International Journal of Applied Sciences: Current and Future Research Trends
(IJASCFRT)
ISSN (Print) , ISSN (Online)

https://ijascfrtjournal.isrra.org/index.php/Applied_Sciences_Journal

Floristic Diversity of the Gbaga Channel Mangroves in Southwest Benin

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Abstract

Mangroves play an important role from an ecosystem and socio-economic point of view for the riparian populations. They are however strongly degraded nowadays, because of anthropic activities. This study aims at evaluating the floristic potential of the mangrove of the Gbaga channel in order to measure the impact of anthropic activities. Within this framework, fifty-two (52) floristic surveys were installed along the channel in four (4) riverside villages. The evaluation of the diversity allowed the identification of thirty-five (35) species divided into 33 genera belonging to twenty-seven (27) families. These species are divided into three groups showing the state of degradation of mangroves. The non-degraded areas still contain species specific to the mangrove in the form of relics. The current state of the mangrove from the floristic point of view requires an urgent restoration for its safeguard.

Keywords: Mangrove; floristic distribution; Gbaga channel;Benin.

1. Introduction

Mangroves have significantly reduced their global extent over the past 50 years, primarily due to deforestation caused by the expansion of agriculture and aquaculture in coastal environments [1,2].

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However, they still play an important role in coastal areas with high population growth and increased poverty. Mangrove ecosystems are important both ecologically and economically, providing many ecosystem services such as coastal erosion control and tsunami and cyclone impacts, nursery and fishing grounds, breeding sites for many estuarine and semi-terrestrial marine organisms, a reliable source of wood, food and traditional medicines [3]. They are a globally important ecosystem that provides a wide range of ecosystem services, such as carbon capture and storage, coastal protection, and fisheries enhancement [2]. They have high productivity and an essential role in coastal food chains [4]. People are the main beneficiaries in terms of self-consumption and improved income [5]. Mangroves thus occupy an important and original place in the world from an ecosystemic, socio-economic and cultural point of view [6].

In Africa, they also provide a significant number of services, both for the coastal forest and fisheries ecosystem and to human livelihoods, including fisheries, timber production, coastal protection, pollution reduction and carbon sequestration. They provide breeding and nursery grounds for many commercial fish and shellfish species. The stilted roots of the mangroves and their muddy surface usually support a variety of oysters, crabs and other invertebrates. The wood found, is also commonly used for salt extraction. Their forests have both socio-economic and ecological importance, especially for the local indigenous populations who over the years have established an amazing relationship with the local environment [7]. They are thus among the most productive terrestrial ecosystems in the world [8] and constitute a renewable natural resource.

In West Africa, their forests dominated by Rhizophoraceae in association with white mangroves (Avicenneaceae), cover an area of more than 27,000 km² in deltas, estuaries and lagoons, and are part of the offshore coastal ecosystem that develops [9].

Mangroves are therefore highly adapted to highly selective and demanding environments with a high degree of ecological stability and environmental inconstancy. As such, they have a variety of ecosystem properties that serve to facilitate and increase recovery or resilience to disturbance including some that are unique, such as a simple architecture [10]. However, they are threatened by various human activities such as overexploitation, logging for the installation of pipelines and seismic lines, draining of wetlands for urban development, the search for wood for energy, the search for wood in the confession of art objects, in the construction of dugout canoes, in the manufacture of wooden needles (shuttle) used to mend nets, etc. Thus, their total area decreased from 18.8 million hectares in 1980 to 15.2 million in 2005 [11]. The disappearance of mangroves will thus deprive the coasts of a natural protection against erosion. Protection of mangroves is essential because their restoration has been shown to provide significant ecosystem service benefits over short periods of time [12] and is important to reverse at least some of the recent declines in mangrove extent [1].

Benin, a coastal country, has a significant number of mangroves in its southern part, particularly in the commune of Grand-Popo. These mangroves, very little studied, constitute today an anarchically exploited, undeveloped ecosystem, little valued, thus risking to further compromise its vital functions, notably the protection of the coast in Benin as well as in Togo through the Gbaga channel.

Present on the marshy soils of the southwestern coast of Benin and southeastern Togo, the mangroves of the

Gbaga Channel are indeed very important for the protection of the coast and the banks of the rivers. They serve to protect them from flooding and soil degradation. They also constitute an important source of income for the riparian populations, who, by their activities exert a significant pressure on the resources available there, notably the flora.

This paper, therefore, aims to assess the floristic potential to measure the importance of anthropogenic actions on floristic diversity.

2. Materials and methods

2.1. Study area

The mangroves of the Gbaga Channel are located in the southwest of Benin (Figure 1) in the commune of Grand-Popo (6°17' North and 1°50' East). It constitutes a natural border between Benin and Togo. The commune enjoys a sub-equatorial Guinean type climate characterized by four (04) seasons: a long dry season from mid-November to mid-March, a long rainy season from mid-March to mid-July, a short dry season from mid-July to mid-September and a short rainy season from mid-September to mid-November.

The average annual rainfall is 900 mm and the very high relative humidity varies between 70 and 90% due to the proximity of the sea. On average, the maximum temperature is 34°C and the minimum temperature is 23°C.

The relief of Grand-Popo is marked by three (03) groups: the coast, which corresponds to the entire southern part of the sea; the marshy or shallow area and the flood zones, which cover most of the land; and finally, the terminal continental shelf, which covers fine, sandy or sandy-clay formations, often ferruginous, running from west to northeast Three types of soils and dominant vegetation correspond to these three major relief areas: the coastal soils are sandy, made up of fine sands, poor in organic matter and very permeable.

There is the vegetation of coconut trees (*Cocos nucifera*) in the process of disappearing; hydromorphic and fertile soils in the plateau sector characterized by a vegetation of tree savannah with *Eleis guinensis* (oil palm), *Borassus aethiopium* (the roast tree) in the process of disappearing; a little further inland in the mangroves, there are alluvial and hydromorphic soils with vegetation dominated by a herbaceous formation, more or less dense lacustrine species such as mangroves and grasses.

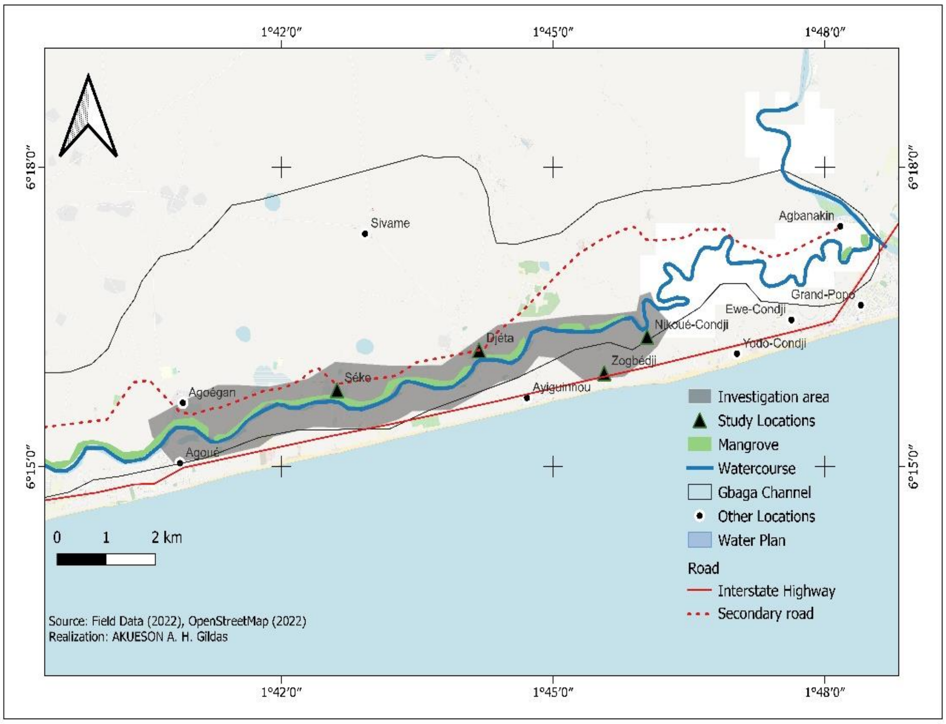


Figure 1: Study area of the Gbaga Channel mangrove of Benin.

2.2. Method of data collection

In order to have a good representativeness, the riparian villages selected for the study were chosen in both Benin and Togo. In each country, two villages were selected: Nicoué-condji and Zogbédji in Benin and Djeta and Seko in Togo.

Floristic data were collected in each of the four villages. The choice of phytosociological survey sites along the channel was made according to the criteria of floristic homogeneity, ecological uniformity and representativeness of the plant formation. Thus, 12 surveys were installed at Nicoué-condji, 14 surveys at Zogbédji, 14 surveys at Djéta and 12 surveys at Seko. That is a total of 52 floristic surveys. These surveys were installed on minimum areas of 50 m in length and 10 m (i.e., an area of 500 m²).

The data collection consisted of an exhaustive inventory of plant species present in each stratum (tree, shrub, sub-shrub and herb layer). The average cover, biological type and phytogeographic type were evaluated for each species. The determination of the cover of each species was carried out by the scale of the coefficients of abundance dominance [13], which is defined as follows:

- 5: species covering 75 to 100% of the survey area, i.e. an average coverage of 87.5%;
- 4: species covering 50 to 75% of the survey area, i.e. an average coverage of 62.5%;
- 3: species covering 25 to 50% of the survey area, i.e. an average coverage of 37.5%;
- 2: species covering 5 to 25% of the survey area, i.e. an average coverage of 15%;

- 1: species covering 1 to 5% of the survey area, i.e. an average coverage of 3%;
- +: species covering less than 1% of the survey area, i.e. an average coverage of 0.5%.

The phytosociological types used in the phytosociological tables are those defined by the Danish botanist Raunkiaer [14] : Phanerophytes (Ph), Chamephytes (Ch), Hemicryptophytes (He), Geophytes (Ge), Hydrophytes (Hy), Therophytes (Th) and Helophytes (Hel). As for the phytogeographical types, they have been established in accordance with the generally accepted chorological subdivisions for Africa [15].

2.3. Analysis method

The phytosociological matrix was analyzed by the numerical hierarchical clustering method using the FactoMineR package under R software (Version 4.2.1) to identify the different groupings. Once the groupings were individualized, their biological, phytogeographical, and weighted spectra were represented. Then, the specific richness, the Shannon index, and the Pielou equitability index of each grouping were determined.

The species richness noted *S* is the number of woody and herbaceous species observed in a plant grouping.

The diversity index of Shannon noted **H' is** expressed in bits. It is defined as follows:

$$\mathbf{H'} = -\sum_{n=1}^{S}\left(\frac{ni}{N}\log_2\left(\frac{ni}{N}\right)\right)$$

with *ni*: the number of individuals counted for a species present

N: the total number of individuals counted, all species combined.

S: the total or cardinal number of the list of species present

The Shannon diversity index is used to evaluate the diversity of plant species. It can take several values:

- the diversity is low if $\mathbf{H'} < \mathbf{3}$ in this case, the environment is not very diverse in species;
- the diversity is said to be average if $\mathbf{H'} \in [\mathbf{3}, \mathbf{4}]$ in this case, the environment is moderately diverse;
- diversity is said to be high if $\mathbf{H'} > 4$ in this case, the environment is relatively diversified in species.

Pielou's equitability allows us to evaluate the weight of each species in the occupation of the space. It is the ratio between the diversity obtained and the maximum diversity of individuals in each plot. It thus makes it possible to apprehend and appreciate the regularity of the distribution of the species in the community. This index was calculated using the formula:

$EQ = \mathrm{H}'/\log_2(\mathrm{S})$.

Equitability is low if $EQ < 0{,}6$. In this case, we say that few species concentrate the majority of the individuals of the environment;

Equitability is average if $Q \in [0{,}6\ ,0{,}8]$;

Equitability is high if $EQ > 0.8,$ we say that the environment is not specialized and therefore the individuals are well distributed within the species.

3. Results

3.1. Identification of plant groups

The phytosociological surveys carried out for the identification of the groupings in the plant formations encountered include 35 species divided into 33 genera belonging to 27 families. The numerical classification method allowed us to distinguish three groups. The factorial map (axis 1, axis 2, and axis 3) obtained by the correspondence analysis method shows the distribution of the records (figure 2).

The eigenvalues of the first eight axes are grouped in Table 1. The reading of the table shows that the first three axes explain 74.17% of the variability between records. This percentage is sufficient for interpretation.

The factorial map reveals discrimination along axes 1 and 3. In fact, axis 1 reveals in its right-hand part a majority of the surveys carried out in low and medium salinity areas and in its left-hand part a majority of the surveys carried out in high salinity areas. It symbolizes a salinity gradient from upstream to downstream.

As for axis 3, the upper part shows the readings taken in the heavily flooded areas and the lower part shows the readings taken in the moderately and lightly flooded areas. It thus symbolizes a flooding gradient due to anthropic activities.

Table 1: Eigenvalues and percentage of variance explained by the eight (8) factors.

	F1	F2	F3	F4	F5	F6	F7	F8
Eigenvalue	23,583	8,750	5,494	3,313	2,288	1,540	1,222	1,176
Variability (%)	46,242	17,157	10,773	6,496	4,487	3,020	2,396	2,306
Cumulative	46,242	63,399	74,172	80,668	85,155	88,175	90,571	92,877

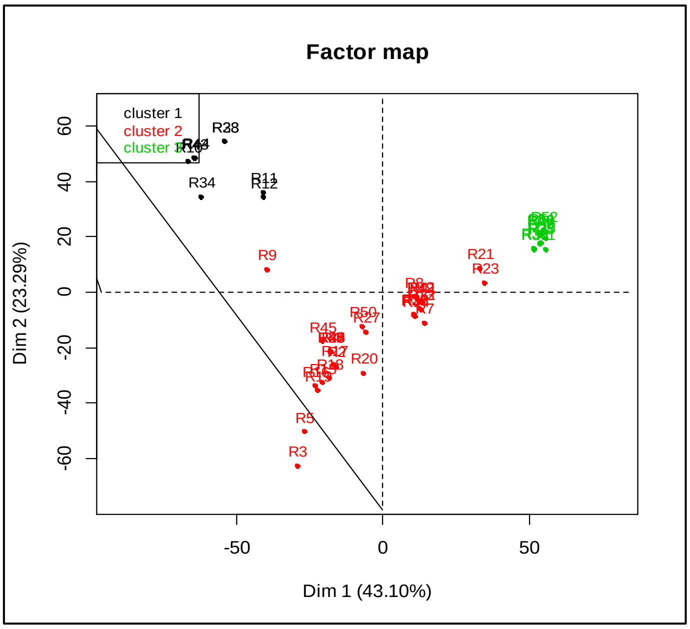


Figure 2: Factor map of plant groupings.

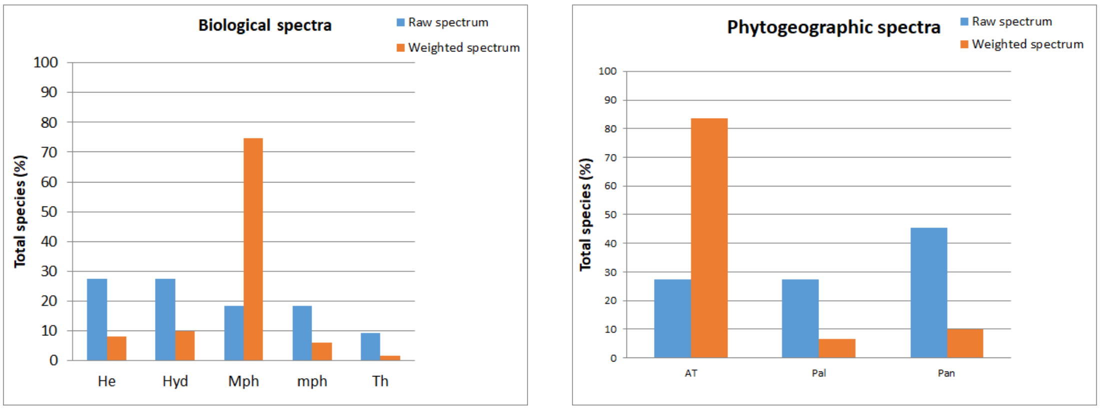
3.2. Characterization of plant groups

Vegetation group with *Rhizophora racemosa and Paspalum vaginatum* (G1)

Group G1 includes 08 surveys conducted along the Gbaga channel. It includes 11 species. There are three strata: the first two (shrub layer and tree layer) are characterized by *Rhizophora racemosa*, *Acrostichum aureum*. The third (sub-shrubby and herbaceous stratum) is characterized by *Paspalum vaginatum*, *Sporobulus virginicus, Echinochloaz pyramidalis, Ethuila conyzoides*.

For this grouping, the species richness (S) is 11 species, the Shannon index (H) is equal to 1.44 bit and the Pielou equitability is equal to 0.41. The low value of the Shannon index (H<3) reveals that the environment constituted by this grouping is not very diversified in species and the low value of the Pielou equitability (EQ<0.6) reveals that few species concentrate the majority of the individuals of the environment.

The analysis of biological types (Figure 3a) reveals that hemicryptophytes (27.27%) and hydrophytes (27.27%) are the most abundant. The weighted spectrum shows that mesophanerophytes (74.64%) followed by hydrophytes (9.68%) are the most dominant. As for the phytogeographical types, Figure 3b shows that the pantropical species (45.45%) are the most abundant, followed by the afro-tropical and paleotropical species (27.27%). On the other hand, the Afro-tropical species are the most dominant (83.48%). They are followed by pantropical species (9.97%).



(a) (b)

Figure 3: Biological spectrum (a) and phytogeographical spectrum (b) of the Rhizophora racemosa and Paspalum vaginatum grouping.

Vegetation group with *Eichhornia crassipes and Oryza barthii* (G2)

This grouping includes 11 surveys and includes 21 species. In this group, the shrub and tree strata are characterized by *Avicennia germinans, Mitragyna inermis*, *Chrysobalanus orbicularis*. The sub-shrub and herbaceous strata are characterized by *Eichhornia crassipes, Oryza barthii Pistia stratiotes, Ethuila conyzoides, Pycreus polystachyos.*

The species richness (S) of the grouping is 21 species, the Shannon index (H) is equal to 1.61 bit and the Pielou equitability is equal to 0.37. The low value of the Shannon index (H<3) shows that the environment constituted by this grouping is not very diversified in species and the low value of the Pielou equitability (EQ<0.6) reveals that few species concentrate the majority of the individuals of the environment.

Figure 4a presenting the biological types of the *Eichhornia crassipes* and *Oryza barthii* grouping shows that hydrophytes are the most abundant in both the gross spectrum (33.33%) and the weighted spectrum (80.01%). The analysis of phytogeographic types in Figure 4b reveals that pantropical species are the most abundant (57.14%) in the gross spectrum, while Afro-tropical species are the most dominant (77.05%) in the weighted spectrum.

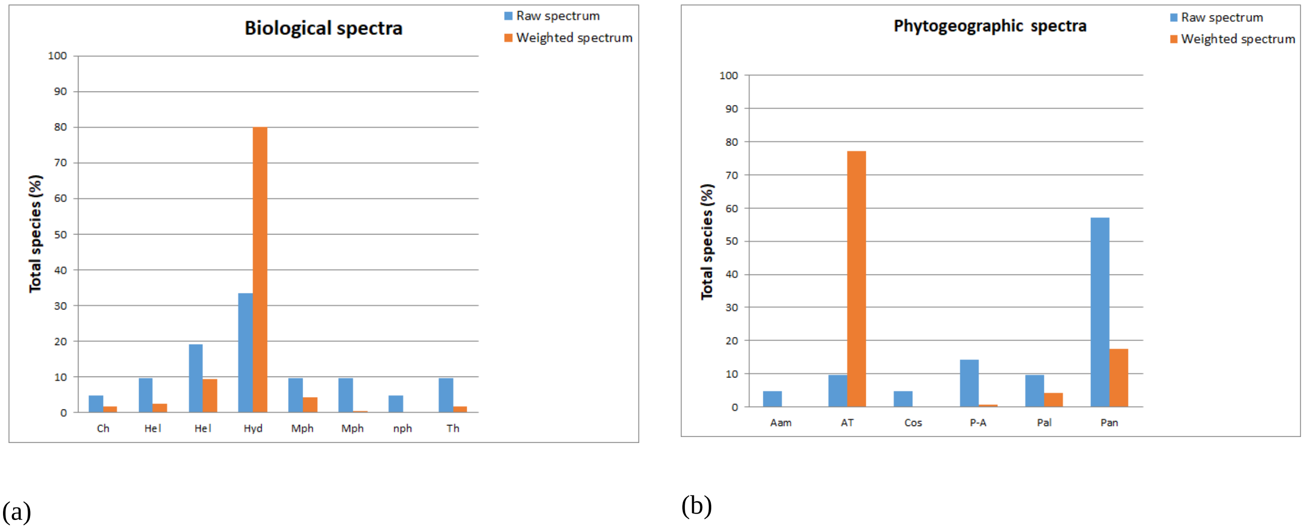


Figure 4: Biological spectrum (a), phytogeographical spectrum (b) of the Eichhornia crassipes and Oryza barthii grouping**.**

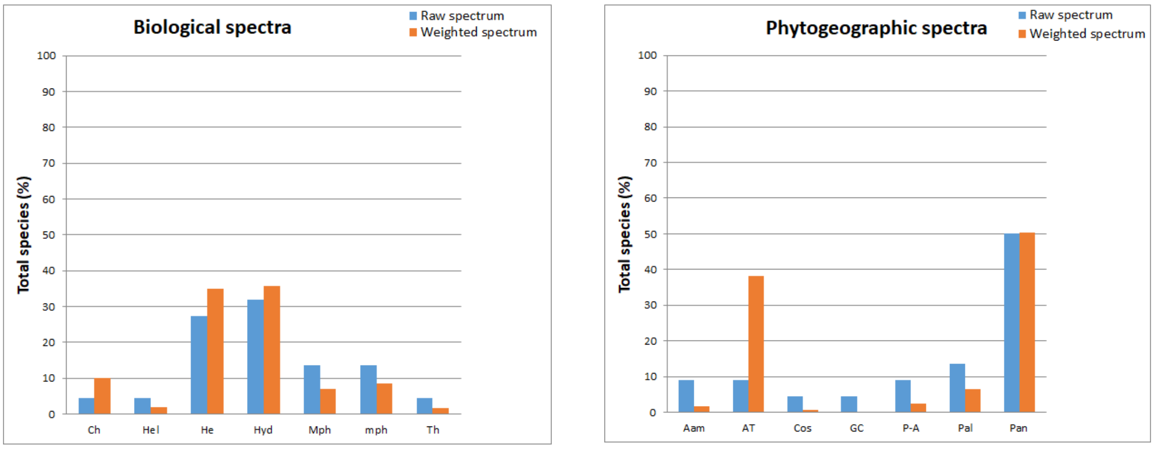
Vegetation group with *Eichhornia crassipes and Paspalum vaginatum (G3)*

This grouping includes 33 surveys conducted along the Gbaga Channel. It has the largest number of species (22 species). The shrub and tree strata are characterized by *Drépanocarpus lunatus*, *Dalbergia ecastaphyllum*, *Mitragyna inermis*, *Zanthoxylum zanthoxyloides*, and the sub-shrub and herbaceous strata are characterized by *Eichhornia crassipes, Paspalum vaginatum*, *Nymphea lotus, Pistia stratiotes, Panicum parvifolium, Schizachyrium sanguineum*, and *Salvinia nymphellula.*

The species richness (S) is 22 species, the Shannon index (H) is equal to 3.06 bits and the Pielou equitability is equal to 0.68. The average value of the Shannon index ($\mathbf{H'} \in [\mathbf{3}, \mathbf{4}]$) indicates that the environment constituted by this grouping is moderately diversified in species and the average value of the Pielou equitability ($EQ \in$ [0,6 0,8]) shows that the distribution of species in the environment is relatively regular.

The analysis of biological types (Figure 5a) shows that hydrophytes are the most abundant in both the raw (31.81%) and weighted (35.81%) spectra.

Figure 5b showing the phytogeographic types of the grouping indicates that pantropical species are the most abundant (50% and 50.41 respectively) in both spectra (raw and weighted).



(a) (b)

Figure 5: Biological spectrum (a) phytogeographical spectrum (b) of the Eichhornia crassipes and Paspalum vaginatum grouping.

4. Discussion

The study of the flora of the Gbaga channel revealed the existence of 35 species divided into 33 genera belonging to 27 families. This number is slightly higher than the one revealed by the studies of Fousseni and his colleagues [16], which is 23 species divided into 23 genera and 17 families, and of the same order of magnitude as that evoked by Roussel & Rivasseau, [17] for the French Overseas Territories (34 species in total, divided into 14 families, are recorded within the eight territories). The specific diversity is however higher than the number of species found in the mangroves of New Caledonia which is 26 species [17].

However, according to the classification of Tomlinson [18] which is generally referred to the plants of the mangrove can be divided into three groups: the true mangroves, the minor elements, and the associated species. The definition of true mangroves corresponds to the definition of exclusive species given by Saenger and his colleagues [19], who distinguish only two stands among all the plant species that can be found in the mangrove. For these authors, there are on the one hand the exclusive species of the mangrove, that is to say those whose presence is limited to the mangrove habitat, and on the other hand the non-exclusive species, which the can be found outside the mangroves but which hold an important place in this habitat. In this context, around sixty exclusive species and around twenty non-exclusive species have been identified on a global scale [19]. However, the estimates of the number of true species, or exclusive species, vary between 50 and 70 according to the authors, without a real consensus having been reached [20]. Mangrove-associated species are generally found in the backwaters. Thus, within the framework of the present study, the analysis of the floristic surveys has allowed the identification of three groups. These are the group with *Rhizophora racemosa* and *Paspalum vaginatum*, which has 11 species, the group with *Eichhornia crassipes and Oryza barthii*, which has 21 species, and the group with *Eichhornia crassipes and Paspalum vaginatum*, which has 22 species. The first group is characterized by a weak presence of anthropic activity leading to the dominance of *Rhizophora racemosa*. Similar observations were made by Fousseni and his colleagues [16], who believe that only three species of the eight characteristic species of mangroves are easily identifiable in the Gbaga mangrove, namely *Rhizophora racemosa and Avicennia germinans, and Achrostichum aureum* Thus the intact areas of the mangrove are low in plant species. These results corroborate with those of Akegbejo-samsons & Omoniyi [9], which state that mangroves often have underutilized ecosystem characteristics, including low species diversity and high productivity.

On the other hand, the second and third group whose impact of anthropic actions is important present a higher diversity and are characterized by the presence of species such as *Paspalum vaginatum, Eichhornia crassipes, Oryza barthii, Drépanocarpus lunatus* and *Dalbergia ecastaphyllum* that are gradually replacing *Rhizophora racemosa* and *Avicennia germinans*. The presence of these species shows the extent of the degradation of the mangrove by human activities [21]. Human activities and the lowering of the standard of living local communities are the real causes of the degradation of the mangroves [22].

Indeed, the tree formations with red mangrove *Rhizophora racemosa* and white mangrove *Avicennia germinans* are increasingly replaced by a herbaceous layer with *Paspalum vaginatum* or shrubby with *Drépanocarpus lunatus* and *Dalbergia ecastaphyllum* [23]. The results thus confirm the intermediate disturbance hypothesis [24], which stipulates that the maximum specific richness is obtained for the stations subjected to intermediate disturbances. Thus the observation of a low floristic diversity in the intact mangroves would be due to the fact that the characteristic species of the mangrove are much more imposing and the mangrove environment much more selective.

The anarchic exploitation of the mangrove is one of the causes of the destruction of plant resources [25]. For other authors, the regression of the mangrove population is due to human policies such as the installation of dams like that of Nagbeto [26]. The search for wood from mangroves as wood energy is also one of the causes of declining mangrove populations [27].

Salinity is also an important parameter that intervenes in the distribution of the mangrove flora of the Gbaga Channel. This result corroborates with those of Hatjé and his colleagues [28], who state that the mangrove flora is characterized by extreme conditions, including high salinity. These results are not dissimilar to those of Verheyden and his colleagues [29], who suggest that spatial differences in soil water salinity influence the distribution of mangrove forest species due to differences in the ability to maintain high and fluctuating salinity among mangrove trees. Salinity is one of the main factors influencing and structuring life in the mangrove ecosystem [30].

5. Conclusion

This work, which aimed to study the diversity of the mangroves of the Gbaga channel, showed that this rich mangrove presents several plant groups with a fairly high diversity of species. However, this diversity is a translation of the state of degradation of the mangrove and shows the impact of anthropic activities. The presence of a few feet of Avicennia germinans and Rhizophora racemosa in the form of relics in undisturbed areas represent an asset for the restoration of the mangrove. Considering the current state of degradation of the mangrove and the important socio-economic role that it plays in the life of the riparian populations; it is urgent that actions be undertaken for its restoration and its development.

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