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ORIGINAL PAPER

Perceptions of biodiversity, environmental services, and conservation of planted mangroves: a case study on Nijhum Dwip Island, Bangladesh

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Abstract Restoration of mangroves is often considered a way to minimize losses incurred from their decline and to provide additional services to coastal communities. However, the success of restoration programs is often focused on biological or ecological criteria. The situation is no exception in Bangladesh, which houses the world's largest mangrove plantations. This study has been undertaken in a south-central estuarine island (Nijhum Dwip) of the Bangladesh coast and aims to understand societal perception on the achievements of a plantation program. Through 110 household interviews and seven group discussions, an assessment was conducted of peoples' perception about major flora and fauna of the mangrove ecosystem, benefits derived from the forest, present condition of the forest, causes of degradation, and ways to improve the situation. Around one-fourth of the respondents mentioned that they were highly dependent on the ecosystem. The most important perceived benefits were: provision of raw materials, prevention against natural disasters, climate regulation and soil retention. However, the majority (>80%) of the respondents perceived the ecosystem to be degrading. Encroachment and illicit felling were identified as the main causes of such degradation. In order to arrest the continued degradation allowed by conventional forest management flaws, adaptive co-management has been recommended to conserve this ecosystem in a more equitable way.

Keywords Adaptive co-management · Bangladesh · Encroachment · Forest degradation · Mangrove plantation · Social attitude

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Introduction

Similar to many other ecosystems, mangroves are declining globally due to anthropogenic and natural causes (Vannucci 2004). Restoration of mangroves is often considered a way to minimize ecological and economic losses incurred from their decline (Saenger 2002). The principles and technologies of mangrove restoration have been developed through experimentation, observation of natural mangroves and learning from other disciplines (Field 1996, 1999; McKee and Faulkner 2000; Lewis 2005). Ecological models have been developed to test these principles according to different restoration criteria (Twilley et al. 1998). In a recent review, Lewis (2005) summarizes that 'ecological restoration of mangrove forests is feasible, … and can be done cost effectively' and Yap (2000)

states that 'of the three major coastal ecosystems [coral reefs, sea-grass beds and mangroves], mangrove forests are probably the easiest habitat to restore'. However, many restoration projects suffer from failure of seedling establishment while established plantations often degrade due to prevailing ecological and social factors (Field 1998). Further, restored forests may fail to transform into more integrated ecosystems (Ellison 2000). Successes of restoration projects are usually measured in terms of project objectives rather than of broader ecological and social goals (Andel and Aronson 2006). The restoration projects often fail to fit with the wider socio-economic setting (Bandaranayake 1998) and are unable to deliver social benefits (Drew et al. 2005) due to lack of appreciation of social values and needs (Tomlinson 1986).

Assessment of local peoples' attitudes towards such interventions is one of the least explored aspects of mangrove restoration science (Kovacs 2000; Glaser 2003). This could be crucial for restoration projects in developing countries, such as Bangladesh, for several reasons (Pereira et al. 2005). Previously, failure to consider local needs and values has brought collapse in many conservation projects (Ostrom 1990). As a result, many developing countries have initiated participatory or community-based natural resources management programs (Zorini et al. 2004). Regional coastal zone development plans are now also formulated (Olsen and Christie 2000). Local people, who were often considered as a direct cause of natural resource decline (Contreras-Hermosilla 2000), are emerging as important stakeholders in such programs (Mbilea et al. 2005). Consultation with them is becoming a pre-requisite (Pickaver et al. 2004).

The need to understand peoples' perception towards mangrove restoration cannot be over-emphasized for Bangladesh (Islam and Wahab 2005). Bangladesh is one of the most disaster-prone and vulnerable countries to climate change impacts (Agarwala et al. 2003). It includes the largest single tract of natural and planted mangroves in the world. Despite these considerations, very few studies (for review see Islam 2004) have concentrated on the social and environmental services of restored mangroves. This study has been undertaken in one of the south-central offshore island (Nijhum Dwip, meaning Tranquil Island; 22°1′–22°6′ N & 90°58′–91°3′ E; Fig. 1) of Bangladesh coast with the following objectives:

- Objective 1: Assess the attitude of the local people towards mangrove plantations
- Objective 2: Assess the social importance of the mangrove ecosystem
- Objective 3: Assess the social perception of the present condition of the ecosystem, existing forest management, and options to improve current conditions.

We first give an overview of mangrove plantation in Bangladesh. This will be followed by a description of the methodology, results, discussion and conclusion.

Mangrove plantations in Bangladesh: an overview

The coast of Bangladesh is prone to natural disasters, such as cyclones, river erosion, salinization and flooding due to its funnel-shaped geomorphology, low-lying elevation, chain of flattened offshore islands, high population density, and poor socio-economic condition (WARPO 2006). From the 1960s, structural measures have been undertaken to reduce the vulnerability of the coastal people to natural disasters (Islam 2004). Embankments (polders) and cyclone shelters have been constructed to control the devastation caused by tropical cyclones and storm surges. However, recognition of the protective role of natural mangroves, the Sundarbans, inspired the government to start a coastal afforestation program in 1966 to strengthen coastal protection. Four Coastal Afforestation Divisions were established to administer the program. During this period an average of 320 ha of plantations were raised annually. Recognizing the long time frame needed for plantation establishment, 497,976 ha of newly accreted lands were transferred to the Coastal Afforestation Divisions in 1976 for a stipulated 10-year period (Canonizado 1999; Islam 2000a, b, c; Iftekhar and Islam 2004). In 1986, it was decided to keep the area under the Forest Department for another 20 years after observing the satisfactory progress of the plantation program (Islam 2000a).

During this time, the primary objective was to mitigate the catastrophic effects of cyclones and storm surges (Siddiqi 2001); however, other objectives were added later, namely timber production, the conservation and stabilization of newly accreted lands, the acceleration of accretion (with the ultimate aim of transferring a large part of this land to agriculture),

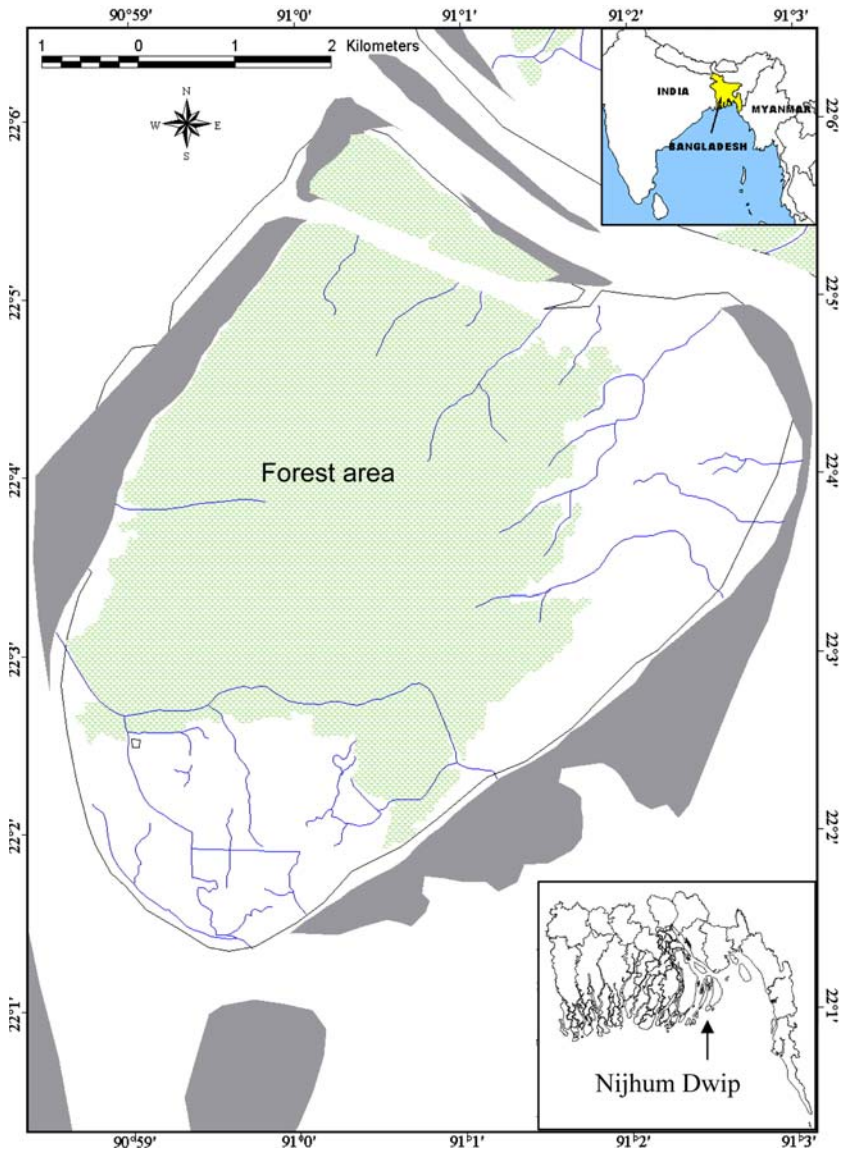

Fig. 1 Forest cover of the Nijhum Dwip, 2005. *Source*: Map collected from the CDSP III (Char Development and Settlement Project Phase III, Bangladesh Water Development Board, Ministry of Water Resources, Government of Bangladesh)

the creation of employment opportunities for coastal communities; and the development of suitable habitat for wildlife and aquatic species (Canonizado 1999). Management plans have been formulated accordingly to achieve these multiple objectives.

At first, the plantation was restricted to a few major species. Later, all the commercially valuable mangrove species were tested (Siddiqi et al. 1993) but of these only two species, keora (*Sonneratia apetala* Buch.—Ham) and baen (*Avicennia officinalis* L.) demonstrated good performance. These two species now constitute about 85% of the plantations (Lewis 2005), which is spread over 800 km^2 (Blasco et al. 2001). As pioneer species in mangrove succession, they can grow well on newly accreted areas with regular inundation (Das and Siddiqi 1985). Other mangrove species include gewa (*Excoecaria agallocha* L.), kankra (*Bruguiera gymnorhiza* (L.) Lam), goran (*Ceriops decandra* (Griff.) Ding Hou) and golpata (*Nypa fruticans* (Thunb.) Wurmb.) (Serajuddoula et al. 1995).

The establishment of plantations requires substantial effort, as repeated planting often has to be carried out for periods of up to 3 years due to the highly dynamic nature of the Bangladesh coastline (Moberg and Rönnbäck 2003). However, once the plantations

are established they often start to suffer from encroachment and illicit felling. Absentee landlords and local landless people are considered to be the main agents of such destruction (Sajjaduzzaman et al. 2005). Moreover, mangrove plantations face other problems, such as poor site suitability, failures of second rotation crop, and pest infestation (Siddiqi 2001). As a result, the growing stock of the forests is being depleted (Revilla et al. 1998).

Nonetheless, mangrove plantations in Bangladesh are considered successful despite such recent vegetation decline (Alongi 2002). The positive effect in protecting coastlines from cyclones and tidal bores has been recognized (Saenger and Siddiqi 1993). Planting of mangroves has been successful in protecting and stabilizing coastal land (Islam and Wahab 2005) and at increasing the potential production of fisheries (Islam and Haque 2004). Furthermore, it is estimated that the plantations have provided 600,000 m^3 of forest products, and have generated more than 5 million man-days of employment for coastal communities, thereby contributing substantially to the local and regional economy (Moberg and Rönnbäck 2003).

Methodology

Description of the study site

The Nijhum Dwip Island is under Haitya Upazila (sub-unit of civil district) and Noakhali civil district. The island began to form in the 1950s, and during the 1970s and 1980s the higher parts of the island silted up to about the mean high water (MHW) line (+2.2 m public works datum) (MES 1998). At present, the total area of the island is 4,057 ha (SA Nur, CDSP III, pers. com.). The soils of Nijhum Dwip are mainly undeveloped with some slightly developed Meghna alluvial deposits. The surface soil is primarily medium textured silt loam and generally poor in organic matter (MES 1998). Human settlement began on the island in the 1970s. Most of the early settlers migrated from adjacent Hatiya Island to escape problems of river erosion (RDC 2000). At present around 500–700 households live on the island (CEGIS 2005) and are mainly dependent on fishing, agriculture and forestry for their livelihood (RDC 2000).

Forestry is a major land use (68% of the area is covered) of the island. The Forest Department started planting mangroves in 1973 with *S. apetala* (about 80%) and *A. officinalis* (15%). Thinning operations were carried out in these plantations from 1988 to 1990 in all areas where the trees were older than 9 years. However, thinning has been discontinued after 1991 due to cyclone damage, its high cost and relatively low returns of the procedure. Following this, very little management and silviculture activities were undertaken such that the trees have remained in close spacing, but protected and left to grow. Currently, many of the *Sonneratia* trees have become infested with stem borer, killing the trees and creating open spots inside the plantation areas (MES 1998).

The ecosystem is biologically very diverse. Through a transect analysis Rosario (1997) estimated that the island contains 68 plant and 66 animal species. The island is at the crossroad of two international flyways, viz. the East-Asia Australasian Flyways and Central Asian Flyways and is the southern-most staging ground of around 60 species of migratory birds. The site supports globally critically endangered species such as the Indian Skimmer (*Rynchops albicollis*), Spoon-billed Sandpiper (*Eurynorhynchus pygmeus*), Nordmann's Greenshank (*Tringa guttifer*), and Asian Dowitcher (*Limnodromus semipalmatus*) by providing their wintering ground (IA Haque, 2003, unpublished document).

To further enhance the biodiversity three pairs of spotted deer (*Axis axis*) were released on the island in 1980. The number of deer has increased to 14,400 at present (estimated in 2006; BFD 2006). Subsequent introductions have included several pairs of monkeys (*Macaca mulatta*), snakes (*Python molurus*) and one pair of Leopard cat (*Felis bengalensis*). As a formal recognition of the biodiversity value, part of the island and adjacent newly accreted lands were declared as a National Park in 2001 under the Bangladesh Wildlife (Preservation) Order 1973. Peoples' entrances in the forest, hunting, killing or capturing any wild animal and damaging or destroying, any plant or tree have been banned (PDO-ICZMP 2004).

Data collection

A total of 125 interviews (18–25% households of the island as CEGIS, 2005 has estimated that 500–700 households are living in the island) and seven group meetings (with average participation of eight people) were organized. A stratified random sampling protocol

was adopted to select the households. Based on existing data and discussion with the key informants, main livelihood groups and their proportionate distribution were assessed. The sample households were distributed into these livelihood groups proportionately and then the samples were selected at random from each livelihood group. From each sample, the head of the household was interviewed. Among them, 28% were female interviewees. It should be mentioned that in Nijhum Dwip the proportion of female-headed households is 5%, while women temporally manage many more households for some parts of the year (RDC 2000). Due to this, the coverage of female respondents was considered to be adequate. The respondents were interviewed using a pre-formulated questionnaire. Pre-testing of the questionnaire was done through a reconnaissance survey. The final survey was completed from June to July of 2006. Two local interviewers (one male and one female) with sufficient expertise were recruited for these activities. Similar methodologies have been followed by others to assess the social importance of mangrove (Bandaranayake 1998 in Sri Lanka; Dahdouh-Guebas et al. 2000 in Kenya; Omodei et al. 2004 in East Africa; Badola and Hussain 2005 in India and Walters 2005 in the Philippines).

Data analysis

For analysis, 110 interviews were used (15 interviews were rejected due to incomplete information). The data are presented using various descriptive statistical techniques such as percentage, mean and standard deviation, while χ^2-test has been used to compare them. Spearman's rank correlation coefficients were determined to assess relationships among different variables (after appropriate conversion of data into ordinal form) (Ebdon 1985). Significance level of up to 10% ($P < 10\%$) has been reported. For analysis MS EXCEL (V 2003) and SPSS (V 14) were used.

Results and discussion

Socio-economic condition of the respondents

The mean age of the respondents was 37 years (±10 years; range: 18–80 years). Average age of the female respondents was slightly lower (34 years ± 10 years) than the male respondents (37 ± 10 years). Their average time of residence in the island was 20 years (±6 years). Mean size of the households interviewed was seven members (±3 members), which is higher than reported averages on the island (6; RDC 2000), district (6; BBS 2003) and nation (5; BBS 2003). It is common for the people who are living in the peripheral vulnerable conditions to maintain large family size (Dasgupta 2001). The literacy rate among the respondent households was 38% (this is higher than the Upazila average; BBS 2003), though average year of schooling of the respondents was only 5 years (±3 years).

Land ownership is a major determining factor of the livelihood and socio-economic status of a rural household in Bangladesh (WARPO 2006). This is reflected in the fact that almost three-fourths of the respondents had migrated to this island either due to loss of their land (predominantly due to river erosion) or to avoid scarcity of land in their localities (Fig. 2).

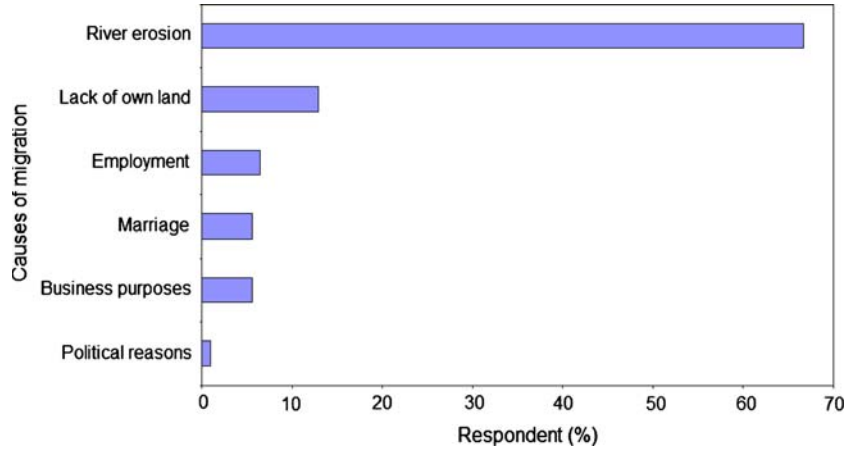

Fig. 2 Proportionate distribution of the respondent households according to their main cause of migration. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked why they came to the place where they are living now

Table 1 Distribution of the respondent households according to their main occupation or source of income

Main sources of income	Proportionate distribution of respondent households	Combination of major livelihood activities
Beggar	1	
Boatman	5	Agriculture
		Agriculture, Fishing
		Agriculture, Fishing, Business
Business	29	Agriculture
		Agriculture, Fishing
		Aquaculture
		Fisher
Daily labor	4	Fisher
Farmer	24	Business
		Daily labor
		Daily labor, fishing
		Fisher, Wage labor
		Fishing
		Livestock
Fisher	20	Agriculture
		Agriculture, Daily labor
		Daily labor
		Daily labor, Housemaid, Begging
Housemaid	1	
Housewife	5	Poultry
		Daily labor
		Service, Agriculture
Service	12	Agriculture
		Agriculture, Business
		Business

Source: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked about their main and secondary sources of income

At present, it was found that each household occupies on an average 0.47 ha of land (±0.52 ha). The occupied land was mostly used for farming (46 ± 40%), homestead (33 ± 32%) and pond (9 ± 18%).

Among the respondents, 36% described their households as good or very good compared to their neighbors, 33% described their socio-economic condition as average, while the rest (31%) considered themselves poor or very poor. Major determinants in the well-being of households were land occupancy, regular and sufficient income, health of the family members, capital and savings, education, professional skill and small family size. The majority of the livelihood activities were natural resource based, such as fishing or farming, with almost all households having multiple livelihood activities (Table 1).

Major flora and fauna of the ecosystem

Flora

When asked to identify five important plant species found in the forest, a total of 38 plant species were highlighted by the respondents. Only a few of the plants (*Sonneratia, Excoecaria, Avicennia, Bruguiera*, and *Nypa*) were deliberately planted or introduced here. This suggests a substantial colonization and migration of species to the island. In the species list, shrubs, trees and climbers cover 37, 21 and 16%, respectively. However, in terms of frequency trees were mentioned most often (65% of the responses) followed by shrubs (21%) and climbers (8%) (Table 2).

According to majority of the respondents, all the major mangrove species (*S. apetala*, *E. agallocha*, *B. gymnorhizae* and *A. officinalis*) have been decreasing regardless of whether they were planted (i.e., mature trees) or had naturally occurred (i.e., seedlings or young trees) (Fig. 3). According to the respondents, the seedlings of *Excoecaria* (which is a mid-seral co-dominant species of adjacent natural mangrove, Sundarbans; Siddiqi 2001) are abundant in the forest floor, whereas the seedlings of *Sonneratia* (a pioneer species in natural mangrove) are declining. This suggests a potential species turnover in the long run.

Fauna

The respondents were also asked to identify five major animal species found in the forest. They identified 64 faunal species, of which half were birds. Mammals, reptiles and insects covered 20, 14, and 6% of the species list, respectively. Mammals were mentioned most frequently (72% of the responses), followed by birds (20%), and other groups (8%) (Table 2). However, a majority of the respondents mentioned that birds and reptiles are decreasing whereas mammals (predominantly deer,

Table 2 Distribution of plant and animal species identified by the respondents into different functional groups

Plant	Species (%)	Frequency (%)	Animal	Species (%)	Frequency (%)
Tree	21.05	64.57	Amphibian	1.56	0.22
Shrub	36.84	21.38	Annelid	1.56	0.22
Palm	2.63	2.94	Arthropod	1.56	0.22
Herb	13.16	1.68	Bird	50	19.21
Grass	7.89	1.47	Gastropod	1.56	0.22
Climber	15.79	7.76	Insect	6.25	2.21
Angiosperm	2.63	0.21	Mammal	20.31	71.74
			Reptile	14.06	3.75
			Sauropsid	3.13	2.21
Total (No.)	38	477		64	453

Source: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked to identify five major plant and animal species found in the mangrove ecosystem. The identified species have been categorized into different groups. Distribution and frequency of them have been expressed as percentage of the total

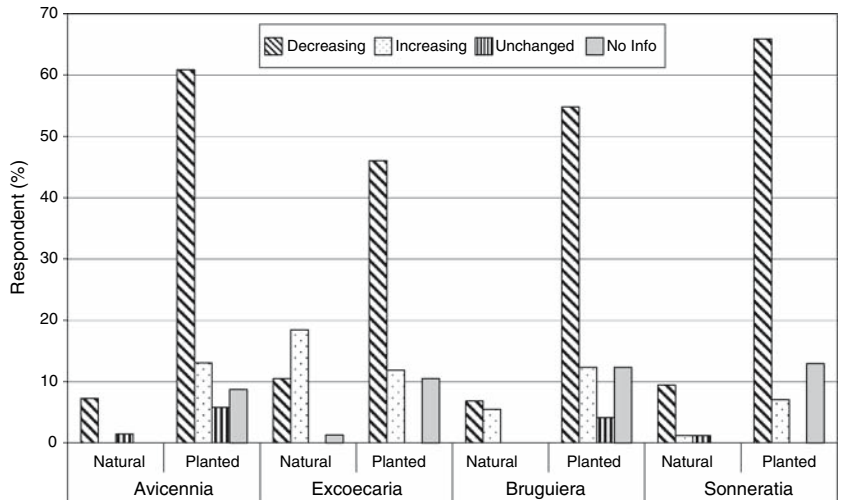

Fig. 3 Peoples' opinion on the trend of major mangrove species of the Nijhum Dwip mangrove ecosystem. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked to identify five major plant species found in the mangrove ecosystem and their origin and trend. The frequency of responses has been expressed as the percentage to the total number of respondents who mentioned the species name

wild buffalo, jackal, and wild dog) were perceived to be increasing (Fig. 4).

Human–wildlife conflict

The majority of the respondents (80%) mentioned that there was conflict between humans and wildlife. People have lost livelihood assets such as crops, trees, seedlings, flowering plants, poultry, and fish from their pond due to wildlife incursions (Fig. 5). The increasing number of deer, jackals, and wild dogs is exerting a negative effect on the islanders, particularly on the farmers. The number of deer may have increased beyond a threshold level. The density of deer in the forest is now 514 per sq km (BFD 2006), whereas in the Sundarbans it is only around 20 per sq km (Siddiqi 2001). During discussions with the respondents, a few causes of such human-deer conflict were identified:

- Absence of natural predators (like tiger) and relative abundance of food facilitated the number of deer to rise initially.
- With maturity of *Sonneratia* trees, the deer started to suffer from fodder crisis, since they primarily feed on the leaves, which become harder to access as trees grow taller.
- In the inter-tidal saline environment, getting fresh water to drink was also a problem, which is aggravated at present due to gradual siltation and maturity of the land.

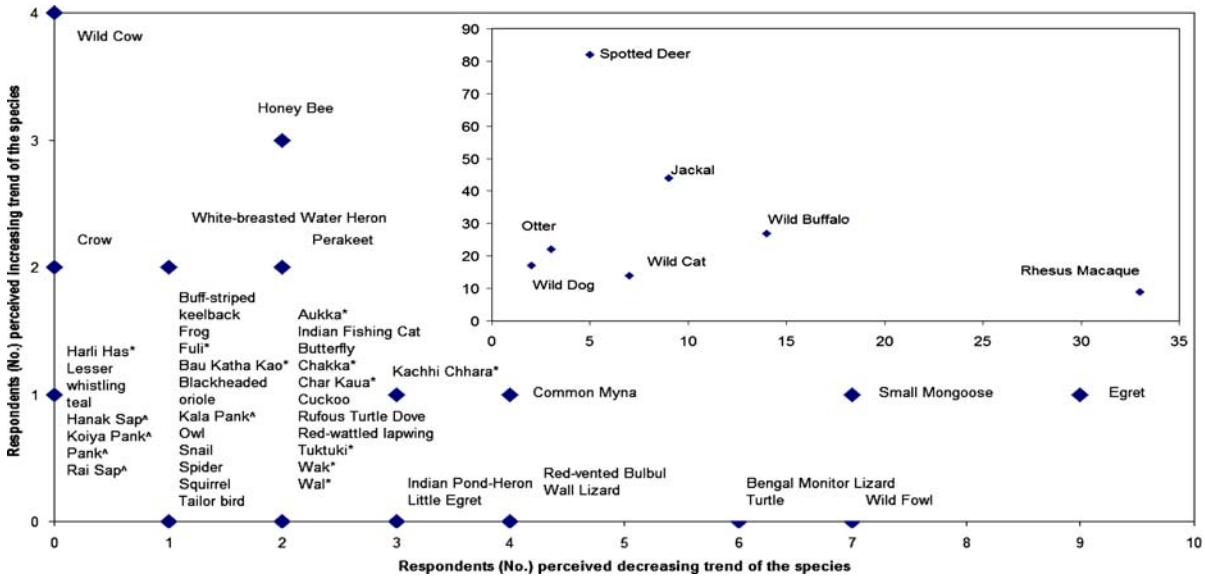

Fig. 4 Peoples' opinion on the trend of major animal species found in the mangrove ecosystem of Nijhum Dwip. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked to identify five major faunal species found in the mangrove ecosystem and their trend. The frequencies of responses for major species have been presented in this figure. Here, ^ = local name for reptilian species, * = local name for birds. Please note that many species have same frequency

More importantly, tree density is gradually decreasing due to illicit felling. More areas are being converted to farmland and settlement. Therefore there is less habitat for wild animals and people are getting closer to the wild animals. The farmers usually construct fences around the cropland and guard it at night during cropping season, although most often this is not sufficient. Many farmers have given up cropping in winter, due to this season having the most deer incursions. In such situations, poaching could be prevalent (Mbile et al. 2005). However, during informal discussions the respondents rejected this

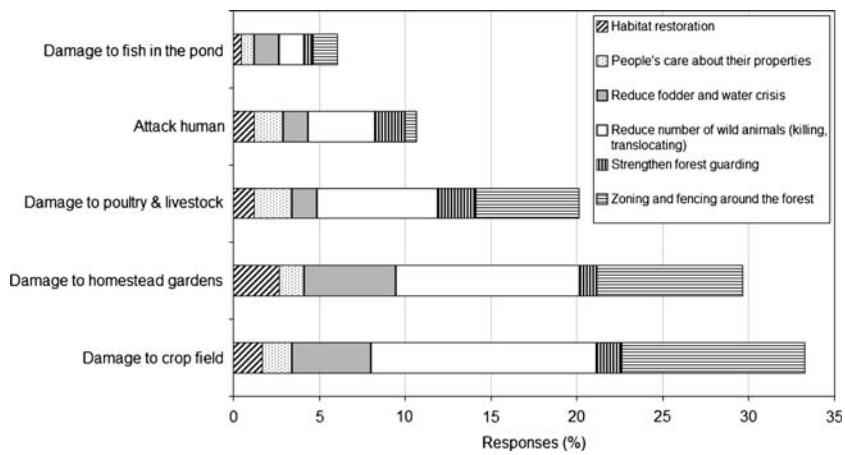

Fig. 5 Distribution of the respondents according to the wildlife damage. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked whether they have any problem with wild animals living in the mangrove. Respondents with a positive response were requested to provide three major problems and three solutions to such conflicts

idea. According to them, the main reason is the difficulty to hide the crime due to smaller number of households in the island. Moreover, deer meat is a luxury product, not an essential commodity for which everybody would have demand. However, this opinion should be taken with caution especially in such situations where trees are felled frequently. Nevertheless, one major suggestion is to reduce the number of wild animals through selective killing, selling through auctions, translocation to another island and exporting to other countries. According to the respondents zoning and demarcation through construction of a fence and embankment around the forest can reduce human wildlife interaction significantly. Reduction of water and fodder crisis through various habitat restoration activities, such as planting *Sonneratia*, and digging some ponds inside the forest can also lessen the conflict.

Dependency on mangroves

Around one-fourth of the respondents mentioned that they had high dependency on the mangrove ecosystem in comparison to their neighbors. Another 36% of the respondents stated that they had low or very low dependency on the forest (Fig. 6). Highly dependent households were usually those who had encroached on the forest and were dependent on it for a large portion of their income. On the contrary, households with low dependency on the mangroves were those who usually harvested fuel wood or a limited amounts of timber from the forest. However,

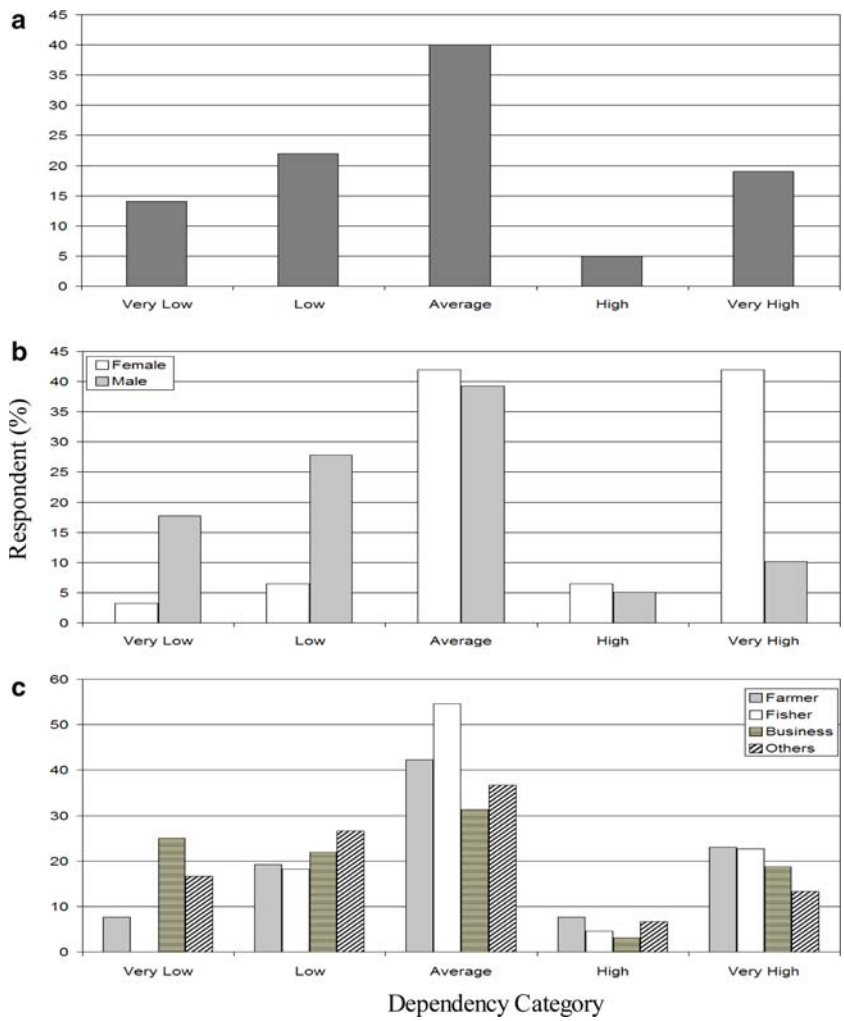

Fig. 6 Proportionate distribution of the respondent households according to their dependency on the ecosystem in comparison to their neighbors. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June-July 2006. The respondents were asked to identify their households into a fixed category depending on their dependency on the mangrove in comparison to their neighbors. Here, (**a**) overall dependency on the forest, (**b**) dependency on the forest according to gender categories, (**c**) dependency on the forest according to different livelihood categories (to run the χ^2-test dependency categories were reduced to low, average, and high dependency categories)

perception of dependency on mangroves is significantly different among gender (χ^2 = 19, d.f. = 4, $P < 0.01$) and different livelihood groups (χ^2 = 12.44, d.f. = 6, $P < 0.10$). Dependency of the household on the forest has a significant negative relationship with household condition ($r_s = -0.65$, $N = 110$, $P < .01$), the number of literate member in the household ($r_s = -0.55$, $N = 110$, $P < .01$), land occupancy ($r_s = -0.25$, $N = 110$, $P < .01$) and family size ($r_s = -0.19$, $N = 110$, $P < .05$). It has a weak non-significant negative relationship with number of earning members in the family ($r_s = -0.07$, $N = 110$, $P = 0.47$), time of residence on the island ($r_s = -0.14$, $N = 109$, $P = 0.14$) and distance of the household from the forest ($r_s = -0.10$, $N = 110$, $P = 0.30$) (Fig. 7), which reinforces the idea that with improving socio-economic condition people become less dependent on adjacent natural resources (Dasgupta 2001). Moreover, female-headed households have higher dependence on the forest than male-headed households. This supports findings of other studies (Steele et al. 2006) which show that in developing countries female-headed households are more dependent on natural resources generally due to their impoverished condition.

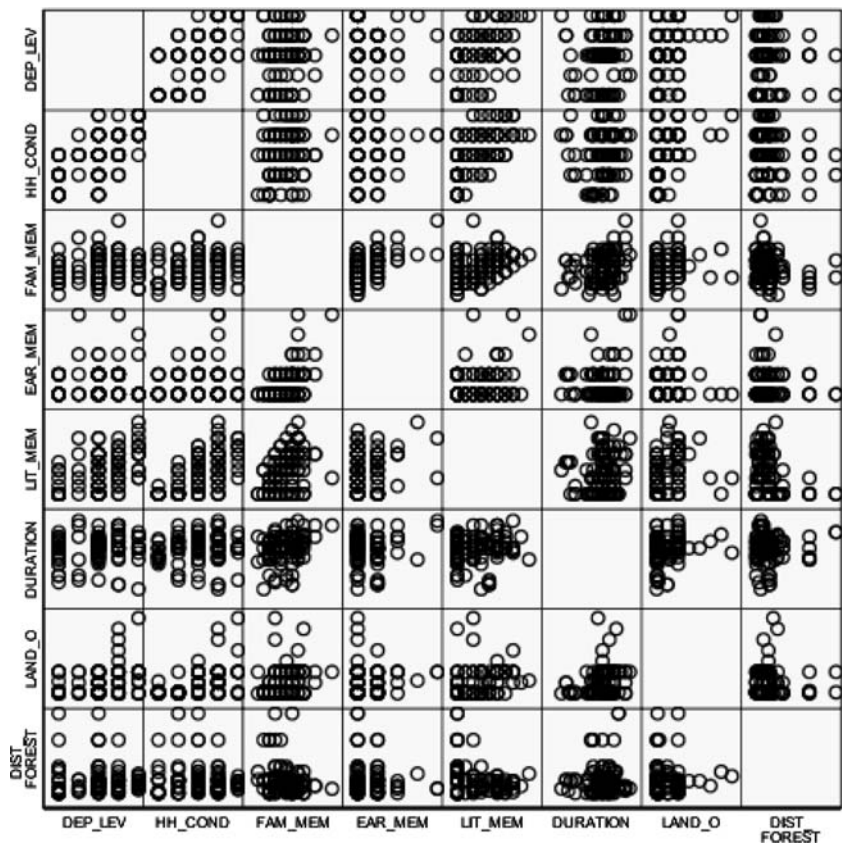

Fig. 7 Scatter Plot diagram showing the relationship among dependency of the household on the mangrove ecosystem and some socio-economic variables of the respondent households. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked about the above-mentioned parameters. Here, DEP_LEV = Dependency of the respondent household on the mangrove ecosystem in comparison to their neighbors (see Fig. 6 for distribution), HH_COND = Household condition of the respondent households in comparison to their neighbors, FAM_MEM = Size of the respondent household (range: 2–20, mean: 7 ± 3), EAR_MEM = Number of earning members in the family (range: 1–5, mean: 2 ± 1), LIT_MEM = Number of literate members in the family (range: 0–12, mean: 3 ± 3), DURATION = Duration of stay in the island (in year) (range: 2–32, mean: 20 ± 6), LAND_O = Land occupied by the respondent household (in Ha) (range: 0–2.83, mean: 0.41 ± 0.51), DIST_FOREST = Minimum distance of the household from the forest (in meter) (range: 0–3000, mean: 480 ± 551)

Importance of mangroves

The respondents were asked to identify the three most important services of the mangrove ecosystem for each of the different categories of needs: personal, social, and national. The most frequently mentioned service was supply of raw materials (57% of the responses), followed by prevention against natural disasters (13% of the responses), climate regulation (13% of the responses), and soil retention (12% of the responses). A substantial portion of the respondents perceived the ecosystem as an important local resource base for livelihoods and economic development (Fig. 8). The main services they get from the ecosystem could be classified as follows (after de Groot et al. 2002).

- Regulation functions and related ecosystem services: The ecosystem plays an important role in the regulation of ecological processes of the island. Some of the most important regulation functions of the mangrove ecosystem as perceived by the respondents were contributions to the physical climate system (such as maintaining the balance of oxygen and carbon dioxide and controlling temperature), acceleration of land accretion, prevention of soil erosion, protection against natural disasters like cyclones and storm surges, and maintenance of soil fertility.
- Habitat functions and related ecosystem services: The ecosystem provides living space for many local, introduced and migratory species. It is providing shelter to a large number of deer, which were introduced in the island during 1980s. Many cows, buffalos, and dogs have developed wild foraging groups. Creeks and small canals inside the forest provide habitat and refuge for many aquatic species. Moreover, every winter large numbers of migratory birds visit the island.
- Production functions and related ecosystem goods and services: The ecosystem provides many resources, like fuel-wood, timber, construction material for houses, furniture, agricultural equipment, fishing boats, fishing equipment, fences, small poles, and wood for bridges, as well as medicinal plants, honey, and fisheries.
- Information functions and related ecosystem goods and services: The respondents identified the ecosystem as important for tourism and local recreation. The island has become a major tourist attraction of the country, with thousand of tourists visiting every year. This contributes greatly to the local economy.

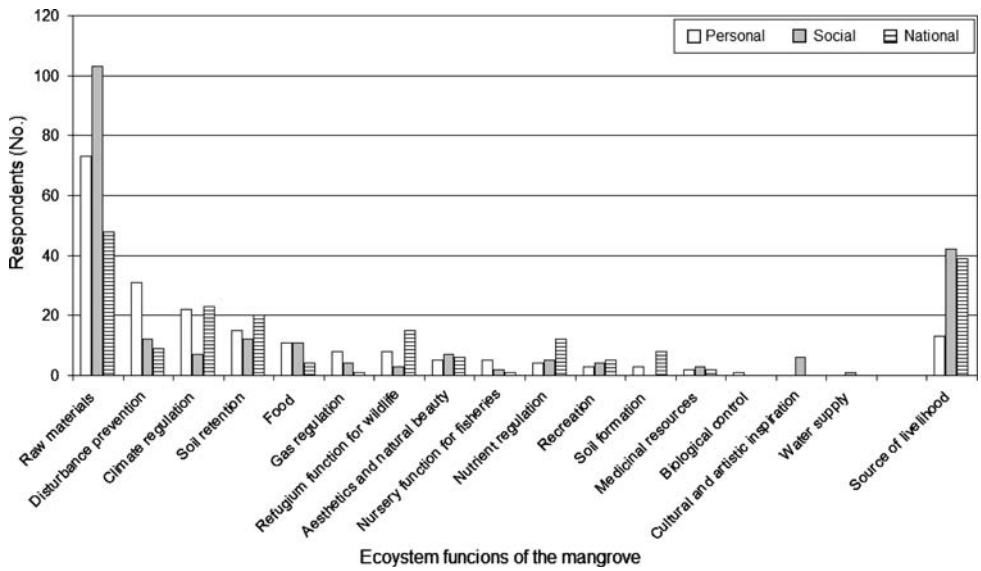

Fig. 8 Ecosystem functions of the mangrove of Nijhum Dwip as perceived by the respondents. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked to identify three services of the mangrove ecosystem, which are most important to satisfy each of his personal, social, and national need

The relative importance of the above-mentioned services for different categories of human needs (personal, social, and national) all show strong positive correlation (r_s = 0.77, N = 13, P < .01 (personal: social), r_s = 0.62, N = 14, P < .01 (personal: national) and r_s = 0.70, N = 13, P < .01 (social: national)), respectively. Moreover, uses of the ecosystem also change with ecosystem age and maturity. At immature stages, the plantation is most useful for new land accretion and nutrient trapping. At mature stages, the forest provides timber, fuelwood, food, fodder, and land for grazing. At overmature stages, it provides timber and land for agriculture, aquaculture and settlement. This indicates that people tend to prefer more exploitative uses at the mature stage of the plantation (Ewel et al. 1998). This could be a deterring factor for long-term sustainability as people might be tempted to utilize the economic potential of the ecosystem through more exploitive uses (Angelsen and Wunder 2003).

Status of the ecosystem

Many respondents (80%) remarked that the ecosystem was not in good condition (Fig. 9). This perception did not vary among different livelihood groups, gender or forest dependency categories (tested through χ^2-test), except among household conditions (χ^2 = 9.16, d.f. = 4, P < 0.10; household categories were combined into poor, average and good and ecosystem status categories to bad, average and good). This perception reflects a very strongly shared concern about the degraded condition of the ecosystem.

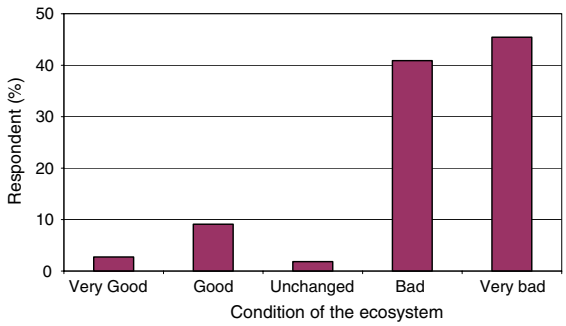

Fig. 9 Peoples' opinion on the condition of the ecosystem. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked about their opinion on the condition of the ecosystem

The respondents identified many causes for such degradation. Encroachment due to land uses such as agriculture, settlement, aquaculture, grazing appeared to be the main cause of forest degradation (Fig. 10). The destitute people who encroach on the forest were influenced by different push factors such as river erosion, natural disasters, population pressure, insufficient employment opportunities, and also pull factors such as the desire to get their own land and local elites' assistance. Pseudo-encroachment by the local elites or influential persons was also a major factor. Usually they do not live on the land, but sell it to others. Illicit felling for multiple uses such as fuel, construction materials, and fishing equipment, was another major cause of degradation. Non-timber forest resources, like fish, are often collected without any permission. Natural disasters such as cyclones, storms and erosion also cause severe damage to the forest. It had been observed by the respondents that during the 1991 cyclone many large trees were uprooted and many wild animals (especially monkeys) were killed. Wild animals, some of which may have increased beyond a threshold level, can negatively influence vegetation dynamics (Sheremet'ev and Prokopenko 2006). For example, the increasing number of deer may be a reason behind the gradual decline of *Sonneratia* seedlings (Siddiqi and Khan 2004).

Perception and knowledge on forest management

A few questions were asked to assess attitude and knowledge of the respondents about current forest management practices. Around half of the respondents knew that the forest was a national park and had heard about the Forest Act. Less than half of them thought that the islanders had good relations with the forest officials. Almost all of them believed that the forest could be better protected and that people should be allowed to participate in forest management decision-making. On the contrary, no one thought that the forest would remain unchanged over the next 30 years time due to different change agents and drivers. Around two-third of the respondents thought that the forestland had more suitable alternative uses (Fig. 11). These issues are elaborated below.

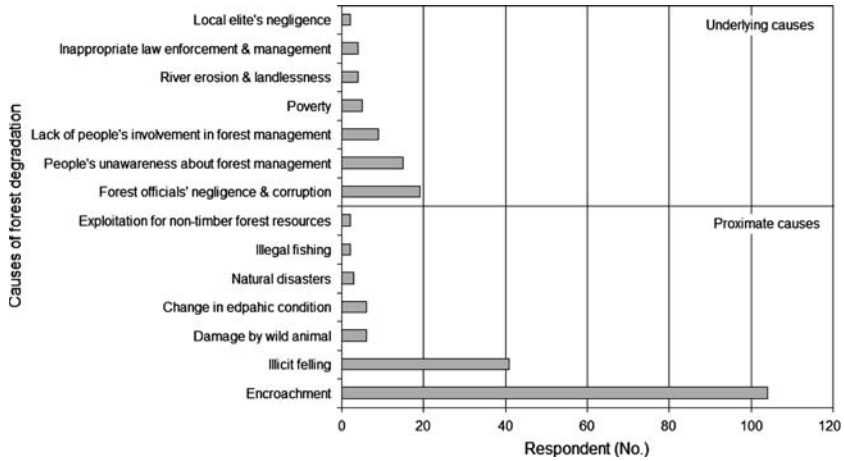

Fig. 10 Peoples' opinion on the main causes of forest degradation. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked whether they think the forest is degrading. The respondents with positive response were requested to identify five major causes of such degradation and their underlying causes

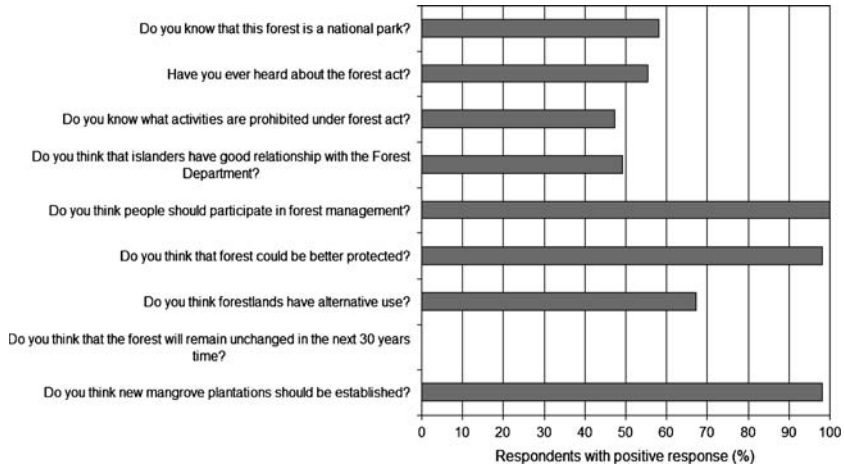

Fig. 11 Peoples' knowledge and attitude towards aspects of forest management. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked the questions

Major stakeholders and suggested measures to improve forest management

It has been apparent from interviews and discussions that the local people have an intricate relationship with the Forest Department. They depend on the forest to a large extent. Sometimes forest officials try to control their access; however, quite often they take advantage of corrupt practices within the Forest Department to illegally encroach, pilfer and collect fuel wood and other raw materials from the forest. Not all sections of the society get equal advantage, as quite often the poorest are criminalized and punished while local elites are not.

The respondents suggested a range of measures to improve the forest condition. Some of these were related to conventional forest management, such as enhancing forest wardening, evicting encroachers, restoring habitat through enrichment planting and zoning, as well as adopting forest management approaches such as social forestry and participatory management. Other suggestions included the overall improvement of the socio-economic condition from employment generation, to alternative sources of energy, and managed settlement for the landless (Table 3). The respondents also identified a range of stakeholders who could be involved in such activities. The police department and land administration affect forest management through their regular activities, while the local government affiliates largely determine development activities in the locality. Political parties exercise power through local and national governments with local elites and civil societies influencing the decision-making process. On the other hand, households with a high dependence on the forest are largely affected by any forest

Table 3 Peoples' suggested measures to improve the condition of the ecosystem

Conventional forest management	Participatory forest management	Beyond forestry sector
• Adequate manpower and security	• Awareness of the local people, politicians & elites	• Better communication infrastructure
• Adopt appropriate forest policy	• Disseminate environment message	• Declare Nijhum Dwip as tourist spot
• Enhanced forest guarding	• Environmental education	• Deploy police, armed force
• Enhanced supervision	• Form a social movement to protect the forest	• Employment
• Eviction of encroachers	• Share forest ownership with local people	• Enhance population control measures
• Habitat restoration through enrichment planting, underplanting	• Social forestry	• Prevent child marriage
• Improved forest management	• Training and motivation	• Proper land use policy
• Increase Forest Department's power		• Provide alternative sources of energy like solar
• Introduce more wild animals		• Reduce corruption of forest officials
• Plantation in newly accreted areas		• Reduce river erosion
• Proper training		• Release established land for settlement
• Protect migratory birds		• Settlement of landless
• Reduce political and other influence		
• Reformation of the FD		
• Zoning, area demarcation and fencing		

Source: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked whether they think that the condition of the ecosystem could be improved. Respondents with positive response were requested to provide three suggestions

management activity. Incorporation of all these major stakeholders was highly recommended by the respondents (Fig. 12).

Alternative uses and future of the ecosystem

Considering factors like increasing population, changing economic activities, competing land-uses and low return from forest trees, around two-thirds of the respondents think that the forestland could be utilized alternatively in a more profitable way. According to them planting of mainland species, which have high timber value and multiple utilities, could be profitable for both the people and government. Many respondents also asked for permanent conversion of the forestland into farmland, settlement and aquaculture ponds (Fig. 13).

This is not surprising then that all of the respondents were afraid that the forest would not remain the same over the next 30 years time. Factors like encroachment, illicit felling, farming, and land maturation will continue to degrade it with cumulative effects. The immediate effect will be on the trees and wildlife, which are already disappearing. Ultimately, this locally rich biodiversity will decline with potential impact on the local environment and peoples' adaptive capacity (Fig. 14).

Phase shift of the ecosystem and options for future management

Over the last four decades, a complex mangrove socio-ecological system has formed in Nijhum Dwip through simultaneous plantation establishment and independent human settlement (Anderies et al. 2004). The settlers have developed a nested social subsystem linked to the mangrove plantations (Folke 2006), which were originally established as a conventional top–down government project (Saenger and Siddiqi 1993). Recently the changes in social sub-systems, such as demographic, socio-economic, and land-use changes, have out-paced the development

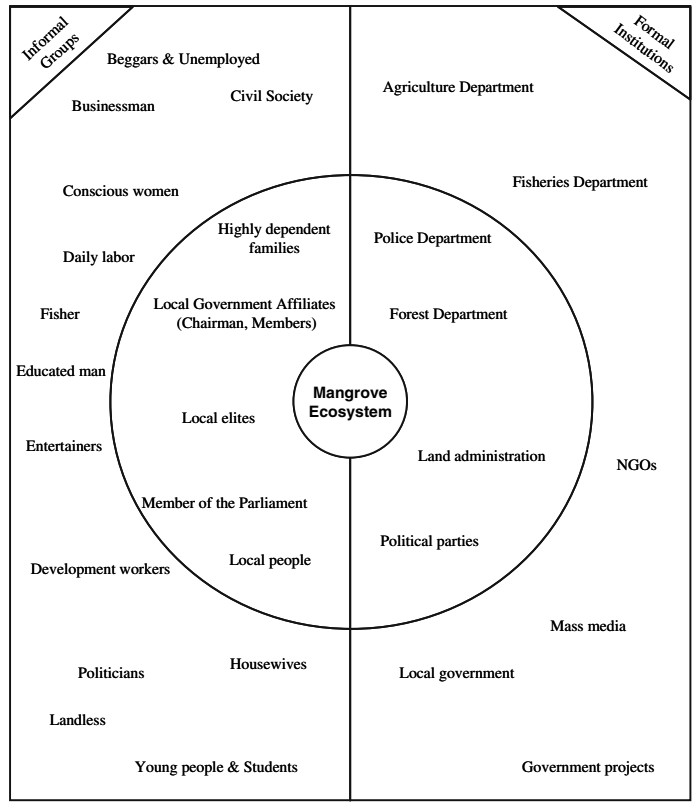

Fig. 12 A schematic diagram on the major stakeholder groups for management of the mangrove ecosystem in Nijhum Dwip Island. *Source*: Structured interview of 110 households and seven group meetings in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked to identify five most important stakeholders who are or might be involved in forest management. Here, the names inside the circle indicate the groups/ institutions with direct strong influence on the forest. Others outside the circle indicate those having indirect influence on the forest

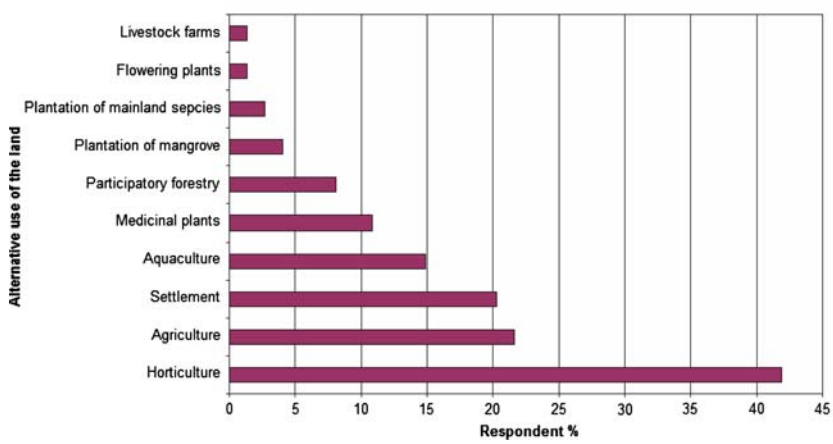

Fig. 13 Alternative uses of the forestland as suggested by the respondents. *Source*: Structured interview of 110 households in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked whether they think the forestland has alternative uses. The respondents with a positive response were requested to identify three alternative uses

of plantation and natural ecological systems with potential consequences on local biodiversity and the landscape (Wilson 2006). The ecosystem is entering into a degradation phase now. The government has already taken a conventional approach to protect the ecosystem. The area has been declared as a National Park and interventions are being planned (PDO-ICZMP 2004). However, both discussions with the respondents and as well as lessons from other parts of the country (Ali 2002) have revealed some inadequacies of this approach. First of all, changes in the hydroedaphic condition are making the land unsuitable for *Sonneratia* (Das and Siddiqi 1985). Second, continuous river erosion in other locations is causing migration of people around the island with subsequent encroachment and changes in land use

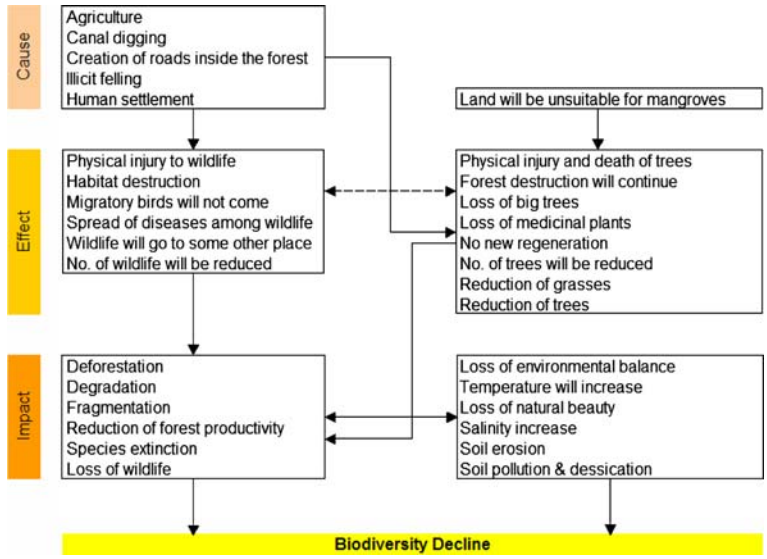

Fig. 14 A schematic diagram on the future scenario of the mangrove ecosystem of Nijhum Dwip. *Source*: Structured interview of 110 households and seven group meetings in the Nijhum Dwip Island executed during June–July 2006. The respondents were asked whether they think the ecosystem will remain unchanged in the next 30 years time. The respondents with negative response were requested to identify three major likely changes and their causes

(Douglas 2006). Meanwhile, if forest laws are applied strictly, islanders may suffer due to their high dependence on forest resources, resulting in increased conflict and further degradation (Kovacs 2000). Lastly, the prevailing socio-economic condition of the country will most likely impede the government from allocating adequate resources to improve ecological and social systems simultaneously (Hammond 2006).

Adaptive co-management is promoted as a pragmatic approach to deal with situations involving complexity and uncertainty (Sutherland 2006). This type of management may be defined as a process (Folke et al. 2002) or a structure (Ruitenbeek and Cartier 2001) that allows stakeholders to participate and share the responsibilities and benefits of management and to learn from their actions through trial and error. The mangroves of Nijhum Dwip have clearly defined system boundaries with the potential for the development of collective decision-making arrangements (Berkes 2006), monitoring, and conflict-resolution mechanisms (Schreiber et al. 2004). Though adaptive co-management is essentially a bottom-up approach, it can be assisted by creating an enabling environment (Berkes 2004). Through a partnership with major stakeholders (see Fig. 12), the government can recognize the rights of the islanders to set rules and working principles for forest management (Olsson et al. 2004). A participative management framework allows greater opportunities for the ecological integrity of the mangroves to be maintained, while economic and ecological potentials can be gradually realized through sustainable use and equitable distribution of benefits (Ostrom 1990).

Concluding remarks

In summary, in Nijhum Dwip mangrove plantation program has been successful in achieving its original objectives. The system, however, appears to be entering into a declining phase due to changes in ecological, hydroedaphic and social conditions. In order to arrest this trend, positive feedback loops that promote comprehensive actions to increase resilience will be required. An adaptive co-management system may be developed to govern the local resource base.

Nijhum Dwip warrants further study, however, as the present study has limited scope in commenting on the ecological dynamics of the ecosystem. It has also not been possible to explore the economic aspects of the system. Therefore, long-term studies with greater spatial and temporal extent and with greater economic, ecological breadth are recommended.

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