Estuarine, Coastal and Shelf Science 140 (2014) 67–75

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Floods and mangrove forests, friends or foes? Perceptions of relationships and risks in Cameroon coastal mangroves

Cecilia A. Munji [a], Mekou Y. Bele [b,*], Monica E. Idinoba [c], Denis J. Sonwa [b]

[a] Department of Natural Resources and Environmental Management, Faculty of Science, University of Buea, P.O. Box 63, Buea, Cameroon
[b] Center for International Forestry Research (CIFOR), Central African Regional Office, P.O. Box 2008, Messa, Yaounde, Cameroon
[c] African Union Commission, P.O. Box 3243, Addis Ababa, Ethiopia

ARTICLE INFO

Article history:
Received 3 September 2012
Accepted 13 November 2013
Available online 1 December 2013

Keywords:
floods
mangrove
relationship
perceptions
risk
Cameroon

ABSTRACT

Faced with the growing influence of climate change on climate driven perturbations such as flooding and biodiversity loss, managing the relationship between mangroves and their environment has become imperative for their protection. Hampering this is the fact that the full scope of the threats faced by specific mangrove forests is not yet well documented. Amongst some uncertainties is the nature of the relationship/interaction of mangroves with climate driven perturbations prevalent in their habitat such as coastal floods. We investigated the relationship between coastal flooding and mangrove forest stabilization, identify perceptions of flood risk and responses to offset identified effects. Random household surveys were carried out within four communities purposively sampled within the Cap Cameroon. Coastal changes were investigated over a period of 43 years (1965–2008). Seasonal flooding improved access to mangrove forests and hence promoted their exploitation for non-timber forest products (NTFPs) such as fuel wood and mangrove poles. 989 ha of mangrove forests were estimated to be lost over a period of 43 years in Cap Cameroon with implications on forest resources base, ecosystem stability, and livelihoods. Alternative livelihood activities were found to be carried out to moderate interruptions in fishing, with associated implications for mangrove forest dynamics. Respondents were of the opinion that risks associated with floods and mangrove deforestation will pose a major challenge for sustainable management of mangroves. These locally relevant perceptions and responses should however enable the identification of pertinent needs, challenges and opportunities to inform and orient effective decision-making, and to facilitate the development and participation in adaptive management strategies.

1. Introduction

Faced with the growing importance of issues of environmental change such as climate change and loss of biodiversity, the protection of mangrove forests has become imperative (Gilman et al., 2008; Heller and Zavaleta, 2009; Butchart et al., 2010). Mangroves are salt-tolerant evergreen forests that often form monospecific communities at inter-tidal or transitional zones between dry lands and the open ocean in tropical and sub-tropical regions found between 25°N and 25°S (Mitsch and Gosselink, 2000). Previously considered only as 'inferior forests' and passed up during forest debates, mangroves are increasingly gaining recognition for the indispensability of their ecosystem services. They perform valued regional and site-specific functions (e.g. Ewel et al., 1998; Gilman et al., 2008). These include provisioning for human well-being and development, regulation (e.g. sedimentation, climate and aquatic ecosystems), habitat, and protection of communities and terrestrial ecosystems during hurricanes, coastal floods and tsunamis (Duke et al., 2007; Suratman et al., 2008). Mangroves are efficient natural carbon sinks which are important in mitigating climate change (Donato et al., 2011). Despite their importance, mangroves are amongst the most threatened forests of the world, yet the full scope of the threats faced by specific mangrove forests is not yet well known. Amongst some of the biggest uncertainties is the nature of the relationship/interaction of mangroves with climate driven perturbations prevalent in their habitat such as coastal floods (Gilman et al., 2008; Polidoro et al., 2010).

Mangrove forests are facing increasing degradation owing to established threats from human activities (WWF, 2001; UNEP, 2007). Over the past 50 years, 50% of the 181,390 km^2 of global mangrove forest has been lost worldwide and it is estimated that

* Corresponding author.
E-mail addresses: b.youssoufa@cgiar.org, yoube_bele@yahoo.com, yoube.bele@gmail.com (M.Y. Bele).

0272-7714/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ecss.2013.11.017

70% of Africa's present total mangrove area of 34,266 km^2 will be lost if current trends of mangrove loss are not arrested (IPCC, 2007; Duke et al., 2007).

In Africa mangrove loss is driven by agriculture, aquaculture, deforestation (e.g. for fuel wood, charcoal and salt production), oil exploration, drilling and production, fishing and hunting, and urban and tourism development. Fuel wood for fish smoking is the main driver behind the loss of Cameroon's mangrove, with deforestation rates of 8.28% per year (Feka, 2005; Ajonina et al., 2008; Alongi, 2008; Feka and Manzano, 2008; Feka et al., 2009; Feka and Ajonina, 2011).

Based on the unique physiological, reproductive and respiratory characteristics of the mangrove trees that make them ideally suited to live in partially inundated salt water environments, it has generally been suggested that mangroves are resilient to climate change (IPCC, 2007; Alongi, 2008). However, sea level rise is acknowledged as the greatest impact of climate change on mangroves (Field, 1995, McLeod and Salm, 2006; Lovelock and Ellison, 2007). Relative sea-level rise is a substantial cause of recent and predicted future reductions in the area and status of mangroves and other tidal wetlands (Ellison and Stoddart, 1991; Nichols et al., 1999; Ellison, 2000; Cahoon and Hensel, 2006; McLeod and Salm, 2006; Gilman et al., 2006, 2007a,b), although, to date, it has likely been a smaller threat than anthropogenic activities (Primavera, 1997; Valiela et al., 2001; Alongi, 2002; Duke et al., 2007). With the associated possibility of more frequent and intense coastal floods, how wetlands will be affected is increasingly becoming an important question (Church et al., 2004). In addition, inundation may result in significant land loss in Cameroon's coastal or small island settlements (Folack and Gabche, 2001). However, little inquiry has been made on the nature of the relationship/interaction between coastal inundation and the mangrove forests surrounding these settlements (Munji, 2010). Therefore, we investigated in this paper how people adapt to a dynamic and challenging mangrove ecosystem. It provides a useful baseline for a follow up study after some of the phenomena detected cause significant changes in the ecosystem observed. The paper also presents the results of a survey of flooding which has not been widely investigated in other mangrove ecosystems.

1.1. Impacts of mangrove forest reduction

Reduced mangrove area and health increase the threats from coastal hazards (e.g. erosion, flooding, storm waves and surges, and tsunami) to human safety and development (Danielsen et al., 2005; Kathiresan and Rajendran, 2005; Dahdouh-Guebas et al., 2005a,b, 2006). Mangrove loss also reduces coastal water quality and biodiversity, eliminate fish and crustacean nursery habitat, adversely affect adjacent coastal habitats, and eliminate a major resource for human communities that rely on mangroves for numerous products and services (Din et al., 1997, 2001, 2002; Ewel et al., 1998; Din and Ngollo, 2002; Mumby et al., 2004, Nagelkerken et al., 2008; Walters et al., 2008). Potentially, coastal floods can cause environmental degradation and disruption of ecological balance. Subsequent impacts include migration of mangrove forest inland or seaward, sedimentation, extinction of migratory bird species, and threats to inhabiting species (IPCC, 2007). Mangrove destruction can also release large quantities of stored carbon and exacerbate global warming and other climate change trends (Kristensen et al., 2008). Accurate predictions of changes to coastal ecosystem area and health (e.g. in response to projected relative sea-level rise and other climate change outcomes), enable site planning with sufficient lead time to minimize and offset anticipated losses (Titus, 1991; Hansen and Biringer, 2003; Gilman et al., 2006, 2007a).

1.2. Natural-human system interactions

Understanding the interaction between natural and human systems must be considered to effectively assess vulnerability of the systems, and the likelihood of transformation of those systems (De Lange et al., 2010). The lack of inquiry into the cumulative effects of climate driven perturbations such as flooding with other drivers of ecosystem destabilization such as deforestation is of particular pertinence in coastal areas. In Cameroon for instance, despite the growing consensus that floods and an increasing concentration of forest-dependent populations are the most prevalent phenomena in the mangrove forests (Molua, 2011), the nature of the relationship between floods, livelihoods and mangrove forests is not well studied (Munji, 2010). While science has an established efficacy in the identification of critical drivers of climate change and risks, impact and vulnerability modeling and analysis, establishing linkages between nature and society is an area where science falls short (Rahmstorf and Zickfeld, 2005). To understand these interactions in a changing environment, there is a need to identify local perceptions of change, risk, and responses (Adger, 2006; Grothmann and Reusswig, 2006).

Grass root level information provides insights into the perceptions and responses to adaptations by the local communities who are directly affected by the changes in the environment. This information is vital to better comprehend, analyze and offer sustainable solutions to the problems related to climate change (Dolan and Walker, 2006).

We aimed to investigate the relationship between coastal flooding and mangrove forest stabilization, identify perceptions of risk, and responses to offset identified effects. Specifically, we investigated the following questions: Does flooding change the physical and biological characteristics of a mangrove forest? Does flooding affect mangrove forest recruitment and regeneration? Does flooding influence sedimentation in mangroves? How do inhabitants of the study area perceive risks related to observed changes? What are the responses taken to protect mangroves?

1.3. Study area

The coastal mangrove forest zone of Cameroon is located in the extreme South West of the country. It stretches discontinuously along the Cameroonian coastline, which is located in the north-eastern end of the Gulf of Guinea and measures 402 km from the Equatorial Guinea border to the Nigerian border (Fig. 1) (Din et al., 2002; Feka and Ajonina, 2011). The mangrove forests extend from the low tide mark to about 30 km inland, covering an area of about 1957 km^2. More than 90% of the mangrove occurs in two estuarine complexes flanking the volcanic horst; the Douala estuary and the Rio-del-Rey estuary (Din et al., 2001; Folack and Gabche, 2001; WWF, 2001).

The climate is of the equatorial type which is characterized by abundant rains (3000–4000 mm per year), and generally high temperatures with monthly mean day temperature of 24–29 °C. Rainfall is generally high during the rainy season that lasts for about 7 months (April–October), with the most rainfall occurring between June and October (Ajonina, 2008). The ecosystem is normally inundated by a tidal variation of about 2 m in the rainy season and 1 m in the dry season (WWF, 2001). The propagation of waves and ebb-tides is enormous, though poorly known (Folack and Gabche, 2001). Historically, settlements within this ecosystem experienced intense floods about once every 5–7 years. The lag time between two successive floods reduced consistently until presently intense flooding occurs within the area every year. Peak flood periods occur within the months of July, August, September, and October (Munji, 2010).

Fig. 1. Location of the study area and sampled sites.

Topographic features along the coast are uneven. Coastal features in the area include estuaries, deltas, lagoons and barrier beaches. Soils range from recently deposited, unconsolidated soft dark mud containing silt, clay and peaty clay to transitional swamps, all of which are associated with different types of vegetation (Din et al., 2001, 2002; WWF, 2001). Vegetation is typically mangrove with six species occurring. *Rhizophora racemosa*, which constitutes 90% of the total cover, is dominant in the tidal and more inundated areas of the coast (UNEP, 2007). Other forms of vegetation include humid coastal forest species which comprise of land-thriving species dotted with mangroves. The settlements are typically small (less than 5 km^2) but densely populated, with an estimated average density of about 3000–4000 inhabitants per square km. The area is characterized by a very low standard of living, i.e. no electricity, no pipe borne water and only elementary schools are available. Most settlements in the area can only be accessed by water, with canoes and motorized canoes being the primary means of transport. Housing is basically wooden, but designs and durability vary depending on the level of flood risk in specific settlements (Munji, 2010).

The area is an international fishing hotspot with artisanal fishing being the main economic activity. To complement this industry, mangrove logging is carried out to fuel fish smoking for preservation before transportation to both national and international markets. Each year, an estimated 75,000 tons of fish and shrimps (representing about 60% of the total catch) is smoked traditionally using mangrove wood (Folack and Gabche, 2001; Feka and Manzano, 2008). Mangrove harvesting is done indiscriminately using crude tools, with availability and accessibility determining the choice of harvesting location (Feka et al., 2009; Munji, 2010).

2. Methods

2.1. Surveys

A reconnaissance survey was carried out once within the study area to get an idea of the specific characteristics of the fishing settlements since these have not been documented. Physical characteristics of the settlements including topography, soils and

Table 1
Sampled sites, location, and number of individuals sampled.

Settlement name	Location (UTM: Universal Transverse Mercator)	Elevation above mean sea level (m)	Mangrove cover situation	Number of individuals sampled
Cap Cameroon	0549133, 0432015	0	Highly deforested	40
Mboma	536267, 434065	2	Highly deforested	30
Bekumu	487390, 485403	3	Moderate	40
Yoyo	0571899, 0403054	0	Protected and regenerated	30
Total				140

vegetation, as well as socio-economic factors such as accessibility and prominence of settlements were described. This information served as basis in choosing the sampling locations. Four communities located within the Cameroon and the Rio del Rey estuaries were selected for further investigations. Data collection spanned a period of six months from August 2008 to February 2009 (3 months in the wet season and 3 months in the dry season).

2.2. Sampling, data collection and analysis

Random household surveys were carried out within four communities located in the Cameroon estuary and the Rio-del-Rey estuary (Table 1). Selection of settlements was guided by background information from the reconnaissance survey and from scientific and local expert opinion. Respondents were randomly selected within the age range 18–70 years old. Age of the respondents was restricted to this particular group because we wanted to source perceptions on an issue that has a historical undertone.

Survey questionnaires were administered to a total of 140 households. Responses in the questionnaire were based on perceptions of the inhabiting population, which were of course subjective and reflect the mind-set of individuals. The use of perceptions of communities in research is increasingly gaining ground and has proven to be very effective in socio-ecological monitoring, especially in the establishment of baselines, and in providing pointers on gaps encountered in the course of purely scientific investigations (Fussel, 2007). Other Participatory Rapid Appraisal (PRA) tools such as semi-structured interviews and visual assessments supplemented questionnaires in identifying adaptive responses. The ground positions of the sampled sites as well as their altitudes above mean sea level were recorded using a Global Positioning Systems (GPS) for subsequent geospatial analysis.

Descriptive statistical analysis (proportions and graphs) using EXCEL was done to show trends, The coordinates of the study sites were superimposed on base topographic maps of 1965, to investigate coastal changes over a period of 43 years using Arcview 9.1.

3. Results

3.1. Flooding and the harvesting of mangrove non-timber forest products (NTFPs)

The mangrove forests of Cameroon were widely exploited for their NTPS. The red mangrove was the most demanded species of mangrove in the area. It was exceptionally valued over other mangrove species for its superior suitability as high energy fuel wood, poles for construction of houses, paddles and sculptures and as a source of medicinal roots and tannin for protection of fishing nets. Other NTFPs exploited in the area included thatch for roofing, periwinkle snails (for their edible fleshy part and shell used for construction and mud control), bivalves and mudskippers. Fuel wood for fish smoking and poles for construction however stand out as the most exploited NTFPs in the study area.

a) *Influence of flooding on the harvesting on fuel wood*

The predominant perception of all the respondents (67.1%) as depicted by Fig. 2 was that harvesting of mangrove for fuel wood intensifies during the flooding season.

The majority of respondents in all studies communities asserted that more fuel wood is harvested during flooding than during the non-flood season. Increased harvesting of fuel wood during peak flood periods was influenced by the creation of water channels during high tides allowing access by canoe to forest areas otherwise inaccessible during non-flood periods. About 19.3% of the respondents mainly from Bekumu and Yoyo asserted that there is no difference in the rate of wood harvested between flood and non-flood seasons. Respondents who claimed that less fuel wood is harvested during flooding than during non-flood season was due to the fact that a reduction in fishing activities during peak flooding periods generally leads to less fuel wood harvesting.

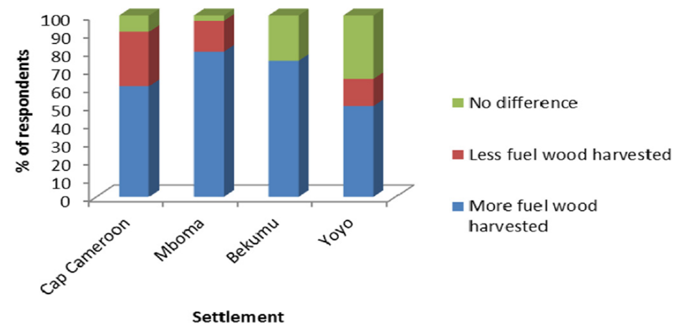

Fig. 2. The impact of seasonal flooding on the harvesting of fuel wood.

b) *The impact of flooding on mangrove deforestation for construction poles*

Perceptions of the impact of flooding on mangrove deforestation for construction poles were diverse as shown in Fig. 3. The majority of respondents (59.3%) from all the study communities were of the opinion that harvesting of mangrove for construction poles intensifies during flooding season.

The majority of respondents from the communities especially Mboma, Bekumu, and Cap Cameroon were of the opinion that flooding directly influenced mangrove deforestation for construction poles. Increased harvest of mangrove poles was due to increased access to the forest during flooding season, and a higher demand for construction poles for reinforcement of houses devastated by flooding.

In contrast, fewer respondents thought there was no difference in mangrove pole harvests between flood and non-flood seasons (21.4%) and only fewer poles were harvested during the flooding season (19.3%).

Both opinions were backed by the explanation that there was either no need for reinforcements or if need be, reinforcements were done well in advance of the flood season.

3.2. Flooding, land use change and mangrove degradation

In reaction to the successive encroachment of the sea and intensifying seasonal surges associated with coastal flooding from

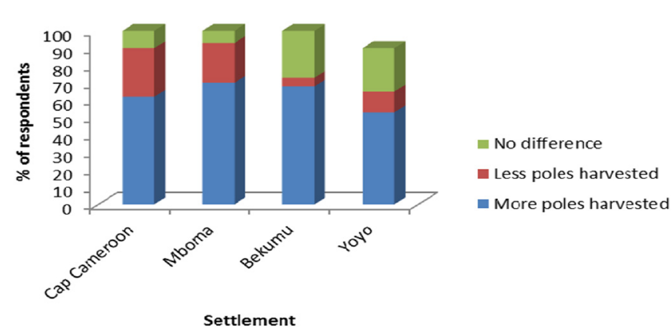

Fig. 3. The impact of seasonal flooding on the harvesting of mangrove poles.

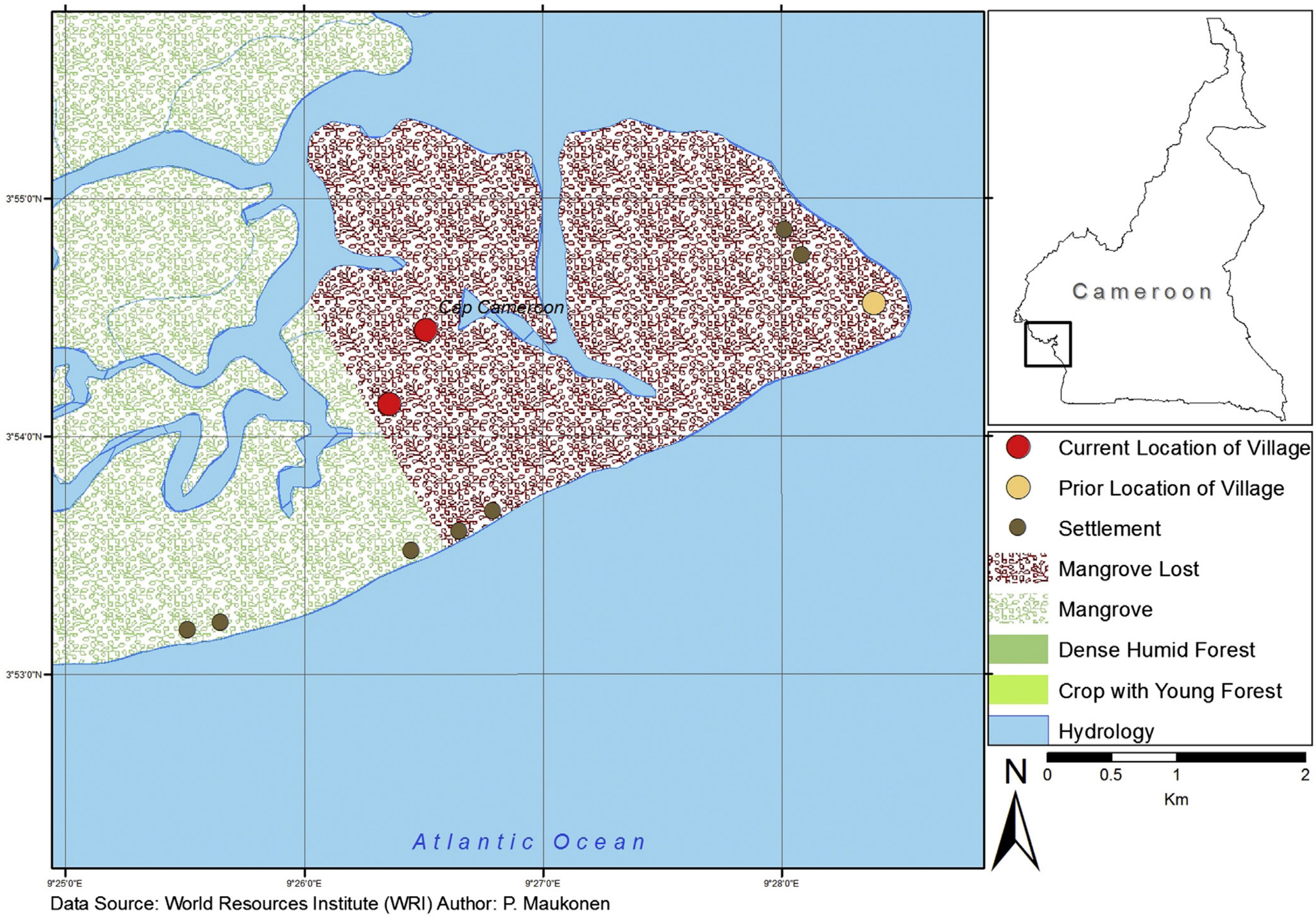

Fig. 4. Trend in mangrove forest destruction related to flooding.

year to year, inland retreat to reduce/avoid the impact of these surges has necessitated the clearing of mangroves to create land for relocation. Inland retreat entails the clearing of forest to create land as well as the dismantling of houses and remounting further inland suspended on mangrove poles or placed on the newly created floor. 14.3% of the respondents carry out inland relocation in adaptation to flooding, with 92% and 8% of this proportion being inhabitants of Cap Cameroon and Mboma, respectively. The relocation of settlements inland has placed the current settlements of Cap Cameroon and Mboma 3500 m and 350 m respectively, from the settlement locations 43 years ago. In contrast, Yoyo and Bekumu did not exhibit this phenomenon. As shown in Fig. 4, forest clearing and subsequent settlement relocation has led to the loss of approximately 989 ha of mangrove forest cover in Cap Cameroon over a period of 43 years.

3.3. *Floods, alternative livelihoods and mangrove degradation*

Adaptations to the effects of flooding on other livelihood activities have implications on the dynamics of mangrove forests. While the primary livelihood activity of the respondents was fishing, 75.7% of them believed that flood had no major impact on the quantity of fish caught. As a matter of fact, they identified industrial fishing trawlers as having impact on the quantity of fish caught. Only 24.3% of the respondents perceived that flooding was the main reason for the disruption of fishing activity in the area. With regards to the frequency of fishing per day, 83% of the respondents reported to fish only once a day during flooding season and at least twice during non-flood season. During flood, only 34.3% of respondents did fishing during the night-time while 65.7% preferred the daytime because of good visibility in rough waters.

Disruptions in fishing resulted in temporal unemployment for fishermen, fish smokers, and fish merchants. This lowered the spending power of the population, which also affected the livelihood of petty traders. Alternative livelihood activities were carried out by some inhabitants as insurance for the interruptions in business. 23.6% of respondents carried out alternative livelihood activities during flood or non-flood seasons, while 76.4% relied only on fishing activities. As an alternative livelihood activity, logging of mangrove forest was found to be very prominent during flooding season (Fig. 5). About 15% more of respondents carried out logging during flooding than during the non-flood season.

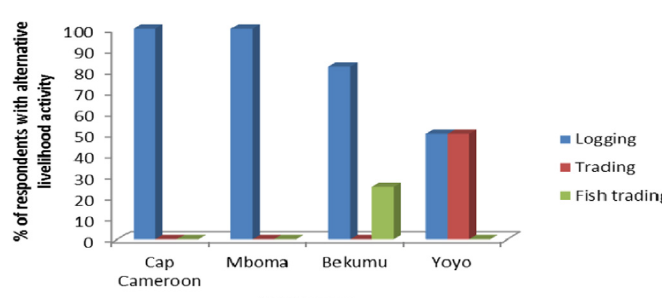

Fig. 5. Alternative livelihood activities during flooding season.

3.4. Flooding and implications for mangrove forest regeneration

54.3% of all the respondents perceived that more mangrove seedlings were washed out to sea while 41.4% reported that more mangrove seedlings were washed further inland. Only 4.3% were of the opinion that seedlings are able to germinate on spot during flooding (Fig. 6).

3.5. Flooding and sediment deposition in the mangrove forest

In the four studied sites, 94.3% of the respondents were of the opinion that seasonal floods resulted in the accumulation of sediment in the mangrove forest areas. Conversely, 5.7% of the respondents especially from Yoyo and Bekumu asserted that seasonal flooding influences beach erosion and removal of sediments earlier deposited (Fig. 7).

3.6. Perceptions on mangrove-flooding dynamics and responses

The majority of respondents considered that there were increasing flood risk within the Cameroon mangrove settlements. About 82.9% of this proportion asserted that flood risk was highest during the months of July, August, September, and October. Sedimentation was perceived as land being gained and was therefore not perceived as a risk but rather as an opportunity.

Thus, the Yoyo settlement has expanded with new buildings erected on the sand deposits along its coasts.

Mangrove destruction was not generally perceived (2%) as a factor contributing to increased flood risk. However, popular explanations that were cited to cause flooding include divine power (53%), heavier rainfall (32), tides and climate change (5%), traditional malpractice (3%), breach of traditional customs (3%), and poor building codes (4%).

Flood management was reported to be the responsibility of family heads (92%), government administrative authorities (7%) and village traditional councils (1%).

Nevertheless, there were some emerging responses which may or may not be specifically designed for mangrove protection but which have implications in flood prevention. For instance, with increased mangrove loss mangrove forests in other locations were sought for exploitation in spite of the correspondingly higher costs in fuel for transportation. Alternatively, less favored mangrove species such as *Avicennia* spp. were increasingly being used for fish smoking. Other emerging responses within communities include banning the cutting down of vegetation (mangrove trees, shrubs and grass) in front of settlements which typically face the sea. is The ban has been sanctioned by the traditional councils and chiefs and obeyed by inhabitants to avoid the wrath of the chiefs. Some communities such as Bekumu and Yoyo have received training from non-governmental organizations (NGOs) on mangrove planting,

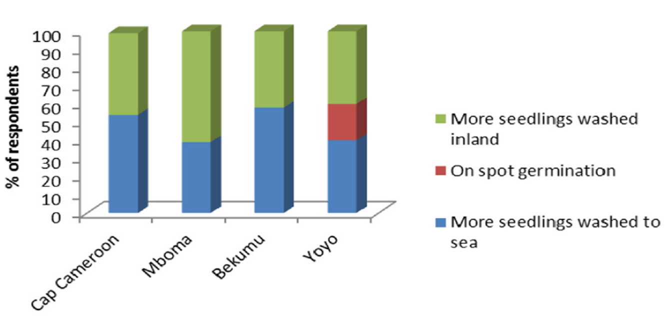

Fig. 6. The implications of flooding for mangrove seedling germination.

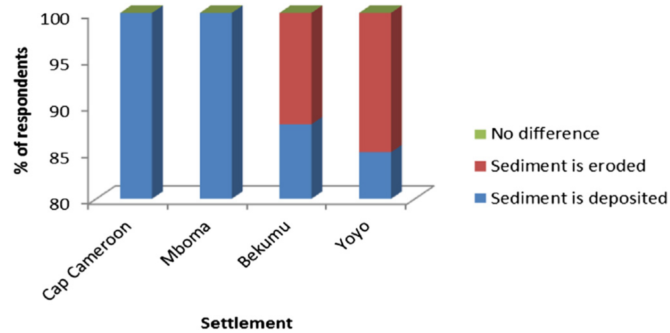

Fig. 7. Perceptions of sediment deposition in the mangrove forests.

Mangrove nurseries have been created to provide seedlings for community mangrove planting schemes. At the administrative level, the Bekumu council has trained some members of its community to plant *Eucalyptus* trees in areas where mangroves have been lost to reclaim the marshland. However, the majority of inhabitants of this council had temporal status and were from different countries. This prevented the development of ownership of the settlements and hence poses a major challenge in ensuring involvement in management schemes.

4. Discussion and conclusion

Seasonal flooding improved the access to mangrove forest and promoted the exploitation of forests for NTFPs such as fuel wood and mangrove poles.

The peaks of flooding during July and August were confirmed to coincide with the peak of mangrove harvesting as reported previously by Feka et al. (2009) and Din et al. (2008).

This access opportunity for mangrove exploitation together with an associated high demand for fuel wood for fish smoking presents a lethal combination of drivers for mangrove deforestation. The implications for mangrove deforestation might however be more significant in areas which have high fish catch or specialize in fish species that require more heat for smoking, especially given the low fuel wood efficiency of traditional smoking systems used in the fishing communities. Feka et al. (2009) also reported that fuel wood extraction within Cameroon's mangroves was directly linked to demand for fish smoking. Therefore the adoption of better fish smoking systems to improve wood efficiency will considerably reduce deforestation. Din et al. (2008) in a study on deforestation in Cameroon's mangroves similarly suggested that sustainable management of mangroves can be achieved only if its economic potential is acknowledged and factored into strategies for the protection of mangroves. Most respondents, especially from Yoyo and Bekumu contrarily claimed that seasonal flooding made no difference on the quantities of fuel wood and mangrove poles harvested. This discrepancy could be explained by the fact that these settlements had access to terrestrial wood sources for fuel wood as well as timber for construction. This is in line with the findings of Feka and Manzano (2008) that mangrove fuel wood consumption in areas with alternative fuel wood from terrestrial sources was relatively low.

Adaptation to flooding was found to influence land use patterns and hence have implications on mangrove dynamics. Settlements who carried out inland relocation in adaptation to flooding such as Cap Cameroon were found to be especially vulnerable to forest clearing and hence mangrove loss. In Cap Cameroon where 989 ha of inland mangrove forest has been lost in 43 years, forest loss of this magnitude could have serious implications on the forest resources base, ecosystem stability and the inhabiting biodiversity especially of fish species that spawn in the mangroves. This finding is in line with findings by De Lange et al. (2010). According to them, vulnerability of the entire ecosystem takes precedence over impacts on single components. In addition, with Cap Cameroon being a small island, the magnitude of these impacts will probably increase significantly when land for inland relocation becomes limited.

Gilman et al. (2008), contrarily suggested that inland retreat as an adaptive action if well managed and jointly coordinated will achieve effective human adaptation and also present an opportunity for inland migration of mangroves. This is probably attainable if flood protection is carried out as part of a participatory integrated coastal zone management effort. However, constrained by finance, capability and setting of priorities, the scope and coordination of retreat are so limited that such benefits are highly improbable in the near future. Molua (2011) concluded in a similar study of Cameroon's coastal settlements that costs for flood protection were very significant and were responsible for the choice of the cheapest protective options.

Alternative livelihood activities were carried out to moderate interruptions in fishing, with associated implications on mangrove forest dynamics. Logging was the most likely alternative livelihood activity and was carried out by twice as many people during flooding than during non-flood season. This suggests that logging was more feasible and/or profitable during flooding season. Feka and Manzano (2008) also found that the logging population increased during flooding season because high tides presented a transportation opportunity by canoe to women and children who are not strong enough to carry logs during non-flood season. Din et al. (2008) also reported that due to the high economic potential of mangroves, the number of permanent loggers had increased.

This access opportunity provided by floods acting in synergy with other incentives for deforestation such as high demand for mangrove fuel wood would significantly accelerate the rate of degradation of mangroves than could be accomplished by each factor on its own. Alongi (2008) also found that the additional effects of deforestation will be more significant than any stand-alone effects of climate change. Additionally, the enabling environment created by the absence of appropriate legislation and weak enforcement of existing forest conservation policies also promoted the emergence of unauthorized, unmonitored and hence, unsustainable mangrove deforestation.

The predominant perception amongst the respondents was that sediment deposition in the mangrove forest has greatly increased over the years. This is in line with the findings of Furukawa and Wolanski (1996) in Nigeria that flooding increased sediment input in the mangroves. It is however doubtful how sedimentation will affect mangroves. In the case of accretion in previously eroded environments, floods might actually provide an opportunity for seaward expansion of mangroves. Assessments by Ellison (1999) and Gilman et al. (2008) contrarily asserted that sediment input may lead to smothering and eventual death of mangroves.

Opinions were diverse as to how flooding will affect mangrove recruitment. The leading perception (54%) was that more seedlings were washed out to sea during flooding. This is probable if seasonal floods coincide with the timing of water-supported seed dispersal, which will result in the flushing out of more seedlings out of mangrove forest into the sea. In such case, recruitment will be impaired in the location of origin but enhanced in similar non-native environments. However, flooding encouraged inland migration of mangroves. Accommodating both schools of thought, IPCC (2007) allows that flooding may lead to inland migration of mangroves but not in every place.

Inland transportation of seedlings could present an opportunity for forest recruitment and migration, especially given the ongoing encroachment of the sea into land and submergence of coastal land. The Environmental Protection Agency (2002) however concluded that the area of mangroves regenerated in this manner will always be smaller than that which has been disturbed. This accounts for the seedlings washed to sea and those rendered non-viable. In line with the observations of Khan (2009) on the influence of flooding on water hyacinth proliferation in mangroves of southwestern coastal Bangladesh, water currents and high tides could also be responsible for the dispersal of *Nypa* palm from neighboring Nigeria, and the proliferation of *Nypa* palm within the Cameroon mangroves. Youmbi et al. (2011) additionally suggested that inundation could alter the zonation of mangroves.

The results suggested that local perceptions on risks associated with floods and mangrove deforestation will pose a major challenge for sustainable management of mangroves. Floods and mangrove deforestation were not singly or jointly considered as risk stimulating phenomena but rather, the flood–mangrove relationship was seen as an incentive for economic gain. As long as this attitude persists, exploitation will always take precedence over protection. This is further exacerbated by the fact that institutional arrangements for flood management and mangrove protection were poorly understood and the communities did not think themselves bound by any legal repercussions, or guided by relevant education to adopt certain responsible attitudes. Individual responses fell more in the line of accidental adaptation from actions geared at ensuring economic security, rather than deliberate efforts at flood or mangrove protection. Community level responses were better aligned with flood protection, however the scope of execution suggested the existence of institutional, financial, and educational constraints for the building of resilience to flood. Institutional involvement was found to be very minimal especially in the domains of risk awareness, prevention and capacity building. Institutional efforts lean more towards mangrove conservation.

These locally relevant perceptions and responses enable the identification of needs, challenges and opportunities pertinent to inform and orient effective decision-making, and to facilitate the development and participation in adaptive management strategies. Dolan and Walker (2006) were also of the opinion that perceptions and experiences with climate extremes can identify inherent characteristics that enable or constrain communities to respond, recover and adapt. Asking the inhabitants what they think about changes in their ecosystem has the benefit of greatly increasing observer input (numbers of observers and period of observation), but has the difficulty of lacking the precision of ecological surveys.

Acknowledgments

Special and heartfelt thanks go to all persons who contributed in one way or the other in making this work a success, most especially the local informants. The financial support of the IDRC-DFID funded Congo Basin Forests and Climate Change Adaptation project (CoFCCA) and the European Union funded Tropical Forests and Climate Change Adaptation project (TROFCCA) projects are gratefully acknowledged. The contributions of Dr. Nkem Johnson, Dr. Ayonghe Samuel and Dr. Yinda Sendze are also gratefully acknowledged. We are also very grateful to anonymous reviewers whose comments and suggestions have substantially improved the manuscript. Special thanks to the Center for International Forestry Research for their assistance, services, and facilities.

References

Adger, W.N., 2006. Resilience, vulnerability, and adaptation: a cross-cutting theme of the international human dimensions programme on global environmental change. Glob. Environ. Change 16 (3), 268–281.

Ajonina, G.N., 2008. Inventory and Modeling Mangrove Forest Stand Dynamics Following Different Levels of Wood Exploitation Pressures in the Douala-Edea

Atlantic Coast of Cameroon, Central Africa. Dr.rer.nat. Thesis. University of Freiburg, Germany, p. 216.
Ajonina, G., Diamé, A., Kairo, J., 2008. Current status and conservation of mangroves in Africa: an overview. World Rainfor. Move. Bull. Issue No. 133.
Alongi, D.M., 2002. Present state and future of the world's mangrove forests. Environ. Conserv. 29, 331–349.
Alongi, D.M., 2008. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. Estuar. Coast. Shelf Sci. 76 (1), 1–13.
Butchart, S.H., Walpole, M., Collen, B., Strein, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Hernández Morcillo, M., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.C., Watson, R., 2010. Global Biodiversity: indicators of recent declines. Science 328 (5982), 1164–1168.
Cahoon, D.R., Hensel, P., 2006. High-resolution global assessment of mangrove responses to sea-level rise: a review. In: Gilman, E. (Ed.), Proceedings of the Symposium on Mangrove Responses to Relative Sea Level Rise and Other Climate Change Effects, 2006. Western Pacific Regional Fishery Management Council, Honolulu, HI, USA, ISBN 1-934061-03-4, pp. 9–17.
Church, J., Hunter, J., McInnes, K., White, N., 2004. Sea level rise and the frequency of extreme events around the Australian coastline. In: Coast to Coast' 04 – Conference Proceedings, Australia's National Coastal Conference, Hobart, 19–23 April 2004, p. 8.
Danielsen, F., Soerensen, M., Olwig, M., Selvam, V., Parish, F., Burgess, N., Hiraishi, T., Karunagaran, V., Rasmussen, M., Hansen, L., Quarto, A., Nyoman, S., 2005. The Asian tsunami: a protective role for coastal vegetation. Science 310, 643.
Dahdouh-Guebas, F., Jayatissa, L.P., Di Nitto, D., Bosire, J.O., LoSeen, D., Koedam, N., 2005a. How effective were mangroves as a defence against the recent tsunami? Curr. Biol. 15, R443–R447.
Dahdouh-Guebas, F., Hettiarachchi, S., Lo Seen, D., Batelaan, O., Sooriyarachchi, S., Jayatissa, L.P., Koedam, N., 2005b. Transitions in ancient inland freshwater resource management in Sri Lanka affect biota and human populations in and around coastal lagoons. Curr. Biol. 15, 579–586.
Dahdouh-Guebas, F., Koedam, N., Danielsen, F., Sørensen, M.K., Olwig, M.F., Selvam, V., Parish, F., Burgess, N.D., Topp-Jørgensen, E., Hiraishi, T., Karunagaran, V.M., Rasmussen, M.S., Hansen, L.B., Quarto, A., Suryadiputra, N., 2006. Coastal vegetation and the Asian tsunami. Science 311, 37–38.
De Lange, H.J., Sala, S., Vighi, M., Faber, J.H., 2010. Ecological vulnerability in risk assessment – a review and perspectives. Sci. Tot. Environ. 408 (18), 3871–3879.
Din, N., Blasco, F., Amougou, A., Fabre, A., 1997. Etude quantitative d'une station de la mangrove de l'estuaire du Wouri (Douala Cameroun): Premiers résultats. Sci. Technol. Dev. 5 (1), 17–24.
Din, N., Priso, R.J., Dibong, S.D., Amougou, A., 2001. Identification des principales causes de dégradation des mangroves dans l'Estuaire du Cameroun. Sci. Technol. Dev. 8 (1), 1–7.
Din, N., Ngollo, D.E., 2002. Perspectives for sustainable management of mangrove ecosystems in Cameroon. Euro. Trop. For. Res. Netw. NEWS 36 (2), 48–51.
Din, N., Priso, R.J., Kenne, M., Ngollo, D.E., Blasco, F., 2002. Early growth stages and natural regeneration of *Avicennia germinans* (L.) Stearn in the Wouri estuarine mangroves (Douala-Cameroon). Wetl. Ecol. Manage. 10 (6), 461–472.
Din, N., Saenger, P., Jules, P.R., Siegried, D.D., Basco, F., 2008. Logging activities in mangrove forests: a case study of Douala Cameroon. Afr. J. Environ. Sci. Technol. 2 (2), 22–30.
Dolan, A.H., Walker, I.J., 2006. Understanding vulnerability of coastal communities to climate change related risks. J. Coast. Res. 39, 1316–1323.
Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M., Kanninen, M., 2011. Mangroves among the most carbon-rich forests in the tropics. Nat. Geosci. 4 (5), 293–297.
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.
Ellison, J.C., Stoddart, D.R., 1991. Mangrove ecosystem collapse during predicted period of sea-level rise: Holocene analogues and implications. J. Coast. Res. 7 (1), 151–165.
Ellison, J.C., 1999. Impacts of sediment burial on mangroves. Mar. Pollut. Bull. 37 (8–12), 420–426.
Ellison, J., 2000. How South Pacific mangroves may respond to predicted climate change and sea level rise. In: Gillespie, A., Burns, W. (Eds.), Climate Change in the South Pacific: Impacts and Responses in Australia, New Zealand, and Small Islands States. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 289–301. Chapter 15.
Environmental Protection Agency, 2002. Costal Zones and Sea Level Rise. Available online at: http://www.epa.gov/climatechange/effects/coastal/index.html.
Ewel, K.C., Twilley, R.R., Ong, J.E., 1998. Different kinds of mangrove forests provide different goods and services. Global Ecol. Biogeogr. Lett. 7, 83–94.
Feka, N.Z., 2005. Perspectives for the Sustainable Management of Mangrove Stands in the Douala-edea Wildlife Reserve, Cameroon. M.Sc Thesis. University of Buea Cameroon.
Feka, N.Z., Manzano, M.G., 2008. The implications of wood exploitation for fish smoking on mangrove ecosystem conservation in the South West Province, Cameroon. Trop. Conserv. Sci. 1 (3), 222–241.
Feka, N.Z., Chuyong, G.B., Ajonina, G.N., 2009. Sustainable utilization of mangroves using improved fish-smoking systems: a management perspective from the Douala-Edea wildlife reserve, Cameroon. Trop. Conserv. Sci. 2 (4), 450–468.
Feka, N.Z., Ajonina, G.N., 2011. Drivers causing decline of mangrove in West-Central Africa: a review. Int. J. Biodiver. Sci. Ecosys. Serv. Manage.. http://dx.doi.org/10.1080/21513732.2011.634436.
Field, C., 1995. Impacts of expected climate change on mangroves. Hydro-biologia 295, 75–81.
Furukawa, K., Wolanski, E., 1996. Sedimentation in Mangrove Forests. Biomedical and Life Sciences, Mangrove and Salt Marshes issue, vol. 11(1). Springer, Netherlands, pp. 3–10.
Folack, J., Gabche, E., 2001. Natural and Anthropogenic Characteristics of the Cameroon coastal zone. A report made by the IRAD Research Station for Fisheries and Oceanography, Project 513 RAF 2041, p. 44. Available online at: http://www.nodc-cameroon.org/anthropo.pdf (accessed 23.02.11.).
Fussel, H.M., 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain. Sci. 2, 265–275.
Gilman, E., Ellison, J., Jungblat, V., VanLavieren, H., Wilson, L., Areki, F., Brighouse, G., Bungitak, J., Dus, E., Henry, M., Sauni Jr., I., Kilman, M., Matthews, E., Teariki-Ruatu, N., Tukia, S., Yuknavage, K., 2006. Adapting to Pacific Island mangrove responses to sea level rise and other climate change effects. Climate Res. 32, 161–176.
Gilman, E., Ellison, J., Coleman, R., 2007a. Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position. Environ. Monit. Assess 124, 112–134.
Gilman, E., Ellison, J., Sauni Jr., I., Tuaumu, S., 2007b. Trends in surface elevations of American Samoa mangroves. Wetl. Ecol. Manag. 15, 391–404.
Gilman, E.L., Ellison, J., Duke, N.C., Field, C., 2008. Threats to mangroves from climate and adaptation options: a review. Aqua. Bot. 89, 237–250.
Grothmann, T., Reusswig, F., 2006. People at risk of flooding: why some residents take precautionary action while others do not. Nat. Haz. 38 (1), 101–120.
Hansen, L.J., Biringer, J., 2003. Building resistance and resilience to climate change. In: Hansen, L.J., Biringer, J.L., Hoffmann, J.R. (Eds.), Buying Time: a User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. WWF Climate Change Program, Berlin, Germany, pp. 9–14.
Heller, N.E., Zavaleta, E.S., 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biolog. Conserv. 142, 14–32.
IPCC, 2007. Coastal systems and low-lying areas. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 315–356.
Kathiresan, K., Rajendran, N., 2005. Coastal mangrove forests mitigated tsunami. Estuar. Coast. Shelf Sci. 65, 601–606.
Khan, S.I., 2009. Protecting the protectors: lessons for adaptation strategies of mangrove forests from Bangladesh. IOP Conf. Series: Earth Environ. Sci. 6, 382025.
Kristensen, E., Bouillon, S., Dittmar, T., Marchand, C., 2008. Organic carbon dynamics in mangrove ecosystems: a review. Aqua. Bot. 89, 201–219.
Lovelock, C.E., Ellison, J.C., 2007. Vulnerability of mangroves and tidal wetlands of the Great Barrier Reef to climate change. In: Johnson, J.E., Marshall, P.A. (Eds.), Climate Change and the Great Barrier Reef: a Vulnerability Assessment. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia, pp. 237–269.
McLeod, E., Salm, R.V., 2006. Managing Mangroves for Resilience to Climate Change. IUCN, Gland, Switzerland, p. 64.
Molua, E.L., 2011. Climate extremes, location vulnerability and private costs of property protection in Southwestern Cameroon. Mitig. Adapt. Strat. Glob. Change 17 (3), 293–310.
Mitsch, W.J., Gosselink, J.G., 2000. Wetlands, third ed. John Wiley and Sons, Inc, USA, p. 920.
Mumby, P., Edwards, A., Arlas-Gonzalez, J., Lindeman, K., Blackwell, P., Gall, A., Gorczynska, M., Harbone, A., Pescod, C., Renken, H., Wabnitz, C., Llewellyn, G., 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427, 533–536.
Munji, C.A., 2010. Vulnerability of Cameroon's Coastal Mangroves to Coastal Flooding. Thesis. University of Buea, Cameroon, p. 130.
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. Aquat. Bot. 89, 155–185.
Nichols, R., Hoozemans, F., Marchand, M., 1999. Increasing flood risk and wetland losses due to sea-level rise: regional and global analyses. Global Environ. Change 9, S69–S87.
Primavera, J., 1997. Socio-economic impacts of shrimp culture. Aquacult. Resour. 28, 815–827.
Polidoro, B.A., Carpenter, K.E., Collins, L., Duke, N.C., Ellison, A.M., et al., 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. PLoS One 5 (4), e10095. http://dx.doi.org/10.1371/journal.pone.0010095.
Rahmstorf, S., Zickfeld, K., 2005. Thermohaline circulation changes: a question of risk assessment'. Clim. Chang. 68, 241–247.
Suratman, M.N., Bravo, F., Jandl, R., LeMay, V., Gadow, K., 2008. Carbon sequestration potential of mangroves in Southeast Asia. Earth Environ. Sci. 17, 297–315. http://dx.doi.org/10.1007/978-1-4020-8343-3_17.

Titus, J.G., 1991. Greenhouse effect and coastal wetland policy: how Americans could abandon an area the size of Massachusetts at minimum cost. Environ. Manage. 15, 39–58.

UNEP, 2007. Mangroves of Western and Central Africa. UNEP-Regional Seas Programme/UNEP-WCMC. This publication is Available Online at: http://www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series/26.htm (accessed 06.03.11.).

Valiela, I., Bowen, J., York, J., 2001. Mangrove forests: one of the world's threatened major tropical environments. Bioscience 51, 807–815.

Walters, B.B., Ronnback, 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. Aquat. Bot. 89, 220–236.

Youmbi, E., Fonkam, N.J.P., Tomekpe, K., Fonbah, C., 2011. Vitro germination and pollen conservation of some Musa species. Asian J. Biotechnol. 3, 554–563.

WWF, 2001. Terrestrial Eco-regions: Central African Mangroves, Cross-Sanaga-Bioko Coastal Forests (AT0107). Wild World WWF Full Report. Available online at: http://www.worldwildlife.org/wildworld/profiles/terrestrial/at/at0107_full.html (accessed 06.03.11.).