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ORIGINAL PAPER

The co-management approach has positive impacts on mangrove conservation: evidence from the mono transboundary biosphere reserve (Togo-Benin), West Africa

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Abstract Literature on conservation science has documented the increasing use of the co-management approach to effectively conserve natural resources. Although some studies found the co-management approach as highly effective, others also reported some uncertainties associated with the use of this conservation approach. Using the mono transboundary biosphere reserve (MTBR) as a case study, this work assessed the effectiveness of the co-management approach for mangrove conservation in West Africa. Data was collected in two protected sites of the reserve (one in Togo and the other in Benin). Exploratory sequential mixed method via in-depth interviews ($n=17$), focus group discussions ($n=14$), household surveys ($n=274$) and expert-based surveys ($n=10$) were carried out, and data was analyzed using the InVEST-based Habitat Risk Assessment (HRA) model, chi-square tests and simple probability of likelihood. Findings showed that the co-management approach has lowered anthropogenic stressors to mangroves in the reserve. Under the co-management approach, all the mangroves located in the Benin side of the reserve are identified as under low risk whereas 42% of the mangrove cover are considered under low risk and 58% under medium risk in Togo. Local perception also portrayed the reduction of mangrove degradation in the study sites following the adoption of the co-management approach in the two countries. However, there are some challenges such as the financial support provision and regular community engagement which need to be thoroughly researched and addressed to achieve the sustainability of the positive impacts of the co-management in the MTBR.

Keywords Co-management · Habitat Risk Assessment · Mangroves · Mono transboundary biosphere reserve · West Africa

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Introduction

Mangroves are coastal forests that grow in the intertidal zones of tropical and subtropical countries. They provide a set of ecosystem services (provisioning services, supporting services, regulatory services, and cultural services), which support the livelihoods of millions of people worldwide (MEA 2005). Benefits provided by mangroves to local communities include but are not limited to food and raw materials provision, climate and flood regulation, ecotourism promotion and biodiversity conservation (Dahdouh-Guebas et al. 2005). They are also important in carbon sequestration, erosion control, and nutrient cycling (Zimmer 2018).

Despite their importance to mankind, mangroves are intensively being degraded around the world predominantly because of human-made actions. The Food and Agriculture Organization (FAO) estimated that approximately 50% of mangroves disappeared globally since 1890 (Jia et al. 2018). Duke et al. (2007) also reported that mangroves are being lost at a rate of one to two percent per year, and this may further increase, up to eight percent a year, in some developing countries. The situation has taken an alarming proportion in West Africa, where mangroves cover has shown a dramatic decline over the last two decades. For example, Padonou et al. (2021) indicated that the sub region has lost about 30% of its mangroves in the last 25 years due to both manmade and climate actions such as coastal development, land encroachment, sea level rise and unsustainable harvesting.

Considering the increasing rate of mangrove degradation in West Africa, decision-makers have decided to involve local communities in the management of the resource by promoting the co-management approach (d'Aquino & Bah 2013). The co-management is an approach whereby government shares authority, responsibilities, and functions with the resource users (Cundill 2010). Although the approach is noted for yielding positive results and impacts, it can also fail to produce the expected results if not well implemented (Nunan et al. 2015). The success of the co-management approach depends on the synergy among the stakeholders associated with the management of the resource and the willingness of the local communities to support the process (Kepe 2008). In West Africa, the co-management is being increasingly used to protect and promote the sustainable use of coastal resources including mangroves. Nevertheless, compared to other parts of the continent where the subject is being increasingly researched and adapted (Hauck and Sowman 2001; Reid et al. 2004; Armitage et al. 2009; O'Leary et al. 2020), there are few attempts to understand the effectiveness of this management approach in mangrove conservation in the West Africa region.

Located in West Africa, the mono transboundary biosphere reserve (MTBR) stretches over the delta, alluvial plain and coastal zone of the Mono River, a 400 km-long transboundary river that runs through south-eastern Togo and gets into the ocean in south-western Benin. It brings together the mosaic landscape and ecosystems of the southern Benin and Togo into a unique protected environment. It was created to contribute to the conservation of the coastal and inland ecosystems located within the Mono Delta which is shared between the two countries. Before the creation of the reserve, mangroves were managed by the Authority of Mono Delta represented by the governments of Benin and Togo. After the creation of the reserve in 2017, decision-makers agreed on the implementation of the co-management approach. Therefore, the management of all the natural resources of the reserve was decentralized, with the active participation of the local communities (Adjonou et al. 2020). Prior to the establishment of the reserve, each community in the area had some local associations which regulated the use of resources at community level, however their operations were subjected to central governments decisions. With the creation of the reserve, it became necessary for all community-based organizations to be merged into one broad organization in each country. For example, all the community-based organizations located within the coastal site "La bouche du Roy" in Benin came together to form the association of conservation and promotion of the site "La bouche du Roy", called ACP-Doukpo. In the other part of the reserve, the community-based organizations located within the site "Le chenal de Gbaga" in Togo created the federation of the associations of mangrove planters of the Channel Gbaga, called FAH-Gbaga. The two newly created associations received later in 2017, the legal authorization from the governments of the two countries to manage the resources under their territories, including mangroves. At community level, the two associations are represented by their focal points which have the mandate to ensure the sustainable use of coastal resources including mangrove ecosystems and escalate any case of the resource degradation to the members of the associations for subsequent actions. The associations also receive support at community level from the head of villages, traditional authorities and other local associations existing in the villages (associations of youth, fishermen, fishmongers for examples) for mangrove conservation. The MTBR offers an interesting case study to assess how the co-management approach has affected mangrove conservation.

This study assessed the effectiveness of the co-management approach in the MTBR, with the assumption that this new management approach is helping to curtail the high anthropogenic pressures on mangroves that prevailed in the area prior to the establishment of the reserve. More specifically, the study sought to assess (i) the extent to which mangroves are at risk by anthropogenic stressors under the current co-management regimes, (ii) the perceived effectiveness of co-management in minimizing mangrove degradation and (iii) the constraints in implementing the approach in the reserve.

Methodology

Study area

Two of the three coastal sites of the reserve were considered for data collection. They included the site "*La bouche du Roy*" in Benin and the site "*Le Chenal de Gbaga*" in Togo (see Fig. 1). The former extends

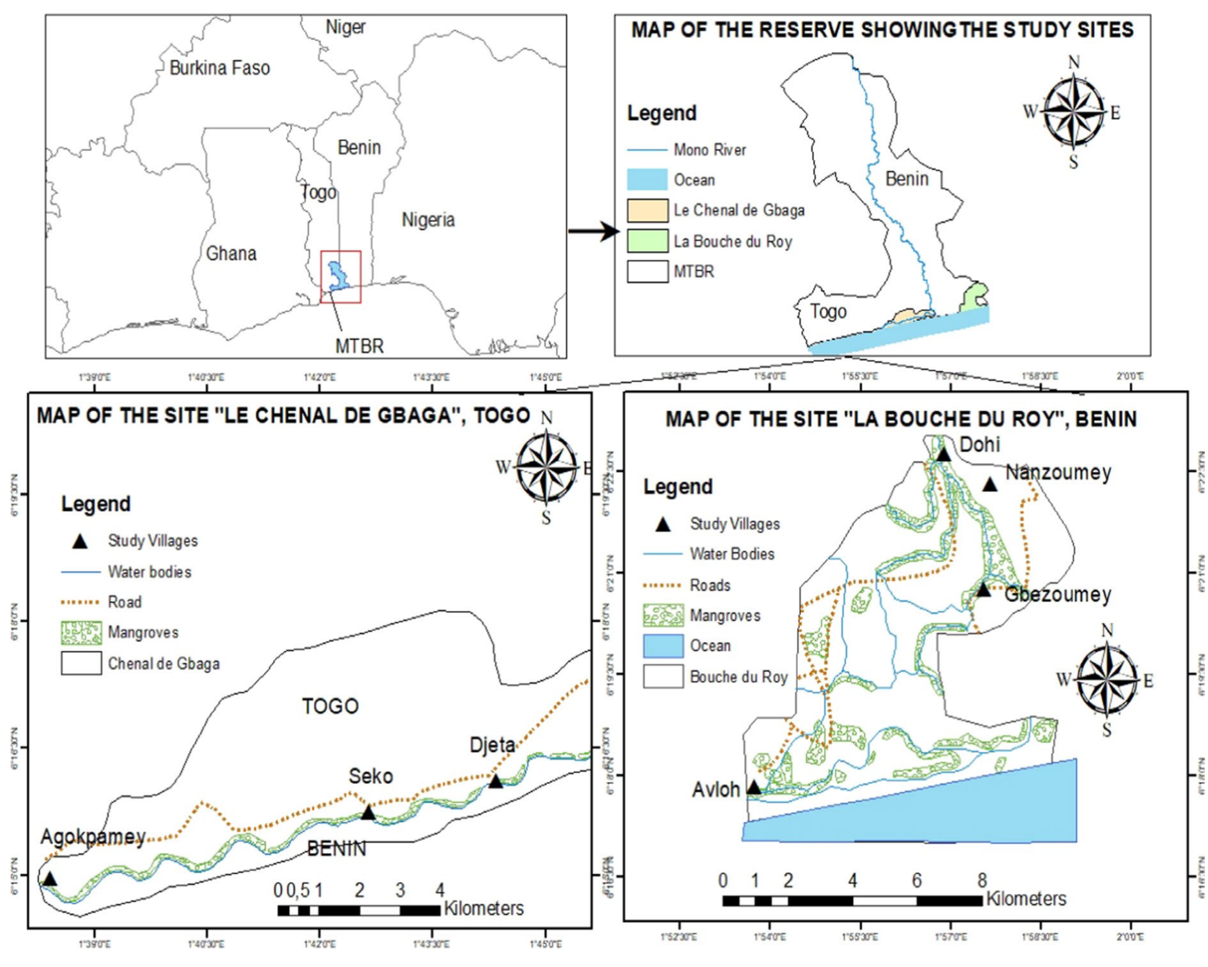

Fig. 1 Map of the study area

from 6° 12′ and 6° 15′ North to 1° 52′ and 1° 59′ East with a surface area of approximately 9678 hectares whereas the latter lies between 6° 17′ and 6° 18′ North and 1° 39′ and 1° 48′ and covers surface area of 4575 hectares. The site "*Chenal de Gbaga*" is a transboundary site with the Gbaga lagoon serving as a natural border between Benin and Togo. Mangroves and the *Gbaga lagoon* represent its major coastal ecosystems with a population dominated by the ethnic group of *Mina*.

Identification of the stressors

Anthropogenic stressors responsible for mangrove degradation in the study sites were identified through extensive literature review, field interactions and direct observations. Firstly, a broad range of articles were consulted to identify the documented threats responsible for mangrove degradation. In addition to this, fourteen focus group discussions (FGDs) involving ten participants per group (140 participants in total) were organized in the two sites to crosscheck and validate the collected information and to record the possible stressors unidentified by the literature review and the direct observations (see supplementary data, Tables S1 and S2). Participants of the focus groups were selected purposively (Sagoe et al. 2021). They include matured residents (30 years and above) who have resided in the reserve for at least ten years and who are knowledgeable about the situation of mangroves in the reserve (threats, services, and functions). Information collected from the focus group participants was further complemented by the in-depth interviews. Key informants considered for the study were selected based on snowball and purposive sampling techniques (Sagoe et al. 2021). In total, twenty key informants including ten resource persons, four NGOs, one state agency and five members of the two associations mandated to manage the sites were consulted (see supplementary data, Tables S5 and S6).

Habitat Risk Assessment (HRA)

After the identification of the stressors, the study assessed the magnitude of risk that they posed to mangroves in the study sites, under the current co-management regime. As such, the Habitat Risk Assessment (HRA) model was run using the InVEST software version 3.9.0. The HRA model allows the assessment of the cumulative risk posed by anthropogenic activities to habitats and/or species as well as the consequences for the provision of ecosystem services and biodiversity (Cabral et al. 2015; Caro et al. 2020; Ghehi et al. 2020; Studwell et al. 2021). Data requirements of the model and how they were generated and used is summarized in Table S6 (See supplementary Data). It incorporates information from exposure and consequence to calculate the risk to ecosystems and species with the assumption that habitats or species with high exposure to human activities and high consequence of the exposure are at high risk (Arkema et al. 2015). The InVEST HRA model firstly determines the degree of exposure of the habitats or species under study to the stressors and the consequence of this exposure (Arkema et al. 2015). Exposure (E) and consequence (C) are rated on a scale of 1 (the lowest) to 3 (the highest) using a set of criteria for each attribute (see Table S7 in the supplementary Data). For this study, scores were assigned based on literature, direct observations from the field and expert-based survey (see supplementary data, Tables S4 and S5). Experts engaged for this study included mangrove-oriented researchers and NGOs officials working in the area. The overall exposure and consequence were determined as weighted average of the consequence values Ci and exposure values Ei for each criterion i from the habitat j and the stressor k (see Eqs. 1 and 2).

$$E = \frac{\sum_{i=1}^{n} \frac{Ei}{di.wi}}{\sum_{i=1}^{n} \frac{1}{di.wi}} \tag{1}$$

$$C = \frac{\sum_{i=1}^{n} \frac{Ci}{di.wi}}{\sum_{i=1}^{n} \frac{1}{di.wi}} \tag{2}$$

In the formulars, di is the data quality rating for criterion i, wi is the importance weighting for criterion i and n represents the number of criteria considered for each habitat (Moreira et al. 2018). For this study, the Euclidean risk equation with linear decay was used (see Eq. 3). This approach combines the exposure and the response values to generate a risk value for each stressor-habitat combination in each grid cell (Ghehi et al. 2020). Euclidean risk calculation considers the risk to habitat j caused by stressor k in each location (cell precisely) and calculates it as the Euclidean distance from the origin in the exposure-consequence. Here, average exposure (Eq. 1) represents the first axis, and the average consequence (Eq. 2) represents the second axis (Ghehi et al. 2020).

$$Rij = \sqrt{(E-1)^2 + (C-1)^2} \quad (3)$$

The model then estimates the risk posed by multiple stressors to habitats or species where risk i caused by stressor j is calculated by multiplying the exposure and the consequence (Eq. 4) (Arkema et al. 2015).

$$Rij = E \times C \quad (4)$$

Effectiveness of the co-management in mangrove conservation

To ascertain whether the management regime put in place is effective in reducing anthropogenic threats to mangrove, a household survey was conducted in the two study sites. Households which partook in the survey were selected based on simple random sampling technique (Gnansounou et al. 2021). The sample size was calculated for each site in a separate manner using the Eq. 5 (Köhl et al. 2006):

$$n = \frac{1}{e^2} p(1-p) U^2_{1-\frac{\alpha}{2}} \quad (5)$$

where, n represents the total sample size, U is the value of the normal random variable ($U^2_{1-\frac{\alpha}{2}}$=1.96 for $\alpha = 0.05$) and e represents the authorized margin error held to be 9% in this survey (Köhl et al. 2006). The pilot survey conducted during the field reconnaissance with fifty households selected in each site helped to calculate the proportion of households who are knowledgeable about the history of mangroves (evolution, degradation, and threats) at each site. After calculation, 184 and 90 respondents were investigated in Benin ($p = 0.7$) and in Togo ($p = 0.9$), respectively (see Table S3 in the supplementary data). Respondents were engaged in a face-to-face interview with paper-based interview guide. Their perception was sought on how effective is the co-management towards mangrove conservation.

Data analysis

Information from the focus group discussions and in-depth interviews was transcribed for understanding and content validity. For each site, the percentages of mangrove surface area under low, medium and high risk under the current co-management system were generated both for all the stressors collectively, and also for each stressor through HRA model using InVEST 3.9.0. Respondents of the household survey were grouped based on their age young householders: < 30 years, adult householders: 30–60 years, and old householders > 60 years in the two countries), activities (artisanal activities, fishing activities, mat weaving, petty trading and salt production in Benin; artisanal activities, fishing activities, farming and petty trading in Togo), gender (Male versus Female in the two countries), ethnic groups (Fon, Mina, Xwlah and Xwedah in Benin; Mina, Ewe and Ouatchi in Togo) and level of education attainment (no education, primary and secondary in the two countries). Then, differences in their perception on the effectiveness of the co-management system across gender, age categories, activities, ethnical groups and educational background were tested using Chi-square test with the software R version 4.0.1 (R Core Team 2020).

Results

Anthropogenic stressors responsible for mangrove degradation in the MTBR

Anthropogenic stressors responsible for mangrove degradation in the MTBR as well as their perceived drivers are summarized in Table 1 and presented in Fig. 2. In total, six stressors including the Illegal Unreported and Unregulated fishing (IUU), pollution, mangrove over-harvesting, bushfire, mangrove clearing and change in salinity of water were recorded in Benin. In Togo, seven stressors were recorded, which included IUU, mangrove clearing, over-harvesting, change in salinity of water, pollution, livestock and invasive species. IUU here refers to any prohibited fishing activity which takes place within mangroves. It was recorded in both study sites. Chief fishermen and resource persons consulted in the two sites acknowledged the use of prohibited fishing gears within mangroves in their

Table 1 Perceived drivers of recorded stressors in the study sites

	Population growth	Unplanned land use	Lack of jobs	Weak enforcement of laws	Inadequate awareness raising	Fish stock depletion	Poor waste management	No public latrine	Urbanization	Coastal cultivation
Benin										
Change in water salinity	–	–	–	–	–	–	–	–	x	–
IUU	x	–	x	x	–	x	–	–	–	
Mangrove clearing	x	–	x	x	–	–	–	–	–	–
Overharvesting	x	–	x	x	–	–	–	–	–	–
Pollution	–	–	–	–	–	–	x	x	x	x
Bushfire	x	x	–	–	–	–	–	–	–	–
Togo										
Change in water salinity	–	–	–	–	–	–	–	–	x	–
IUU	x	–	x	x	–	–	–	–	–	–
Mangrove clearing	–	–	–	x	x	–	–	–	x	–
Overharvesting	x	–	x	–	x	–	–	–	–	–
Pollution							x			x
Invasive species	–	–	–	–	–	–	–	–	x	–
Livestock	–	–	–	x	–	–	–	–	–	–

x, at least one informant associated the driver to the stressor; –, no informant associated the driver to the stressor; IUU, Illegal Unreported and Unregulated fishing

Fig. 2 Some manmade threats to mangroves in the reserve: **a** mangroves cleared for house construction, **b** aquaculture development within mangroves, **c** bushfire within mangroves, **d** small mesh size net operating within mangroves, **e** Unsustainable *R. racemosa* collection for sale, **f** pesticide used around mangroves

communities. Mangrove overharvesting indicates the overexploitation of mangrove wood for different purposes. Mangroves are being increasingly harvested in the study sites for two major uses: commercial purposes and domestic uses for cooking and construction. Information collected from the field showed that salt producers prefer to use mangrove wood during the salt preparation process, particularly *R. racemosa*. The same species is said to be of paramount importance for house construction as a result of its hardness and resistance against insects. Mangrove clearing as portrayed in this study refers to the conversion of mangrove ecosystems to other land use types, following complete or partial removal of mangrove species. Mangroves are being cleared in the study sites mainly for aquaculture development, farming activities or salt ponds installation. Bushfire is another stressor which caused a lot of damages to mangrove ecosystems in the study area. It was recorded only in Benin and occurs predominantly during the dry season. Mangrove pollution and change in water salinity were also cited by key informants in both sites and were attributed to manmade actions. In addition to these stressors, livestock and invasive species were also recorded but uniquely in the site of Togo.

Risks posed by the identified stressors to mangroves in the MTBR under the co-management regime

Risk from all stressors

The output of the HRA model indicated that the highest values of the cumulative risk scores of the two study sites did not exceed the upper medium score limit which is 1.86 for all habitat-stressor combinations. The cumulative risk score recorded in Benin was 0.48 indicating that all the stressors recorded in Benin pose low risk to mangroves. In Togo, the model showed a cumulative risk score of 0.89, indicating that all the stressors recorded in Togo pose low and medium risks to mangroves. Figure 3 shows the maps of habitat-specific cumulative risks from all stressors in grid cell for the two study sites. It shows that all the mangroves (100%) in the site of Benin were under low risks (Fig. 3a), whereas those in Togo were under low and medium risks (42% under low risk and 58% under medium risk).

Risk from each stressor

Table 2 summarizes the risk posed by each stressor to mangroves in the study sites. It indicates that in Benin, change in salinity of water and mangrove pollution put the total surface area of mangroves (100%) under low risk, with an average risk of 0.33 and 0.06 respectively. IUU, mangrove clearing and bushfire put 19.37%, 6.20% and 41.86% of the mangrove cover under medium risk whereas 80.62%, 93.79% and 58.13% were under low risk respectively, with an average risk of 0.43, 0.17 and 0.8. Regarding the overharvesting, it has led to low risk for 58.13% of the mangrove coverage and high risk for 41.86% of the mangrove surface area, with an average risk of 1.06. Stressors recorded in Togo appeared more detrimental to mangroves than Benin. The model showed that change in salinity of water, mangrove pollution, invasive species and livestock put 82%, 30%, 34% and 24% of the mangrove coverage under medium risk and 18%, 70%, 66% and 76% under low risk respectively, with an average risk of 1.28, 0.58, 0.85 and 0.52. Regarding IUU, mangrove clearing and mangrove overharvesting, they presented an average risk of 0.30, 0.67 and 2.05 respectively. IUU and mangrove clearing posed high risk to 12% and 20% of the total mangrove cover of the site but represented low risk to 88% and 80% respectively. Likewise, over-harvesting put 82% of mangroves under high risk, but poses low risk to 18% of the mangrove cover of the area.

Perceived impact of the co-management on mangrove protection in the reserves

The perception of residents about the extent to which the co-management system promote mangrove conservation in the reserve is summarized in the Fig. 4. In Benin, 32.6% of the respondents reported a drastic reduction of human-led pressures on mangroves following the adoption of the co-management while 45.6% asserted that these pressures have somewhat reduced. On the other hand, 21.7% of the respondents indicated that the adoption of the co-management system has not yet produced any result in terms of mangrove conservation (see Fig. 3a). Peoples' perception in Benin varied significantly across ethnical groups ($\chi^2 = 21.09$, $p < 0.001$) but not among age categories ($\chi^2 = 6.17$, $p = 0.18$), sex ($\chi^2 = 1.36$, $p = 0.5$), activities ($\chi^2 = 10.66$, $p = 0.22$), and educational background ($\chi^2 = 2.68$, $p = 0.61$). In particular, most Xwlahs and Xwedahs reported the reduction of manmade pressures to mangroves following the advent of the co-management regime in Benin. In Togo, 49.7% of the interviewees informed that manmade pressures to mangroves have drastically reduced since the advent of the co-management, 36.2% indicated that the situation has somewhat changed and 14.1% reported that it has remained the same (see Fig. 3b). Here, respondents' perception was significantly influenced by the ethnical groups ($\chi^2 = 12.29$, $p = 0.01$) and activities ($\chi^2 = 6.46$, $p < 0.001$) but did not vary according to sex ($\chi^2 = 1.01$, $p = 0.6$), educational background ($\chi^2 = 5.01$, $p = 0.28$), and age categories ($\chi^2 = 3.88$, $p = 0.42$). As in Benin, respondents belonging to Mina ethnic group mostly reported that the situation of mangrove degradation in Togo has reduced as a result of the new management approach as compared to the Ouatchi and the Ewes. However, in the two study sites, no respondent indicated the situation whereby mangrove degradation has increased ever since the co-management has become effective.

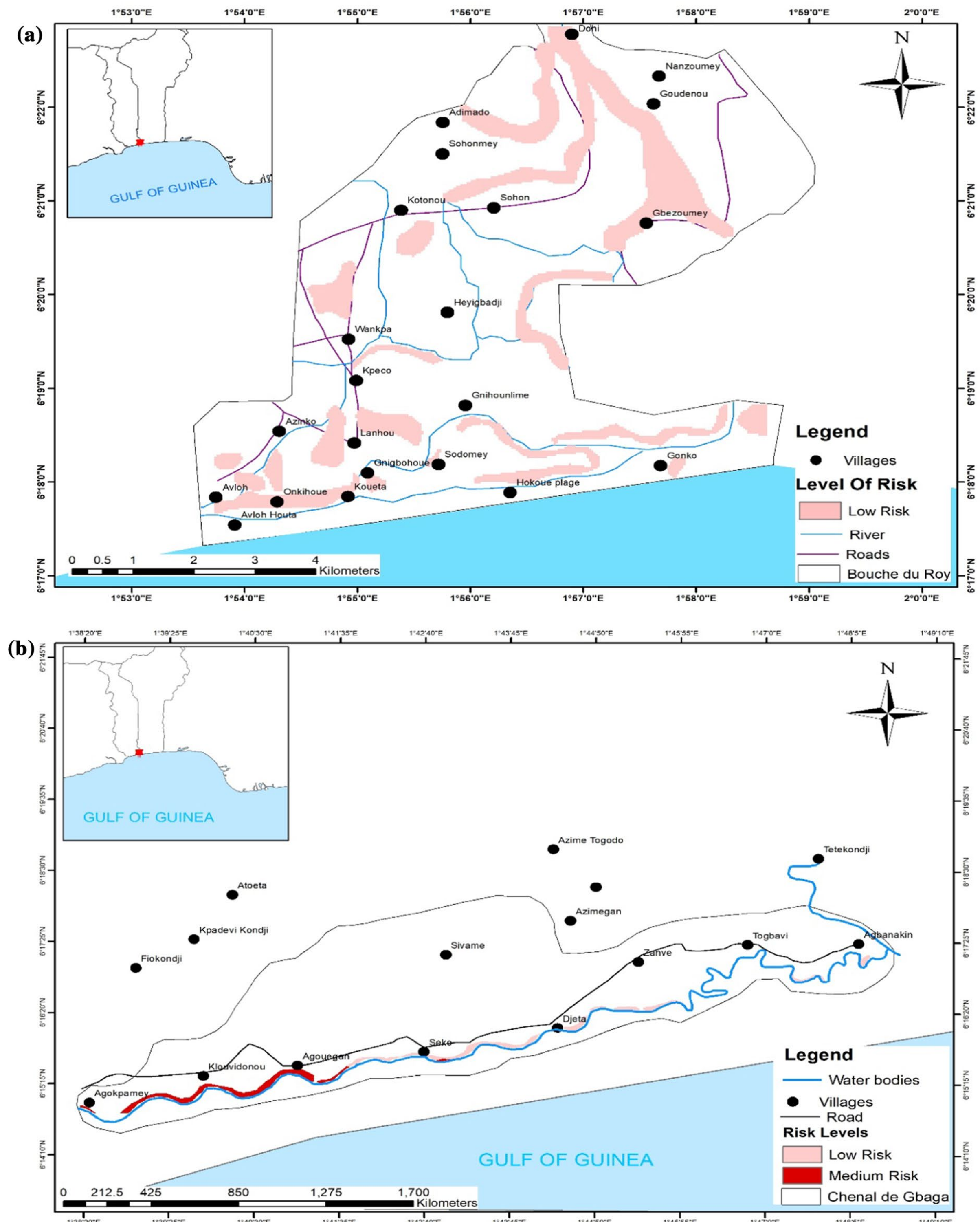

Fig. 3 Habitat-specific cumulative risks from all stressors in Benin (**a**) and Togo (**b**)

Table 2 Risk posed to mangroves by each stressor taken individually from the InVEST HRA model

Stressors	Benin				Togo			
	R_mean	R_High	R_medium	R_Low	R_mean	R_High	R_medium	R_Low
Change in salinity of water	0.33	0	0	100	1.28	0	82	18
IUU	0.43	0	19.37	80.62	0.30	12	0	88
Mangrove clearing	0.17	0	6.20	93.79	0.67	20	–	80
Over-harvesting	1.06	41.86	0	58.13	2.05	82	0	18
Pollution	0.06	0	0	100	0.58	0	30	70
Bushfire	0.80	0	41.86	58.13	–	–	–	–
Invasive species	–	–	–	–	0.85	0	34	66
Livestock	–	–	–	–	0.52	0	24	76
All stressors	0.48	0	0	100	0.89	0	42	58

R_mean = average score for the risk

R_High = Score for the high risk

R_medium = Score for the medium risk

R_Low = Score for the low risk

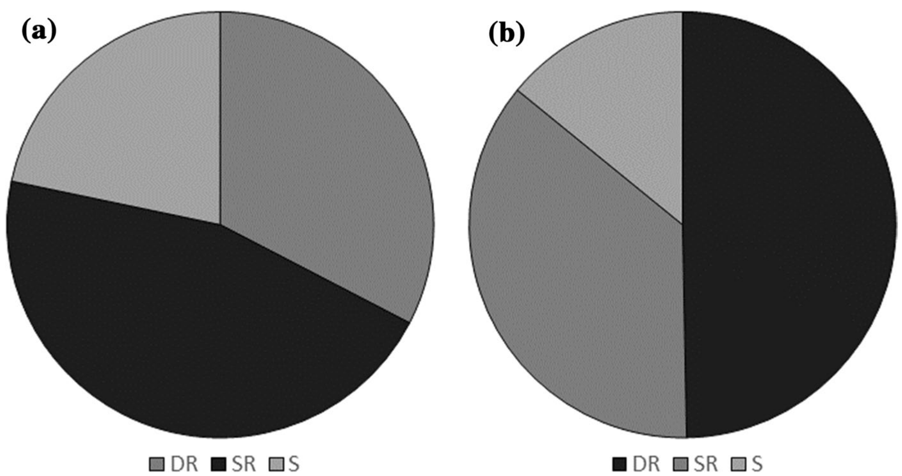

Fig. 4 Perceived effectiveness of the co-management in reducing threats to mangroves in the study area, Benin (**a**) and Togo (**b**). *DR* drastically reduced, *SR* somewhat reduced, *S* same situation

Constraints associated with mangrove management in the study sites

Meetings held with the members of the local associations, NGO officials and state agencies helped to understand some of the challenges associated with the local management of mangroves in the study sites. NGOs and local associations lamented the lack of financial support to efficiently protect mangroves. They also raised issues of inadequate canoes, outboard motors and fuel to conduct patrol exercises. They indicated that they heavily resort to international organizations for funding. They further explained that supports from the government are rare and limited to residents' engagement on special occasions (National Tree Planting Day for example). They also reported the lack of commitment of some local dwellers to participate in key activities such as decision-making-oriented meetings, mangrove restoration campaigns as well as awareness raising.

Discussion

Co-management approach and its implications in mangrove conservation in the study sites

The contribution of the co-management regime in reducing anthropogenic threats to mangroves in the MTBR depicted a strong geographical variation looking at the cumulative risk of all stressors to mangroves in the study sites. The success of the co-management in mangrove conservation has already been demonstrated by a large body of research worldwide (Yandle 2003; Chuenpagdee et al. 2004; Gelcich et al. 2008; Levine and Richmond 2014). Katon et al. (2000) revealed that the co-management has helped to rehabilitate a lot of mangrove resources at Cogtong bay in the Philippines. Mangroves located in the site of Benin were all under low risk of human-led degradation under the newly implemented co-management regime. Indeed, the local association mandated to manage the site of Benin has put in place some participatory measures, which fostered mangrove management and local governance. The strong involvement of the customary laws that governed the area coupled with the use of traditional means to protect mangroves within the site yielded tremendous results, and enhanced mangroves conservation in the area. Firstly, the customary laws known for *Xwlah* ethnical group, which represented over 50% of the local population within the site (Gnansounou et al. 2021) have been set as general rules to fight against mangrove pollution in the reserve. These laws, which include the ban of open defecation as well as sewage and waste dumping into the water bodies in the area have helped to considerably limit mangrove pollution. This aligns with Aheto et al. (2016) and Sagoe et al. (2021) who pinpointed the roles of customary laws in management of coastal resources in West Africa. The authors explained that traditional rules and regulations are easy to enforce and simple to comply with and therefore, contribute more to mangroves management. To curb the ongoing degradation of mangroves, stakeholders in Benin have also sought contribution from the local deities, especially the *Zangbeto*. This has resulted in the identification of many mangrove ecosystems as sanctums, and people were prohibited from accessing, using or clearing. These sanctum ecosystems have over the years promoted ecotourism in the areas and serve as habitats for variety of species including migratory birds. Research conducted by Zanvo et al. (2021) in the area demonstrated that the creation of sanctums from mangrove forests highly contributed to mangrove conservation in Benin. The authors compared tree taxonomic diversity, structural diversity and dominance patterns in mangroves subjected to low and high wood harvesting intensity and observed that mangroves that showed higher tree density, structural diversity and growth characteristic were those protected with the local divinity *Zangbeto*. The non-implementation of these traditional and customary means in Togo could account for the medium risks recorded in this site. It could also be due to some internal factors including the governance of mangroves, conflicts among stakeholders or the institutional arrangement-oriented biases that may be revealed by further studies.

Effectiveness of the co-management in mangrove protection and constraints associated with the approach

Although a lot of conservation efforts need to be made particularly in the site of Togo, information collected from the field showed a satisfactory trend regarding the contribution of the co-management approach in conserving mangroves within the reserve. For example, no interviewee in the two study sites reported the escalation of mangrove degradation since the creation of the reserve. This meets the main objective of the establishment of the reserve, which was to create a conducive environment for a successful conservation of coastal resources located within the Mono Delta (Ecobenin 2018). While majority of the respondents in the two study sites described a situation of large reduction of manmade threats to mangroves following the implementation of the co-management approach, a handful of interviewees (21.7% in Benin and 14.1% in Togo) asserted that the situation remained unchanged even with the new management regime. They further supported their point of view by the surface area of mangroves, which has not shown significant change in the reserve ever since the co-management is being implemented. This may be due to the inadequate awareness raising activities within the reserve. Studies revealed that it takes decades for mangrove ecosystems to bounce back to normal if they undergo serious disturbances. This was the case in the area prior to the establishment of the reserve in 2017 (Adjonou et al. 2020; Teka et al. 2019). This necessitates a lot of restoration and conservation efforts currently underway within the reserve with the support of many international institutions (Guelly et al. 2020). It is therefore important to carry out quantitative and qualitative research to understand the various misconceptions of mangroves functioning, phenology and ecosystem services in order to restructure sensitization activities based on local communities' perception. The results of the chi-square test showed a significant influence of the ethnicity on the perceived impacts of the co-management on mangroves protection in the reserve. Most Xwlahs and Xwedahs in Benin, and most Minas in Togo reported the reduction of manmade pressures to mangroves as a result of the co-management. These ethnic groups represent the indigenous sociocultural groups of the area (Gnansounou et al. 2021), and therefore are more knowledgeable about the degradation of mangroves in the reserve. This concurs with Nyangoko et al. (2021) who found difference in perception in the local use of mangroves in Tanzania with a significant variation across ethnic groups.

Persistent anthropogenic threats to mangroves under the co-management regime

The anthropogenic stressors recorded in the two study sites are similar to those listed by Feka and Ajonina (2011) who documented the anthropogenic threats to mangroves within the subregion. Informants indicated their large contribution to mangrove degradation and biodiversity loss in the area before the establishment of the reserve. Notwithstanding stakeholders' efforts, some anthropogenic stressors still undermine the effective conservation of mangroves in the study sites. Threats like IUU, bushfire and overharvesting represent respectively medium and high risk to mangroves in the reserve. This calls for urgent actions in order to deal with these threats, which could cause severe harm to mangrove ecosystems going forward. Direct observation from the field showed that mangroves overharvesting is taking an alarming proportion in the study sites, particularly in Togo. Mangroves' woods are being harvested in the study mainly for domestic uses. This concurs with the findings of previous works carried out in the reserve (Gnansounou et al. 2021; Adanguidi et al. 2020; Zanvo et al. 2021). The growing interest on mangroves' woods for domestic uses in the study sites may be due to the demographic growth currently prevailing in the reserve (Teka et al. 2019). Research on the cooking fuels within the reserve will undoubtedly help to propose alternative and affordable fuel sources in order to curb the increasing domestic use of mangroves for cooking purposes. Furthermore, awareness raising must be increased in the reserve in order to advert the growing clearing of mangroves. Bushfire is also being detrimental to mangrove species in the MTBR. It happens predominantly in Benin in the violation of the legal instruments which protect mangroves in the country. In addition, IUU poses also a serious threat to mangroves under the current co-management regime. Though the use of mangrove species to establish the *acadja* has drastically declined in the two study sites following the creation of the reserve and the subsequent implementation of the co-management approach, other illegal fishing techniques continue to degrade mangroves in the study sites. This may be due to the dwindle in fish stock in the marine and coastal waters of the subregion (Asiedu et al. 2021; Nunoo et al. 2014). A study of livelihood need assessment is therefore important in order to ascertain the preferred livelihood options of the fishermen and farmers operating within the study sites of subsequent actions in order to limit bushfire and IUU-induced mangrove degradation in the reserve. There are many challenges associated with the implementation of the co-management approach in the MTBR. Constraints raised by the informants in this study were also reported by other authors (Nunan 2020; Buck et al. 2004). Linke and Bruckmeier (2015) also highlighted the lack of commitment of the local population towards the co-management can lead to dire implications to resource conservation in the area. There is therefore crucial to document the causes of the current and possible future challenges that may undermine the successful implementation of the co-management in the reserve for informed policy making.

Conclusion

This work investigated the contribution of the co-management in mangrove conservation in West Africa, using the MTBR as case study. Lessons learnt from this study as well as the information shared by the study informed the significance of the co-management approach in mangroves conservation in the reserve. The model used for this study together with the interactions with the community members helped to know the importance of the co-management system in curbing mangroves-oriented anthropogenic pressures in the reserve. Findings showed that there is a drastic reduction of the frequency and the intensity of anthropogenic stressors to mangroves in the MTBR following the adoption and the implementation of the co-management approach. However, there are some specific challenges such as the lack of financial support and equipment which need to be thoroughly researched and addressed to enhance the positive impacts of the co-management approach as well as the resilience of mangrove ecosystems in the study area.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval Prior to data collection, ethical approval reference UCCIRB/CANS/2021/20 was obtained from the University of Cape Coast Institutional Review Board (UCCIRB). Within the study communities, the purpose of the work was thoroughly explained to each interviewee as well as the possible risks associated with their participation. Oral consent was also sought from participants before engaging them in the study.

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