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Local uses of mangroves and perceived impacts of their degradation in Grand-Popo municipality, a hotspot of mangroves in Benin, West Africa

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ABSTRACT

Detailed understanding of interactions between humans and their surrounding ecosystems is essential for designing sustainable use and management of these ecosystems. Mangroves are one of the most productive ecosystems worldwide, yet amongst the most threatened. This study (1) explored main activities of local communities in relationship to mangroves and variation across geographical locations, gender, and age categories, (2) investigated plants and animals used and collected from mangroves and their adjacent areas, and (3) assessed local perception on the impacts of their activities on the degradation of mangroves and potential effects of this degradation on their life attributes (security, income, health and culture). The study was conducted in Grand-Popo municipality, a hotspot of mangroves and the only one coastal municipality embedded in the Mono Transboundary Biosphere Reserve in Benin. Data were collected through individual interviews ($n = 360$) in nine villages of the municipality. Results showed that local communities of Grand-Popo practice nine income generating activities (IGA) within mangroves and fishing (31.65%), wood collection (22.73%), *Cyperus articulatus* collection (21.67%), medicinal plant collection (8.98%), and salt production (5.56%) were frequent. There were important differences across geographical locations, gender, and age categories with regard to used mangrove resources and socio-economic activities. Respondents reported twenty-three fish species, two shrimp species, two crab species and one oyster species as fishery resources commonly collected from mangroves. Most interviewees (58.33%) believed that their activities do not negatively impact mangroves despite popular recognition of the dwindling of mangroves' coverage (75% of respondents). Our findings provide important information on resources collected and used in mangrove ecosystems and highlight strong geographical locations, gender, and age categories variation. Implications for sustainable participative management were discussed.

1. Introduction

Mangroves are considered as evolutionary hotspots where terrestrial species have re-adapted to marine life, and marine species have undergone the transition to terrestrial species (Ajonina et al., 2014). As forest ecosystems, mangroves provide an array of ecosystem services (provisioning services, supporting services, regulating services and cultural services), thus supporting the livelihood of millions of people worldwide (Cannicci et al., 2008). They provide shelters for most fish inhabiting the coastal zones (Thayer et al., 1987) and serve as nursery grounds for many animal and plant species. Fishery success in many tropical coastal zones therefore largely depends on mangrove health because of the spawning and nursery grounds they offer for most species (Valiela et al., 2001). Due to the important downfall of litter, mangroves are amongst the most productive ecosystems worldwide (Alongi, 2002). Mangroves also play pivotal role in carbon storage and sequestration and hence in climate change mitigation (Alongi, 2002). Therefore, mangroves represent an important coastal resource, which is vital to the livelihood of local communities (Teka et al., 2019). Despite the aforementioned important roles, mangrove forests are facing severe decline globally (Alongi, 2002). According to Walters et al. (2008), worldwide, mangroves have lost 0.66% of their areas per year from 1985 to 2005. The rate of mangrove deforestation is high in many developing countries (Duke et al., 2007; Giri et al., 2007). The causes of such losses

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include not only human activities such as coastal land-use development (Nfotabong-Atheull et al., 2009), expanding agriculture, overexploitation, and other human-related drivers such as pollution (Hossain et al., 2009; Adite et al., 2013) but also natural hazards such as sea-level rise resulting from climate change-induced ice melting (Di Nitto et al., 2008; Mukherjee et al., 2010), tsunamis (Barbier et al., 2011), etc. While natural hazards can be difficult to control, detailed knowledge on human activities in mangroves and their subsequent management can help to curtail human impacts on mangrove ecosystems.

In Benin, mangrove ecosystems are mainly found in the municipality of Grand-Popo (Ajonina et al., 2014). The municipality is one of the hotspots of mangroves in Benin. Its mangrove coverage accounts for about 50% of mangrove coverage of the country (Sinsin et al., 2018). Moreover, the municipality is part of the newly created Mono Transboundary Biosphere Reserve where efforts are being put by national and international stakeholders for an effective conservation and sustainable management of coastal resources including mangroves.

Research activities on mangroves in Benin, particularly in the municipality of Grand-Popo are relatively recent and several aspects are still uncovered. Adite et al. (2013) described fish assemblages in degraded mangrove ecosystems, while Ajonina et al. (2014) established the carbon budget. Teka et al. (2019) reported six main uses of mangroves in the region, namely fuelwood, timber/wood for construction, forage, salt production, medicinal uses and fisheries. The authors also found that the medicinal uses, fisheries and fodder were the main uses in Grand-Popo municipality. They also reported differential uses across gender, age categories, and ethnic groups. Dossou-Yovo et al. (2017) conducted an ethnobotanical survey on mangrove plant species used as medicine and found that malaria was ranked as the most important disease for which mangrove plant species are used. While information on uses of mangroves by local people are important to understand the importance of mangroves, detailed knowledge on the activities practiced by local people in mangrove ecosystems, especially its geographical variation can provide additional insights on potential threats to the ecosystem. Also, assessing the uses of mangroves based on main use categories as in Teka et al. (2019) does not provide enough details at species level to well understand which species are mainly used, for what purposes and which potential risk it may undergo if the use is uncontrolled or not regulated. Yet this information is essential to engage sustainable management actions at species level. Furthermore, local people are aware of mangroves degradation and the need to restore and sustainably manage the ecosystem (Teka et al., 2019). However, perceived potential impacts of mangrove degradation on their life attributes (security, income, health, and culture) have seldom been evaluated, despite their importance for the wellbeing of coastal dwellers (MEA, 2005). The overall aim of this study was to assess the relationships between local communities and mangroves in Grand-Popo municipality. Specifically, the study aimed at (1) exploring the main activities of local communities in relationships to mangroves and its variation across geographical locations, gender, and age categories, (2) investigating plants and animals collected and used from mangroves and adjacent areas, and (3) assessing local perception on the impacts of their activities on the degradation of mangroves and potential effects of this degradation on their life (security, income, health and culture).

2. Materials and methods

2.1. Study area

The study area is the municipality of Grand-Popo, Republic of Benin (Fig. 1). This municipality is part of the coastal area of Benin with a population of 57,636 people (INSAE, 2016). Over three million of people inhabit the coastal zone of Benin (INSAE, 2016). The Municipality of Grand-Popo is also part of the newly created Mono Transboundary Biosphere Reserve extended between Benin and Togo (Adjonou et al., 2020). The littoral is in the sub-humid tropical climate zone and characterized by two rainy seasons from April to July and October to November, and two dry seasons, from August to September and December to March. The annual precipitation ranges from 820 to 1300 mm and the annual average temperature is about 33 °C. The most significant soil types are sandy soils, hydromorphic soils, and ferralitic soils. Vegetation includes savanna of *Elaeis guinneensis* and *Borasus aethiopum*. Other tree species as *Mitragyna inermis, Adonsonia digitata, Ceiba pentandra, Milicia escelsa* can also be found (Adanguidi et al., 2020). Furthermore, inside mangroves (lagoon and marshy zones), soils are alluvial and hydromorphic with a vegetation dominated by an herbaceous formation and species like *Rhizophora racemosa* and *Avicennia germinans*. The lagoon of Grand-Popo long of 15 km which gives access to Aho channel, receives marine waters from the Atlantic Ocean and freshwater from the Mono River and communicates with the lagoon of Ouidah. The history of Grand-Popo's population turns around its main ethnic groups which are Xwlas, Xwédas and Minas. Xwlas are the main ethnic groups and can be found everywhere in the municipality. They represent over 51% of the total population of the municipality (INSAE, 2016). Xwéda and Mina are less numerous than Xwla and have colonized respectively the districts of Gbéhoué and Agoué. Apart from these dominant groups, other ethnic groups are present in the municipality of Grand-Popo. They include Watchis, Sahouès, Fons, Adjas, Kotafons, Aïzos, Haoussas, Yorubas, Peuhls etc. The main activity of Grand-Popo's population is fishing. However, as a result of the dwindling of fish catch in the municipality (Lederoun et al., 2015) many fishermen are progressively converting into farming activities, namely market gardening. The municipality of Grand-Popo is actually one of the main places of market gardening, supplying many urban areas in vegetables in Benin (Atidegla et al., 2017). Local trade and tourism are other expanding activities in the municipality because of the increasing number of tourists interested in the municipality's natural and historic monuments. Women play also an instrumental role in the development of the municipality. They participate in some fishing-related activities (crab and oyster collection) and are involved in trading and other income generating activities. Their priorities are the transformation and the commercialization of aquatic products, artisanal salt production, vegetable growing, mat fabrication etc. (INSAE, 2016).

2.2. Sampling

Data were collected between June and December 2016. Villages considered for the study were selected based on field reconnaissance conducted throughout the municipality and meetings held with the local authorities, particularly the District Chief Executives (DCE). Our primary observations indicated that mangroves were well represented, and contribute to people's livelihoods in three districts (Grand-Popo Centre, Avlo and Agoué), but absent in two districts (Djanglamè and Sazué). Nine villages were then selected in the three districts where mangrove occur, namely the districts of Grand-Popo-Centre (Gbèkon, Hêvê and Gbèfa), Avlo (Houéta, Avlo Centre and Azinko) and Agoué (Zogbédji, Agoué Centre and Hillacondji). They were selected at the beginning; at the middle and at the end of each district using the map of the municipality.

The sample size was calculated per village. Prior to the calculation, fifty respondents were randomly selected from the local population of each village. The fifty persons per village were only asked whether they have been collecting any resource from mangrove or using mangrove habitats for the sake of making money, self-consumption or any other uses in order to determine the proportion p of people who directly use mangroves. The sample size was then determined for each village based on the following formula (see Mensah et al., 2017)

$$n = \frac{U^2_{1-\alpha/2}}{d^2} \times p(1-p)$$

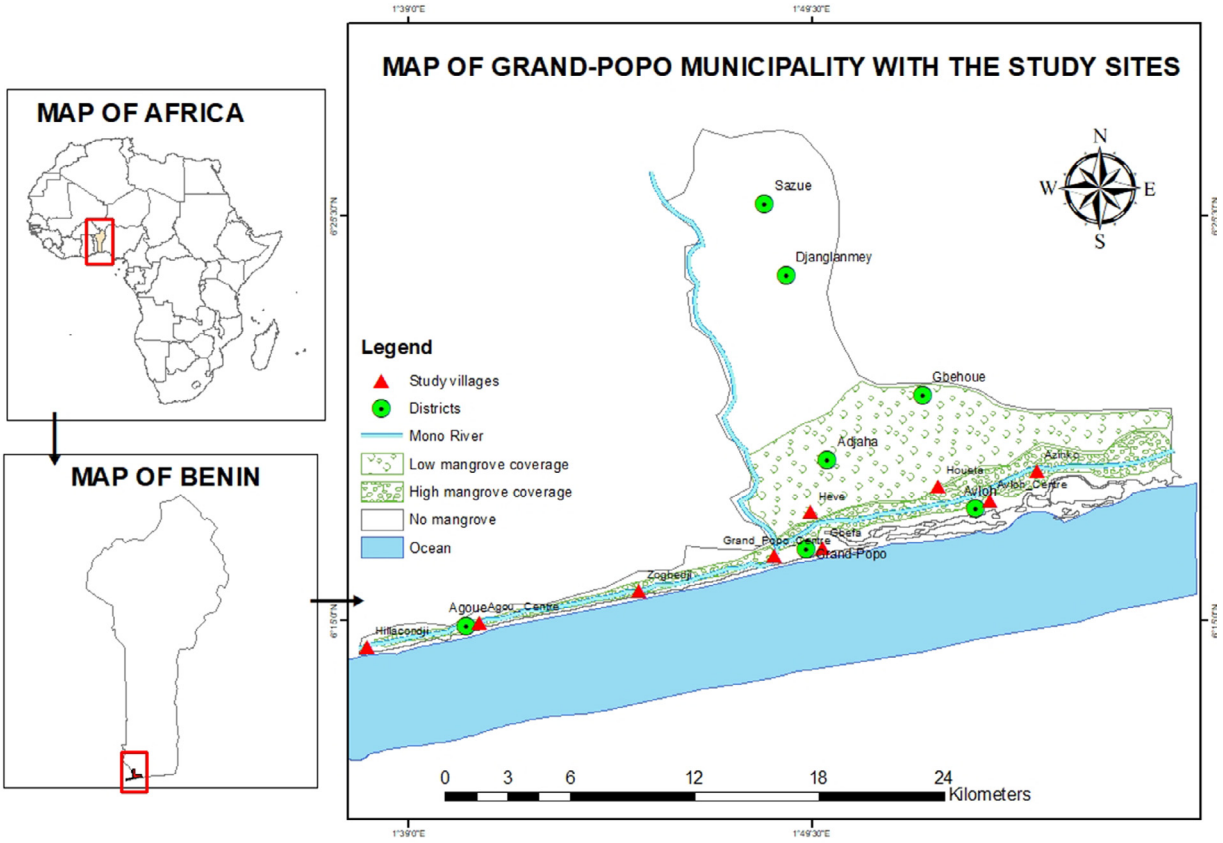

Fig. 1. Map of the Municipality of Grand-Popo with the study sites (Benin).

In the formula, n is the estimates sample size, U is the value of the normal random variable (1.96 for α=0.05) and d, the authorized margin error from the survey, and taken to be 9%.

A total of 360 respondents were surveyed in the nine villages including 66 respondents at Avlo Centre (p = 0.842%), 45 respondents at Houéta (p = 0.898), 36 respondents at Azinko (p = 0.921), 27 respondents at Hillacondji (p = 0.938), 45 respondents at Zogbedji (p = 0.898), 27 respondents at Agoué Centre (p = 0.938), 36 respondents at Gbèkon (p = 0.921), 45 respondents at Hêvê (p = 0.898) and 33 respondents at Gbèfa (p = 0.929). The sample considered for this study comprised five ethnic groups namely Xwlas (57.78%), Xwédas (5.83%), Minas (10.28%), Sahouès (6.94%), Adjas (4.72%) and Watchis (14.45%). More than half of the respondents were men (59%) whereas women represented 41% of the interviewees.

2.3. Data collection and mangrove resources identification

Data collection protocols commenced with community-entry meetings with the head of village and traditional leaders of each selected village. The meetings paved the way for the research team to undertake field activities. After receiving approval from local and traditional authorities in each village, we engaged local residents, especially those operating within and around mangrove ecosystems with our paper-based interview guide using the simple random sampling technique. The interview guide is a three-part semi-structured guide made up of both open-ended and close-ended questions. The first section focused on demographic information including gender, age, ethnic group, education, marital situation, and occupation. The second section encompassed the uses of mangrove resources by the respondents. The third section has to do with respondents' perceived impacts of their activities on the mangroves and the effects of mangroves degradation on the aforementioned life attributes. Each interview lasted between 40 and 70 min. Respondents were engaged in the course the day in order to have a better understanding of their interactions with mangrove ecosystems.

Each respondent was asked (i) to provide the activities practiced within the mangroves or their surrounding areas, (ii) fishery (fish, shrimps, oysters, and crabs) and plant resources collected from mangroves with details on species collected and its specific uses, (iii) the perceived impacts of their activities on mangrove degradation (no impact, little impact, or high impact), and (iv) the perceived impacts (no impact, little impact, or high impact) of mangrove degradation on their life considering four attributes such as security (personal safety, and the one of their property and family members), income, health, and culture. The animal and plant resources mentioned by the respondents were listed and collected from the field on daily basis. Herbarium of the plant resources were constituted and sent to the National Herbarium of Benin at the University of Abomey-Calavi for identification. Regarding animal resources, they were regularly collected from fishermen on duty, conserved in ice chest containing ice block and identified at the Laboratory of Hydrobiology and Aquaculture (LHA) of the Faculty of Agricultural Sciences (FSA) at the university of Abomey-Calavi (UAC).

2.4. Human subjects and ethical considerations

Ethical issues concerning the investigated local population were given high credence, and duly addressed during data collection. The purpose of the study was explained to each respondent along with the possible risks associated with their participation. We sought oral consent from all the respondents we interviewed before engaging them. That form of consent was used as some respondents are uneducated and could not read and approve the written consent before signing. Interviewees were guaranteed the strict confidentiality of their responses, narratives and experiences and approval was sought to record interviews and to take notes when needed.

2.5. Data analysis

Respondents were grouped into two age groups: adults (between 18 and 40 years) and old people (≥ 40 years) (Goudegnon et al., 2017). Proportions of respondents who practice each activity were calculated and a binomial logistic generalized linear model was applied to test for the effect of gender, age categories and villages on the likelihood of practicing each activity. For animal and plant resources collected from mangroves, the relative frequency of citation (RFC) was calculated as a measure of its local importance (popularity); the higher RFC, the higher the importance. Differences in perception of respondents on the impacts of their activities on the degradation of mangroves across villages, gender, and age groups were tested using a Chi-square test. The same statistical test was used to examine differences in perception of respondents on the impact of degradation of mangroves on their life attributes. All statistical analyses were performed in R software version 3.5.1 (R Core Team 2018).

3. Results

3.1. Activities of local people in mangroves and variation across villages, age categories, and gender

Respondents listed nine income generating activities being carried out within and around mangroves at Grand-Popo. They include fishing, growing of vegetables, wood collection, medicinal plant collection, *Cyperus articulatus* collection, salt production, fluvial transportation, edible fruits collection, and tourism.

Fishing activities in the context of this study include the harvesting of fish, shrimps, crabs, and oysters. Wood collection has to do with the collection of wood for firewood, construction and for other specific uses (fabrication of furniture, traps, etc.). Growing of vegetables refers to the production of carrot, cabbage, onion, tomatoes, pepper and other leafy vegetables for consumption and commercial purposes whereas medicinal plant collection deals with the collection and use of plant species from mangroves and adjacent habitats to cure ailments. Tourism refers to the taking of visitors through mangroves for commercial purposes whereas salt production implies the artisanal preparation of the cooking salt for consumption and commercialization. Fluvial transportation designates the transportation of people and goods from one place to another using canoes while *C. articulatus* collection and edible fruits collection represent respectively the collection of *C. articulatus* for artisanal mat processing and the collection of edible fruits (coconut, mangoes, palm nut etc.) from mangroves and their surrounding environments for local consumption and selling.

The ranking exercise performed on the listed activities categorized fishing as the most practiced activity within and around the mangroves of the municipality (31.65% of the respondents), followed by wood collection (22.73%), *C. articulatus* collection (21.67%), medicinal plant collection (8.98%), salt production (5.56%), edible fruits collection (2.47%), tourism (2.15%), fluvial transportation (1.78%) and vegetable growing (0.45%).

When examining the influence of the socio-demographic factors on the activities implemented within and around mangroves, our results showed that fishery is influenced by the gender with men mostly engaged in this activity than women (estimate = 1.98, $p < 0.01$, Table 1). Furthermore, the activity is more developed at Gbekon (estimate = 3.91, $p < 0.01$, Table 1), Hèvè (estimate = 2.05, $p < 0.01$, Table 1) and Hillacondji (estimate = 2.94, $p < 0.01$, Table 1). Vegetables were mostly grown at Azinko (estimate = 1.24, $p < 0.05$, Table 1), Gbèfa (estimate = 1.7, $p < 0.01$, Table 1) but less at Hèvè (estimate = −1.59, $p < 0.1$, Table 1). The activity is predominantly practiced by men (estimate = 1.73, $p < 0.01$, Table 1) whose age is above 40 (estimate = 2.53, $p < 0.01$, Table 1). Medicinal plants are predominantly derived from mangroves at Azinko (estimate = 1.24, $p < 0.05$, Table 1) and Gbèfa (estimate = 1.70, $p < 0.01$, Table 1) but less collected from mangroves

Table 1
Summary of Binomial GLM describing the effects of gender, village and age groups on the citation of activities implemented around mangroves: estimate (standard error).

Factors	Fisheries	Vegetable growing	Wood collection	Medicinal plant collection	*C. articulatus* collection	Salt production	Fluvial transport	Edible fruit collection	Tourism
Intercept	−3.5*** (0.66)	−4.10*** (0.68)	0.77** (0.37)	−4.10*** (0.68)	−0.65 (0.40)	−1.71*** (0.58)	−1.98*** (0.50)	−9.18 (1.93)	−3.18*** (0.78)
Village (*Agoué Centre* as reference level)									
Avlo	6.64*** (1.11)	−0.77 (0.73)	0.11 (0.47)	−0.77 (0.73)	1.13** (0.49)	0.69 (0.69)	−2.1 (2.58)	−1.95* (1.17)	−5.6 (8.67)
Azinco	5.87 (1.60)	1.24** (0.61)	−2.17*** (0.53)	1.24** (0.61)	1.13** (0.49)	2.63*** (0.66)	3.02*** (0.64)	−9.64 (4.05)	1.39* (0.37)
Gbefa	−7.31 (1.60.)	1.70*** (0.62)	−1.59*** (0.48)	1.70*** (0.62)	−7.47 (1.01)	−0.33 (0.88)	2.28*** (0.58)	−1.98* (1.17)	2.05*** (0.80)
Gbekon	3.91*** (0.71)	0.92 (0.62)	−1.35*** (0.47)	0.92 (0.62)	−7.4 (1.0)	16.32 (8.06)	0.70 (0.53)	−9.64 (4.05)	1.01 (0.87)
Heve	2.05*** (0.65)	−1.59* (0.88)	−0.82* (0.46)	−1.59* (0.88)	1.76*** (0.50)	−0.77 (0.91)	−0.04 (0.53)	−9.64 (4.05)	0.08 (1.07)
Hilalacondji	2.94*** (0.67)	−7.91 (1.50)	−1.37*** (0.47)	−7.91 (1.70)	−1.49** (0.70)	−0.30 (0.89)	−2.14 (2.58)	−2.02* (1.17)	0.43 (0.94)
Hio	0.49 (0.71)	−8.11 (1.52)	−1.59*** (0.48)	−4.8 (5.21)	1.54*** (0.49)	−1.50 (1.15)	−4.6 (2.58)	−1.88 (1.17)	−0.01 (1.27)
Zogbedji	−7.31 (4.60)	−8.04 (1.52)	−0.05 (0.47)	−8.04 (1.52)	−1.13* (0.64)	−0.32 (0.81)	−2.89 (258)	−1.95* (1.17)	0.02 (1.27)
Gender (*Female* as reference level)									
Male	1.98*** (0.40)	1.37*** (0.39)	−0.09 (0.23)	1.37*** (0.39)	−0.33 (0.28)	−1.81*** (0.45)	2.34*** (0.39)	8.72 (1.93)	0.34 (0.37)
Age categories (*Age ≤ 40* years as reference level)									
Age > 40 yrs	0.02 (0.36)	2.53*** (0.44)	−0.21 (0.23)	2.53*** (0.44)	−0.62** (0.28)	0.22 (0.32)	−0.06 (0.35)	−1.61* (0.844)	0.11 (0.33)

Note:.
* $p < 0.1$;.
** $p < 0.05$; ** $p < 0.01$.

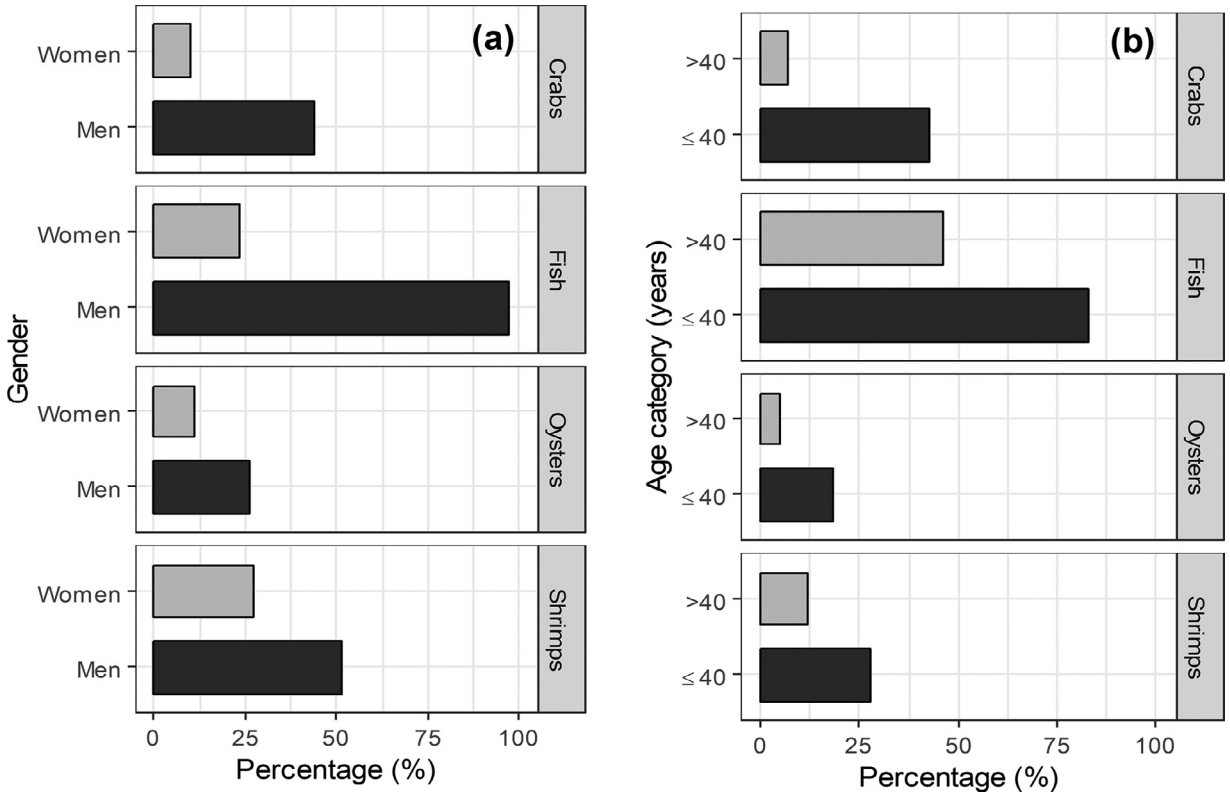

Fig. 2. Fishery resources collected from mangroves according to gender (a) and age category (b).

at Hèvè (estimate = −1.59, $p < 0.1$, Table 1). Like the vegetable growing, medicinal plants were also mostly collected by men (estimate = 1.37, $p < 0.01$, Table 1) and old people (estimate = 2.53, $p < 0.01$, Table 1). The variation of wood harvesting was only locational-based and prevailed at Hèvè (estimate = 0.82, $p < 0.01$, Table 1) as compared to other villages. Old people (age > 40) were less engaged in *C. articulatus* collection (estimate = −0.62, $p < 0.05$, Table 1) which is overwhelmingly practiced at Avlo (estimate = 1.13, $p < 0.05$, Table 1), Azinko (estimate = 1.13, $p < 0.05$, Table 1) and Hèvè (estimate = 1.76, $p < 0.01$, Table 1) but was less important at Hillacondji (estimate = −1.49, $p < 0.1$, Table 1) and Zogbédji (estimate = −1.13, $p < 0.01$, Table 1). Salt production was predominant at Azinko (estimate = 2.63, $p < 0.1$, Table 1) and less practiced by men (estimate = −1.81, $p < 0.1$, Table 1) whereas tourism was well developed at Azinko (estimate = 1.39, $p < 0.1$, Table 1) and Gbèfa (estimate = 2.05, $p < 0.05$, Table 1) as compared to the other villages. Fluvial transportation was significantly affected by the villages and the gender. It was predominantly practiced by men (estimate = 3.02, $p < 0.01$, Table 1) at Avlo (estimate = 2.28, $p < 0.01$, Table 1) and Azinko (estimate = 2.34, $p < 0.01$, Table 1) than the other villages. Regarding edible fruits, they were less collected by adults (estimate = −1.61, $p < 0.1$, Table 1).

Fish was the main animal resource collected from the mangroves. Majority of men (97.22%) collect fish whereas 51.66% collect shrimps, 43.8% harvest crabs and 26.11% go for oysters. Contrary to men, only 23.33% of women were into fish collection meanwhile 27.22% collect shrimps, 10% harvest crabs and 11.11% collect oysters. With respect to age category, 82.77% of adults are interested in fish against only 27.77%, 42.77% and 18.33% that are interested in shrimps, crabs and oysters, respectively. Similarly, old people are mostly into fish collection, (46.11%) whereas only 11.66%, 6.66%, and 5% are interested in shrimps, crabs, and oysters, respectively (Figs. 2a and 2b).

Regarding wood collection (Figs. 3a and 3b), we found that men collect wood from mangroves for firewood (52.77%), construction (79.44%), and other uses (27.22%) whereas 60.55% of women collect wood for firewood for domestic uses and fish smoking, 3.33% for construction and 1.66% for other uses. With respect to age category, 39.44% of adults collect wood for firewood against 52.77% and 12.22% who harvest wood for construction and other uses, respectively. Old people also agreed that they are engaged in wood harvesting in mangroves for firewood (68.33%), construction (42.77%) and other uses (16.66%). Other uses include fodder, *acadja* (park of branches installed in the aquatic ecosystems in Benin in order to attract fishes), vegetable brush, fish traps fabrication, furniture fabrications, etc.

Avicennia germinans and *Rhizophora racemosa* were the two species mainly harvested from mangroves for wood. Actually, 83.9%, 91.66% and 24.44% of the respondents used *R. racemosa* respectively for firewood, house construction and other purposes (fodder, *acadja*, vegetal brush, fish traps fabrication, furniture fabrications etc.) whereas only 28.33%, 1.94% and 26.94% go for *A. germinans* for firewood, house construction and for other purposes, respectively (Fig. 4).

3.2. Medicinal plants collected from mangroves and adjacent habitats

Fifteen species belonging to fourteen genera and eleven families were listed by respondents as medicinal plants collected from mangroves and their adjacent habitats (Table 2). This list comprised *R. racemosa, A. germinans, Paspalum vaginatum, Caesalpinia bonduc, Mangifera indica, Cocos nucifera, Elaeis guineensis, Azadirachta indica, Moringa oleifera, Annona senegalensis, Spondias monbin, Senna occidentalis, Newbouldia laevis, Jatropha curcas* and *Senna alata*. The most cited plant species were in order *R. racemosa, A. germinans, M. oleifera, A. indica, J. curcas*, and *C. nucifera* (Table 2). Health disorders mainly cured with these plants included malaria, anaemia, sores, fever, haemorrhoid, hypertension, cough, digestive issues, sexual weakness, and headache, infertility, abortion, cancer, and stomach pains. Some plants like *R. racemosa* were also associated with abortion.

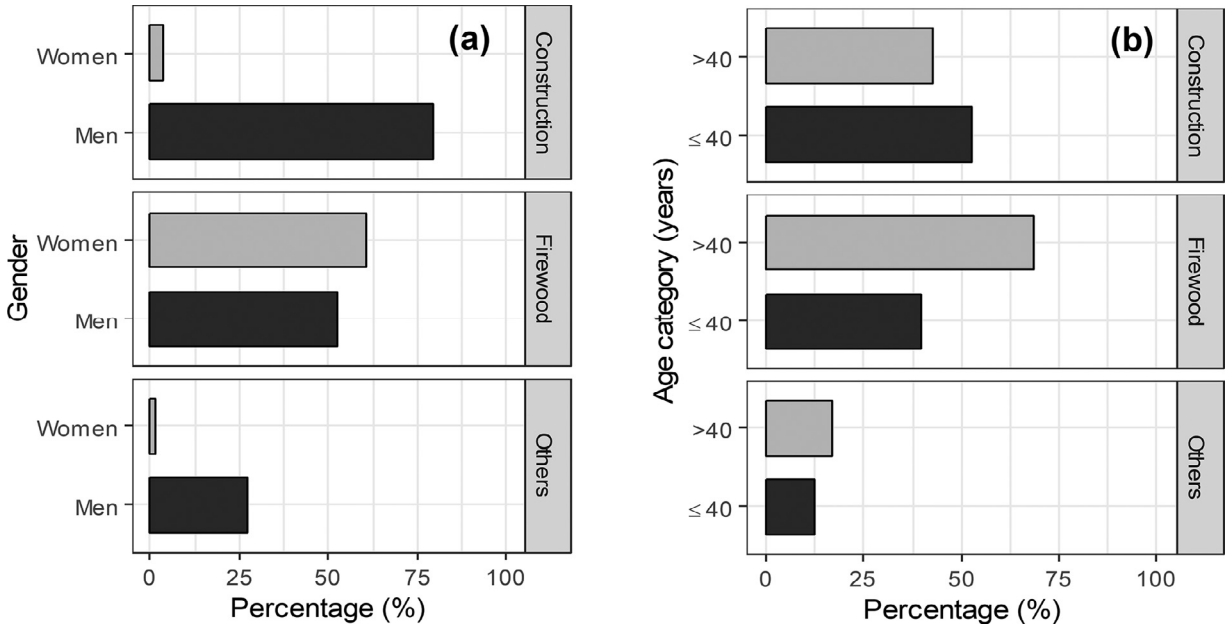

Fig. 3. Specific uses of wood collected from mangroves according to gender (a) and age category (b).

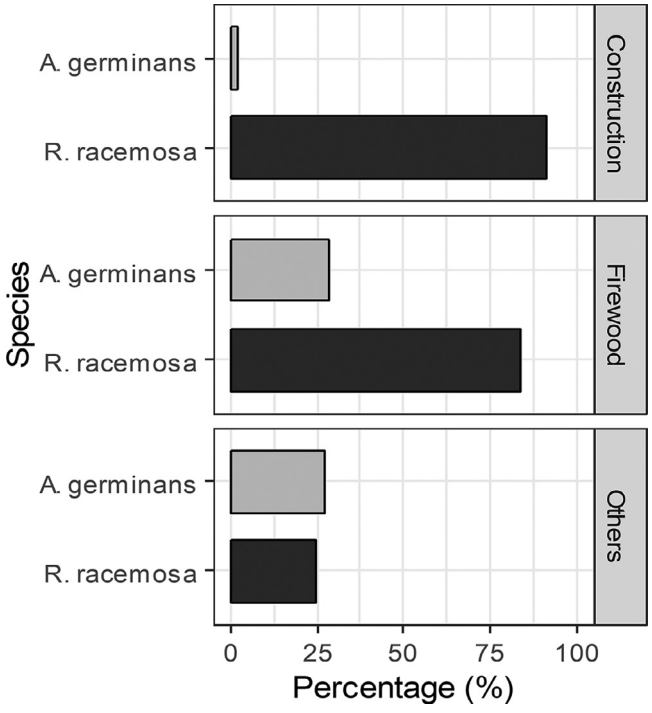

Fig. 4. Specific uses of the two main mangrove plant species at Grand-Popo.

3.3. Animal resources collected through fishing and their importance

Twenty-three species of fish, two species of shrimps, two species of crabs and one species of oyster were listed by respondents as fishery resources commonly collected from mangroves and their surrounding environments (Table 3). The fish species mostly cited were *Clarias gariepinus, Sarotherodon melanotheron, Oreochromis niloticus, Lates niloticus, Coptodon guineensis, Parachanna obscura* and *Chrysichthys nigrodigitatus* (Table 3). *Macrobrachium macrobrachion* and *Macrobrachium vollenhovenii* were the two cited shrimp species and they were mentioned by at least ⅔ of the informants. *Callinectes amnicola* and *Cardisoma armatum* were the two cited crab species, the first being cited by at least ⅘ of informants and the second by less than half the informants. The only one oyster cited was *Crassostrea gasar* and it was mentioned by about ⅓ of the informants.

3.4. Local perception of the impacts of human activities on mangroves degradation

Majority (58.33%) of respondents declared that their activities do not contribute to mangrove degradation which they rather related to natural disasters whereas about ⅓ (34.16%) considered that they activities contribute slightly to mangrove degradation. Less than 10% (7.5%) declared that their activities contribute highly to mangrove degradation (Fig. 5a). Local perception of the impact of human activities on mangrove degradation varied significantly across villages (χ^2 = 146, df = 16, $p < 0.001$) and gender (χ^2 = 229, df = 8, $p < 0.001$) but not between age categories (χ^2 = 1, df = 8, p = 0.740) indicating that, respondents of Avlo, Hillacondji and Agoué hold mostly the view that their activities have no impacts on mangrove degradation whereas respondents of Gbèfa, Houéta, Gbèkon, Zogbedji, Hêvê and Azinko agreed in majority that their activities contribute to mangroves degradation in their localities. Furthermore, several men declared that their activities degraded mangrove ecosystems whereas several women hold the view that their activities do not degrade mangrove ecosystems.

3.5. Local perception of the impact of mangrove degradation on their life attributes

Perception of respondents about impacts of mangrove degradation on their live varied significantly according to life attributes (χ^2 = 109, $p < 0.001$) (Fig. 5b). They declared little impact (85.27%) on their culture, but high impact on their income (46.94%), health (72.77%) and security (81.94%), although some (40.82%) declared low impact on their income.

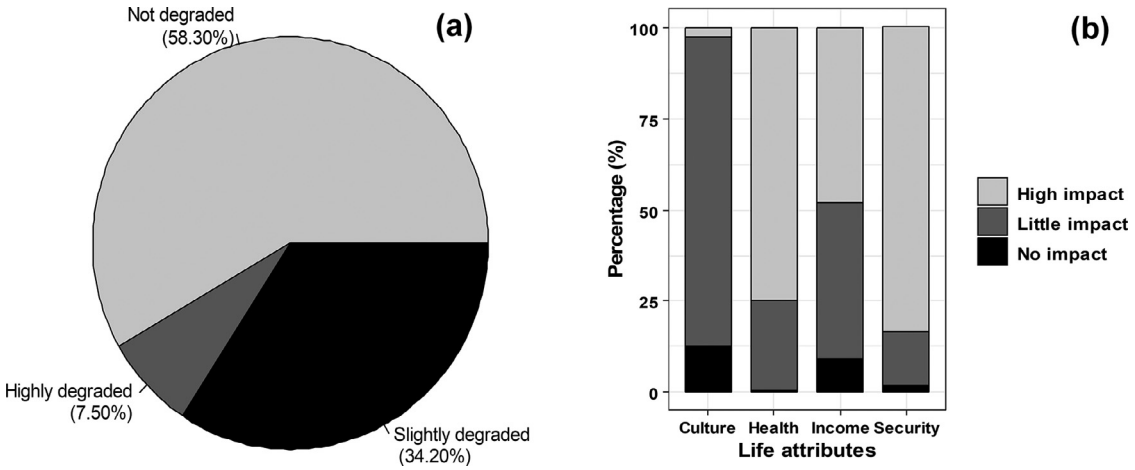

Fig. 5. Local perception of (a) the impact of human activities on mangrove degradation, (b) potential effect of mangroves degradation on their life attributes.

4. Discussion

4.1. Activities of local communities in mangroves and their perceived impacts on the ecosystem degradation

Mangroves of Grand-Popo provide important services to local communities. In total, nine activities were reported as the most important economic occupations of local communities in the study area. These activities are part of the ones mentioned in the coastal zone of Cameroon (Nfotabong Atheull et al., 2009; Ajonina et al., 2015; Feka et al., 2009), Ghana (Aheto et al., 2016), Kenya (Walters et al., 2008) and Asia (Vincentius et al., 2019). But as compared to Teka et al. (2019) who have also reported the economic activities of the coastal zone of Benin, four new activities have been found as economic activities carried out within mangrove ecosystems of Grand-Popo, namely vegetable growing, *Cyperus articulatus* collection, fluvial transportation, and tourism. These activities might have been overlooked, yet locally important. Actually, it is assumed that tourism is one of the economic activities that can help local people realize the potential of their resources and protect them (Salam et al., 2000). However, we found with Teka et al. (2019), similar important activities like wood collection and fishing. In addition, to *C. articulatus* collection, these activities may impact the long-term sustainability of mangroves in the locality as they are practiced by several people within the catchments of mangroves in the area, yet were reported as activities occasioning mangroves degradation, if not controlled (Nfotabong-Atheull et al., 2011). Moreover, even though vegetable growing is practiced by few respondents (0.45%), it can be detrimental to mangroves if not environmentally friendly.

Findings showed that fishing is the most important activity of the coastal population of Grand-Popo. It has been already proved that fishing is one of the predominant activities of the populations of west-African coasts (Aheto et al., 2016; Teka et al., 2019; Adite et al., 2013).

Table 3
Fishery species of mangroves: scientific names, local designation, and relative frequency of citation (RFC, %).

Classes	Scientific names	Local designation in Xwla*	Family	RFC
Fish	*Sarotherodon melanotheron* (Rüppell, 1852)	Sokpoé	Cichlidae	99.32
	Clarias gariepinus (Burchell, 1822)	Adinhoué	Clariidae	92.12
	Coptodon guineensis (Günther, 1862)	Azéguin	Cichlidae	77.34
	Chrysichthys nigrodigitatus (Lacepède, 1803)	Blolo	Claroteidae	76.51
	Oreochromis niloticus (Linnaeus, 1758)	Akpavi	Cichlidae	54.87
	Parachanna obscura (Günther, 1861)	Noukplato	Channidae	43.17
	Chrysichthys auratus (Geoffroy Saint-Hilaire, 1809)	Efin	Claroteidae	32.76
	Lates niloticus (Linnaeus, 1758)	Zokin	Centropomidae	28.32
	Hemichromis fasciatus (Peters, 1857)	Gbatoé	Cichlidae	17.19
	Ethmalosa fimbriata (Bowdich, 1825)	Ahouèvi	Clupeidae	16.10
	Mugil cephalus (Linnaeus, 1758)	Guéssou	Mugilidae	13.98
	Heterotis niloticus (Cuvier, 1829)	Houa	Osteoglossidae	10.20
	Liza falcipinnis (Valenciennes, 1836)	Wétin	Mugilidae	6.98
	Lutjanus goriensis (Valenciennes, 1830)	Agnanto	Lutjanidae	5.18
	Galeoides decadactylus (Bloch, 1795)	Tchikoué	Polynemidae	5.50
	Pseudotolithus senegalensis (Valenciennes, 1833)	Kan	Sciaenidae	3.19
	Schilbe intermedius (Rüppell, 1832)	Aziakè	Schilbeidae	3.17
	Porogobius schlegelii (Günther, 1861)	Agbodoè	Protopteridae	3.15
	Chromidotilapia guntheri (Sauvage, 1882)	Akpa	Cichlidae	3.15
	Eleotris senegalensis (Steindachner, 1870)	Wontinkpoé	Eleotridae	3.15
	Hepsetus odoe (Bloch, 1794)	Zadou	Hepsetidae	1.89
	Synodontis schall (Bloch & Schneider, 1801)	Sossogloso	Mochokidae	1.19
	Cynoglossus senegalensis (Kaup, 1858)	Ignon	Cynoglossidae	1.18
Shrimp	*Macrobrachium macrobrachion* (Herklots, 1851)	Osron	Palaemonidae	78.32
	Macrobrachium vollenhovenii (Herklots, 1857)	Atchochi	Palaemonidae	66.23
Oyster	*Crassostrea gasar* (Dautzenberg, 1891)	Adakpin	Ostreidae	33.87
Crabs	*Callinectes amnicola* (Rochebrune, 1883)	Asson	Portunidae	89.10
	Cardisoma armatum (Herklots, 1851)	Agassa	Gecarcinidae	43.17

* The most popular local language of Grand-Popo.

Table 2
Medicinal plants cited by respondents, their specific uses and relative frequency of citation (RFC,%).

Scientific name	Local designation in xwla*	Typical habitats	Family	Parts used	Specific uses	RFC
Rhizophora racemosa	Wéto	Mangroves	Rhizophoraceae	Roots, Bark, leaves, propagules and stem	Anaemia, sores, fever, haemorrhoid, cough, abortion	53.6
Avicennia germinans	Akpontin	Mangroves	Avicenniaceae	Leaves	Haemorrhoid	46.8
Paspalum vaginatum	Gbakon	Mangroves	Poaceae	Leaves and bark	Strengthen babies' organism	1.1
Caesalpinia bonduc	Adjikouintin	Adjacent habitats	Caesalpiniaceae	Roots	Sexual weakness	0.3
Mangifera indica	amanga	Adjacent habitats	Anacardiaceae	Bark and roots	Malaria	0.5
Cocos nucifera	Agontin	Adjacent habitats	Arecaceae	Coconut water	Malaria	10.2
Elaeis guineensis	Détin	Adjacent habitats	Arecaceae	palm oil	Earache	3.2
Azadirachta indica	Kininitin	Adjacent habitats	Meliaceae	Bark and leaves	Malaria, headache,	26.2
Moringa oleifera	Kpatiman	Adjacent habitats	Moringaceae	Leaves, seed, roots and bark	Malaria, anaemia, wound, fever, haemorrhoid.Hypertension, cough, digestive issues	41.2
Annona senegalensis	Agnouglwetin	Adjacent habitats	Annonaceae	Leaves	Sexual weakness and infertility	3.2
Spondias monbin	Akinkontin	Adjacent habitats	Anacardiaceae	Stem	Fight against evil spirits	0.3
Senna occidentalis	Kinkeliba	Adjacent habitats	Caesalpiniaceae	Leaves and roots	Malaria, stomach pains, headache, digestive issues	0.3
Newbouldia laevis	Hounman	Adjacent habitats	Bignoniaceae	Leaves	House purification, convents' protection	2.3
Senna alata	Lakpalakpaman	Adjacent habitats	Caesalpiniaceae	Leaves	Skin infections	1.3
Jatropha curcas	Gnoukpotou	Adjacent habitats	Euphorbiaceae	Leaves	Malaria, digestive issues, cancer	12.2

* The most popular local language of Grand-Popo.

However, the rapid growth of human population and the uncontrolled anthropogenic activities along the coastal environment often lead to fish overexploitation, posing severe threats to mangroves and their animal and plant species.

Wood collection was also well-developed by the coastal population of Grand-Popo (22.73%) where woods are generally collected either for sale or for domestic uses. And even though it is prohibited to exploit mangrove woods in some villages like Avlo, Agoué and Hillacondji, some local residents still break that ban of mangroves cutting and fraudulently harvest mangrove plant species, particularly *Rhizophora racemosa* and *Avicennia germinans*. This preference for mangrove woods for local utilization may be due to the lack of local plantations to supply people with wood for domestic uses. In fact, other natural forests are very rare and no public or private plantation is established to supply firewood to population in the area. Thus, local people around mangroves have no choice apart from invading mangroves to collect wood for their daily consumption. This dependency on mangroves for wood supply in Benin has been raised by Kasso et al. (2008) and recently by Teka et al. (2019). Merely 20% of Avlo people (Grand-Popo) purchase firewood or domestic gas for food cooking (Kasso et al., 2008). They prefer to collect firewood from mangrove ecosystems. An additional reason for the preference to fuelwood from mangroves may be linked to their calorific properties which are believed to be well appreciated by coastal dwellers (Scales and Friess, 2019). Dependency of local people on mangroves for firewood for domestic uses, salt production and construction was also noticed elsewhere, e.g. in Malaysia (see Satyanarayana et al., 2010). The authors reported about 4,713,040 tons of *R. racemosa* and *A. germinans* collected in 2008 for salt production and domestic uses, resulting in the deterioration of the health of mangroves in this country. In addition, Din et al. (2008) argued that 1000 ha of mangroves were yearly destroyed in Cameroon because of wood extraction.

Amongst mangrove plant species, the most harvested for construction and firewood is *R. racemosa*. This may be due to the resistance of this species to the insects and its high solicitation for fish smoking. Actually, many respondents reported that the timber of *R. racemosa* is a strong raw material for house building and doesn't easily decay. Moreover, women unanimously estimated that the best firewood species collected from mangroves for fish smoking is *R. racemosa.* The same trends of *Rhisophora* species overexploitation have been yet raised by Nfotabong Atheull et al. (2009).

In this study, we found that fishing was mainly practiced men. Women were generally involved in fish commercialization, and fish smoking. They prefer the transformation and the commercialization of fishing products as fishing requires a lot of physical efforts. This predominance of men in fishing has been already mentioned in the coastal zone of Benin by Teka et al. (2019) and Adite et al. (2013).

At Grand-Popo, the different activities practiced in each village depend on the level of conservation of mangrove ecosystems of the village. When mangrove ecosystems are highly protected (e.g. Azinko, or Gbèfa), people do not openly engage in activities like wood collection and then, the increased density of *R. racemosa* and *A. germinans* communities attracts tourists and others people and allows women to engage in commercial activities (foods selling, farming products selling, etc.). However, when mangroves are unprotected (e.g. Hêvê), the degradation of mangroves resulting from anthropogenic activities hamper ecotourism development and other related activities such as fluvial transportation. Salt production practiced within the study area has the potential to highly impede mangroves development. Indeed, salt production requires an important amount of firewood collected from mangroves. It is assumed that extraction of 100 Kg of salt requires 1 m^3 of mangrove wood (Kasso et al., 2008). *Acadja* and other fishing practices underway at Grand-Popo during the period of data collection also require similar and even higher quantity of mangrove wood. Likewise, crabs and shrimp traps are generally fabricated with mangrove woods. All those activities may ultimately degrade mangroves in the study area if not regulated.

Many respondents declared that their activities do not degrade mangroves despite acknowledging the depletion of mangrove resources over the years. This is likely indicating that from the perspective of most of them, mangrove degradation is mainly due to natural disturbances rather than human activities. Yet, according to the National Forestry Department of Benin, mangrove degradation in the country predominantly result from human activities (see DGEFC, 2017), and may suggest a lack of awareness on the potential threats of their activities. Also, Adjonou et al. (2020) after assessing the land use land cover of the Mono Transboundary Biosphere Reserve including the study area reported that 93% of the mangrove coverage of the reserve have been lost from 1986 to 2015 as a result of anthropogenic activities. amongst those who acknowledged the impacts of their activities on mangrove degradation, men predominated. Teka &Vogt (2010) reported that gender is one of the main factors affecting local communities' attitude towards natural resources conservation. Glaser (2003) also mentioned a gender differentiation in decision-making at the village and household levels and concluded that men constitute the most influential people to be considered during the planning of natural resources management. Similarly, Feka et al. (2011) demonstrated the limitation of access to information on resources conservation of households headed by women due to traditional and social barriers which may explain the observed trend in our study area.

4.2. Plant and animal resources collected from mangroves and adjacent areas and their uses

Traditionally, medicinal plants constitute in developing countries a precious natural wealth and greatly contribute to their health care (Adomou et al., 2012). They are mostly used in indigenous care facilities and serve as important healing agents as well as vital raw materials for the modern medical industry (Vinoth et al., 2019). Mangroves are also sources of medicinal plants (Aye et al., 2019). Actually, several mangrove plants are being exploited worldwide especially in the indigenous pharmaceutical industry. Similarly, several mangroves genera are being processed to produce highly effective drugs (Vinoth et al., 2019). In the context of our study, fifteen medicinal plants including some of those reported by Dossou-Yovo et al. (2017) in some coastal villages of Benin have been listed by the local populations. However, *R. racemosa* is predominantly used for medicinal matters. All the parts (roots, bark, leaves, propagules, and stem) of this species are collected to cure diseases. The growing pressure on this species is as a result of its high medicinal properties as compared to the other mangrove plant species. Vinoth et al. (2019) reported that mangrove true species in general and those belonging to the genera *Rhizophora* in particular have high anti-diabetic, anti-oxidant and anti-cancer properties. Apart from *R. racemosa, A. germinans* is also well utilized by local populations (RFC = 46.8%) and was collected to treat haemorrhoid. The medicinal use of *A. germinans* was previously mentioned by Hernández et al. (2005). The authors explained that a special tea has been developed from the leaves of *A. germinans* by the local populations of the Mexican Pacific coast to cure gastric diseases.

Apart from medicinal uses, *R. racemosa* and *A. germinans* were locally used for many others purposes (Firewood, charcoal, construction, etc.). They were the most cited amongst the plant species reported by the local population. This may likely happen because they are the commonest species in mangroves in Benin, congruently with the "ecological apparency hypothesis" which predicts that most common species are likely to me more known and hence more used (Soldati et al., 2017). Regarding animal species listed, a total twenty-three species of fish, two species of shrimps, two species of crabs and one species of oyster were reported by local populations as mangrove edible fishery resources commonly collected. Amongst those resources, the cichlidae (*S. melanotheron, O. niloticus* and *C. guineensis)* were most cited. It has been demonstrated that Cichlidae represent generally the major part of fishermen' fish catch at Grand-Popo due to their ability to colonize both brackish water and freshwater (Lederoun et al., 2018). On the other hands, the scrutiny of the fish composition of this research showed that species listed by the local communities were predominantly marine and estuarine species. This might be due to the connection between the sea and the coastal lagoon of Grand-Popo through the "La bouche du Roy", enabling marine species to migrate into the lagoon. The study also indicated that Grand-Popo' mangroves are home of many vulnerable fish species. Actually, *Pseudotolithus senegalensis* (Valenciennes, 1833), Lutjanus goriensis (Valenciennes, 1830), and *Cynoglossus senegalensis* (Kaup, 1858), all listed by the local population are respectively, endangered, Vulnerable and Near Threatened according to the IUCN red list status (IUCN, 2020). They rarity within mangroves in the study area likely justifies their low relative frequency of citation (respectively 3.19%, 5.18% and 1.18%).

4.3. Implications for a sustainable use of mangroves

Most respondents revealed that their income, health and security are mostly impacted by mangrove degradation, suggesting the importance of these attributes to the local population. Non-governmental and other stakeholders involved in mangrove conservation in Benin can target these attributes during their sensitization exercises and awareness raising. Awareness is also essential for local populations to understand the impact of human activities on mangrove degradation as they massively associated the depletion of the mangrove resources of their communities with natural disasters rather than their activities.

The study also noted a heavy dependency of local population on animal and plant species mangrove. In addition to their importance in protecting the coastal environment and coastal dwellers against natural and manmade disasters, mangroves also play a pivotal role in the fish replenishment of coastal and inland waters. It is then needed to set up local woody plantations along the coast and to engage a lot of fishermen in aquaculture and other alternative livelihoods to curb the unabated pressures exerted on mangrove animal and plant resources.

Some activities being implemented within the study such as vegetable production are dangerous to aquatic ecosystems and dire to mangrove ecosystems if they are not environmentally friendly. The use of pesticides and other chemical products in agriculture are detrimental to mangroves and their components. It is then urgent to conduct additional research along the coast to find out the type of agriculture implemented around mangroves and engage the concerned farmers in agroecological agriculture if necessary.

The mostly collected resources are fish, shrimp, oysters and crabs and they are likely overexploited at Grand-Popo as the result of the increasing human population. Additional studies are needed to understand the impacts of such exploitation on the species populations to guide their sustainable use. Our findings provide important information on resources collected and used within mangrove ecosystems and highlight strong geographical locations, gender, and age categories variation which can be used to plan sustainable participative management of mangroves in Benin, particularly in the newly created Mono Transboundary Biosphere Reserve which encompasses the study area. Actually, the Mono Transboundary Biosphere Reserve is a MAB-UNESCO reserve where three main management zones are distinguished: the integrally protected zones, the buffer zones, and the transition zones. The integrally protected zones are devoted to only conservation activities and no human activities are allowed, except scientific research, surveillance, rituals ceremonies for local divinities and environmental education. Activities such as fishing, hunting, wood harvesting, mangrove exploitation, non-timber forest products collection, etc. are prohibited. In the buffer zones, activities such as ecotourism, private reforestation, conservation agriculture, regulated market gardening, controlled firewood collection, environmental education, controlled exploitation of mangroves, regulated fishing, and aquaculture are allowed. In the transition zones, there are no specific management regulations, the zones are under the national regulations of the forestry and fishing sectors. Our results show that local people highly depend on most of the resources on which the

creation of the reserve implies restricted access in some zones. The creation of the reserve, with the regulations, if duly abide by, have the potential of reducing the manmade pressures on mangrove ecosystems in Grand-Popo. However, this will also impact the livelihoods of local communities who as shown by our results highly depend on the mangrove resources on which restrictions have been put with the creation of the reserve. Therefore, alternative income generating and environmentally-friendly activities have to be participatorily developed along with capacity building of local communities in value-added activities. Environmental education also needs to be strengthened so that local people can easily adhere to the regulations of the reserve.

5. Conclusion

Mangroves, appear as a source of livelihood for thousands of local people living the coastal environment of Benin. Nine socioeconomic activities were recorded at Grand-Popo as activities carried out within mangroves and their surrounding areas of whom fishing, wood collection, and *C. articulatus* collection, were the most important. Fish, shrimps, crabs and oysters were the most important fishing resources collected from mangroves and their adjacent areas whereas *R. racemosa* and *A. germinans* were the most harvested plant species. Majority of the respondents believed their activities to not have any negative impact on mangroves despite their large acknowledgement of the decrease of mangrove surface area in the municipality. The life attributes of local population mostly impacted by mangrove degradation were income, health and security.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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