Chapter 9

Analysis of the Conservation of Central American Mangroves Using the Phytosociological Method

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Abstract

Our study of mangrove swamps revealed a total of 120 species, of which 13 are characteristics of mangrove swamps, and 38 of flooded areas with low salt. All the others are invasive species which have taken advantage of the degradation of these natural ecosystems. The scenario is not very different in Laguna de Tres Palos in Mexico. The frequent fires in the low-growing semi-deciduous rainforest (dry forest) have caused intense erosion, with the consequence that the site has silted up. As a result, the first vegetation band of *Rhizophora mangle* is extremely rare. Instead, *Laguncularia racemosa* and *Conocarpus erectus* are dominant, along with a band of *Phragmito-Magnocaricetea* with a high occurrence of *Phragmites australis* (Cav.) Trin., which acts as an indicator of sediment silting. It is extremely frequent for several reasons: as it is the decrease of the salinity of the water, the scarce depth due to the accumulation of sediments and the contamination by the entrance of residual waters of the nearby populations. When the depth and salinity of the water are suitable, the dominant species are *Rhizophora mangle*, *Laguncularia racemosa*, and *Avicennia germinans*.

Keywords: mangrove, conservation, phytosociological method

1. Introduction

Mangrove communities are located in tropical and subtropical areas on different continents between parallel 30° N and 30° S [1]. They are also located in Central America in all the territories of the Caribbean, Atlantic areas of Brazil and on the Pacific Ocean Coast; Ecuador, Colombia, Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, Mexico, California, Florida. Mangrove ecosystems are important because they serve as a refuge for a high diversity of animal species. However, there are various threats that can damage these ecosystems, and deforestation, sediment clogging, and pollution can cause loss of animal species of high ecological value.

Recently, Mendes and Tsai [2] carried out a study of mangrove swamp sediments in a transect from the outermost to the innermost areas of the mangrove swamp. Specifically, they sampled three points containing the species *Laguncularia racemosa*, *Avicennia shaueriana*, and *Rhizophora mangle* and analysed a range of physical and chemical parameters as well as microbial activity. This research highlights the need to preserve mangrove areas against deforestation. Research into the deforestation of forests in protected areas [3] of Latin America reveals that this phenomenon increased from 0.04% to 0.10% between 2004 and 2009, with a significant increase in the number of hectares affected. This is due to the

Figure 1. Caribbean mangrove forests (Dominican Republic) with an intense introgression of the invasive species *Eichhornia crassipes*.

Figure 2. Caribbean mangrove forests (Dominican Republic) showing the severe impact of cutting which leads to GHGs emissions.

Figure 3. Pacific mangrove forests (Mexico). Mangrove swamps threatened by the silting up of the lake basin as a result of the deforestation of the surrounding area. There is currently a severe invasion of *Phragmites australis*.

Figure 4. Mangrove of the Laguna de Tres Palos, Mexico.

density and proximity to the habitat of the rural population and to the decrease in funding for protected areas; however, it is somewhat offset by protection measures in these threatened areas. We recently pointed to the need to establish conservation measures for Central American mangrove swamps [4], as they are facing a number of different threats. One of these is particularly the high rate of sediment deposit caused by the deforestation of surrounding areas which is silting up areas of mangrove; this is the case of several mangrove swamps in Mexico (Laguna de Tres Palos, Acapulco, Mexico). The result is the substitution of the habitat of *Rhizophora mangle* with that of *Laguncularia racemosa*, whose habitat is in turn substituted by *Conocarpus erectus* due to the reduction in the depth of the lake basin, an increased inflow of fresh water and a decrease in salinity. This horizontal dynamic is accompanied by the proliferation of *Phragmites australis* communities, as a species whose optimal development occurs in sites with shallow standing water with low salinity, quite the opposite of the requirements for mangroves. Mangrove communities should therefore be regarded as fragile owing to the fact that they demand a particular depth of water and salinity. Another danger threatening the mangrove habitat is deforestation by the rural population for use as firewood, charcoal, kindling, and as an energy source. This could be reduced if the per capita income of the population were higher, thereby affording them access to other energy sources. In view of these considerations on the situation of these habitats, our aim is to determine their degree of diversity and state of conservation (**Figures 1–4**). Therefore, we collected phytosociological data, which is essential to understand species diversity and community pattern in Central America. We have also discussed how results from this study can help in conserving mangroves in Central America.

2. Material and methods

We study the diversity and state of conservation of mangrove forests based on the analysis of 16 plant communities distributed throughout Central America (Mexico, Cuba, Dominican Republic) (**Figure 5**) using floristic inventories compiled by several authors [4–6]; this analysis uses over 70 field samplings grouped by ecological, physiognomic and floristic affinity in 16 plant communities. For each sampling, data were taken of the plot size in m2, (40 x 20) coordinates, coverage in percentage, average height of the dominant species and all the species present. Each plant community presents a particular floristic composition; therefore, in the statistical treatment, we will only take into account the flora of each plant association, since

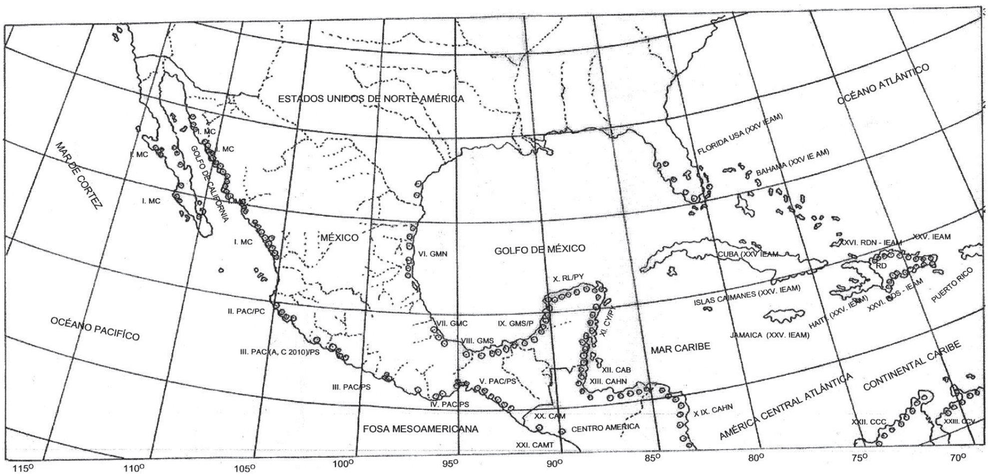

Figure 5. Mangrove areas studied in Central America [4].

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Asociaciones	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Avicennia germinans (L.) L. **	II	IV	V	II	IV	II		V						V	III	V
Laguncularia racemosa (L.) Gaertn.**	V	V	V	II	V	III	IV	I								V
Rhyzophora mangle L.**	V	IV	III	II	I	III	V						V			
Conocarpus erectus L.**	II	II	III	V	III	V	III		V	I		V				II
Batis maritima L.**	II	I	III	I				V							III	II
Dalbergia ecastaphyllum (L.) Taub.*	II	I					V			V						
Rhabdadenia biflora (Jacq.) Muell.Arg.**	II	II	I	II			III	I								
Coccoloba uvifera (L.) L.*	II	I	I	I					V							
Pavonia paludicola Nicols.**	II	I	I				V									
Acrostichum aureum L.*	II	I	II	I												
Annona glabra L. *	II	I	III	I	I											
Bucida buceras L.*	II		II	I												
Bacopa monnieri (L.) Pennell*	I															
Borriria arborescens (L.) DC.*		I	I	I												
Conocarpus erectus L. var. *sericea* (Forst.) Borhidi					I			I								
Crataeva tapia L.*					I	II										
Cydista aequinoctialis (L.) Miers*	I															
Cyperus alternifolius L.*		I														
Cyperus odorata Vahl*	II	I														
Dalbergia berterii (DC.) Urb.*	II															
Echinochloa polystachya (Kunth) Hitchc.*		I														
Eichlornia crassipes (Mart.) Solm**		I														
Eleocharis interstincta (Vahl) R. & S.*		I														
Eleocharis mutata (L.) Roem. & Schult.*		I														
Heterostachys ritteriana (Moq.) Urg.-Sternb.**		I														
Hippomane mancinella L. *	II															
Ipomoea tiliacea (Willd.) Choisy*	I		I	I												
Lonchocarpus palmeri (Rose) *M. Souza**					III											
Ludwigia octavalvis (Jacq.) Raven*		I								II						
Lycium tweedianum Griseb.*	II	I		I												
Machaerium lunatum (L.f.) Ducke*	II	II		I												
Mimosa pigra L.*					I											
Morinda citrifolia L.*	II			I												

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Nephrolepis multiflora (Roxb) Jarrett ex Morton *	II															
Paspalum geminatum L.*				I												
Phragmites australis (Cav) Trin.*					I	II										
Phyllanthus elsiae Urban**					I											
Pithecellobium lanceolatum (Willd.) Benth.**					I											
Polygonum acuminatum H.B.K.*		I														
Pterocarpus acapulcensis Rose*						II										
Pterocarpus officinalis Jacq.*	II	I														
Rachicallis americana (Jacq.) Ktze.**				I												
Rhynchospora corymbosa (L.) Britton**																
Roystonea hispaniolana L. H. Bailey*	II	I														
Sabal causiarum (Cook.) Becc.*	II															
Salicornia bigelobii Torr.**	I	I														
Sesuvium portulacastrum (L.) L.**	II	I		II				I							III	
Sthalia monosperma (Tul.) Urb.*	II		III													
Typha domingensis Pers.*	II	III		I	I	I										
Bucida palustris Borhidi							III									
Tabebuia angustata Britt.							III									
Roystonea regia (HBK) Cook							I									
Sabal parviflora Becc.							I									
Sarcostemma clausum L.							II	I								
Cissus trifoliata L.							I									
Hohenbergia penduliflora (A. Rich.) Mez.							II									
Tillandsia fasciculata Sw.							II									
Tillandsia usneoides L.							II									
Tillandsia valenzuelana A. Rich.							II									
Baccharis halimifolia L.								II								
Iva cheiranthifolia L.								I								
Distichlis spicata (L.) Greene								I								
Fimbristylis spathacea Roth								I								
Salicornia perennis Mill.								I								
Suriana maritima L.									II							

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Cannavalia maritima (Aub.) Thons	I								r	II			r			
Morinda royc L.									r				r			
Caesalpinia bonduc (L.) Roxb.									r	V			r			
Ipomoea alba L.	I									V	II					
Cordia sebesteana L.									r				r			
Dalbergia brownei (Jacq.) Urb.										III	V					
Muntingia calabura L.											I					
Panicum purpurascens Raddi										r						
Chamaecrista diphylla (L.) Greene										r						
Cyperus tenuis Sw.										r						
Spilanthes urens Jacq.										r						
Acacia macracantha H. & B. ex Willd			I													
Aristolochia trilobata L	I		I													
Bursera simaruba (L.) Sarg.	I		I													
Calophyllum calaba L.	I															
Capparis flexuosa (L.) L.	I	I	II	I	I											
Cassytha filiformis L.	I															
Cecropia schreberiana Miq.	I															
Chrysobalanus icaco L.	I															
Cissus verticillata (L.) Nicols.	I	I	II													
Citharexylum fruticosum L.				I												
Clusia rosea Jacq.	I															
Corchorus hirsutus L.			I													
Costus speciosus (J.Konig) Sm.																
Crescentia cujete L.	I		I													
Erithalis fruticosa L.	I															
Ficus velutina H. & B. ex Willd.	I															
Guapira discolour (Spreng.) Little				I												
Guazuma ulmifolia Lam.					I					r						
Harrisia nashii Britt. & Rose				I												
Hippocratea volubilis L.	I		I													
Ipomoea pes-caprae (L.) R. Br.	I															
Ipomoea violacea L				I												

Asociaciones	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Leucanea leucocephala (Lam.) De Wit									r				r			
Lonchocarpus domingensis (Turp.) DC.	I		I													
Lonchocarpus pycnophyllus Urb.				III												
Luffa cilindrica L.			I													
Maclura tinctoria (L.) D. Don				I												
Mikania cordifolia (L.f.) Willd.	I	I														
Mucuna pruriens L.					I											
Paullinia pinnata L.	I		I													
Pentalinum luteum (L.) Hansen & Wunderlin				I												
Pereskia quisqueyana Alain				I												
Phoradendron quadrangulare (HBK) J. K. & U.						I										
Pithecellobium unguis-cati (L.) Mart.				I												
Prosopis juliflora (Sw.) DC.				I	I											r
Randia aculeata L.	I		I													
Salpianthus purpurascens (C.ex Lag.) H. et A.					I											
Sapindus saponaria L.				I												
Sophora tomentosa L.	I															
Stigmaphyllon bannisterioides (L.) A. E. Anderson		I														
Terminalia catalpa L.	I															
Thespesia populnea (L.) Soland.	I	I	I	I						II	I					
Vigna luteola (Jacq.) Benth.	I															
Wedelia trilobata (L.) Hitchc.	I															
Zamia debilis L.				I												
Ziziphus rignoni Delp.				I												

1—As. *Machario lunati-Rhizophoretum manglis* Cano et al. 2012. 2—As. *Rhabdadenio biflori-Laguncularietum racemosae* Cano et al. 2012. 3—As. *Sthalio monospermae-Laguncularietum racemosae* Cano et al. 2012. 4—As. *Lonchocarpo pycnifolli-Conocarpetum erecti* Cano et al. 2012. 5—As. *Lonchocarpo sericei-Laguncularietum racemosae* Cano et al. 2012. 6—As. *Crataevo tapiae-Conocarpetum erectae* Cano et al. 2012. 7—*Dalbergio-Rhizophoretum manglis* Borhidi 1991 (Borhidi 1991, Table 97 inv. 1–5). 8—As. *Batidi-Avicennietum germinantis* Borhidi & Del-Risco & Borhidi 1991 (Borhidi 1991, Table 98 inv. 1–6). 9—As. *Conocarpo erectae-Coccoloetum uviferae* Reyes in Reyes & Acosta 2003 (Reys & Acosta 2003, Table 2 inv. 1–6). 10—*Caesalpinio bonduc-Dalbergietum ecastophylli* Reyes & Acosta 2003 (Reyes & Acosta 2003, Table 3 inv. 1–6). 11—*Dalbergietum browney* Reyes & Acosta 2003 (Reyes & Acosta 2003, Table 4 inv. 1–4). 12—*Conocarpetum erectae* Reyes in Reyes & Acosta 2003 (Reyes & Acosta 2003). 13—*Rhizophoretum manglis* Cuatrecasas 1958 (Reyes & Acosta 2003, Table 6 inv. 1–10). 14—As. *Avicennietum germinantis* Reyes & Acosta 2003 (Reyes & Acosta 2003, Table 7 inv. 1–10). 15—As. *Batidi-Avicennietum germinantis* Borhidi & Del-Risco & Borhidi 1991 (Reyes & Acosta 2003, Table 8 inv. 1–3). 16—As. *Laguncurio racemosae-Avicennietum germinantis* Reyes & Acosta 2003 (Reyes & Acosta 2003, Table 9 inv. 1–7).

Table 1. Synthetic table of the plant associations studied.

each association presents its own characteristic species and companions; we add a synthetic index to each species from r, +, I to V, to represent the presence/absence of species in the community. These indices are transformed into Van der Maarel indices [7] for statistical treatment, with the following equivalences: The value r means that the species is very rare, and that it only appears very sporadically, we assign it the same value as +; r, + = 2; value 2 indicates the species is rare and only found in certain isolated inventories in the plant community; I = 3, indicating the species is present in under 40% of the total samplings for the community; II = 4, in 40–55%; III = 5, in 55–70%; IV = 6, in 70–80%; and V = 7, in 90–100% of the total samplings carried out for a particular community (**Table 1**). We then run a series of statistical analyses on the Excel table with the 16 plant communities: cluster (Jaccard's distance) to determine the similarity between communities, diversity (Shannon) for A, B, C and ordination by DCA. We used the statistical packages CAP (Community Analysis Package III) and Past. For the state of conservation, we follow [8].

$$\text{Degree of conservation Gc } = \frac{\text{C} \times \text{AM} \times (\text{A/Dcar.–A/Dcom.}) \times \text{RF} \times \text{Sm}}{\text{R}}$$

1. C = Coverage on a per unit basis
2. AM = Average height of dominant species
3. Acar. – Acom. = Difference between the average values of the abundance indices of characteristics in higher syntaxonomic units in the association and the average values of the association companions.
4. RF = Floristic richness (value 1 if all the species are characteristic; 0.5 if characteristics and companion species are 50%, and 0 where there is no characteristic of the community, signifying that the original community has disappeared.
5. Sm = Minimum area in relation to the area of distribution of the community (subsector, district value: 0.5; sector: 1; subprovince, province: 2; group of provinces: 3.
6. R = Extremely rare phytocoenosis; value 3, rare 2 and normal 1.

   a. **Species that live in humid environments that are temporarily or permanently waterlogged and have high salinity (mangrove forest plants), in environments in which the salinity ranges between 0.2% and 1.3%, according to [9].

   b. *Species that live in humid or temporarily waterlogged environments with or without slight salinity (species in transition between the mangrove forest and neighbouring communities); in this case, the salinity gradient is less than 0.2%. These are species that live in places that are waterlogged with freshwater, as in the case of Gran Estero in the Dominican Republic [10].

   c. Invasive species from nearby communities typical of dry environments. These are species from communities in the surroundings, essentially belonging to the dry forest [11].

3. Results and discussion

This study revealed findings about mangrove community and adjacent vegetation's structure in Central America. This kind of phytosociological studies is ecologically significant and useful in conserving and managing ecosystems. The study identified that deforestation leads to siltation of soil, which can alter vegetation structure in surrounding areas.

3.1. Community analysis

Jaccard's analysis of similarity/dissimilarity shows that coincidences/differences between the plant communities are between 40 and 60%. The highest differences occur between group I (1–7) and group II (9–15) of the cluster (**Figure 6**). This is due to the different floristic composition of the plant communities caused by the influx of invasive species. This cluster analysis is confirmed by applying the DCA analysis (**Figure 7**), which shows two clearly differentiated groups of communities. Group GA in this analysis belongs to communities 9, 10, 11, 12, 13, 14, 15, which are characterised by a low presence—and even the absence—of mangrove species; in contrast, group GB has a very high presence of mangrove species. **Table 1** reveals the presence of 16 species (13.11%), which require strict ecological conditions of salinity and depth, as opposed to 33 species (27.04%) that grow in a low or non-existent salinity gradient, and 73 opportunistic invasive species from neighbouring habitats that penetrate owing to the significant silting of the lake basin (59.83%); this can be seen in the following vegetation profile (**Figure 8**) showing the introgression of dry forest species in the mangrove forest.

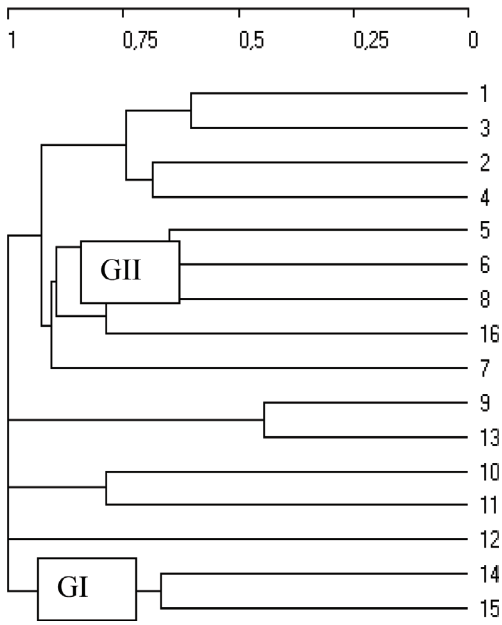

Figure 6. Jaccard similarity/dissimilarity cluster analysis of the 16 plant communities.

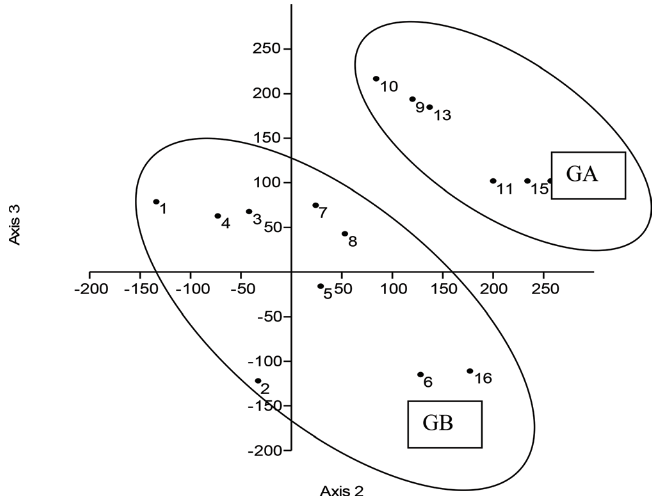

Figure 7. DCA ordination analysis separating the two groups (group GA and group GB) of mangrove communities.

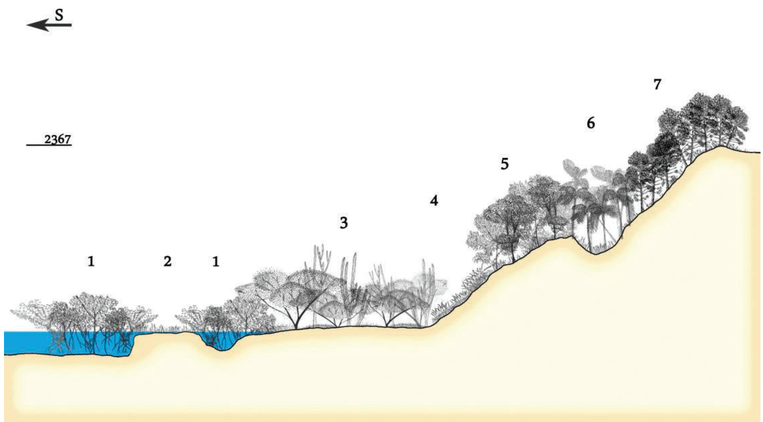

Figure 8. Profile of the vegetation of the cloud forest of Sierra Bahoruco. (1) *Rhabdadenio biflori-Laguncularietum racemosae* and *Lonchocarpo pycnophylli-Conocarpetum erecti*. (2) Salt marshes of *Batidi-Salicornietea*. (3) *Lonchocarpo pycnophylli-Cylindropundietum caribaeae*. (4) *Melocacto pedernalensis-Leptochloopsietum virgatae*. (5) Broad-leaved forest. (6) and (7) Cloud forest of *Prestoea montana*.

The communities in group I of the cluster have 11.68% of characteristic mangrove species, as opposed to 4.96% in group II. Salinity gradient in a given area depends on hydrology of that area. Lugo and Snedaker [12] first formulated the mangrove forest ecological classification system based on physiographic and structural components of mangroves of Florida. This study also showed vegetation groups based on salinity gradient. Modification of environmental parameters, such as salinity, depth of water, as a consequence of clogging, is a cause of change in the structure and diversity of the mangrove [13], and this change implies an increase in diversity due to a decrease in species specific to the mangrove and an increase in invasive species from nearby ecosystems. By analysing the state of conservation and the diversity of these ecosystems, it can be seen that those with a high Shannon value are not better preserved; on the contrary, the best preserved are those that have few species, but all or most of them are typical of the mangrove ecosystem.

3.2. Diversity analysis

Shannon's diversity analysis was applied to the characteristic mangrove species, the invasive species and the total species in the mangrove forest, and to the 16 plant communities. This was done based on the synthetic table published by ourselves [7]. This table comprises 16 characteristic mangrove plants, 33 plants that grow in areas of wetland and standing water with a low salt content (these are invasive plants in wetland sites), and 73 opportunistic invasive species from nearby areas that penetrate into mangrove forests due to a decrease in the depth of the lake basin as a result of silting.

Table 2 reveals that communities 1–8 have a greater floristic richness than 9–16. There are 10 communities in which the Shannon index ** for characteristic species is greater than 1, and all the other communities have the value zero, signalling that these communities are not rich in mangrove species or have one single species. Paradoxically, in all communities except 12 and 16, the Shannon values for invasive species is equal or are higher than the values for characteristic species. This highlights the negative impact on the mangrove forest, and its substitution by invasive species. There are also anomalous situations such as community 14, where the Shannon value is zero in all cases; or 6, in which the total diversity value, 1.099, coincides with the characteristic species diversity, 1.099, due to the fact that the community has only mangrove species. In practically all cases, the typical floristic richness of characteristics** is very low compared to the floristic richness of invasive species S* + invasive plants, signalling a significant threat for mangrove forests. **Figures 9–11** show that communities 9–15 present a very low species diversity of characteristic mangrove plants, compared to the first communities, which are more diverse. Communities 9, 10, 12, 13 and 14 have a single mangrove species—thus constituting monospecific populations—and in communities 11 and 15 the species** totally disappear.

3.3. Analysis of the state of conservation

To determine the state of conservation of the 16 plant communities studied in Central America, we apply the degree of conservation index (Gc) established by ourselves [8]. The best conserved communities are evidently the most biodiverse, as in these communities (1–8) the floristic richness (Rf) is high, ranging between 0.5 and 0.11; while communities 9–16 have a floristic richness (Rf) of between 0.01 and 0.04. In this second case, community 10 has a value Gc = −0.091, due to the fact that Acar = 1 (average values for the abundance of characteristic species) and Acom = 2.63 (average values for the abundance of companion species). **Table 1** shows that community 10 has a single mangrove species** and 12 S* + invasive plants; in this case, the community is under major threat. However, the other communities −9, 11, 12, 13, 14, 15 and 16– present higher values for Acar than Acom, so the threat of

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	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Shannon_H (total)	3.965	3.46	3.252	3.503	2.842	2.164	2.733	2.419	2.004	2.502	1.723	1.554	1.537	0	0	1.099
Shannon_H**	2.157	2.34	1.899	2.044	1.881	1.365	1.598	1.703	0	0	0	1.349	0	0	0	1.099
Shannon_H (* + invasive plants)	3.797	3.082	2.978	3.251	2.384	1.6	2.365	1.785	1.887	2.423	1.609	0	1.318	0	0	0
Shannon_H (other invasive plants	3.219	1.609	2.559	2.697	1.609	0	2.286	1.785	1.785	2.241	1.609	0	1.318	0	0	0
Taxa_S_t	54	33	27	34	18	9	16	12	8	13	4	1	6	1	3	5
Taxa_S_**	9	11	7	8	7	4	5	6	1	1	0	1	1	1	0	4
Taxa_S_* + invasive plants	45	22	20	26	11	5	11	6	7	12	4	0	5	0	0	1
Taxa_S_Invasive plants	25	5	13	15	5	1	10	6	6	10	4	0	5	0	0	1
Individual_t	193	114	103	113	65	39	76	45	33	56	17	7	22	7	15	25
Individual_**	41	45	35	33	30	21	30	26	7	3	0	7	7	7	0	22
Individual_* + invasive plants	152	69	68	80	35	18	46	19	26	53	17	0	15	0	0	3
Individual_invasive plants	75	15	41	47	15	3	39	19	19	42	17	0	15	0	0	3

Table 2. Shannon values for characteristic mangrove species and invasive species: number of species and individual per community.

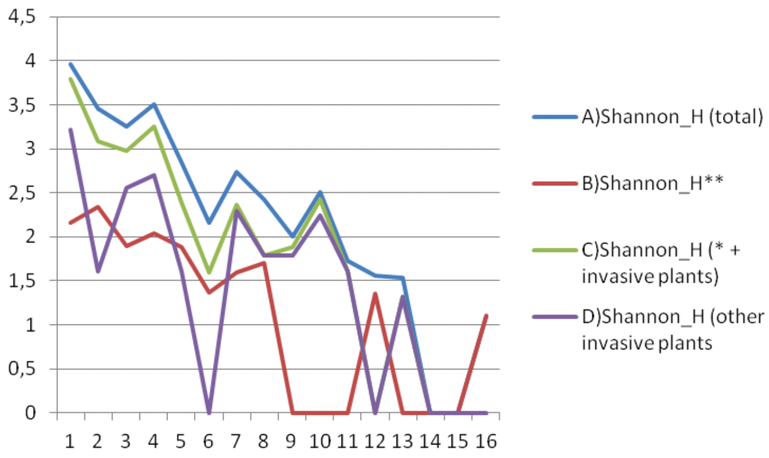

Figure 9. Shannon diversity graph of the four situations. (A) the total species in the community; (B) only characteristic mangrove species; (C) invasive species (both those growing in flooded areas, and invasive species due to the loss of the lake basin); (D) invasive species from nearby communities due to the silting of the lake basin.

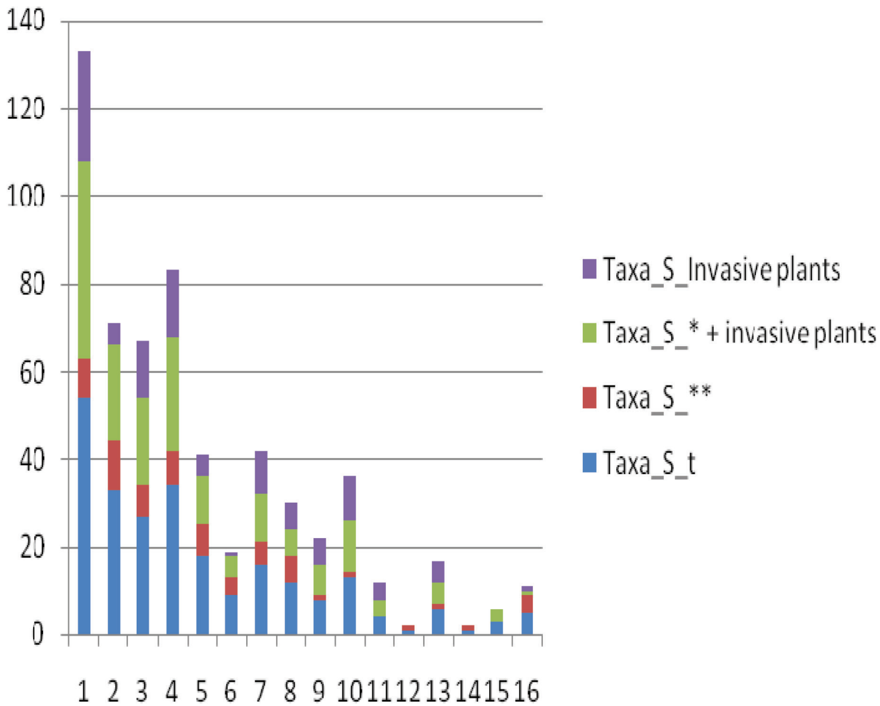

Figure 10. Graph showing the number of characteristic and invasive species.

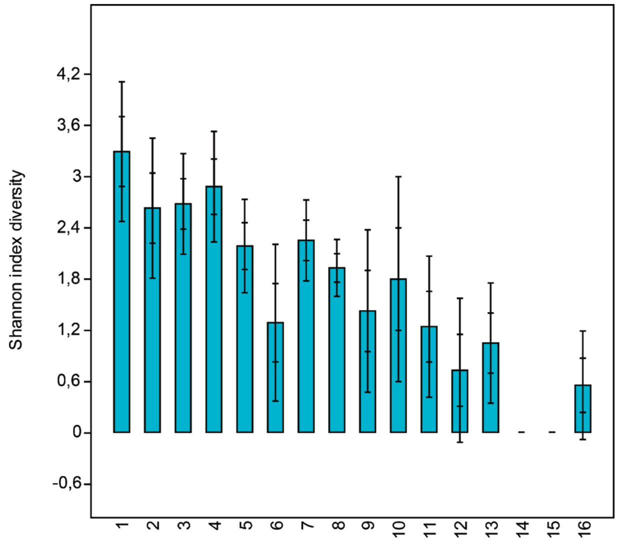

Figure 11. Box plot of the Shannon index.

	C	AM	Aca	Aco	Aca-Aco	Rf	Sm	R	Gc
1	0.948	8.20	2.55	1.37	1.18	0.09	1	2	0.412
2	0.923	7.70	2.09	1.13	0.96	0.11	2	1	1.506
3	0.883	7.20	3.00	1.40	1.60	0.07	3	1	2.150
4	0.880	6.50	2.12	1.07	1.05	0.07	2	1	0.129
5	0.100	10.0	2.28	1.18	1.10	0.07	2	2	0.077
6	0.980	5.20	3.25	1.60	1.65	0.05	2	2	0.420
7	0.920	18.5	4.00	2.00	1.70	0.05	2	2	1.702
8	0.691	6.50	2.33	1.16	1.17	0.06	2	2	0.315
9	0.900	7.00	5.00	1.85	3.15	0.01	2	2	0.198
10	0.800	7.00	1.00	2.63	(− 1.63)	0.01	2	2	(−0.091)
11	0.800	4.00	5.00	1.00	4.00	0.01	2	2	0.128
12	0.900	5.00	4.50	1.00	3.50	0.04	2	2	0.630
13	0.900	8.50	5.00	2.25	2.75	0.01	2	2	0.210
14	0.900	10.0	5.00	0.00	5.00	0.01	2	2	0.450
15	0.691	6.50	5.00	0.00	5.00	0.01	2	2	0.224
16	0.900	12.0	3.50	0.00	5.50	0.04	2	2	1.510

Table 3. Analysis of the degree of conservation of the mangrove communities.

these communities disappearing is negligible or non-existent, with the particularity that communities 14, 15 and 16 have values of Acom = 0 and have no invasive companion species and are thus the best conserved communities. In the first group of communities (**Table 3**), although the floristic richness of ** is high, the Rf of * + invasive plants is also high, implying a significant degree of threat.

The threats that affect the mangrove are several; among which we highlight tourism, industries, infrastructure and deforestation. The methodology used to find out the conservation status of these ecosystems is based on the phytosociological method. With this method, 16 plant communities have been described, which present ecological and floristic differences. Each plant association presents its own characteristic species (Acar), and companion species (Acom) belonging to neighbouring communities. For this reason, and for the first time, we take stock of the relationship between characteristic and companion species, and in response to this, the state of conservation of the plant association. The state of conservation of the mangrove is high when all its species are characteristic, as this ecosystem is poor in characteristic species, its conservation is good, but if it presents a high diversity, it means that it presents many opportunistic companion species, and the state of conservation the mangrove is bad.

4. Conclusions

The floristic diversity presented by some mangrove communities is not synonymous with a good state of conservation, but rather the reverse: this diversity is a cause for concern, as it is due to the high number of invasive species that are difficult to eradicate while the current threats are maintained, in the form of cutting, burning, forest fires, charcoal manufacture, and so on.

Therefore, the best conserved mangrove communities are those which present only typical mangrove species and no companions, even in the case of monospecific populations of *Rhizophora mangle, Laguncularia racemosa, Avicennia germinans, Conocarpu erectus.* The mangrove forest must be regarded as a fragile ecosystem as it demands ecological conditions of depth of water, salinity, and a very specific substrate, and in which any alteration triggers the deviation and substitution of these communities by neighbouring ones.

Based on the results obtained, we propose concrete measures to mitigate and prevent the destruction of the mangrove communities:

1. Not to carry out deforestation in peripheral areas to avoid erosive phenomena and the consequent filling of the lagoon vessel.
2. Deforestation with the aim of obtaining energy (coal) must be prohibited.
3. Implement policies for the integration of rural populations in their environment.
4. Control of mass tourism.

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