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Mangrove Ecosystem Services, Associated Threats and Implications for Wellbeing in the Mono Transboundary Biosphere Reserve (Togo-Benin), West-Africa

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Abstract: Mangroves are important coastal ecosystems, which deliver diverse and crucial services to humans. This study explored the diversity of mangrove ecosystem services, their associated threats as well as their contribution to livelihoods and wellbeing of coastal communities in the Mono Transboundary Biosphere Reserve (MTBR) located between Benin and Togo. Data were collected using the exploratory sequential mixed method. The approach included field reconnaissance, focus group discussions (n = 14), in-depth interviews (n = 17), household survey (n = 274) and direct observations. A total of 21 services and 7 associated threats were recorded in the entire reserve. Provisioning services were the most important service for mangroves in the reserve followed by supporting services, regulating services and cultural services. Change in water salinity, mangrove overharvesting and illegal, unreported and unregulated fishing were the three major threats to mangrove ecosystem services in the reserve. Most of the respondents indicated that the current flow of provisioning services, regulating services and cultural services does not sustain their wellbeing and livelihoods. However, the perception varied significantly across respondents' gender, ethnical groups, educational background and country. Our study showed some similarities between the two countries but also highlighted important differences which can assist the sustainable management of mangroves in the MTBR.

Keywords: wellbeing; mangroves; ecosystem services; mono transboundary biosphere reserve; West-Africa



Citation: Gnansounou, S.C.; Salako, K.V.; Sagoe, A.A.; Mattah, P.A.D.; Aheto, D.W.; Glèlè Kakaï, R. Mangrove Ecosystem Services, Associated Threats and Implications for Wellbeing in the Mono Transboundary Biosphere Reserve (Togo-Benin), West-Africa. *Sustainability* **2022**, *14*, 2438. <https://doi.org/10.3390/su14042438>

Academic Editor: Ivo Machar

Received: 14 November 2021

Accepted: 7 January 2022

Published: 20 February 2022

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1. Introduction

Mangroves are ecosystems generally found in the intertidal zones of the tropical and subtropical countries [1]. Mangrove species globally distinguish themselves from the other inland species by their ability to cope with some extreme conditions, notably an elevated level of salt, frequent tidal floods, saturated soils and wave effects [2]. As reported worldwide, mangroves offer direct and indirect benefits to coastal communities in West Africa [3]. Their roles in supporting coastal dwellers in West Africa have been largely documented, ranging from coastal protection and erosion control to the provision of various goods and services to coastal communities [4,5].

Unfortunately, mangroves are being severely degraded in the West African coastal countries. For example, 30% of their cover has been lost in 25 years, predominantly because of anthropogenic activities [6].

Given the large mangrove degradation along the West-African coast, efforts are being made to protect them from further degradation and to restore the degraded patches. Areas encompassing a large extent of mangrove are being massively designated as “protected areas” for an effective conservation of coastal resources. This is the case of the Mono Transboundary Biosphere Reserve (MTBR) located within the Mono Delta shared by Benin and Togo (see supplementary data, Figure S1). Started in 2014, the process of the designation of the reserve funded by the Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety of the Federal Republic of Germany was completed in 2017 with the delineation and recognition of the reserve as UNESCO Man and Biosphere Reserve (MAB). One of the reasons underlying the creation of the MTBR was the conservation and the sustainable use of its coastal resources in order to attain coastal resilience, with a focus on mangroves which had lost 93% of their coverage in the area between 1980 and 2015 [7]. Though the reserve brings together a mosaic landscape and ecosystems of the southern Benin and Togo into a unique protected environment, the management of its natural resources remains country specific. Within the reserve, stakeholders and management systems put in place for mangrove conservation in Benin are quite different from the ones in Togo. For instance, different community-based associations are in charge of mangroves’ management in the reserve, with different working systems in terms of community engagement and mangroves’ protection. The association in Benin is called “ACP-Doukpo” whereas the one in Togo is known as “FAH-Gbaga”. As such, in addition to the broader characterization of mangrove ES at reserve-level, accounting for the services and their associated threats at country-level is paramount in attaining the sustainable use of mangroves. This will also help to support country-specific decision-making in the reserve.

There are several pieces of evidence of a strong correlation between mangrove degradation and mangrove ecosystem services (ES) depletion [4,8,9]. Mangrove degradation has the potential to impact mangrove biodiversity, fish provision and productivities and by extension the quality of life in communities close to mangrove forests [10]. Given the high degradation of mangroves in the MTBR, many international stakeholders including Ramsar convention, West Africa Coastal Areas Program (WACA) and some Non-Governmental Organizations (NGOs) are working restlessly to design an effective conservation tool for mangrove conservation and sustainable use in the reserve. However, their actions are somewhat limited due to the paucity of scientific knowledge that should foster their decision making.

Research on the coastal resources, especially mangroves in the MTBR, is relatively nascent and limited, with aspects associated with ES still understudied. Existing scientific information on the part of the reserve in Benin covers aspects pertaining to the local use of mangroves in Grand-Popo, one of the municipalities embedded in the reserve in Benin [11]. It also covers the characterization of the provisioning services delivered by mangroves in some localities of the reserve [12–14] and the carbon storage capacity of mangroves [15]. In the Togolese part of the reserve, no scientific record exists on mangrove ES to our knowledge.

The link between mangrove ES provision and human wellbeing is often multifaceted, and some of these services are more delivered than others [16]. In addition, the rate of provision and the threats to mangrove ES are context-specific and depend on geographical and socioeconomic characteristics at community-level as well as the local management framework [16]. Therefore, a clear and broad characterization of mangrove ES in the MTBR will undoubtedly help incorporate local population’ perceived benefits, priorities and preferences in decision making [17]. Knowledge on ES to be promoted and those to be monitored for a sustainable use of mangroves in the reserve is also paramount to stakeholders. Moreover, investigating the different threats to mangrove ES is essential to trigger site-specific actions to curb the wanton ongoing anthropogenic pressures on mangrove ES in the MTBR [16]. This will ultimately help to attain the sustainable development goals (SDGs), especially the SDGs 3 and 14 which advocate respectively for healthy lives and

promotion of wellbeing for all and for the conservation and the sustainable use of oceans, seas and marine resources [18].

This study used the social valuation of ES approach and aimed at documenting the services delivered by mangroves in the MTBR, their associated threats as well as their contribution to sustaining the wellbeing and the livelihoods of the local communities surrounding mangroves in the reserve. More specifically, the work sought to address the following questions:

- (a) What are the perceived ecosystem services provided by mangroves to local communities in the MTBR?
- (b) What are the most important services in the reserve?
- (c) Are local residents satisfied with the extent to which the current supply of mangrove ES sustains their wellbeing and livelihoods in the reserve?
- (d) What are the threats to mangrove ES in the MTBR and how are they spatially distributed?
- (e) Are mangrove ES and their associated threats similar between the two countries which share the MTBR?

2. Materials and Methods

2.1. Study Area

Two protected sites of the reserve were considered in this study: “*La bouche du Roy*” in Benin and “*Le Chenal de Gbaga*” in Togo (Figure 1). Dominated by the ethnic groups *Xwlah* and *Xwedah*, the site “*La bouche du Roy*” lies between 6°12' and 6°15' North and 1°52' and 1°59' East and covers four municipalities (Come, Grand-Popo, Ouidah and Kpomasse) with a surface area of approximately 9678 hectares. The site is demarcated into continental and marine areas and locally managed by the Association of Conservation and Promotion of the Community Biodiversity Conservation Area of “*La Bouche du Roy*” (ACP-Doukpo). The site “*Chenal de Gbaga*” is a transboundary site with the *Gbaga lagoon* serving as a natural border between Benin and Togo. It extends from Agbanakin to Agokpame, lying between 6°17' and 6°18' North and 1°39' and 1°48' East and covering a surface area of 4575 hectares. Mangroves and the *Gbaga lagoon* represent its major coastal ecosystems with a population dominated by the ethnic group of *Mina*. The site is locally managed by the Association “FAH-Gbaga”.

The MTBR is in the sub-humid tropical climate zone and is characterized by two rainy seasons from April to July and October to November, and two dry seasons, from August to September and December to March. The annual precipitation ranges from 820 to 1300 mm and the annual average temperature is about 33 °C. The most significant soil types are sandy soils, hydromorphic soils and ferralitic soils [11]. Vegetation includes savanna of *Elaeis guineensis* and *Borassus aethiopum*. Other tree species such as *Mitragyna inermis*, *Adonsonia digitata*, *Ceiba pentandra* and *Milicia esculsa* can also be found. Inside mangroves, soils are alluvial and hydromorphic with a vegetation dominated by an herbaceous formation and species like *Rhizophora racemosa* and *Avicennia germinans* [13]. In terms of ethnicity, *Xwlah* and *Mina* are more numerous than *Xwedah*. Apart from these dominant groups, other ethnic groups are present in the reserve, including *Ouatchi*, *Sahoue*, *Fon*, *Adja*, *Kotafon*, *Aïzo*, *Haoussa*, *Yoruba* and *Peuhl*, among others [13].

2.2. Study Design and Data Collection Procedures

For the purpose of this research, field reconnaissance, focus group discussions (FGD), in-depth interviews, household survey and direct observations were conducted (See Figure 2) using the exploratory sequential mixed method. It is the most suitable design for examining the wellbeing, public health and other related issues in society [19]. The qualitative phase was firstly instituted to explore the views of participants on key issues affecting mangrove ES in the study areas. This is important given the fact that there was no published research, to the best of our knowledge, on mangrove ES in the Togo divide of the MTBR. Data from the qualitative study was therefore used in the development of the instrument for quantitative data collection. Importantly, the quantitative phase was conducted

to statistically measure the extent to which variables discussed in the qualitative study were relevant in the study areas. Data were collected from November 2020 to June 2021 and subjected to various qualitative and quantitative analyses using the methodological framework in Figure 2.

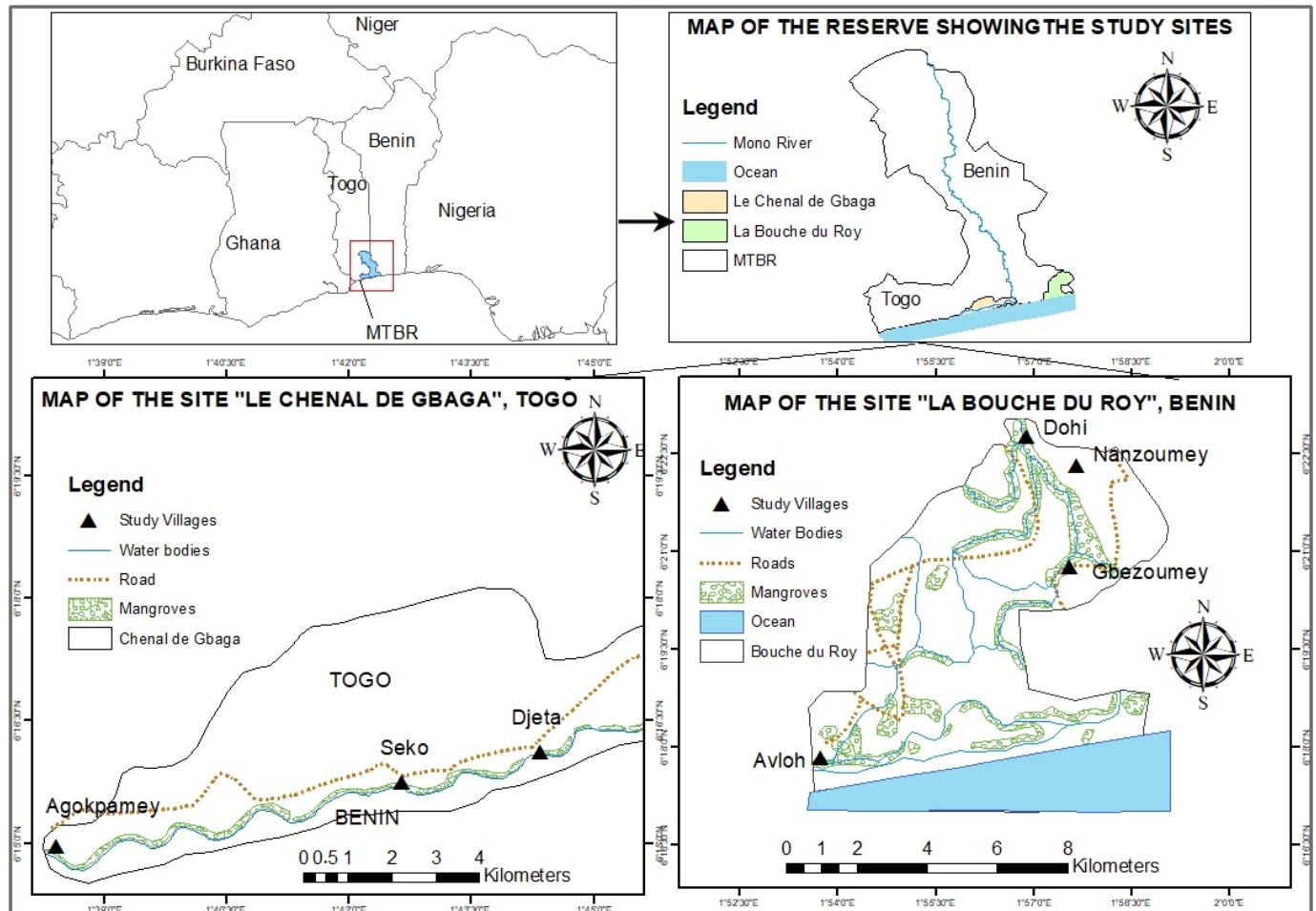


Figure 1. Map of the study area.

2.2.1. Field Reconnaissance

Data collection begun with a reconnaissance survey. This enabled the research team to have first-hand knowledge of mangrove ES and put into perspective the complex issues surrounding mangrove ES and anthropogenic interferences in the study areas. The reconnaissance survey provided the team with insights into the determinants of sample size and selection of communities for the pre-test of the instruments for data collection. Communities for the study were selected based on the availability and accessibility to mangroves, high dependence of local people on mangroves for livelihood, heavy presence of human and natural capitals, among others [20]. Consequently, four communities were selected in Benin, namely Avlo, Dohi, Nanzoumey and Gbezoumey and three villages in Togo including Djeta, Seko and Agokpamey, proportionately to the mangrove extent in the two sites [11] (Figure 1).

2.2.2. Focus Groups Discussion

A total of fourteen focus group discussions involving ten participants per group (140 participants in total) were organized in the seven selected villages to collect data about ES provided by mangroves and their associated threats. Participants were recruited from different backgrounds and occupations following snowball and purposive techniques (see supplementary data, Table S1). The purposive sampling, also called judgmental or

selective sampling, is a form of non-probability sampling in which researchers rely on their own judgment to select those who will participate in their surveys. It is largely used by qualitative-oriented researchers [21]. To avoid biases that could arise from influence of men over women, groups of males were separated from that of females. Matured residents (30 years and above) whose main livelihood activities were mangrove-dependent and/or who knew the situation of mangroves (importance, services and threats) in their communities were identified with the aid of the local authorities and invited for further discussions.

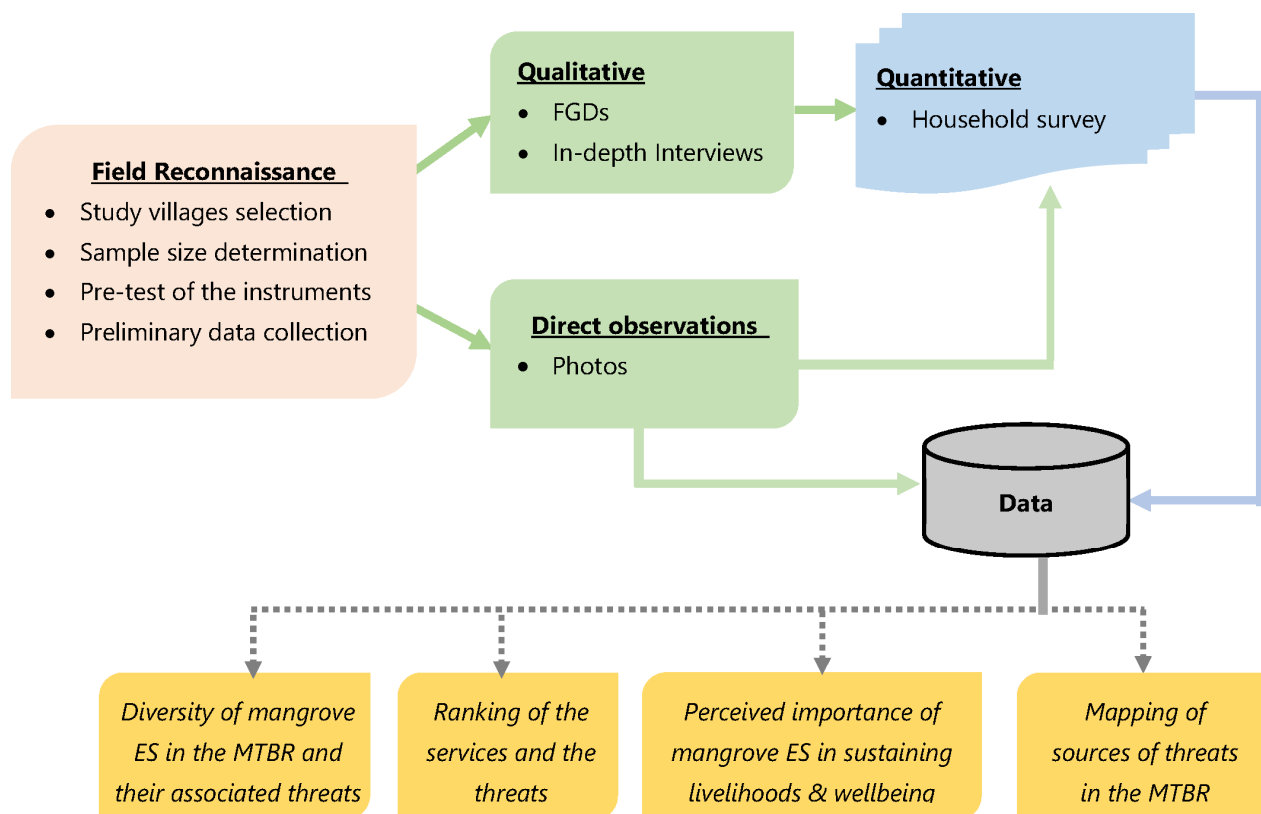


Figure 2. Flow chart of the methodological approach used. Legend: FGD = Focus Group Discussions, MTBR = Mono Transboundary Biosphere.

2.2.3. In-Depth Interviews

Key informants who partook in the in-depth interviews were selected based on snow-ball and purposive sampling procedures [22]. A total of seventeen key informants were interviewees in the two countries. Firstly, ten resource persons including chief fishermen, traditional and community leaders were approached in the two countries to complement the information gathered during the focus group discussions. Additionally, four local NGOs (Coordination for Environmental Research and Development (CORDE) and ECOBENIN in Benin and Solidarity Cooperative Group (COSOL PG) and Humanitarian Aid Action for Development (AHD) in Togo) and one state agency (the Agency for the Integrated Development of the Economic Zone of Lake Ahémé and its Channels (ADELAC) in Benin), all actively engaged in mangroves restoration and conservation in the reserve were consulted. The two local associations mandated to manage the sites (ACP-Doukpo in Benin and FAH-Gbaga in Togo) were also consulted for the interviews (see supplementary data, Table S2).

2.2.4. Field Observations

Field observations and copious notes were done during data collection. The research team visited various important locations such as water points, sacred forests, salt ponds, among others, where mangroves were being utilized. Activities such as salt preparation,

fish harvesting, ecotourism, mat weaving, fish processing, taking place in/around mangroves were observed as a way of appraising the use of mangroves, their importance in sustaining livelihood and wellbeing and how they were being degraded by human activities.

2.2.5. Quantitative Household Survey

For the household survey, each respondent was engaged in a face-to-face interview with paper-based interview guide that lasted approximately one hour. All the services enumerated during the focus group discussions and the in-depth interviews and their associated threats were printed in image and used to guide respondents. For each household, the head and his/her spouse were separately engaged as in [23]. Respondents were asked to score the provision of the broad categories of ecosystem services as well as the sub-services enumerated during the qualitative phase, using the 5-points Likert scale (1-very low provision, 2-low provision, 3-moderate provision, 4-high provision, 5-very high provision). Respondents were also asked to perform the same scoring exercise on how the identified threats were degrading mangrove ES in their communities (1-very low degradation, 2-low degradation, 3-moderate degradation, 4-high degradation, 5-very high degradation). They were further probed on how the current flow of mangrove ES is sustaining their wellbeing (0-Not Satisfied, 1-Satisfied). Households which participated in the survey were selected using simple random sampling technique [24]. The sample size was calculated for each site in a separate manner using the same formula as [25]:

$$n = \frac{1}{e^2} p(1 - p) U_{1-\frac{\alpha}{2}}^2$$

where n represents the total sample size, U is the value of the normal random variable ($U = 1.96$ for $\alpha = 0.05$) and e represents the authorized margin error held to be 9% in this survey [25]. The pilot survey conducted during the field reconnaissance with fifty households selected in each site helped to identify the proportion of residents who enjoyed any mangrove ES in the reserve. After calculation, 92 households comprising 184 respondents were investigated in Benin ($p = 0.7$) whereas 45 households composed of 90 respondents were surveyed in Togo ($p = 0.9$) (see supplementary data, Table S3).

2.2.6. Participatory Mapping of the Major Threats

The participatory mapping exercise involved the top three threats to mangroves in the study areas. Hard copies of recent maps of the reserve and the study sites were retrieved from [26,27], printed and brought to the field. Two focus groups of five participants each including chief fishermen, local authorities, traditional leaders, members of the local associations managing the sites (ACV-Doukpo and FAH-Gbaga) and members of NGOs involved in mangroves restoration and conservation were formed per site based on purposive sampling procedures. Maps of all the villages embedded in each site were downloaded from Google Earth, printed and distributed to the groups for the identification of landmarks and other physical features to make sure all the participants mastered the study sites. They were then asked to demarcate places where each threat prevails using the map of each site. Thereafter, the results of the two groups were put side by side per study site and consensus was reached regarding the spatial distribution of threats to mangroves.

2.2.7. Ethical Considerations

This work received ethical approval reference UCCIRB/CANS/2021/20 from the University of Cape Coast Institutional Review Board (UCCIRB) in Ghana. In the study communities, the purpose of the research and possible risks associated with their participation were thoroughly explained to the respondents and oral consent was sought from each participant before data collection.

2.3. Data Analysis

2.3.1. Qualitative Data

Recorded interviews were transcribed and augmented with the handwritten notes to make sure that all information provided was well captured. The transcribed data were analysed using various themes derived from the qualitative data. Ecosystem services mentioned by participants during the interviews were noted and identified using the ES identification guide proposed by the Common International Classification of Ecosystem Services (CICES) V5.1 [28]. The identified services were thereafter categorized in provisioning, regulating, supporting and cultural services using the ES framework of the Millennium Ecosystem Assessment [17].

2.3.2. Quantitative Data

All analyses were conducted with the R software (version 4.0.1) [29]. Identified services (broad categories and subservices) and their associated threats were ranked following the analysis of scores according to the Relative Importance Index (*RII*) using the following formula [5]:

$$RII = \frac{\sum_i^n W_i}{A \times N}$$

where “ W_i ” is the weighting given to each ES by respondent i , ranging from 1 to 5, “ A ” is the highest weight (i.e., 5 in this study) and N is the total number of respondents. The relative importance index (*RII*) ranges from 0 to 1. *RII* was also used to rank the threats to ES delivery.

Using a generalized linear model (GLM) with negative log-log distribution, the study assessed the extent to which various determinant factors of the population affected the flow of mangrove ES and sustain peoples’ wellbeing and livelihoods. The negative log-log distribution was used because the lower response category which is the “No” is more probable (see Figure 3) [30]. The determinant/predictor variables were the various characteristics of the respondents which included: (i) age (young householders: <30 years, adult householders: 30–60 years and old householders > 60 years in the two countries); (ii) activities (artisanal activities, fishing activities, mat weaving, petty trading and salt production in Benin; artisanal activities, fishing activities, farming and petty trading in Togo); (iii) gender (male versus female in the two countries), (iv) ethnic groups (Fon, Mina, Xwlah and Xwedah in Benin; Mina, Ewe and Ouatchi in Togo) and (v) level of education (uneducated, primary and secondary in the two countries) among others. The outcome variables which were the surrogates of the respondents’ wellbeing and livelihoods involved the dichotomous issue of whether respondents were satisfied (coded 1) or unsatisfied (coded 0).

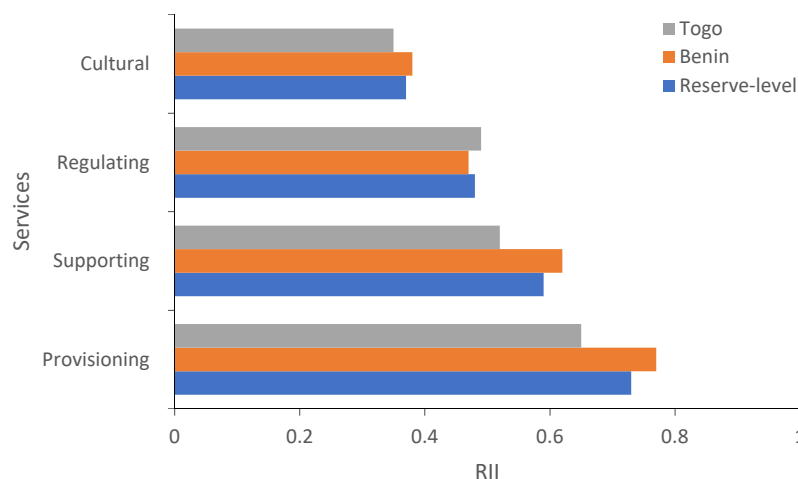


Figure 3. Ranking of the broad categories of services at country and reserve level.

3. Results

3.1. Perceived Mangrove Ecosystem Services in the MTBR

A total of twenty-one ES including nine provisioning services, four regulating services, three supporting services and five cultural services were listed by participants as the services provided by mangrove to local communities in the MTBR (Table 1). All the recorded ES were reported in Benin, while only fifteen of them were listed in Togo. Services such as non-timber forests products [NTFPs (provisioning service)], oyster provision (provisioning service), erosion control (regulating service), water purification (regulating service), social relationships (cultural service) and spiritual and religious values (cultural service) reported in Benin were not listed in Togo (Table 1). Most of the provisioning services were listed without probing participants, whereas some regulating, supporting and cultural services were mentioned after probing them (Table 1). In Benin, spiritual and religious services delivered by mangroves were mostly reported by men.

Table 1. Mangrove ES listed by participants in the reserve.

	Services	Country				Summary of Participants' Narratives
		Benin	Togo			
Provisioning services	Provision of Fish	A *	A *	-	We have been collecting diverse fish in mangroves	
	Provision of Crab	A *	A *	-	Mangroves give us edible crab species	
	Provision of Shrimp	A *	A *	-	We have been harvesting shrimp from mangroves	
	Provision of Oyster	A *	-	-	Mangroves provide oyster for consumption and commercialization	
	Fodder	A *	B **	-	Goats appreciate leaves of <i>Rhizophora racemosa</i> as food	
	Non-Timber Forest Products	A *	-	<ul style="list-style-type: none">- We get games like varan and snacks from mangroves- We collect medicinal plants from mangroves- Branch of <i>Rhizophora racemosa</i> serves as vegetal brush- We grow <i>Cyperus articulatus</i> in the adjacent areas of mangroves for mat weaving- We use <i>Rhizophora racemosa's</i> leaves to dye crabs, nets, etc.		
	Timber	A ***	A *	<ul style="list-style-type: none">- We use <i>Rhizophora racemosa's</i> wood for construction because it is hard- We collect wood of <i>Avicennia germinans</i> and <i>Rhizophora racemosa</i> to manufacture local stool, drums, etc.		
	Firewood	A **	A **	-	We collect wood from mangroves ecosystems for cooking and selling	
	Water supply	B *	A *	<ul style="list-style-type: none">- Some of us prefer bathing in mangroves because the water is always fresh- We use water from mangroves to produce salt		

Table 1. Cont.

Services	Country				Summary of Participants' Narratives
	Benin	Togo			
Regulating services	Climate Regulation	A *	A *	-	Mangroves play an important role in air purification Mangroves contribute to weather regulation in our village
	Erosion control	A ***	-	-	Mangroves prevent sand from moving from one place to another when the wind blows Roots of <i>Rhizophora racemosa</i> make the soil compact
	Water purification	A ***	-	-	Roots of <i>Rhizophora racemosa</i> sanitize water surface by retaining waste that finds its way into the water body <i>Rhizophora racemosa</i> species retain pollutants and waste from reaching water surface
	Natural hazards control	B *	B *	-	Mangrove protects us again flooding and storms Mangroves serve as windbreak and protect us from the effects the wild wind blowing from the sea
Supporting services	Spawning and Nursing grounds	A *	A **	-	Mangroves help to attain the fish replenishment of our water body Fish get conducive environment to reproduce within mangroves
	Biodiversity support	A *	A *	-	Mangroves are home to a variety of animals Aside from fish species, we have snacks, crocodile, varan, monkeys, turtles, etc. in our mangrove forests Mangroves are the preferred nesting zones for birds
	Nutrient cycling	A *	A *	-	Leaves of mangrove species fall in the water, decompose and become food for aquatic organisms
Cultural services	Social relationships	B ***	-	-	Every 10th of January, all the villagers gather within our sacred forest which is a mangrove forest to celebrate the nationwide voodoo day
	Educational values	B *	B *	-	Students come frequently for data collection, field trip and excursion within mangroves in our villages
	Aesthetic values	A *	A ***	-	Mangrove makes our villages look beautiful
	Spiritual and religious values	B *	-	-	We mostly use mangroves as convent for our deity called <i>Zangbeto</i> The protector of our village which is a deity called " <i>Djohon</i> " resides in mangroves
	Leisure, recreation and tourism	A *	A *	-	White people and local residents come to visit mangroves just go have fun and take pictures We navigate within mangroves sometimes just to admire nature

A: Services identified without probing interviewees B: Services identified after probing interviewees, -: services unidentified in the country, *: services identified by both the groups of men and women in the surveyed village, **: services identified by only the group of men; ***: services identified by only the group of women.

3.2. The Most Provided Mangrove Ecosystem Services in the MTBR

At reserve-level, provisioning services were ranked as the most provided services in the reserve ($RII = 0.73$) followed respectively by supporting services ($RII = 0.59$), regulating services ($RII = 0.48$) and cultural services ($RII = 0.37$) (Figure 3). The trends remain similar

when we break it down for each country. Indeed, provisioning services were also considered as the most provided services in Benin ($RII = 0.77$) and Togo ($RII = 0.65$). This was followed by supporting services in Benin ($RII = 0.62$) and Togo ($RII = 0.52$) and regulating services in Benin ($RII = 0.47$) and Togo ($RII = 0.49$), as well as cultural services in Benin ($RII = 0.38$) and Togo ($RII = 0.35$) respectively (Figure 3).

For the subservices, “provision of fish” ($RII = 0.78$) was the most ranked provisioning services whereas “provision of oyster” ($RII = 0.25$) was least ranked in Benin. Like in Benin, provision of fish was the most ranked provisioning services in Togo ($RII = 0.77$) while the least provided was fodder collection ($RII = 0.24$). Respondents of both countries ranked climate regulation as the most delivered regulating services, Benin ($RII = 0.70$) and Togo ($RII = 0.71$), whereas water purification ($RII = 0.35$) and natural hazards control ($RII = 0.50$) were least ranked in Benin and Togo respectively. For the supporting services, biodiversity conservation was ranked first in the two countries, Benin ($RII = 0.75$) and Togo ($RII = 0.67$), while nutrient cycling ($RII = 0.48$) and nursing and spawning ground ($RII = 0.48$) were least ranked respectively for Benin and Togo. Concerning the cultural services, the use of mangroves for tourism, recreation and leisure purposes was least ranked in the two countries, Benin ($RII = 0.35$) and Togo ($RII = 0.33$), whereas educational values ($RII = 0.50$) and aesthetic values ($RII = 0.41$) were ranked highest in the two countries. Some services like timber collection, firewood collection, crab collection, shrimp collection, natural hazard control and spiritual values were highly ranked in the two countries whereas others such as water supply and erosion control were ranked low (Table 2).

Table 2. Ranking of the subservices at country level.

Categories	Services	Benin			Togo		
		Rank	TS	RII	Rank	TS	RII
Provisioning services	Fish provision	1	724	0.78	1	333	0.74
	Timber collection	2	588	0.63	5	201	0.44
	Crab provision	3	553	0.60	2	261	0.58
	NTFPs	4	524	0.56	-	-	-
	Firewood collection	5	471	0.51	3	226	0.50
	Shrimp provision	6	382	0.41	4	222	0.49
	Water supply	7	353	0.38	6	140	0.31
	Fodder	8	327	0.35	7	108	0.24
	Oyster provision	9	230	0.25	-	-	-
Regulating services	Climate regulation	1	652	0.70	1	321	0.71
	Natural Hazards control	2	448	0.48	2	226	0.50
	Erosion control	3	346	0.37	-	-	-
	Water purification	4	328	0.35	-	-	-
Supporting services	Biodiversity conservation	1	695	0.75	1	303	0.67
	Nursing and spawning ground	2	651	0.70	3	206	0.45
	Nutrient cycling	3	445	0.48	2	287	0.63
Cultural services	Educational values	1	469	0.50	2	174	0.38
	Spiritual and religious values	2	440	0.47	-	-	-
	Aesthetic values	3	395	0.42	1	186	0.41
	Social relationship	4	386	0.41	-	-	-
	Tourism, recreation and leisure	5	331	0.35	3	152	0.33

TS = total score, RII = Relative Importance Index, NTFPs = Non-Timber Forest Products.

3.3. Mangrove Ecosystem Services and Its Effects on Wellbeing and Livelihoods of Local Communities in the MTBR

When asked the extent to which the provision of mangrove ES sustains peoples' wellbeing and livelihoods at reserve level, most of the respondents indicated that the current flow of provisioning services (63.13%), regulating services (63.86%) and cultural services (60.58) does not sustain their wellbeing and livelihoods, whereas 59.12% of them agreed that the current supply of supporting services is enough to sustain their wellbeing and livelihoods. Narrowing it down to country level, less than half of the respondents in Benin agreed that the current flow of provisioning services (41.84%), regulating services (34.23%) and cultural services (46.19%) sustained their wellbeing and livelihoods (Figure 4a). However, 78.80% declared that the current flow of supporting services was enough to sustain their wellbeing and livelihoods. In Togo, higher proportions of the respondents were generally not satisfied with the provisioning services (73.33%), supporting services (81.11%), regulating services (60%) and cultural services (74.44%) provided by mangroves and feared the services could not sustain their livelihoods and wellbeing (Figure 4b).

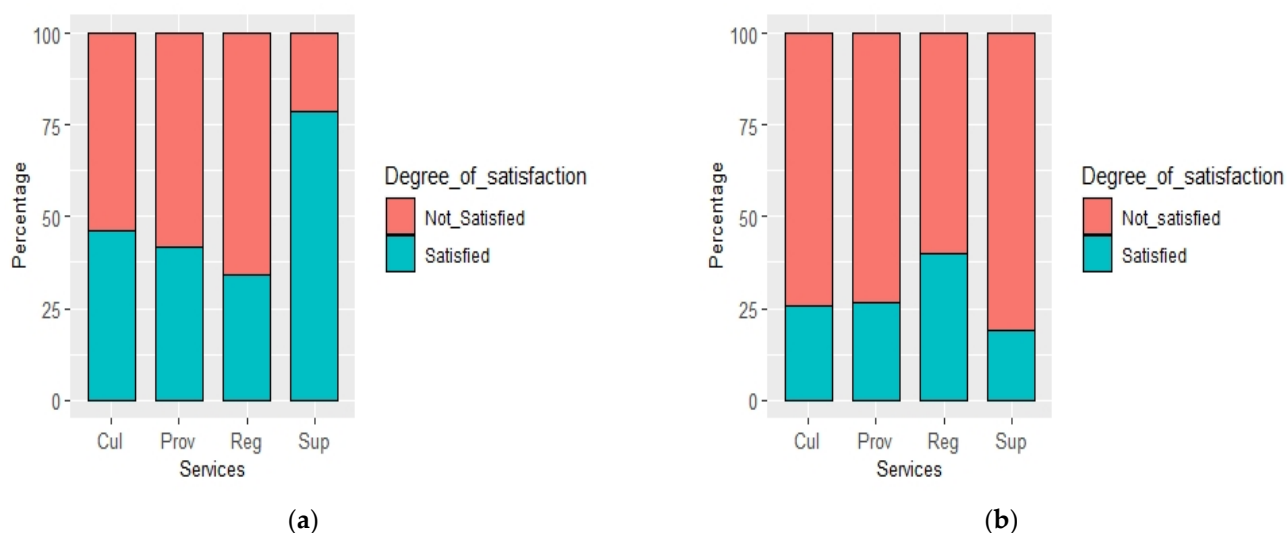


Figure 4. Rate of satisfaction about mangroves ES in the Benin (a) and Togolese (b). Legend: Cul = Cultural, Prov = Provisioning, Reg = Regulating, Sup = Supporting.

Results of the generalized linear model (GLM) were summarized in Table 3. Gender and country were significant predictors of the household members' perceptions on provisioning services. Males and respondents investigated in Togo were less satisfied with the extent to which provisioning services were sustaining their wellbeing and livelihoods (Males: $\beta = -1.73$ and $p < 0.01$; Togo: $\beta = -1.54$ and $p < 0.05$). Only country of origin had significant effects on the delivery of supporting services and respondents of Togo were less satisfied with these services (Togo: $\beta = -4.09$ and $p < 0.01$). However, there were significant effects of ethnical groups, educational background and country on the household members' perception on the extent to which cultural services determined their wellbeing and livelihoods. While respondents belonging to Ewe ethnic group and those from Togo were less satisfied (Ewe: $\beta = -3.24$ and $p < 0.01$; Togo: $\beta = -1.54$ and $p < 0.05$) with the extent to which cultural services sustained their wellbeing and livelihoods, respondents with secondary level were more satisfied ($\beta = 1.08$ and $p < 0.05$).

Table 3. Summary of the generalized linear model (GLM) with binomial error distribution showing the relationships between socio-economic factors and the perceived importance of mangroves in sustaining people's wellbeing and livelihoods in Benin: values in columns are coefficient estimates (standard error).

Factors	Provisioning	Supporting	Regulating	Cultural
Intercept	1.60 (0.94)	1.12 (1.12)	0.58 (0.82)	0.07 (0.90)
Young (Old as reference level)				
Adults	0.22 (0.36)	0.64 (1.21)	0.19 (0.34)	−0.16 (0.37)
Old	0.02 (0.38)	−0.14 (0.44)	−0.11 (0.36)	−0.68 (0.43)
Gender (Female as reference level)				
Male	−1.73 (0.38) ***	−0.25 (0.43)	−0.31 (0.34)	0.11 (0.39)
Ethnic groups (Fon as reference level)				
Mina	−1.08 (0.87)	−0.97 (1.15)	−0.39 (0.76)	0.06 (0.84)
Xwedah	0.17 (0.66)	0.43 (0.77)	−0.20 (0.57)	−0.73 (0.63)
Xwlah	0.39 (0.69)	0.37 (0.85)	−0.45 (0.63)	−0.34 (0.67)
Ouatchi	−0.13 (0.82)	−1.55 (1.13)	−0.81 (0.74)	−0.60 (0.80)
Ewe	−0.26 (0.82)	−0.93 (1.13)	−0.87 (0.75)	−3.24 (0.89) ***
Activity (Artisans as reference level)				
Fishermen	−0.28 (0.64)	−0.28 (0.80)	−1.25 (0.58)	−0.04 (0.65)
Mat weavers	−0.37 (0.45)	0.84 (0.51)	−0.35 (0.41)	0.97 (0.48)
Petty traders	−1.29 (0.74)	1.73 (0.98)	−0.67 (0.73)	−0.29 (0.91)
Farmers	−0.70 (0.52)	1.54 (0.63)	−0.38 (0.48)	0.66 (0.56)
Salt producers	−1.62 (0.70)	−0.07 (0.73)	−1.42 (0.70)	−0.50 (0.77)
Education (Primary as reference level)				
Secondary	−0.02 (0.35)	0.84 (0.44)	−0.02 (0.33)	1.08 (0.38) **
Uneducated	−0.81 (0.38)	−0.13 (0.44)	−0.05 (0.36)	0.40 (0.43)
Country (Benin as reference level)				
Togo	−1.54 (0.58) **	−4.09 (0.87) ***	−0.05 (0.51)	−1.54 (0.58) **

Note: ** $p < 0.05$; *** $p < 0.01$.

3.4. Threats to Mangrove Ecosystem Services in the Reserve

The perceived threats to mangrove ES in the reserve included the illegal, unreported and unregulated fishing (IUU), mangrove overexploitation, bushfire, mangrove clearing, change in water salinity, livestock, invasive species and pollution (Table 4). The geographical distribution of the reported threats showed slight difference between the countries. Indeed, six out of the eight identified threats were reported in Benin whereas seven were listed in Togo. At reserve-level, IUU recorded the highest score ($RII = 0.54$) followed respectively by mangrove overexploitation ($RII = 0.53$), change in water salinity ($RII = 0.43$), mangrove clearing ($RII = 0.38$), bushfire ($RII = 0.36$), pollution ($RII = 0.32$), invasive species ($RII = 0.16$) and livestock ($RII = 0.13$). The country-specific ranking of the identified threats revealed that mangrove overharvesting ($RII = 0.55$), bushfire ($RII = 0.55$) and IUU ($RII = 0.51$) represent the three major threats to mangrove ES in Benin whereas IUU ($RII = 0.61$), mangroves clearing ($RII = 0.52$) and mangrove overharvesting ($RII = 0.51$) are the major threats to mangrove ES in Togo (Table 4). The participatory mapping indicated in Benin that mangrove overharvesting prevails at the southern part of the study site whereas IUU and bushfires are much more pronounced at the northern part of the study site (Figure 5). In Togo, almost the entire site of “*chenal de Gbaga*” is threatened by IUU

while mangroves' clearing and mangroves' overharvesting prevail at Seko, Togbavi Djeta and Agouegan (Figure 6).

Table 4. Country-specific ranking of the threats.

Threats	Benin			Togo		
	Rank	TS	<i>RII</i>	Rank	TS	<i>RII</i>
Mangrove Overharvesting	1	512	0.55	3	232	0.51
Bushfire	2	494	0.53	-	-	-
IUU	3	472	0.51	1	275	0.61
Change in water salinity	4	369	0.40	6	180	0.4
Mangroves clearing	5	308	0.33	2	236	0.52
Pollution	6	297	0.32	7	142	0.31
Livestock	-	-	-	4	218	0.48
Invasive species	-	-	-	5	224	0.49

Legend: TS = total score, *RII* = Relative Importance Index, NTFPs = Non-Timber Forest Products, -: services unidentified in the country.

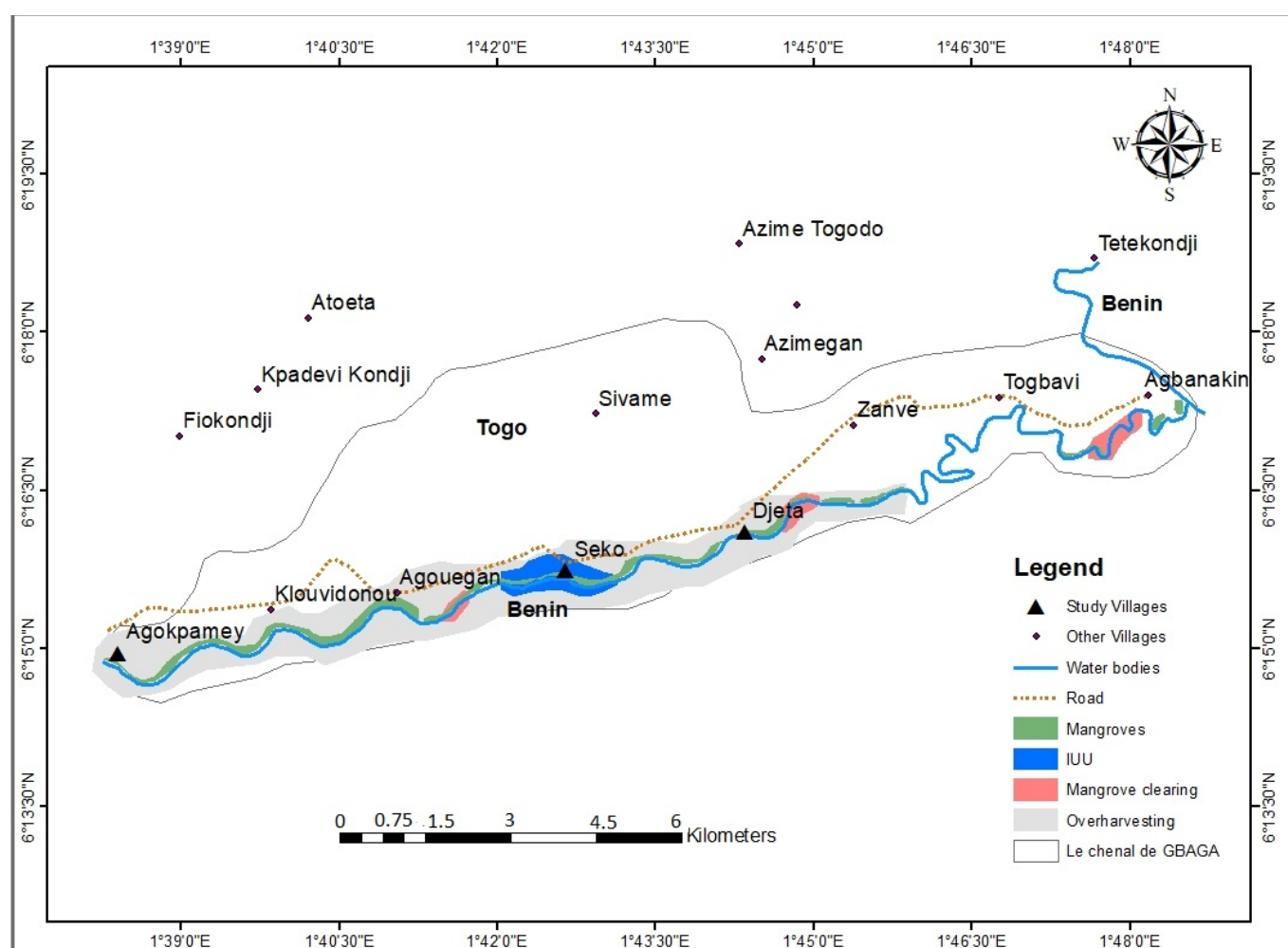


Figure 5. Spatial distribution of the top 3 threats in Togo.

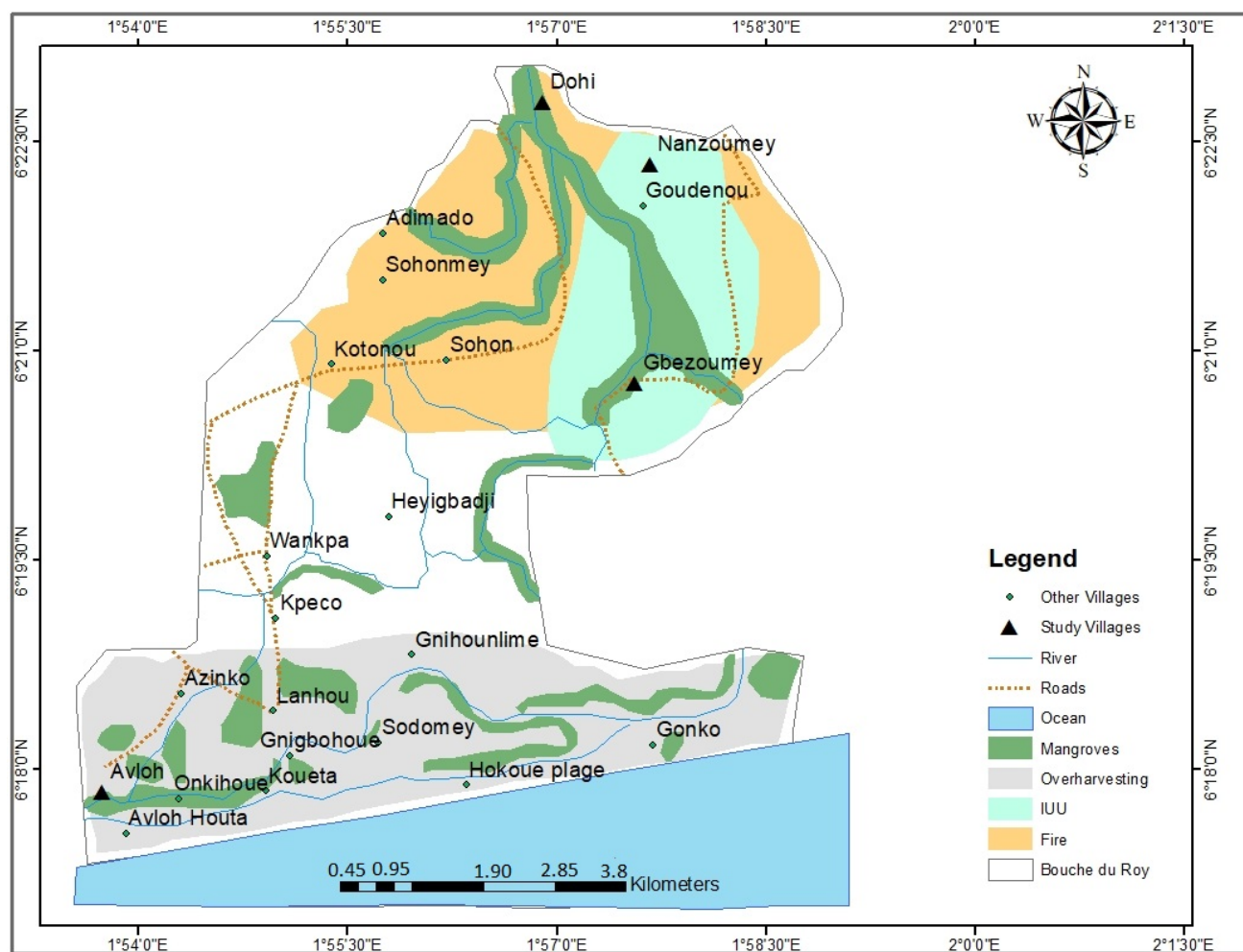


Figure 6. Spatial distribution of the top 3 threats in Benin.

4. Discussion

4.1. Diversity of Mangrove ES in the MTBR

Mangroves in the MTBR provide a wide range of services to local populations. In total, twenty-one services were identified in the reserve. Mangrove ES reported by interviewees in this study are consistent with those found in many other studies [16,31] with a slight difference in nomenclature. This difference in nomenclature is justified by the fact that there is not to date a unique form of classification of the subcategories of ES [32]. However, the services recorded in the reserve outnumber the ones reported by [16] and [31] who investigated mangrove ES respectively in Mexico and Tanzania using the same approach. The former reported thirteen mangrove ES while the latter recorded sixteen. This difference may arise from the extent of the study area, which is much larger in our case, covering two countries with multiple sociocultural groups. One of the important aspects of this work in terms of the identification and the classification of the ES is the narrative of the local communities which is deeply linked to their sociocultural affiliations and their country of origin. This remains a valuable contribution of the socio-cultural consideration when it comes to ES valuation [16].

Some important mangrove ES reported by other studies were less or not mentioned by interviewees in our case. For instance, no focus group discussion participant or key informant in the two countries mentioned mangrove-based beekeeping, although this was documented as an important provision service of mangroves capable of supporting the livelihood of a lot of people if well implemented [33]. This is probably because they were unaware of the activity in their community or because they were not interested in it.

Cyperus articulatus, medicinal plants and other relevant non timber forest products (NTFPs) collected from mangroves in Benin were absent in Togo. No interviewee in Togo was collecting medicinal plants from mangroves. This portrays a gap of knowledge about the medicinal use of mangrove in Togo stemming undoubtedly from the complete elimination of mangroves from the country in the past [26]. In addition, *C. articulatus* predominantly collected from the wild or cultivated in mangroves' adjacent environment in Benin for mat weaving were also totally absent in Togo. This may be because local communities investigated in Togo are not into mat weaving [26] and therefore are not interested in growing the species. Interviewees were able to easily identify most of the provision services such as the regulating, the supporting and the cultural ones in the reserve. This aligns with the findings of many authors including [24,32], among others, who reported that it is easy for local populations around mangrove ecosystems to identify provision services as compared to the other services as a result of their importance in livelihood-support and their direct market value. A large extent of mangroves in the reserve in Benin are protected by local deities, particularly the "Zangbeto" (the guardian of the night) in order to curb their overexploitation. This behaviour, which was reportedly inherited from participants' forebearers, contributed not only to mangrove conservation but also helped protect their services [14]. The non-implementation of this traditional ecological knowledge in Togo may likely explain the large degradation of mangrove ecosystems and the few mangroves ES recorded in Togo as compared to Benin.

4.2. Predominance of Mangrove ES in the MTBR

Results showed that mangroves provide more provisioning services than the other services in the reserve irrespective of the country, indicating the heavy dependence of local populations of the reserve on provisioning services. Regarding the subservices, the provision of fish is the most delivered provisioning service in the reserve. Local populations in the reserve both in Benin and Togo acknowledge that they mostly collect fish from mangroves for their daily consumption and for commercial purposes. Even those who were not fishermen by profession went for fish, just for household consumption, justifying the high score obtained by fish provision. This is consistent with [11] who have already reported fishing as the predominant activity of local populations in some localities of the reserve in Benin. Other provisioning services highly ranked in the reserve are timber collection and firewood collection. Even if mangrove cutting is officially banned in the two countries [12,34], the local population in the MTBR still collects firewood and timber from mangroves for diverse domestic and commercial uses. This illustrates a weak enforcement of the conservation measures put in place for mangroves protection in the reserve. In Benin, NTFPs obtained a high score because of the economic importance of *Cyperus articulatus*. The species is of paramount importance for the local population, particularly in this COVID-19 period, serving as an alternative livelihood for fishermen whose activities are certainly perturbed following the outbreak of the pandemic as in other African countries like Ghana [35].

Water supply scored low as local populations in the study communities use surface water from mangroves for bathing and washing occasionally, especially from June to September when the water is less salty. Though important for the local economy, Oyster (*Crassostrea gasar*) was scored low by respondents in the reserve. The species was no longer present in the Togolese site according to interviewees. In Benin, the species is said to be confined at the southern part of the reserve, from Nanzoumey to Gbezoumey, and appears to be the least delivered provisioning service following respondents' ranking. The overexploitation of the mangrove oyster (*Crassostrea gasar*) in the reserve has been already observed by [36].

Biodiversity conservation was the supporting service mostly provided by mangroves in the reserve. Diverse species of plant, bird, fish, reptile and primates inhabiting mangroves were enumerated by interviewees in their local languages. They further stated the seasonal presence of migratory birds coming from European countries into the mangroves

of the study area. The increasing biodiversity conservation shown by mangroves in the reserve may be due to the ornithological sites created within mangroves in the reserve particularly at *Agokpamey* (in Togo) and *Avloh* (in Benin). These sites set up by the project GIZ advocate for the integrated protection of birds, primates and other mangrove animal species in the reserve [27]. The high biodiversity conservation in the reserve has already been reported by [11] who identified fifteen plant species, twenty-three fish species, two shrimp species, two crab species and one oyster species in mangroves at Grand-Popo, one of the municipalities of the reserve in Benin.

The number of cultural services identified was higher in Benin than Togo. Services such as “social relationship” and “spiritual and religious values” mentioned in Benin were not listed in Togo. These services are deity related and are absent in Togo as no mangrove hosts local divinities in that country. “Educational values” was the cultural service most provided in Benin. This indicates that studies and academic field trips are increasingly carried out in mangroves in Benin. This agrees with [12] who asserted that research in mangroves have received keen attention in Benin over the past ten years. However, tourism, recreation and leisure recorded low scores in the reserve. This is because there is no local association of ecotourism in Togo. In Benin, ecotourism is carried out only at *Avloh* by an NGO. There is reportedly no qualified tour guide in the other villages to guide tourists. Though young residents are reportedly interested in tourism in the study villages, the activity is still underdeveloped. Even at *Avloh*, where it takes place, tour guides lamented no-ready markets and inadequate equipment such as boats, outboard motors and life jackets among others.

4.3. Mangrove ES Sustaining Peoples’ Livelihood and Wellbeing in the MTBR

Respondents belonging to the Ewe ethnical group perceived that the current supply of cultural services do not sustain their wellbeing and livelihoods. This is probably because ecotourism is not well developed in the reserve to provide livelihoods to most communities. This aligns with [5] who reported the underdevelopment of mangrove-based tourism in the reserve. Men were also less satisfied with provisioning services, likely because of the prohibition of mangrove cutting in the reserve, limiting their rate of wood harvesting from mangroves. This may also be due to the dwindling of fish catch in mangroves, since most of the men in the study communities are fishermen [26].

4.4. Major Threats to Mangrove ES in the MTBR

Threats to mangrove ES in the MTBR are diverse in nature and relatively similar in the two sites. Overexploitation of mangroves was the highest ranked threat in Benin. Despite the increasing sensitization carried out by stakeholders, local residents continue to illegally harvest mangroves. This situation was reported by many research works conducted in the area, particularly in Benin [13,14]. The heavy dependence of mangroves’ plant species for domestic uses found in this study raises again the concern of the inadequacy of alternative source of energy in the reserve already reported by [37]. Bush burning came second in Benin in terms of ranking. Local populations reportedly set fire to mangroves adjacent areas for crab’s holes identification in order to lay traps and harvest them. Most of the time, the fire ends up burning mangroves resulting in habitat degradation and biodiversity loss. Illegal, unreported and unregulated fishing also contribute significantly to mangrove degradation in the reserve in Benin. Unsustainable fishing techniques such as offspring shrimp harvesting, juvenile fish harvesting and the use of fine mesh net to collect fish continue to take place in mangroves in Benin despite their ban [27]. The participatory mapping showed that mangrove overharvesting mostly takes place within communities situated at the southern part of the reserve in Benin. This may be attributed to the intensification of fishing activities in these communities due to the presence of a variety of aquatic ecosystems including the open sea, Mono River, Lagoon of Grand-Popo and Sazué River. This situation increases the demand for firewood for fish processing in these communities, resulting in mangrove overharvesting. Unlike in Benin, IUU is the

topmost threat to mangrove ES in Togo as indicated by the participatory mapping (see Figures 5 and 6). Mangrove clearing is also taking an alarming proportion in Togo. Local populations reported that mangrove ecosystems closer to human habitats are being cleared as they host dire reptiles including crocodiles, alligators and a variety of snakes that cause havoc to the local residents, particularly children (Figure 7).

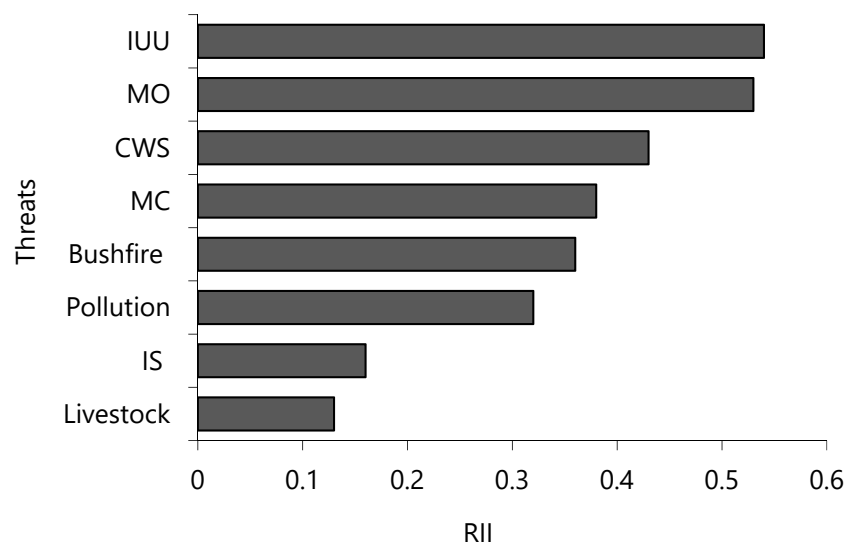


Figure 7. Ranking of the identified threats at reserve-level. Legend: IUU: Illegal, Unreported and Unregulated fishing, MO: Mangrove overexploitation, CWS: Change in Water Salinity, IS: Invasive species.

4.5. Implications for Management Policies

The ranking carried out in the MTBR indicated that mangroves in the reserve deliver provision services more than the other categories of ES. Some provision services such as fish provision, firewood and timber collection, crab provision and others, which had high scores, should therefore be monitored to ensure that they are being sustainably collected, since the overexploitation can lead to the destruction of the ecosystem and the collapse of its services. In addition, sensitization needs to be intensified in the reserve, particularly in Togo to educate local residents on mangrove ES, especially regulating and supporting services, because they are not well known by respondents. Alternative sources of energy, including local plantations and domestic gas at subsidized cost, should be proposed to local populations to reverse the burgeoning mangrove harvesting for cooking and construction. NGOs and state institutions mandated to enforce mangrove protection-oriented laws in the reserve lamented about inadequate equipment and resources (both human and financial resources). There is then the need to equip them in order to intensify patrols and enforcement actions for an effective conservation of mangroves. Income generating activities such as beekeeping and ecotourism, although important sources of livelihood, are underdeveloped in the reserve. Local residents in the reserve also suffer an inadequacy of alternative livelihoods, leading to the overuse of mangrove resources. In addition to beekeeping and the ecotourism, other activities such as aquaculture, snail rearing, animal breeding among others should be developed in Benin and Togo to reduce the high pressure on mangrove resources. Results of this study showed that oysters were confined in Benin with a low provision score. Their collection should thus be restricted and research carried out on the stock assessment of the species within the reserve for subsequent actions. It is also important to protect some of the mangroves located in the Togolese part of the reserve with the “zangbeto” as in Benin or any other local deity to avoid their total dieback given the increasing population growth in the reserve.

5. Conclusions

Mangroves play a key role in livelihood support and ES provision in the MTBR. Twenty-one mangrove ES were identified in the reserve. Threats to mangrove ES are similar

in the two countries with mangrove overharvesting and IUU being the topmost respectively in Benin and Togo. Our results suggest the intensification of conservation actions, research and sensitization to attain the sustainable use of mangroves in the MTBR given the strong dependence of local residents on their services, particularly the provisioning services.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/su14042438/s1>, Figure S1: The Mono Transboundary Biosphere Reserve and its protected sites, Table S1: Sociodemographic attributes of the FGDs participants, Table S2: Categories of key informants interviewed, Table S3: Number of surveyed households per village.

Author Contributions: Conceptualization: S.C.G.; Methodology: S.C.G., K.V.S., A.A.S. and D.W.A.; Data analysis: S.C.G. and K.V.S.; Original draft preparation: S.C.G., Manuscript editing: K.V.S., A.A.S., P.A.D.M., D.W.A. and R.G.K.; Supervision: D.W.A. and R.G.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the project ACECoR (African Centre of Excellence in Coastal Resilience) through the World Bank ACE Grant Number 6389-G.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the University of Cape Coast Institutional Review Board (UCCIRB)—Clearance Number UCCIRB/CANS/2021/20.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data used for this study is available and can be provided by the corresponding author upon request.

Acknowledgments: This paper is derived from the M. Phil studies of the first author in the Centre for Coastal Management (Africa Centre of Excellence in Coastal Resilience), University of Cape Coast, Ghana. The authors are therefore grateful to the World Bank, the Government of Ghana and the Centre for Coastal Management (CCM), University of Cape Coast for the financial and technical support.

Conflicts of Interest: The authors declare no conflict of interest.

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