UNIVERSITY OF CAPE COAST

MANGROVES ECOSYSTEM SERVICES OF THE MONO TRANSBOUNDARY BIOSPHERE RESERVE: DIVERSITY, ANTHROPOGENIC STRESSORS AND SOCIOCULTURAL IMPORTANCE

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's signature…… Date …….

Name : Constant Setonde Gnansounou

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal supervisor's signature…… Date …….

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ABSTRACT

Mangroves are coastal ecosystems present in many coastal states in tropical Africa, Asia, and America. Information on their benefits in marginally studied areas is essential to improve the global understanding of their importance and the threats thereof. This study therefore evaluated the ecosystem services delivered by mangroves in the Mono Transboundary Biosphere Reserve (MTBR) (Togo-Benin), and their associated threats and contribution to livelihoods and wellbeing. Data were collected using the mixed method approach via focus group discussion (n= 14), household survey (n= 274), in-depth interviews (n= 17) and expert-based survey (n= 10). Data collected were analysed using Habitat Risk Assessment model (InVEST), negative binomial Generalized Linear Model, and simple probability of likelihoods. Results showed that fifteen ecosystem services and seven associated threats were recorded in Togo, while twenty-one services and six associated threats were reported in Benin. In the reserve Benin's mangroves are not at risk whereas 58% of mangroves in Togo are under medium risk and 42% are under low risk. differences in the local communities' perceived diversity, importance, and threats to mangrove ecosystem services between the two countries. Sensitization activities should be intensified in Benin and livelihood options provided in Togo to protect mangroves in the reserve.

KEYWORDS

Mangroves

Ecosystem Services

InVEST Habitat Risk Assessment

West Africa

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DEDICATION

This work is dedicated to my lovely daughter *Sènami Kendra Princesse Merveille Gnansounou*.

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LIST OF ACRONYMS

ACECoR	Africa Centre of Excellence in Coastal Resilience
ASEAN	Association of Southeast Asian Nations
C	Consequence
CBD	Convention on Biological Diversity
CICESS	Common International Classification of Ecosystem Services
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSO	Civil Society Organizations
E	Exposure
ES	Ecosystem services
FGDs	Focus Group Discussions
GIS	Geographic Information System
GLM	Generalized Linear Model
Ha	Hectare
HRA	Habitat Risk Assessment model
IDIs	In-depth Interviews
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
ITTO	International Tropical Timber Organization
REDD+	Reducing Emissions from Deforestation and Forest Degradation, and Enhancing Forest Carbon Stocks in Developing Countries
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNECE	United Nations Economic Commission for Europe

UNESCO	United Nations Educational, Scientific and Cultural Organization
IUU	Illegal, Unreported and Unregulated fishing
LBR	La bouche du Roy
LCG	Le chenal de Gbaga
MAB	Man, and Biosphere
MRV	Measurement, Reporting and Verification
MTBR	Mono Transboundary Biosphere Reserve
NGOs	Non-Governmental Organizations
SDGs	Sustainable Development Goals
UNFCCC	United Nations Framework Convention on Climate Change
WACA	The West Africa Coastal Areas Management Program (WACA)

CHAPTER ONE

INTRODUCTION

Background of the study

Coastal ecosystems deliver many goods and services to humankind. Wetlands, coastal forests, lakes, lagoons among others contribute to people's wellbeing worldwide by delivering diverse range goods and services (Dugan et al. 2008). In addition to providing some non-timber and timber products, coastal ecosystems provide habitats for critically endangered plant and animal species, mitigate flood and serve as sites for recreation and ecotourism, they contribute to soil formation and play a prominent role in nutrient cycling among others (Torres-Miralles et al. 2017). These services provided by coastal ecosystems to humans are referred to as ES (Brown et al. 2015). Historically, the term ES was first used by Ehrlich and Ehrlich in 1981 who used the expression to refer to the value of ecosystem functions to the public population (Peterson et al. 2010).

The notion of ecosystem services has captured the attention of scientists, decision makers and all stakeholders involved in ecosystems management worldwide for the past few decades (MEA 2010). It is being increasingly factored into the agenda of local government and international organizations, with a higher range of interests allocated (Charrua et al. 2020). Tewari (2001) showed that the commercial forestry industry in South Africa including coastal mangroves has employed over 575,000 people with approximately 2,100,000 people depending on it for their survival. In addition to their capacity to generate food and other needful items such as fishes, crabs

and oysters, mangroves are of paramount importance in mitigating natural disasters (Kathiresan & Rajendran 2005).

Notwithstanding their benefits, coastal ecosystems are being degraded at a faster rate, occasioning the decline of the services they are noted for (Charrua et al. 2020). MEA (2010) noted that mangroves have been strongly affected in recent times, particularly from the 20th century causing a total disruption of their structures, functioning, and basic services. As a result, conservation projects are increasingly taking place worldwide, especially in West-Africa to protect the remaining patches of mangroves (Paavola & Hubacek 2013). The success of these conservation projects depends partially on the assessment of mangrove ES (Sun et al. 2017; Ashournejad et al. 2019), which provides relevant guidelines to stakeholders to regulate their intervention in order to secure its benefits for future generations (Kenter et al. 2011).

Problem Statement

Developing countries, particularly West African countries have recently gone through severe challenges that diverted the attention of political leaders from concentrating on environmental education and biodiversity conservation (Ameen & Mourshed 2017). For example, issues of diseases outbreak, poverty, and other human-related concerns were prioritized over environmental challenges such as sanitation, climate change, environmental degradation and coastal ecosystems protection (Henry et al. 2006). The limited attention paid to the latter has led to the deficit of information essential for their conservation. Mangroves are important for local economy in developing

countries, generating for example fisheries resources worth over $400 million per year (Boateng 2018).

According to the FAO, over 35% of mangroves were lost in the world from 198 to 2000 (Jia et al. 2018). The situation escalated from 2005 as a result of demographic growth of the worldwide population (Feka & Ajonina 2011). Duke et al. (2007) indicated that from 1 to 2 per cent of mangrove cover are lost every year. The situation is escalating in Benin and Togo where mangroves have drastically declined over the two past decades. In Benin, Sinsin et al. (2018) established that mangrove areas decreased from 13,306.05 ha in 1995 to 9,452.52 ha in 2015, amounting for a loss of 29% in twenty years. The same alarming trend of mangrove degradation is occurring in Togo, resulting from the large scale cutting of mangrove for domestic use (Fousseni et al. 2020).

West African countries have ratified international conventions that provide guideline mangroves conservation. The implementation of the directives of these conventions has triggered the restoration of several mangrove ecosystems across the West African Coast where community-based management is being increasingly factored into the conservation schemes (Aheto et al. 2016). Human-induced stressors to mangroves in the sub region range from unplanned urbanization to land reclamation for agricultural purposes as well as diverse forms of pollution and clearing for domestic uses (Adanguidi et al. 2020). The large degradation of mangrove ecosystems has triggered some robust measures worldwide to curb their deterioration and to promote their sustainable use. In West Africa, areas encompassing large extent of coastal environment including mangroves (Aheto et al. 2016), estuaries,

coral reefs, kelp forests, coastal lagoons (Feka & Ajonina 2011) and other inland 'sacred' forests are being massively designated as areas of international importance and protected by legal protocols (Fousseni et al. 2020).

Situated in West Africa, the MTBR was established to foster the conservation of the important ecosystems present in the Mono Delta (WACA 2020). The process towards the designation of the MTBR was initiated in 2014. However, studies conducted in the reserve after designation indicated the same trend of massive mangrove degradation (Sinsin et al. 2018; Teka et al. 2018; Adanguidi et al. 2020). Also, existing scientific information indicated that mangrove degradation affects the services that they provide (Ghaley et al. 2013; Jiang et al. 2016). Sharma et al. (2019) also asserted that mangrove degradation decreases the biodiversity and fishery resources and affects the local communities around the ecosystem. Also, the cutting of mangrove comes with a lot of environmental implications ranging from coastal flooding to global warming exacerbation as ascertained by Charrua et al. (2020)

Unfortunately, research on mangroves degradation and its implications on ES provision in the MTBR are relatively recent, sparse and few in number. The existing scientific research within the Benin side of the reserve has merely focused on the characterization of some of the provisioning services (Teka et al. 2018; Adanguidi et al. 2020) and Carbon budget (Ajonina et al. 2014). In Togo, there is also limited record on mangroves ES. According to Sun et al. (2017) assessing ES is of paramount importance to design a good and adequate conservation scheme for mangrove conservation.

Walker et al. (2020) emphasized that the conception and implementation of a good restoration policy of any ecosystem must be

preceded by a thorough investigation of the ES it provides to coastal dwellers. Walters et al. (2008) also stated that understanding the impacts on human capital and ES in a protected area is important in promoting decision making in order to support both ES delivery and biodiversity conservation. There is the need to investigate ES delivered by mangrove in the study reserve in a holistic approach.

Aim and Objectives of the study

This study investigated the ES delivered by mangroves in the MTBR and the anthropogenic pressures leading to their depletion. The objectives of the study are the following:

1. Assess the ES delivered by mangroves to local communities within the MTBR.
2. Identify the priority services for enhanced decision making.
3. Investigate the anthropogenic stressors leading to ES depletion in the MTBR.
4. Ascertain the risk posed by the anthropogenic stressors to ES provided by mangroves in the reserve.

Significance of the Study

This research provides technical and scientific support to stakeholders involved in the management of the MTBR about the ES provided by mangroves within the protected areas studied and their spatial change as a result of man-made threats. The study also contributes to mangroves protection in the MTBR by providing scientific information to international organizations and treaties such as the Ramsar Convention, the West Africa Coastal Areas Management Programme (WACA) and other national and

international CSO engaged in coastal protection in West Africa. In addition, the study outlines detailed information and provides strategic recommendations for the effective management of the MTBR in order to sustain mangrove ES as a way of meeting the Sustainable Development Goals (SDGs), especially the SDGs 3 and 14 which prioritize good health and wellbeing as well as life below water respectively.

Limitations of the study

Since this work collected data from social perspectives, it is difficult to certify that all the services provided by mangroves in the reserve were reported by the interviewees engaged during the data collection. However, this did not affect the work because a significant proportion of mangrove ES were captured owing to the mixed method-based approach used and the large number of FGDs and In-depth interviews conducted. Services were ranked based on the scores attributed by local residents situated in the catchments of mangroves in the study communities. The scoring might have been influenced by some parameters such as respondents' activities. For example, it is likely that fishermen attribute high score to fisheries products. Also, the InVEST model run does not account for past disturbances but focuses only on the current anthropogenic stressors.

Delimitations of the Study

The study took into account all the ES delivered by mangrove ecosystems in the MBR as listed by the local population, as well as all the stakeholders involved in their management and conservation. As a matter of international standards, data collection protocols were set up based on the conceptual and theoretical frameworks used by many other authors in

literature and easily implementable. Data were collected in the two countries covered by the reserve (Benin and Togo), thereby making the study a sub-regional work.

Definition of terms

Anthropogenic stressors: Stressors resulting from or exacerbated by human activities.

Consequence: Specific responses of a habitat or a species to a given exposure

Ecosystem services: Benefits provided by an ecosystem or a species to human beings.

Exposure: The extent to which a species or a habitat is under stress

Mangroves: Coastal Forest occurring in specific conditions in many tropical and subtropical countries

Wellbeing: State of being happy, healthy or comfortable

Drivers of stressors: Causes of the stressors.

Mangrove overharvesting: Over collection of mangrove wood for different purposes.

Mangrove clearing: Partial or total removal of mangrove ecosystems.

Organization of the study

The present thesis is structured in six chapters. The first chapter explained the reasons leading to the conduct of the study. The second chapter reviewed literature on mangrove ecosystem and services, changes as a result of anthropogenic activities and climate-related challenges. Information depicted in this Chapter were retrieved from existing official sources namely scientific books, peer-reviewed journals, and other relevant sources. The

review was done based on the objectives of the study and was separated in two aspects: conceptual and empirical reviews.

Chapter three expantiates the methodology that was adopted in carrying out the study. It described the research design, the study area, the population of the study, the sampling procedure, the instruments used for data collection, the data collection procedures, and the data processing and analysis. Chapter four outlines the results. In chapter five, the outcomes are profoundly discussed and compared to the existing data in literature. Chapter six concludes the study as a whole and provides some technical recommendations critical for future studies and indispensable for sustainable management of mangrove ecosystems in the reserve.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The notion of ES has been extensively used over the last two decades to generate requisite scientific data for effective natural resource management worldwide (Shareena et al. 2018). Many scholars discussed the rationale behind the consideration of ES in ecosystem management (Brander et al. 2013; Ajonina et al. 2018; Chowdhury et al. 2019). However, there are a lot of controversies the understanding and the quantification of (Brown et al. 2015). Rey-valette et al. (2017) reviewed the ES assessment methods commonly used by researchers worldwide and reported four degrees of assessment and appropriation. They include the identification, quantification, monetization, and the marketing. The authors also established that the identification is mostly related to ecology whereas the quantification ha mostly to do with inventories and the use of GIS-related methods to study and map out services.

Brown et al. (2015) cited economic valuation as another important way of assessing ES. This method which captures the monetization and the marketing reported by Rey-valette et al. (2017) is one of the most utilized valuation techniques worldwide (Gress et al. 2016). It uses approaches like cost-benefit analyses or hedonic pricing to ascertain the values of ecosystem services (Brown et al. 2015). While many scholars and decision makers encouraged the economic valuation of ecosystem services (Kenter et al. 2011), others have raised concerns about their limits for informed decision-making (Wrede et al. 2018). Cowling et al. (2008) who documented the limits of the

economic valuation voiced that "*prices are not to be confused with values, and prices are not the only values that are important*".

Ninan (2009) argued that although some values can be accurately assessed by economic valuation techniques, they fail to consider all the values of the ecosystems, particularly the nonmarketable services. They include cultural services such as spiritual value considered by the MEA as paramount both for coastal dwellers and coastal environment (Ninan 2009). These services are however being increasingly assessed with the sociocultural valuation of ES(Reyes-arroyo et al. 2021). The recent implication of major international initiatives like the Millennium Ecosystem Services, has triggered the development of new techniques of ES assessment (Nematollahi et al. 2020).

InVEST is one of the software developed to evaluate ES. It is a set of free and open access models meant for the mapping and the valuing of the benefits delivered by ecosystems (Zhao et al. 2019). Studies have demonstrated that the usefulness of the InVEST models in habitat risk assessment (Caro et al. 2020; Ghehi et al. 2020; Studwell et al. 2021), habitat quality assessment (Terrado et al. 2016; Sallustio et al. 2017; Nematollahi et al. 2020; Zhang et al. 2020), carbon storage estimation (Bianchi et al., 2013) sediment retention (Hamel et al. 2015; Marques et al. 2021) among others. Apart from the InVEST models, other tools for ecosystem services assessment like the Tessa Toolkit and the software Zonation have emerged (Birch et al. 2014; Peh et al. 2020) and are being variously utilized worldwide to assess ES. For this study, the InVEST HRA model was combined with the sociocultural valuation approach to investigate mangrove ecosystem services.

Theoretical Review

The Sociocultural Valuation of Ecosystem Services

Local populations derive many services from ecosystems, and therefore have different perceptions on how ecosystems provide services (Arkema et al. 2015). There are different ways of evaluating services provided by ecosystems. However, the thorough evaluation of their health requires an integrated approach (Christie et al. 2020). Investigating ES using an adequate approach enables the taking of good decisions for management purpose (Carpenter et al. 2009). The notion of ES has dynamically evolved in the 1900s, with particular focus on the economic values that they provide (Zhang et al. 2007). As part of the methods for assessing ES, the sociocultural valuation tries to understand the attitudes and perception of local population regarding ES and therefore, remains a relevant method to evaluate ES (Cabell & Oelofse 2012; Martín-lópez et al. 2019)

Many studies discussed the importance of the sociocultural dimension of ES assessment for a requisite decision-making (Cabell & Oelofse 2012; Martín-lópez et al. 2019). The approach is said to provide adequate information to prevent natural hazards, and thus influences decision making on ecosystem protection and the maintenance of ES deliver (Overå 2011). It also provides important quality information on community perception that can be considered for conservation strategies (Arias-arévalo et al. 2018). Walz et al. (2019) reported a total of five different applications of the sociocultural evaluation of ES, including accounting, awareness raising, priority settings, litigation uses and instruments development. Lau et al. (2019) explained that assessing ES through the lens of nonmonetary valuations is an important step

towards understanding the interplay among services. The authors further mentioned that this information is instrumental to make decision to improve local populations' well-being. Other relevant research also reported that listening to local populations and factoring their concerns and perceptions into decision making processes is helpful in the successful management of projects (Felipe-lucia et al. 2014; Awuor et al. 2019). Over the last decade, the consideration of the sociocultural valuation of ES gained keen notoriety owing to the large body of research which has addressed the issue (Scholte et al. 2015).

Studies that covered the sociocultural valuation of ES in coastal zones, particularly those oriented towards mangroves are geared towards the conservation and the management of these ecosystems(Schaafsma & Turner 2015). According to Scholte et al. (2015), ES can be evaluated both quantitatively and qualitatively. Carter et al. (2015) emphasized that ES must be measured quantitatively through nonmonetary ranking or scoring whereas Reyes-arroyo et al. (2021) proposed methods including narratives and free listening as qualitative methods to capture the extent to which people value the ES they derive from socioecological systems. Lau et al. (2019) also asserted that qualitative methods are important in identifying nontangible ES like spiritual values. Most of the social assessment of ES conducted worldwide have been carried out with the use of quantitative methods(Walz et al., 2019), meanwhile research that used mixed methods, combining quantitative and qualitative approaches are limited (Lau et al. 2019). Nyangoko et al. (2021) highlighted that both economic or monetary and socio-cultural valuations can be applied to assess ES.

Several authors advocated for the use many approaches when conducting ES valuation (Spangenberg et al. 2015; Martín-lópez et al. 2019). It is therefore advisable to use quantitative and qualitative methods while assessing ES through the lens of sociocultural valuation (Reyes-arroyo et al. 2021). When well implemented, sociocultural valuation can unfold different and/or opposing values that people place on ES (Saunders & Luck 2015). This is because perceptions are not only based on physical attributes, but also stem from peoples' conception of the environment. Therefore, social valuation of ES can help to unravel factors underlying values placed in ES such as wellbeing, drivers of change and rate of provision of the services delivered by a particular ecosystem.

The InVEST HRA Model

The InVEST HRA model helps to investigate how human activities put ecosystems and species under threats. Since its establishment, the HRA model has been largely used across the world. While risk occurring as a result of exogenous human factors can be mitigated by management intervention, those caused by endogenous factors are expected to be addressed through monitoring and preparedness (see figure 1). Many authors have reported the significance of the HRA model in informing decision-making processes. Moreira et al. (2018) assert that the model enables the identification of areas where risks are high and ascertains the species or habitats which are highly threatened. Studwell et al. (2021) added that the model helps to identify the main causes of the risks and explain how they can change under future scenario.

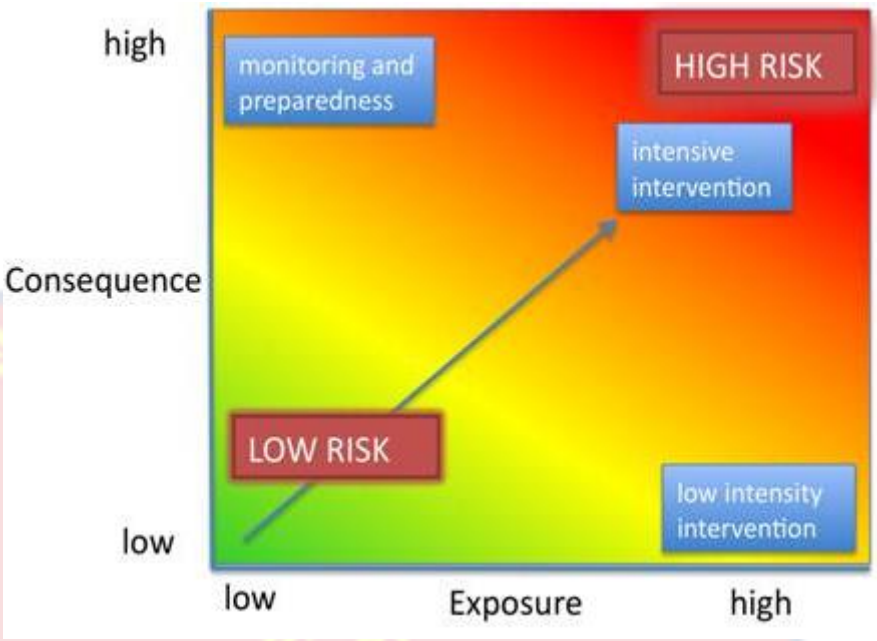

Figure 1: Linkage between the risk and the exposure in the HRA model
Source: www.naturalcapitalproject.stanford.edu

Firstly, the InVEST HRA model calculate the extent to which a habitat or species is exposed to stressors, and the consequence of this exposure. The exposure (E) and the consequence (C) are measured using a scale of 1 (the lowest) to 3 (the highest). 0 can also be used when no score exists for a particular criterion. To determine the overall exposure and consequence, the weighted mean values of the consequence and the exposure of each criterion are considered for the habitat *j* and the stressor *k* (Eq. 1 and 2).

$$E = \frac{\sum_{i=1}^{n} \frac{Eijkl}{dijkl.wijkl}}{\sum_{i=1}^{n} \frac{1}{di.wi}} \quad \text{Eq.1}$$

$$C = \frac{\sum_{i=1}^{n} \frac{Cijkl}{dijkl.wijkl}}{\sum_{i=1}^{n} \frac{1}{dijkl.wijkl}} \quad \text{Eq.2}$$

In the previous equation, Ei is the specific score of the exposure, di is the data quality rating and wi is the importance weighting. In this study, we

considered the Euclidean risk equation with linear decay (Eq. 3). The exposure and response values were combined together to compute a risk value for each habitat-stressor combination in grid cell (Ghehi et al. 2020).

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

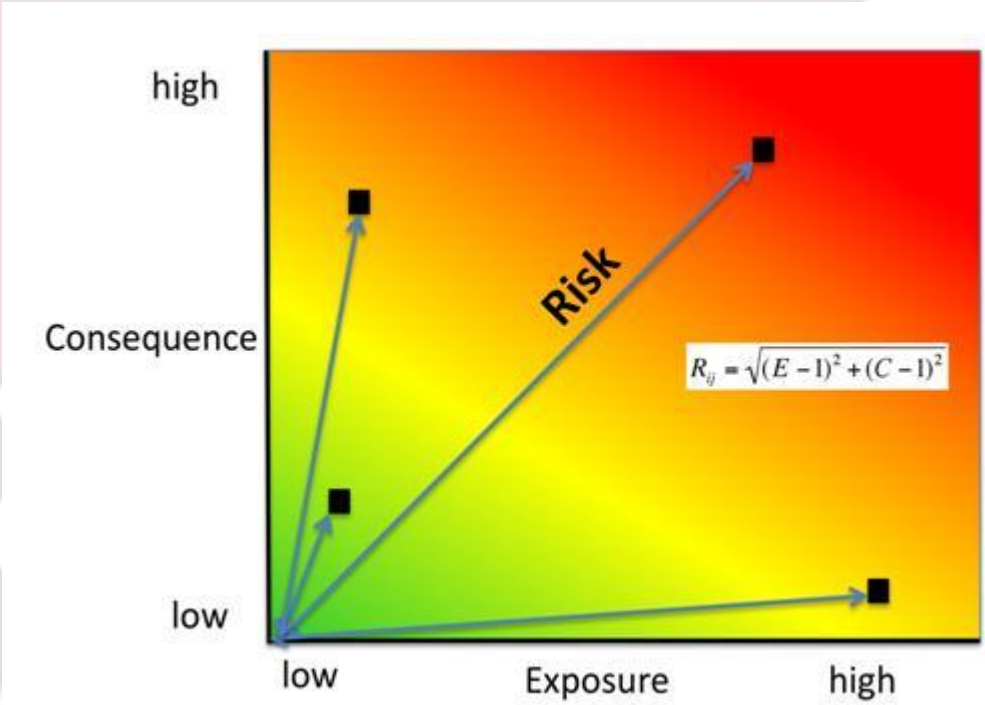

Figure 2: Multiplicative risk calculation in the HRA model
Source: www.naturalcapitalproject.stanford.edu

The risk posed by all the stressors to habitats or species was calculated by the following formula: (Eq.4) (Arkema et al. 2015)

$$Rij = ExC \qquad \text{Eq.4}$$

Empirical Review

Mangrove Ecosystems: Ecology, Distribution, and Importance

Mangroves are tidal habitats predominantly made up of a particular set of species (Mukherjee et al. 2014). Mangrove areas also include salt flats in arid regions or areas influenced by tide (Mukherjee et al. 2014). Mangroves species are different from species occurring in inland forests due to the fact

that they have the capacity to withstand difficult conditions such as saturated soils, high salt level and frequent tidal floods (Alongi 2015). Other Scientific works dedicated to their growing conditions associate their occurrence with some conditions in terms of climate (Kairo et al. 2001), topography (Walters et al. 2008) and hydrology (Srivastava et al. 2014). Mangroves present a particular ecological assemblage demonstrated by the uniqueness of their biodiversity composition (Mukherjee et al. 2014). The harsh environmental conditions characterizing their niche has resulted in a low species diversity compared to the other ecosystems (Alongi 2015).

There is a plethora of research dedicated to mangrove ecosystems across the world, looking at the aspects related to the ecology (Barbosaa et al. 2001), , distribution (Jayatissa et al. 2002), biology and use values (Saintilan & Wilton 2001). Studies that documented the distributional ranges of mangroves reported their presence in 118 to 124 countries and territories worldwide, with their occurrence on all the continents (Quisthoudt et al. 2013; Duke, 2013; Mukherjee et al. 2014). Jayatissa et al. (2002) emphasized that the distributional range of mangroves is controlled by some important climate-related variables, including the weather events, the aridity, and the salinity.

Even though some studies conducted by Duke (2013) and Srivastava et al. (2014) tend to hold the same view over the number of species existing within mangroves, the classification of these species is controversial. Spalding (2010) in his classification reported seventy-three mangrove species, of which thirty-eight were core species or foundation species. Moreover, Polidoro et al. (2010) after listing 70 species, refuted the notion of hybrid species mentioned by the previous author. Mangroves were grouped into two broader categories

namely the "true" mangroves and the mangrove "associate" species. According to the authors, "true" mangroves are characterized by their ability to (i) occur in mangrove environment and do not extend to terrestrial land, (ii) shape the structural patterns of the community, (iii) adapt to the environment using morphological specialization, (iv) exclude the salt from their system using physiological mechanisms and (v) have taxonomic isolation from terrestrial relatives.

Arguably, failure to differentiate "true" mangrove species from "associates" mangrove species can result in alarming ecological distortion, because mangrove associates can replace mangrove trees in certain areas where mangroves occur, leading to the change in mangrove functionality (Spalding 2010). The consideration of some beach grasses and coastal scrub vegetations as part of mangrove associates generally exacerbates the issues of mangrove species classification, making it more controversial. Consequently, mangrove species identification on molecular attributes is widely suggested in the literature to fix the issue (Lo 2010). The surface area of mangroves around the world is estimated between 15.6 and 19.8 million of hectares (Spalding 2010). Asia hosts the largest proportion of worldwide mangroves with a surface area extending originally over 6.8 million of hectares, followed by Africa which has 20% of mangroves, North and Central America with 15%, and Oceanic which harbours 12%, South America with 11% and Australia with 7% (Spalding 2010). The mangroves of the western Atlantic section makes up approximately 1.5 million hectares of the mangroves in Africa, followed respectively by the ones of the eastern Indian Ocean and central Atlantic sections (Ajonina et al. 2018). Nigeria is considered as the African

country which hosts the largest mangrove ecosystems, with a coverage area of 0.8 million ha, principally situated in the Niger Delta (Onyena & Sam 2020). Climatic conditions within the coastal zones of African countries are principally humid and tropical, suitable for the growth and the development of mangrove species. However, these tropical conditions change to more temperate towards Angola, putting mangroves under severe threats (Onyena & Sam 2020).

Mangroves and the International Environmental Laws

Mangrove degradation has now gone beyond a site-specific matter into a global concern over the years. Threats from climate change and anthropogenic activities have gradually deteriorated mangrove environments worldwide, leading to a significant collapse of the ES they provide (Mmom & Arokoyu 2010). As part of the natural environment, several international conventions provide decision-makers implementable guidelines for an effective conservation of mangroves around the world (Iftekhar & Islam 2004). Literature has widely documented the basic roles of international environmental laws in protecting mangroves in the recent time (Barbosaa et al. 2001; Cordeiro & Costa 2010; Azis et al. 2018).

The Ramsar Convention adopted in 1971 is one of the most relevant international conservation instruments which addresses issues of mangrove degradation. It compels contracting parties to make a fair use of the wetlands of their territories in other to ensure sustainability. The convention considers wetlands as “permanent or temporary areas of fresh, brackish or salt water with a depth of no more than five meters at low tide” and urged the contracting party to select at least one site and promote its conservation

(Pramanik et al. 2019). Jia et al. (2018) reported that over 260 mangrove sites have been recorded by the Ramsar Convention, totalling more than 30,000,000 ha accounting for over 10% of Ramsar sites across the world. World Heritage Convention is another well documented international convention that advocates for mangrove conservation. It promotes the protection of sites of outstanding universal value through the establishment of the lists of cultural and natural sites, the convention reportedly serves as a tool to conserve mangroves in 26 sites, including both natural and cultural ones (Sarker et al. 2016).

Another international convention which advocates for the conservation of mangrove ecosystems is the Convention on Biological Diversity (CBD). Even though the convention is not directly meant for mangroves, many of its articles are being used around the world to protect the biological diversity of mangroves (Iftekhar & Islam 2004). The contracting parties of the convention are required to take into consideration biodiversity in their sectoral and cross-sectoral plans, their conservation programs and policies, and national biodiversity strategies as a way of developing their action plans and national strategies for biodiversity conservation (Oliveira et al. 2011).

As part of their benefits for mankind, mangroves admittedly address issues associated with climate change. They are increasingly relevant in both mitigation and adaptation of climate change. Together with salt marshes and seagrasses, mangrove reportedly sequestrate 50-70% of the blue carbon (Suratman 2008). As a result, mangroves have been targeted by the Paris Agreement (Suratman 2008). REDD+ mechanisms stemming from the UNFCCC enabled the development of some results-based financings to spur

reduction of emissions from forested and vegetated land as a way of combatting environmental degradation. Participating countries are required to implement the MRV to assess their forest carbon stocks and receive incentives as compensation for the sustainable management of their forests. Many carbon sequestration studies have taken place over the past decades within mangroves to apply for the fund (Azis et al. 2018).

The UNECE convention (Water Convention) is also one of the water-related conventions favourable for mangrove conservation. The convention was adopted in 1992 and appeals for a good cooperation from the contracting parties to develop "harmonized policies, programs and strategies" destined to protect environments influenced by international waters (Hasselberg et al. 2020). Together with the UN Watercourses Convention, the UNECE Convention provide a framework to legally manage transboundary wetlands, including mangroves shared between two or more countries. Apart from the aforementioned popular environmental laws, other international legal instruments and programs are reported in the literature as relevant for mangrove conservation.

They include the CITES which take into account in its Appendices species living in mangroves such as the mangrove black hawk, the mangrove hummingbird and several species of reptile (Mojiol et al. 2008), the UNCLOS which requires from the contracting parties the conservation of the maritime space under their jurisdiction and the conservation of scarce fragile marine ecosystems like mangroves (Tahir 2017), the UNESCO Man and Biosphere Program which is involved in the designation of sites in the World Network of

Biosphere Reserves (Spalding 2010) and the ITTO which operates under the framework of the International Tropical Timber Agreement (Spalding 2010).

International environmental laws brought about important principles, processes and mechanisms that support the sustainable use of mangroves (Saxena 2015). The precautionary principle for instance enables decision-makers to take adequate action in case of uncertainty over the protection of mangroves (Udoh 2017). The polluter pay principle also imposes obligations for nature restoration or compensation after disturbances (Lal 2003). Apart from these aforementioned principles, other principles are highly reported by diverse authors, as international environmental law-created, that can be applied to foster the sustainable use of mangroves. For instance, principles of public participation, of access to information and of justice are some of the innovations of the international environmental law that empower coastal states to make suitable management decisions regarding mangroves conservation (Huang et al. 2012). Additionally, Cohen (2004) evoked the principle of state sovereignty that is grounded in the premises that the states have been endowed with sovereign right on their resources including mangrove ecosystems and can make decision for their management.

The principle confers the right to states to manage their resources based on their own environmental policies (Gioia & Gioia 2007). The implementation of this principle has led to a variety of management policy for mangroves according to the goal set by coastal states around the world. The principle of responsibility for transboundary harm is another provision made by international law that applies to mangroves (Takano 2018). This principle, which is much older than the principle of sovereignty, prevents the state from

causing transboundary harm. In addition to the CBD and the UN Watercourses Conventions, this principle advocates for the regular implementation of the Environmental Impact Assessment (EIA) as an important avenue to preserve the ecological health of ecosystems (Srivastava et al. 2014). Based on this principle, projects implemented within mangroves around the world are gradually being preceded an Environmental Impact Assessment as an instrument to appraise the possible ecological impacts of the projects to the environment and people on a local, national and international basis (Srivastava et al. 2014)

Damage caused to mangroves can be irreversible, affecting the interconnected ecosystems and by extension an entire community. The precautionary principle that stemmed from the Rio Declaration and has been incorporated over time to many international conventions such as the UNFCCC, the UNECE water convention and the CBD for example remains to date a powerful tool to curb mangrove degradation. The principle indicated that the "*lack of full scientific certainty where there are threats of serious or irreversible damage shall not be the deterrent to postpone co-effective measures to prevent environmental degradation*" (Mollick et al. 2021). It serves as a guide for decision making in a condition of uncertainty and risk. In the case of mangroves, the precautionary principle spurs the regulation of activities that potentially damage mangroves even where there is no total certainty about their detrimental effects (Vanderzwaag 2002).

The polluter pays principle is another provision geared towards the protection of worldwide ecosystems of which mangroves (Woerdman et al. 2008). The principle seeks to change polluter behaviour by charging damage

and harm done to the environment. Pramanik et al. (2019) concluded that the principle of polluter pays is a crucial mean to deter drivers leading to mangrove degradation and loss by compelling mangrove polluters and degraders to pay for any misconduct that can occasion mangrove disruption.

Over the past decade, the question of sustainable development dealing with mangroves management has been predominantly raised worldwide. Sustainable development holds the view that social development and long-term economic development are strongly dependent on adequate management and conservation of environmental resources (Giljum et al. 2008). Many international laws related to the environment including the CBD and the Rio declaration have also recognized the concept of sustainable development and its importance. Wight (2002) described three principles which are important for the sustainable development, namely the ones of intergovernmental equity, the corollary principle of intragenerational equity and the principle of sustainable use. The latter is being strongly used worldwide to protect mangroves (Seto & Fragkias 2007). According to Agenda 21 which provides directives to achieve sustainable development, “mangroves are among the most highly diverse, integrated and productive ecosystems on earth”.

Even though the SDGs adopted in 2015 do not reference mangroves, their (SDGs) achievement partly depends on mangroves. Goal 15 seeks for instance to overcome the unsustainable use of forests and wetlands, stopping and reversing deforestation and minimizing degradation of natural habitats (Saxena 2015). Sampantamit et al. (2020) added that mangroves play a relevant role in meeting the targets of the SDGs by eliminating poverty, fostering food security, and curbing natural disasters. Principles of “good

neighbourliness" and "good governance" depicted in several international environmental legal instruments are also applicable to the mangroves and are being used worldwide to conserve those ecosystems (Maynou et al. 2013). International instruments that regulate mangrove management together with their principles constitute a worldwide legal framework that can lead to a sustainable management of mangroves (Carter et al. 2015). Mcintyre (2006) listed fourteen principles emerging from the international environmental laws that have been applied to conserve mangroves in Indonesia.

Ecosystem services and wellbeing

Maes et al. (2015) explained that ecosystems are highly dynamic complex set of organisms, including plant, microorganism, and animal. According to MEA (2010), humans play a significant role in ecosystems. Ecosystem provides an important framework for appraising the link between human and nature (Korhonen 2001). The concept has been endorsed by many environment-related laws (Morgera & Tsioumani 2011). Moore et al. (2002) reported that policy makers must appraise the complexity of ecosystems to implement the ecosystem approach.

MEA (2010) has categorized the benefits provided ecosystems into four groups. They included the provisioning services, the regulating services, the supporting services, and the cultural services. The provisioning services refer to the various products people derive from ecosystems (Lannas & Turpie 2009). Regulating services indicate the goods and services that people obtain when ecosystems regulate the local environment (Brander et al. 2013). Daniel et al. (2012) described the cultural services as non-tangible benefits people derive from ecosystems through recreation, ecotourism and spiritual values

whereas Wrede et al. (2018) indicated that supporting services are the services that support the functioning of other services like the primary production, soil formation or photosynthesis.

CICESS provides a detailed guide for ES identification, making their assessment relatively easier for researchers (Reyes-arroyo et al. 2021). Bagstad et al. (2013) reported that a thorough evaluation of the interplay between people and ecosystems requires a multiscale approach due to its capacity to better reflect the complex nature of decision making. The authors reiterated that this situation help to understand how ecosystem changes impact policy responses. The concept of ES underpins the complex connection among the structures, the processes and the services of ecosystems (Larondelle & Haase 2013). Though some services can exhibit synergies and trade-offs happen between others. The conceptual framework laid down by the MEA (2005) put human wellbeing at the centre of ES assessment. Based on the strong relation between humans and ecosystems, the framework indicated that ES are essential for four pillars of people's wellbeing including their security, social and cultural relations, basic materials for good life, and health (MEA 2010).

These wellbeing-related pillars also influence the freedoms and the choices of people (Jiang et al. 2016). Aside from the MEA, other studies have also presented different frameworks to understand and accommodate the concept of ES. For instance, Martín-lópez et al. (2019) have designed a conceptual framework for a good apprehension of drivers of change of in ecosystems. The authors emphasized that trade-offs between changing and disparate goals require the resolution of conflicts coming from factors like

resource inequalities and inequal distribution of incomes (Martín-lópez et al. 2019).

Mangrove Ecosystem Services and Drivers of their Decline in West-Africa

Nortey et al. (2016) reported the essential benefits of mangroves, ranging from food and water provision to coastal hazard mitigation and pollution control. This is backed by Sagoe et al. (2021) who found that mangroves protect the coastal environment from coastal flooding and land accretion. Other studies have also reported at mangrove ecosystems deliver a lot of provisioning services to coastal dwellers (Zimmer et al. 2018). Kairo et al. (2001) further reported the huge contribution of mangroves in biodiversity conservation and nutrient cycling. Gnansounou et al. (2021) reported that 90% of the world's fishing activities take place in coastal ecosystems including mangroves.

In Malaysia, the Philippines, India and Japan, the health and extent of mangrove coverage positively influence fishing activities (Brander et al. 2013). Sandilyan and Kathiresan (2014) argued that mangrove ES constitute a large support for economic and social life and environmental protection. In addition to providing shelter for critically endangered species (Zimmer et al. 2018), mangroves are important in biodiversity conservation because of their high primary productivity (Teka et al. 2018). The authors also reported that the global biomass of mangrove ecosystems revolves around 8.7 gigatons dry weight. Organic matter from mangroves are generally decomposed by bacteria and fungus, enters the food chain and constitute feeding source for aquatic organisms (Rahman et al. 2021). They are also sources of basic and fundamental goods for local communities and tremendously contribute to their

wellbeing (Sinsin et al. 2021). They provide support for coastal aquaculture and other income generating activities (Zanvo et al. 2021).

Coastal fisheries and other related livelihood-support activities provide over 300 million of jobs worldwide, and these activities occur the global south (Failler et al. 2020). Most of the small-scale fishermen operating in the West African coastal environment including those fishing in mangroves use prohibited fishing gears and techniques (Marquette et al. 2002). Diverse techniques of fish processing are used in the West Africa's coastal environment to preserve fish.

The large collection of wood from mangroves in Benin engendered the rapid degradation of their services (Adanguidi et al. 2020). "Acadja" is another cause of mangrove ES depletion in West-Africa (Zanvo et al. 2021). This technique widely developed in West Africa refers to the use of mangrove branches and leaves to mimic natural habitat in order to trap fish species and harvest them (Adite et al. 2013). Salt production also leads to high degradation of mangroves. Kasso et al. (2008) reported that to produce 63 kg of salt, 1 m^3 of mangrove wood is needed. The same authors indicated that about 47,613 m^3 of mangrove woods are collected annually to produce 30,000 tons of salt.

Coastal cultivation also contributes to mangrove degradation and mangrove ES depletion in West Africa. The topology of West African subregion coupled with the favourable climatic conditions foster coastal cultivation (Nortey et al. 2016). However, population growth in the West Africa has led to the increase of land demand for farming (Padonou et al. 2021). Din et al. (2008) informed that Cameroon has lost over 1000 ha of

mangroves from 2005 to 2007. Coastal development also contributes mangrove destruction in West Africa. Capital cities such as Dakar, Cotonou, Accra, and Freetown were built within the coastal environment of the subregion.

The Research Design used and its significance

This study was conducted using the pragmatism research paradigm. This worldview derived from the work of Ruwhiu & Cone (2010) came out from situations, actions and consequences rather than antecedent conditions. For the pragmatists, the world is not an absolute unity, so many approaches can be used to gather, analyse and interpretate data (Christ 2013). As a result, instead of focusing on only one method as indicated by constructionists or positivists, pragmatists urge researchers to make use of all the approaches available to understand the situation under study (Minteer 2008). This encourages the use of the mixed method design, including qualitative and quantitative approaches when undertaking research.

This is because of its ability to better explain the research problem in a detailed manner. The paucity of scientific information concerning the diversity of mangrove ES in the study area, their significance in sustaining livelihood and wellbeing and their associated threats make the subject difficult to assess using only quantitative approach. Moreover, there is a need to statistically analyse data emerging from this research in order to come out with generalizable outcomes. This cannot be achieved using only a qualitative approach. Qualitative approach tries to be open-ended without any predetermined response whereas a quantitative method tends to be close-ended where predefined response categories are found in the data collection

instrument (Johnson & Onwuegbuzie 2004). Three broad research designs fall under the mixed method approach. They are the concurrent parallel mixed method, the explanatory sequential mixed method and the exploratory sequential mixed method. (Johnson & Onwuegbuzie 2004). For the purpose of this research, the exploratory sequential mixed method was adopted.

CHAPTER THREE

MATERIALS AND METHODS

Study Area

The study area is the MTBR. The area is situated in-between Benin and Togo and is watered by the Mono River. The reserve is subdivided into three different zones: the core area, the buffer zone, and the transition zone and is comprised of 13 protected sites (Appendix, Figure 7). The core area of the reserve covers a surface area of 14,496 ha whereas the buffer and transition zones extend over 43,378 ha and 288,412 ha respectively (Guelly et al. 2018). This study focused on two protected sites of the reserve which are "*La bouche du Roy*" in Benin, "*Le chenal de Gbaga*" and "*La forêt sacrée d'Akissa*" in Togo (Figure 3).

They were selected based on their accessibility and the high interaction between mangroves and local populations. "*La bouche du Roy*" is situated between 6°12' and 6°15' North and 1°52' and 1°59' East. It covers four cities, namely Comè, Grand-popo, Ouidah and Kpomassè. The site covers a surface area of 9,678 ha and is divided in continental and marine areas. The management of the site "La bouche du Roy" is assured by the Association of Conservation and Promotion of the Community Biodiversity Conservation Area "*ACP-Doukpo*". Conversely, "Chennal of Gbaga" is a transboundary site crossed by the the Gbaga lagoon which separates Benin from Togo. The area lies from Agbanakin to Agokpamin and is located between 6°17' and 6°18' North and 1°39' and 1°48' East. The area covers a surface of 4,575 ha and is dominated my mangrove ecosystems. Seven villages were selected in the reserve for data collection. They included Avlo, Nanzounmey, Dohi and

Gbèzounmey in Benin and Seko, Djeta and Agokpamey in Togo. Their selection was based on the density of their population, the accessibility of their mangrove ecosystems and the strong dependence of their local population on the mangroves for their livelihood and wellbeing (Gnansounou et al. 2021).

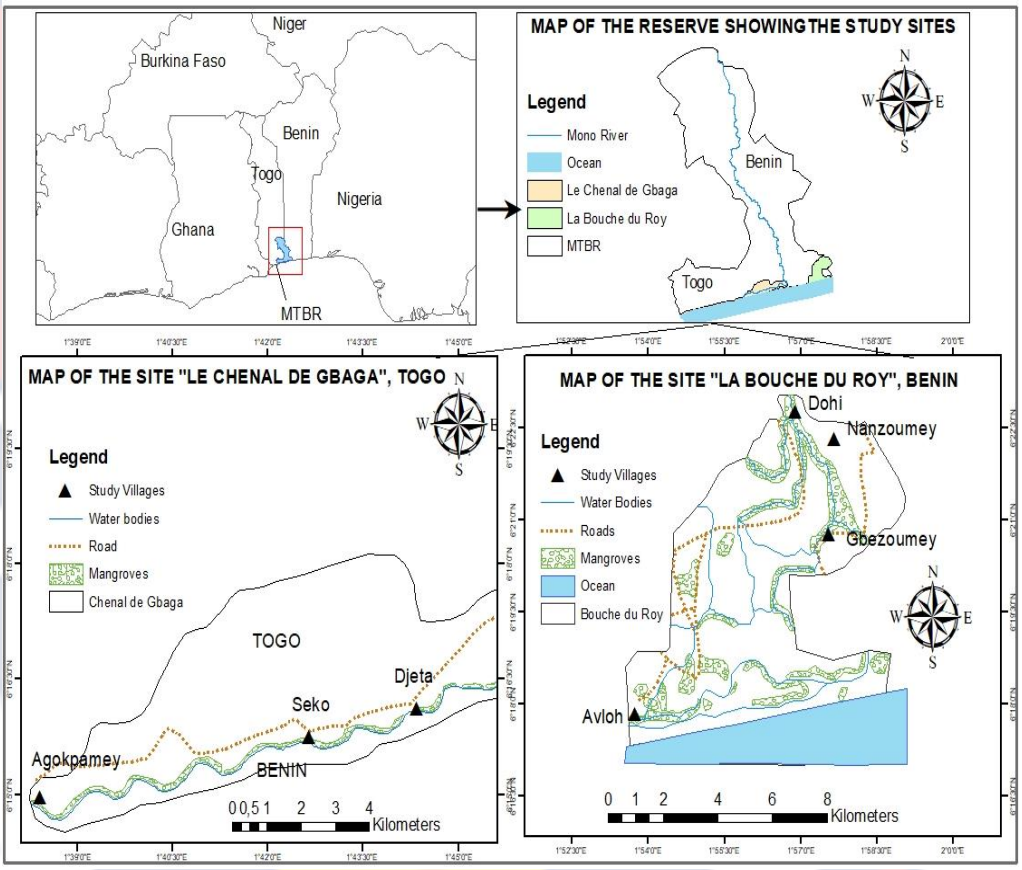

Figure 3: Map of the study area
Source: Field work, 2021

Population

The residents of the communities within the catchment of the MTBR, particularly those living within the sites LBR and LCG represent the main units of analysis in this study. They were considered because of their heavy dependence on mangroves for different purposes including fishing, salt production, wood collection, flood protection among others. For example, local residents of LBR in Benin harvest large quantity of firewood for local

and commercial purposes (Gnansounou et al. 2021). They also strongly depend on fishing activities and commercial salt production (Sinsin et al. 2018). Others, especially those living in Togo also engage in firewood and other provisioning services collection as well as vegetable farming in and around the mangrove ecosystems (GIZ 2018). The poor management regime of mangroves in the area coupled with the demographic growth prevailing in the West African coastal environment (Teka et al. 2018) have resulted in a negative influence on mangrove ES provision that need to be investigated.

Four categories of people constituted the study population from whom primary data was collected. The first category of people included the local residents of the selected sites who participated in the household survey. The second category of the target population consisted of farmers, tour guides and chief fisherfolks in the selected sites whose activities are mangrove related. These groups of people were selected because they depend directly on mangrove resources and based on the assumption that their activities may either affect mangroves negatively or support their normal functioning. They were specifically defined for the first phase of the study and were engaged through FGDs. The third category included the head of communities, the elderly people, and the traditional leaders. They are paramount in mangrove management in the area, hence are crucial in meeting the research objectives. The last category of the study population were the experts engaged to run the HRA model. They included key stakeholder institutions, mangrove-oriented scientists, civil society organizations, local associations and agencies engaged in mangrove conservation in the area. They were considered because their

expertise and activities on the issues being investigated are considered paramount.

Sampling Procedures

Key informants and local residents who participated in the qualitative phase of the work were recruited using purposive and snowball sampling procedures whereas simple random sampling technique helped to select households (Sagoe et al. 2021). Participants were selected with the help of community leaders from the elderly people who had stayed within each community for over 10 years and know about the importance of mangroves. A pilot survey was carried out per site whereby fifty households were randomly selected to determine the proportion of household who depend on mangrove ES for their livelihoods or wellbeing. For the sample size calculation was done using the following formula (Mensah et al. 2017):

$$n = \frac{1}{e^2} p(1-p) U^2_{1-\frac{\propto}{2}} \quad \text{Eq.5}$$

Here n was the total sample size, U is the value of the random variable (U=1.96 for α = 0.05), e is the margin error held at 9%.

Data Collection Instruments

Instruments used for data collection in this study included structured and semi-structured interview.

Guide for the In-depth Interview

An in-depth interview guide was conceived to engage each of the key informants investigated for the qualitative phase. The interview guide used was designed to highlight some major issues, including mangrove spatial coverage, the evaluation of their status and their dynamics in the reserve and

the threats that they undergo, institutional arrangement of the reserve, and planning and management strategies for the reserve.

Guide for the Focus Group Discussions

Another guide was designed to assist the moderation for the FGDs. This guide captured all the research questions to be answered. The guide was flexible to allow the moderator probe for more information on the subject under discussion.

Guide for the Structured Interview

The structured interview guide was a paper-based face-to-face interview. It was made up of multiple-choice close-ended questions with 5-point-Likert-scale to conduct the household survey. The first part of the guide solicited information on the demographic characteristics of the investigated households, notably their gender, activities, age, education, marital situation etc. The second section sought information on how respondents prioritize ecosystem services and relate them to their wellbeing. The third part of the guide, it focused on the threats to mangroves in the area.

Data Collection Procedure

Data was collected from October 2020 to Jun 2021. The research team was composed of the main researcher and two field assistants hired for the purpose. Data collection procedure included the preliminary field assessment and the qualitative and quantitative data collection.

Preliminary field assessment

Field Reconnaissance

Field reconnaissance activities enabled the research team to understand the reality on the ground in order to adjust the methods of data collection. The

field reconnaissance helped to perform the community-entry protocols, study villages selection, sample size calculation and the pretesting of the data collection instruments. Additionally, contacts were built to facilitate data collection. Some local residents were also engaged to collect primary information about mangrove ES in the study communities.

Community entry protocols

Community-entry protocols is the surest way of introducing the research outfit to the community leaders in order to seek approval to collect data. As a result, seven meetings were organized with traditional leaders and heads of villages before starting data collection. The meetings served as an entry point in the selected villages. During the meetings, the objectives, the research approaches, and the expected results were fully explained to participants as well as their roles in facilitating the research activities The meetings were also used as a medium to seek oral consent from the community leaders and traditional chiefs to interact with local residents.

Qualitative data collection

Direct observations

Direct observations were made at the community level throughout the data collection period. It entails the visits strategic areas like salt ponds, water points, mangrove catchments, where mangroves are exploited in various ways. Activities such as salt production, ecotourism, mat fabrication, and fish processing were critically observed to assess the local use of mangrove ecosystems and their role in providing job opportunities to people locally.

Focus Group Discussions

FGD is one of the qualitative methods increasingly recommended in natural resource management, landscape management and ES assessment. It is an effective, bottom-up and participatory method of data collection that takes advantage of the knowledge and expertise of local residents (Nyangoko et al. 2021). Two FGDs were organized per community resulting in fourteen FGDs in the seven study communities involving one hundred and forty participants. The groups of men were separated from the ones of the females to avoid gender bias (see Plate 1). The sociodemographic of those who participated in the FGDs are summarized in Table 1. Each session lasted between 40 minutes to 60 min and was attended by 10 individuals. Prior to the discussions, the terms ES, livelihood, and wellbeing were explained in detail to the participants. They were then asked to list all the services they obtain from mangroves and how these contribute to their wellbeing. They were also engaged on the anthropogenic threats which contribute to mangrove degradation in their communities. Other aspects associated with land use, ownership regimes and land right tenures were also discussed during the sessions.

Table 1: Socio-demographic Attributes of FGD Participants

	Benin		
Villages	Main activities	Ethnical groups	Age categories
Avloh	Mat weaving, fishermen, fishmongers, Salt producers	Xweda, Xwla, Mina	29 to 60
Dohi	Mat weaving, fishermen, fishmongers, Salt producers	Xweda, Ouatchi	35 to 55
Gbezoumey	Mat weaving, fishermen, fishmongers, Salt producers	Fon, Xwla, Xweda	29 to 65
Nanzoumey	Mat weaving, fishermen, fishmongers, Salt producers	Xweda, Fon	37 to 59
	Togo		
Djeta	Fishermen, Petty traders, fishmongers	Mina, Ouatchi, Ewé	29 to 51
Seko	Fishermen, Petty traders, fishmongers	Mina, Ouatchi, Ewé	36 to 63
Agokpamey	Fishermen, Petty traders, fishmongers	Mina, Ouatchi, Ewé	33 to 59

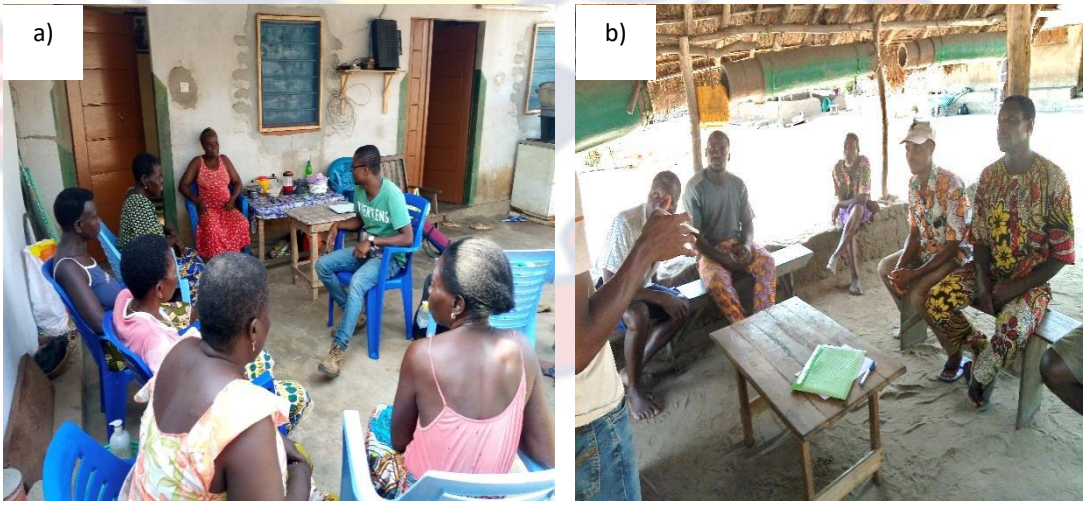

Plate 1: FGDs with women at Seko, Togo (a) and with men at Nanzoumey, Benin (b)
Source: Field work, 2021

Key Informant Interviews

In total, 17 key informants were engaged for the study. They included 10 resource persons (chief fishermen, community leaders and traditional priests), 4 NGOs (CORDE-BENIN and ECO-BENIN, COSOL-PG and AHD) and 1 state agency (ADELAC) (Table 2). Key informants engaged for this study are all active in mangrove restoration in the reserve. Apart from they, the two local associations which manage mangroves in the reserve (ACV DOUKPO and FAH GBAGA) were also engaged. Key information was noted down whereas the full interview of each informant was recorded after seeking approval from each interviewee (See Plate 2).

Table 2: Categories of Key Informants Interviewed

Benin		
Category	Number of people consulted	Nature
Resource persons	6	- Chief fishermen (2) - Traditional leaders (2) - Community leaders (2)
NGOs	2	- Coordinator of CORDE (1) - Program officer of ECOBENIN (1)
Association	1	- President of the Association ACP-Doukpo
State Agency	1	- Head of Department of Aquatic Resources Management and local economy promotion of ADELAC
Togo		
Resource persons	4	- Chief fishermen (2) - Traditional leaders (1) - Community leaders (1)
NGOs	2	- President of AHD (1) - Head of remote sensing, GIS and local governance department of COSOL-PG
Association	1	- President of the Association FAH-GBAGA

Plate 2: In-depth interviews in Agokpamey, Togo (a) and Dohi, Benin (b)
Source: Field work, 2021

Participatory Mapping

Participatory mapping exercises were conducted in the two study sites just after the completion of the FGDs and IDIs (Plate 3). It helped to obtain the shapefiles of the anthropogenic stressors in order to run the HRA model. For the mapping, hard copies of the maps of the reserve were obtained from Guelly et al. (2020) for the site of Togo and GIZ (2018) for the site of Benin. Two FGDs were therefore organized with traditional leaders, local authorities and members of local associations and NGOs. During the discussions, the maps of each village downloaded from Google earth were given to participants to identify landmarks and other physical features. They were further asked to identify from the maps areas where threats prevail. Afterwards, the results of the two groups were confronted and consensus built on the spatial distribution of the threats.

Plate 3: Participatory mapping
Source: Field work, 2021

Quantitative data collection

Household Survey

Before embarking on the household survey (Plate 4), the structured interview guide was pre-tested with the community leaders and adjustments made to make both interviewees and enumerators comfortable in participating in the exercise. The interview guide was designed based on the information collected during the reconnaissance survey. All the services enumerated during the FGDs were printed in images and sent to the field to guide respondents. In each house, the two heads of family namely the husband and the wife were separately engaged as suggested by Kusakari et al. (2014). Respondents were given the opportunity to provide score to each broad category of ES and each subcategory using the 5-point Likert scale (1-very low provision, 2- low provision, 3- moderate provision, 4- high provision, 5- very high provision).

In addition, they were asked to provide details about how mangrove ES contribute to their wellbeing using binomial response (0= not satisfied, 1= satisfied). During the survey, visual observations of some socio-economic characteristics like the clothing, household type, livelihood assets, nutritional

status of family members as well as the reactions of interviewees to various questions were made. A total of ninety-two households comprising one hundred and eighty-four respondents were interviewed in Benin (*p= 0.7*) whereas forty-five households involving ninety people were investigated in Togo (*p= 0.9*). The number of households investigated in each village is proportionate to the total number of households in this village (Table 3).

Table 3: Total number of households investigated.

		Benin	
Villages	Total number of households	Number of households surveyed	Number of respondents
Avlo	135	20	40
Dohi	277	41	82
Gbezoumey	98	15	30
Nanzoumey	111	16	32
Total	621	92	184
		Togo	
Djeta	125	18	36
Seko	105	15	30
Agonkpamey	71	11	22
Total	301	44	88

Source: INSAE, 2013

Plate 4: Household survey in Togo (a) and Benin (b)
Source: Field work, 2021

Habitat Risk Assessment (HRA)

The first phase of this study identified the stressors to mangroves in the study area. Thereafter, the study was interested in assessing the extent to which these stressors put the ecosystem at risk. As a result, the HRA model was used with InVEST software version 3.9.0. The HRA model is one of the InVEST models largely used by scholars (Arkema et al. 2015; Caro et al. 2020; Ghehi et al. 2020) and enables to ascertain the cumulative risk that an ecosystem or a species which is subjected to high anthropogenic activities undergoes. It also uncovers the consequences of these risks for ES supply and biodiversity conservation. Table 4 presents the data used for the model and how they were collected and processed. The model uses information on exposure and consequence to compute how an ecosystem or a species is at risk. It is based on the assumption that the species or the ecosystem which is subjected to high human activities is under high risk(Arkema et al. 2015).

Table 4: Data collected for the HRA model.

	Inputs	Data	Source
HRA model	Maps of the habitats	Shapefiles for mangrove cover of the sites	Obtained from GIZ (2018) for Benin and from Guelly et al. (2020) in Togo.
	Map of the stressors	Shapefiles of the stressors	Mapping of the stressors recorded during the qualitative phase.
	The files of the habitat stressors	A CSV table containing the information of each habitat and stressor layers and the buffer distance for the input layer.	Conceptualized by authors based on the preliminary data collected during the qualitative phase.
	The criteria used for the scoring	It is also a CSV table which contains the criteria scores for all the habitats and stressors.	Assigning of scores based on expert-based survey. Details were given in Tables 13 and 14.
	Resolution of Analysis	500	
	Maximum criteria score	3	
	Risk Equation	Euclidean	Arkema et al. (2015)
	Decay Equation	Linear	Arkema et al. (2015)

Data analysis

Qualitative data

Interviews recorded during data collection were transcribed and compared to information noted in the field. Transcribed information was used to identify the services mentioned by participants. The identification was done based on the guide issued by the CICES (Common International Classification of Ecosystem Services) (Nyangoko et al. 2021). The services identified were

categorized into four categories including the provisioning services, the regulating services, the supporting services and the cultural services using the Millennium Ecosystem Assessment (MEA 2010).

Quantitative data

Quantitative data collected for this study was analysed with the software R version 4.0.1. Services that were identified during the fieldwork and the threats were ranked based on the analysis of scores using the Relative Importance Index (RII) which ranges from 0 to 1. (Aheto et al. 2016):

$$RII = \frac{\sum_i^n W_i}{A \times N} \quad \text{Eq.6}$$

In the formula, "Wi" represents the weight of each ES, and N is the total number of respondents.

The impacts of the sociodemographic characteristics on the perceived impact of ES provision and peoples' wellbeing are assessed with a generalised linear model (GLM) with binomial error distribution. Prior to this, respondents were grouped based on their age, activities, gender, ethnic groups, and educational background. To assess the magnitude of pressure undergone by mangroves in the reserve, the percentage of mangrove cover under low, medium, an moderate risks were computed with the HRA model using the InVEST 3.9.0.

CHAPTER FOUR

RESULTS

Ecosystem Services delivered by mangroves in the study area

Diversity of mangrove ecosystem services listed by participants

In total, 15 services including 7 provisioning services, 2 regulating services 3 supporting services and 3 cultural services were cited by participants in Togo whereas 21 services including 9 provisioning services, 4 regulating services, 3 supporting services and 5 cultural services were cited in Benin (Tables 5 and 6). Majority of the provisioning cited by respondents in Benin without probing them, whereas some of the cultural, regulating and supporting services were listed after probing (Tables 5 and 6). In Benin, spiritual and religious services provided by mangroves were listed by men. Also, services like erosion control, water purification, spiritual and religious values, oyster provision, NTFPs and social relationships reported in Benin were not mentioned in Togo (Tables 5 and 6).

Table 5: Services people collect from mangroves in Togo (P: provisioning services, S: supporting services, R: regulating services, C: cultural services)

Mangrove Ecosystem Services	Villages			Summary of participants' narratives
	Djeta	Seko	Agokpamey	
Fish provision (P)	A*	A*	A*	- We collect different types of fish from mangroves
Crab provision (P)	A*	A*	A*	- We collect crab species from mangroves ecosystems
Shrimp provision (P)	A*	A*	A*	- Shrimps are collected from mangroves
Fodder (P)	-	B**	B*	- Leaves of *Rhizophora racemosa* are collected from mangroves
Timber (P)	A*	A*	A**	- Timber is collected from mangroves
Water supply (P)	A*			- People collect water from mangroves for different uses
Firewood (P)	A**	-	-	- Firewood is collected from mangroves
Climate Regulation (R)	A*	A*	A*	- People come to mangroves to get fresh air - Mangroves make the local environment cold
Natural hazards control (R)	B*	B*	-	- Mangroves mitigate flooding - Mangroves protect our villages against wild wind
Spawning and Nursing grounds (S)	A*	A**	A*	- Mangroves enable the reproduction of many aquatic species
Biodiversity support (S)	A*	A*	A*	- Many animals and bird species live in mangroves
Nutrient cycling (S)	A*	A*	A*	- Mangroves generate food for fish thank to their leaves
Educational values (C)	B*	B*	B*	- Researchers and students come to study mangroves
Aesthetic values (C)	A***	-	-	- Our villages are beautiful thanks to mangroves
Leisure, recreation, and tourism (C)	A*	A*	A*	- Tourists come from different places to visit mangroves

A: Services identified without probing interviewees B: Services identified after probing interviewees, -: services unidentified in the village, *: 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.

Table 6: Services people collect from mangroves in Benin (P: provisioning services, S: supporting services, R: regulating services, C: cultural services)

Mangrove Ecosystem Services	Villages				Summary of participants' narratives
	Nanzoumey	Dohi	Avlo	Gbezoumey	
Fish provision (P)	A*	A*	A*	A*	- Mangroves harbour variety o -fish species
Crab provision (P)	A*	A*	A*	A*	- Crab species are harvested in mangroves
Shrimp provision (P)	A*	A*	A*	A*	-Mangroves have many shrimp species
Oyster provision (P)	A*	-	-	A*	- Oyster are caught from mangroves
Fodder (P)	A*	A*	A*	A*	- Leaves of *Rhizophora racemosa* are food for goats
NTFPs (P)	A*	A*	A*	A*	- Mangroves are also used for hunting purposes - Medicinal plants are also collected from mangroves - We use branch of *Rhizophora racemosa* as vegetal brush - *Cyperus articulatus* is also grown in mangroves for mat weaving - *Rhizophora racemosa's leaves* are also used to dye crabs and nets,
Timber (P)	A***	A**	A***	A***	- Wood of *Rhizophora racemosa* is used as construction wood- Wood of *Avicennia germinans* and *Rhizophora racemosa are collected to fabricate local stool and drums.*
Firewood (P)	A**	A**	A*	A*	- Firewood is collected from mangroves for domestic use.
Water supply (P)	B*	B*	B*	A*	- We bath in mangroves - Water is collected from mangroves for salt production.
Climate Regulation (R)	A*	A*	A*	A*	- Mangroves play an important role in air purification in our vicinity - Mangroves regulate the weather
Erosion control (R)	-	A***	-	-	- Mangroves make the soil compact
Water purification (R)	-	A***	-	-	- Mangroves retain pollutant and fight against pollution

Natural hazards control (R)	B*	B*	B*	A*	- Mangroves mitigate flooding
Spawning and Nursing grounds (S)	A*	A*	A*	A*	- Mangroves provide habitat for fish reproduction
Biodiversity support (S)	A*	A*	A*	A*	- Mangroves harbour various animals - Mangroves represent nesting ground for birds
Nutrient cycling (S)	A*	A*	A*	A*	- Mangroves'leaves serve as food for fish in the water
Social relationships (C)	-	B***	-	-	- Gathering happens each 10th January in manrove forest to celebrate the nationwide voodoo day
Educational values (C)	B*	B*	B*	B*	- Many students come here for educational
Aesthetic values (C)	A*	A*	A*	-	- Our villages are beautiful because of the presence of mangroves
Spiritual and religious values (C)	B**	B**	B**		- Mangroves harbour a lot of divinities
Leisure, recreation and tourism (C)	A*	A*	A*	A***	- We receive tourists here because of the mangroves

A: Services identified without probing interviewees B: Services identified after probing interviewees, -: services unidentified in the village, *: 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.

Services mostly provided in the study area.

In Benin, and Togo, provisioning services were reported as the most provided services (Benin: RII=0.77, Togo: RII=0.65), followed respectively by supporting services (Benin: RII=0.62, Togo: RII=0.52), regulating services (Benin: RII=0.47, Togo: RII=0.49) and cultural services (Benin: RII=0.38, Togo: RII=0.35) (Table 8). For the subservices, respondents ranked fish provision first (RII=0.78) whiles oyster provision was the last (RII=0.12) in Togo. In Benin, fish provision was also ranked first (RII=0.77) while the least provided service was fodder collection (RII=0.24). Respondents in the two countries considered climate regulation as the most delivered regulating service (Benin: RII=0.70, Togo: RII=0.71) while water purification and hazards controls (RII=0.35 and RII=0.50 respectively) were least ranked in Benin and in Togo.

Regarding the supporting services, the first service in the two countries was biodiversity conservation (Benin: RII=0.75, Togo: RII=0.67) meanwhile nutrient cycling (RII=0.48) and nursing and spawning ground (RII=0.48) were less ranked in Benin and Togo respectively. As for cultural services, ecotourism was least ranked in the two countries (Benin: RII=0.35, Togo: RII=0.33) whereas educational values (RII=0.50) and aesthetic values (RII=0.41) were highly scored in Benin and Togo respectively. Moreover, some services like timber collection, crab collection, timber collection, shrimp collection, natural hazard control, spiritual values obtained high scores whereas water supply and erosion control obtained low scores (Table 7).

Table 7: Scores obtained by the broad categories of services.

Benin (N=184)				Togo (N=90)			
Rank	Services	Total score	RII	Rank	Services	Total score	RII
1	Provisioning	717	0.77	1	Provisioning	295	0.65
2	Supporting	576	0.62	2	Supporting	237	0.52
3	Regulating	437	0.47	3	Regulating	221	0.49
4	Cultural	357	0.38	4	Cultural	159	0.35

Table 8: Scores obtained by the subservices.

Benin (N = 184)				Togo (N = 90)			
Rank	Services	TS	RII	Rank	Services	TS	RII
Provisioning services							
1	Fish provision	724	0.78	1	Fish provision	333	0.74
2	Timber collection	588	0.63	2	Crab provision	261	0.58
3	Crab provision	553	0.60	3	Firewood collection	226	0.50
4	NTFPs	524	0.56	4	Shrimp provision	222	0.49
5	Firewood collection	471	0.51	5	Timber collection	201	0.44
6	Shrimp provision	382	0.41	6	Water supply	140	0.31
7	Water supply	353	0.38	7	Fodder provision	108	0.24
8	Fodder	327	0.35				
9	Oyster provision	230	0.25				
Regulating services							
1	Climate regulation	652	0.70	1	Climate regulation	321	0.71
2	Natural Hazards control	448	0.48	2	Natural Hazards control	226	0.50
3	Erosion control	346	0.37				
4	Water purification	328	0.35				
Supporting services							
1	Biodiversity conservation	695	0.75	1	Biodiversity conservation	303	0.67
2	Nursing and spawning ground	651	0.70	2	Nutrient cycling	287	0.63
3	Nutrient	445	0.48	3	Nursing and	206	0.45

	cycling				spawning ground		
Cultural services							
1	Educational values	469	0.50	1	Aesthetic values	186	0.41
2	Spiritual and religious values	440	0.47	2	Educational values	174	0.38
3	Aesthetic values	395	0.42	3	Tourism, recreation and leisure	152	0.33
4	Social relationship	386	0.41				
5	Tourism, recreation and leisure	331	0.35				

TS = total score

Mangrove ecosystem services sustaining wellbeing and livelihoods of local communities in the MTBR.

Few respondents in Benin agreed that the current flow of provisioning services (41.84%) regulating services (34.23%) and cultural services (46.19%) sustains their livelihoods and wellbeing (Figure 3a). Contrariwise, 78.80% of them reported that the supply of supporting services contributes substantially to their wellbeing and livelihoods. In Togo, most of the respondents declared that they are not satisfied about the current rate of provisioning services (73.33%), supporting services (81.11%) regulating services (60%) and cultural services (74.44%) (Figure 4).

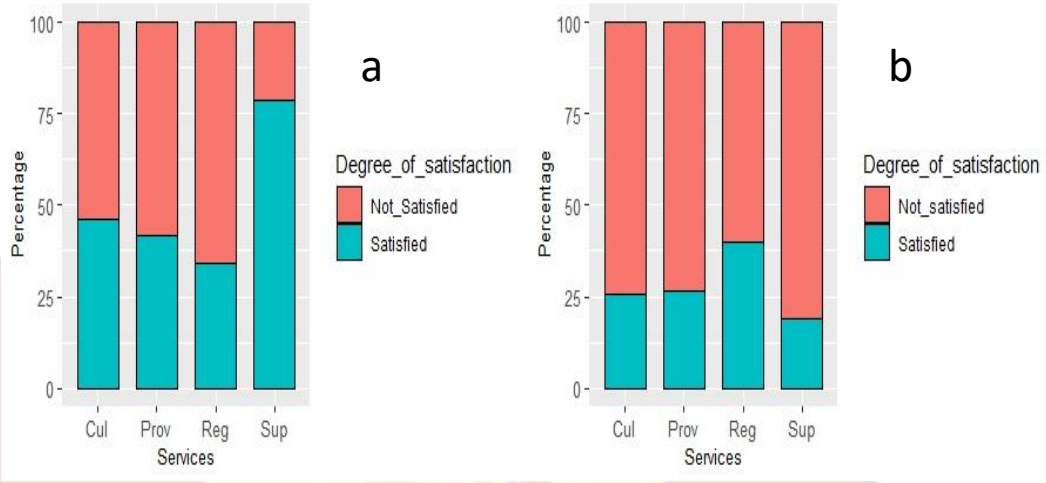

Figure 4: Perceived contribution of mangrove ES in sustaining peoples 'wellbeing and livelihoods.
Source: Field work, 2021

The results of the GLM model are presented in Table 9. In Benin, respondents' perception was influenced by all the predictors of the model such as age, sex, ethnic groups, activities, and level of education. Young householders had significantly low scores for cultural services ($\beta = -1.50$ & $P < 0.05$). This indicates that they are not satisfied with the current flow of cultural services, compared to the old and adult heads of household. Ethnic group, activity and level of education also influenced the respondents' perception. While the Xwlas were less satisfied with how cultural services sustain their wellbeing and livelihoods, ($\beta = -3.35$ & $P < 0.05$), respondents working in the fishing industry and those who had educational background were more satisfied ($\beta = 1.58$ & $P < 0.05$, $\beta = 1.19$ & $P < 0.05$). Unlike the age category, ethnic groups, activities and level of education, sex did not significantly affect respondents' perception on the flow cultural services sustaining their wellbeing. None of the factors significantly influenced respondents' perception about the delivery of regulating and the supporting services. However, age category, ethnic groups and activity were significant predictors

of the householders' perception on the flow of provisioning services. Male, fishermen, and salt producers were not satisfied about the supply of provisioning services (β = -1.63 & P< 0.01, β = -0.95 & P< 0.05, β = -2.09 & P< 0.05), whereas respondents belonging to Mina ethnic groups were more satisfied (β = 1.23 & P< 0.05). Furthermore, age category and level of education did not significantly affect respondents' perception in Benin.

In Togo, there were no significant effects of age, sex, ethnic groups, and level of education on the householders' perception on the provision of cultural services sustaining their wellbeing and livelihoods. Only their activities had significant effects. Respondents who are into farming were not satisfied (β = -0.39 & P< 0.05) with the flow of cultural services. Likewise, only the gender showed significant differences on respondents' perception on the delivery of provisioning services. Accordingly, men were less satisfied (β = -2.67 & P< 0.05) with the flow of provisioning services sustaining their wellbeing and livelihoods compared to women.

Table 9: Results of the GLM model

Factors	Provisioning	Supporting	Regulating	Cultural
Benin				
Intercept	0.83 (0.74)	-0.04 (0.86)	0.62 (0.71)	-0.64 (0.82)
Age (Old as reference level)				
Young	-0.30 (0.49)	0.71 (0.65)	0.33 (0.49)	-1.50 (0.63) **
Adults	0.40 (0.41)	0.66 (0.51)	0.09 (0.41)	-0.12 (0.45)
Gender (Female as reference level)				
Male	-1.63 (0.47) ***	0.28 (0.52)	-0.31 (0.44)	0.65 (0.50)
Ethnical groups (Fon as reference level)				
Mina	1.23 (0.57) **	1.41 (0.86)	0.20 (0.52)	-0.82 (0.57)
Xwedah	0.94 (0.53)	-0.67 (0.58)	-0.37 (0.49)	-0.50 (0.56)
Xwlah	A.88 (0.55)	-0.13 (0.59)	-0.63 (0.51)	-3.35 (0.67) ***
Activity (Artisans as reference level)				
Fishing industry	-0.95 (0.53) **	1.04 (0.52)	-0.59 (0.52)	1.58 (0.65) **
Mat weavers	-1.71 (0.92) *	1.97 (1.08)	-0.94 (0.82)	0.58 (1.05)
Petty traders	-1.37 (0.69)	1.58 (0.84)	-0.82 (0.66)	1.48 (0.77)
Salt producers	-2.09 (0.78) **	0.13 (0.82)	-1.64 (0.77)	0.06 (0.86)
Education (Primary as reference level)				
Secondary	0.23 (0.43)	0.89 (0.60)	-0.56 (0.43)	1.19 (0.52) **
No formal education	-0.72 (0.45)	-0.14 (0.52)	-0.22 (0.45)	0.19 (0.55)
Togo				
Intercept	-0.93 (1.23)	-2.19 (1.34)	-0.10 (0.90)	-1.31 (1.05)
Age (Adults as reference level)				
Young	0.79 (0.70)	-1.89 (1.11)	-0.38 (0.57)	0.04 (0.63)
Old	-0.66 (0.87)	0.75 (0.78)	0.45 (0.66)	-0.03 (0.74)
Gender (Female as reference level)				
Male	-2.67 (0.80) ***	0.06 (0.95)	-0.29 (0.61)	-0.48 (0.68)
Ethnical groups (Ewe as reference level)				
Mina	0.33 (0.72)	0.47 (0.79)	-0.24 (0.59)	-0.78 (0.65)
Ouatchi	-0.02 (0.74)	0.38 (0.91)	-0.42 (0.66)	-0.44 (0.70)
Activity (Artisans as reference level)				
Farming	1.39 (1.02)	-0.62 (1.04)	-1.21 (0.70)	-0.39 (0.78) **
Fishing industry	2.17 (1.22)	0.37 (1.03)	-0.27 (0.80)	0.54 (0.91)
Petty traders	0.66 (0.98)	1.20 (1.17)	0.15 (0.77)	0.16 (0.86)
Education (Primary as reference level)				
Secondary	-0.26 (0.66)	0.47 (0.74)	0.76 (0.57)	1.44 (0.69)
No formal education	-0.88 (0.74)	-0.15 (0.82)	0.47 (0.64)	1.00 (0.77)

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$, coefficient estimate (standard error)

Anthropogenic stressors to mangroves in the MTBR

Discussions with the participants of the qualitative phase enabled to identify the anthropogenic stressors which cause mangroves degradation in the study area. In total, 6 threats including IUU, fire outbreak, pollution, overharvesting, mangroves clearing and change in water salinity were reported in Benin whereas 7 threats including IUU, overharvesting, mangrove clearing, change in water salinity, pollution, livestock, and invasive species were cited in Togo. The spatial distribution of the threats is presented in Plate 5. It indicated that IUU prevails in the two sites both in Benin and in Togo. Moreover, key informants investigated for this study reported the use of prohibited fishing gears in the study villages.

Plate 5: (a) Small mesh size used in mangroves, (b) *Acadja* installed within mangroves
Source: Field work, 2021

Regarding the exploitation of mangroves, they are increasingly collected in the study communities for two main uses. They include collection for commercial purposes and also for domestic uses. Data collected from the field showed that salt producers collect mostly mangroves wood from for salt

production, particularly *R. rasemosa*. This same species is also important for house construction because of their resistance to insects and hardness.

Mangroves are also used in the study areas for firewood (Plate 6). Owing to the large preference of mangrove woods for multiple uses in the study villages, many respondents have shown keen interest in the selling of mangrove woods, in the breaching of the legal instruments that govern mangroves use in the two countries. Respondents who are into mangroves selling reported that they collect mangrove species far from the bank of the river. They indicated that mangroves situated in their plots of land belong to them and can be collected without any approval.

Plate 6: *R. racemosa* harvested in Djeta, Togo (a) and Avloh, Benin (b)
Source: Field work, 2021

Mangroves clearing was also reported in both sites. In Benin, mangroves clearing happen for aquaculture development, farming, and salt production (Plate 7). Participants of the qualitative phase recognized that mangroves are mainly cleared for sugarcane growing or salt production. In Togo, participants acknowledged the systematic removal of mangroves to protect their family against the wild animals like snakes, crocodiles, and lizards.

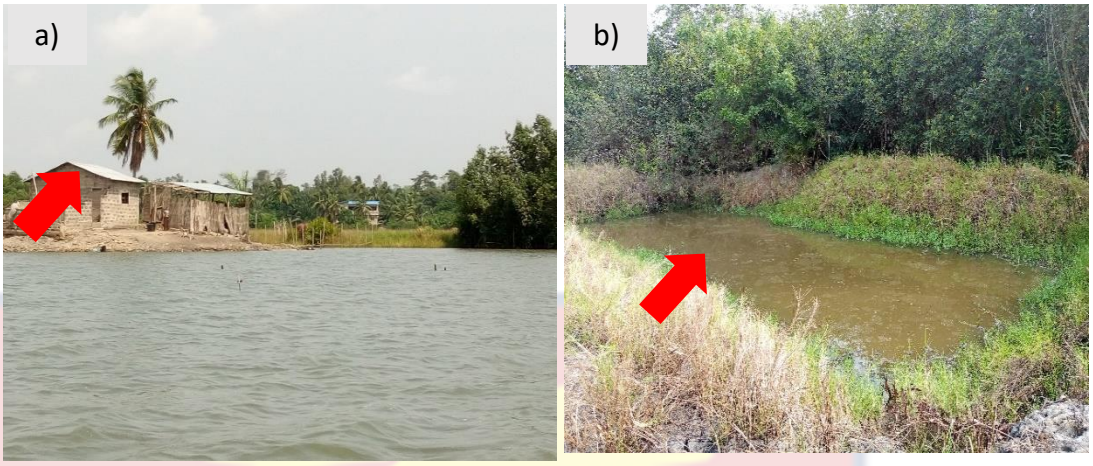

Plate 7: Mangroves cleared for house construction (a) and aquaculture development (b) within the reserve in Benin.
Source: Field work, 2021

Fire outbreak was another threat recorded from the field (Plate 8). It was recorded only in Benin, particularly during the dry season. Participants of the qualitative phase unveiled that fire is generally set around mangroves during dry season for hunting purposes. Other key informants narrated that they set fire to prepare land for vegetable growing or coastal cultivation. They also set fire when mangrove areas are bushy enough to endanger the local populations. Fire set generally reach mangroves and destroy the habitat.

Plate 8: Mangrove habitats destroyed by fire within the reserve in Benin.
Source: Field work, 2021

Pollution of mangrove ecosystems and change in water salinity were also reported as threats which impede the development of mangroves in the study area. They were identified both in Benin and Togo and were attributed

to manmade actions. Livestock also poses severe threat to mangroves in the study area but was recorded only in Togo.

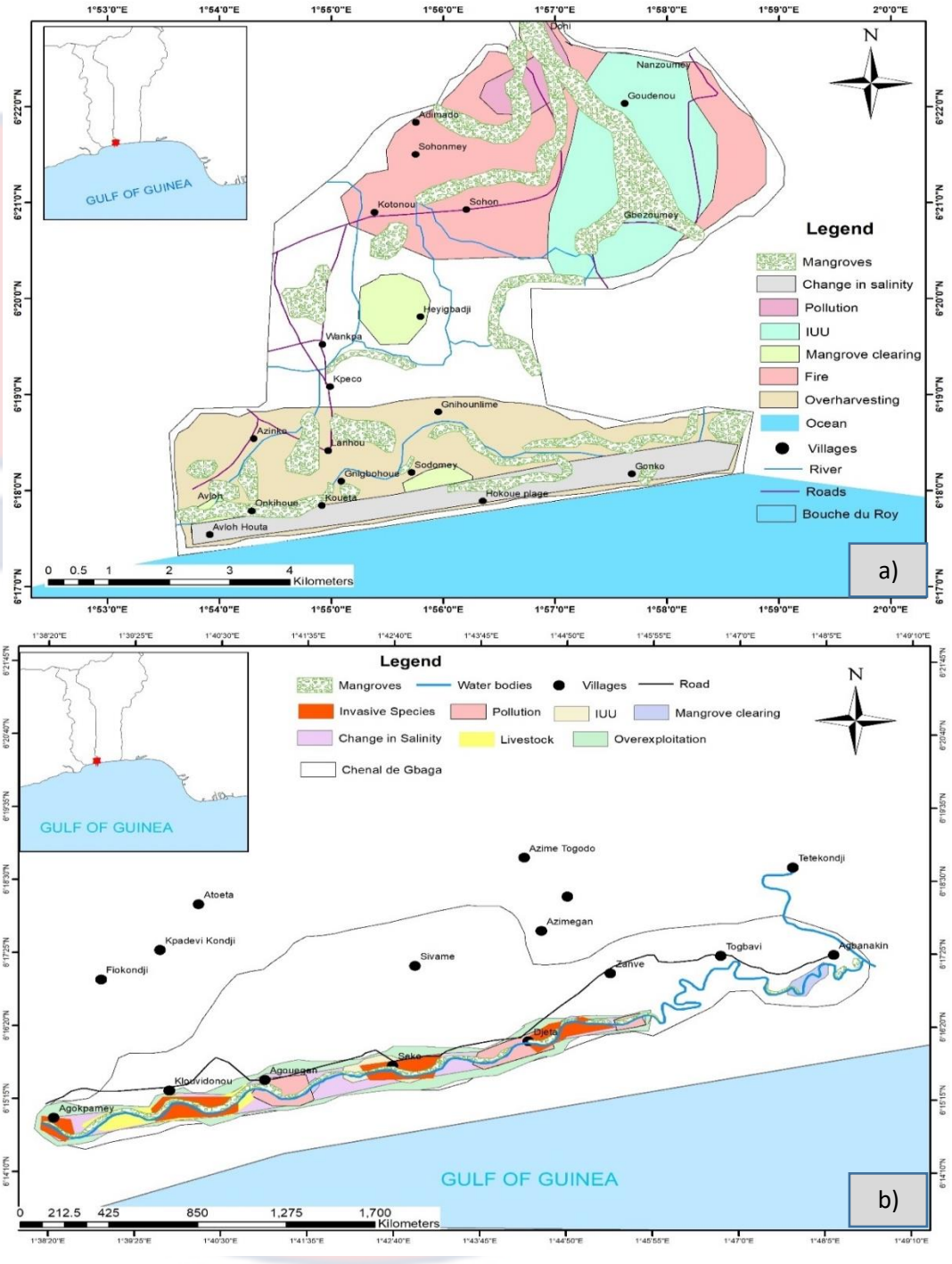

Figure 5: Spatial distribution of the identified stressors in Benin (a) and Togo (b)

Perceived drivers of the stressors

Table 10 summarizes the perceived drivers of the recorded stressors in the study sites. In Benin, informants associated the change in water salinity and the pollution to coastal urbanization, especially to the construction of the Nagbeto dam. Indeed, the Mono River which is connected to mangroves in the reserve is dammed at Nagbeto in Togo in order to supply electricity to the local population in the two countries. Informants engaged in Benin explained that the frequent freshwater release from the dam results in the modification of the water salinity, impeding the regeneration process of mangroves in the area. Regarding the pollution, it was strongly associated with poor waste management policy, lack of public toilets and coastal cultivation. In some parts of the reserve, sewage is channelled in the mangroves. This is further compounded by open defecation as well as solid waste disposal around mangroves, leading mangrove pollution.

On the other hand, IUU, mangrove clearing, and mangrove overharvesting and fire were predominantly related to population growth, high unemployment rate, unplanned land use and weak enforcement of coastal-related legal instruments. Village leaders and traditional authorities recounted that some community members build their houses within the buffer zones of mangroves and set fire sometimes to avoid snakes and other reptiles. The trends remain almost the same in Togo where key informants also associated invasive species and changes in water salinity to the damming of the river, the high rate of unemployment and inadequate awareness.

Table 10: 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
Fire	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

Investigating the risks posed by the recorded threats to mangrove ES in the study area

Cumulative risk posed by all the stressors.

Results of the HRA model showed that the cumulative risk of all the threats put together did not exceed the threshold of 1.86 for the habitat-stressor combinations. The value of the cumulative risk recorded in Benin was 0.48 whereas the one recorded in Togo was 0.89. This indicates that the combined effect of all the stressors results in low risk for mangroves in Benin and low to medium risk for mangroves in Togo. This was more explained by Figure 15 which shows the maps of the habitat risks for the two sites. The maps indicates that all the mangroves in Benin (100%) are under low risks whereas those in Togo are under low to medium risk (Figures 15 a and b).

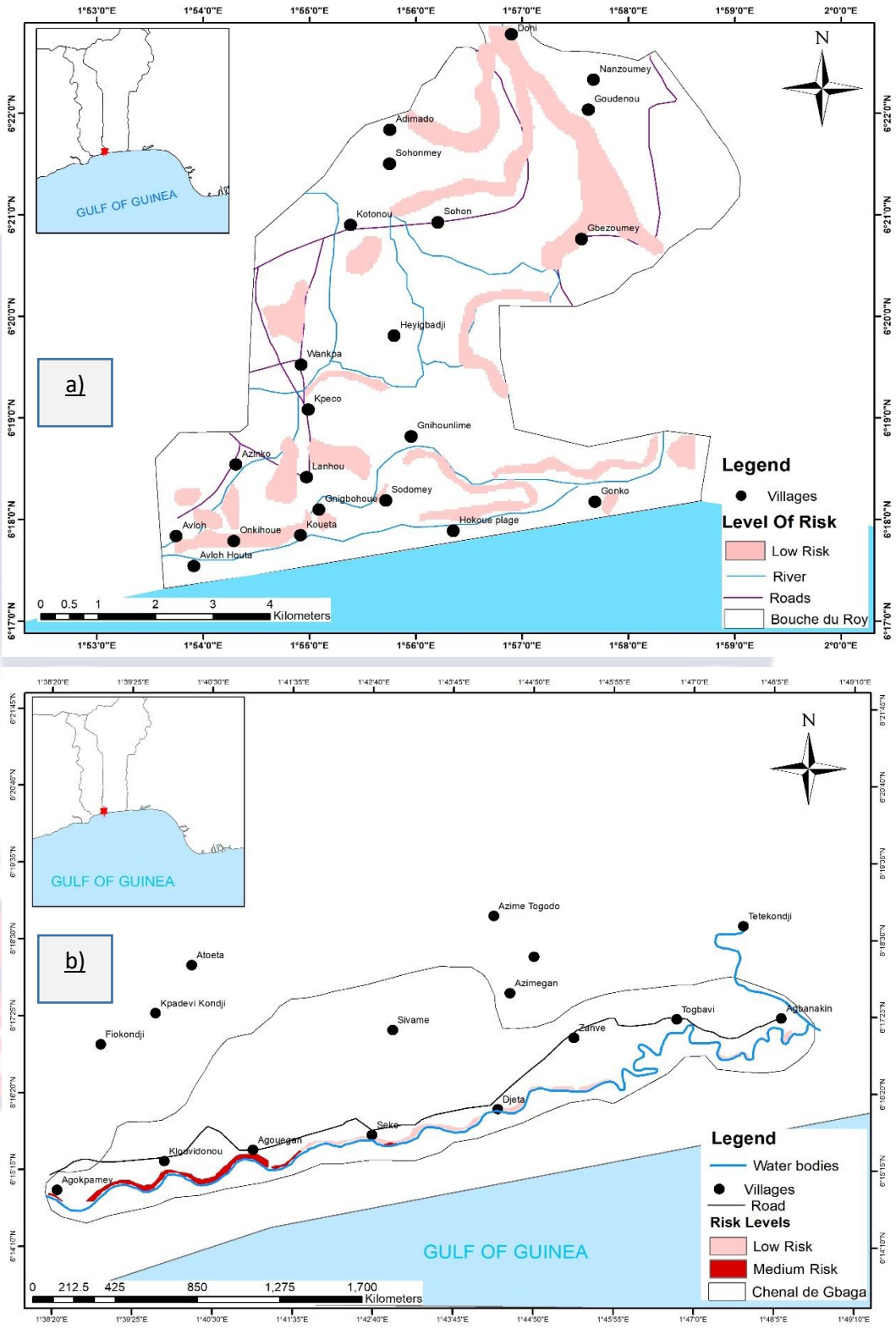

Figure 6: Habitat-specific cumulative risks from all stressors in Benin (a) and Togo (b)

Individual risk posed by each threat to mangroves.

Table 11 presents the individual risk posed by each threat to mangroves in the study villages. It shows that in Benin, change in water salinity and mangrove pollution resulted in low risk for mangroves, with a mean risk score of 0.33 and 0.06 respectively. However, IUU, mangrove clearing, and fire resulted in 19.37%, 6.20% and 41.86% of medium risk and in 80.62%, 93.79% and 58.13% of low risk respectively, with a mean risk score of 0.43, 0.17 and 0.8 respectively. As for the overharvesting, it has resulted in low risk for 58.13% of mangrove and high risk for 41.86% of mangroves respectively, with a mean risk score of 106.

In Togo, threats recorded were more devastating than Benin. The results of the model showed that change in water salinity, mangroves pollution, invasive species and livestock resulted in medium risk to 82%, 30%, 34% and 24% of mangroves and in low risk to 18%, 70%, 66% and 76% of mangroves respectively, with a mean risk score of 1.28, 0.58, 0.85 and 0.52. Concerning IUU, mangroves clearing, and mangroves overharvesting, they presented a mean risk score of 0.30, 0.67 and 2.05 respectively. Moreover, IUU and mangroves clearing resulted in high risk for 12% and 20% of mangroves and in low risk for 88% and 80% of mangroves respectively (Table 12).

Table 11: Risk posed by the stressors to mangroves in the study sites

	Benin				Togo			
Stressors	R_mean	R_High	R_medium	R_Low	R_mean	R_High	R_medium	R_Low
Change in water salinity	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
Overharvesting	1.06	41.86	0	58.13	2.05	82	0	18
Pollution	0.06	0	0	100	0.58	0	30	70
Fire	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

Source: Output of the InVEST HRA (Version 3.9.0.)

CHAPTER FIVE

DISCUSSION

Diversity of mangrove ES in the MTBR

This study shows the large range of services supplied by mangrove ecosystems to coastal dwellers in the MTBR. This is well illustrated by the large number of services listed by respondents in the two countries (fifteen in Togo and twenty-one in Benin). Mangrove ecosystem services mentioned by local respondents and reported in this study are similar to those enumerated by many other studies (Grabowski et al. 2012; Ghaley et al. 2013; Awuor et al. 2019) with a slight difference in nomenclature. However, the services reported in this study when we consider the two study sites outnumber the ones reported by Reyes-arroyo et al. (2021) and Nyangoko et al. (2021) who documented mangrove ecosystem services in Mexico and Tanzania respectively. Reyes-arroyo et al. (2021) reported 31 services whereas Nyangoko et al. (2021) documented 16 services. Information collected from the field showed that some ecosystem services were less or not mentioned. For example, no FDG participant or key informant reported beekeeping.

Participants in all villages stated they have never seen beekeeping in the mangroves of their vicinities. However, one respondent stated during the quantitative phase of the study that he is into mangrove-based beekeeping at *Avlo,* Benin. Trained and equipped by an NGO, he explained that he is the only one engaged in mangrove-based honey production in the reserve as his other trained colleagues stopped practicing because they deemed it difficult and are afraid of bee sting. Participants in *Avlo* failed to mention beekeeping as mangrove ES during the FGDs and IDIs since most people are not aware of

the activity in their villages because of the lack of interest. As the service is unknown by the general public and is being carried out just in one village, it was not considered for the ranking exercise because of its potential to generate biases as it will be difficult for many respondents to score it.

Services like *Cyperus articulatus*, medicinal plant collection and other important NTFPs cited in Benin were not mentioned in Togo. This illustrates a difference in the use of medicinal plants coming from mangroves in Togo. knowledge about the medicinal use of mangroves in Togo, probably coming from the total removal of mangroves from the Togolese site years ago. Also, the large collection of *C. articulatus* in Benin for mat fabrication are not reported in Togo. It may also be possible that local communities investigated in Togo are not into mat weaving (Guelly et al. 2020), hence not interested in the species. Interviewees were able to easily identify most of the provision services than the regulating, supporting and cultural ones. This corroborates many authors including Mensah et al. (2017) and Nyangoko et al. (2021), who indicated the easiness to identify provisioning services than the other services because of their importance in providing source of income to local populations. Unlike in Togo, many patches of mangroves are protected by the local deity called *zangbéto* in Benin. It practice is reportedly taken from the grandfathers of the current occupant of the study villages and helps to prevent mangrove degradation (Zanvo et al. 2021). Failure to implement this practice in Togo would have accounted for large degradation of mangroves noted in this side of the reserve.

Rate of provision of mangrove ES in the MTBR

Results of this study indicated that mangroves deliver more provisioning services than the other services. This shows that people highly depend on provisioning services in the study area. As for the subservices, fish provision is mostly cited in the two countries than the other subservice. Respondents in the two study sites reported that they mostly collect fish from mangroves. Fish species collected from mangroves are used both for consumption and commercialisation. This justified the high scoring of fish collection in the two countries. This observation corroborates Gnansounou et al. (2021) who identified fishing as the most practiced activity in the reserve. Firewood collection and timber collection are two other provisioning services highly scored in the communities. Albeit banned in the study communities, local populations in the MTBR continue to collect mangrove woods for domestic uses. This shows the weak law enforcement of the institutional arrangements which regulate mangrove uses in the reserve (Adanguidi et al. 2020; Fousseni et al. 2020). NTFPs collected from mangroves were highly ranked in Benin because of economic importance of the species *Cyperus articulatus* It is significant for coastal dwellers, particularly with the advent of Covid-19 crisis, and is used as alternative livelihood for fishermen since their activities are affected by the pandemic as the case in Ghana (Okyere et al. 2020).

Water supply was also ranked high because populations of the investigated villages use water from mangroves for their basic needs (bathing and dish washing), particularly between Jun and September. Conversely, Oyster has become rare in the study community. The species was not reported

in Togo and was only cited just in NAnzounmey and Gbezounmey in Benin. Also, the species represented the least ranked provisioning service in Benin. This concurs with Adite et al. (2013) who has already highlighted the rarity of the species in Benin.

Biodiversity conservation represented the mostly ranked supporting services both in Benin and in Togo. Many plants, fishes, birds, reptiles, and primates found in mangroves were cited by the populations in their local languages. They also indicated the presence of migratory birds in many villages. This high biodiversity conservation maybe due to the establishment of the ornithological sites in Agokpamey and Avlo. These sites were established by the GIZ to increase the conservation of plant and fish species (GIZ 2018). The high biodiversity in the reserve has already been reported by Gnansounou et al. (2021) who identified 15 plant species, 23 fish species, 2 shrimp species, 2 crab species and 1 oyster species in mangroves in the reserve.

The cultural services identified in Benin outnumber the ones reported in Togo. For example, services like “social relationship” and “spiritual and religious values” reported in Benin were not cited in Togo. These services are controlled by local deities and are absent in Togo because they do not use traditional beliefs to conserve their mangroves. “Educational values” is the mostly reported cultural service in Benin. This entails the increasing research and educational actions being done on mangroves in Benin and aligns with Teka et al. (2018) who reported the keen attention received by mangroves for education, learning and experiments over the past decade. However, tourism and recreational activities were less cited in the two countries. This maybe as a

result of the few numbers of qualified tour guides and the lack of equipment to operate.

Mangrove ES sustaining peoples' livelihood and wellbeing in the MTBR

Young heads of household interviewed in Benin were not satified about how the current flow of cultural services sustain their wellbeing and livelihoods. This is because of the underdevelopment of ecotourism in the area. This is in accordance with Sinsin et al. (2018) who has already noted the less development of mangrove-based ecotourism in the study area. Likewise, *Xwlahs* are less satisfied with the current rate of provision of cultural services. In comparison with the other ethnic groups investigated in Benin, Xwlahs and Xwedahs are mostly into traditional religion. As a result, the ongoing mangroves degradation in some part of the reserve impact their cultural attributes as some sacred mangroves forests and convents are being encroached upon for farming purposes (Adjonou et al. 2020). People into salt production were also not satisfied with the provisioning services. This is because mangrove cutting is formally banned in the reserve.

Like mentioned in Benin, men in Togo were not satisfied with the rate of supply of the provisioning services. This may be explained by the decrease of fish stock in mangroves in the study villages as already reported by Guelly et al. (2020).

Major anthropogenic threats to mangroves and their impacts on ES provision

The threats identified in by this study are similar to the ones cited by Nortey et al. (2016) and Aheto et al. (2016) who reported threats to mangroves in West Africa. The HRA model positioned mangrove overharvesting as the

topmost threat in the study sites. Although a lot of sensitizations are being conducted in the study area, residents continue to harvest mangroves. This has been already indicated by many research works conducted in the reserve, mainly in Benin (Adanguidi et al. 2020; Zanvo et al. 2021) has the potential to compromise the capacity of mangroves to provide services, particularly the provisioning services. Warren-Rhodes et al. (2011) reported that the overharvesting of mangrove species has the potential of affecting their density and structure and hindering their ability to supply some key services like biodiversity conservation. The high dependence of people to mangroves raised the concern of the lack of alternative livelihood in the study communities (Kasso et al. 2008).

IUU is part of the mostly devastating activities to mangroves. Practices like juvenile fish collection known in Benin as *gbagbaloulou*, pack of branches installed in the water body and used to attract and harvest fish (known in Benin as *Acadja)* and fish harvesting in mangroves using bare hands after cutting mangroves' prop roots (known in Benin as *Alohè*) are still occurring in mangroves in Benin. This has the potential of affecting the natural replenishment of the fish stock in the area and exacerbating the already collapsed fishing activity in the reserve as demonstrated by Jones et al. (2010). The participatory mapping revealed that mangroves are still being intensely cut in the two study sites. This may source from the intensification of fishing activities in the reserve. Indeed, the processing of the fish harvested demands a high quantity of firewood, resulting in mangroves overexploitation.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary

The MTBR is a transboundary protected area shared by two West African countries: Benin and Togo. The reserve was created in 2017 to help protect the inland and coastal resources embedded in the Mono Delta, a transboundary river which serve as the natural border between the two countries. It is a combination of many protected sites, subjected to a co-management regime. The coastal resources of the reserve include mangroves, coastal lagoons, salt marshes, the marine environment, and coastal wetlands. These resources provide a lot of benefits to residents who exploit them in various ways in order to sustain their wellbeing and livelihoods. The increase in human population in the reserve coupled with the impacts of climate change have resulted in the degradation of resources, requiring critical attention and robust management to curb further destruction.

Earlier studies widely documented the overexploitation of mangrove resources, with high anthropogenic pressures on *Rhizophora racemosa* and *Avicennia germinans*. Research works that focused on the reserve after its establishment have all indicated the large degradation of mangroves in the reserve. This drew the attention of many international stakeholders including the World Bank and GIZ to undertake some projects for the successful conservation of mangroves in the reserve.

This is exemplified by the WACCA project being currently carried out in the reserve and which aimed at restoring and conserving mangroves in the reserve. Most studies worldwide advocate the assessment of ES before

designing and implementing a conservation scheme for a sustainable use of forest ecosystems, particularly those located at the coast. Thus, this study assessed the ES delivered by mangroves to local populations in the MTBR. The study was carried out in two protected sites of the reserve: LBR in Benin and LCG in Togo. Data collection followed the exploratory sequential mixed methods, drawing evidence from qualitative and quantitative primary information.

Results of this study showed that mangroves deliver many services. A total of 21 services were reported in Benin whereas 15 were cited in Togo. Provisioning services were mostly scored in the two study sites, followed by the supporting services, regulating services and cultural services. Six manmade threats were including pollution, overharvesting, fire, mangrove clearing and change in water salinity were reported in Benin whereas seven threats namely mangroves clearing, overharvesting, change in water salinity, pollution, livestock, IUU and invasive species were reported in Togo. The cumulative effect of the recorded threats resulted in a low risk of the entire surface of mangroves in Benin (100%). Conversely, 42% of mangroves in Togo were under low risk whereas 58% were under medium risk. Mangroves overharvesting and fire represent the more detrimental threats to mangroves in Benin, whereas IUU, mangrove clearing, and mangroves overexploitation are more destructive to mangroves in Togo.

Conclusion

Information provided by the work is paramount for effective mangrove conservation in the reserve. The ranking of the services helped to understand that some crucial services like ecotourism need to be promoted for the

betterment of the local communities. There is a large difference in knowledge across the two study sites. Local residents in Benin understand and know much about mangrove ES than their Togolese counterparts. This is evidenced by the total number of services listed by the interviewees in each country. The study further documented the anthropogenic threats that largely cause mangrove degradation and mangrove ES depletion in the area. While stressors like mangrove clearing, IUU or mangrove overexploitation have been largely documented in the reserve, anthropogenic threats such as fire or livestock which have remained undocumented for long were mentioned in this study. This will undoubtably inform decision making for subsequent action.

Threats recorded are considered critical to mangrove development with severe implications on the services they provide. Surprisingly, the cumulative effect of the stressors showed no harm to mangrove ES in the study sites given the risk that they pose to mangrove (low risk in Benin and low to medium risk in Togo). But taken individually, some stressors like mangrove overexploitation, IUU or mangrove clearing put mangroves under high risk and need to be addressed as a matter of urgency.

Recommendations

For Policy management

Although some efforts are being made for mangroves conservation in the reserve, some anthropogenic threats continue to undermine the conservation of mangroves in the MTBR. This is therefore needed to deal with these threats with immediate effect to prevent more damages to the ecosystem. Awareness creation is also important to stop the large pressure on mangroves in the study communities. Apart from beekeeping and ecotourism, other

sources of livelihoods need to be created in the reserve to alleviate the poverty of local populations. Initiatives such as aquaculture, snail rearing, animal breeding and crops farming can be implemented. The surveys indicated that provisioning services are more delivered than the other categories of services. It is essential to monitor provisioning services that obtained high scores to make sure they are being sustainably collected.

For Further studies

Observations from the fields indicated that the overharvesting of mangroves is occurring in alarming proportion in the reserve. Research on the cooking fuels is important to propose affordable fuel sources to residents. Some environmentally unfriendly fishing techniques continue to degrade mangrove ecosystems. A study on livelihood options is therefore essential to understand the preferred alternative livelihoods of local populations for conservation actions.

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APPENDICES

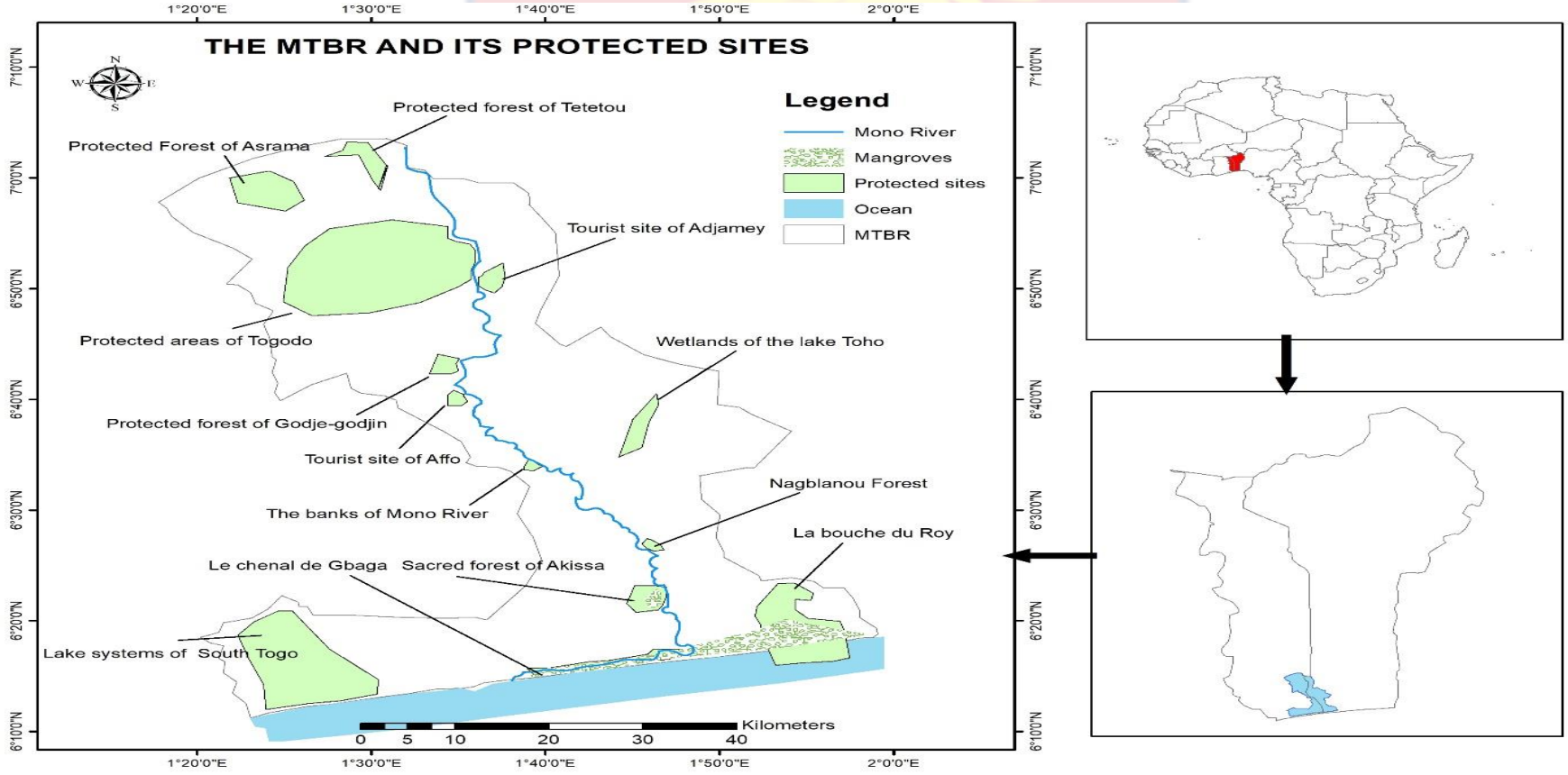

Figure 7: The Mono Transboundary Biosphere Reserve and its protected sites