5 A preliminary classification of habitats of the Pantanal of Mato Grosso and Mato Grosso do Sul, and its relation to national and international wetland classification systems

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Abstract

Large wetlands such as the Pantanal are composed of many different subsystems, ranked as ecosystems or habitats. These subsystems are subjected to different environmental conditions, harbor different plant and animal communities, and interact with each other in many ways. Therefore, the functioning of the Pantanal can only be understood by closely examining the structures and functions of its individual subsystems and their interactions. Successful plans for the sustainable management and protection of the Pantanal and its biodiversity must take into account the specific requirements of these subsystems. Accordingly, the elaboration of an ecological classification of the habitats of the Pantanal is a prerequisite for future scientific research, management, and environmental legislation. In this chapter, we propose a preliminary ecological classification system based on a hierarchical order that considers climate, hydrology, soil and water chemistry, and plant cover. We discuss the position of our system in the context of other classification systems and point out its advantages for scientists, decision makers, politicians, and the local population.

5.1 Introduction

With an area of about 140,000 km2, the Pantanal is one of the largest wetlands in the world. The beauty of its landscape and its large species diversity are expressions of its habitat diversity and account for the enormous interest in this area. Details

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regarding the Pantanal's landscape units and habitats are given by Nunes da Cunha & Junk (chapter 12) and have been previously reported by Nunes da Cunha et al. (2007). Habitat diversity is a challenge for all those who interact with the Pantanal, mainly the people living in the region (pantaneiros), but also scientists and planners who study and manage it. Pantaneiros use the resources of the Pantanal in traditional ways, such as low-density cattle ranching, and for more than 200 years have employed strategies that consider the benefits of its specific habitats and their sustainable maintenance (chapter 28). However, changing economic requirements have placed economic pressure on the pantaneiros to intensify their management systems or even change them completely, at the cost of the integrity of the Pantanal's ecosystems. Moreover, major changes in the upper catchment area of the Pantanal have brought about modifications in the water discharge and a large increase in sediment load of the main tributary rivers of the Pantanal, which have dramatically and to differing extents affected the habitats inside the Pantanal (chapter 26). It is the responsibility of the politicians, planners and scientists to elaborate management plans and regulations that allow the pantaneiros and other stake-holders to make use of the multiple benefits of the Pantanal without destroying it. They also must control and reduce negative impacts involving the catchment area. Furthermore, they must develop cooperation with Bolivia and Paraguay, which also participate in the Pantanal, in the elaboration of sustainable, wetland-friendly development strategies. However, the successful management and protection of the Pantanal require that its complex landscape and floristic diversity be specifically assessed. This is best achieved through an analysis in which the Pantanal is broken down into easily recognized units that can be described by scientific methods.

This chapter provides a preliminary classification system for the major subsystems of the Pantanal of Mato Grosso and Mato Grosso do Sul. The classified subsystems can have the rank of ecosystems or habitats. They can serve, individually or in functional groups, as the basis for further scientific analyses, in the design of specific management options, in the development of regulations, and for environmental protection. The classification system is not offered as an alternative but as a supplement to previous ones, and is open to additions and modifications.

5.2 The position of the new classification system in the context of international wetland definitions and classification systems

Cowardin et al. (1979) stated that there is no single, indisputable, ecologically sound definition for wetlands, primarily because of their diversity and the fact that the demarcation between dry and wet environments is rather a continuum. The definition of wetlands suggested by those authors emphasized three key attributes: (1) hydrology, especially the degree of flooding or soil saturation; (2) wetland vegetation (hydrophytes); and (3) hydric soils. All wetlands must have enough water at some time during the growing season to cause hydric stress for those plants and animals not adapted for life in water or water-saturated soils.

The Ramsar Convention defined wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Iucn 1971). The International Biological Program (IBP) defined a wetland as "an area dominated by specific herbaceous macrophytes, the production of which takes place predominantly in an aerial environment above the water level while the plants are supplied with amounts of water that would be excessive for most other higher plants bearing aerial shoots" (Westlake et al. 1988). According to the definition of the U.S. Fish and Wildlife Service (USFWS), "wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.

Our wetland definition follows that of the Ramsar Convention (Iucn 1971). There are also classification systems of the many different wetland types, e.g. the Ramsar Classification System (RCS) (Scott & Jones 1995), the classification systems of the USFWS, (Cowardin et al. 1979) and the Scientific Committee on Problems of the Environment (SCOPE), International Council of Scientific Unions (Gopal et al. 1990), and the geomorphic classification system of Semeniuk & Semeniuk (1995). All of these treat large complex wetlands in a very general way and do not consider their habitat diversity. The Pantanal and the Okawango Delta are considered as inland deltas. Habitat diversity in these large wetlands is very high and includes habitats that are described also from other wetland categories. This simplified treatment does not satisfy the requirements of scientists, planners, or the different stake-holders.

5.3 Brazilian classification systems of the Cerrado and Pantanal

The uplands surrounding the Pantanal are covered by different savanna-types (cerrado) that is reflected by the vegetation and fauna of the Pantanal wetland, which contains many cerrado elements. Ibge (2004) considers the Pantanal as a biome, however, this view is challenged by different authors. Coutinho (2006) considers the Pantanal as a mosaic of different biomes. Eiten (1972), calls the Pantanal a hyperseasonal savanna. Indeed, other hyperseasonal savannas e.g. the Bananal at the Araguaia River are considered part of the cerrado, and not specific biomes. We consider the Pantanal as a wetland belonging to the type of periodically inundated savannas and part of the cerrado biome.

There are different classification systems for the various types of cerrado vegetation, including wetland vegetation units. Some of them are similar to those found in the Pantanal. Forests growing along streams and rivers and in wetlands have been described by many botanists (e.g., Mantovani 1989; Rodrigues & Leitão Filho 2004; Durigan & Leitão Filho 1995). Riverine forests have also been noted in studies that classified Brazilian vegetation types (Rizzini 1979; Ratter 1980; Eiten 1972, 1983; Veloso & Goes 1982, and others). These efforts were synthesized by the Instituto Brasileiro de Geografia e Estatística (Veloso et al. 1991; Igbe 1992). The phytophysiognomic classification of Ribeiro & Walter (1998) revised the classification of the principle vegetation types of central Brazil and included terms used by the local population. The authors based their approach on physiognomic, edaphic, and floristic characteristics. Rodrigues & Leitão Filho (2004) discussed the different terms used to describe Brazilian riverine forests and proposed a classification system based on hydrological and phenological aspects.

The first system to classify the Pantanal's vegetation was the one elaborated by Loureiro et al. (1982), who defined five phytoecological sub-regions: (1) savanna (cerrado), (2) savanna steppe (chaquenha), (3) semi-deciduous seasonal forest, (4) deciduous seasonal forest, and (5) areas of ecological tension subjected to anthropogenic modification.

Prance & Schaller (1982) described different floristic types of the Fazenda Acurizal, an area at the border of the Pantanal. They characterized cerrado, semi-deciduous forest, swamp vegetation types, and xeric vegetation types. Ratter et al. (1988) used phytosociological information to study the cerrado and semi-deciduous forest. AB'SABER (1988) differentiated 4 lake types in the Pantanal, which we have adopted in our classification system.

Nunes Da Cunha et al. (2006) elaborated a physiognomic vegetation map at a scale of 1:100,000 for the area north of the Poconé based on a modification of the classification of Veloso (1991). Using satellite images of the Pantanal, the authors delineated: (1) one type of seasonal semi-deciduous forest; (2) four types of savanna (cerrado): forested savanna (cerradão), seasonally flooded low tree and scrub woodland (cerrado aberto), seasonally flooded savanna parkland including campos de murunduns, paratudal, piuval, and campos with capões, and seasonally flooded grass-wood savannas including fields of Thalia geniculata, Ipomoea carnea, and Combretum lanceolatum; (3) transition systems or ecological tension areas of two types: seasonally flooded evergreen forests, including cambarazais, and floating aquatic vegetation (batumes); and (4) secondary systems including deforested areas and bare soil.

Silva et al. (2000) elaborated maps of the vegetation of the Pantanal based on aerial surveys, focusing on the management and protection of major animals, such as caimans, capybaras, jaguars, and swamp deer. They distinguished 16 vegetation classes and one comprising miscellaneous structures.

The classification of aquatic habitats of the upper Paraguay River floodplain system by Wantzen et al. (2005) was based on the fluvial hydrosystem concept (Petts & Amoros 1996; Drago et al. 2008a, b), which states that the ecohydrological conditions of the fluvial hydrosystem and its subsystems depend on the dynamic interactions of hydrogeomorphological and biological processes. The classification system of those authors therefore emphasizes the structural and functional aspects of the river-floodplain system and it is especially appropriate for aquatic habitats. We have thus incorporated parts of it into our classification system.

The Nature Conservancy (TNC) proposed a classification of the freshwaters of the Upper Paraguay Basin (Tnc 2003; Higgins et al. 2005) based on river catchments of decreasing size, supplemented by information on geomorphology, geology, biota, and human impacts. While advantageous for the planning of protection areas, it is not compatible with international classification systems and thus hinders comparisons with other wetlands. Furthermore, it is very abstract and does not include the habitat differentiation used by the local population. This makes it difficult to motivate the local population to become actively involved in environmental protection.

In 2007, Nunes da Cunha et al. published an article on the floristic and physiognomic types of arboreal vegetation of the Pantanal of Poconé. This information has been incorporated in the new hierarchical classification presented in the following.

5.4 The new classification system

This new classification of the major habitats of the Pantanal is based on climatic and hydrological parameters, physical and chemical parameters of soils and water, and botanical parameters. The Pantanal is a wetland with a pronounced annual aquatic phase as well as a terrestrial one and therefore belongs to the floodplain category. The structures and functions of floodplain ecosystems were described in Junk et al. 1989, Junk 2005, and Junk & Wantzen 2004. Only a few habitats occupying a minor portion of the entire Pantanal (20–30%) are covered permanently by water or are waterlogged. The remaining area belongs to the aquatic terrestrial transition zone (ATTZ), which extends between permanently terrestrial and permanently aquatic habitats.
The change of habitats imposed by the pronounced aquatic and terrestrial phases makes classification of the Pantanal difficult. In the key, we have differentiated

between intermittent aquatic systems periodically covered with standing water and intermittent terrestrial systems. Both describe habitats covering the same area during different periods of the yearly cycle. Trees and shrubs are present in many of the intermittent systems and many of the trees are terrestrial species. Therefore, our classification is based on plants that dominate the terrestrial phase. It is an ecological approach from the perspective of wetland scientists. For a description of major landscape and vegetation units see Nunes da Cunha & Junk (chapter 12). The new classification system is presented in Table 1. It is based on four groups of factors:

Climate has the greatest effect on wetlands and their habitats because it influences all other classification criteria. Climatologists have divided the globe in climatic zones, starting from the equator to higher latitudes. Our focus is the Pantanal, a large tropical wetland located in the tropical/subtropical savanna belt and with a climate that shows pronounced wet and dry periods.

Hydrology is an essential aspect of wetlands and factors dealing with hydrology are ranked second in our classification system. However, many plant species growing in the Pantanal show a large physiological plasticity to cope with flooding. Therefore, the inundation periods given in the classification describe only the most frequent position of the different vegetation units on the flooding gradient. Other factors such as the origin of water, e.g. from rain, rivers, or groundwater also affect the vegetation cover, but our knowledge about their impact is still small and can not yet be considered. Furthermore, in a wet-dry climate, drought stress in combination with fire has a strong impact on the vegetation and is still little understood. Most habitats of the Pantanal are permanently or periodically inundated. Some are dry for many years except during extreme flood events. But at the surroundings and inside the Pantanal, there are areas that are never flooded. They are mentioned in our classification because they serve as refuges for animals during extreme floods or offer additional breeding conditions, and act as step-stones for plants and animals to colonize the adjacent wetland habitats at least periodically, increasing the overall species diversity of the entire area.

Physical and chemical properties of water and soils comprise the third level because they are of fundamental importance for species composition and productivity in water and wetlands. Our data base about these factors is not sufficient yet to include these parameters in an adequate manner in the classification. But in general it can be stated that all terrestrial and aquatic habitats of the Pantanal are of low nutrient status, with a low to intermediate content of mineral salts [electric conductance typically <100 uS cm-1, and neutral to slightly acidic (pH 5-7)]. Exceptions are the high-salinity salinas, some high-salinity soils in the southern Pantanal, and the soils of the capão de aterro, which are of increased fertility because of human activity. Most soils are sandy with a low water-retention capacity

Table 5.1 Preliminary classification of the habitats of the Pantanal

Hydrological status	Functional unit	Mesohabitat with botanical characterization (when possible)
1. Permanent aquatic systems		
1.1 Standing water		
	1.1.1 Fresh water	**Mesohabitats of all functional units of 1.1:** Open water, vegetated shorelines, vegetation-free shorelines,substrate-defined patches, macrophyte-defined patches (*Eichhornia crassipes, E. azurea, Oxycaryum cubense, Salvinia auriculata* and many others)
	1.1.1.1 Oxbow lakes	
	1.1.1.2 Large depression lakes at the border of the Pantanal	
	1.1.1.3 Medium sized depression lakes inside the Pantanal	
	1.1.1.4 Small lakes of paleo-fluvial activity	
	1.1.2 Saline water	
	1.1.2.1 *Salinas* (no or few macrophytes, mainly *Oscillatoria, Aphanothece, Anabaenopsis (Cianobacteria)*	
	1.1.3 Artificial systems	
	1.1.3.1 Reservoirs	
	1.1.3.2 Ponds (e.g., excavation ponds and trenches along earth roads)	
1.2 Running water		
	1.2.1 River channels according to river order	
	1.2.1.1 Central channel strip	Substrate defined patches Mobile sand bedforms Rocky outcrops
	1.2.1.2 Bank strip	Meander scour pools Substrate-defined patches Slackwater areas Logjams Vertical clay banks Aquatic vegetation belts (many species)
	1.2.2 Water distribution systems inside the Pantanal	
	1.2.2.1 Recent shortcuts through the levees of the river channel (*furos, bocas*) 1.2.2.2 Paleo river channels (*corixos*) 1.2.2.3 Artificial channels	
2. Intermittent aquatic systems		
2.1 Systems with periodically flowing water (water distribution systems inside the ATTZ)		
	2.1.1 Channels covered with herbaceous plants (*vazante*), *Reimarochloa brasiliensis.*	
	2.1.2 Channels covered with woody plants (*landi*), *Calophyllum brasiliense, Licania parvifolia, Erythroxylum anguifugum, Alchornea discolor.*	

Hydrological status	Functional unit	Mesohabitat with botanical characterization (when possible)
	2.2 Systems covered periodically by standing water (see periodically terrestrial systems) 2.3 Artificial systems (rice paddies)	
3. Permanently terrestrial systems		
	3.1 Habitats bordering the Pantanal (transition zone to the Cuiabá depression)	
	3.2 Habitats inside the Pantanal	
	3.2.1 Habitats of paleo-fluvial origin	
		3.2.1.1 Paleo-levees (*Capões* and *cordilheiras*). See also habitat 4.4.2.1. *Trichilia stellatotomentosa*, *Combretum leprosum*, *Cordia glabrata*, *Dilodendron bipinnatum*, *Dipteryx alata*, *Scheelea phalerata*, *Tabebuia heptaphylla*, *Tabebuia impetiginosa*, *Tabebuia roseoalba*, *Enterolobium contortisiliquum*, *Anadenanthera colubrina* var. *cebil*, *Hymenaea courbaril*, *Sclerolobium aureum*, *Terminalia argentea*, *Vitex cymosa*, *Aspidosperma cylindrocarpon*, *Casearia sylvestris*, *Inga marginata.*
		3.2.1.2 Habitats of tectonic origin (inselbergs): *Myracrodruon urundeuva, Aspidosperma* cf. *parvifolium, Caesalpinia taubertiana, Cordia glabrata. Chomelia obtusa, Coutarea hexandra,Ditaxis* sp., *Erythroxylum laetevirens,Tocoyena formosa, Cereus* spp.,*Cleistocactus baumannii, Hippeastrum miniata, Cereus peruvianus, Tillandsia* spp, *Terminalia fagifolia.*
		3.2.1.3 Habitats of biogenic origin (termite mounds, *murunduns*) *Curatella americana*
		3.2.1.4 Habitats of anthropogenic origin 3.2.1.4.1 Habitats of indigenous origin (*capão de aterro, capão de bugre*) *Genipa americana, Unonopsis lindmanii, Ficus* sp., *Cassia grandis, Sapindus Saponaria, Rheedia brasiliensis, Acalypha communis, Dalechampsia scandens, Talisia esculenta.* 3.2.1.4.2 Habitats of modern times (dike-roads, dikes, many plant species from the upland)
4. Intermittent terrestrial systems		
	4.1 Systems covered periodically during periods of varying length with water, without or with sparse vegetation	
	4.1.1 Sand banks	
	4.1.2 Steep shores (*barrancos*)	
	4.1.3 Rocks	
	4.2 Systems covered periodically during periods of varying length with water, with herbaceous plants	
	4.2.1 Natural grasslands (*campo limpo natural*)	

Hydrological status	Functional unit	Mesohabitat with botanical characterization (when possible)
		4.2.1.1 Natural grassland rarely flooded with *Elyonurus muticus* (*campo de caronal)*
		4.2.1.2 Natural grassland flooded during periods of about 3 months with *Axonopus leptostachyus* (*campo de rabo de burro)* our of capim-vermelho (*Andropogon hypogynus*)
		4.2.1.3 Natural grassland flooded during periods up to 6 months (campinas, campos de baixada or campos de mimoso; *Axonopus purpusii* (capim mimoso), *Reimarochloa brasiliensis* (capim-mimosinho), *Panicum laxum, Setaria geniculata.*
		4.2.1.4 Herbaceous communities on low-lying levees or lower parts of levees flooded up to 6 months with *Polygonum ferrugineum, Ludwigia decurrens, Echinochloa polystachya*, *Aspilia latissima*, and different sedges
	4.2.2 Man-made grasslands of native species flooded during periods of different length, (*campo limpo artificial*)	
	4.2.3 Man-made grasslands of exotic species flooded during periods of different length (*Brachiaria humidicola, B. decumbens, B. brisantha*)	
4.3 Systems covered with herbaceous plants, shrubs, and isolated trees		
	4.3.1 Termite savanna flooded for several weeks, (*campo de murundum*) *Curatella americana*, *Andira cuyabensis*, *Simarouba versicolor*, *Vatairea macrocarpa*, *Tabebuia aurea*, *Sclerolobium aureum.*	
	4.3.2 Woodlands flooded for periods < 3 months (*Campo sujo* of *canjiqueira, Byrsonima orbignyana*, and of *lixeira, Curatella americana*)	
	4.3.3 Woodlands flooded for periods up to 6 months (*Campo sujo* of *pombeiro vermelho*, *Combretum laxum,* and of *pombeiro-branco, Combretum lanceolatum*	
4.4 Systems predominantly covered with shrubs and trees		
	4.4.1 Monospecific systems	
		4.4.1.1 Savannas flooded up to 4 months with *Tabebuia aurea* (*Paratudal)*
		4.4.1.2 Savannas flooded up to 8 months with *Copernicia alba (Carandazal)*
		4.4.1.3 Evergreen forests flooded up to 8 months with *Vochysia divergens (Cambarazal)*
		4.4.1.4 Evergreen forests flooded up to 8 months with *Licania parvifolia* (*Pimental*)
		4.4.1.5 Evergreen forests flooded up to 8 months with *Erythrina fusca (Abobral)*
	4.4.2 Polyspecific systems	

Hydrological status	Functional unit	Mesohabitat with botanical characterization (when possible)
	4.4.2.1 Deciduous forests (forests on terrestrial habitats, waterlogged or shortly inundated only during extreme floods, e.g., high levees and paleo-levees) For species composition see also habitat 3.2.1.1 *Astronium fraxinifolium,Anadenanthera colubrine, Combretum leprosum, Casearia gossypiosperma, Bromelia balansae, Seguieria paraguayensis and Sebastiana brasiliensis.*	
	4.4.2.2 Semi-deciduous forests (forests on shortly inundated habitats, e.g. low paleo-levees) *Tabebuia roseoalba, Scheelea phalerata, Aspidosperma cylindrocarpon,*	
	4.4.2.3 Semi-evergreen forests (forest on long inundated habitats, e.g., forests on flat low-lying areas, forests at the edges of levees, *capões* and *cordillheiras*). *Unonopsis lindmanii* , *Psychotria carthagenensis*, *Calyptranthes eugenioides*, *Mouriri guianensis*, *Thieleodoxa lanceolata*, *Zygia cauliflora*, *Trichilia catigua*, *Salacia elliptica*, *Aptandra liriosmoides*, *Buchenavia oxycarpa*, *Homalium guianense*, *Inga vera* subsp. *affinis*, *Crataeva tapia, Pouteria glomerata*, *Ceiba samauma, Cassia grandis* and *Tabebuia heptaphylla.*	
	4.5 Systems covered with shrubs (*arbustal,* flooded during intermediate to long periods)	
		4.5.1 Shrubland flooded up to 4 months with *Mimosa pellita (espinhal)*
		4.5.2 Shrubland flooded up to 4 months with *Byrsonima* spp (*Canjiqueiral*)
		4.5.3 Shrubland flooded up to 8 months with *Combretum lanceolatum* and *C. laxum (pombeiral)*
5. Swamp systems (soils permanently or for long periods saturated or covered with water)		
	5.1 Swamp systems predominantly covered with herbaceous vegetation	
		5.1.1 Swamps in the transition zone to the upland *cerrado* (marshy grasslands) *Schizachyrium tenerum, Echinolaena inflexa, Loudetia flammida*, *Erianthus asper* and many others
		5.1.2 Swamps in the Pantanal (*brejos*)
		5.1.2.1 Swamps with *Cyperus giganteus (Pirizal)*
		5.1.2.2 Swamps with *Thalia geniculata*
		5.1.2.3 Swamps with *Canna glauca (caitezal)*
		5.1.2.4 Swamps with high species diversity
		5.1.3 Dense periodically floating islands (*Batumes*) *Oxycaryum cubense, Ludwigia nervosa* and many others
	5.2 Swamp systems covered with herbaceous plants and trees	
		5.2.1 Swamps with *Mauritia flexuosa (Buritizal)*

during the dry phase. A large part of the clay fraction consists of caolinite with a low ion-exchange capacity (Irion et al. this volume).

Biological criteria form the fourth level. Higher plants are of particular importance because they are long-lived and reflect the impact of all environmental conditions over years, decades, or even centuries at the specific habitat. In some permanently aquatic habitats, there are no higher plants that can be used as bio-indicators. Animals may also be appropriate indicators for the classification, at least for certain habitats; but their mobility creates additional problems and our knowledge is not sufficient yet.

5.5 Discussion

The elaboration of national wetland classifications must take into account their linkage to international classification systems. Internationally recognized wetlands classifications are necessary (a) to provide a readily understood terminology for use in scientific research and conservation projects with an international dimension (b) to provide a framework for implementation international legal instruments for wetland conservation and (c) to assist international dissemination of information to as many relevant individuals and organizations as possible" (Scott & Jones 1995).

The problems in elaborating a classification system that addresses these issues and which adequately cover the necessary inventories were discussed by Finlayson & van der Valk (1995). Those authors pointed out the need to resolve differences among existing systems in the definition of a wetland and how wetland types are defined. Furthermore, they called for the standardization of data collection, storage, and dissemination techniques in order to generate more extensive international inventories. However, many international classification systems were formulated decades ago and often do not satisfy modern scientific requirements and national peculiarities. For instance, despite the existence of large riverine floodplains along the Mississippi, Ohio, and Missouri Rivers, the USFWS system does not treat floodplains as a specific wetland category nor does it consider the large habitat diversity of these systems. The SCOPE classification system includes the category "floodplains" but does not distinguish minor sub-units. According to the Ramsar classification system, the Pantanal is as an "inland, riverine intermittent floodplain system," but it is also a "perennial, emergent inland delta." Due to its large size, about 160,000 km2, the Pantanal includes habitats that can be classed with all the riverine and lacustrine subunits and some of the palustrine subunits of the RCS. For example, in the RCS, ephemeral bahias are "seasonal freshwater lakes," perennial bahias are "permanent freshwater lakes," salinas are "permanent saline lakes," river channels are "permanent rivers/streams," etc.

These different options support the need to connect national classification systems with the higher ranks of international ones. At lower levels, specific classification systems that reflect regional conditions are required (Finlayson & van der Valk 1995). For large wetland complexes such as the Pantanal, the Okavango Delta, large river floodplains, the Everglades, or the Tonle Sap system, individual hierarchical classification systems must consider the wetland complex as a landscape unit whose habitats and organisms are interlinked. The individual sub-units should be defined by internationally recognized parameters so as to be easily incorporated for comparative reasons in other internationally accepted classification systems.

Our approach makes use of the habitat types and/or vegetation units distinguished by the local population, and is thus similar to the system devised by Gopal & Sah (1995) in their classification of wetlands of the Indian subcontinent. Local denominations of habitats and vegetation units are the result of long-term observations of specific geological, hydrological, and biological characteristics, and they provide insight into specific functions of the landscape. Local denominations also facilitate acceptance of a classification system by the local population, which is of fundamental importance in the development and enforcement of protection measures. Functional diversity and species diversity are related to habitat diversity, and habitat diversity is threatened by inadequate management strategies. Today's battle between stake-holders and environmental protection is often not with respect to ecoregions but on a much smaller scale—to habitats and plant communities and their functions in the landscape.

The new classification system of major habitats of the Pantanal is based on well-defined hydrological, water- and soil-chemistry, and plant community characteristics. It is an ecological classification aimed at overcoming the following problems: (1) the lack of fixed boundaries between many habitats, (2) the changes in habitat conditions in the ATTZ throughout the year due to the flood pulse, (3) the large-scale changes in habitat conditions and the related changes in vegetation cover due to multi-annual climate changes, and (4) the effect of two centuries of human impact, which has changed plant communities in a manner that is difficult to reconstruct.

Our classification system is still preliminary, because the size of the Pantanal and the difficulty in accessing some of its regions did not allow us to survey it in its entirety or to study all of its habitats in detail. Furthermore, our knowledge about the physical and chemical properties of water and soils, the impact of the origin of water, and the impact of drought and fire stress on the vegetation is still insufficient. The fact that different plant communities are found at the same position on the flooding gradient shows that complex interactions between the different abiotic factors create different habitat conditions. The recently created National

Institute on Science and Technology of Wetlands (INAU) at the Federal University of Mato Grosso, Cuiabá, will close these gaps during the next years.

However, the classification is advanced enough that it can be used as the basis for discussion with other scientists and with people living in the Pantanal, both of whom can add information regarding additional habitats or modify proposed ones such that a definitive classification system is finally reached. Furthermore, the complexity of the Pantanal has thus far hindered the elaboration of laws regulating the use of its natural resources. Our classification system breaks this complexity down to units that can be used by local authorities as the scientific basis for the formulation of such laws and which can be understood by the pantaneiros, who will be expected to follow them.

We consider our classification as part of a major classification system of Brazilian wetlands that is still to come. This general wetland classification system should synthesize already existing classification systems of different wetland types to provide the scientific basis for a wetland-friendly national and state policy, according to the requirements of the Ramsar Convention, which Brazil signed in 1993.

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