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Features and conservation of the Brazilian Pantanal wetland

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Abstract

The Pantanal is a 140,000 km^2 sedimentary floodplain in western Brazil and one of the largest wetlands in the world. The main landscapes and phytophysiognomies, according to flood origin, are briefly described and some of the characteristic plant species are mentioned: (a) river flood (1–5 m) on clayey eutrophic soils with gallery forests, pioneer forests and scrub, *Tabebuia* and *Copernicia* parks, seasonal swamps, grasslands and oxbow lakes; and (b) rain flood (10–80 cm) mainly on dystrophic sandy soils (72% of the total area) with savanna ("cerrado") grasslands and woodlands, with or without ponds. Regulating factors of the vegetation such as wet-and-dry cycle and management are considered. Dynamics of the vegetation, in particular the aquatic types, are shortly depicted. The role of grazing for conservation is discussed, and we suggest that 200 years of cattle ranching apparently did not cause major changes in the vegetation, except turning tall grass into short swards, as the domestic herd found a nearly empty niche. However, severe threats to the flora and fauna of the Pantanal originate outside the floodplain. Siltation of the Taquari river is pointed out as the worst environmental problem, changing the hydrology (wet-and-dry to wet), fauna and flora, e.g. eliminating riparian forest.

Introduction

The Pantanal is one of the largest wetlands in the world, covering 140,000 km^2 in Central Western Brazil between 16° and 22°S and 55° and 58°W (Brasil 1997). An approximate 20% additional area continues into Bolivia and Paraguay. It is a Quaternary sedimentary floodplain, an inland delta, draining a 280,000 km^2 watershed. The land is very flat, with altitudes between 80 and 180 m, with some low Precambrian inselbergs near the edges. In the middle of the largest alluvial fan (50,000 km^2), formed by the Taquari river, sediments reach 400 m deep. The climate of the region is Köppen's Aw with mean temperatures of 32 °C in the summer and 21 °C in the winter. Annual rainfall is 1000–1400 mm with a very seasonal distribution (Brasil 1997).

The economy of the region consists mainly of cattle ranching, followed by fishing and, more recently, tourism. The entire Pantanal, except two parks, is privately owned and fenced into ranches averaging some 10,000 ha. A herd of 3.5 million cattle is held on rangelands of essentially natural grasslands, with added cultivated pastures on flood-free ancient levees (4% deforested area, Brasil 1997) and on very shallow-flooded savannas. The traditional fishery and tourist sport fishing are closed during spawning season and monitored by the forest police. Poaching for native animal skins became illegal and is now under strict control. In addition, the rural inhabitants do not hunt to eat,

with exception of the non-native feral pig. Fauna is very abundant (Mourão et al. 1998), contributing to the growing ecotourism. There is only one paved highway (Miranda-Corumbá) in the Pantanal and there are very few unpaved roads. All other roads are just tracks and there is no town inside the Pantanal. This isolation, the extremely low human population density, and the attitude of local people to their natural environment have long favored conservation of this floodplain.

There are few comparative descriptions of the Pantanal (Junk 1993) and few comprehensive studies of its vegetation (Dubs 1994; Prado et al. 1994; Schessl 1999). There is yet less quantitative information on vegetation dynamics and other ecological aspects. In this paper, supported by a short literature review and some of our observations during 20 years, we aim to contribute to the information base on the flora of this enormous floodplain.

Plant communities in the Pantanal

There are three basic land elevations in relation to flooding, each with their respective major vegetation formations: flood-free ridges (ancient levees) with trees, seasonally flooded plains with grasslands, and water bodies with aquatic macrophytes. A refinement of these categories recognizes 16 types (Adámoli and Pott 1999). Seasonal flooding may be fluvial (riverine) and/or pluvial (heavy precipitation) in origin and defines the two main types of mosaic landscapes. Areas where fluvial flooding occurs (1–5 m deep) consist of clayey eutrophic soils with vegetation consisting of gallery forests, forest islands, pioneer forests and monodominant scrub, park savanna of *Tabebuia aurea* (Manso) B. and H. ex S. Moore and palm savanna of *Copernicia alba* Morong, seasonal swamps and oxbow lakes. Pluvial flooding (10–80 cm deep) occurs mainly on dystrophic sandy soils (72% of the whole area) with savanna ("cerrado") grasslands and woodlands, with or without ponds. The nutrient status of waters and soils tends to increase from NE to SW (Hamilton et al. 1999).

The flora of the Pantanal is related to the surrounding biomes. There are phytogeographic influences mainly from cerrado or Central Brazilian savanna (e.g. *Caryocar brasiliense* Cambess.), Amazonia (e.g. *Licania parvifolia* Hub., *Vochysia divergens* Pohl), Chaco (e.g. *Aporosella chacoensis* (Morong) Spegazz., *Bulnesia sarmientoi* Lorentz ex Griseb.) and Atlantic forest (e.g. *Rheedia brasiliensis* (Mart.) Pl. & Tr., *Salacia elliptica* (Mart.) Peyr), plus a great number of species of wide distribution (mainly grasses) (Prance and Schaller 1982; Pott and Pott 1997a, 1999; Adámoli and Pott 1999). There are few endemics (Prance and Schaller 1982) (e.g. *Habranthus pantanensis* Ravenna, *Stilpnoppapus pantanalensis* H. Rob., *Xanthosoma pottii* E. G. Gonçalves). Many species found on the higher surroundings do not occur on the plain (e.g. *Heteranthera reniformis* Ruiz & Pav., *H. zosterifolia* Mart., *Ludwigia sericea* (Cambess.) Hara, *Nymphaea ampla* (Salisb.) DC., *Ottelia brasiliensis* (Planch.) Walp., *Potamogeton illinoensis* Morong) (Pott and Pott 2000). Some species useful to humans such as *Acrocomia aculeata* (Jacq.) Lodd. may have been spread by aborigines (Pott and Pott 1999).

The checklist of the phanerogamic flora has 1863 species, the main families being Leguminosae *lato sensu* (240 species), Poaceae (212), Cyperaceae (92), Asteraceae (82), Euphorbiaceae (78), Rubiaceae (62), Malvaceae (47) and Myrtaceae (45), and the main genera are *Paspalum* (35), *Cyperus* (29), *Ipomoea* (24), *Panicum* (22) *Eugenia* (20), *Ludwigia* (19), *Mimosa* (18), *Rhynchospora* (18) and *Polygala* (17) (Pott and Pott 1999). Most ferns are aquatic, such as *Salvinia* (3), *Azolla* (2), and *Marsilea* (2) (Pott and Pott 1997b, 2000).

The woody vegetation varies from deciduous forest to savanna woodland ("cerradão"), the latter being the main type and widely occurring on sandy soils. There is a mesotrophic "cerradão" form on better soils, with calciphilous trees like *Anadenanthera colubrina* var. *cebil* (Griseb.) Altsch., *Magonia pubescens* A. St.-Hil., *Scheelea phalerata* (Mart.) Bur. (Ratter et al. 1988). In oligotrophic woodlands some of the main trees are *Andira vermifuga* Mart., *Eugenia aurata* Berg, *Hymenaea stigonocarpa* (Mart.) Hayne, *Qualea parviflora* Mart. (Adámoli and Pott 1999). A general understory element is *Bromelia balansae* Mez, which is an indicator of the limit reached by flood (Pott and Pott 1994).

The *Elyonurus muticus* (Spr.) Kunth savanna, with fire tolerant shrubs with xylopodes e.g. *Annona dioica* A. St.-Hil. and barky trees like *Mouriri elliptica* Mart., is an intermediate level

between the flood-free ridge and the floodable open grassland, only becoming waterlogged or rarely and briefly inundated. Other common types are pioneer woodlands e.g. *Vochysia divergens* Pohl, scrubs like *Combretum lanceolatum* Jacq. and *Byrsonima orbignyana* A. Juss., and savannas of e.g. *Curatella americana* L., the most wide spread woody species, varying from dwarfed shrubby forms on wetter ground to 10-m trees on drier sites (Pott 1994).

The aquatic vegetation is one of the three basic formations of the Pantanal wetland. It is linked to depressed relieves of temporary and permanent ponds, seasonal streams, rivers, false rivers, and flooded grasslands. The subregions Nhecolândia, Abobral and Aquidaunana are rich in ponds. Some of those are called "salinas" and are surrounded by closed ridges and have brackish water (pH 8–10). These are poor in macrophytes and restricted to a few species such as *Chara rusbyana* Howe, *Najas guadalupensis* (Spreng.) Magnus, *Paspalidium paludivagum* (Hitchc. & Chase) Parodi and *Paspalum vaginatum* Sw. (Pott and Pott 2000). One of the main species in temporary ponds is *Pontederia parviflora* Alex. (Pott and Pott 2000). The Western side of the Paraguay River contains larger lakes, interpreted as remnants free of sedimentation, mostly with open waters and macrophytes restricted to the borders. Oxbow lakes, habitat of *Victoria amazonica* (Poepp.) Sowerby, backswamps and a divergent branched channel system are common to most rivers.

Large areas are amphibious environments, with alternating aquatic/terrestrial phases. Often there is microrelief of small earthmounds that bear more species than the flats in between (Pott 1994). On these savannas prevail grasses, the main species being *Axonopus purpusii* (Mez) Chase, *Paspalum* spp., *Reimarochloa* spp. When flooded, intermingled aquatic plants appear within a few days from dormant rhizomes and seeds, including *Echinodorus grandiflorus* Mich., *E. tenellus* (Mart.) Kunth, *Eleocharis acutangula* (Roxb.) Steud., *Marsilea deflexa* A. Braun, *Nymphoides grayana* (Griseb.) Kuntze, and *Sagittaria guayanensis* H. B. K.

The aquatic vegetation of these amphibious environments is very dynamic, adjusting to alterations dependent on seasonal and pluriannual hydrological cycles and on internal (cattle ranching) and external anthropic factors (inadequate land management on headwaters). Some species are exclusive to lentic environments (e.g. *Hydrocleys nymphoides* (Willd.) Buch., *Utricularia poconensis* Fromm-Trinta), some to seasonal streams (e.g. *Ludwigia inclinata* (L. f.) Raven and *Nymphaea oxypetala* Planch.), and some to rivers (e.g. *Polygonum ferrugineum* Wedd.). Many plants, such as *Eichhornia azurea* (Sw.) Kunth, are common to all types of water bodies, but plant size is proportional to nutrient level. Sandy soils present many different species (e.g. *Limnocharis laforestii* Duch.) compared to species exclusive to clay (e.g. *L. flava* (L.) Buch. and *Ipomoea carnea* subsp. *fistulosa* (Mart. & Choisy) Austin) (Pott and Pott 2000).

Floating aquatic vegetation

Floating mats are a common feature of the aquatic communities of the Pantanal. In dry pond beds, such floating mats die and become oxidized, releasing nutrients. They may also be affected by fire. Hydrophytes with exposed buds, like aerial branching grasses, are sensitive to fire. Fire also favors germination of hard seeds of *Mimosa* spp. Plant succession in replenished ponds, or after removal of the floating mats by bait catchers, restarts with free floating macrophytes (*Salvinia auriculata* Aubl., *Pistia stratiotes* L., *Limnobium laevigatum* (H. B. K.) Heine) and *Eichhornia azurea*. Within a few years, succession again reaches the stage of a floating meadow of sedges, first with *Oxycaryum cubense* (Poepp. & Kük.) Lye, then with *Eleocharis mutata* (L.) Roem. & Schult., and later with the ferns *Pityrogramma calomelanos* (L.) Link and *Thelypteris interrupta* (Wild.) Iwatsuki. Finally, when substrate build-up is not interrupted, the 3-m tall shrub *Ludwigia nervosa* (Poir.) Hara may become established. The aquatic orchid *Habenaria repens* Nutt. is also frequent on this floating organic soil (Pott and Pott 2000).

Impact of grazing

Although little floodplain remains undisturbed by cattle ranching (Schessl 1999), grazing during two centuries apparently did not cause major changes

in the vegetation, except turning tall grass into short swards. Apparently, the bovine herd found a nearly empty niche on the natural grasslands, which cover 2/3 of the Pantanal, because of a scarcity of large native herbivores (Pott 1994). Native herbivores, like capybara (*Hydrochaeris hydrochaeris*) and marsh deer (*Blastocerus dichotomus*), feed mostly on aquatic plants, overlapping to some extent with domestic stock grazing. Cattle graze *Aeschynomene* spp., *Discolobium* spp., *Neptunia* spp., *Eleocharis acutangula* (Roxb.) Steud., *Hymenachne amplexicaulis* (Rudge) Nees, *Leersia hexandra* Sw., *Luziola* spp., *Oryza* spp., *Paspalidium paludivagum*, and others that are partially protected by access difficulty in waters beyond one meter deep. However, *Discolobium psoraleifolium* Benth. is threatened by selective grazing, although its population probably had always been low due to scarcity of water bodies in the eastern zone. Ground orchids of the genera *Habenaria*, *Galeandra* and *Stenorrhynchus* also seem affected. Tree saplings like *Cecropia pachystachya* Tréc. and *Sterculia apetala* (Jacq.) Karst avoid browsing within the prickly *Bromelia balansae* Mez, while most *Ficus* species start as epiphytes (strangler figs). Intense trampling alters pond edges and temporary ponds, which may then become invaded by *Senna* spp. and annuals. Overgrazing near water and cattle yards can lead to weedy native plants such as *Ipomoea carnea* subsp. *fistulosa*. Without cattle, there is succession to pristine type tall grasses, reducing the number of small herbs like *Bacopa* spp., Cyperaceae, Eriocaulaceae and Gentianaceae (Pott and Pott 1997a).

In a pond in the Nhecolândia subregion the macrophyte richness increased after removal of buffaloes, animal which did not become widely adopted in the Pantanal, and of which some feral populations remain. Horses cause disturbance with their grazing habits in aquatic environments. The feral pig digs wet soil of large areas in search for food like rhizomes of *Nymphaea* and *Paspalidium*. This way, they provoke pioneer stages of secundary succession, with annuals like *Hyptis brevipes* Poit. and *Setaria geniculata* (L.) Beauv., and weeds (e.g. *Senna* spp.). Invertebrates are abundant and important consumers of aquatic plants. They also serve as diet items for fish, caiman and birds.

Fire

Grazing has a close interaction with burning intensity. Even though fire is recognized as an old factor in the region, it has become more frequent in recent times. Despite restrictions on the use of fire, the expensive fee to obtain a permit has actually led to an increase in uncontrolled fire. Observations from cattle exclosures, kept free from fire for a few years, and from consequent wildfires, promoted by a succession from short to undisturbed type tall grasses with a subsequent accumulation of fuel, indicated that moderate grazing and prescribed burning favor conservation of the flora. For example, the orchid *Catasetum fimbriatum* Lindl., which grows at ca. 1.5 m above ground on *Copernicia alba*, survives yearly grass fires, but does not withstand burning of accumulated dry grass and dropped palm leaves. Burning reduces fire-sensitive trees of gallery forest islets such as *Genipa americana* L. and leads to "cerradization", or increase of "cerrado" savanna trees with corky bark (Pott 1994). One of the few Amazonian trees present with thick bark (except when young) is *Vochysia divergens*, but dense stands shade the grasses out, however, and only the boundary is therefore affected by the flames.

Exotic species

Rare exotic species expand in flooded environments, mainly in disturbed regions. Such species include *Panicum repens* L. in sandy areas and tanner grass *Brachiaria subquadripara* (Trin.) Hitchc. (*B. arrecta* (Hack.) Stent.) on clay. Thus far, however, no exotic shrub has become a problem. A few cultivated woody plants, such as lemon and guava, are common ruderals on disturbed flood-free ground, as is *Mangifera indica* L. on river sides. The widely introduced *B. humidicola* (Rendle) Schw. has not spread away from the cultivated pastures and pantropical weeds have not invaded water bodies, only disturbed flood-free areas, such as road sides and homesteads, where many exotics, such as *Dactyloctenium aegyptium* (L.) Beauv. and *Ricinus communis* L occur. In general, there has been little interference in flooded areas, except excavation of water holes in dry years, favoring aquatic plants. Dowstream floating

mats, which may eventually block looping curves of the hydrovia at flood, are removed and sand banks are dredged in some points.

Threats to plant communities

By far the most serious environmental problem of the Pantanal is severe siltation on the lower Taquari river due to heavy sediment loading from intense erosion mainly on the sandy highlands. This affects over 11,000 km^2 of lowland, greatly changing the hydrology (i.e. from wet-and-dry to permanent wet) and consequently the fauna and flora. This rise in flood level and watertable kills the riparian forest and woods and changes seasonally flooded grasslands to permanent marshes. One sign that even the largest areas of dry forest in the Pantanal (Mata do Cedro and Mata do Fuzil) are undergoing changes is the appearance of *Lemna aequinoctialis* Welw. in slight depressions that become new water bodies, as well as the encroachment of *Triplaris americana* L., a riparian pioneer tree. The river side peasants are moving to suburban slums because flood and waterlogging have wiped out their small plantations (banana, cassava, orange, etc.) and the disactivated navigation left them stranded. Death of gallery forest and forest islets is causing expulsion of mammals. Other rivers are becoming silted as well.

Tree kill also occurs in the headwaters, when increased runoff and sediments from cleared microbasins silt up the stream and choke the *Mauritia flexuosa* L. f. marshy gallery vegetation and the species rich sponge-like herbaceous community (grasses, sedges, burheads, Eriocaulaceae, Xyridaceae, etc.) on both stream sides. An exception with good management is the Formoso microbasin, part of the Miranda basin in Bonito. Here, very clear springs and rivers in limestone are full of aquatic gardens and fish are an important tourist attraction.

Conservation

Conservation of the Pantanal depends mainly on conservation of the higher watershed, preserving the remaining natural vegetation and restoring it on degraded areas. Priority areas have already been mapped and emphasized (Brasil 1997).

On the plain, the ongoing traditional cattle ranching, now specializing in calf production and organic beef, and growing tourism seem to be appropriate economic activities.

The Pantanal National Park and the Taiaman Preserve are the only official protected areas in the Pantanal. They are unfortunately far from representative of the diversity of habitats and of species. However, private preserves are increasing in number and importance. One of those is as large as 90,000 ha (Reserva do SESC). Here, cattle have been removed and fire control has become the major concern. It is important to maintain fire-free areas for conservation of some animals and to observe which plant species may reappear.

Conclusion

Conservation of the Pantanal depends mainly on conservation of the higher watershed. On the plain, cattle ranching and growing tourism seem to be appropriate economic activities.

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