

# THREATS TO THE BIODIVERSITY OF THE BRAZILIAN PANTANAL DUE TO LAND USE AND OCCUPATION

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## Introduction

The biodiversity of the Pantanal has been divulged in several works of published literature. There are about 2,000 species of plants with strong biogeographic elements of the neighboring biomes: Amazon, to the north, Brazilian savanna known as Cerrado, east, Atlantic Forest, south-central, and the Chaco of Bolivia and Paraguay, west (ALHO, 2005; POTT et al., 2011a). In addition to flooded fields, there are phytophysiognomies of the Cerrado, such as patches of savanna, locally named “capão de cerrado”, denser savanna or “cerradão” and forest formations, such as deciduous and semi-deciduous seasonal forests, pioneer formations, dominated by a plant species such as “cambarazal” (*Vochysia divergens*), “pirizal” (*Cyperus giganteus*), “canjiqueiral” (*Byrsonima orbignyana*) and others (POTT et al., 2011a). Some 280 aquatic macrophytes of the Pantanal are related to seasonally flooded environments (POTT et al., 2011b). The plants are adapted to the seasonal water regime (SCREMIN-DIAS et al., 2011).

The Pantanal is a wetland (150,355 km<sup>2</sup>), located in the center of South America, between parallels 15° 30' and 22° 30' south and meridians 55° 00' and 57° 00' west, mostly in Brazil (140,000 km<sup>2</sup>), touching Bolivia and Paraguay (Figure 1).

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Figure 1. The geomorphological depression, in the center of South America, which is the Pantanal - lies at 60 and 150 meters above sea level, and the plateaus of its surroundings, varying from 200 to 1,000 meters in height, where the springs of the rivers that seasonally supply the floodplain are found.



Source: Prepared by the authors, based on ANA / GEF / UNEP / OAS (2005).

The wildlife of the Pantanal is distributed according to the mosaic of habitats of the region. Although fauna diversity is not very different from that of neighboring biomes, abundance of species is relevant (ALHO, 2005; ALHO, GONÇALVES, 2005; NUNES, 2011). However, for mammals in general (TOMAS et al., 2017) and for bats, in particular (FISCHER et al., 2018a), the species richness in the Pantanal has been shown to be higher than in the neighboring biomes, when considered in relation to the total area of each biome. The argument presented by these authors, in these studies, is evidenced by the occurrence of more species per hectare in the Pantanal than per hectare in the other biomes. Because the Pantanal is located in the center of South America, it potentially becomes an ecotone, surrounded by large biomes, where the geographical distribution of species, typical of the different biomes, occurs. The abundance is expressed by the vigorous populations of capybara *Hydrochoerus hydrochaeris*, spectacled- caiman *Caiman crocodilus*, crab-eating-fox *Cerdocyon thous*, marsh-deer *Blastocerus dichotomus*, among others (ALHO, 2005; ALHO et al., 2011a). Among the abundant populations of birds are the wood-stork *Mycteria americana*, the great heron *Ardea alba*, the gray heron *Ardea cocoi*, the maguari-stork *Ciconia maguari*, the little-egret *Egretta thula*, and the jabiru *Jabiru mycteria*.

The abundance of species is favored by the high ecological productivity of the Pantanal (ALHO, 2005).

The diversity of species includes 174 mammals, counting terrestrial, semi-aquatic, aquatic, and flying mammals (ALHO et al., 2011a); more than 580 species of birds (NUNES, 2011); and more than 260 species of fish (BRITSKI, et al., 2007).

The Pantanal's biodiversity is not only a source of admiration and scientific fascination. The vigorous biological resources that occur in the biome have contributed to the well-being of local people (ALHO, 2012a; OLIVEIRA et al., 2011; ALHO, 2012) for commercial, subsistence and sport fishing, and also for tourism (ALHO, REIS, 2017, CHIARAVALLI et al., 2017; TORTATO et al., 2017).

The growth of the regional human population is evidenced by data from the Brazilian Institute of Geography and Statistics (IBGE). The historical view that nature needed to be conquered was the goal from the gold rush in the eighteenth century to the March to the West in the 1950s that spread the idea that the region of the country was an "empty space" to be occupied (GALETTI, 2000).

Livestock also expanded on the plain. The cattle herds between 1985 and 2015 grew more in the central-west region than in other regions, expanding from 40 million cattle to 75 million in 2015. Pantanal municipalities, such as Corumbá and Cáceres, retained large herds (IBGE, 2017).

The objective of this study is to identify and evaluate the environmental threats to the Pantanal's biodiversity and also its socioeconomic threats (those that affect the economic and social component of the local human population), in search of conservation and sustainable use, as analysis factors. There are two primary concerns: (1) protection of natural habitats; and (2) the relationship of biodiversity resources to potential socioeconomic benefits to local residents. The article explores what environmental threats mean for the use and valuation of biodiversity.

## Methods

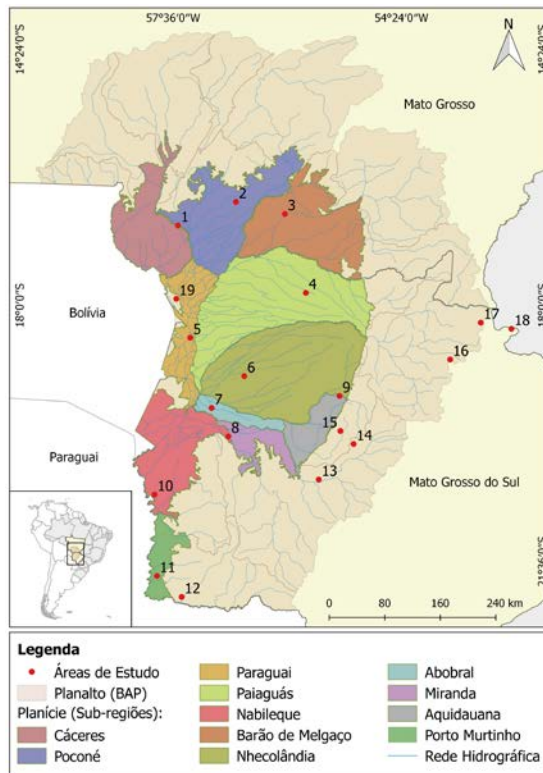
The authors have been working for a long time in the Pantanal. Recent fieldwork was carried out at different points in the 11 sub regions of the Pantanal (SILVA; ABDON, 1998), established according to the following criteria: (1) flood regime, (2) relief, (3) soil type, and (4) vegetation type. Eight regions of the plateau were also sampled (Figure 2)

The sampled areas were:

Pantanal, in the following sub regions:

1. Pantanal of Cáceres (16° 52' 21.09 "S, 57° 32' 04.47" W): boat trip along the Paraguay River, from Cáceres to the Ecological Station of Taiamã.
2. Pantanal of Poconé (16° 32' 33.21 "S, 56° 43' 20.91" W): along the Transpantaneira highway.
3. Pantanal of Barão de Melgaço (16° 42' 36.51 "S, 56° 02' 09.71" W): Private Reserve of Natural Heritage of SESC, between the Cuiabá and São Lourenço rivers.
4. Pantanal of Paiaguás (17° 49' 15.94 "S, 55° 44' 29.10" W): terrestrial course for three days.
5. Paraguayan Pantanal (18° 27' 05.68 "S, 57° 21' 46.01" W): overflight carried out in the dry season and monthly field work (four days each), October 2015 to September 2016.

Figure 2. Points sampled by the field work. The upper Paraguay River basin, which includes the high part of the plateau and the depression, which is the Pantanal.



Source: Prepared by the authors, based on SILVA; ABDON (1998)

6. Pantanal of Nhecolândia (18° 59 '25.05 "S, 56° 36' 15.85" W): Fazenda Nhumirim, Embrapa and surroundings.

7. Pantanal of the Abobral (19° 26 '25.51' S, 57° 03 '45.24 "W): Western portion of the sub region, November 2014 to January 2017, Park Highway, Pantanal (MS-184), to the south, to the limit of the sub region.

8. Pantanal of Miranda (19° 50 '20.20 "S, 56° 49' 39.53" W): Park Highway, South Pantanal, Buraco das Piranhas, Miranda River Bridge, Morro do Azeite and Carandazal, 2011-2016.

9. Pantanal of Aquidauana (19° 16 '11.99 "S, 55° 16' 11.99" W): Aquidauana and Pantanal of the Negro River.

10. Pantanal of Nabileque (20° 39 '20.42 "S, 57° 51' 47.13" W): Barranco Branco, Nabileque River, Aquidauana River (February 2008) and two in the dry season (June and October 2015).

11. Pantanal of Porto Murtinho (21° 48 '02.37 "S, 57° 49' 47.18" W): Porto Murtinho, Apa River mouth, Ilha da República, Ingazeira, full season (February 2008) and two in the dry season (June and October 2015).

Plateau in the following regions:

12. Plateau of the Apa River basin (22° 05 '43 "S, 57° 28' 56" W): five days in December 2015.
13. Maracajú Plateau (20° 26 '40.6 "S, 55° 33' 38.2" W): monthly work 2014-2016, lasting one year.
14. Planalto de Maracajú, Furnas region of Boa Sorte (19 ° 56 '44.4 "S, 55 ° 04' 18.7" W): monthly work 2014-2016.
15. Serra de Maracaju, region of Taboco (19 ° 45 '45.6 "S, 55 ° 15' 30.4" W): bi-monthly work 2014-2016.
16. Plateau of the river source of the Taquari (18° 45 '25.34 "S, 53° 43' 10.05" W): monthly work in 2014.
17. State Park Nascentes do Rio Taquari (18° 14 '21.29 "S, 53° 17' 20.56" W): sporadic work in 2014.
18. Emas National Park (18° 19 '36.7 "S, 52° 51' 34.99" W): Monthly work 2005-2007 and 2011-2015.
19. Serra do Amolar (17° 54 '18.48 "S, 57° 33' 27.79" W): monthly work, from October 2015 to December 2016.

The records were made through direct observation of representative habitats and complemented by informal interviews with the local people.

The published literature was synthesized to support the field annotations, which were evaluated in consultation with the satellite images (with more detail for the Pantanal do Abobral sub-region), aiming at an integrated analysis in each space analyzed. Each occurrence observed in the field was also checked on the maps, including the Google Earth feature and MapBiomias, both available on the world-web.

For the classification of the conservation status of each species, we consulted the "Livro Vermelho da Fauna Brasileira Ameaçada de Extinção" (ICMBio/MMA, 2018).

## Results and discussion

As a wetland ecosystem, the Pantanal is characterized by an indistinct, but always changing, boundary between aquatic and terrestrial environments (ALHO; SILVA, 2012; JUNK; SILVA, 1999). River waters flow from the plateau toward the depression of the Pantanal, and in their flows the rivers move slowly as they reach the flat lands of the Pantanal plain, periodically flooding the marginal areas. The seasonal flooding system causes an annual biogeochemical cycle of influx of nutrients, particles, microorganisms, and invertebrates, which form a dynamic ecosystem with a mosaic of habitats, which sustains biological diversity (ALHO, 2005; JUNK et al., 2006).

The seasonal productivity of food and other ecological resources favors biodiversity and abundance of wildlife populations. Seasonally, many parts of the Pantanal change from terrestrial environment to aquatic environment and vice versa. Generally, from May to October the land dries, and natural fields and bodies of water that remain in depressions in the ground arise.

## Determinant factors threatening biodiversity

The identification, characterization and evaluation of environmental threats to biodiversity are important tools for strategic conservation actions (KUKKALA; MOILANEN, 2013; MARGOULIS et al., 2013; SALAFSKY et al., 2008). Some threats identified here are of a technical-scientific nature, such as those that influence the structure and function of ecosystems. Others are of a political, social and administrative nature, and can often be avoided with control actions.

### 1. Threat: Conversion of natural vegetation into pasture for livestock and agricultural field

Deforestation has been observed in the cattle farms within the Pantanal and mainly in the upland Cerrado plateau. It also occurs along roads, as observed in our field activities in the flood land of Abobral and in plateau regions (Alcinópolis, Figueirão and Costa Rica). Monitoring activities of 2008 showed the Pantanal with 85% of its vegetation, while the plateau maintained only 41% of the natural vegetation (CI-BRASIL, ECOA, AVINA, SOS PANTANAL, WWF-Brazil, 2009). The monitoring of 2012-2014 (WWF-BRAZIL; SOS PANTANAL, 2015) found that 58% of the natural areas in the plateau and 42% in the lowlands were converted to anthropic use, totaling 1,875 km<sup>2</sup> of altered area.

Analyses conducted by us on vectorial maps derived from satellite images produced by IBAMA in the years 2009-2010 and 2010-2011 indicated:

- In the period 2009-2010, 732.5 km<sup>2</sup> were deforested and in 2010-2011, 1,300 km<sup>2</sup>, creating approximately 2,582 km<sup>2</sup> of deforested area;
- Two large deforestation areas were identified, both in the municipality of Corumbá, one of 41.5 km<sup>2</sup> in the Paiaguás sub region and another 22 km<sup>2</sup> in the Nhecolândia sub region.

Our study conducted in the Pantanal of Abobral showed a decline of 3.1% of the forest formations (patches of savanna cerrado, denser savanna or cerradão ranges and riparian forests) between 1995 and 2015. It represented a decline of 84 km<sup>2</sup> of native vegetation compared to the territorial extension of Abobral, with 2,833 km<sup>2</sup> (SILVA, ABDON, 1998).

Inspections we made in that region in 2015, in a sample area of 80 km<sup>2</sup> along the Park-Highway Pantanal (MS-184), where patches of cerrado and cerradão or cordilheira represented only 5% of the area, revealed anthropic occupation, with the presence of exotic species, fences, corrals, rubbish, cemeteries, logging, among other human use actions.

During those field observations, in patches of cerrado and cerradão (cordilheira), we recorded burned and fallen trees, forming clearings, besides trampling by the presence of cattle. The excessive occurrence of some plant species was also noted, such as the caraguatá (*Bromelia balansae*), inside the forest, and the acuri (*Attalea phalerata*), on the edge of the forest. These species are pioneer heliophiles, developing in areas with intense

sun exposure and that have suffered some type of disturbance (POTT et al., 2011a). The trampling on the soil by cattle affects the development of seedlings of other trees that are important for the regeneration of vegetation.

The acuri fruit is a source of food that is much sought after by cattle during the dry season, and both *cerradão* and *cerrado* patches represent a refuge for cattle during the flood (ALHO; GONÇALVES, 2005). The dominance of this plant in the vegetation is evidence of the effect and impact that the presence of cattle exerts on the vegetation, disseminating its seed and limiting the recruitment of larger tree species.

Monitoring by the Ministry of the Environment (MMA, 2011) showed a deforested area of 23,160 km<sup>2</sup> up to the year 2009, with 188 km<sup>2</sup> deforested in the period 2008-2009. In 2008, the remaining vegetation in the Pantanal had 83% of its natural habitats and in 2009 this percentage decreased by less than 1% and, by 2019, the biome lost 18% of vegetation cover. The areas that most lost natural vegetation in 2008-2019 were on the upland plateau.

Between 1976 and 2008, 12.14% of the Pantanal was deforested, and it was suggested that the natural vegetation of the region may be eliminated by the year 2050 (SILVA et al., 2011).

Recent monitoring by satellite image concluded that although the Upper Paraguay Basin (plateau plus Pantanal) still contained 58.7% of its vegetation cover, only 45.5% of the plateau area maintained natural cover, while 82% of the Pantanal area still maintained original vegetation (WWF-BRASIL; UNIVERSIDADE CATÓLICA DOM BOSCO; FUNDAÇÃO TUIUIÚ, 2017). However, it should be noted that many changes in natural habitats are not detected in the satellite imaging monitoring, as shown below, in this study.

Deforestation advances to the riverside, modifying or eliminating riparian forests, which violates Brazilian legislation (Novo Código Florestal Brasileiro - Law No. 12.651 of 2012), which determines a permanent preservation area.

In the plateau, the deficit of native plant species is already severe, tending to reach a critical level of degradation (ROQUE et al., 2016).

Alluvial fans, to a certain extent, are normal in the Pantanal, but as can be seen in the case of the Taquari River fan, the hydrodynamic process with avulsion of the river channel is exacerbated by deforestation of riparian forests (ALHO, SILVA, 2012). This phenomenon was also observed by us, to a lesser extent, in the São Lourenço River.

The deforestation that we have observed in Pantanal riverside forests should also be related to the feeding and reproductive strategy of certain fish, known in the literature (ALHO; REIS, 2017). During the beginning of the flood season, when river water in the lowland region begins to overflow and to flood the riparian forest, some fish leave the riverbed to explore the flooded area of the forest. This is the case of pacu *Piaractus mesopotamicus*, one of the Pantanal's most important fish from the socioeconomic perspective. The main food item of the pacu is the fruit of the native palm of the riparian forests *Bactris glaucescens* (GALETTI et al., 2008). Deforestation, therefore, affects the biology of these species.

In summary, the productivity of Pantanal's aquatic and terrestrial ecosystems depends on three factors: (1) the amount of nutrients carried by the rivers that flow from

the plateau to the plains, with a strong association with biodiversity; (2) the extension of the Pantanal, with all its complexity of natural habitats and vegetation cover; and (3) seasonal dynamics of flood-ebb-drought and its association with biodiversity.

## 2. Threat: Alteration of natural habitat

Disturbances within the tree area are generally not detected by satellite monitoring. This is the case of the changes that the cattle make in the forest patches, locally named cordilheiras. Another effect of the extensive presence of livestock is manifested by intense herbivory, preventing growth, with negative effect on biomass, besides trampling and compacting the soil, altering the vegetation. In protected areas, such as the SESC-Pantanal Reserve in the Poconé sub region, we observed that shrub vegetation, without the presence of cattle, grows up to about two meters high.

Selective cutting of trees for fences and other uses also affects biodiversity. This is the case of the cutting of mature trees, such as the manduvi, *Sterculia apetala*, whose cavity serves as a nest for the hyacinth macaw *Anodorhynchus hyacinthinus* and other birds, and jenipapo, *Jenipa americana*, whose fruit is consumed by the howler *Alouatta caraya*, and other trees.

The collection of live bait has been observed by us in several points of the Pantanal. This involves capture of small fish (jeju *Hoplerhynchus unitaeniatus*, tuviras *Gymnotus* spp., among others), and also crustaceans (crab *Dylocharcinus paguei*), which supply the growing sport fishing demand. These species live in shallow floodplain, low current, water retained in depressions, locally named baías, small creeks named corixos, ebbing small valleys, named vazantes, dominated by aquatic macrophytes. At least two negative impacts are observed: (1) the intense capture, until exhaustion, of these species that serve as live bait; and (2) the effect on habitat degradation and on the ecological community of which these live bait are a part.

In the sub-region of Nhecolândia, at some points we observed the pasture advancing to higher areas, in the forests that surround the salinas, one of the icons of the landscape of the region. In these salt marshes, we noted the presence of migratory birds, including *Himantopus mexicanus*, which indicates another important element of this environment for biodiversity. In Nhecolândia it was frequently possible to see several mammals listed as threatened with extinction, such as the marsh deer *Blastocerus dichotomus*, the pampas-deer *Ozotoceros bezoarticus*, the anteater, *Myrmecophaga tridactyla*, and the giant-river-otter *Pteronura brasiliensis*, among others.

In this region of Nhecolândia, the pasture advanced to include the deforestation of cordilheiras (large forest patches of dense cerrado or cerrado), with the introduction of African forage, as pasture for livestock, both factors leading to the degradation of natural habitats. Evidence for this environmental threat is shown in the study conducted in forested habitats of the Pantanal using habitat occupation models, and occupied by the bat *Artibeus planirostris*, which feeds on fruits. This study pointed out that vegetation structure was determinant for the detectability of this species of bat (SILVEIRA et al., 2018). According to this study, introduced pasture areas (brachiaria) represented con-



ditions below the threshold of occupation by the species of bat. Thus, even a species of generalist bat that is widespread in the Pantanal suffers the negative effect of the threat from the introduced pastures. This environmental disturbance, with loss and modification of forested habitats, also affects eight species of primates that occur in the Pantanal (ALHO; PASSOS, 2019).

### 3. Threat: Effect of wildfire

Farmers have a habit of setting fire to the vegetation during the dry season to “clear” the area, opening pasture for livestock. Some farms dedicated to tourism also usually burn the garbage produced. During the field observations around the Park Highway of the Pantanal, in the southern area, we found several places where the garbage dump generated by the tourist farms accumulated. This is a risky practice because it is commonly done in places hidden by the forest canopy and difficult to access.

Our field observation, including by overfly, showed that both in the Pantanal and in the plateau areas there were fire events consuming huge areas during the dry season. Our consultations of IBAMA's Prevfogo program (2017) and INPE - National Institute of Space Research (2017) confirmed intense fires throughout the Pantanal during the last five years.

Grass fields, named caronal, formed by *Elyonurus muticus*, capim-fura-bucho *Paspalum carinatum* and *Paspalum stellatum* and capim-rabo-de-burro *Andropogon bicornis* and capim-rabo-de-lobo *Andropogon hypogynus* are burned. The fire expands and reaches forest environments.

This change in habitat potentially impacts wild rodents, with habitat-generalist species and other habitat-specialist species, which are very demanding in elements of microhabitats associated with vegetation (ALHO, 2005; ALHO et al., 2011 a, b). It also affects reptiles like lizards and snakes and birds of terrestrial habit.

### 4. Threat: Changing the hydrological regime with alterations in flood patterns

The hydrological regime influences nutrient cycling, ecological community, phenology, upstream migration of fish (piracema) and other factors (ALHO; SILVA, 2012; ALHO; REIS, 2017). There are more than 100 small hydroelectric plants planned, mainly for the northern part of the plateau, where the rivers that feed the Pantanal are born (ANEEL, 2016, CALHEIROS et al., 2009).

The Pantanal fish that migrate to the headwaters for spawning behavior are: cachara *Pseudoplatystoma reticulatum*, pintado *Pseudoplatystoma corruscans*, dourado *Salminus brasiliensis*, piraputanga *Brycon hillari*, piavuçu *Megaleporinus macrocephalus*, and curimatá *Prochilodus lineatus*. The spawning takes place at the headwaters; the eggs are carried by the water downstream and the young fish grow in the productive waters of the floodplain. At the beginning of the rainy season, the schools of fish go up the rivers for spawning. If they encounter obstacles, such as hydroelectric dams, the migration (piracema) is interrupted.

In addition to the potential effect of small hydroelectric plants (SHPs), other infrastructure, such as roads, fragment the plains in various parts, interrupting the shallow flood transit. Small landfills on farms also affect flooding. There is the action of landowners who, by means of landfills, build airstrips, raise the level of roads for vehicular traffic, modify the land for constructions, among other infrastructure works that negatively affect the structure and function of seasonally flooded natural habitats. There is, therefore, the need to implement conservation actions to mitigate or avoid this disturbance in the natural environment.

There is a clear link between the Pantanal's normal flood regime and the availability of food for wildlife. For example, the jabirus or tuiuiús have specialized beaks to catch their prey, such as the mussum fish (*Symbranchus marmoratus*), which is encapsulated in the mud during the dry season. Since fish is one of the most important items for waterfowl in the Pantanal, regular floods renew the stock of prey during the ebb season, causing the prey to spread beyond the confined riverbed. Due to the seasonal supply of abundant food, the birds exhibit synchronized reproduction, with flocks of wood stork (*Mycteria americana*), herons (*Egretta thula* and *Pilherodius pileatus*) and others. The colonies form the "ninhas", favoring the synchronized nesting of different species in the same place by the reproductive guilds.

Seasonal fluctuations also influence the availability of food for various species of wildlife, such as capybara (*Hydrochoerus hydrochaeris*). Some of the protein-rich food items preferred by capybara tend to be more seasonal than the protein-poor items (ALHO, 2005).

A common phenomenon that has been observed in the Pantanal's various study areas is the so-called "dequada", with deterioration of water quality, linked to water seasonality, which leads to fish mortality (MACEDO et al., 2015).

## **5. Threat: Effects of unregulated tourism and the need for institutional strengthening**

There is a growing demand for inns (local pousadas) in the Pantanal from national and international tourists, showing good economic potential for the region. However, the logistics of these enterprises lack practices of sustainable tourism and have too few qualified professionals. Tourist lodges, at the farms, and the sport fishing boats, both lack adequate collection and treatment of the garbage produced. Our observations showed that garbage is buried or burned nearby. In some inns, the garbage is buried in the middle of the vegetation of riparian forests. When it comes to sudden flooding, the garbage is washed up and scattered.

The inns usually provide feeders to attract species of birds close to the tourist, as it is common to offer acuri seed for the hyacinth macaw. This has a positive aspect of species protection, but, under the ecological approach, potentially modifies its search behavior and competition for food. In the inns visited in the Pantanal of Abobral, in the drought of 2015, we observed tourists and staff feeding fox (*Cerdocyon thous*), who usually visit camping areas and dumps near the inns in search of food in the daytime, although the species has a nocturnal habit.

In the Paraguay River there was an increase of solid waste in the riverbed and on the river banks from the time of the opening of the fishery season. Despite the socio-economic benefits encouraged by the growing number of tourists seeking sports fishing on the Paraguay River from the city of Corumbá, there are negative implications that the activity encourages: there is sex tourism camouflaged by amateur fishing, especially in hotel boats, in addition to unsustainable interference in fish stocks and demand without adequate management of environmental resources (TUFAILE, 2011).

The lack of control in river vessel traffic has been verified, mainly by the waves that this produces in the water, affecting the sites for nesting of birds on the sandy beaches during the drought. Bird species such as *Rynchops niger*, *Sternula superciliaris* and *Phaetusa simplex* make their colonial nests on the sands near the water line.

Agricultural pesticides were seen being sprayed at several points in the perimeter boundary of the Emas National Park and in the Nascentes do Taquari State Park - core areas of the Pantanal Biosphere Reserve. Several environmental pollutants have been detected contaminating the waters of the Pantanal (ALHO; VIEIRA, 1997). Also, the small and large towns of the Pantanal region pour untreated sewage into the rivers; This is evidenced by the water pollution of the Cuiabá and São Lourenço rivers, due to the effect of sewage disposal (LIMA et al., 2015).

There is a lack of inspection even in areas of great environmental relevance, such as in protected areas that have a Management Plan, but their implementation is precarious (ALHO, 2011).

A good indicator of the valuation of biodiversity is that, in some inns, the presence of the jaguar (*Panthera onca*), to be seen and photographed, has become a great attraction, with a strong appeal for its protection and, consequently, an economic incentive (TORTATO et al., 2017). At Fazenda Santa Clara, in the Pantanal of Abobral, one of our study areas, we observed the presence of the jaguar in the region.

In contrast, in the vicinity of farm houses, where there is greater human interference, we observed a greater presence of species of fauna that have general habits and that take advantage of this disturbed environment, such as the fox *Cerdocyon thous*, the curicaca bird *Theristicus caudatus*, and the caracara hawk *Caracara plancus*, among others.

## 6. Threat: Effect of introduced exotic species

Following human occupation, the introduction of exotic plants and animals has been deliberate or accidental, with consequent alterations of the natural ecological communities of the Pantanal (ALHO et al., 2011c).

Our field experience showed that there are considerable numbers of exotic species introduced into the Pantanal. They include plants, mollusks, fish, feral pigs, cats, dogs, cattle and others. We have observed the presence of these exotic animals even in protected areas, which conflicts with the management plan. This interrelationship is evidenced by the protozoan parasite *Trypanosoma evansi*, which infects horses, cattle, dogs, capybaras, coatis, and small wild rodents of the Pantanal. The vector of disease - "mal-das-cadeiras" - is the hematophagous fly *Tabanus*, of the genus *Tabanus*. In addition to the problem of

zoonosis, among other effects, it weakens and kills horses with anemia, causing socio-economic losses for farmers (SILVA et al., 1995; ALHO, 2012b)

Two African forage species were introduced as pasture for cattle ranching: *Urochloa decumbens* (former *Brachiaria decumbens*) and *Urochloa humidicola* (former *Brachiaria humidicola*), converting the natural vegetation into cultivated pasture. The common pig (*Sus scrofa*), which becomes feral, locally called porco-monteiro, is commonly seen in large open areas, being present in all areas sampled by us for this study. The golden mussel (*Limnoperna fortunei*) is an Asian mollusk that reached the Pantanal through the La Plata-Paraguay river system, and has spread to aquatic habitats. Another invader is the Amazonian tucunaré fish (*Cichla cf. ocellaris*), introduced in the Pantanal, and which is a voracious predator, feeding on prey of the local ecosystem. Another Amazonian fish that has been seen in fisheries in the Pantanal is the tambaqui *Colossoma macropomum*.

## 7. Threat: Unregulated traffic on roads that cross the Pantanal

Anyone who crosses the Pantanal by the major highways, like the Transpantaneira, which goes from Poconé to the interior of the plain, and many others, such as highways BR-262, BR-060, BR-267, is faced with road-killed animals. In addition to run-over wildlife, the barrier effect, and the artificial environments created by incoming soil, we can also observe deforestation along the roads, creating the so-called border effect (MMA, 2003).

Roads do not have animal passages under the highway or other forms of management to mitigate roadkill. On only one of our trips we recorded 21 mammals (anteaters, foxes, armadillos, capybaras and others) run over on highways BR 267 and 060. Reptiles and birds were recorded killed along highway BR 262, which cuts through the Cerrado towards the Pantanal (Campo Grande to Corumbá), showing 930 animals run over, 29 reptiles and 47 birds (FISCHER et al., 2018b). This monitoring, which lasted four years (1996-2000), indicated 20 run-over species that did not appear in previous records.

On the paved roads, the degradation of palm trees that form the buritizal is verified by soil compaction, sediment transport, water retention, and other factors.

## 8. Threat: Effect of hunting and trafficking of wildlife

Although illegal, hunting is still practiced in some parts of the Pantanal. There is indirect evidence of the intensity of the trafficking of wild animals. The CRAS (Center for the Recovery of Wild Animals) of Campo Grande receives seized animals that are captured for illegal trade, mostly parrot chicks. Inspection is poor. Trafficking in wild animals is considered to be one of the most important illicit acts, along with drug and arms trafficking (RENCTAS, 2001).

Legislative and enforcement agencies, such as the Environmental Military Police and IMASUL of Mato Grosso do Sul and FEMA of Mato Grosso, along with Ibama, have shown institutional deficiency to inspect the immense Pantanal.

## 9. Threat: Climate change

Although this theme is broad, yet its perception, to a certain extent, can be detected in the field. The variability of annual and inter-annual flood patterns that influence the Pantanal can be evidenced in the field through the occurrence of certain vegetation patterns. This occurs in places with abnormally long-term floods, such as in the Taquari River, or in prolonged drought sites, as well as along the Transpantaneira highway in the Pantanal sub-region of Poconé. Two trends are observed: (1) in prolonged drought events, some woody plants colonize the former seasonally flooded fields with homogeneous formations. These species are documented in the published literature: *Annona dioica*, *Bowdichia virgilioides*, *Buchenavia tomentosa*, *Curatella americana*, *Hymenaea stigonocarpa*, *Luehea paniculata* (POTT et al., 2011a); (2) in prolonged periods of flood, water-tolerant trees, such as *Vochysia divergens*, are observed to form homogeneous or monodominant blocks; as well as being documented in the literature (ABDON et al., 2005; ALHO, SILVA, 2012).

While fires in the Pantanal and surrounding areas contribute to the greenhouse effect of climate change, this huge wetland can play a key role in the regional and global climate as elements for its conservation (KEDDY; FRASER, 2005; KEDDY et al., 2009).

## Conclusion

The effects of the threats involve the ecological focus, but also the socioeconomic focus, since many elements of the Pantanal's biodiversity serve to leverage factors of use.

There is extensive legislation relevant to the biodiversity of the Pantanal, starting with the international conventions signed and ratified: the Convention on Biological Diversity, the RAMSAR Treaty on Wetlands, and the UNESCO Biosphere Reserve. In addition, there is a whole legislation focusing on the protection of biodiversity, such as Federal Law 9.985 of the National System of Conservation Units and others.

Among the large projects carried out in the Pantanal that deal with the biodiversity issue are: (1) EDIBAP - Study for the Integrated Development of the Upper Paraguay Basin, executed between 1977 and 1989; (2) PCBAP - Plan for the Conservation of the Upper Paraguay Basin, 1997; (3) GEF-Pantanal (ANA / GEF / UNEP / OAS) - Strategic Action Program for the Integrated Management of the Pantanal and Upper Paraguay Basin, executed by the National Water Agency - ANA, in 2005. In addition, regional organizations, including universities, have contributed to studies and activities on biodiversity.

The results of this study reinforce the scope of the assumptions established in light of these documents and the knowledge disseminated (Table).

**Table. Relevance and magnitude of the environmental threats identified and analyzed and their relationship to biodiversity.**

Relevance to biodiversity	Evidence found
Protecting biological diversity	The identified threats were evidenced by the vulnerability of several species recorded in the field, given their sensitivity to one or more environmental or socioeconomic risks.
Conserving representative samples of natural ecosystems	The annotations of the field work involve the main sub regions of the Pantanal and also the plateau, covering representativeness. This coverage seeks to reflect the importance of the Pantanal as a biome, compared to the neighboring biomes.
Protecting endangered species	Threats discussed affecting the species listed by the “Livro Vermelho da Fauna Brasileira Ameaçada de Extinção” (ICMBio/MMA, 2018).
Protecting fish diversity and fishery resources	Threats analyzed affecting fish assemblages and the considerable potential of commercial, subsistence and sport fishing.
Protecting water resources and water flow	The threats related to the seasonal rhythm of the Pantanal flood are discussed and illustrated with several observations recorded in the field.
Protecting landscapes and scenic beauties	Threats highlight the Pantanal’s phytophysiognomies, including the “salinas” of Nhocolândia
Encouraging visits with recreation (ecotourism)	The analyzed threats that interfere with the loss of biodiversity that affects the enormous potential of ecotourism.
Promoting knowledge and scientific research	The threats discussed open up opportunities for an extensive field of research, including ecological processes, preference and habitat selection by species of fauna, habitat and microhabitat, fauna conservation, herbivory and effect of livestock, ecological behavior with food guilds and reproduction and many other relevant topics.

Source: Prepared by the authors.

The overall negative impacts of human activity on the natural environment of the Pantanal produce three effects: (1) degradation of natural habitats, affecting biodiversity; (2) predatory use of natural resources; (3) introduction of alien species into the ecosystem. Three other major impacts are commonly perceived: (4) occurrence of zoonoses; (5) increase of toxic elements in the environment and (6) climate change. These factors involve the degradation of biodiversity by human activity: the association with human population growth and its multiple unsustainable uses of natural resources.

The threats analyzed are generally linked to ineffective control and the lack of implementation of existing legislation, due to inefficient institutional infrastructure. Lack of law enforcement is evident in relation to illegal deforestation, trafficking in wild species, illegal fishing (commercial and sporting), hunting and other factors. Inefficient surveillance is the most apparent cause. Lack of environmental awareness is another factor. Better institutional capacity building is needed to put the legislation into practice.

The conservation action plan should integrate the actors involved in the search for the implementation of legislation and normative instructions, including inspection and control.

The conservation and management plan for the Pantanal's biodiversity must face certain inherent difficulties, such as: (a) political-institutional lack related to the environmental theme and insufficient knowledge on the part of decision-makers regarding biodiversity conservation and ecosystem services; (b) lack of ability of local human communities and other actors to be prepared and effectively participate in the conservation agenda; and (c) insufficient political motivation and low levels of citizen participation.

Finally, there are at least two reasons for optimism: (1) the growing awareness of the Brazilian people in general, and of the local people (pantaneiros) in particular, regarding the need to protect biodiversity in the region and (2) the growing certainty that biodiversity, besides its intrinsic value, can also promote socioeconomic benefits, due to the region's ability to promote the sustainable use of tourism, fishing and other rational uses of the Pantanal's biological wealth.

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Submitted on: 08/09/2017

Accepted on: 31/05/2019

<http://dx.doi.org/10.1590/1809-4422asoc201701891vu2019L3AO>

2019;22:e01891  
Original Article

# THREATS TO THE BIODIVERSITY OF THE BRAZILIAN PANTANAL DUE TO LAND USE AND OCCUPATION

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## THREATS TO THE BIODIVERSITY OF THE BRAZILIAN PANTANAL DUE TO LAND USE AND OCCUPATION

**Abstract:** The Pantanal is a wetland located in the central region of South America (150,355 km<sup>2</sup>), mainly in Brazil (nearly 140,000 km<sup>2</sup>), touching Paraguay and Bolivia. The floodplain is fed by the Paraguay River and its tributaries, where the headwater of the rivers is located on the surrounding upland. Only 40% of this plateau retains its natural vegetation. Although the natural habitats of the Pantanal are still considered well preserved, retaining 80% of the vegetation cover, the biome faces environmental and socioeconomic threats that affect its biodiversity. The seasonal flux of the rivers is a fundamental ecological element for regional biodiversity. Habitat alteration and deforestation have affected terrestrial and aquatic habitats and their associated wildlife. This work identifies and analyses the threats to biodiversity considering land use, based on research experience in the region plus field work. Based on this, it discusses a strategic action plan for the biome's biodiversity.

**Keywords:** biodiversity, conservation, environmental threats, land use, Pantanal.

## AMEAÇAS À BIODIVERSIDADE DO PANTANAL BRASILEIRO PELO USO E OCUPAÇÃO DA TERRA

**Resumo:** O Pantanal é uma área úmida no centro da América do Sul (150.355 km<sup>2</sup>), principalmente no Brasil (140.000 km<sup>2</sup>), tocando o Paraguai e a Bolívia. Planície sazonalmente inundável, é alimentada pelo rio Paraguai e seus tributários, com suas nascentes no planalto do entorno, o qual conta apenas com 40% da vegetação natural remanescente. A relação do fluxo hídrico planalto-planície é fundamental para o ciclo biogeoquímico de nutrientes e para a produtividade ecossistêmica. Embora o Pantanal mantenha ainda 80%

de sua cobertura vegetal, enfrenta ameaças ambientais e socioeconômicas que afetam a biodiversidade. Destruição e alteração de habitats têm afetado os ambientes terrestres e aquáticos. Este trabalho identifica e analisa as ameaças à biodiversidade, considerando o uso e a ocupação do solo, empregando a experiência em pesquisa na região durante muitos anos, e também em trabalho de campo recente. Com base nisso, propõe estratégias de conservação da biodiversidade para o bioma.

**Palavras-chave:** ameaças ambientais, biodiversidade, conservação, Pantanal, uso do solo.

## AMENAZAS A LA BIODIVERSIDAD DEL PANTANAL BRASILEÑO POR EL USO Y OCUPACIÓN DEL SUELO

**Resumen:** El Pantanal es una enorme planicie de inundación (150,355 km<sup>2</sup>) en Suramérica central. Se extiende por las fronteras entre Paraguay, Bolivia y Brasil (140,000 km<sup>2</sup>). Con inundación estacional es alimentado por el río Paraguay y sus tributarios, incluyendo nacientes en mesetas que lo contornan y donde apenas resta 40% de la vegetación nativa. La relación del flujo hídrico mesetas-planicies es fundamental para el ciclo biogeoquímico de nutrientes y para la productividad del ecosistema. Aunque el Pantanal aún mantenga el 80% de su cobertura vegetal nativa, enfrenta amenazas ambientales y socioeconómicas que afectan su biodiversidad. Destrucción y alteración de habitats están degradando los ambientes terrestres y acuáticos. Esta investigación identifica y analiza las amenazas a la biodiversidad, considerando el uso y ocupación del suelo, empleando la experiencia de años estudiando la región y trabajos de campo recientes. Con esa base se proponen estrategias de conservación para la biodiversidad del bioma.

**Palabras-clave:** amenazas ambientales, biodiversidad, conservación, Pantanal, uso del suelo.

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