Chapter 3

The Comparison of Vascular Epiphytes Diversity Related to their Occurrence in Natural and Artificial Mangrove Channels, Greenfields, Eastern Coast of Nicaragua

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.79133

Abstract

The eastern Nicaraguan coasts bordered by mangrove forests are often negatively affected by catastrophic events. One of the most destructive was hurricane Joan in 1988, which damaged as much as 80% of the forests. Though neotropical mangrove woodlands are not famous for their high species richness, vascular epiphytes occurring in the mangrove canopies are characterized by high biodiversity. The research presented in this study was focused on vascular epiphytes found in a private Nicaraguan reservation Greenfields. The main aim of the work presented here was to compare two parts of same-age mangrove area surrounding a water channel that runs through the forest stands in the reservation. The biodiversity observed in the initial natural part of the water channel was compared with the biodiversity observed in the artificial part at the end of the channel. In total, there were identified 13 epiphyte species belonging to 5 families on both banks. The Shannon-Wiener index amounts to 1.63 and Simpson index equates to 0.7. In natural channel, there was Shannon-Wiener index of 1.77 and Simpson index 0.75 and for the artificial part it was 0.82 and 0.46. The most common vascular epiphyte species was *Tillandsia bulbosa* belonging to *Bromeliaceae* family; there were exactly recorded 141 occurrences of this specie which amounts to more than a half of all the individual epiphytes examined in the research.

Keywords: mangrove flora, vascular epiphytes, species diversity, red mangroves, Greenfields, Nicaragua, hurricane Joan

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1. Introduction

Mangroves are notable amphibious ecosystems with narrow habitat specificity. They are adapted to coping with harsh conditions in coastal brackish water. Owing to their ability to persist in extreme environmental conditions such as salinity, anoxic soil conditions or tidal inundation, mangroves form a very important transition between terrestrial and aquatic ecosystems.

The effect of tropical cyclones and mangrove roles in the process of tidal inundation is essential for the proper functioning of the mangrove ecosystems. Periodic destruction of Caribbean mangrove forests by cyclonic storms is proposed as one explanation for their characteristically low structural complexity as well as the lack of typical climax components in the vegetation [1]. Hurricane Joan toppled or snapped in southeastern Nicaragua 80% of the trees and completely destroyed 500,000 hectares (1,200,000 acres) of canopy [2]. Meteorological data are not available for the Greenfields but data from Bluefields 25 km away from there show records of sustained wind speeds of more than 200 km h^{-1}. Rainfall totalled more than 400 mm for the period between October 21 and 23, 1988 [3]. Therefore, Greefields was attacked seriously, and the mangrove vegetation was completely changed. One of the after effects of the hurricane attack was the start of mangrove regeneration which occurred naturally with only minor artificial intervention. However, the human interventions to the natural succession of the ecosystems were as a minor, at the same time, the end part of the water channel was constructed as a prolongation of the natural one. This meant in fact the most significant human influence on the new ecosystem development in relation to the hurricane Joan affects in the area of Greenfields.

Mangrove habitats have relatively low levels of species richness compared to other tropical habitats such as, for example, tropical rain forests [4]. In the American tropics, only 10 species of mangroves have been recognized [5]. In general, floristic diversity equates directly to structural diversity and function of mangroves. The same factors which limit species presence and growth also affect the functions and benefits of particular mangrove stands such as shoreline stabilization, primary production, and habitat for a range of dependent organisms [6]. Regardless of what is the level of species diversity, mangroves are characterized by many specific life strategies and adaptations. Mangrove uniqueness is derived from their pneumatophore arthropod assemblages together with aerial roots which are responsible for the root fixation mostly in estuarine water exposed in anaerobic sediments.

Epiphytes, as for trees, are generally distributed mostly on branches and trunks; however, minor occurrence was also noticed on the aerial roots. The bulk of the epiphytic biomass in the Pacific and many other areas is on branches and although studies of epiphytes on main trunks can be informative, and trunks are not necessarily representative of branches [7]. Vascular epiphytes are a conspicuous part of tropical rainforest canopies, representing a large fraction of plant biodiversity [8] and forest nutrient capital [9].

Many epiphytes also grow on mangrove trees: these include an assortment of creepers, orchids, ferns, and other plants, many of which cannot tolerate salt and therefore grow only high in the mangrove canopy [10]. In Ref. [11], there was mentioned that most vascular epiphytes are

intolerant of salt; thus, one encounters only a limited range of species in the black mangal, while the range is relatively high in the canopy, and in areas transitional to adjacent terrestrial communities where the epiphytes are more characteristics. On the other hand, in Ref. [12], Benzing and Davidson wrote that halophytism has not been reported so far in epiphytes, but a certain level of salt tolerance has. This observation is further proved by Griffiths' note [13] with an example of *Tillandsia paucifolia* growing on *Rhizophora mangle* in South Florida which contained quantities of sodium up to several percent of shoot dry weight. Species of vascular plants associated with mangroves whether as climbers or true epiphytes are the same as those that occur in adjacent terrestrial communities. They are unable to tolerate high salt levels and therefore do not penetrate deeply into the mangrove habitat. There are, however, some apparent exceptions. Some bromeliads, for instance, have succulent leaves and seem to accumulate salt within their tissues. This suggests that they have evolved a degree of salt tolerance parallel to the mangrove trees on which they grow [14]. Benzing and Davidson [12] made a special study of the effects of salt on some epiphytic bromeliads that can occur in Mangroves in South Florida: despite the statement that they can be "dense" on mangroves, it is suggested that *Rhizophora mangle* supports few or no epiphytes because of an axenic bark response, even though seedlings of *Tillandsia pauciflora* can be experimentally germinated on its bark if well-watered.

More than half (about 55%) of the epiphytes live in Americas (New World), in part because neither *Bromeliaceae* nor *Cactaceae* ranges beyond this region except all terrestrials. The responsibility for this asymmetry lies with the heavily epiphytic pantropical families (e.g., *Araceae, Gesneriaceae,* and *Orchidaceae*), a majority of which experienced their robust arboreal radiations in Neotropic woodlands [15].

Atwood [16] estimated that 73% of all species of *Orchidaceae* family are epiphytic; however, considering the relative numbers of epiphytic to terrestrial species validly described since 1986, that percentage has risen. Some species are temporarily submerged during periodic flooding. Although there are no truly marine orchids, some species of *Brassavola, Myrmecophila, Dendrobium*, and other genera are epiphytic on mangroves in estuaries; many others have adapted to salt spray and soil salinity in established coastal dunes [17–19].

Epiphytes and epizoites generally have an adverse effect on the mangroves on which they grow because they block lenticels and impede gas exchange [20]. Mangrove forests occupy about 15 million hectares of tropical and subtropical coastline worldwide. Although they amount to only 1% of the total area of tropical forests, mangroves are highly productive ecosystems rich in biodiversity consisting of a wide variety of plant species that provide important habitats for a wealth of fauna and flora [21].

Within the mangrove environment, most plant species are relatively widely dispersed. However, major differences in the environmental connections also occur, particularly in relation to water, salt, nutrients and light, and it seems clear that the sharp boundaries between areas dominated by different species are often the direct result of competition [22].

It seems no known epiphyte species are exclusive to mangroves. Most bromeliads extend over large altitudinal ranges, nevertheless bromeliads are characteristic epiphytes of mangroves in

tropical and subtropical regions of Central and South America [22]. Common mangrove epiphytes include *Aechmea bracteata* and some species of genera Tillandsia [23].

There is a significant deficiency of information focused on the epiphytes diversity in mangrove forest. One of few studies focused on the assessment of the plant diversity was carried out in Malaysia, but in general, this assessment targets to the quantitative study of the mangrove vegetation primarily [24]. Another study has been done in more similar conditions in Brazil focusing on the diversity and distribution of epiphytic bromeliads in mangroves. This study aimed to assess the diversity of epiphytic bromeliads in a subtropical mangrove, evaluating their distribution and relationship with their host trees [25].

Presented study aimed to characterize and analyze vascular epiphytes species occurring in mangroves and their comparison on the example of Greenfields, East Nicaragua. The research was centered around a hypothesis which suggests that there is more significant level of species richness in natural mangrove channels in comparison with channel constructed artificially. To verify this thought, an observation was held which focused on the measurement of species diversity.

2. Materials and methods

2.1. Study site and plant survey

The study area is located in Nicaragua, South Caribbean Coast Autonomous Region approximately 2 km south of Kukra Hill town, 12°13′ N, 83°44′ W. The research area is a part of a private forest reservation owned by Gaudens Pfranger, which was established to support nature conservation and protection of endangered species. The area is connected to the sea by meandering water channel leading through the mangrove stands. These coastal ecosystems border an adjacent terrestrial biome—a tropical rain forest stand (see **Figure 1**).

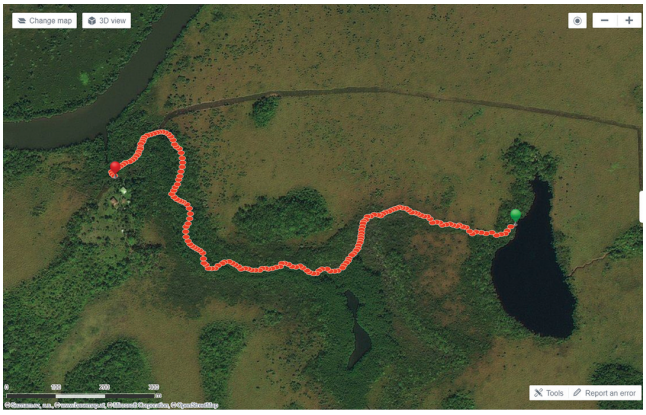

Figure 1. Location of study area and map of the channel (Greenfields, Nicaragua).

The entire forest stands including the mangrove forests in the east coast were destroyed by hurricane Joan in 1988. Although this event may thus appear catastrophic at the first sight, it in fact, triggered a system of regenerative mechanisms leading to necessary succession. Existing water channels surrounded by mangrove ecosystems were reserved and afterwards were established new artificial ones. The artificial channels were excavated in the original mangrove area and in fact opened the previous mangrove stands. Occurring secondary mangrove forests originated from previous mangrove stands was starting their redevelopment by the regeneration after the hurricane attack in 1988. Now they are dominated by red mangroves with prevailing *Rhizophora mangle* in species composition, as was also found in the present study. All the surveyed trees were determined as *Rhizophora mangle*. All mangroves are as was mentioned secondary forest stands, and current forest age is approximately of 30 years.

2.2. Methods

The research took place during a period from May 2015 to July 2015 and was conducted on the banks of a 2-km long mangrove channel in which first part (1200 m) is of natural origin, while the subsequent part (800 m) is artificial, as it was constructed shortly after the hurricane attack. The age of the mangrove stand was considered to be approximately the same (roughly 30 years), considering the concurrent natural regeneration after the hurricane attack and visual homogeneity of the forest stand (homogeneous DBH, mean value 12 cm and tree height, mean value 5.5 m). There was no undergrowth layer under the canopy. Considering that the forest stands on the banks of these two parts are in almost the same age, grow in similar environmental conditions, and the same habitat, it was concluded that the two channel parts could be compared to each other. The density of the forest stand was visually approximated (for mean approximately 30 mangrove stems per 100 m^2) and was recognized as similar as well as the distance between adjacent trees.

The average height of the mangrove forest stand was 5–6 m in total and spread over 22 ha. Due to the high density of the forest stand, the research was carried out according to the following design. A channel leading through the mangrove stand was divided into 20 sectors, each 100 m long. Two edge trees situated directly within the channel bank at the end of each sector were marked and surveyed: one tree on the right side of the channel and one tree on the left side. These trees were determined into the species and epiphytes occurring there were determined as well. Each mangrove tree was surveyed in an appropriate way. In the case of epiphyte occurrence on higher sprays, it was necessary to climb the tree for the purpose of determining the epiphyte species. Additionally, canoes were used in the process of determining the epiphyte species on the lower branches. This two-tree design was chosen due to the enormous number of epiphyte individuals that can be found in the majority of mangroves.

There were two parameters recorded and evaluated in the research: occurrence of epiphytic individuals and vascular epiphytes' diversity. The recorded values were matched with the channel sector where they had been collected, and therefore the parameters were studied at the background of the particular part's origin.

The diversity was analyzed using of two types of diversity indexes—Simpson index [26] and Shannon-Wiener index [27].

3. Results and discussion

Fourty trees were examined in the mangrove channel which was divided into twenty transect, each one hundred meters long. All these tree individuals were determined as *Rhizophora mangle*, which in agrees with conclusions of the available sources stating that more than 40% of the stand on the Nicaraguan Atlantic coasts is formed by red mangrove [28].

Consequently, there were two trees chosen at the end of each 100 m sector, that is, 20 trees on the right bank and 20 on the left bank in total, and the number of epiphytes found on these trees was recorded. Through this method, there were 273 vascular epiphytes found in total. The distribution of the vascular epiphyte individuals is presented in **Table 1**. As was mentioned above, epiphytes prefer habitats on branches rather than on trunks or aerial roots. In agreement with this observation, all the recorded vascular epiphytes occurred on the branches, while no vascular epiphytes were found on the mangroves' stems, which is in agreement with conclusions of Pike's study [7].

Furthermore, it was also observed that there were differences in epiphyte distribution depending on the origin of the channel. The data obtained in the first 1200 m long part of the mangrove channel show a significantly asymmetric distribution of vascular epiphytes (presented in **Table 2**) in comparison to the shorter (800 m) artificial part of the channel (presented in **Table 3**). An

No.	Species	Family	No. of individuals	Natural water channel		Artificial water channel	
				Left side	Right side	Left side	Right side
1	*Tillandsia bulbosa Hook.*	*Bromeliaceae*	141	39	51	36	15
2	*Tillandsia caput- medusacae E. Morren*	*Bromeliaceae*	28	18	10	-	-
3	*Catopsis berteroniana (Schult. & Schult. f.) Mez*	*Bromeliaceae*	26	-	8	15	3
4	*Oncidium* sp.	*Orchidaceae*	19	9	10	-	-
5	*Vriesea* sp.	*Bromeliaceae*	16	4	8	2	2
6	*Tillandsia utriculata L.*	*Bromeliaceae*	11	10	1	-	-
7	*Peperomia* sp.	*Piperaceae*	8	6	2	-	-
8	*Tillandsia anceps G. Lodd.*	*Bromeliaceae*	8	3	5	-	-
9	*Aechmea bracteata (Sw.) Griseb.*	*Bromeliaceae*	7	4	3	-	-
10	*Anthurium trinerve Miq.*	*Araceae*	4	2	2	-	-
11	*Encyclia alata (Bateman) Schltr.*	*Orchidaceae*	3	2	-	1	-
12	*Brassavola* sp.	*Orchidaceae*	1	-	1	-	-
13	*Polypodium fraxinifolium Jacq.*	*Polypodiaceae*	1	-	1	-	-

Table 1. The distribution of the vascular epiphyte individuals.

The natural mangrove channel												
Segment of the channel (km)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Right bank (no. of epiphytic individuals)	0	8	2	6	0	1	1	9	23	0	7	32
Left bank (no. of epiphytic individuals)	0	6	7	17	5	18	1	4	7	1	5	39

Table 2. Distribution of vascular epiphyte in the natural part of the channel.

The artificial mangrove channel							
Segment of the channel (km)	1.3	1.4	1.5	1.6	1.7	1.8	1.9
Right bank (no. of epiphytic individuals)	6	0	0	0	0	0	35
Left bank (no. of epiphytic individuals)	8	1	0	0	0	0	6

Table 3. Distribution of vascular epiphyte in the natural part of the channel.

amount of 73% of all vascular epiphytes were found in the natural channel. However, this is a quit high value, it would be unwise to base any conclusion on this number, as it is necessary to take into consideration the asymmetry between lengths of the natural and the artificial parts of the channel. Therefore, the comparison of biodiversity was based on the following indexes in order to prevent the difference in length from influencing the results.

As the research also focused on epiphyte species diversity, the observed epiphytes were determined into species and families and were evaluated according to their localization within the channel parts. There were 13 epiphytic species and 5 families found in the whole mangrove channel (**Table 1**). The most abundant occurrence was observed for *Tillandsia bulbosa*, *Bromeliaceae* —exactly 141 individuals—which is a number representing more than a half of all the epiphytes that were found here, more precisely 52% (see **Table 1**). The survey led to the discovery that the vast majority of occurrences belong to family *Bromeliaceae.* Seven species belonging into *Bromeliaceae* family were observed in the mangroves, namely, *Tillandsia bulbosa* Hook., *Tillandsia caput-medusae* E. Morren, *Catopsis berteroniana* (Schult. & Schult. f.) Mez, *Oncidium* sp., *Vriesea* sp., *Tillandsia utriculata* L., *Peperomia* sp., *Tillandsia anceps* G. Lodd., *Aechmea bracteata* (Sw.) Griseb., *Anthurium trinerve* Miq., *Encyclia alata* (Bateman) Schltr., *Brassavola* sp., and *Polypodium fraxinifolium* Jacq (**Table 1**). *Orchidaceae* was detected as the family with the second most abundant occurrence and was represented by genera *Oncidium*, *Brassavola,* and *Encyclia alata (Bateman) Schltr.* Epiphytes belongs to family *Orchidaceae* were not found in artificial mangrove channel with the exception of one individual *Encyclia alata (Bateman) Schltr. (***Table 1***).* All the plant species were determined according to the taxonomy used in Flora de Nicaragua [29].

To the comparison of two parts of the mangrove channel in consideration of their origin was to detect essential difference between natural and artificial channel. The species distribution as well as the frequency of occurrence was lower in the artificial channel. There were only four vascular epiphytes species determined in the artificial channel: *Tillandsia bulbosa Hook., Catopsis berteroniana (Schult.* & *Schult. f.), Mez, Vriesea sp.*, and *Encyclia alata (Bateman) Schltr*.

	Simpson index	Shannon-Wiener index
Mangrove channel total (2 km)	0.7	1.63
Natural channel (1.2 km)	0.75	1.77
Artificial channel (0.8 km)	0.46	0.82

Table 4. Comparison of biodiversity indexes results.

For the comparison of the two channel parts, there were two types of indexes used to determine the biodiversity—Simpson and Shannon-Wiener indexes (see **Table 4**). Diversity indices provide more information about community composition than simply species richness.

Based on the collected data, it was found that the values of Simpson and Shannon-Wiener indexes differ depending on the origin of the mangrove channel where the data were collected. The results showed that the epiphytes were abundant on the surveyed mangrove trees in both of natural and artificial channels. The Shannon-Wiener index equals to 0.7 and Simpson index equates to 1.63 (**Table 4**).

In the natural channel, the Shannon-Wiener index was 1.77 and Simpson index 0.75, while for the artificial part, it was 0.82 and 0.46 (**Table 4**). Comparing Simpson index 0.75 for the natural channel and 0.46 for the artificial channel could indicate higher value of evenness of natural mangrove channel (1 is a maximum value—being complete evenness). In case of Shannon-Wiener index, the relative abundances of different species were also taken into account. There should be noticed as well as in the first index higher value in the case of natural channel 1.77 a 0.82. Considerably small value of Shannon-Wiener index could point out the small amount of species, H decreases dramatically as the number of species decreases.

All researched epiphytes were present on the mangrove branches. This fact can be caused by the high level of tidal inundation in a narrow water channel, which does not allow to colonize the basal part of trees or also by the effortless colonization of horizontal parts of mangroves.

4. Conclusion

Based on the results presented above, the following statements can be summarized:

- The diversity of epiphytic communities within the study area is taking into account the results of used indexes relatively high where the diversity of epiphytes located in the natural part of the channel is approximately two times higher than in case of artificial one as was expected definitely. This is very important finding especially when the mangrove ecosystems are generally known as the ecosystems with relatively low species richness [4].
- The epiphytic communities located in the natural channel mangrove forests served (and probably still serves) as a refugium for the new developing epiphytic communities in the artificial part (no epiphytic species different than those which originated in the natural part was found there).

- Even after 30 years of developing the new epiphytic communities in mangrove forests surrounding the artificial part of the channel the diversity is not on the level of the natural one there; however, the abiotic determining abiotic conditions (esp. light conditions) are seemed the same.
- After 30 years of development, the current status of new epiphytic communities located in the mangroves of artificially constructed water channel are on the level of approximately 50% (60% as for Simpson index and 46% as for Shannon-Wiener index) of the fully developed mature epiphytic communities of the mangroves located by the natural one. This fact can be highlighted as an important in the consequences of generally accepted opinion of fast forest community development in tropic areas.
- The differences in the epiphytes distribution are mainly determined by the light conditions on the "stand walls" (i.e., vertical edges) which are in case of natural channel long time opened contrary to the case of artificial channel opened only for 30 years. The main result which authors want to point out is that even after this period the new epiphyte community (in artificial channel) still does not reach the diversity level of original natural one (natural channel).

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