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BIOLOGICAL DIVERSITY IN THE AYAPEL (COLOMBIA) FLOODPLAIN SYSTEM

DIE BIOLOGISCH-GEOÖKOLOGISCHE VIELFALT DES CIENAGA AYAPEL-SYSTEMS IM SANJORGE-CAUCA-MAGDALENA BINNENLANDDELTA, KOLUMBIEN

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ABSTRACT

Ayapel marsh and hundreds of water-bodies in the surroundings are permanent wetlands that belong to the inland delta of the San Jorge and Cauca rivers in the Caribbean coast of Colombia. The delta covers more than 140 km² during the flood period. Because of its strategic position near the foothills, close to Andean settlements, and being the first large wetland of the Momposina Depression, there are several important reasons to study Ayapel. Scientific data compiled by the University of Antioquia through the GAIA and GeoLimna research groups, have conclude geological, hydrological, limnological and geographical projects in the last decade. One of the most conspicuous criteria by which Ayapel is well known, is for its Fauna and Flora, especially by the numerous and diverse migratory birds, endangered mammals species and the variety and size of fish. The fish production in the 80›s reached 30,000 Ton annually. This document is an approach to the description and quantitative analysis of the biological diversity found in different studies in the zone, which has never before been compiled. Secondary information was used as source of data, with which we are proposing the interest to subscribe Ayapel as a Ramsar-Convention site.

Keywords: marsh, wetlands, biodiversity, flooding period, migration birds, endangered mammals, wet savannah climate, RAMSAR

ZUSAMMENFASSUNG

Die tropische Flachseeregion (Cienaga) von Ayapel mit hunderten von stehenden und saisonal kommunizierenden Gewässern in der Umgebung ist dauerhaftes Feuchtgebiet des Binnenlanddeltas, das von den Flüssen Rio San Jorge und Rio Cauca im karibischen Küstentiefland Kolumbiens gebildet wird. Es bedeckt während der Überschwemmungsperiode eine Fläche von ca. 140 km². Wegen seiner großen amphibischen Fläche sowie der damit verbundenen Artenvielfalt an Flora und Fauna, aber auch der Nähe zu andinen Städten Kolumbiens unmittelbar am Fuße des Berglands, hat Ayapel schon früh das Interesse der Menschen auf vielfältigste Weise geweckt. Deshalb haben Wissenschaftler der Institutionen GAIA und Geo Limna der Universität von Antioquia im letzten Jahrzehnt intensive geographische, geologische, hydrologische, limnologische, biologische und ökologische Studien in diesem Bereich durchgeführt. Eines der wichtigsten Kriterien, weshalb die Cienaga so bekannt ist, sind die zahlreichenden Ressourcen an Fauna und Flora, mit temporärem Aufenthalt von Migrationsvögeln und der Beheimatung von gefährdeten Säugetieren sowie der einmaligen Artenvielfalt und Mengean Süßwasserfischen (in den 80er Jahren wurden ca. 30,000 Tonnen Fisch jährlich gefangen). Das vorliegende Dokument bietet eine quantitative Analyse der bisherigen Bestandsaufnahme biologischer und ökologischer Vielfalt, die es weiter zu ergänzen und vor allem zu erhalten gilt. Deshalb laufen intensive Bemühungen die Region der Cienaga von Ayapel unter den Schutz der RAMSAR-Konvention zu stellen.

Schlüsselworte: Cienaga = tropische Flachsee- und Sumpfgebiete, Artenvielfalt – Biodiversität, Wasserstandsamplituden, Migrationsvögel, gefährdete Säugetiere, Feuchtsavannenperiodizität, RAMSAR

1 INTRODUCTION

Tropical Marshes or Cienagas, as they are called in Colombia, refer to lakes on floodplains, are shallow bodies of water with direct or indirect connection to a river (temporary or permanent). They have a water column of no more than 10m, presenting stratification and mixing during the day and isothermic properties at night (polymictic warm systems) according to Lewis (1983). They are subject to the fluctuating level of the river, which is related with the hydrological regime (Montoya and Aguirre, 2009-1). Additionally, they show temporarily floating and rooted vegetation, high concentration of humic substances and saturated soils. According to Roldan and Ramirez (2008), this kind of ecosystem presents three different ecological zones:

1. Area of open water of variable depth.

2. Areas of bays, usually shallow.

3. Marginal vegetation zones.

It is estimated that Colombia has 1,900 wetlands with a total area of 478,418 ha. The Magdalena river floodplain is highlighted with an area of 320,000 ha, being the largest (Arias et al. 1983). The Ayapel Floodplain System (AFS) is the fourth in size among these ecosystems in the country. The Cienaga of Ayapel (see Fig.1) belongs to the floodplain of Cauca and San Jorge rivers. The zone has an altitude of 25 m.o.s.l. in a warm humid tropical climate and is situated at 8°20› 32» N and 75°05› 47» W.

One of the most emphasized aspects in the literature about Ayapel wetland, is the highlighted biological richness (Hernandez 2011, Aguirre et al. 2011, Villabona et al. 2010, Montoya et al. 2011-1). Some current and past studies about biological features are widely reported, which has motivated the interest in the region. The most common references are on fish, which are very well-known and exploited resources in the region, as much for the size of

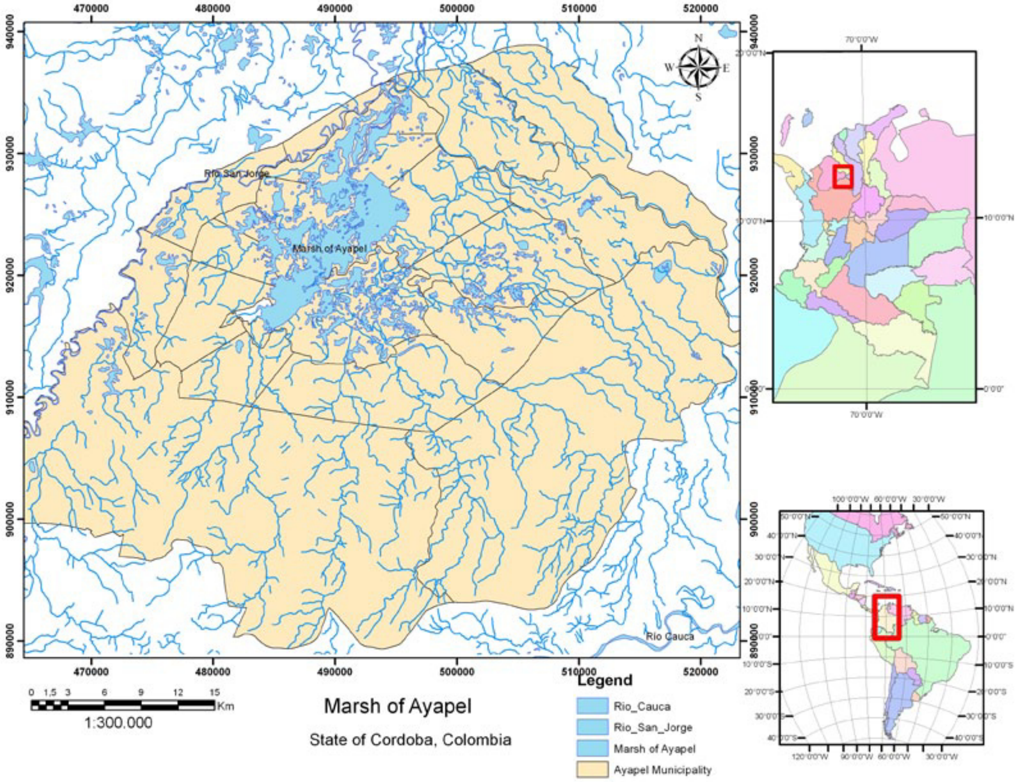

Fig.1: *Cienaga of Ayapel, State of Cordoba, Colombia. Ayapel is under the influence of a flood pulse with a flood period between May and November and a drought period between December and April.*

Abb.1: *Die Schwemmlandebene Cienaga von Ayapel im Departament Cordoba, Kolumbien bei mittlerem Wasserstand. Das Einzugsgebiet der Cienaga von Ayapel wird durch den jährlichen Wechsel von Flut in den Monaten Mai bis November und Niedrigwasser von Dezember bis April geprägt.*

fish as for the abundance of specimens (Marin 2012). References on biological and environmental issues are in several other studies and inventories (Montoya and Aguirre 2013-2, Montoya et al. 2013-1).

There are also biophysical studies conducted by Ecoestudios (1989) and CIA-U. DE A. (1990) which focus on the environmental impact generated by gold mining in the past decades. Subsequently Aguirre et al. (2005) led a study about the river-marsh relationship and its effect on fish production. Also Palacio (2007) developed the study for the CVS1 about the environmental management plan of the Ayapel marsh.

Since 2005 several studies including different living forms and their distribution, abundance, biotope structure, environmental quality and socialization of this information, were made. Studies, mostly in Spanish language, whose results were transmitted to the community includes (Hernandez 2011, Aguirre et al. 2011, Villabona 2010, Montoya et al. 2011-1, Marin 2012, Aguirre et al. 2005, Palacio 2007, Hernandez et al. 2008, Jaramillo and Aguirre 2012-1, Villabona et al. 2011, Jimenez et al. 2010, Aguirre and Gonzalez 2011, Gallo et al. 2009, Chalarca et al. 2007, Gonzalez et al. 2012, Montoya and Aguirre 2009-2, Montoya and Aguirre 2009-3, Montoya et al. 2011-2, Montoya and Aguirre 2011-3, Montoya et al. 2012, Montoya et al. 2013-3, Montoya and Aguirre 2013-4, Montoya and Aguirre 2013-5, Montoya et al. 2013-6, Vouilloud et al. 2014, Velez and Jordan 2011, Ramos et al. 2012, Jaramillo and Aguirre 2012-2, Restrepo et al. 2006).

Floodplains have favourable conditions for the appearance of marshes due to the topography with low slope, poorly drained soils, the presence of rivers, and climatic conditions of the basin with flood-drought cycles. According to Junk (1996), floodplains are areas that periodically flooded by lateral spill of rivers and lakes or by direct precipitation or by groundwater. The resulting physical-chemical environment, causes an adaptive response in biota at levels of morphological, anatomical, physiological, phenological and behavioural aspects, and produces characteristical structures in the communities. Fig.1 shows the floodplain in the Colombian Caribbean near to AFS. Organisms must adapt themselves to the hydrological cycles (droughts and floods) by using different strategies that include mobility of species, time of fertility, breeding season, states of dormancy, seed production and develop of organs adapted to potamophase. However, the mortality of species is high which is offset with short life cycles and high reproductive rates, known all them as strategies (Junk 1996, Neiff 1990, Neiff et al. 1994, IGAC 1973).

In various technical studies that have been done in the Mojana region 2 and the Ayapel during the 80's, there are comments on the richness on flora and wildlife that exist there. In early studies, it was formulated that since there were few farms at that time, there were abundant natural vegetation areas (IGAC 1986). Subsequently the IGAC3 (1986), reported that natural vegetation was removed and replaced by pastures and therefore forest relicts, could currently be found only in road sides, as fence sand in both sides of streams. Other studies (Ecoestudios 1989, CIA-U. DE A. 1990, Aguirre et al. 2005, Palacio 2007) confirmed that the natural forest almost disappeared; only some representative species, and an incremental incorporation of more land devoted to pastures is observed. This brings a negative effect on trophic levels.

In this paper a numerical analysis of the biotic richness was based on researches conducted by the authors mentioned in this article. Living beings were classified at different scales to make an approach and understanding the integral global diversity of this ecosystem and the importance of its conservation.

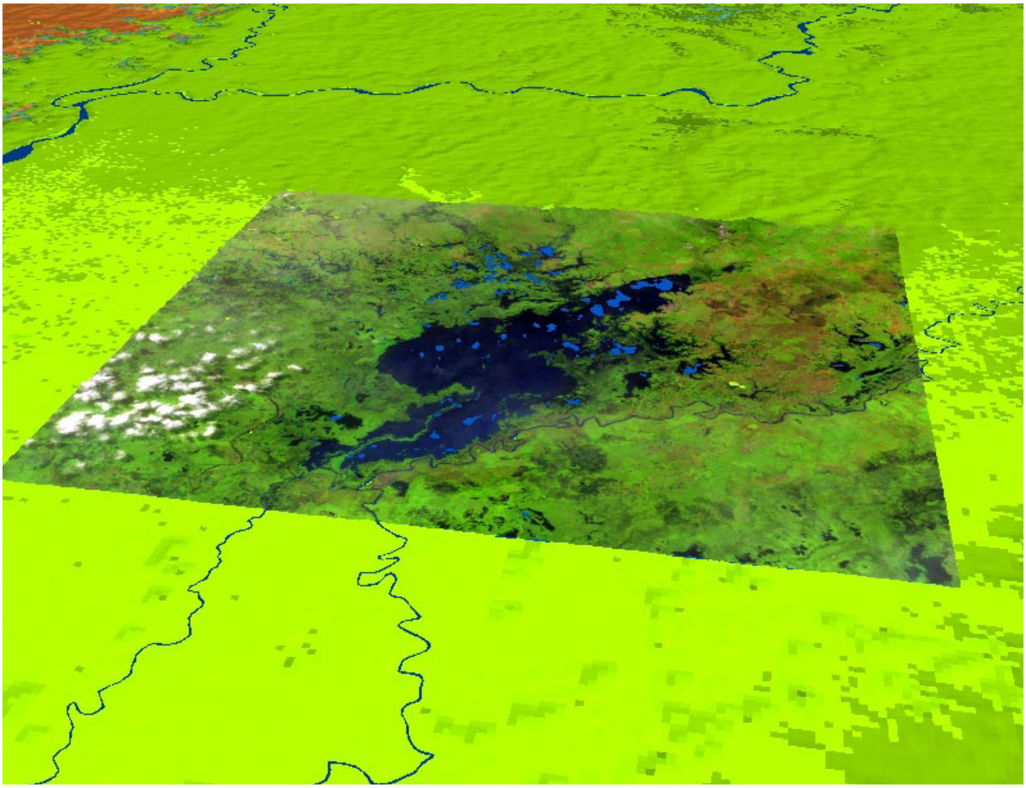

Fig.2: *View of the floodplain from north to south, where the Cienaga of Ayapel interacts with the Cauca River (above) and San Jorge River (at center). Source: Landsat satellite image from Januar, 2010 upon SRTM image.*

Abb.2: *Schematischer Überblick über die Schwemmlandebene von Nord nach Süd in dem das Flachseeniveau Ayapels in ständiger Wechselwirkung mit den Wasserständen der Flüsse von Rio Cauca und Rio San Jorge steht.*

2 METHODOLOGY

For this study, the results of some recent researches conducted by the University of Antioquia in the SCA were considered. The information was systematized and processed to obtain categorized values. Among the studies made by the University of Antioquia are (Hernandez 2011, Aguirre et al. 2011-1, Villabona 2010, Montoya et al. 2011-1, Marin 2012, Aguirre et al. 2005, Palacio 2007, Villabona et al. 2011, Jimenez et al. 2010, Aguirre and Gonzalez 2011-2, Gallo et al. 2009).

3 RESULTS

Tab.1 is a compilation of the systematized data. In it is showed the number of taxa in a biological group with the most representative genres. Therefore, this table provides a quantitative standard by which the richness in the AFS was measured in terms of biodiversity.

The information was processed and systematized in tables and graphics produced for the analysis.

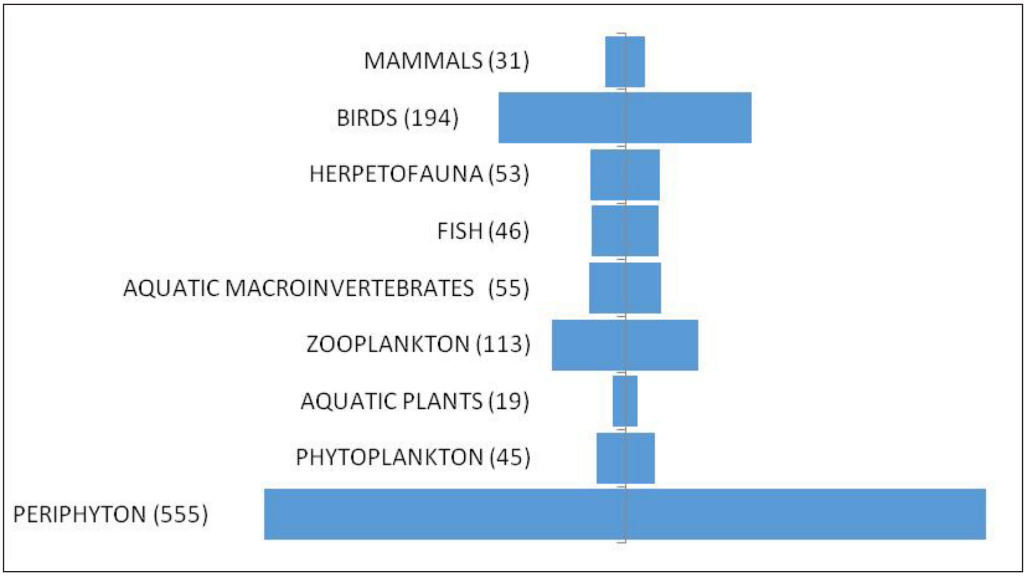

Fig.3: *Distribution by the number of found taxa, show in a trophic pyramid. Source: is a compilation from different studies of the Antioquia University.*

Abb.3: *Überblick über die Verteilung der in der Ayapel-Flachseeregion (Cienaga) gefundenen Taxa nach Studien der Universidad de Antioquia.*

Tab.1: *Biological Diversity in the AFS.*

Tab.1: *Die Biologische Diversität im Komplex der Cienaga de Ayapel.*

Biologic group	Most abundant Genera	Taxa number	Bibliographic sources
Pleuston (Floating aquatic macrophytes)	*Eichornia crassipes, E. azurea, E. heterosperma, Salvinia minima, Ludwigia helminthorrhiza, L. sedoides, Marsilea quadrifolia, Nymphoides humboldtiana, Utricularia foliosa, Aeschinome americana*	19	Aguirre et al. 2011-1, Aguirre et al. 2005
Necton (Fish)	*Prochilodus magdalenae, Cyphocharax magdalenae, Astyanax fasciatum, Astyanax magdalenatum, Pseudoplatistoma fasciaticus, Ujeta sp. Brycon sp., Tylapia Hoplias malabaricus sp., Cyphocharax magdalenae, Roeboides dayi, el género Astyanax, Triportheus magdalenae, Trachelyoptherus insignis, Eigenmania virescens, Prochilodus magdalenae*	52	Marin 2012, Aguirre et al. 2005, Jimenez et al. 2010
Reptiles and Amphibians	*Centrolene prosoblepon, Chiasmocleis panamensis, Colostethus inguinalis, Colostethus pratti, Craugastor longirostris, Craugastor raniformis, Dendrobates truncatus, Dendropsophus ebraccatus, Dendropsophus subocularis, Boa constrictor, Bothriechis schlegelii, Bothrops asper, Chironius carinatus, Dendrophidion percarinatus, Hemidactylus brookii, Lepidoblepharis sanctae martae, Leptodeira septentrionales, Liophis epinephelus, Liophis melanotus, Mastigodryas danieli, Micrurus dumerilii, Micrurus mipartitus,* *Caiman crocodylus, Polychrus marmaoratus marmoratus, Iguana iguana iguana, Anolis chloris*	53	Palacio 2007
Aquatic invertebrates	*Cyzicus, Chironomidae Chironomus, Hydrocanthus y Chonchostraca,* *Bratislavia sp., Hellobdella sp., Ostracoda, Macrobrachium sp, Caenis sp., Erythrodiplax sp., Belostoma sp., Dytiscus sp., Hydrocanthus sp., Tropisternus sp., Leptonema sp., Pomacea, Biomphalaria sp*	55	Aguirre et al. 2011-1, Aguirre et al. 2005, Palacio 2007
Phytoplankton	*Cylindrospermopsis raciborskii,* *Phacus orbicullaris,* *Mallomonas sp.,* *Centrytractus sp.,* *Aulacoseira granulata,* *Ankistrodesmus sp.*	45	Hernandez 2011
Zooplankton	*Brachionus calyciphorus, Brachionus caudatus, Brachionus falcatus, Brachionus havanaensis, Conochilus dossuarius, Lechani proiecta* *Diaphanosoma birgei, Moina minuta, Ceriodaphnia cornuta Thermociclops decypiens, Microcicolps alius, Noto diaptomus cf. maracaibensis*	113	Villabona et al. 2010, Jaramillo and Aguirre 2012-1, Villabona et al. 2011, Gallo et al. 2009
Periphyton	*Cylindrospermopsis raciborskii, Lymbia* sp., *Oedogonium* sp., *Synedra goulardii, Ulnaria ulna, Planothidium lanceolatum, Actinella langebertaloti, Encyonema minutum, Eunotía naegeli, Eunotia minor, Navicula cryptocephala, Diadesmis confervacea, Frustulia krammeri, Aulacoseira granulata, Eunotia flexuosa, Gomphonema parvulum, Fragilaria capucina, Aulacoseira granulata var angustissisima, Fragilaria familiaris, Synedra goulardii, Euastrum sinuosum*	555	Montoya et.al. 2013-1, Montoya et al. 2013-6
Birds	*Chauna chavaria,* *Ortalis guttata columbiana,* *Myiarchus apicalis,* *Dendrocygna autunnalis, Milvago chimachina, Falco sperverius, Bulbu losibis, Jacana jacana, Chrotophaga ani, Buteo magnirostria, Penelope purpurescens*	resident species 178 migratory species 16	Palacio 2007, Junk 1996
Mastofauna	*Tamandua mexicana, Choloephus hoffmanni, Dasypus novemcinctus, Alouatta palliata, Lontra longicaudis, Trichechus manatus, Hydrochoerus hydrochaeris, Cuniculus paca, Pecari tajacu*	31	Palacio 2007

The numerical results of the above table were represented in Fig.3 population pyramid, which gives an account of the biodiversity of the AFS, its distribution and the representativeness of each division in the trophic scale.

Although not all species took into account in this article are described in Rangel (1995) it allows one to infer that, for example, birds in AFS represent near 20% of the total in only 1/1000 of the area. Fig.4 presents the distribution in percentage of the species grouped between producers and consumers.

We notice that in relation with the wealth of the productive taxa, Fig.5 shows that the dominance occurs in the producers over the consumers. This is expected, since the productive base forms the sustainability of the ecosystem. Taxa are expressed as number of species and their percentages as they occur for each aquatic biological group.

In Fig.6 the food web illustrates the relationships between organisms and ecosystemic compartments that occur in the AFS. This show a global network of relationships, but of some specific levels we do not have information on stomach contents, making it difficult to infer more links.

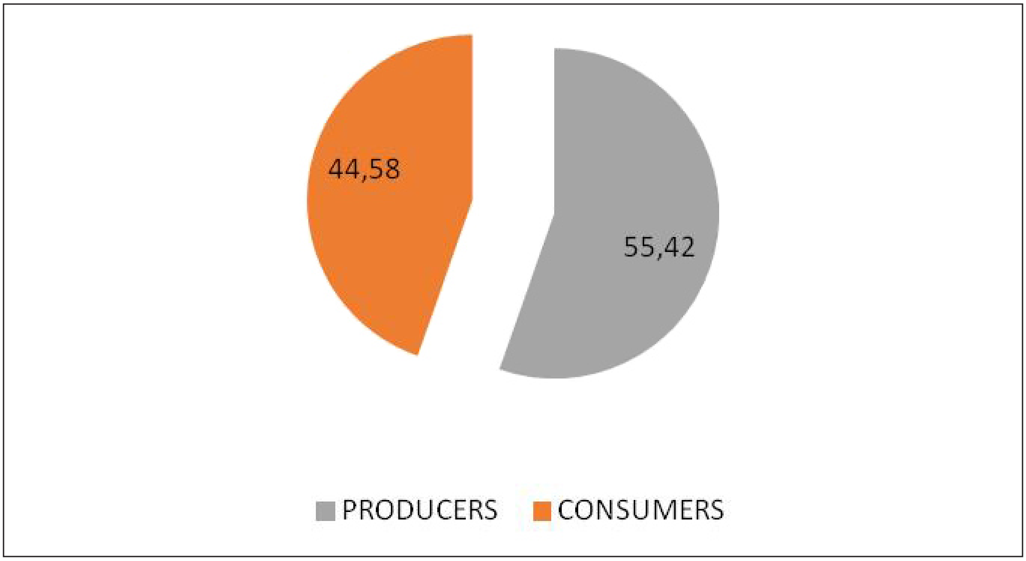

Fig.4: *Distribution in percentage of species organized from producers to consumers. Source: compiled from studies of the Antioquia University.*

Abb.4: *Prozentuale Verteilung der auftretenden Arten differenziert nach Produzenten und Konsumenten zusammengestellt aus Studien der Universidad de Antioquia.*

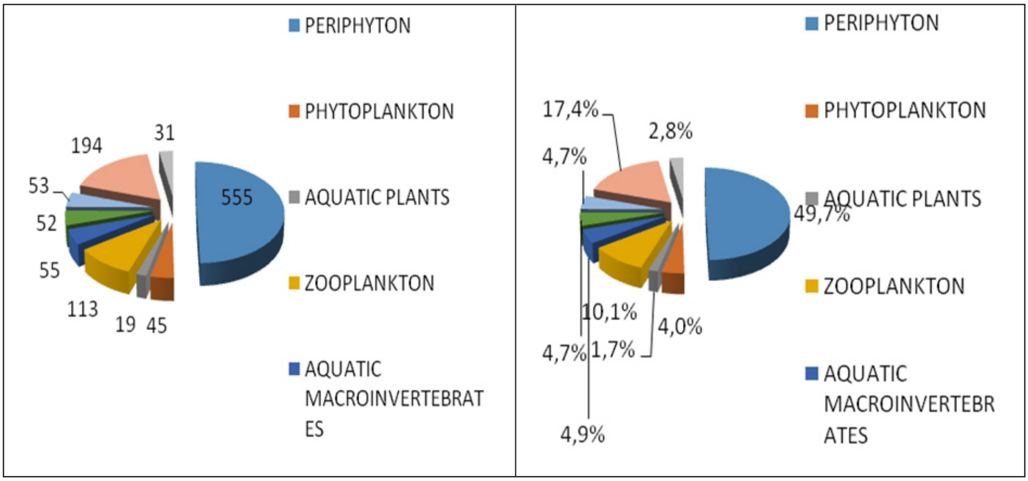

Fig.5: *Percentage of taxa for biological group. Source: compiled information from different studies of the University of Antioquia.*

Abb.5: *Prozentuales Verhältnis der nach biologischen Gruppen differenzierten Taxa in der Schwemmlandebene von Ayapel zusammengestellt aus Studien der Universidad de Antioquia.*

4 DISCUSSION

There are reports with similar investigations around the world (Posa et al. 2011, Anthelme et al. 2014, Busbee et al. 2003, Cintra et al. 2007, Tisseuil et al. 2013) describing species abundance and indexes of biodiversity. In comparison to other studies, the richness on Fauna in Ayapel is similar to the registered in some other places. Somehow like in Thailand, where studies have showed that bird diversity is also outstanding (George et al. 2009) although no necessarily linked to swamps. In other way, literature offers information about the use of indexes to describe some biodiversity characteristics in a place (Hain et al. 2012), which is very useful for remarking not only the value of a place, but also to compare between similar areas with common anthropic activities (Strayer and Dudgeon 2010, Turner et al. 2012).

The high number of species may be due to geographic isolation that presents the system in continental shallow waters, particularly in the case of Ayapel. It is located in a kind of Mesopotamia area that is favoured by the output of large amounts of matter and energy from the AFS to the consecutive wetlands downstream, and also promoted by the influence of its own micro-watersheds and the connection with the two big rivers.

The flood pulse in expansion phase fails to homogenized biologic assemblages, situation that happens also in contraction phase. Each subsystem responds in a particular way to the hydrological characteristics of the system; this response is somewhat mediated by their silience of the subsystem (Montoya and Aguirre 2011-3). It is hypothesized that, due to low hydraulic retention time that occurs in the Ayapel marsh, the effect of flood pulse is reduced; also to that is added the effect of the varied morphometric of the system, the hydraulic short circuits and the differential characteristics of the effluents. All of these conditions reflect the particular characteristics for the assemblage, which favours the high richness of species found.

Organism showed changes in their structure in relation to the flood pulse. The organisms are indicators of the environmental variability occurred in the AFS, like the physic-chemical gradient, which is reflected and is evident in the structure of epiphytic and planktonic communities.

Montoya and Aguirre (2013-4) found that the average value of electrical conductivity in the marsh is three times lower than the value in other wetlands of the region. A value of 100 μS/cm can be considered as a factor useful for discriminating between lower values among swamps, and higher values in the streams.

There was not relationship between transparency and the concentration of photosynthetic pigments that could be considered as an indicator of a lower level in the trophic system. The temporary level of all evaluated forms of nutrients presents differences which indicates the importance of the effect of the phase of flooding through the hydrological cycle.

With the decline of the column of water in times of drought, there was an increase on Nitrogen concentrations. This is favoured by the re-suspended materials from the bottom of the marsh.

Phosphorus concentration is sensitive to spatial variation. This nutrient cycle is associated with the sediments and the composition of the soil of each basin. We found that for the same phase in successive cycles of the pulse, there are differences in the hydrologic system dynamics, so that, when the sampling is performed, the main factor is the behaviour of the physic-chemical conditions of the system.

The planktonic biota has a homogeneous distribution possibly due to the mixing regime of the water body produced by the wind, and by the water circulation promoted at the mouths of streams and creeks. Community structure varies during the hydrological cycle.

Respect to zooplankton densities were higher for rotifers; and this group also showed the highest number of species. The dominance of rotifers has been associated with an incremental of the trophic conditions due to their ability to ingest small particles, such as bacteria and organic detritus (Matsumura and Tundisi 2005) and may be related to their opportunistic characteristics (r-strategists species adapted to rapid population growth during short favourable seasons), a situation that occurs in unstable and dynamic environments like marsh of Ayapel (Jaramillo and Aguirre 2012-1).

In relation to the phytoplankton, they were dominated by taxa that were adapted to low concentrations of nutrients in inorganic form. Thus Lyngbya and Cylindrospermopsis possess a high affinity for the phosphorus. Additional Cylindrospermopsis has the ability to fix atmospheric nitrogen, so that the species can become dominant under low nutrient concentrations (Hernandez et al. 2008).

The phyco periphyton was dominated in composition and abundance for diatoms. The richness recorded in the AFS is high because of the 681 registered diatom species in Colombia (Montoya and Aguirre 2013-2) 248 taxa were found in the system, among which 26 are recorded for the first in the country and three were species reported for first time.

Between fish species dominates the characiformes order. In abundance, the predominance of small species is well known. In rising and high waters, the ictic biomass increases greatly in

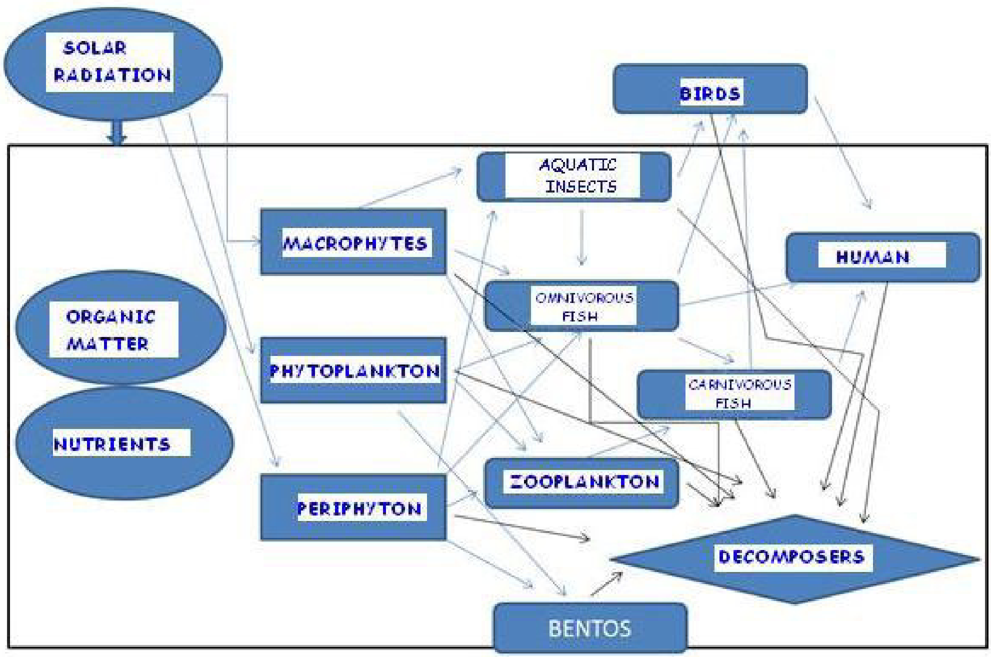

Fig.6: *Global Trophic Network in AFS, according to Montoya and Aguirre (2011-3).*

Abb.6: *Das Wechselwirkungsnetzwerk der tropisch geprägten Schwemmlandebene Cienaga de Ayapel (Montoya und Aguirre 2011-3).*

the main water body, while it decrease in low waters. The opposite was observed in the rivers, which is well known, the rivers becoming a refugee for the species. Indeed the importance of preserving these habitats is evident.

Fish in the Ayapel marsh have a homogeneous spatial distribution. In fact, a unique association of species was observed as opposed to the many different associations linked to the environments of each wetland surveyed within the AFS. Only during the dry season weres lightly differentiated associations of species for such environments observed (Marin 2012).

It was seen that during a complete hydrological cycle, environmental conditions in the swamp will vary, showing a high dependence with depth in many aspects, including the structure of the different communities.

Another aspect of hydrologic influence on the AFS is the low residence time:

1. Shallow waters. Increase the effect of each system (streams and swamps) on the assemblage due to the reduction of the flow of the river and streams (flood desiccation phase). This determines the structures of biologic assemblages that were different from one system to another.

2. Low water rising. Creates a reduction of the effect on each system on the increase of the assembly and an increase in the effect of flood pulse.

3. High water. Promotes uniformity in the physic-chemical conditions in the streams and swamps because of the entry of water from the river. Similarity uniformity of the composition of the species in the different environments is favoured by high water.

4. High water in descent. There is a reduction in the uniformity in physical-chemical conditions with decreased water flow from the river. There is also a reduction in the similarity of the species composition of assemblages from different environments. In a flood caused by the Cauca River in 2010, the fishermen of the area noted initially a positive effect of this event in terms of the occurrence of species not seen normally in the marsh because the overfishing. For example the reappearance of tarpon specie which was not seen in the waters of Ayapel for several years.

The studies on which these findings are based have restrictions in terms of when the information was taken. The AFS has a drought cycle in the months of February until April where low waters are the norm. From May to September the system reaches its higher water level and this holds until December. December is the month when waters begin to descend. It is noteworthy that since 2009 this cycle was interrupted, and the AFS has remained under high waters, which has affected species and the inhabitants of the banks of the marsh.

Why phyco periphyton represents 50% of the species richness of the AFS?

The dominance of epiphytic algae over the rest of species of the AFS can be analyzed from several perspectives:

1. Organism scale: organism of generally smaller size scale had a higher species richness

2. High variability in ecological optimum, what may promote niche overlap and besides it is presented a similar situation as in the paradox of the plankton

3. Taxonomic aspects: impede progress towards the identification of organisms, since a wide variety of flora is presented and is not counted in Colombia by microalgae taxonomists

4. Generation time: low generation time favours the colonization of new environments and stability of the assembly

5. Availability of habitats: the fluctuating mosaic of spatial and temporal levels favour the availability of resources and habitats for organisms

6. Influence of flood pulse: connects and disconnects system zones, contributes to nutrient inputs and leads the fluctuation of the water level

7. Residence time: has a low mean value in comparison to other swamp systems, which implies an excess of turbulent energy in the system, added to the nocturnal mixing and high nutrient recycling

8. High-speed recycling: the high temperatures in the area (> 30 Celsius degrees) favour mineralization processes of organic matter

9. Variability in physic-chemical constituents (nutrients, COD, conductivity, light, flow): stimulates the formation of environmental gradients, which affect the formation and variability of assemblages, since algae exhibit optimal variables values

10. Percentage of the illuminated volume of the swamp: the high value of this variable (>70%) of the volume of AFS promotes primary production in the system and an excess of energy that facilitates cell plasticity forms

5 CONCLUSIONS

Biodiversity is an absolute index upon which the importance of an ecosystem can be measured.

In the case of the Marsh of Ayapel, is the first time that the information of inventories is systematically compiled. This procedure has allowed seeing the richness of the region in terms of its biodiversity that shows in it holds a prominent place in the list. There is a shortage of studies of this kind in Colombia.

Amid the lack of a more extensive and complete coverage of the region during the different seasons, the ecosystems of Ayapel have demonstrated their value. The region clearly merits consideration as a place to be protected, and we believe that human activities in the region need to be regulated.

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