Ocean & Coastal Management 71 (2013) 225–237

Contents lists available at SciVerse ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

# Are the mangroves in the Galle-Unawatuna area (Sri Lanka) at risk? A social-ecological approach involving local stakeholders for a better conservation policy

Behara Satyanarayana [a,b,c,d], Sara Mulder [e], Loku Pulukkuttige Jayatissa [f], Farid Dahdouh-Guebas [a,b,*]

[a] Laboratory of Systems Ecology and Resource Management, Département de Biologie des Organismes, Faculté des Sciences, Université Libre de Bruxelles – ULB, Avenue Franklin D. Roosevelt 50, B-1050 Brussels, Belgium
[b] Laboratory of Plant Biology and Nature Management, Mangrove Management Group, Vrije Universiteit Brussel – VUB, Pleinlaan 2, B-1050 Brussels, Belgium
[c] Institute of Oceanography, University Malaysia Terengganu – UMT, 21030 Kuala Terengganu, Malaysia
[d] Malkolak Knowledge Centre (Marine Studies Division), Hyderabad - 500034, India
[e] Department of Social Sciences, Wageningen University, Wageningen, The Netherlands
[f] Department of Botany, University of Ruhuna, Matara, Sri Lanka

ARTICLE INFO

*Article history:*
Available online 26 October 2012

ABSTRACT

Despite the known ecological and economic importance of mangrove ecosystems, research is still lacking as to what extent local populations depends on various forest products, or how this might be related to their economic status (i.e. poor, middle and rich), age, or gender (male and female) relations. In the present study, the percentage of people depending on such resources in the Galle-Unawatuna area (Sri Lanka) for their subsistence needs was assessed through a survey. The results indicated that local people rely on mangroves to a greater extent for fishery products, fuelwood, and edible plants, than for house/boat construction material, medicinal and other non-timber forest products. All people under the poor, middle and rich categories use mangrove resources, although greater dependency of the poor is common. In relation to age, the mangrove resources utilization was high among old (>60 years) people. A gendered division of labor indicating the men involved in fishery-related activities and women in edible plant collection was observed. In addition, the use of mangrove resources is not necessarily poverty-driven: preference and tradition also play important roles.

However, the physical infrastructure developments (i.e. construction of a cement factory, dam and road) have had several negative impacts ranging from water quality deterioration and dynamic shifts in mangrove vegetation to reduced fish production in the vicinity. Given our results, possible amendments to the existing rules governing forest conservation are recommended in order to provide long-term benefits for local livelihoods as well as ecosystem.



## 1. Introduction

Mangroves are distributed all over the (sub) tropical coastlines and play a significant role as nursery grounds for fish and biomass production, and in the local livelihoods as well as coastal protection (Adeel and Pomeroy, 2001; Primavera et al., 2004; Mumby et al., 2004; Dahdouh-Guebas et al., 2005a; FAO, 2007; Walters et al., 2008; Feagin et al., 2010; Bayas et al., 2011; Satyanarayana et al., 2012). However, they gained renewed attention after the incident of Indian Ocean tsunami (26 December 2004) that caused vast devastation across Southeast and South-central Asia (Dahdouh-Guebas, 2006; Dahdouh-Guebas and Koedam, 2006; Baird, 2006; Barbier, 2006, 2008; Alongi, 2008; Osti et al., 2008; Ellison, 2008). In this context, several researchers found that there was less destruction to both people and property in mangrove areas that had not previously been degraded (Dahdouh-Guebas et al., 2005b; Roy and Krishnan, 2005; Williams, 2005; Stone, 2006; Chang et al., 2006; Quartel et al., 2007; Tanaka et al., 2007; Cochard et al., 2008; Sanford, 2009; Teh et al., 2009; Yanagisawa et al., 2009).

On the other hand, loss of mangroves is substantial in many parts of the world due to lack of awareness or of perseverance in conservation and management strategies already implemented and/or proposed (Farnsworth and Ellison, 1997; Foell et al., 1999; Primavera, 2000; Kovacs, 2000; Armitage, 2002; Dahdouh-Guebas et al., 2002, 2005b; Feagin et al., 2010). This is not exceptional, since

* Corresponding author. Laboratory of Systems Ecology and Resource Management, Département de Biologie des Organismes, Faculté des Sciences, Université Libre de Bruxelles – ULB, Avenue Franklin D. Roosevelt 50, B-1050 Brussels, Belgium. Tel.: +32 (0) 2 6502164; fax: +32 (0) 2 6502125.
*E-mail address:* fdahdouh@ulb.ac.be (F. Dahdouh-Guebas).

0964-5691/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ocecoaman.2012.10.008

mangroves are often located close to densely populated urban or rural settlements, which ensures constant pressure on these ecosystems (Dahdouh-Guebas et al., 2002; Mohamed et al., 2009). At the same time, when considering the interaction between humans and ecological components (Crona et al., 2010), one should not underestimate the functions that mangrove ecosystems play in local livelihoods (Farnsworth and Ellison, 1997; Armitage, 2002; Duke et al., 2007; Walters et al., 2008; Mangora, 2011). Therefore, the information about different trade-offs and priorities should be taken into account with the aim to develop better mangrove management policies (FAO, 1994; Nickerson, 1999). Data on ecological and socio-economic aspects (which remains unavailable or outdated in many cases creating a knowledge gap) are indeed essential for appropriate planning and conservation of coastal and marine habitats (Bart, 2006; Ban et al., 2009; Weeks et al., 2010).

In Sri Lanka, several policies and regulations were formulated to protect forests and biodiversity (FAO, 1997). After assessing the impacts of forest cover loss on climate and the environment, further actions have been taken to strengthen the conservation efforts and improve law enforcement (De Zoysa, 2001). However, no efforts seem to have been made to monitor and manage the Galle-Unawatuna area, where conservation policies and regulations are not widely implemented. The dynamic shifts observed in this mangrove ecosystem are due to considerable human encroachment over the last 50 years (1956–2004) (e.g. conversion to agricultural fields, settlements, and construction activities) (Dahdouh-Guebas et al., 2000a; Dahdouh-Guebas and Koedam, 2002; Dahdouh-Guebas et al., 2005b; Satyanarayana et al., 2011). This has raised several scientific *questions – whether or not the local households in Galle-Unawatuna really need mangrove resources for their subsistence, whether or not the observed ecological changes have had any adverse effects on the households that depend on mangroves,* and *whether or not it is important to protect this area finally.*

This paper is aimed at addressing the above questions, and first analyses the socio-economic importance of Galle-Unawatuna mangroves for different categories of people, e.g. in relation to age, gender and economic status (§3.2–§3.5 and §4.1–§4.4). Second, the impacts of physical infrastructure development (i.e. the construction of a cement factory, dam and road) on mangroves as well as on local peoples' livelihoods were assessed (§4.5). Finally, after evaluating both the importance of mangrove resources and the impacts of such developments in this area, we turn to a discussion of the need for a better mangrove conservation policy, with possible changes in the existing rules (§4.6).

## 2. Material and methods

### 2.1. Study area

The Galle-Unawatuna mangroves (~1.5 km$^2$) (06°01′N and 80°14′E) are located in the wet climatic zone of Sri Lanka (Fig. 1). It is generally hot and humid, with an average annual temperature of 21.1–32.2 °C, and intense rainfall between May and November (Ashton et al., 1997). The mangroves are represented by *Rhizophora*

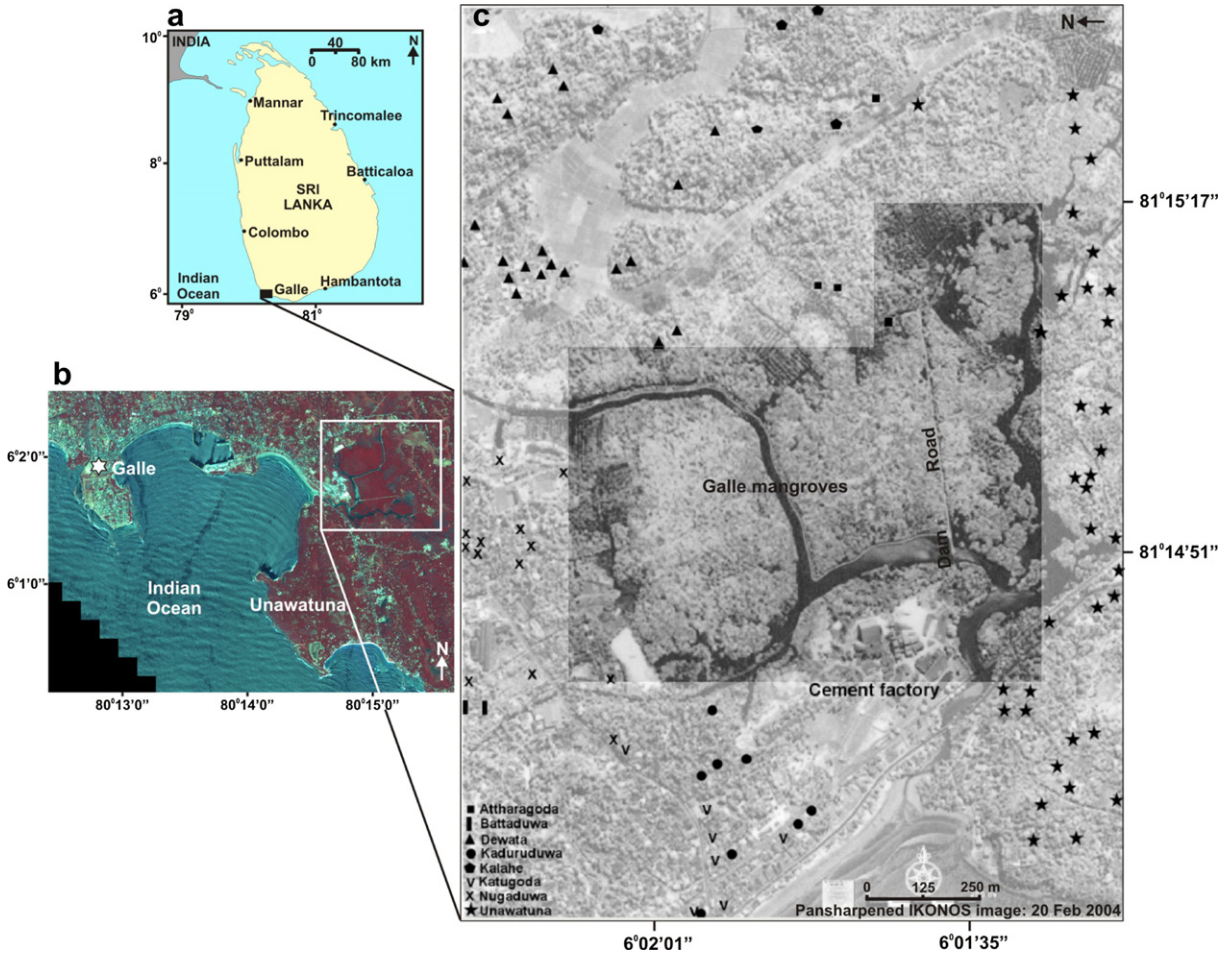


**Fig. 1.** (a) Location of Sri Lanka, (b) Galle-Unawatuna on the south coast of Sri Lanka (2004 IKONOS multispectral satellite image) and, (c) the study area of Galle-Unawatuna (2004 IKONOS panchromatic image) showing mangroves (in dark toned area) and the 95 households interviewed in the 8 villages adjacent to the mangroves (black symbols).

*apiculata* BL., *Rhizophora mucronata* Lamk., *Bruguiera gymnorrhiza* (L.) Lamk., *Bruguiera cylindrica* (L.) Blume, *Excoecaria agallocha* L., and *Sonneratia caseolaris* (L.) Engler. The areas dominated by these 'strict' or 'true' mangrove species (*cf.* Tomlinson, 1986), with their fidelity to the ecotone influenced by tides, are generally referred to as 'core' mangrove zones (Kathiresan and Bingham, 2001) and, in most cases, their degradation is associated with human activities (Singh et al., 2010). According to Sri Lanka's Department of Forest Conservation, the Galle-Unawatuna area falls under the category of 'state forests' where no activities, except for traditional fishing for local human consumption, are legally permitted (DWC, 2009).

### 2.2. Sampling

Sampling (July–October, 2004) was carried out using a semi-structured questionnaire (Appendix A), based on simple random sample (SRS) design (Poate and Daplyn, 1993). The head of ninety-five households living in eight villages (Attharagoda, Battaduwa, Dewata, Kaduruduwa, Kalahe, Katugoda, Nugaduwa and Unawatuna) adjacent to the mangroves of Galle-Unawatuna in Galle District were interviewed (Fig. 1). The sample size represented seven percent of the total (1394) number of households and five percent of the total (10,198) population in the villages (DCS, 2003).

The mangrove resources utilization was assessed by the percentage of people who responded positively (during the questionnaire survey), and depend on Galle-Unawatuna area for their livelihoods.

Factors such as age, gender (male or female), religion, education and economic status (poor, middle or rich), of the interviewed people were also considered. The 'poor', 'middle' and 'rich' categories are defined by house construction material (i.e. clay, wood or cement used for building walls) and certain assets (e.g. motorized vehicle, telephone, television, refrigerator, etc.) to which the households have access (*cf.* Ellis, 2000). The 'age' and 'gender' have been highlighted to establish the relationship between mangrove resources use with respect to local people's age, and to identify male/female involvement in natural resources collection, respectively. When discussing trends in mangrove resources and their use, the terms 'past' and 'present' were used by the interviewer to ask people's perception of time. However, since keeping track of time was difficult for some respondents and the term 'past' was relative, we interpreted the results with caution and using back-up form secondary data. The secondary data we used were published papers, Dahdouh-Guebas et al. (2000a, 2005a, 2010), Satyanarayana et al. (2011).

### 2.3. Timber and non-timber forest products from mangroves

The head of households were interviewed about their use of mangroves as construction material (for making boats or houses, fishing stakes, etc.), fuelwood, medicinal and edible plants, and about other non-timber forest products (masks, hats, and ornaments). In the case of fuelwood, questions were asked about their preferences for mangrove wood (including for personal use and for sales), in contrast to wood from non-mangrove trees and/or non-woody resources such as gas and kerosene. In addition to the data obtained from questionnaires, other methods were used, such as personal observation (to verify in the field), free listing (to determine the mangrove species used for fuelwood), plant identification (to cross-check species identity comparing local people's knowledge, vernacular names, and scientific literature), and mapping (to distinguish the areas of exploitation) (*cf.* Cotton, 1996). The same methods were used to identify the role of mangroves as suppliers of edible plants (with emphasis on its uses, collection, selling practices, and people's preferences), together with reasons for decreased consumption over time.

### 2.4. Fish resources from mangroves

Apart from the interviews, we also paid attention to local observations and personal eyewitness accounts of fishery-related activities in the area. People were found to be relatively more involved in mangrove fisheries compared with fuelwood and/or edible plant collection.

### 2.5. Physical infrastructure development and the perceptions of their consequences

The cement factory, dam and road constructions in the vicinity (Fig. 1) have presumably exerted substantial pressure on the Galle-Unawatuna mangrove ecosystem. The Ruhunu cement factory was constructed in the neighborhood of the mangrove in 1967, and has been under the management of Holcim (Lanka) Ltd. since 1999. It is intended that the factory will deliver maximum production (around one million tons per year) in such a way that it conforms to international standards and is sustainable (U. Gamage, Manager Galle Operations, personal communication). Both the dam (across the River Galu Ganga) and road (providing access to dam through the middle of the mangroves) were built by the Dept. of Irrigation (1985) to prevent paddy fields from being flooded by seawater intrusion in an area slightly upstream of the mangroves. The dam gates are supposed to open in accordance with the level of water in the streams (Kumara Ranasingha, District Irrigation Engineer, Galle, personal communication). It is worth mentioning that neither the mangroves nor the villages where this study was conducted were affected on the long-term by the Indian Ocean tsunami (Dahdouh-Guebas et al., 2005b): in February 2006, the dam and the road appeared like before and also the cement factory was operational (personal observation). Tsunami witness accounts indicated that the mangrove forest had protected lives and properties located behind the vegetation (Y.L. Michael Vijedasa, personal communication).

Local people's opinion about the changes that they observed and experienced in this environment were collected via interviews (i.e. open questions evoking qualitative responses) (Appendix A). Then, in addition to the irrigation and cement factory authorities cited above, other stakeholders i.e. Forestry Department officials and scientists working in this area, were consulted to have their opinions about the importance of the mangroves for household subsistence, to assess the changes in this mangrove ecosystem due to physical infrastructure developments, and to improve conservation policy in relation to local peoples' livelihoods.

### 2.6. Data analysis

Information obtained during the survey was entered into SPSS *v.*13 to produce the frequency tables and clustered column charts. The results were also processed using Bayesian statistics (i.e. prior, likelihood and posterior probability) with "LearnBayes" package of R software *v.* 2.15.1 (R Development Core Team, 2011) to observe the statistical significance of respondents (in relation to age, mode of resources collection, etc.) versus mangrove use. In this context, possible predictions on the number of mangrove users and their utilization patterns were expressed by the Bayesian posterior probability. Chi-square ($\chi^2$) was used to test the statistical difference between two datasets (e.g. past and present).

## 3. Results

### 3.1. Demographic information

Among the interviewed population, most people are Buddhist (79%) and many houses are headed by males (89%) (female headed

households: 11%). Also, more than half of those interviewed had completed either senior secondary school (Grade 11) or college education (Grade 13).

### 3.2. Observations about mangrove forest product use

The present study indicated that 66% of the interviewed households in Galle-Unawatuna area were using mangrove resources at the time of the study, whereas seven households (about 10%) had stopped (Table 1). However, the Bayesian (posterior) probability is indicating a chance for more resource users (up to 73%) in the near future. Fig. 2 shows the household's percentage of dependence on various forest products in the past and in the present. People often mentioned more change in their use of mangrove fuelwood, edible plants, and fish products compared with the use of construction material, medicinal and other non-timber forest products. A decrease of 40–60% in the fuelwood and medicinal use categories was recorded compared to 0–16% in other categories ($\chi^2 = 2.22$; d.f. = 1; n.s.) (Fig. 2).

People obtained mangrove resources through purchase, personal collection, or both (Table 2). The number of people purchasing mangrove products was considerably higher (52%) than the number collecting and, among the 30 households obtaining mangrove resources partly or totally through collection (Table 2), only seven were selling such goods on the local market. If the usage of mangroves is compared with age of the respondents, higher utilization was found among the old people (Table 3). The Bayesian probability shows that current mangrove usage may increase in 60–69 years age class (from 64 to 81%), and decrease in >70 years age class (from 92 to 86%). The households with 60 years and above aged people indicated that they purchase mangrove products, whereas others (i.e. people aged between 20 and 49 years) were involved in both collection as well as purchase.

In the case of economic status, most of the population (80%) could be considered as middle class (houses made of clay/wood with limited facilities), followed by the rich (11%) (houses made of cement and with good facilities), and the poor (9%) (houses made of clay/wood with no facilities), respectively. All people under these three categories used mangrove resources at the time of the study, although the poor are more dependent (Table 4). On the other hand, mangrove resource use was remarkable among the rich people, who purchased, rather than collected, mangrove products (Table 5).

### 3.3. Mangrove fuelwood

Following the trend in mangrove fuelwood usage (Fig. 2), a large part of the interviewed households (84%) are still dependent (in partly or fully) on clay-firing kilns (wood stove) for cooking, whereas few (12%) got other options that work with kerosene or gas (Table 6). Although they showed 9 locations for the collection of mangrove fuelwood in Galle-Unawatuna (sites A, C–J in Fig. 3), not many signs of fuelwood collection were witnessed in those places during the period of study. However, some occurrences like the cutting of a large mangrove tree (at site K in Fig. 3), and collection of coconut leaves (*Cocos nucifera* L.) (at site L in Fig. 3) were observed. Many households (~71%) obtain mangrove fuelwood by cutting the trees and shrubs, whereas the rest stated they collect twigs and branches on the ground.

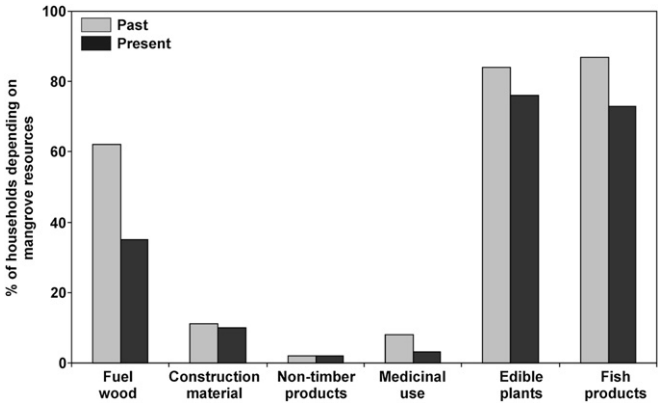


**Fig. 2.** Changes in the utilization of various mangrove resources in the vicinity of Galle-Unawatuna. We emphasize the existence of the change more than the period of time in which the change took place (see methodology).

The respondents have mentioned 8 species names for their fuelwood collection, and a tree called *kadol* (in Sri Lankan's Sinhala language) (that corresponds to *R. apiculata*) was frequently cited. Regular collection of mangrove roots from this species was also observed in the same area during other season (Fig. 4A). The use of other mangrove (e.g. *B. gymnorrhiza*, *E. agallocha*, *R. mucronata* and *S. caseolaris*), and non-mangrove species (e.g. *Cerbera odollam* Gaertn., *Dolichandrone spathacea* (L.f.) K. Schumann, and *Thespesia populnea* (L.) Soland. ex.Corr.) for fulewood was mentioned (Table 7).

### 3.4. Edible mangrove plants

The collection of edible mangrove plants is one of the important uses in Galle-Unawatuna area (Fig. 2). Tender leaves of *Acrostichum aureum* L. (vernacular name: *Karen*) are used for making a typical vegetable curry, and the ripened fruits of *Sonneratia caseolaris* (vernacular name: *Kirilla*) in beverages (Table 8) (Fig. 4B). Throughout time, about half of the interviewed households (51–54%) are purchasing these edible plants (Fig. 4C). As per the Bayesian statistics, this purchasing trend may increase (up to 66%) in the near future. Although the respondents mentioned 10 locations for the collection of edible plants (sites A–J in Fig. 3), only few observations of *A. aureum* collection and sales (in small local shops) were made. While the associated mangrove – *A. aureum* is found widely in the forest, *S. caseolaris* had a restricted distribution and lower abundance.

### 3.5. Mangrove fishery resources

The fishing activities were observed all along the Thalpe Ela and Galu Ganga Rivers in Galle-Unawatuna, with a preference close to the dam (Fig. 1). The fish (e.g. species belonging to *Heteropneustes*, *Mugil*, *Mystus*, *Terapon*, *Tilapia*, etc.), crabs (e.g. *Portunus* and *Scylla*

**Table 1**
The 'past' and 'present' users of the mangrove resources in Galle-Unawatuna area ($n = 95$).

| | Past | | Present | | Change | |
|---|---|---|---|---|---|---|
| | No. of respondents | % | No. of respondents | % | No. of respondents | % |
| Yes | 70 | 74 | 63 | 66 | 7 | 10 |
| No | 25 | 26 | 32 | 34 | 7 | 28 |
| Total | 95 | 100 | 95 | 100 | 7 | 7 |

**Table 2**
Mangrove resources collection in Galle-Unawatuna area ($n = 63$).

| | Frequency | % |
|---|---|---|
| Purchase | 33 | 52 |
| Personal collection | 10 | 16 |
| Purchase and personal collection | 20 | 32 |
| Total | 63 | 100 |

**Table 3**
Mangrove users related to age classes in Galle-Unawatuna area ($n = 95$).

| Age class | Mangrove resources utilization | | | | | |
|---|---|---|---|---|---|---|
| | Yes | | No | | Total | |
| | Frequency | % | Frequency | % | Frequency | % |
| 20–29 years | 7 | 58 | 5 | 42 | 12 | 100 |
| 30–39 years | 12 | 57 | 9 | 43 | 21 | 100 |
| 40–49 years | 15 | 56 | 12 | 44 | 27 | 100 |
| 50–59 years[a] | – | – | – | – | – | – |
| 60–69 years | 7 | 64 | 4 | 36 | 11 | 100 |
| >70 years | 22 | 92 | 2 | 8 | 24 | 100 |
| Total | 63 | 66 | 32 | 34 | 95 | 100 |

[a] No respondents with the age class: 50–59 during the interviews.

spp.), shrimps (e.g. *Metapenaeus* and *Penaeus* spp.), and edible bivalves (e.g. *Saccostrea* and *Polymesoda* spp.) are caught on small scales (using fishing-lines, dip-nets, cast nets, fishing traps, etc.), and sold on the local market or streets (Fig. 4D). Most households reported fish, shrimps, crabs and bivalves (in order of preference) obtained from this mangrove environment (Table 9).

## 4. Discussion

### 4.1. Mangrove resources and their utilization

Though the importance of mangrove ecosystems for human subsistence has been reported before (Rönnbäck, 1999; Saenger, 2002; Walters, 2003; Wattage and Mardle, 2005; FAO, 2007; Nagelkerken et al., 2008; Walters et al., 2008), research on the extent on which the livelihoods of different users depend on certain resources (based on their economic status, age and gender differences) is still lacking. Answering to our first scientific question – *whether or not the households in Galle-Unawatuna really need mangrove resources for their subsistence* (see Section 1), the present study documents the importance of mangroves (along with its substantial commercial value) for local people on the basis of their dependence (66% of the households) (Table 1) as well as involvement (84% of the households) in purchase and personal collection of the available resources (Table 2).

The use of wild (forest) resources by age class is also helpful for making predictions on their future utilization (Ladio and Lozada, 2001, 2004; Howard, 2003; Pieroni, 2003). In view of the higher mangrove usage by old people (Table 3) as well as our predictions on their future utilization, there is a possibility for continued exploitation in the Galle-Unawatuna area. In addition, we corroborated that all people irrespective of their economic status (i.e. poor, middle and rich) use wild resources, but reliance is known to be considerably high among the poor (Overman and Demmer, 1999; Howard, 2003). Besides the higher exploitation and use by poor households (Table 4), remarkable utilization of mangrove resources by the rich people (60%) is also in agreement with other researches elsewhere (Ellis, 2000; Takasaki et al., 2001; Gammage et al., 2002; Daniggelis, 2003; Ertug, 2003). The hypothesis that poor households are mostly involved in forest resources collection, while the richer ones often buy them (Ellis, 2000), is also true in the case of mangroves.

**Table 4**
Mangrove users in relation to their economic status in Galle-Unawatuna area ($n = 95$).

| Economic status | Mangrove resources utilization | | | | | |
|---|---|---|---|---|---|---|
| | Yes | | No | | Total | |
| | Frequency | % | Frequency | % | Frequency | % |
| Poor | 9 | 100 | 0 | 0 | 9 | 100 |
| Middle | 48 | 63 | 28 | 37 | 76 | 100 |
| Rich | 6 | 60 | 4 | 40 | 10 | 100 |
| Total | 63 | 66 | 32 | 34 | 95 | 100 |

In addition to economic status and age criteria, the involvement of people in natural resources collection also differs between men and women (Howard, 2003). However, not many studies were focused on these divisions in the mangrove resources exploitation, only with some exceptions in fishery related activities (Magalhães et al., 2007). This gender-disaggregate information is also crucial for determining the importance of mangroves for local populations. While men are usually involved in household income generation, the women play an important role in household subsistence collection or food preparation (Feka et al., 2011). Moreover, the female subsistence uses were often overlooked in research therefore creating bias in the assessment of the importance of natural resources (Ellis, 2000; Daniggelis, 2003; Howard, 2003; Price, 2003; Turner, 2003). Within the 30 households that collect mangrove resources in this study (Table 2), a gendered division of labor was noticed in which the men (37%) are involved mostly in fishery-related activities and women (43%) in edible plant collection. It has been stated that in many societies the exploitation and use of wild resources (e.g. fuelwood, edible/medicinal plants, nuts and seeds, etc.) belongs to the women's domain (Ellis, 2000; Howard, 2003; Price, 2003).

Yet, the decreasing trend of mangrove resources usage (between past and present) in Galle-Unawatuna area is of great concern. This was further analyzed by means of three household groups i.e. the respondents who never used mangrove resources before, the respondents who stopped using them currently, and the respondents still using mangrove resources, but less than before. The reported reasons for never using mangroves was the large destruction already caused by local people, whereas the discontinued and/or reduced use is due to imposed rules and prohibition, economic deficit, age and health-related factors, recent advancements (e.g. construction activities) and pollution, availability of other resources (e.g. kerosene, gas, etc.), and also changed occupation and feeding habits of the young generation.

### 4.2. Mangrove fuelwood

Among the coastal communities, mangrove fuelwood is one of the major extractable uses (Dahdouh-Guebas et al., 2000b; Glaser, 2003; Walters, 2005; Lopez-Hoffman et al., 2006; Rönnbäck et al., 2007; Walters et al., 2008), but it is also a major threat (along with timber) for the mangroves in Asia and Africa (Hernández-Cornejo et al., 2005). However, to judge the consequences of fuelwood collection and to make appropriate conservation policy, basic information such as importance of this activity for local people, different wood harvesting practices, the mangrove species affected, etc., should be known (Feka et al., 2011).

In the Galle-Unawatuna area, many of the fuelwood users (82%) (Table 6) have declared their preference for mangrove wood due to its burning efficiency, and better taste and flavor when cooking. This could validate the assumption that mangrove use here may not be totally poverty-driven but rather based on preference and tradition. Similar results were reported from India, where government alternatives to mangrove fuelwood were rejected by the local fisherfolks (Dahdouh-Guebas et al., 2006). Principle reasons behind the reduced usage of mangrove fuelwood these days consist of imposed rules/prohibition and the age-related factors. The majority of the respondents (who used to collect mangrove fuelwood in the past i.e. 82% of the interviewed households) claimed that they can also collect fuelwood in their own gardens or buy from the nearby

**Table 5**
Mangrove resources collection based on the people's economic status in Galle-Unawatuna area ($n = 63$).

| Economic status | Mangrove resources collection | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Purchase | | Personal collection | | Purchase/personal collection | | Total | |
| | Frequency | % | Frequency | % | Frequency | % | Frequency | % |
| Poor | 3 | 33 | 4 | 44 | 2 | 22 | 9 | 100 |
| Middle | 24 | 50 | 6 | 12.5 | 18 | 37.5 | 48 | 100 |
| Rich | 6 | 100 | 0 | 0 | 0 | 0 | 6 | 100 |
| Total | 33 | | 10 | – | 20 | – | 63 | – |

shops, whereas others stated that the shopkeepers are now selling mostly non-mangrove wood (due to the imposed ban). Regardless of problems in obtaining the mangrove fuelwood, many have shown their affinity to use it instead of kerosene and/or gas which are expensive.

Jayatissa et al. (2002) identified 20 mangrove species and 18 common mangrove associates along the south-western coast of Sri Lanka. From the discussions with respondents, it was learnt that the most abundant tree in the mangroves is *R. apiculata* or *kadol*, and the vernacular names *sirikanda*, *thelakiriya* and *ela kadol* correspond (after taxonomic identification) to *B. gymnorrhiza*, *E. agallocha* and *R. mucronata*, respectively (Table 7). The dense and hard nature of mangrove wood (with rich tannins) (e.g. *Rhizophora* spp.) is also known popularly for making charcoal or consuming directly as fire-wood (Walters, 2005; Dahdouh-Guebas et al., 2006; Walters et al., 2008). In contrast, the information on mangrove fuelwood trade in this area is still suspicious since there is a lack of eye-witness accounts, disabling us from concluding whether the goods observed originated from this mangrove location (i.e. Galle-Unawatuna) or a nearby area. However, "nearby" areas are located at least 10 km away.

### 4.3. Edible mangrove plants

Wild food plants are not only used by hunting societies, but also by agricultural societies because of their rich contribution to culinary and cultural diversity as well as for food security and nutrition (Cotton, 1996; Price, 2003). In the Galle-Unawatuna area, the reason for cooking the tender leaves of *A. aureum* is that they believe it is healthy, natural (no chemicals and fertilizers involved), enjoyable (it gives coolness to body during summer) and nutritious; whereas the beverage prepared from *S. caseolaris* is healthy as well as tasty. Jayatissa et al. (2006) developed a novel method for using the pulp of *S. caseolaris* in making fruit drink and ice creams that has been patented in Sri Lanka. However, due to technical difficulties, the commercialized (in collaboration with Small Fishers Federation of Lanka - SFFL) product of *S. caseolaris* juice (Fig. 4B) is temporarily unavailable in the local markets (L.P. Jayatissa, personal communication). The non-commercialized version, however, remains available and is prepared by order at the University of Ruhuna (pers. obs.).

**Table 6**
Mode of cooking by the households in Galle-Unawatuna area ($n = 95$).

| Availability of other stoves for cooking | Cooking on wood stoves (clay-firing kilns) | | | | | |
|---|---|---|---|---|---|---|
| | Yes | | No | | Total | |
| | Frequency | % | Frequency | % | Frequency | % |
| Yes | 21 | 22 | 11 | 12 | 32 | 33 |
| No | 59 | 62 | 4 | 4 | 64 | 67 |
| Total | 80 | 84 | 15 | 16 | 95 | 100 |

### 4.4. Mangrove fishery resources

The mangrove ecosystems have been proved important in serving food and shelter for several fin and shellfish communities (Adeel and Pomeroy, 2001; Primavera et al., 2004; Crona and Rönnbäck, 2005; Dahdouh-Guebas et al., 2006; FAO, 2007; Dahdouh-Guebas and Koedam, 2008; Walters et al., 2008; Cannicci et al., 2008; Mwandya et al., 2009). In Galle-Unawatuna area, most of the interviewed households (about 76%) are purchasing fishery products (i.e. fish, crabs, shrimps and bivalves) in connection with their better economic status represented by rich (11%) and middle (80%), than the poor (9%). The recent survey on household income

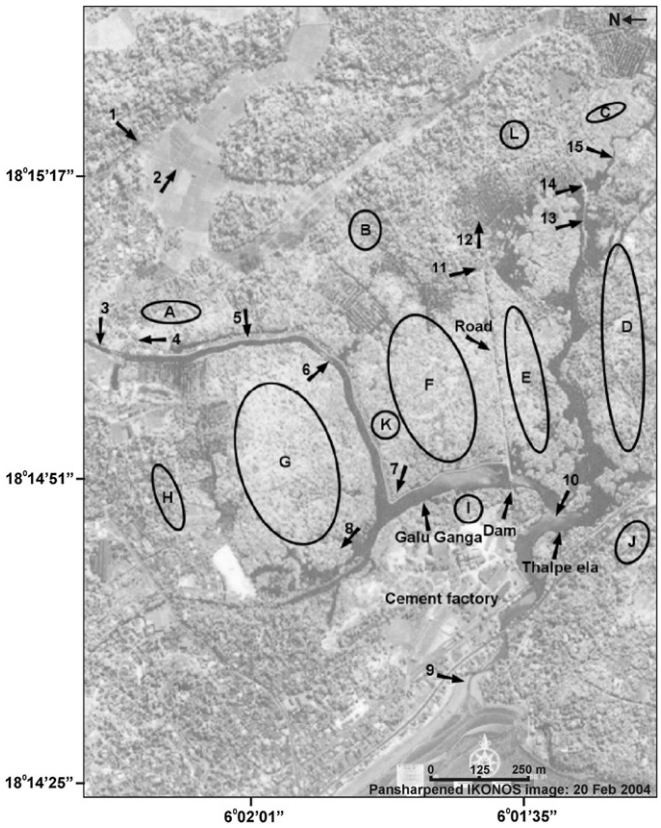


**Fig. 3.** Visual observation on different landmarks in and around Galle-Unawatuna, and the areas for fuelwood and edible plants collection shown by respondents during the household interviews. Landmarks: 1. main road from Galle to Akuressa, 2. road from Attharagoda to the main road, 3. point where the road from Kaduruduwa to the mangroves meeting the river, 4. direction to Kaduruduwa, 5. fishermen houses, 6. bridge to Kaduruduwa, 7. bend in the road from the dam to Kaduruduwa, 8. direction to Dewata, 9. Moya, 10. cement factory junction, 11. Attharagoda junction, 12. direction to Yatagama, 13. seaside of the Unawatuna bridge, 14. Unawatuna bridge and, 15. riverside of the Unawatuna bridge. Areas of exploitation: A, C–J. edible plant and fuelwood collection, B. edible plant collection, K. visual observation of a big tree felled and, L. visual observation of a man collecting coconut leaves.


**Fig. 4.** (A) Photograph showing *Rhizophora apiculata* trees from which the prop roots have been cut for fuelwood collection; (B) bottled drink prepared from the pulp of *Sonneratia caseolaris*; (C) sale of *S. caseolaris* fruits in the local market; (D) the fin and shellfish products obtained from mangrove areas for sale in the local market (the photographs B and C are adopted from Jayatissa et al., 2006).

and expenditure in Sri Lanka (DCS, 2011) also indicated 7.9% households as poor (households with no facilities: 9.1%) in the entire (Galle) district. At the same time, many people point to limestone excavation, and domestic and industrial sewage, including waste from the illegal arrack (i.e. local liquor) distillers inside the mangroves, as a cause for their decreased consumption over the years (overall decrease constitutes 16–19%) (Table 9) (Fig. 2).

**Table 7**
Mangrove and non-mangrove species used for fuelwood collection in Galle-Unawatuna area.

| Vernacular name(s) in Sinhala | Vernacular name(s) in English | Scientific name | Mangrove/ non-mangrove | No. of times mentioned by respondents |
|---|---|---|---|---|
| *Sirikanda* | Large-leafed orange mangrove | *Bruguiera gymnorrhiza* | M[a] | 3 |
| *Thelakiriya* | Blind-your-eye mangrove | *Excoecaria agallocha* | M[a] | 9 |
| *Kadol* | Red mangrove | *Rhizophora apiculata* | M[a] | 15 |
| *Ela kadol* | Asiatic mangrove | *Rhizophora mucronata* | M[a] | 5 |
| *Kirilla* | Mangrove apple | *Sonneratia caseolaris* | M[a] | 1 |
| *Gon kaduru* | Sea mango | *Cerbera odollam* | M-A[b] | 1 |
| *Diya danga* | Mangrove trumpet-tree | *Dolichandrone spathacea* | M-A[b] | 1 |
| *Suriya* | Tulip tree | *Thespesia populnea* | M-A[b] | 1 |

[a] Mangrove.
[b] Mangrove associate.

### 4.5. Physical infrastructure developments and their impact on mangroves and mangrove dependent households

Local people generally will observe changes in the ecosystem where they live if this results in an increase or decrease production of resources (Ward et al., 2000). In Galle-Unawatuna area, many respondents observed ecological changes in relation to the cement factory, dam and road, and more than half of the respondents were concerned about the decreased fish in mangrove water channels due to these factors (Fig. 5). They referred to improper exchange of sea and freshwater (which is known to affect fish migration and breeding in scientific literature) because of dam and road constructions (*cf.* Dahdouh-Guebas et al., 2010), and to the cement factory's air pollution (affecting mangrove and coconut vegetation) and water pollution (mass mortality of fish with the release of sewage). In contrast, some have indicated low or nil pollution due

**Table 8**
List of mangrove and non-mangrove species used as edible plants in Galle-Unawatuna area.

| Vernacular name | Scientific name | Mangrove/ non-mangrove | Frequency | % |
|---|---|---|---|---|
| *Kirilla* | *Sonneratia caseolaris* | M[a] | 10 | 21.0 |
| *Karen* | *Acrostichum aureum* | M-A[b] | 19 | 39.5 |
| Both | | | 19 | 39.5 |
| Total | | | 48 | 100.0 |

[a] Mangrove.
[b] Mangrove associate.

**Table 9**
Mangrove fish products consumption in the past ($n$ = 55) and present ($n$ = 61) timings at Galle-Unawatuna area.

| Preferred mangrove fish product | Past | | Present | | Change | |
|---|---|---|---|---|---|---|
| | Frequency | % | Frequency | % | Frequency | % |
| Fish | 52 | 94 | 42 | 90.5 | −10 | −19 |
| Shrimp | 46 | 84 | 38 | 83.0 | −8 | −17 |
| Crab | 37 | 67 | 31 | 67.0 | −6 | −16 |
| Bivalves | 29 | 53 | 21 | 52.0 | −5 | −17 |

to a halt reported in the cement production recently. This was however not supported by our in situ observation. Overall, the above observed impacts of the three infrastructure developments answered our next scientific question – *whether or not the ecological changes have had any adverse effects on the households that depend on mangroves* (see Section 1), appropriately. On the other hand, some respondents mentioned few merits such as prevention of saltwater intrusion into paddy fields, better access to mangroves, etc., in relation to the three infrastructure developments (Fig. 5).

Also from the scientific point of view, these three physical infrastructure developments were considered responsible for mangrove degradation (Dahdouh-Guebas et al., 2000a, 2002; Dahdouh-Guebas and Koedam, 2002; Dahdouh-Guebas et al., 2005b, 2010). Both the dam and the road have already caused drastic changes in physico-chemical conditions of the water and ultimately mangrove species' distribution (Verheyden et al., 2002; Dahdouh-Guebas et al., 2005b). Dahdouh-Guebas et al. (2000a) reported major dynamic shifts in this mangrove forest (between 1956 and 1994), where some species have lost their grounds in benefit of others and *vice versa*, describing the pattern of this (mangrove) distribution as 'moving mosaic' characterized by an irregular topography. This was further supported by Satyanarayana et al. (2011) with their findings between 1994 and 2004 using very high resolution remote sensing and very high resolution ground-truth data. Because of the cement dust, reduced photosynthetic efficiency in mangroves was previously reported by Dahdouh-Guebas et al. (2000a). Most recently, Dahdouh-Guebas et al. (2010) also made simulations of the hydrological conditions that influence mangrove propagule predation and dispersion before and after the construction of dam and road across the mangroves in Galle-Unawatuna area. However, the stakeholders (i.e. Irrigation Department and Ruhunu cement factory authorities) who are responsible for the functioning of these three infrastructures were not aware of any ecological changes or consequences being reported. The present results are also in agreement with the literature reporting that different people have different perspectives on the environmental changes and assumed causes (as a result of their own interests) (Cotton, 1996; Gammage et al., 2002; Lee and Zhang, 2004; Hernández-Cornejo et al., 2005). The same reason is also valid for possible knowledge-gaps between the stakeholders when a scientific data or relevant information was transmitted from one to another (Oba and Kotile, 2001; Gammage et al., 2002; Lee and Zhang, 2004).

### 4.6. Mangrove conservation and management

A lack of accurate information on the part of forest managers and policy makers, together with the fact that these environments have often been classified as wastelands, explains poor mangrove management in many developing countries (Adeel and Pomeroy, 2001; Gammage et al., 2002; Lynagh and Urich, 2002). In Sri

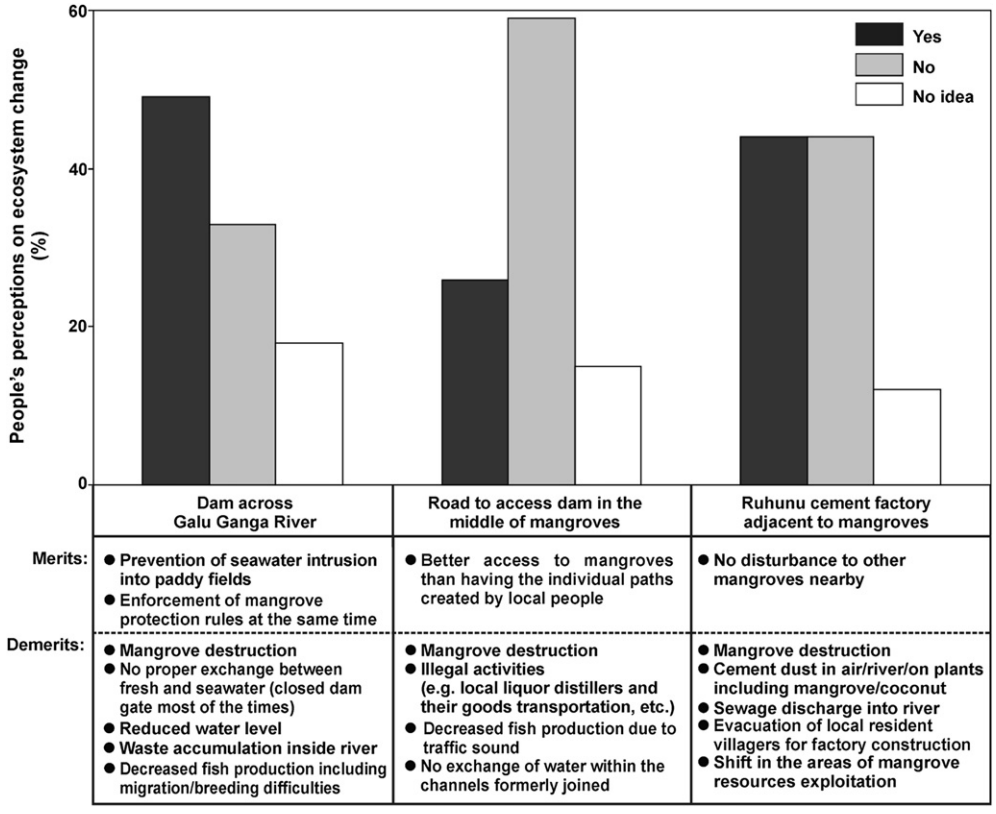


**Fig. 5.** The local people's perceptions on ecosystem changes in Galle-Unawatuna area in relation to the three major physical infrastructure developments.

Lanka, the Forest Department (FD) and the Department of Wildlife Conservation (DWC) are responsible for protection and management of the forests (FAO, 2009). In the case of mangroves, a National Mangrove Committee (NMC) was also established in 1990 to administer these wetlands on the west and southern coasts. Besides the traditional fishing allowed in mangrove areas similar to Galle-Unawatuna, no person shall fell, lop, tap, burn or damage or destroy any plant, or collect or remove any plant, or make any fresh clearings (DWC, 2009). In addition, prioritized participatory approaches (e.g. absorbing local communities into planning, decision making and implementation of forestry activities), ecotourism development, decentralization of administrative and technical activities, are some of the recent measures proposed for mangrove conservation and management in Sri Lanka (FAO, 2009).

Although Sri Lanka has a strong traditional background in forest conservation (De Zoysa, 2001), the loss of mangroves is still visible (Karunathilake, 2003). The mangrove management strategies in Galle-Unawatuna area appeared to be ineffective (along with weak enforcement) and deserve adequate scientific direction. Viewing the importance of mangrove resources for local peoples' livelihoods, it is now possible to recommend the authorities for necessary amendments in the (existing) forest conservation rules, i.e. permitting sustainable resource utilization (*cf.* Lacerda, 2002) rather than imposing a complete ban in this ecosystem. The consistent and unambiguous rules should be transparently communicated to all groups of the stakeholders that have any interest in this area. In addition, periodic opening of the dam gate (taking into account the water level, land elevation and extent of inundation, fin and shellfish migration and breeding seasons characteristic to this area, etc.) is also advisable to keep this vulnerable habitat alive. At the same time, both men and women engaged in fishery, wood harvesting and edible plant collection needs to follow the (sustainable) conservation policy/regulations informed by the local irrigation and forest departments. Not only on the basis of our scientific observations, but also to allow future generations to enjoy the benefits of this ecosystem, the mangroves at Galle-Unawatuna should be protected. This is indeed an answer to the last scientific question – *whether or not it is important to protect this area* (see Section 1).

## 5. Conclusions and recommendations

The importance of mangroves near the Galle-Unawatuna area is clear through high use percentages of fuelwood, edible plants, and fishery products, among the surveyed population. Of these three salient use categories, the local people depend on fishery resources and edible plants to a greater extent (73–76%) than on fuelwood collection (35%) due to their better economic situation. The reasons that respondents have indicated for using mangrove resources are determined largely by their preference, and to a lesser extent, by lack of economic means. However, the decreased utilization of mangrove resources over the years (i.e. 40–60% in fuelwood, medicinal use and, 0–16% in edible plants, fishery products, construction material) was explained by several internal and external factors such as imposed rules and prohibition, developmental activities accompanied by destruction and pollution, economic deficit, aging, changed occupation and feeding habits of the young generation. Other possible reasons for not observing fuelwood and/or edible plant collection in situ (during the period of study) may be related to the phenology of the species used, or the observed goods may have come from other mangrove areas, or people may have been hiding their collection activity inside the mangroves. The three major physical infrastructure developments i.e. cement factory, dam and road have not only started showing their negative impacts in the ecosystem in terms of water quality deterioration, dynamic changes in the mangrove vegetation to biological productivity, but people also experience and report this as negative. Priority should be given to the people depending on the mangrove forest (for fuelwood, edible plants and fishery products), hence warranting a careful reconsideration of the existing rules toward sustainable resource utilization as well as efficient management of this mangrove ecosystem. The present study, invoking both socio-economic (i.e. households depend on mangroves, mangrove resources and their utilization patterns) and ecological aspects (i.e. impact of the physical infrastructure developments on mangroves and mangrove dependent households), has fulfilled the gap of knowledge in order to recommend a better conservation policy for Galle-Unawatuna mangroves.

With a known fact of dependence on mangroves for timber and non-timber forest products by coastal communities (e.g. Walters et al., 2008; Nfotabong Atheull et al., 2009; Crona et al., 2010; Nfotabong Atheull et al., 2011; Satyanarayana et al., 2012), the similar studies should be undertaken in other mangrove areas and update, if necessary, the conservation and management strategies prevailing and/or proposed. A law integrating economic efficiency, social equity and environmental sustainability can generate good society or peaceful living environment for the people (Boyd, 2003; Howlett and Ramesh, 2003).

## Acknowledgments

The present work was carried out as part of the Master Thesis of Sara Mulder (2005) under the project, "Contribution of biological and hydrographical settings to ecosystem change investigated using retrospective and predictive models", under the International Geosphere-Biosphere Programme (IGBP). The present study was performed according to national/institutional rules of Sri Lanka on biodiversity. Author BS is supported by the Belgian National Science Foundation (FNRS) and author SM received financial aid from the Alberta Mennega Stichting. Author BS wrote the manuscript based on the thesis of SM while performing additional statistical analyses, updating the literature and presentation of the results. Author SM conducted field surveys and interviews, statistical analyses and interpretations of the results. Author FDG assured the design and coordination of the research, and participated in the fieldwork. LPJ was responsible for the exchanges with the University of Ruhuna, and is following up the wider and longer research in the area. FDG supervised SM together with Patricia Howard. BS and FDG developed the comparisons and links with recently published studies on mangroves and did additional field visits in 2012. FDG drafted parts of the manuscript, and critically revised and finalized the paper with the above-mentioned persons, who also agreed on the author structure. All authors read and approved the final manuscript. We thank Patricia Howard for her comments and language corrections in the paper. We also thank Sanath Hettiarachi, Chamika Ukwatte, Mihiran Jayasakara, Irosha Weerabaddana, Y.L. Michael Vijedasa, Vinitha Kaljani, Ananda Gabriele Volpato, Gisella Cruz Garcia, Daimy Godinez and expedition colleagues from Belgium and Italy for their kind support. The logistic help rendered by the members from the Wildlife Conservation Society (Galle) is also greatly acknowledged. We also wish to express our sincere gratitude to all the respondents of the villages. Md. Nabiul Islam Khan provided initial help to compute the Bayesian statistics in R. Authors are also very grateful to the two unknown referees and Dr. Rupananda Widanage for their objective criticism and invaluable suggestions.

## APPENDIX A

**I. GENEARAL**

1. Questionnaire N°:
2. Date:
3. Result:
   - i. complete
   - ii. incomplete
   - iii. rejected
   - iv. resident absent
4. Observations:
5. Visits:
   - i. ……
   - ii.……
   - iii. …….
6. Name of the household
7. Address
8. Village
9. Name of the person(s) interviewed

**II. SOCIO-DEMOGRAPHIC AND ECONOMIC TRAITS**

1. Sex
2. Age/age class
3. Religion: Islam / Christian / Buddhist / Hindu / Other
4. Marital status: Single / Married / Widowed
5. Household size:

| No. | Name | Age | Sex | Relationship |
|---|---|---|---|---|
| | | | | |

6. Is there anyone in the house away at the time of interview?
7. Place of birth
8. In case if born in another village/area
   - i. when did they move to this place
   - ii. what age
   - iii. before/after marriage
   - iv. before/after cement factory construction
   - v. before/after dam construction
   - vi. before/after road construction
9. Literacy level and education
10. Principle occupation (source of income)
11. Secondary occupation (optional)
12. Own assets/facilities at home

| | | | |
|---|---|---|---|
| i. agricultural land | v. boat | ix. family car | xiii. telephone |
| ii. house | vi. bicycle | x. TV | xiv. wooden stove |
| iii. electricity | vii. motorbike | xi. refrigerator | xv. gas stove |
| iv. water | viii. three-wheeler | xii. air-conditioning | xvi. kerosene stove |

13. Visits abroad
14. Housing material
    - i. wall/floor: clay / wood / cement / other
    - ii. roof: coconut leaves / fiberglass / cement / tiles / other

**III. MAIN USES OF THE MANGROVES AS VEGEATTION/ECOSYSTEM**

1. Place of birth
2. Preference in living close to mangroves: dependency / cost of living / healthy / others
3. Role of mangrove in the local livelihoods
4. Mangrove resources utilization: yes / no
5. Main usage of the mangrove products: fuelwood / construction / service wood / medicinal use / edible plants / fishery products / others
6. Frequency of visiting mangroves:
   - i. times per week/month
   - ii. whenever go for fishing
   - iii. whenever go for fuelwood
7. Transport to go to mangroves: by foot / boat / bicycle / others

**FUELWOOD**

8. Source of fuel for household cooking: wood / charcoal / kerosene / gas / electricity / others
9. Mangrove fuelwood collection: purchase / own collection / both purchase and own collection
10. Purpose of mangrove fuelwood: cooking / heating / others
11. Responsible person to collect mangrove fuelwood (including age and sex)
12. Mangrove species used for fuelwood
13. Reasons for choosing mangrove fuelwood: burning efficiency / taste / flavor / easy to find / nothing else affordable / others
14. Time to spend in mangroves for fuelwood collection
15. Area(s) of mangrove fuelwood collection (superimposed on study area map)
16. Mangrove fuelwood collection methods: cutting (tree/stem/branch) / collection on ground / others
17. Sales of mangrove fuelwood
18. Changes (if any) observed due to recent developments (dam, road, cement factory, etc.) in the vicinity

**EDIBLE PLANTS**

19. Are there any edible plants in the mangrove environment?
20. Vernacular/scientific name of the plant(s) used for edible purpose
21. Edible mangrove plants collection: purchase / own collection / both purchase and own collection
22. Responsible person to collect edible plants (including age and sex)
23. Reasons for cooking the edible mangrove plants: taste / healthy / tradition / others
24. Time to spend in mangroves for edible plants collection
25. Area(s) of edible mangrove plants collection (superimposed on study area map)
26. Sales of edible mangrove plants
27. Edible mangrove plants collection methods: cutting (tree/stem/branch) / collection on ground / others
28. Changes (if any) observed due to recent developments (dam, road, cement factory, etc.) in the vicinity

**FISHERY RESOURCES / RELATED ACTIVITIES**

29. Frequency of mangrove fish resources collection: times per week/month
30. Mangrove fishery resources collection methods: purchase / own collection / both
31. Preferred mangrove fishery products: fish / shrimp / crab / bivalves
32. Name of the fishing net / traps used for collection
33. Responsible person to collect mangrove fishery products (including age and sex)
34. Vernacular/scientific name of the fish species available in mangrove environment
35. Vernacular/scientific name of the shrimp species available in mangrove environment
36. Vernacular/scientific name of the crab species available in mangrove environment
37. Area(s) preferred for mangrove fishery products collection
38. Changes (if any) observed due to recent developments (dam, road, cement factory, etc.) in the vicinity

## References


Adeel, Z., Pomeroy, R., 2001. Assessment and management of mangrove ecosystems in developing countries. Trees 16, 235–238.

Alongi, D.M., 2008. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76, 1–13.

Armitage, D., 2002. Socio-institutional dynamics and the political ecology of mangrove forest conservation in Central Sulawesi, Indonesia. Global Environmental Change 12, 203–217.

Ashton, M., Gunatilleke, S., de Zoysa, N., Dassanayake, M.D., Gunatilleke, N., Wijesundera, S., 1997. A Field Guide to the Common Trees and Shrubs of Sri Lanka. WHT publications (Pvt.) Ltd for the Wildlife Heritage Trust of Sri Lanka, Colombo.

Baird, A.H., 2006. Myth of green belts. Samudra Report 44, 14–19.

Ban, N.C., Hansen, G.J.A., Jones, M., Vincent, A.C.J., 2009. Systematic marine conservation planning in data-poor regions: socioeconomic data is essential. Marine Policy 33, 794–800.

Barbier, E.B., 2006. Natural barriers to natural disasters: replanting mangroves after the tsunami. Frontiers in Ecology and the Environment 4, 124–131.

Barbier, E.B., 2008. In the wake of tsunami: Lessons learned from the household decision to replant mangroves in Thailand. Resource and Energy Economics 30, 229–249.

Bart, D., 2006. Integrating local ecological knowledge and manipulative experiments to find the causes of environmental change. Frontiers in Ecology and the Environment 4, 541–546.

Bayas, J.C.L., Marohn, C., Dercon, G., Dewi, S., Piepho, H.P., Joshi, L., van Noordwijk, M., Cadisch, G., 2011. Influence of coastal vegetation on the 2004 tsunami wave impact in west Aceh. Proceedings of the National Academy of Sciences of The United States of America 108, 18612–18617.

Boyd, D.R., 2003. Unnatural Law: Rethinking Canadian Environmental Law and Policy. UBC Press, Canada.

Cannicci, S., Burrows, D., Fratini, S., Smith III, T.J., Offenberg, J., Dahdouh-Guebas, F., 2008. Faunistic impact on vegetation structure and ecosystem function in mangrove forests: a review. Aquatic Botany 89, 186–200.

Chang, S.E., Adams, B.J., Alder, J., Berke, P.R., Chuenpagdee, R., Ghosh, S., Wabnitz, C., 2006. Coastal ecosystems and tsunami protection after the December 2004 Indian Ocean tsunami. Earthquake Spectra 22, S863–S887.

Cochard, R., Ranamukhaarachchi, S.L., Shivakoti, G.P., Shipin, O.V., Edwards, P.J., Seeland, K.T., 2008. The 2004 tsunami in Aceh and Southern Thailand: a review on coastal ecosystems, wave hazards and vulnerability. Perspectives in Plant Ecology, Evolution and Systematics 10, 3–40.

Cotton, C.M., 1996. Ethnobotany: Principles and Applications. John Wiley & Sons, Singapore.

Crona, B.I., Rönnbäck, P., 2005. Use of replanted mangroves as nursery grounds by shrimp communities in Gazi Bay, Kenya. Estuarine. Coastal and Shelf Science 65, 535–544.

Crona, B., Nyström, M., Folke, C., Jiddawi, N., 2010. Middlemen, a critical social-ecological link in coastal communities of Kenya and Zanzibar. Marine Policy 34, 761–771.

Dahdouh-Guebas, F., 2006. Mangrove forest and tsunami protection. In: McGraw-Hill Yearbook of Science & Technology. McGraw-Hill Professional, New York, pp. 187–191.

Dahdouh-Guebas, F., Koedam, N., 2002. A synthesis of existent and potential mangrove vegetation structure dynamics from Kenyan, Sri Lankan and Mauritanian case studies. Académie royale des Sciences d'Outre-Mer 48, 487–511. Bulletin des séances (Brussels).

Dahdouh-Guebas, F., Koedam, N., 2006. Coastal vegetation and the Asian Tsunami. Science 311, 37.

Dahdouh-Guebas, F., Koedam, N., 2008. Long-term retrospection on mangrove development using transdisciplinary approaches: a review. Aquatic Botany 89, 80–92.

Dahdouh-Guebas, F., Verheyden, A., De Genst, W., Hettiarachchi, S., Koedam, N., 2000a. Four decade vegetation dynamics in Sri Lankan mangroves as detected from sequential aerial photography: a case study in Galle. Bulletin of Marine Science 67, 741–759.

Dahdouh-Guebas, F., Mathenge, C., Kairo, J.G., Koedam, N., 2000b. Utilization of mangrove wood products around Mida creek (Kenya) amongst subsistence and commercial users. Economic Botany 54, 508–522.

Dahdouh-Guebas, F., Zetterström, T., Rönnbäck, P.R., Troell, M., Wickramasinghe, A., Koedam, N., 2002. Recent changes in land-use in the Pambala-Chilaw lagoon complex (Sri Lanka) investigated using remote sensing and GIS: conservation of mangroves vs. development of shrimp farming. Environment, Development and Sustainability 4, 185–200.

Dahdouh-Guebas, F., Hettiarachchi, S., Sooriyarachchi, S., Lo Seen, D., Batelaan, O., Jayatissa, L.P., Koedam, N., 2005a. Transitions in ancient inland freshwater

resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. Current Biology 15, 579–586.
Dahdouh-Guebas, F., Jayatissa, L.P., Di Nitto, D., Bosire, J.O., Lo Seen, D., Koedam, N., 2005b. How effective were mangroves as a defence against the recent tsunami? Current Biology 15, R443–R447.
Dahdouh-Guebas, F., Collin, S., Lo Seen, D., Rönnbäck, P., Depommier, D., Ravishankar, T., Koedam, N., 2006. Analysing ethnobotanical and fishery-related importance of mangroves of East-Godavari Delta (Andhra Pradesh, India) for conservation and management purposes. Journal of Ethnobiology and Ethnomedicine 2, 24.
Dahdouh-Guebas, F., Koedam, N., Satyanarayana, B., Cannicci, S., 2010. Human hydrographical changes interact with propagule predation behaviour in Sri Lankan mangrove forests. Journal of Experimental Marine Biology and Ecology 399, 188–200.
Daniggelis, E., 2003. Women and 'wild' foods: nutrition and household security among Rai and Sherpa forager-farmers in Eastern Nepal. In: Howard, P.L. (Ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London, pp. 83–97.
DCS (Department of Census and Statistics), 2003. Census of Population and Housing – 2001. DCS, Colombo, Sri Lanka.
DCS (Department of Census and Statistics), 2011. Household Income and Expenditure Survey 2009–2010. Ministry of Finance and Planning, Colombo, Sri Lanka.
De Zoysa, M., 2001. A review of forest policy trends in Sri Lanka. Policy Trend Report, 57–68. Available from: http://enviroscope.iges.or.jp/modules/envirolib/upload/370/attach/p57-68_SriLanka.PDF (accessed 05.06.10.).
Duke, N.C., Meynecke, J.-O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I., Dahdouh-Guebas, F., 2007. A world without mangroves? Science 317, 41–42.
DWC (Department of Wildlife Conservation), 2009. Fauna and Flora Protection (Amendment) Act, No. 22. Department of Government Printing, Sri Lanka.
Ellis, F., 2000. Rural Livelihoods and Diversity in Developing Countries. Oxford University Press, New York.
Ellison, A.M., 2008. Managing mangroves with benthic biodiversity in mind: moving beyond roving banditry. Journal of Sea Research 59, 2–15.
Ertug, F., 2003. Gendering the tradition of plant gathering in Central Anatolia (Turkey). In: Howard, P.L. (Ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London, pp. 183–196.
FAO (Food and Agriculture Organization), 1994. Mangrove Forest Management Guidelines. FAO, Rome. Forestry paper 117.
FAO (Food and Agriculture Organization), 1997. Asia-Pacific forestry sector outlook study: country report - Sri Lanka. FAO, Rome. Working paper no. APFSOS/WP/16.
FAO (Food and Agriculture Organization), 2007. Mangrove Guidebook for Southeast Asia (RAP/2006/07). Dharmasarn Co., Ltd., Bangkok.
FAO (Food and Agriculture Organization), 2009. Asia-pacific Forestry Sector Outlook Study II: Sri Lanka Forestry Outlook Study. FAO, Bangkok. Working paper no. APFSOS II/WP/2009/29.
Farnsworth, E.J., Ellison, A.M., 1997. The global conservation status of mangroves. Ambio 26, 328–334.
Feagin, R.A., Mukherjee, N., Shanker, K., Baird, A.H., Cinner, J., Kerr, A.M., Koedam, N., Sridhar, A., Arthur, R., Jayatissa, L.P., Lo Seen, D., Menon, M., Rodriguez, S., Shamsuddoha, Md., Dahdouh-Guebas, F., 2010. Shelter from the storm? Use and misuse of coastal vegetation bioshields for managing natural disasters. Conservation Letters 3, 1–11.
Feka, N.Z., Manzano, M.G., Dahdouh-Guebas, F., 2011. The effects of different gender harvesting practices on mangrove ecology and conservation in Cameroon. International Journal of Biodiversity Science, Ecosystem Services & Management 7, 108–121.
Foell, J., Harrison, E., Stirrat, R.L., 1999. Participatory Approaches to Natural Resource Management – the Case of Coastal Zone Management in the Puttalam District, Sri Lanka. Summary Findings of DFID Funded Research on 'participatory Mechanisms for Sustainable Development of Coastal Ecosystems' (Project R6977). School of African and Asian studies, University of Sussex, Falmer, Brighton, UK.
Gammage, S., Benítez, M., Machado, M., 2002. An Entitlement approach to the challenges of mangrove management in El Salvador. Ambio 31, 4.
Glaser, M., 2003. Interrelations between mangrove ecosystem, local economy and social sustainability in Caete Estuary, North Brazil. Wetlands Ecology and Management 11, 265–272.
Hernández-Cornejo, R., Koedam, N., Ruiz Luna, A., Troell, M., Dahdouh-Guebas, F., 2005. Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio-Macapule lagoon complex, Sinaloa, Mexico. Ecology and Society 10, 16.
Howard, P. (Ed.), 2003. Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London.
Howlett, M., Ramesh, M., 2003. Studying Public Policy and Policy Cycles and Policy Subsystem. Oxford University Press, Canada.
Jayatissa, L.P., Dahdouh-Guebas, F., Koedam, N., 2002. A review of the floral composition and distribution of mangroves in Sri Lanka. Botanical Journal of the Linnean Society 138, 29–43.
Jayatissa, L.P., Hettiarachi, S., Dahdouh-Guebas, F., 2006. An attempt to recover economic losses from decadal changes in two lagoon systems of Sri Lanka through a newly patented mangrove product. Environment, Development and Sustainability 8, 585–595.
Karunathilake, K.M.B.C., 2003. Status of mangroves in Sri Lanka. Journal of Coastal Development 7, 5–9.
Kathiresan, K., Bingham, B.L., 2001. Biology of mangroves and mangrove ecosystems. Advances in Marine Biology 40, 81–251.
Kovacs, J.M., 2000. Perceptions of environmental change in a tropical coastal wetland. Land Degradation & Development 11, 209–220.
Lacerda, L.D. (Ed.), 2002. Mangrove Ecosystems: Function and Management. Springer, New York.
Ladio, A.H., Lozada, M., 2001. Nontimber forest product use in two human populations from Northwest Patagonia: a quantitative approach. Human Ecology 29, 367–380.
Ladio, A.H., Lozada, M., 2004. Patterns of use and knowledge of wild edible plants in distinct ecological environments: a case study of a Mapuche community from northwestern Patagonia. Biodiversity and Conservation 13, 1153–1173.
Lee, H.F., Zhang, D.D., 2004. Perceiving desertification from the lay perspective in Northern China. Land Degradation & Development 15, 529–542.
Lopez-Hoffman, L., Monroe, I.E., Narvaez, E., Martinez-Ramos, M., Ackerly, D.D., 2006. Sustainability of mangrove harvesting: how do harvesters' perceptions differ from ecological analysis? Ecology and Society 11, 14.
Lynagh, F.M., Urich, P.B., 2002. A critical review of buffer zone theory and practice: a Philippine case study. Society and Natural Resources 15, 129–145.
Magalhães, A., da Costa, R.M., da Silva, R., Pereira, L.C.C., 2007. The role of women in the mangrove crab (*Ucides cordatus*, Ocypodidae) production process in North Brazil (Amazon region, Pará). Ecological Economics 61, 559–565.
Mangora, M.M., 2011. Poverty and institutional management stand-off: a restoration and conservation dilemma for mangrove forests of Tanzania. Wetlands Ecology and Management 19, 533–543.
Mohamed, M.O.S., Neukermans, G., Kairo, J.G., Dahdouh-Guebas, F., Koedam, N., 2009. Mangrove forests in a peri-urban setting: the case of Mombasa (Kenya). Wetlands Ecology and Management 17, 243–255.
Mulder, S., 2005. Local Resource Use and Stakeholders' Perceptions of the Dynamics of Mangrove Degradation in Galle, Sri Lanka, with Implications for Conservation Policy and Research. MSc. Biology. Universiteit Wageningen, The Netherlands.
Mumby, P.J., Edwards, A.J., Arias-González, J.E., Lindeman, K.C., Blackwell, P.G., Gall, A., Gorczynska, M.I., Harborne, A.R., Pescod, C.L., Renken, H., Wabnitz, C.C.C., Llewellyn, G., 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427, 533–536.
Mwandya, A.W., Gullström, M., Öhman, M.C., Andersson, M.H., Mgaya, Y.D., 2009. Fish assemblages in Tanzanian mangrove creek systems influenced by solar salt farm constructions. Estuarine. Coastal and Shelf Science 82, 193–200.
Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.-O., Pawlik, J., Penrose, H.M., Sasekumar, A., Somerfield, P.J., 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. Aquatic Botany 89, 155–185.
Nfotabong Atheull, A., Din, N., Longonje, S.N., Koedam, N., Dahdouh-Guebas, F., 2009. Commercial activities and subsistence utilization of mangrove forests around the Wouri estuary and the Douala-Edea reserve (Cameroon). Journal of Ethnobiology and Ethnomedicine 5, 35.
Nfotabong Atheull, A., Din, N., Essomè Koum, L.G., Satyanarayana, B., Koedam, N., Dahdouh-Guebas, F., 2011. Assessing forest products usage and local residents' perception of environmental changes in peri-urban and rural mangroves of Cameroon, Central Africa. Journal of Ethnobiology and Ethnomedicine 7, 41.
Nickerson, D.J., 1999. Trade-offs of mangrove area development in the Philippines. Ecological Economics 28, 279–298.
Oba, G., Kotile, D.G., 2001. Assessments of landscape level degradation in Southern Ethiopia: pastoralists versus ecologists. Land Degradation & Development 12, 461–475.
Osti, R., Tanaka, S., Tokioka, T., 2008. The importance of mangrove forest in tsunami disaster mitigation. Disasters 33, 203–213.
Overman, H., Demmer, J., 1999. The effects of wealth on the use of forest resources: the case of the Tawahka Amerindians, Honduras. In: Ros Tonen, M.A.F. (Ed.), Proceedings of NTFP Research in the Tropenbos Programme: Results and Perspectives. The Tropenbos Foundation, Wageningen, pp. 107–113.
Pieroni, A., 2003. Wild food plants and Arbëresh women in Lucania, southern Italy. In: Howard, P.L. (Ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London, pp. 66–82.
Poate, C.D., Daplyn, P.F., 1993. Data for Agrarian Development. Cambridge University Press, Cambridge.
Price, L.L., 2003. Farm women's rights and roles in wild plant food gathering and management in Northeast Thailand. In: Howard, P.L. (Ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London, pp. 101–114.
Primavera, J.H., 2000. Development and conservation of Philippine mangroves: institutional issues. Ecological Economics 35, 91–106.
Primavera, J.H., Sadaba, R.B., Lebata, M.J.H.L., Altamirano, J.P., 2004. Handbook of Mangroves in the Philippines – Panay. SEAFDEC Aquaculture Department, Iloilo, Philippines.
Quartel, S., Kroon, A., Augustinus, P.G.E.F., Santen, P.V., Tri, N.H., 2007. Wave attenuation in coastal mangroves in the Red River Delta, Vietnam. Journal of Asian Earth Sciences 29, 576–584.
R Development Core Team, 2011. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria (ISBN 3-900051-07-0). Available from: http://www.R-project.org/ (accessed 25.06.12).
Rönnbäck, P., 1999. The ecological basis for the economic value of mangrove forests in seafood production. Ecological Economics 29, 235–252.

Rönnbäck, P., Crona, B., Ingwall, L., 2007. The return of ecosystem goods and services in replanted mangrove forests - perspectives from local communities in Gazi Bay, Kenya. Environmental Conservation 34, 313–324.
Roy, S.D., Krishnan, P., 2005. Mangrove stands of Andamans vis-à-vis tsunami. Current Science 89, 1800–1804.
Saenger, P., 2002. Mangrove Ecology, Silviculture and Conservation. Kluwer Academic Publishers, Dordrecht, London.
Sanford, M.P., 2009. Valuing mangrove ecosystems as coastal protection in post-tsunami South Asia. Natural Areas Journal 29, 91–95.
Satyanarayana, B., Koedam, N., De Smet, K., Di Nitto, D., Bauwens, M., Jayatissa, L.P., Cannicci, S., Dahdouh-Guebas, F., 2011. Long-term mangrove forest development in Sri Lanka: early predictions evaluated against outcomes using VHR remote sensing and VHR ground-truth data. Marine Ecology Progress Series 443, 51–63.
Satyanarayana, B., Bhanderi, P., Debry, M., Maniatis, D., Foré, F., Badgie, D., Jammeh, K., Vanwing, T., Farcy, C., Koedam, N., Dahdouh-Guebas, F., 2012. A socio-ecological assessment aiming at improved forest resource management and sustainable ecotourism development in the mangroves of Tanbi Wetland National Park, the Gambia, West Africa. Ambio 41, 513–526.
Singh, S., Kar, R., Khandelwal, A., 2010. Impact of modern pollen rain studies from South and Little Andaman Islands, India, to interpret present and past vegetation. Current Science 99, 1251–1256.
Stone, R., 2006. A rescue effort for tsunami-ravaged mangrove forests. Science 314, 404–1404.
Takasaki, Y., Barham, B.L., Coomes, O.T., 2001. Amazonian peasants, rain forest use, and income generation: the role of wealth and geographical factors. Society and Natural Resources 14, 291–308.
Tanaka, N., Sasaki, Y., Mowjood, M.I.M., Jinadasa, K.B.S.N., 2007. Coastal vegetation structures and their functions in tsunami protection: experience of the recent Indian Ocean tsunami. Landscape and Ecological Engineering 3, 33–45.
Teh, S.Y., Koh, H.L., Liu, P.L.-F., Ismail, A.I.M., Lee, H.L., 2009. Analytical and numerical simulation of tsunami mitigation by mangroves in Penang, Malaysia. Journal of Asian Earth Sciences 36, 38–46.
Tomlinson, P.B., 1986. The Botany of Mangroves. Cambridge University Press, New York.
Turner, N., 2003. Passing on the new's: women's work, traditional knowledge and plant resource management in indigenous societies of north-western North America. In: Howard, P.L. (Ed.), Women and Plants: Gender Relations in Biodiversity Management and Conservation. Zed books, London, pp. 133–149.
Verheyden, A., Dahdouh-Guebas, F., Thomaes, K., De Genst, W., Hettiarachchi, S., Koedam, N., 2002. High resolution vegetation data for mangrove research as obtained from aerial photography. Environment, Development and Sustainability 4, 113–133.
Walters, B.B., 2003. People and mangroves in the Philippines: fifty years of coastal environmental change. Environmental Conservation 30, 293–303.
Walters, B.B., 2005. Patterns of local wood use and cutting of Philippine mangrove forests. Economic Botany 59, 66–76.
Walters, B.B., Rönnbäck, P., Kovacs, J.M., Crona, B., Hussain, S.A., Badola, R., Primavera, J.H., Barbier, E., Dahdouh-Guebas, F., 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquatic Botany 89, 220–236.
Ward, D., Ngairorue, B.T., Apollus, A., 2000. Perceptions and realities of land degradation in arid Otjimbingwe, Namibia. Journal of Arid Environments 45, 337–356.
Wattage, P., Mardle, S., 2005. Stakeholder preferences towards conservation versus development for a wetland in Sri Lanka. Journal of Environmental Management 77, 122–132.
Weeks, R., Russ, G.R., Bucol, A.A., Alcala, A.C., 2010. Shortcuts for marine conservation planning: the effectiveness of socioeconomic data surrogates. Biological Conservation 143, 1236–1244.
Williams, N., 2005. Tsunami insight to mangrove value. Current Biology 15, R73.
Yanagisawa, H., Koshimura, S., Goto, K., Miyagi, T., Imamura, F., Ruangrassamee, A., Tanavud, C., 2009. The reduction effects of mangrove forest on a tsunami based on field surveys at Pakarang Cape, Thailand and numerical analysis. Estuarine, Coastal and Shelf Science 81, 27–37.