Large Tropical South American Wetlands: An Overview

J. J. NEIFF
Centro de Ecología Aplicada del Litoral (CECOAL), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Casilla de Correo 222, 3400 Corrientes, Argentina

M.H. IRIONDO
Universidad Nacional del Litoral (UNL)-CONICET, Casilla de Correo 487, 3100 Paraná, Entre Ríos, Argentina

R. CARIGNAN
Université du Québec, INRS-Eau, C.P. 7500, Ste-Foy (Qc), Canada G1V 4C7

INTRODUCTION

The concept of "wetland", as defined by ecologists and biogeographers in the last decades, has proven to be useful for Latin America, where areas of alternating drought and waterlogged phases are called "pantanales" or "humedales" or "bañados" or "esteros" in spanish, or "brejales" in portuguese.

These areas characterized by more or less periodical flooding and/or inundation exhibit a greater degree of genetic and environmental diversity than formerly supposed (Wilson, 1988).

Taking advantage of the body of research accumulated in recent years, we may attempt a summary of the subject, especially considering the lack of comprehensive information encompassing all of South America.

The accumulation of specific data on wetlands has been substantial and has led to an increasingly rich and complex panorama. As a result, it has become difficult to agree on general concepts as defined by early researchers.

At first, the wetlands that served as model systems, and upon which much of the thinking has been based, are ecotones, marginal areas, located near lakes and rivers as a consequence of water level fluctuation. This type of wetland, generally displaying transitional characteristics, was adequately defined by Holland in 1988.

The large wetlands or "Pantanales" can be considered typical of South America. However, there are analogues on other continents. Examples in Africa include the "inner delta" of the Niger River, and the confluence region of the Blue Nile and White Nile in Sudan.

In South America, a few large wetlands have been reclaimed and altered in the last century. The valley of Cochabamba, for example, which originally possessed a large alluvial wetland, was drained and cultivated by precolombian civilizations.

A copious bibliography regarding the loss of natural wetlands has been produced in the United States. Today, the U.S. is one of the most active countries involved in wetland creation and restoration.

Our field work in South America has revealed the existence of extensive wetlands forming true macrosystems of diverse origin and physiographic characteristics. These are usually associated with the great plains of the center of the continent; they cover tens of thousands of square kilometers and, on the whole, comprise systems whose understanding requires distinct conceptual and methodological tools.

DEFINITIONS AND ESSENTIAL CHARACTERISTICS

We propose the following operational definition for the large wetlands of South America:

> Systems of sub-regional extent in which the spatial & temporal presence of a variable cover of water causes characteristic biogeochemical fluxes, soils of accentuated hydromorphism, and a biota whose structure and dynamics are well adapted to a wide range of water availability. They can be considered macrosystems whose complexity grows with hydrosedimentological variability and geographic extent.

ORIGIN

The great South American wetlands have geological and climatological origins. They consist of sunken blocks of continental crust resulting from extensive movements of the continental shelf and other processes. Such depressions may occur simultaneously to crustal movement, or take place millions of years later, owing to the compaction of accumulated sediments. These areas are generally rectangular or deltoidal, and average tens to thousands of kilometers in width. The largest wetlands on the continent are located within warm, moist climatic zones. The exceptions are of such little importance (lowlands of Izozog, Copo and some other minor areas) that it can be postulated that a moist climate is a necessary condition for the creation and maintenance of large wetlands. Wetlands resulting from the surfacing of phreatic waters are uncommon in South America.

The life span of a typical wetland seems to be on the order of some millenniums (Iriondo, 1990). Of great evolutionary significance, geological conditions permitting, is the tendency of wetlands to form repeatedly in the same region over tens of millions of years.

PRINCIPAL CHARACTERISTICS OF LARGE WETLANDS

Large wetlands constitute complex systems that generally include various ecosystems. For this reason, it is necessary to consider them as macrosystems composed of permanent and seasonal wetlands, and also sections of upland habitat.

The macrosystem constitutes a functional ecological unit, because it has its own internal fluxes of materials and energy. This capacity for transformation shows itself in tables of cenotic affinity comparing terrestrial environments, wetlands, and aquatic environments from the same region. If one investigates the differences between each of these environments on the basis of distribution and abundance curves of populations, or comparing strategies of growth and development of plants and animals, clear differences emerge between aquatic, terrestrial, and wetland environments.

The macrosystem "large wetland" (e.g. Pantanal, Mato Grosso, Iberá) is the working unit for integrated ecological management in the same way as the watershed is considered as an integrated part of the ecosystem in river management. However, macrosystems such as the Mato Grosso and Iberá can be usefully analyzed ignoring the tracts of river below them. The reverse is neither useful nor logical, because of the directionality of the hydrographic systems in which the great wetlands are included.

The structure and function of large wetlands as macrosystems is directed by the movement of water over and through the soil. Each large wetland and its associated subsystems has their own characteristic FITRAI (Neiff, 1990) (Figs. 1 and 2).

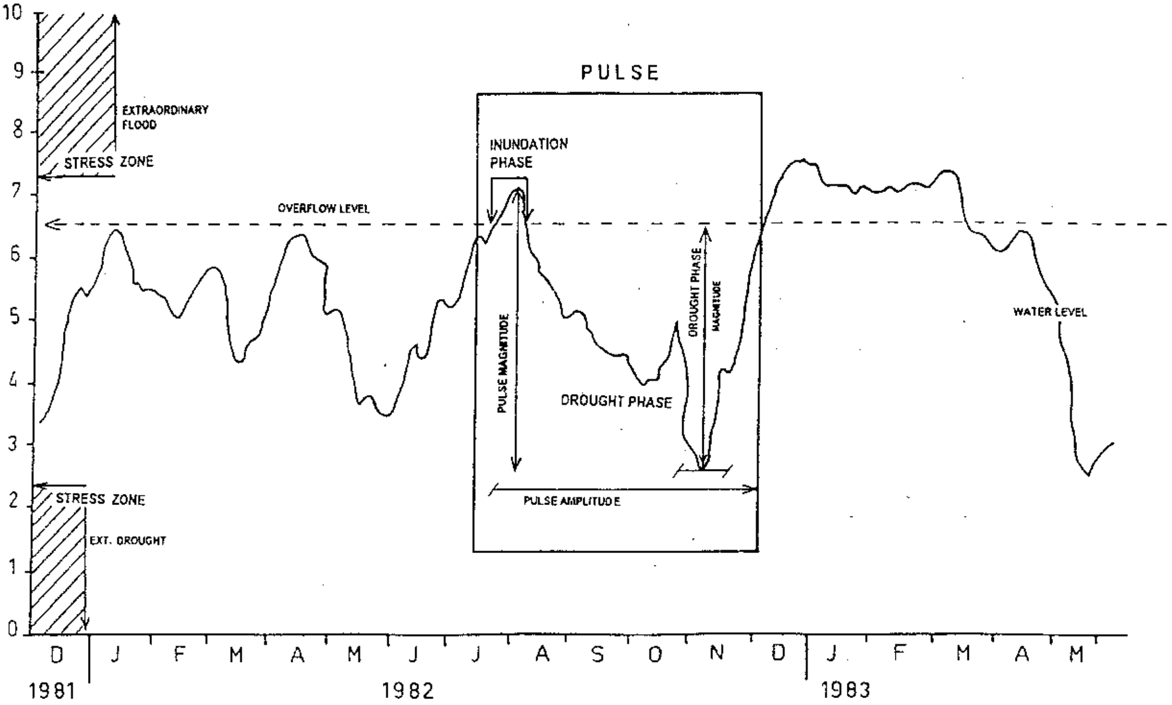

Figure 1. Lowland of Choui Island (Paraná River, 58°55'W; 27°30'S)

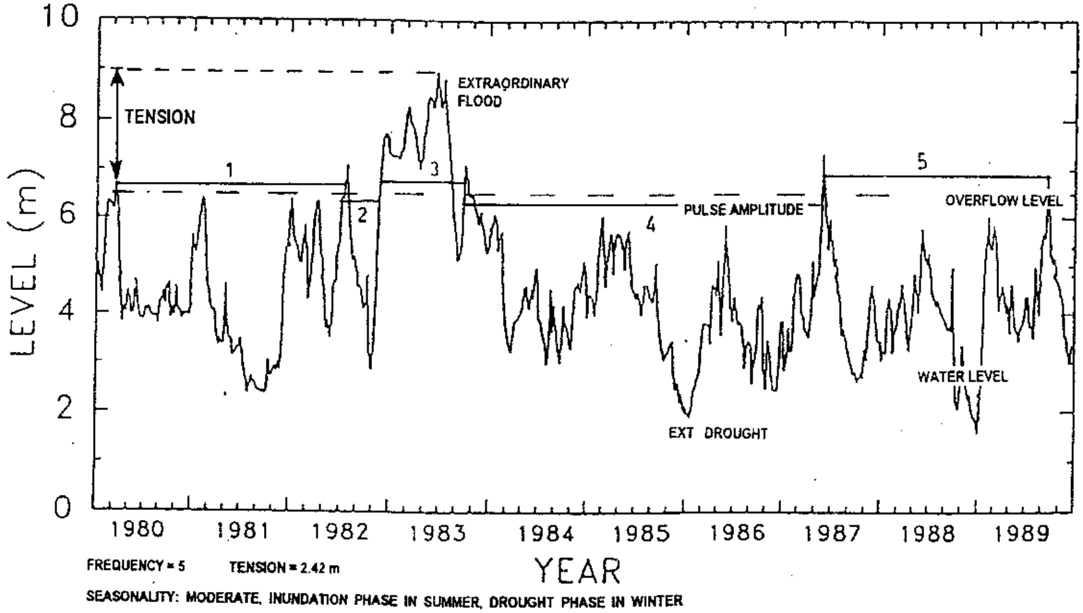

Figure 2. Hydrometric level of the Paraná River at Corrientes during the 1980-1990 decade

Table 1. Large Wetlands in Tropical South America

System	Area (*)	Area (+)	Source	Waterlogging-Inundation (frequency)
-Pantanal - Mato Grosso	138	?	Adámoli, 1984	A + I = annual
-Mar de arena pampeano	100	2	Iriondo, 1990	A = secular
-Plains of the Orinoco	90	?	Welcomme, 1985	A + I = annual
-Pantanal of Rio Branco-Negro	80	?	Iriondo, 1992	I = annual
-Central Amazonia	75	?	Sioli, 1975	A + I = annual-seasonal
-Bananal Island	50	?	Irioindo, 1990	A = ??
-Chaco Oriental	42	3.4	Neiff, en prep.	A + I = annual
-Paraná	38	5	Neiff, en prep.	I = seasonal-annual
-Roraima and Rupununi Lowlands	33	?	Klinge et al.	?? = annual
-Ucamara	30	?	Iriondo, 1992	I = annual
-Lowlands of Napo	30	?	Iriondo, 1992	I = annual
-Lowlands of South Brazil	30	?	Klampt, 1982	A+I+F = annual
-Magdalena	20	?	Garcia Lozano y Dister, 1990	A + I = annual
-Plains of the Mamore	15	2.5	Iriondo, 1992	A + I = annual
-Iberá	12	7.8	Neiff, en prep.	A = annual
-San Antonio	8	?	Welcomme, 1985	? ?
-Bajo Guayas valley	7.5	?	Iriondo, 1992	A+I=quinquennial
-Lowlands of the Poopó Region	6	?	Iriondo, 1992	A + I = annual
-Lowlands of Mar Chiquita	6	?	Iriondo, 1992	A + F = decennial
-Atrato	5	?	Welcomme, 1985	
-Catumbo	5	?	Welcomme, 1985	

(*) Maximum area in $km^2 \times 10^3$

(+) Minimum area in $km^2 \times 10^3$

A = rainfall accumulation

I = inundation

F = ground water resurgence

To describe the spatio-temporal variability of a large wetland, it is necessary to define its FITRAI. However, it is uncommon to encounter reference to this function; and very rarely is the range of spatio-temporal variability, or at least spatial variability, defined for wetlands (see Tables 1 and 2).

An original and potentially useful descriptive parameter is the elasticity of the macrosystem, defined as the quotient between the area occupied during the period of

Table 2. Wetlands in The Biosphera

Continent	Area (*)	Area (+)	Source
North America	543	?	Sabol, 1974
Asia	400	?	
South America	820.5	?	Neiff, en prep.
Africa	195	45	Welcomme, 1985

(*) Maximum area in $km^2 \times 10^3$
(+) Minimum area in $km^2 \times 10^3$

greatest flooding and/or inundation, and that occupied at the period of maximum drought. This value is influenced by:

-the geomorphological characteristics of the macrosystem

-the capacity for water storage in the soil and subsoil

-the regional meteorological variability (precipitation/evapotranspiration-infiltration)

-the variability of allochthonous water inputs (in floodplain systems)

To a large extent, the elasticity of the system explains the distribution and abundance of populations, nutrient storage and mobility, redox conditions, the importance of accumulation or degradation of organic matter and, in general, sheds light on biogeochemical fluctuations that occur in the system.

From Table 3, elasticity is 12.35 for the Eastern Chaco, 7.6 for the Lower Paraná, and just 1.53 for Iberá. These values are of interest in the interpretation of species richness and/or life forms, and vegetative cover. Elasticity measurements are also useful for planning housing, roads, service structures, or emergency routes.

Without any doubt, in contrast to terrestrial systems and more typical aquatic habitats, large wetlands constitute macrosystems of high spatio-temporal variation (Pinay *et al.*, 1990). This does not imply, however, that they are systems of low stability.

Because of the aforementioned, the great majority of the large wetlands of South America are not ecotones or interfaces between aquatic and terrestrial ecosystems as was put forth as the general concept for wetlands by Holland, 1988 (FIDE: MAB Digest 4, UNESCO, 1991). The characteristics of the large South American wetlands are not essentially defined by "a combination of characteristics defined only by scales of time and space and by the magnitudes of the interactions between these same systems" (in reference to the systems adjacent to the wetlands). Rather they are defined essentially by their capacity for internal transformation by their geographic extent and by the systems that receive their influence.

The structure and function of the large South American wetlands is regulated by the hydrosedimentological regime. Direct measurement of this regime, as well as other indicators, provides understanding and permits intelligent management. Large wetlands have a fundamental role in the regulation of deep and surface water movements, which is poorly understood. These macrosystems can function as "nutrient traps", transforming chemical substances, with characteristic processes of storage and liberation which depend on the origin (rainfall, drainage, river) and internal circulation of the water.

Table 3. Elasticity of Some Large Wetlands

System	Area (*)	Area (+)	Source	Elasticity quotient
-Chaco Oriental	42	3.4	Neiff, in prep.	12.35
-Paraná	38	5	Neiff, in prep.	7.6
-Iberá	12	7.8	Neiff, in prep.	1.54

(*) Maximum area in km^2 x 10^3
(+) Minimum area in km^2 x 10^3

The biota of the large South American wetlands have amphitolerant populations whose distribution, abundance, and productivity are adjusted to the fluctuating water regime, as is shown by population distribution curves (Neiff, 1986a, 1986b; Neiff *et al.*, 1985; Reboratti and Neiff, 1987).

Primary production and the decomposition of organic matter are principally regulated by the hydrological regime.

In South American large wetlands fire (natural and/or anthropogenic) is a discrete regulating factor that has positive and negative effects on the biotic complexity of the system, which are still poorly known.

When the geographical area occupied by a wetland macrosystem increases, the stock of [illegible] species obviously increases, as well as the trophic complexity. In large wetlands, however, species diversity (number of species/area) and environmental complexity are often higher than in purely terrestrial or aquatic systems. The minimum area required to preserve species richness and the patterns of biological interactions is unknown for the majority of South American wetlands.

Water flow and direction over large wetlands directly affects the rates of exchange of dissolved and suspended solids between the wetlands and the adjacent ecosystems (Hypothesis 11 of MAB Digest 4, Naiman *et al.*, 1991). Additionally, the rates of exchange of dissolved and suspended solids between adjacent ecosystems and wetlands are related to internal processes such as the water residence time, response time of the vegetation, and to the stock of particulate and dissolved organic matter of vegetative origin; they are only secondarily dependent on regional climatic seasonality (Naiman *et al.*, *op.cit.*: Hypothesis 12 modified by us).

Collectively, the large South American wetlands form one of the most important banks of biodiversity, recruitment, and productivity. This is particularly true for the fishes of the large rivers which receive water from extensive neotropical wetlands (Neiff, 1990b).

In South America, there are two well-defined type of large wetlands. One of these is sandy, with expanses of fossil and aeolian dunes, poorly-organized surface drainage, numerous water bodies that become separated at medium or low water: these can be termed water-logged wetlands or "pantanales".

The impermeable layer can occur close to the surface, or can be found up to tens of meters below. Depending on the position of this layer, two phases can be distinguished: a) the accumulation (or saturation) phase; b) the water logged phase, when the rainfall exceeds the soil's storage capacity.

At high waters the soil can become covered with up to two meters of water. The excess of water on the landscape is from local rainfall. The water percolates through the sand of the highest portions of the landscape (the fossilized sand dunes) and slowly infiltrates the depressions over several weeks. The major anions are generally chlorides and carbonates that are leached from aeolian deposits.

The scarcity of nutrients is due to the lack of clays in the system and to the origin (direct rainfall) of the water. Many of these wetlands exhibit oligotrophic characteristics during the dry phase, and become eutrophic during the rainy season, owing to the transport and circulation of minerals in surface-flowing water. Net primary productivity is sustained fundamentally by macrophytes, with values of 10-15tn/ha/yr occurring during growth periods not longer than eight months (Neiff, 1981).

The other type of large wetland is the floodplain. In such wetlands, the saturation of the soil (with a sheet of water 2-4 m deep) is in large part a consequence of river overflow, with the water originating in other regions. As a consequence, water inputs to the system originate from distant sources, consequently, the result being that the change of seasons in the system may be out of phase by some months with rainfall and water levels (for example the Lower Paraguay floodplains).

This type of wetland is characterized by a predominance of fluvial features, both modern and ancient: alluvial levées; ancient oxbows of meanders, etc. The drainage of the inundated areas is more or less "organized", though very slow; water tends to form networks of anastomosing channels, tending to reunite watercourses below.

Sediments are predominantly fine (very fine sands, loams and clays); this results in a markedly higher capacity for nutrient and major ion storage. Furthermore, inundation and water movements generate an important influx and/or translocation of materials (solutes, suspended sediments, colloidal organic matter).

In alluvial wetlands or floodplains, large morphologic and biotic spatial gradients are observed in relation to the distance to the main river channel.

CLASSIFICATION OF LARGE SOUTH AMERICAN WETLANDS

According to the above considerations, the South American wetlands can be classified into a few hierarchical groups defined by physiographic and dynamic factors, where geomorphology and lateral exchanges with neighboring ecosystems are important parameters.

Large wetlands	Pantanales Floodplains
Marginal wetlands	Fluvial Lacustrine Littoral

Definitions:

Large wetland: macrosystem where the principal factor is rainfall accumulation and, secondarily, flooding.

Pantanal: large sandy depressions periodically inundated by predominantly local rainwater, and with poorly organized superficial drainage. (Water exchanges are largely vertical).

Floodplain wetland: large wetland presenting fluvial forms fashioned by alluvial fine-grained deposits with organized (directional) fluxes of allochtonous water.

Marginal wetland: area periodically covered by water adjacent to and directly influenced by a large body of water (lake, river, sea). (Water exchanges are largely horizontal).

Marginal fluvial wetland: periodically flooded area adjacent to a river whose biotic structure is cause and consequence of bi-directional interactions with the river.

Marginal lacustrine wetland: periodically flooded area adjacent to a lake. Such wetlands generally correspond to ecotones between terrestrial and lacustrine systems.

Marginal littoral wetlands: periodically flooded coastal areas with biological characteristics influenced by recurring daily and seasonal cycles.

ANALOGIES WITH OTHER CONTINENTS

The large pantanals can be considered as typical of South America. However, similar systems are also found on other continents. In Africa, for example, the interior delta of the Niger and the confluence of the White Nile and the Blue Nile can be considered as pantanals. In Europe, most large wetlands have been drained ("reclaimed") and transformed to such an extent that they are now unrecognizable. The Hungarian lowlands and parts of the Guangdong and Jiangsu Provinces of southeastern China are good examples. At least one such "reclamation" case can be found in South America where the Cochabamba valley, which originally had a large floodplain, has been drained and cultivated by precolombian civilizations.

Lakes are generally scarce on the South American continent, with the exception of Patagonia and of the southern Andes. On the other hand, the surface area occupied by large wetlands is relatively important, as shown in Table 2. Although there are few comparative data for other continents, Table 2 gives an idea of the probable global geographic extent of wetlands in the biosphere.

FINAL REMARKS

Even if the above considerations amply justify further efforts to understand the function and dynamics of South American wetlands, we cannot ignore the dramatic situation described by the International Hydrological Program (UNESCO) relative to the worldwide distribution and abundance of drinking water. It is therefore easy to understand the present and future importance of preserving freshwater supplies in South America.

Although the large continental wetlands of South America already show signs of deterioration due to various causes (gold mining, agriculture, man-made fires, chemical contamination, abusive exploitation of the flora and fauna, poor hydrological management), enormous extents of natural wetlands still exist.

This situation is precarious, however, due partly to a poor knowledge of the mechanisms that regulate wetland stability, partly to a lack of appropriate conservation technologies, and above all due to a lack of legal mechanisms that take into consideration the future importance of these macrosystems.

Obviously, the environmental management of wetlands should include all sectors of society. It should also consider that a fluctuating water level is not a problem in itself for the great majority of biological communities.

This change in attitude towards wetlands will only be possible once it is understood that they are a necessary and useful part of the environment and that impacts perceived as negative can be greatly alleviated by the development of flood prediction models and sustainable development strategies.

We think that some techniques and knowledge acquired by ancient civilizations for multiple and sustainable use of wetlands could be used advantageously by modern societies.

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