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Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India

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SUMMARY

The ecosystem services provided by mangroves are often ignored in the ongoing process of mangrove conversion. Services provided by the Bhitarkanika mangrove ecosystem in India and estimated cyclone damage avoided in three selected villages, taking the cyclone of 1999 as a reference point, were valued by assessing the socio-economic status of the villages, the cyclone damage to houses, livestock, fisheries, trees and other assets owned by the people, and the level and duration of flooding. Eleven variables were used to compare damage in the villages, one protected by mangroves, one unprotected by mangroves, and the third possessing an embankment on its seaward side. Attitude surveys were carried out in 10% of the households in 35 villages located in the Bhitarkanika Conservation Area to assess local people's perceptions regarding the storm protection function of mangroves and their attitude towards mangrove forests generally. In the mangrove-protected village, variables had either the lowest values for adverse factors (such as damage to houses), or the highest values for positive factors (such as crop yield). The loss incurred per household was greatest (US$ 153.74) in the village that was not sheltered by mangroves but had an embankment, followed by the village that was neither in the shadow of mangroves or the embankment (US$ 44.02) and the village that was protected by mangrove forests (US$ 33.31). The local people were aware of and appreciated the functions performed by the mangrove forests in protecting their lives and property from cyclones, and were willing to cooperate with the forest department in mangrove restoration.

Keywords: attitudes, economic valuation, ecosystem services, local people, mangrove ecosystem, storm protection function

INTRODUCTION

Ecosystem functions are the conditions and processes through which natural ecosystems and their constituent species sustain and fulfil human life (Daily 1997). Ecological services are those ecosystem functions that are perceived to support human welfare (de Groot 1992; Ehrlich & Ehrlich 1992; Barbier *et al*. 1994; Costanza *et al*. 1997*a*; de Groot *et al*. 2002). Biodiversity at genetic, species, population and ecosystem levels contributes to maintaining these functions and services. Mangrove ecosystems are widely recognized as providers of a great variety of goods and services to people, providing 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. They are valuable sources of fuel wood, fodder, timber, tannin and other natural products for local people (Rasolofo 1997; Spaninks & van Beukering 1997). Mangrove forests protect freshwater resources against saltwater intrusion; they protect the land from eroding waves and winds (Semesi 1998) and stabilize the coastal land (Carlton 1974). Mangrove forests can be considered as natural barriers protecting the life and property of coastal communities from storms and cyclones. The above-ground root system retards water flow that not only encourages sediment to settle, but also inhibits its resuspension (Gilbert & Janssen 1998). Stabilization of sediments provides protection to shorelines and associated shore-based activities and can lead to land gains (Spaninks & van Beukering 1997).

Despite centuries of biological research on mangrove structure, productivity and ecosystem dynamics (Rollet 1981) and an understanding and recognition of mangrove benefits by scientists, governments and local populations, destruction of mangrove ecosystems continues (Saenger *et al*. 1983; Field *et al*. 1998; Semesi 1998). The ecosystem services provided by mangroves are often ignored in the ongoing process of mangrove conversion (Barbier 1993; Ruitenbeek 1994; Swallow 1994). The economic value of direct products from mangrove forests proves more important in decision making for their management as these usually accrue locally (Adger *et al*. 1997). Hence, the exploitation of mangroves usually focuses only on single uses based on narrow economic valuations. For mangrove conservation and exploitation to occur simultaneously, economic analyses that focus on multiple-use aspects of mangroves are needed (Ruitenbeek 1994). Appropriate values for ecosystem services once derived may be inserted into the decision-making process in order to correct the market signals (Costanza *et al*. 1989).

Economic valuation is an attempt to assign quantitative values to the goods and services provided by natural resources where market prices are not available, and thus help to inform decisions regarding resource allocation (Barbier *et al*. 1997; Daily *et al*. 1997). In the field of protected area

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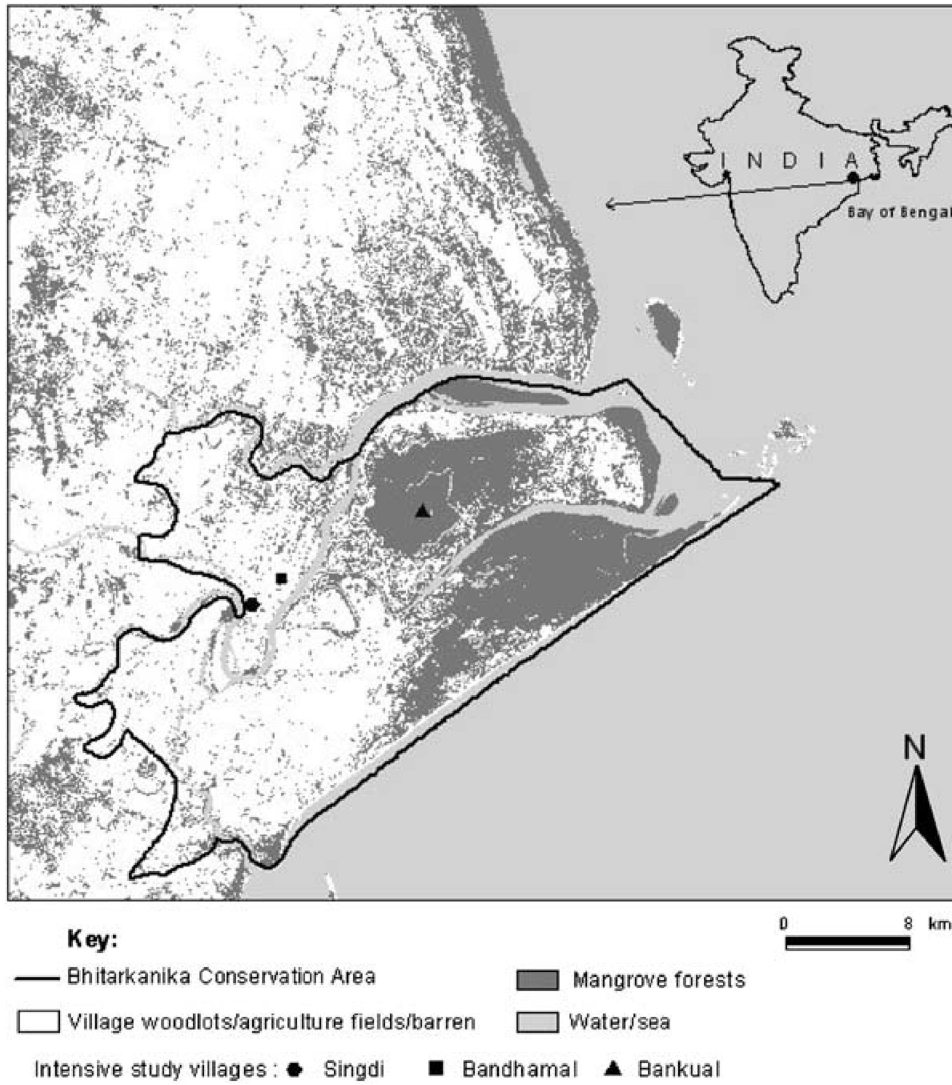

Figure 1 Kendarapara and Bhadrak districts of Orissa, India, showing the location of Bhitarkanika Conservation Area and the extent of mangrove forests.

management, economic valuation can be useful to indicate the real opportunity cost of alternative uses of natural resources (Richards 1994). The estimated economic value of mangrove forests ranges between US$ 9900–US$ 35 921 per hectare (see Costanza *et al*. 1997*b*; Sathirathai & Barbier 2001). Although the range of value may vary, for example as a consequence of site specificity and method used, with such calculus mangrove conservation becomes a tangible value that can help in land-use decision making.

The Bhitarkanika mangrove ecosystem is the second largest mangrove forest of mainland India (Fig. 1). Originally around 672 km^2, it is now limited to an area of 145 km^2 and is a wildlife sanctuary (Chadah & Kar 1999). This deltaic, mangrove forest harbours the highest diversity of Indian mangrove flora, the largest known rookery of the olive ridley sea turtle *Lepidochelys olivacea* in the world, the last of the three remaining populations of saltwater crocodiles *Crocodylus porosus* in India, the largest known population of king cobra *Ophiophagus hannah* and the water monitor lizard *Varanus salvator* (Patnaik *et al*. 1995). It is also one of the largest heronries and an important refuge for migratory waterfowl (Nayak 2002), besides being rich in fishery-target fish and shellfish (Chadah & Kar 1999). The mangrove and associated forests help meet subsistence requirements for timber, fuel wood, tannin, honey, fodder and thatch and provide livelihood opportunities for local people (Badola & Hussain 2003).

The loss of Bhitarkanika mangrove forests has been mainly a result of human encroachment, reclamation of land for agriculture and unsustainable practices such as aquaculture and mechanized fishing (Chadah & Kar 1999). Recent developments, such as construction of jetties and roads and a possible major port at Dhamra, threaten the ecosystem (Badola & Hussain 2003). Declaration of the mangrove forests of Bhitarkanika as a protected area (PA) has reduced access to life support, while the unsustainable resource use in the area has been a major threat to its continued existence. The scenario is one of mutually exclusive conservation efforts and development initiatives that translate into resource-use conflicts between the forest department and the local communities.

With a view to valuing the uses and ecological services provided by the Bhitarkanika mangrove ecosystem, quantifying the dependence of local communities on it, identifying marginalized stakeholders, and examining the attitudes of local communities towards present management, we set out to value the storm protection functions of the Bhitarkanika mangrove forests. This was based on the perceptions of local people regarding the services provided by mangrove forests and their attitudes towards these forests generally. We aimed to measure the economic losses attributed to the cyclone relative to the prevailing socio-economic conditions of the study villages.

A super cyclone with a wind speed of around 260 km h^{-1} and a storm surge of about 9 m hit the Orissa coast in the month of October 1999. This storm travelled more than 250 km inland and, within a period of 36 h, ravaged more than 20 million ha of land, affecting around 15 million people (Tynkkynen 2000). We evaluated the extent of damage caused in areas that were in the cover of mangrove forests and areas that were not, in the wake of this super cyclone. In 1971, embankment was created along the entire Orissa coast. Therefore, we also studied the effectiveness of such man-made structures in providing storm protection, as opposed to mangrove forests.

Study area

The Bhitarkanika Conservation Area (BCA) is located in the eastern state of Orissa, (86° 45′–87′ 50′ E and 20° 40′–20° 48′ N; Patnaik *et al*. 1995). This mangrove forest and the associated coast harbour the highest diversity of Indian mangrove flora and fauna (Naskar & Mandal 1999). The mangrove forests of Bhitarkanika differ considerably from other mangroves because of the dominant tree species *Sonneratia apetala, Heritiera fomes, H. littoralis* and several *Avicennia* species. In addition, there is one species of grass *Myriostachya wightiana*, which is very common in the area but practically unknown elsewhere (Blasco 1977). There are 64 species of plants in BCA, which include 28 true mangroves, four mangrove associates and 32 other species (Badola & Hussain 2003).

In 1975, the mangrove forests and the adjacent land of Bhitarkanika were declared a wildlife sanctuary encompassing an area of 672 km^2, with a core area of 145 km^2 being designated national park. The coastline stretches 35 km along its eastern side, constituting the Gahirmatha Marine Sanctuary (GMS). The Bhitarkanika National Park (BNP), the Bhitarkanika Wildlife Sanctuary (BWS) and parts of the GMS, together with 336 villages and adjacent cultivated agricultural lands within the BWS, together constitute the BCA, an area of *c*. 3000 km^2 (Fig. 1). The mangrove formations of the BCA were once widespread, but are now restricted to the BNP, whereas the BWS has a few degraded mangroves and palm swamps (Badola & Hussain 2003).

Within the BNP the initial band of vegetation at the water's edge is usually the tall *Myriostachya wightiana* grass, while landward of this the mangrove is dominated by *Avicennia officinalis* and *Hibiscus tiliaceus*, with occasional *Sonneratia apetala*. Climbers like *Caesalpinia cristata* and *Dalbergia spinosa* are abundant in the riverine patches, making them almost impenetrable. In the small open patches, undershrubs of *Acanthus* predominate. The influence of the ocean is reflected in the floral composition. *Avicennia marina*, *Sonneratia apetala* and some rare Rhizophoraceae increase in frequency towards the ocean and *Hibiscus tiliaceus* disappears completely. *Aegialitis rotundifolia* and *Avicennia marina* are found only in areas of high salinity. The other two species of *Avicennia*, namely *A. alba* and *A. officinalis*, show a wider range of salt tolerance. *Brownlowia tersa* and *Merope angulata* are found mostly in small creeks. *Phoenix paludosa* occurs in degraded areas, being abundant in some patches. *Hibiscus tiliaceus* is a species preferring drier areas where the water level has fallen and inundation is rare. *Cynometra* spp. are found in association with *Pongamia* spp., *Hibiscus* spp. and *Salvadora* spp., and *Dalbergia* spp., *Heritiera* spp. and *Excoecaria* spp. occur in firm ground away from the shoreline. *Sonneratia* spp. occurs on the shoreline and survives on loose substratum (Badola & Hussain 2003).

METHODS

We used the damage-cost avoided approach (Bann 1998) to value the storm protection function of the Bhitarkanika mangrove ecosystem. The actual damages avoided due to mangrove forest were estimated after a cyclone hit the area in October 1999. Socio-economic data pertaining to local demography and economic conditions were collected from 35 villages located in and around the BCA. Data on demography, land use and occupational patterns, resource use, and perceptions and attitudes were gathered through a questionnaire survey from 10% of the households. We collected preliminary information randomly by asking people about the losses they incurred because of the 1999 cyclone. On this basis, we tried to compare the impact of the cyclone in villages that had mangrove cover with those unprotected by mangrove forests, but since coastal embankments have been constructed in Orissa to prevent seawater intrusion into reclaimed paddy fields, it was imperative that the effects of embankments and mangroves be separated. Hence, the following three situations were identified: (1) a village in the shadow of mangrove (2) a village not in the shadow of mangrove and having no embankment, and (3) a village not in the shadow of mangrove, but with an embankment on the seaward side.

Based on a land-use cover map prepared in a geographical information system domain (Fig. 1), three study villages were identified, representing the three situations. Care taken to avoid variations in damage attributable to wind, water logging and distance of villages from the coast and mangrove forests limited the sample size to three villages. Bankual village was in the shadow of mangrove forest, Singidi village was neither in the shadow of mangroves nor protected by embankment from storm surge, and Bandhamal village was not in the shadow of

Table 1 Overall characteristics of the village agroecosystem in the Bhitarkanika Conservation Area, India. (n = 35 villages; SEM = standard error of the mean).

	Mean	*SEM*
Habitation (ha)	113.27	3.98
Average size of paddy fields	1.32	0.120
Overall paddy yield (kg ha^{-1})	948.83	0.56
Net area sown (irrigated, ha)	1.46	0.59
Net area sown (non-irrigated, ha)	6.44	2.61
No. of coconut trees/household	9.44	1.05
Income of the family (US$ yr^{-1})	488.86	10.401
% People unemployed	13.58	0.613

mangroves, but had seaward side embankment. The intensity of the impact of the 1999 cyclone on these villages should have been fairly uniform, as all the three selected villages were equidistant from the seashore and had similar aspects. The two villages outside mangrove cover were located close to each other, but both were far from the mangrove forest in order to eliminate any effect of mangrove forest presence (Table 1). We conducted a door-to-door survey and sampled 100% of the selected households 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. To assess the type of damage caused to houses, we developed a composite score or damage rating (DR) for each of the households surveyed in the three villages. The scores were in the range of 0–19 depending on the intensity of damage to the house. A value of 19 signified total collapse, i.e. the sum of the damage to all the structures (thatch, poles, roof, beams and walls) of the house. We used Statistical Package for the Social Sciences (SPSS) software for data processing and performed one-way ANOVA tests (Zar 1984) to compare the means of various variables for the three villages.

RESULTS

The villages situated around the Bhitarkanika mangrove forests had a mean area of *c*. 113.27 ha per village and the economy was primarily agricultural, possessing small land holdings and being dependent on the monsoon. The average size of paddy fields was 1.32 ha, and the total area sown was *c*. 7.9 ha per village, of which only 1.46 ha was irrigated. In addition to the single crop of paddy, small quantities of vegetables, coconut and fish were produced. Every household owned around nine coconut trees and about 38 coconuts were produced from each tree. The average family income was low at US$ 488 yr^{-1}. About 13.5% people were unemployed (Table 1). Apart from a small proportion of people engaged in government service, most of the people's livelihoods were based on agriculture and fisheries and related business.

The overall human density in the study villages was 260–340 people km^{-2}, the mean household size being between 4.5 (Bankual) and 8.2 people (Singdi) (Table 2). The literacy level was highest for Singdi and lowest for Bankual. In Singdi and Bankual, 70% of people were engaged in agriculture, whereas in Bandhamal, 61% were labourers (Table 2). Most of the houses (94%) were made of mud and thatch.

Table 2 General characteristics of the three intensively studied villages in the Bhitarkanika Conservation Area, India.
* House made of brick and cement.
** House made of mud and thatch.

General characterstics	*Villages*		
	Singdi	*Bankual*	*Bandhamal*
Location details			
Distance from mangrove forest (km)	9.2	0	8.2
Distance from sea coast (km)	12.65	12.13	12.18
Distance from dyke (km)	No dyke	2.37	0.45
Demographic characteristics			
Total area (ha)	122.63	55.75	147.27
Human density (persons km^2)	314	340	260
Number of households	58	42	56
Mean household size	8.2	4.5	6.8
Total population	353	189	383
Literacy (%)	56.7	31.2	38.6
Economic characteristics			
People involved in agriculture (%)	70.6	70.6	14.4
People involved in fishing, animal husbandry and allied activities (%)	0	14.7	0
People involved in labour (%)	22.4	2.95	61.4
People involved in other activities (%)	7.03	11.8	24.4
Type of houses			
Total no. of houses (n)	37	38	32
Pucca* (%)	5.4	0	0
Pucca with thatched roof (%)	0	2.6	9.4
Partially pucca (%)	2.7	0	0
Fully kutcha** (%)	91.9	97.4	90.6

Table 3 Basic description and mean values of the variables (per household) examined for comparing the damage due to cyclone in three study villages in the Bhitarkanika Conservation Area, India. (US$ 1 = INR 45, August 2004).

Variables	*Description*	*Villages*		
		Singdi	*Bankual*	*Bandhamal*
DR	Damage to houses (0–19 scale)	9.40	5.34	10.44
PTD	Tree damage (%)	21.0	3.3	15.5
DPP	Damage to other personal property (INR)	108.11	0.00	2375.00
DL	Damage to livestock in money terms (INR)	54.05	127.63	1044.37
FP	Flooding in premises (m)	0.34	0.29	0.58
FF	Flooding in fields (m)	1.99	1.09	1.39
WLF	Water logging in fields (days)	9.46	5.63	12.87
CR	Cost of repair and reconstruction (INR)	996.97	682.86	973.21
Y99	Yield for the year 1999 (kg ha^{-1})	531	1479.5	335.9
LFS	Loss of fish seedlings (fingerlings) released prior to cyclone (INR)	310.81	69.74	260.94
TML	Total quantifiable variables (INR)	1983.3	61454.13	6918.62

Table 4 Results of the ANOVA for each variable and significance of their means. See Table 3 for variable definitions.

Variable	*n*	*df*	*F*	*p value*
DR	107	1	14.633	0.000
PTD	93	1	9.891	0.000
DPP	107	1	6.814	0.002
DL	107	1	5.398	0.006
FP	103	1	7.670	0.001
FF	100	1	35.102	0.000
WLF	102	1	18.654	0.000
CR	96	1	1.270	0.286
Y99	59	1	99.029	0.000
LFS	107	1	1.506	0.227
TML	98	1	17.936	0.000

Damage attributed to wind and storm surge

The high-speed winds and storm surge generally damaged the mud and thatch houses, with not many cases of damage to roof frames being reported. However, about 49.5% of houses had their roof blown away, accompanied by either cracking of walls or their partial collapse on some sides, the maximum mean DR being 9.4 ± 0.7 for Singdi village and the minimum mean DR being 5.3 ± 0.5 for Bankual village (Table 3). Mean DR to houses varied among the three villages (Table 4). The percentage of trees dying (PTD) attributed to the cyclone was highest in Singdi (21.0%), while only 3.3% of trees were damaged in Bankual (Tables 3 and 4), which had the highest number of trees (Table 2). Costs for reconstruction work per household (CR) did not differ between villages (Table 4). The highest value was INR 997.0 ± 182.18 (US$ 22.15) for Singdi, while the lowest was INR 682.9 ± 144.05 (US$ 15.17) for Bankual. Loss to private property such as boats, nets (DPP) and livestock casualties (DL) were highest in Bandhamal (Tables 3 and 4), the village far from the mangrove forests but protected by the embankment (Table 2).

Damage attributed to saline water intrusion

Flooding levels in houses and crop fields differed among villages (Table 4), saline water intrusion into houses (FP) being highest in Bandhamal (0.6 m ± 0.05 m) and lowest for Bankual (0.3 m ± 0.04 m) (Table 3). The highest level of saline water intrusion in the crop fields (FF) was for Singdi, followed by Bandhamal and Bankual. Flood water remained in fields (WLF) for longest duration in Bandhamal, flood retreat for Singdi and Bankual being faster (Tables 3 and 4).

The standing crops of paddy were severely affected by the cyclone. Crop production differed among the three villages (Table 4), Bankual having the greatest paddy yield for 1999 (Y99) of 1479.5 kg ha^{-1}, while in Singdi the yield was 531 kg ha^{-1} and in Bandhamal it was 335.9 kg ha^{-1} (Table 3). The mean paddy yield differed for all three villages between the years 1999 and 2001 ($F = 99.029$, df = 1, $p = 0.000$); in 1999 it was 568 kg ha^{-1} while in 2001 it was 1012.7 kg ha^{-1}.

At the time of this study, the fishponds had not been harvested, however, the loss to fisheries was significant because of the loss of the fingerlings released that year. The greatest damage to fish seedlings per household (LFS) was in Singdi, where INR 310.8 ± 144.97 (US$ 6.91) of seedlings released were washed away, and the least damage was in Bankual (INR 69.7 ± 32.20, US$ 1.55; Table 3).

Total monetary loss

Total losses in monetary terms were calculated for each of the households in the three villages by combining the values of the cost of repair and reconstruction (CR), damage to other personal property such as boats, fishing nets and household goods (DPP), damage to livestock (DL) and loss of agricultural products (i.e. difference in total paddy production between 2001–1999, taking the area cultivated in 1999 as the basis).

The loss incurred per household (TML) was highest in Bandhamal (US$ 153.74) followed by Singdi (US$ 44.07) and Bankual (US$ 32.31) (Tables 3 and 4).

Attitudes and perceptions of local people

When asked to rank the ecological services performed by mangrove forests, 89% of respondents gave the highest preference to cyclone mitigation and flood control. They

Table 5 Ranking of various functions performed by the mangrove forests by the people of the Bhitarkanika Conservation Area, India ($n = 268$).

Ecological functions/values	*Rank 1 (%)*	*Rank 2 (%)*	*Rank 3 (%)*
Cyclone mitigation and flood control	88.6	11	0.4
Land erosion prevention	50	50	0
Aesthetic value	38	61.2	0.8
Augment agricultural production	8	92	0
Contribute in fish production	1.9	96.2	1.9
Historical and cultural value	8.8	88.9	2.3
Others	18.9	70.3	10.8

Table 6 Attitudes of local people towards Bhitarkanika Wildlife Sanctuary, India and conservation initiatives taken by Forest Department of Government of Orissa ($n = 268$).

	Responses (%)		
Questions	*Yes*	*No*	*Indifferent*
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 problems because of park?	5.6	84.7	9
Are you in favour of integrated conservation and development projects for the area?	92.9	2.2	4.9
Would you like to cooperate with forest department for mangrove restoration?	43.3	23.1	36.6

ranked the land erosion prevention function second (Table 5). In the villages located far from the mangrove forest, 92.5% of males and 97.5% of females perceived that mangroves were beneficial to their lives and property. The contribution of mangrove forests to increasing agricultural productivity, as well as providing protection from storms and cyclones, was considered most important. However, more people from villages located near mangrove forests appreciated their contribution to agricultural productivity, while more people from the villages far from mangroves regarded storm protection as an important contribution. About 90% people in the area were aware that the Bhitarkanika mangrove forests have protected status. A high percentage (84%) of people felt responsible for the conservation of flora and fauna, while 93% were in favour of an integrated conservation and development programme (ICDP). Approximately 43% of people were willing to cooperate with the forest department in mangrove restoration. Only 18% people felt the park's declaration violated rights, the main reason being the access denied to firewood (Table 6).

DISCUSSION

Every year about 80 tropical cyclones with winds $\geq$ 35 knots form in the world's waters (McBride 1995), about 6.5% of them occurring in Bay of Bengal and Arabian Sea (Neumann 1993). The cyclones forming in the Bay of Bengal hit the east coast of India, particularly the states of Andhra Pradesh, Orissa and West Bengal, every year, causing heavy loss of life and property. Along the Indian coast, all those areas that are vulnerable to tropical cyclones once had natural mangrove cover. During the last century, mangroves from these areas were destroyed or degraded by people, making these areas vulnerable to the damage caused by cyclones.

Many authors have emphasized the protection from storms and cyclones that mangroves offer to coastal areas (see Carlton 1974: Maltby 1986; Semesi 1998), however there are few empirical studies that provide quantitative information on this function of mangrove forests. Although only indicative, we show that the damage attributed to the cyclone was more extensive in villages further away from the mangrove shadow. The embankments constructed in 1971 after a previous cyclone to prevent intrusion of saline water into agricultural fields and villages were ineffective during the high storm-surge; in fact they acted as a barrier to run-off when the water was receding. The embankments suffered a number of breaches that resulted in the flooding of villages such as Bandhamal, which was surrounded on all sides by the embankment. Singdi village with no mangrove cover and no embankment suffered the highest level of field inundation, however the seawater receded quickly, resulting in less damage to agricultural crops. Bankual village, which was in the shadow of mangrove forest and had little embankment around it, suffered the least. Although this study is not conclusive, the lack of breaches in the embankment closer to forest is indicative of the protection provided by mangroves to the embankment. In areas far from the forest, several breaches in the embankment were observed. Water levels were higher and the flooding was of longer duration in Bandhamal. The cyclone uprooted almost all the trees in the immediate vicinity of the coast and caused much damage to trees several kilometres inland. Unofficially, the damage to horticulture and orchards was estimated to be INR 200 billion (Tynkkynen 2000). However, mangrove forests and trees in the shadow of mangrove forests were intact.

We contend that the vulnerability of many coastal human communities to cyclones is heightened by the removal of mangroves for development, agriculture and habitation. While property damage from storms and hurricanes is highest in the developed northern nations, 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). Mangrove forests are natural buffers against storm surges (Maltby 1986), protecting tropical shores from erosion by tides and currents. Macintosh (1983) recommended that a mangrove strip at least 100 m wide should be left as a buffer zone on more exposed shores. During the present study, we realized that the artificial sea defences were not only expensive to build and repair, but they were also, in many cases, ineffective. Extensive *Casuarina* plantations established as a storm protection measure along the Orissa coast were ineffective in preventing damage; rather, they caused destruction to olive ridley sea turtle *Lepidochelys olivacea* nesting beaches (Pandav & Chaudhury 2002). Ecological functions such as storm protection may be very important components in the total economic value of a wetland and may constitute almost 80% of the estimated value (Costanza *et al.* 1989). This is a major indirect benefit and the principal reason for restoring mangrove forests along much of the low-lying deltaic coasts. There is a 20–30% reduction in repair and maintenance costs of sea-dyke systems depending on the width of mangrove stand in front of the dyke (Adger *et al.* 1997).

In the present study, the local people valued most highly those functions (cyclone mitigation) and uses (agriculture and tourism) which were directly linked to their survival and to their well-being. The villages in the immediate vicinity, which directly benefited from the nutrient inputs derived from mangroves, attached importance to the contribution of mangroves to increased agricultural productivity. Similarly, the villages away from mangroves that suffered more from cyclones appreciated the storm protection function of mangroves. It is of great importance for conservation policy makers and officials to know the attitudes and awareness of stakeholders regarding environmental issues so that they may accordingly allow more effective resource allocation and planning (Badola 1998). In order to ensure the sustainability of the ecosystem services provided by the Bhitarkanika mangrove ecosystem, it is important to ensure the sustainability of the local agroecosystems as well as livelihoods; in the present situation these lack robustness and are susceptible to trends such as cyclones, floods and sea-level rise. Rawls (1987) has argued that policies that represent an overlapping consensus of the interest groups involved will most likely be fair, effective and resilient. Bhitarkanika is a Ramsar site, which implies wise use of its resources. This is possible through careful planning, management, regulation or even prohibition of certain activities and can effectively be made possible only through proper consultation and agreement with the local communities. The awareness and appreciation by the local people of the functions performed by the mangrove forest is a positive sign for conservation of the area.

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