolution**:** The contour interval level is generally 20-30 m on 1:50,000 and 100 m on 1:25,000 Survey of India toposheets. The areas with good coverage will have 10 m contour (Asthana *et al*., 1992).

Benchmarks**:** The geodetic datum is a fixed reference plane adding to the uncertainty of sea level mainly due to non-availability of information on local datum. The other major difficulty in determining regional sea level trends for tropical Asia relate to the limited amount of historical tide gauge data and the regions decadal and interannual variability. For instance, only one station

(Bombay) in the region has records exceeding 75 years. The number of station in India has now increased but information is of fewer years.

The map given in Figure 6.1 is an approximation of lands near mean sea level rather than predicted future shorelines. The data on elevation model in this map is modeled from various sources.

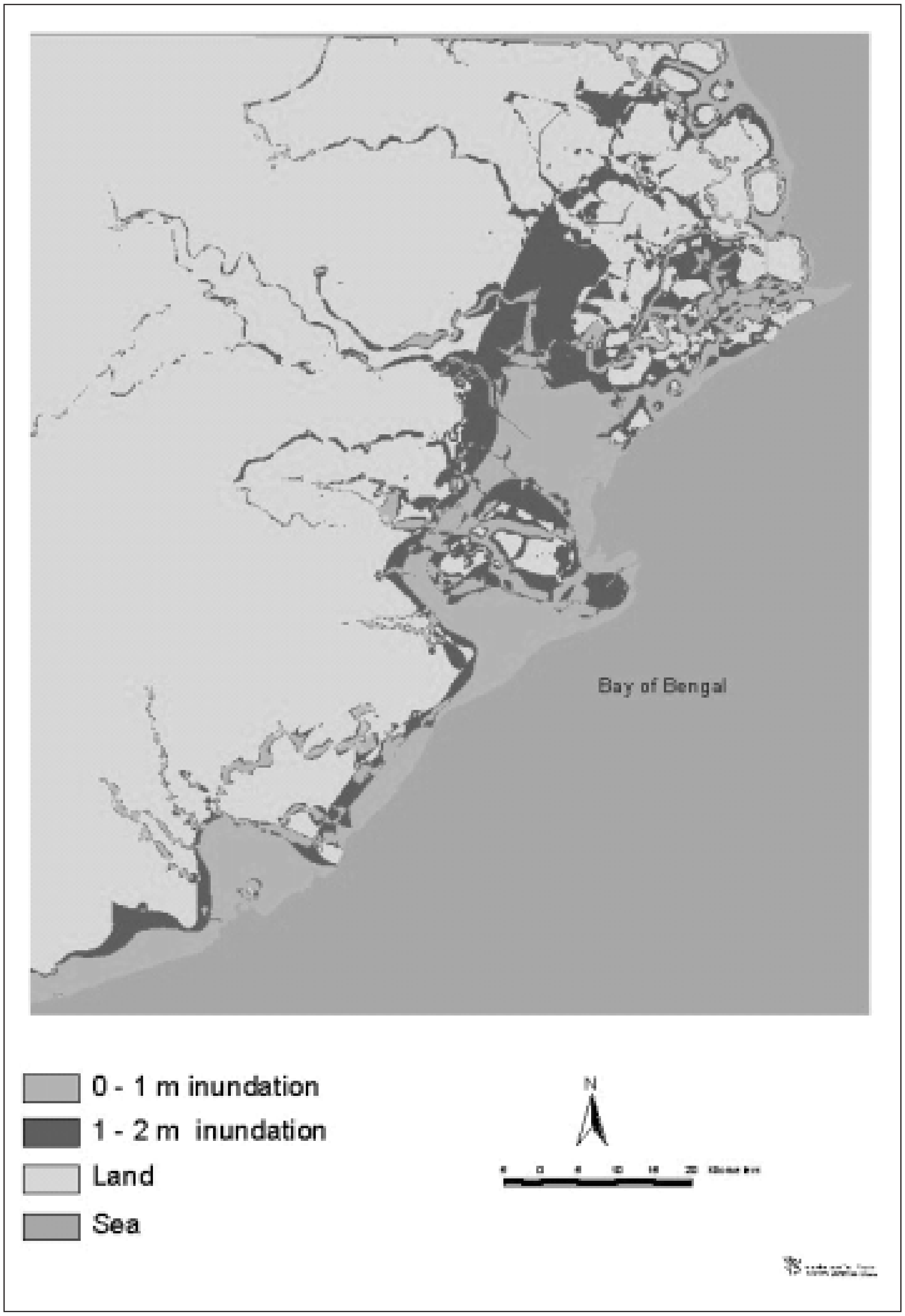
Figure 6.1 Probability of inundation to one meter sea level rise, Bhitarkanika, Orissa



(i) Digital chart of the world
(ii) EROS
(iii) 1:25,000 scale maps, Survey of India
(iv) 1:50,000 scale maps, Survey of India
(v) Other published spatial and aspatial data

The data from different maps was generated in the form of point information of elevation and then the digital elevation model was interpolated. The barriers like existing (1974 survey only) bunds were not considered in this study. The map is depicted with two levels of inundation (Figure 6.2).

Figure 6.2 Inundation with mean sea level rise along the Bhitarkanika coast, Orissa



(a) 0-1 m: This indicates the predicted sea level rise of 1 m (Titus and Richman, 2000).

We have used one meter rise in sea level as per Das and Radhakrishnan (1993) and (Titus and Richman, 2000). The tide gauge records at five coastal locations in India; Mumbai, Kolkata, Cochin, Kandla and Sagar Islands have reported an increase in sea level. The change in sea level appears to be higher on eastern coast compared to western coast. The average sea level rise for India has been reported as 2.5 mm/year since 1950's (Das and Radhakrishnan, 1993).

(b) 1-2 m: If an area gets inundated up to 1 m due to sea level rise, then 2m elevation will be good approximation of area getting inundated at high tide on the basis of local tide data Titus and Richman (2000).

The local coastal process and wave pattern are not considered at present due to lack of reliable information that can be extrapolated at large scale. We have used IDRISI 4.1, ArcInfo 8.03, ArcView 3.1, Eras Imagine 8.5, Excel and SPSS 8.0 for data analysis.

In our model we considered two levels of uncertainties or errors, (i) Spatial database errors and (ii) Aspatial or decision based uncertainties. The RMS error for the elevation data was estimated to be 30 percent of the contour data, with assumption that 90 percent of the points fall within half a contour interval. The decision uncertainty was assumed to be 50 percent *i.e*. there is equal chance of land being flooded or not flooded to one meter height above MSL by the year 2200.

The land between 0-1 meter elevations was estimated to have probability of 73.2 to 63.9 percent to be inundated by year 2200. The area getting affected by one meter inundation and up to two meter due to high tide is given in Table 6.1. The possible area of inundation at three levels is 194.77 km^2, 253.71 km^2, and 448.48 km^2 respectively.

Table 6.1. Vegetation types and probable area of inundation due to sea level rise at three levels

Vegetation Type	Probability of sea level rise 0-1 m (Km^2)	1-2 m (Km^2)	0-2 m (Km^2)	0-1 m Area (%)	1-2m Area (%)	0-2m Area (%)
Salt Marsh	3.17	3.97	7.13	1.62	1.56	1.59
Palm-Tamarix Swamp	6.53	7.17	13.69	3.35	2.83	3.05
Brakish Water Mixed Mangrove	42.12	43.26	85.37	21.62	17.05	19.04
Salt Water Mixed Mangrove	3.69	4.05	7.73	1.89	1.60	1.72
Mangrove Forest	14.68	11.66	26.34	7.54	4.59	5.87
Mangroove Scrub	7.59	8.07	15.66	3.90	3.18	3.49
Village Woodlot/Agriculture	15.43	23.63	39.06	7.92	9.31	8.71
Agriculture/Habitation	65.96	96.19	162.15	33.87	37.91	36.15
Barren Area/Sand/Mud Flats	17.01	29.48	46.49	8.73	11.62	10.37
Mixed Mangrove-Non Mangrove	8.14	6.74	14.87	4.18	2.66	3.32
Degraded Mangrove	10.47	19.51	29.98	5.38	7.69	6.69
Total	**194.77**	**253.71**	**448.48**	**100.00**	**100.00**	**100.00**

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Chapter 7

Policy Implications and Management Recommendations

7.1 Policy implications

Ecological systems play a fundamental role in supporting life on earth at all hierarchical scales. They form the life support systems within which all economic development takes place. However, most of the natural ecosystems are under stress as a result of the pressure of population growth and economic development. The social inefficiency in natural resource use is not a consequence of multiple use conflicts itself, but result from a combination of information failures, market failures and policy or intervention failures. The supply of the products, functions and attributes of the natural ecosystem is directly affected by their conversion. Loss or impairment of natural ecosystem values is generally associated with economic cost and in many cases, with a reduction in opportunities for sustainable development. Conversely, maintenance of natural products, functions and attributes is likely to have economic benefits (Shine and de Klemm, 1999).

Much of the conversion of mangroves has occurred because this habitat has, traditionally been regarded as unproductive wasteland. The loss of mangrove areas could be attributed to information failure such as a general lack of awareness among people about the values of conserving mangrove ecosystems, or absence of a direct, easily observed relationship between mangrove forests and the benefits it provides; market failures because of excessive abstraction of open-access resources when there is no mechanism to attribute economic values to the public goods provided by the wetlands; and intervention failure such a general ineffectiveness or absence of appropriate integrated resource management policies and inter-sectoral policy inconsistencies, leading to mangrove loss and degradation. As a result it is often concluded that mangroves should be developed for uses that generate directly marketable products, such as aquaculture. However, such decisions ignore the opportunity cost of development. Moreover, such views increase the conflicts in areas that have already been declared as Protected (National Parks/Sanctuaries).

Does market failure affect Bhitarkanika Mangrove Ecosystem?

In the present study we assessed the value of the few of the ecological services and direct use benefits provided by the Bhitarkanika Mangrove ecosystem. This empirical study suggests that the value of the estimated goods and services provided by the Bhitarkanika mangrove ecosystem is significantly high when compared to other land uses in the area such as aquaculture, paddy cultivation and development options. Here it is also crucial to consider the fact that these constitute only a few known services performed by the Bhitarkanika mangrove ecosystems. With the short allocated time for the study it was not possible to value these. Moreover, the ecosystem services provided by the natural systems cannot be substituted by man-made capital. Therefore it is trivial to ask their value to humankind. Their value is infinite in total (Costanza *et al.,* 1997).

The usefulness of mangrove forests can be attributed to both the diversity among forests and the diversity of goods and services that they supply. Understanding the importance and best use of different parts of a forest may help in formulating management policies that enable the continued supply of essential goods and services. Exploiting a mangrove forest for one product may reduce its ability to provide others. However, we do not yet understand all the consequences of disturbances to mangrove forests and therefore we cannot yet define acceptable limits of harvesting of mangrove resources that can be used to formulate management policies (Ewel *et al.,* 1998).

Whether people are adequately informed or aware of the importance of Bhitarkanika Mangrove Ecosystem?

Our findings points out that people are able to appreciate the contribution of Bhitarkanika mangroves to their lives and livelihoods directly in the form of increased production of fish and prospects for better tourism. A high percentage of people (88.6%) recognized the contribution of mangroves in cyclone and flood mitigation. The people have recognized even functions such as biodiversity conservation and ground water recharge. Majority of the local populace *i.e.* about 89.6% are aware that Bhitarkanika forests have protected status and that it is a declared Wildlife Sanctuary. Staggeringly high percentages (84.3 %) of people feel that they have got a responsibility towards conservation of flora and fauna.

Despite these positive attitudes there is a high degree of resource extraction by the local people. This is because of the fact that the local people do not have any other livelihood options other than paddy cultivation and fishing. Consequently more and more mangrove areas are being converted into paddy fields. As observed during the study, the local people do pisiculture in their homesteads but they do not support or do prawn culture, by removing mangroves. Outsiders who do not have long-term stakes in the area for their livelihoods are carrying out intensive prawn culture in the area, by financing some local agencies. Intensive prawn culture has resulted in large scale removal of mangroves from the Mahanadi delta, situated south to the Bhitarkanika.

According to Rodgers (1989), real values of conservation *i.e.* water, soil, environmental buffering are appreciated but often elicit a "not in my backyard" response, which in present study indicates that people are willing to conserve the forest resources and cooperate with forest department in conservation initiatives but not at the expense of their livelihood**.** The study of socio-demographic characteristics, economic situation, and other aspects of life in these mangrove villages reveal a high degree of resource use and dependence on mangrove resources for their livelihood. Another factor that emerges is the weak participation of the local community in the decisions and management strategies undertaken by the forest department.

Whether appropriate intervention measures have been taken?

This area has had a strong protection history. In 1951, under the rule 'Kanika Raj Jungle Mahal Niyamawali'', 29 forest blocks with good forests were demarcated of which 6 blocks were designated as class I forests, prohibiting entry into these. Rest 23 blocks were managed on a rotational basis and permit for limited collection of specific forest produce were given to local inhabitants. Surrounding areas having degraded forests were open to resource extraction. Subsequently in 1961, this area was declared as Protected Forest under section 29 of the Indian Forest Act, 1927. In 1975, the Government of India declared 672 km^2 of the area as a Wildlife Sanctuary under the Indian Wildlife Protection Act, 1972, with a core area of 145 km^2 which was upgraded to a National Park status in 1988. In 1997, 1,435 km^2 area was declared as Gahirmatha Marine Sanctuary, with a core area of 725.5 km^2. This shows that there is no intervention failure at the primary level in case of the Bhitarkanika area.

However, at a higher spatial scale there seems to be ample evidence of all the three types of failures occurring in case of the Bhitarkanika mangroves. This is because of two reasons primarily- the inability of the government to implement the Wildlife Protection Act effectively, and lack of inter-sectoral coordination. During 1951-61 there was unprecedented growth of population in the area due to the resettlement of refugees from West Bengal. Between 1994-95 with scant regard to Wildlife and Forest Conservation Acts, the revenue department legalized a large number of illegal settlements within the Sanctuary area. As per law the creation of villages in the sanctuary limit was illegal and had to be taken into account during the finalization of rights in the Sanctuary leading to loss of Mangrove area (Chadha and Kar, 1999). Similarly despite the protected status of the Bhitakanika area and the existence of a strong Maritime Act (1982) of the Government of Orissa and Orissa Marine Fishing Regulation Act (1982) and rules (1983) there are unabated development activities such as construction of port and defense structures, and inshore fisheries using mechanized vessels in the area. This is the result of information failure on part of the fisheries, waterways, defense and other government departments. In the absence of valuation studies the forest department has been unable to articulate the importance of conserving this ecosystem in the face of developmental pressure that promise higher turnover.

All these factors combined together exert pressure on the Bhitarkanika mangrove ecosystem. However, all these can be managed by developing and implementing an Integrated Conservation and Development Plan for the area. But we do not have control over factors resulting from change at the global level such as global warming leading to sea level rise. Our study had revealed that a two-meter rise in sea level by the year 2200 would result in the inundation of 299 km² area. This will change the vegetation composition of the entire area affecting productivity of the ecosystem as well as the local people. The Government of India is a signatory of the various protocols such as Montreal and Kyoto Protocols that restrict the use of ozone depleting substances and emissions of greenhouse gases. Besides at the international level India is also a signatory of the Ramsar Convention, 1971 that requires the contracting parties to identify, formulate and implement conservation planning for wetlands of International importance so as to promote their sustainable use. The wise use concept adopted in1987, proposes sustainable utilization of wetlands for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem.

Bhitarkanika is a proposed Ramsar site and in this case its wise use would imply careful planning, management, regulation or even prohibition of certain activities. This can effectively be made possible only through a proper consultation and agreement with the stakeholders. This would also result in better support for its conservation. Higher level of positive attitude of people towards conservation is a positive sign for conservation of the area.

7.2 Management recommendations

Ecodevelopment initiatives

Ecodevelopment seeks to conserve biodiversity through economic development of local people and by developing alternatives to forest resources, thereby weaning them away from dependence on forests (Panwar 1992). One of the hallmarks of ecodevelopment is that it is to be planned and implemented with the participation of local people. Community participation can also be seen as a means to increase efficiency, as a moral right, or to initiate mobilisation for collective action, empowerment and institution building (Pimbert and Pretty 1995). By trying to ensure that benefits of development should flow from conservation (*e.g.* using water from the PAs for people's benefit) strengthens the conservation development linkages. It further tries to create a legal and social environment for people's participation in conservation.

In the context of PA management, the basic requirements of the local people can be fulfilled through consumptive benefits from PAs, substitute to natural resources, income from non-consumptive use of PA, income generation/access to social services. Since the first option is not legally feasible, the PA authorities will have to concentrate on the later three. The following sections provide broad guidelines on the possible points of intervention o that the objectives of biodiversity conservation are met along with the basic needs of the local people.

Reducing dependency of people

It is crucial to address the dependence of the local communities on the PA resources. Resource extraction from the PA is not permitted under the current law (Wildlife Protection Act, 1972). However, the 324 villages located inside the Sanctuary have no option but to use the resources from the PA. The use in this case is *defacto* that is always indiscriminate. Our study suggests that the National Park *i.e.*, the core zone has to be maintained as a *sanctum sanctorum* and all resource use therein will have to be stopped. The possibility of meeting the needs of the people who are actually dependent on the PA resources for their livelihoods, particularly those living within 1.5 km of forest boundary, has to be explored from the buffer zone. The buffer zone in this case is a Wildlife Sanctuary where resource extraction is not permitted. A policy to permit controlled resource extraction in this zone can be permitted, provided that it should not affect the ecological process of the system.

During the study it was found that the dependency of local people on forest for fuel wood was high for villagers residing within 1.5 km from the forest. Fuel wood extraction is one of the major causes of deforestation of mangrove in the region. Switching to other sources of energy can reduce pressure on mangrove forest. Various non-conventional sources of energy such as solar cookers, biogas plants can be introduced in the area. Fuel-efficient chullhas can be distributed in the villages. Further to reduce pressure on existing mangrove forest for fuel wood and timber, plantations should be initiated in the marginal lands available in villages and on the sides of dykes. There is a need to develop better approach and communication facilities since the dependence of people particularly on firewood is due to the fact that alternatives to these are not accessible/available to them. Since the income levels of people in this area are already high, it can result in shift to other alternate fuel.

Forest blocks such as Mahisamunda, Ragdapatia and Kalibhanjdia were found to be under tremendous pressure due to fuel wood extraction. Mangrove plantation should be taken up extensively at these areas and for facilitating the growth of mangrove and mangrove associated species.

People of many villages near National Park have been traditionally dependent on the Park as they used to get permit for extraction of *Nalia* grass as many households in these villages are engaged in basket weaving. To stop excessive exploitation of *Nalia* grass, its extraction was completely banned, which created problem for local people. To overcome this problem plantation of *Nalia* grass should be taken up extensively, as it will not only provide raw material to the local people but will also help mitigating soil erosion on riverbanks. The area for extraction of this grass should be allocated on rotational basis to the local people.

Subsistence fishing can be allowed in the main rivers where illegal fishing is already being carried out. Fishing in rivers like Dhamara, Brahamnai, Baitarani, Hansua and Pathsala should be legalized. It will not have major impact on ecological balance as long as the nursery grounds of the fishes *i.e.* the small creeks *viz*. Thanpati, Ganjeikhia, Jalahar, Suajore, Gokhani and main Bhitarkanika River remain undisturbed. Honey collection permits to selected poor families may enhance their income levels.

To allow regulated resource use from the sanctuary area the possibility of changing the status of the buffer zone to other categories of Protected Areas as proposed under the amended Wildlife Protection Act is other option. The proposed amendment suggests two more categories of PAs, Community and Conservation Reserves that legally allow resource use within them while giving a high priority to biodiversity conservation.

Income generation activities

The villages located within 0-1.5 km distance from forests have higher number of unemployed population. For these villages income generating program should be initiated. Some programs have been started in few villages by forest department and local NGOs, which is a good step taken up to reduce dependency on forest resources. These programs should be extended to more villages. Pisiculture and apiculture can be introduced through these programs as it has tremendous scope in the region. As most of the villages have sufficient number of ponds to sustain fish population and have basic equipment and knowledge to carry out such programs. Many villages around National Park are involved in making of different handicraft products, like wood carving at Righagarh and basket weaving at Khamarsahi etc. which have good potential to be commercially exploited but this traditional handicraft industry is gradually dying out due to lack of marketing facility. Opening of the exhibition cum sale outlets of these handicraft products at different tourist spots can encourage local handicrafts and help in reviving these traditional craft. Help of the rural development departments can be taken for all these activities.

Involving local people in tourism

It is imperative to involve local communities in tourism by training them as guides. This will provide employment for the local population and will give them a sense of responsibility. It should be made mandatory for visitors to have a trained tourist guide with them that will not only facilitate these visitors but will also help in monitoring the activities of the visitors. The entry fee to the park is very low, which should be increased so as to generate revenue for the forest department. Funds generated through entry fee should be used to set up ecodevelopment/village development funds as is being done by the states of West Bengal, Madhya Pradesh and Rajasthan.

Overnight stay facility for tourists should be developed at other sites beside Dangmal and measures should be taken for up gradation of already existing forest guesthouses at Ekakula and Habalikhati so as to distribute the tourism pressure. Villagers can be encouraged to build ethnic huts at places like Khola and Gupti, which will facilitate the stay of tourists and will be an alternate income source to these villagers. Already existing nature trail inside Bhitarkanika forest block and heronry at Bagagahana should be properly maintained.

Maintenance of existing roads and bridges should be done so as to improve transportation facility for local people and tourists. Many important bridges such as at Khola need to be repaired, as it is the only connecting bridge to the Dangmal. Regulation of boat movement in the inner creeks should be done so as to reduce the disturbance to birds and crocodiles.

Develop an effective public awareness program

Sustainability of conservation management approaches will depend on awareness of the values of conservation being perceived by local communities, governments and other stakeholders. Environmental awareness is a powerful tool for gaining support for conservation. During our survey we have come across a large section of people who have very poor knowledge about the values of wildlife conservation or about the behavior of wild animals found in the study area such as crocodile, king cobra and python. Moreover, most of this knowledge of behavior of wild animals is based on myths and ignorance. As a result there is conflict between the communities and wild animals, resulting in a negative attitude towards wildlife conservation. Not only the local communities but also the lower level forest staff has poor knowledge about the behavior of wild animals and various ecological processes. It has also come out as one of the reasons for the human casualty due to crocodiles in our study. Effective environmental awareness programs for this area need to be developed. A large section of the population particularly those living in and around Bhitarkanika in remote areas are uneducated. Here, role of programs that cater to visual literacy become important. There is a need to develop the skills and expertise of grassroot level NGOs so as to enable them to develop site-specific environmental awareness programs that would target different sections of the local society. There is a need that these NGOs work in close coordination with the forest department and also involve local people in developing awareness programs thereby using their valuable local knowledge and skills.

Although prawn farming is banned in the sanctuary area, number of illegal prawn farms is mushrooming in the areas. Frequently the Forest Department has been demolishing these farms or *Gherries.* But forceful destruction of these *Gherries* has resulted in conflict of local people with the FD. To mitigate this conflict local people should be taken in confidence and an awareness program should be run alongside with the demolition of these *Gherries*, to educate the people about the negative impact of these *Gherries* on agriculture production. A level of awareness already exists about the harmful effect of *Gherries* among the people as found by the study.

Interpretation is an approach in communicating the rationale behind the protection of natural ecosystems to an array of target group(s) consisting of visitors to an area, politicians, media, bureaucrats, local people and planners. Dangmal has an interpretation center, which should be upgraded. Interpretation can be executed through a range of illustrative media *i.e.*, signage, publications, self-guided activities, exhibits (both indoor and outdoor) and audiovisual programmes. The approach should encourage environmentally responsible behaviour by fostering awareness, knowledge, attitude, skills and participation.

Other management issues

During the extreme situations such as cyclones, water from the sea crosses the dyke and floods the villages and agriculture land. The villagers during the 1999 cyclone faced this situation, small sluice gates should be made at strategic locations at dyke so that this water is quickly drained out when water starts receding during flooding.

Although trawling is strictly prohibited within 5 km range from shoreline, illegal offshore fishing by using mechanized trawlers is carried out which causes large-scale mortality of sea turtles. Restriction on mechanized fishing in the coastal zone should be imposed with aid from coast guards and fishery department. The present field staff number is very low to patrol the NP, for effective patrolling of the Park the manpower should be increased. Forest Department has registered many cases of poaching during our study period, hence there is an urgent need of strengthening a network of informers in different areas. To check the smuggling of timber and wildlife articles sufficient number of enforcement staff with VHF sets and transport facility will have to be deployed at all entry gates for proper checking of incoming and outgoing vehicle at Dangmal, Khola, Gupti and Chandbali.

Integrated conservation planning for the Bhitarkanika Mangrove Ecosystem

Rational management of watercourses and associated wetlands units can only be carried out through an ecosystem-based approach to management. However, while the concept of integrated coastal zone management has been endorsed by many different institutions over the last decade, the legal and institutional frameworks necessary for this purpose are totally lacking or in their relative infancy (Shine and de Klemm, 1999). Integrated coastal zone management is a process, which provides a thoughtful structure for gathering and utilizing scientific information, which involves stakeholders in a genuine analysis of land use alternatives, and which establishes clear and measurable objectives, can provide for rational development activities including those for the conservation of biodiversity in the region. It addresses the interactions between terrestrial and aquatic systems along with considering the demands of those who use and who would use these systems and aims to control the impacts of human intervention on the environment.

There is an abundance of statutes dealing with many aspects of use, management and improvement of coastal resources. Their main objective is to control the allocation of resources between various users and minimize conflicts between them. There also exist several sectoral laws, controlled by different government agencies, which are being used to regulate various activities irrespective of whether these affect the ecological integrity of this ecosystem. Most of these agencies work in isolation pursuing their respective departmental agenda while being largely unconcerned about the holistic picture. For example, in the Bhitarkanika area forests and parts of the river that are under the PAs come under forest and wildlife legislation but outside these areas fishing and trawling is covered by the maritime, port and fisheries acts. The forest law can prohibit cutting of forest areas but cannot prevent the destruction or alteration of the forest. Neither can it control land use and developmental activities, outside of its area of jurisdiction, which may have adverse impact on the conservation values of the area e.g the resettlement of refugees and legalization of illegal settlements in the sanctuary area by the revenue department. An example is the construction of Dhamara Port. The local people also support this but its construction will have detrimental impact on the Bhitarkanika National Park. Increased movement of boats due to construction of Port will be destructive for the nesting sites of turtles, and the social impact will hamper the integrity of the entire ecosystem.

In order to solve the existing and future problem arising from un-coordinated resource use and allocation it is important to deal with the problems and issues on a spatial scale rather than addressing these sectorally. It is proposed that a *Bhitarkanika Conservation Area Management Authority* be set up. The authority should have adequate representation from the policy makers of central and the state government, local communities and other government departments functioning in the area apart from eminent scientists from reputed institutions. The authority should:

- set standards and objectives for the integrated management of the Bhitarkanika Conservation Area as a single unit and determine the cost of achieving these objectives
- establish a process of cooperation and collaboration among various stakeholders in the Bhitarkanika Conservation Area
- collect and collate existing information on physical, biotic, and socioeconomic characteristics of the Bhitarkanika Conservation Area
- identify status and trends of landscape level processes and functions within the Bhitarkanika Conservation Area
- identify current and future landscape disturbance regimes that are affecting or may affect the ecosystem
- select the best among a number of development alternatives by identifying costly and environmentally unstainable effects of the possible alternative projects
- establish a series of strategies, with timetables and benchmarks with detailed financial goals and budget projections, as well as criteria and methods for evaluating progress towards meeting the established goals.
- prioritize strategies and specific actions to carry out required policy and legal changes and monitoring of compliance at regular intervals.

7.3 Conclusions

For effective conservation and management of the Bhitarkanika Conservation Area, it is important to go beyond protection measures for certain areas, habitats or landscape features, and impose binding requirements for coordination of sectoral policies at the scale of an ecological unit. We can have lessons from the experience of other countries such as Australia, USA, Italy and France who have been able to elicit the participation of local communities and other stakeholder groups in decision making relating to land and water use at a regional scale. However, it can only be done in practice by the presence of enabling legislation backed by strong political will.

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