Oecologia Australis
16(4): 958-978, Dezembro 2012
http://dx.doi.org/10.4257/oeco.2012.1604.17

SEASONAL PANTANAL FLOOD PULSE: IMPLICATIONS FOR BIODIVERSITY CONSERVATION – A REVIEW

Cleber J. R. Alho[1*] *& José Sabino*[1]
[1]Universidade Anhanguera/Uniderp, Programa de Pós-Graduação em Meio Ambiente e Desenvolvimento Regional. Rua Alexandre Herculano, 1400 – Bairro Jardim Veraneio – 79037-280 Campo Grande, MS, BRASIL.
E-mails: alho@unb.br, sabino-jose@uol.com.br

ABSTRACT

The Pantanal is fed by tributaries of the Upper Paraguay River in the center of South America, mainly in Brazil. The landscape is marked by contrasts between the seasonally floodplain (Pantanal) and the surrounding highland (Planalto). The floodplain regulates highland riverine discharge by temporarily storing water during flood season and can enhance water loss by evapotranspiration and infiltration**.** The flood level gradient creates a range of major habitats in a complex mosaic of annual and pluri-annual seasonal patterns. The Pantanal ecosystem is characterized by recurrent shallow water flooding near the surface of the substrate, due to the slow drainage of the vast plain inundated for longer, with variable conditions regarding to physical, chemical, and biological traits. Water discharge, geomorphology, type of soil and biodiversity are the main ecosystem components of the Pantanal. The complex vegetation cover and the seasonal productivity support a diverse and abundant fauna. Many endangered species still occur in health population conditions, including jaguar (*Panthera onca*). Waterfowl are exceptionally abundant during the dry season. Deforestation with the loss of natural habitats and their associated biodiversity in the Pantanal has been drastic during the last decades, particularly in the upland region of the *Cerrado* plateaus surrounding the flooding plain. Another threat is unsustainable agricultural and cattle ranching practices, which convert the natural vegetation into pastures and plantation crops such as soybean, especially on the surrounding plateaus where the river springs are located. Fires caused by humans are severe and have become part of the annual productivity cycle for cattle ranch owners. Recently there has been river flow modification due to implantation of small hydroelectric plants on the upland plateaus. The aim of this study is to put together a comprehensive report on the role of the flood pulse on the biodiversity using our research experience in the region and also reviewing published information.
Keywords: biodiversity; conservation; ecological processes; environmental threats; Pantanal.

RESUMO

EFEITOS DO FLUXO SAZONAL DE RIOS NO ECOSSISTEMA DO PANTANAL: IMPLICAÇÕES PARA A CONSERVAÇÃO DA BIODIVERSIDADE – UMA REVISÃO. O Pantanal é alimentado pelos tributários da Bacia do Alto Paraguai, no centro da América do Sul, com sua maior parte no Brasil. A paisagem é marcada por contrastes entre a planície sazonalmente inundável (Pantanal) e as terras altas do seu entorno (Planalto, que não é inundável). A planície pantaneira regula a descarga dos rios estocando temporariamente a água durante a estação de cheia e pode aumentar a perda de água por evapotranspiração e infiltração. O gradiente em nível de inundação cria uma escala complexa de mosaicos de diferentes hábitats, com sazonalidade anual e pluri-anual. Definido como área úmida, o Pantanal é um ecossistema caracterizado pela inundação rasa e recorrente próxima à superfície do substrato, devido à baixa capacidade de drenagem do sistema de rios. O fluxo de água, geomorfologia, tipo de solo e biodiversidade são os principais componentes do ecossistema. A complexa cobertura vegetal e a produtividade sazonal dão apoio a uma fauna diversa e abundante. Muitas espécies listadas como ameaçadas de extinção ainda contam com populações vigorosas, incluindo a onça (*Panthera onca*). Aves aquáticas são excepcionalmente abundantes durante a estação seca.

Desmatamento no Pantanal, com perda de hábitats naturais e sua biodiversidade associada, tem sido drástico durante as últimas décadas, particularmente no Cerrado do planalto, circundando a planície. Outra ameaça é a agricultura não sustentável e a prática de pecuária bovina, ambos convertendo a vegetação natural em pastos e plantações como as de soja, principalmente no planalto do entorno, onde estão as nascentes dos rios. Incêndios causados pelo homem são severos e têm sido parte do ciclo anual dos fazendeiros criadores de gado. Recentemente tem havido modificação no fluxo dos rios, pela implantação de pequenas centrais hidrelétricas nos rios do planalto. O objetivo deste estudo é o de prover uma revisão compreensiva sobre o papel do fluxo dos rios na biodiversidade, com base em nossa própria experiência na região e na informação publicada.
Palavras-chave: biodiversidade; conservação; processos ecológicos; ameaças ambientais; Pantanal.

RESUMEN

EL PULSO DE INUNDACIÓN ESTACIONAL EN PANTANAL: IMPLICACIONES PARA LA CONSERVACIÓN DE LA BIODIVERSIDAD-UNA REVISIÓN. El Pantanal es alimentado por los tributarios de la cuenca del Alto Paraguay, en el centro de América del Sur, principalmente en territorio de Brasil. El paisaje está marcado por los contrastes entre la planicie estacionalmente inundable (Pantanal) y las tierras altas del entorno (Planalto, que no es inundable). La planicie inundable regula la descarga de los ríos almacenando temporalmente el agua durante la estación de lluvias e incluso allí puede incrementarse la pérdida de agua por evapotranspiración e infiltración. El gradiente de niveles de inundación crea una escala compleja de mosaicos de diferentes hábitats, con estacionalidad anual y multianual. Definido como un área húmeda, el Pantanal es un ecosistema que se caracteriza por la inundación somera y recurrente cerca de la superficie del sustrato, debida a la baja capacidad de drenaje del sistema de ríos. El flujo del agua, la geomorfología, el tipo de suelo y la biodiversidad son los principales componentes del ecosistema. Una cobertura vegetal compleja y una productividad estacional soportan una fauna diversa y abundante. Muchas especies en categoría de amenaza de extinción, tienen allí poblaciones numerosas, incluyendo la pantera onca (*Panthera onca*). Las aves acuáticas son excepcionalmente abundantes durante la época seca. La deforestación en el Pantanal, con la pérdida de hábitats naturales y su biodiversidad asociada, ha sido drástica durante las últimas décadas, particularmente en el Cerrado de Planalto, que circunda la planicie. Otra amenaza es la agricultura no sostenible y la práctica de la ganadería bovina, ambas actividades convirtiendo la vegetación natural en pastos y plantaciones como las de soya, en las partes altas de los ríos. Los incendios causados por el hombre son severos y han sido parte del ciclo anual de los hacendados criadores de ganado. Recientemente se han modificado los cauces de los ríos por la implantación de pequeñas centrales hidroeléctricas en los ríos del Planalto. El objetivo de este estudio es proporcionar una revisión comprehensiva sobre el papel de la dinámica hidrológica de los ríos en la biodiversidad, con base en nuestra experiencia propia y en la información publicada.
Palabras clave: biodiversidad; conservación; procesos ecológicos; amenazas ambientales; Pantanal.

INTRODUCTION

Annual and pluri-annual flooding determines the ecosystem structure and function of the Pantanal. It is fundamental to know how the system works in order to understand the landscape units, the kinds of natural habitats, and the magnitude and abundance of its biodiversity, so as to apply conservation measures (ANA 2005, Alho 2005a, 2008, Junk *et al.* 2006, Alho & Sabino 2011; Alho & Silva 2012). The flow regime is considered in ecology of wetlands a fundamental attribute of the ecosystem, which in turn is crucial to understand biotic composition (Bunn & Arthington 2002, Junk *et al*. 2006). A flooding regime forms distinct sub-regions within the Pantanal (Silva & Abdon 1998). Local flora and fauna of the Pantanal are adapted to flooding regime and respond to seasonal water levels variation since they have evolved specialized life history strategies (Alho 2008, Scremin-Dias *et al.* 2011).

The distinct annual tides of the rivers, causing the wet and dry seasons, result in hydrological seasonality with productivity of feeding and breeding grounds for wildlife subject to biochemical cycles (Junk 1993, Vinson & Hawkin 1998, Wantzen & Junk 2000, Junk *et al.* 2006, Alho *et al.* 2011). The habitats change as a function of the water discharge carrying nutrients and sediments, depositing inorganic and organic matter that enriches the microhabitats, favoring the proliferation of microorganisms, invertebrates, fish, and so on. Most chemical weathering of minerals seems to take place in the upland drainage basins rather than on the Pantanal floodplain (Hamilton *et al.* 1997). Contact of the river water with the floodplain results in depletion of dissolved oxygen.

The hydrological station at Ladário (near the city of Corumbá) has been measuring the level of the Paraguay River in the Pantanal for more than a century, from 1900 up to 2012. Annual and pluri-annual variations in the degree of flooding can be detected. The hydrology of the Pantanal rivers is unregulated since floods and droughts are not regular in frequency and intensity (Alho & Silva 2012). Changes in the length and severity of floods and droughts potentially affect wildlife since severe floods can cover areas where vegetation may be changed in terms of community structure, population size and phenology, with consequences for both wild and domestic animals. The Pantanal's seasonal hydrological changes have their greatest impact on the region's wildlife when the regime of floods and droughts is unusually severe.

The flood mark of the Paraguay River at Ladário is four meters. This was exceeded in 72 of the studied years, or 65% of the analyzed period (Alho & Silva 2012). Extreme floods, beyond 6.5 meters, were recorded for only four years (1905, 1982, 1988 and 1995). Mark zero or negatives were recorded in 23 of the years or 21% of the studied period.

There are at least 280 species of aquatic macrophytes on the Pantanal floodplain, considering various degrees of dependence on water (Pott *et al.* 2011a). The flora of the Pantanal, with nearly 2.000 species, is a pool of elements of wide distribution and from adjacent phytogeographic provinces, such as *Cerrado*, dry seasonal forests, Chaco, Amazonia and Atlantic Forest (Pott *et al.* 2011b). Fish resources are important, both ecologically and socially. Britski *et al.* (2007) listed 269 species for the Pantanal. However, a survey performed in the Negro River region of the Pantanal showed that 19% of the species collected are believed to be new to science (Willink *et al.* 2000). This list does not include species living in the upper river habitats. The number of fish species increases from the headwaters (*Planalto*) to the base of the drainage (Pantanal). Compared to other Brazilian biomes the Pantanal presents a herpetofauna low in diversity but high in abundance. There are 135 species living on the floodplains (40 anuran amphibians, three species of turtles, 25 species of lizards, two species of amphisbaenians, 63 snakes and two crocodilians: Junk *et al.* 2006). There are 444 bird species recorded only for the floodplains, 665 species when the uplands are included (Tubelis & Tomas 2002). The total number of wild mammal species that occur in the Pantanal count 174 species (Alho *et al.* 2011).

Environmental threats have been negative to the Pantanal's biodiversity, including deforestation, environmental contaminants, infrastructure and unplanned human occupation (including river flow modification with implantation of small hydroelectric plants on the upland plateaus), unregulated tourism, fragility of law enforcement, introduction of exotic species and other causes (Alho 2011, Alho & Sabino 2011).

The aim of this paper is to analyze the role of water pulse in ecological processes, and to address how it is connected to Pantanal biodiversity and conservation, by the reviewing and interpretation of the existing literature.

GEOMORPHOLOGY AND RIVER FLOW SHAPING WETLAND CHARACTERISTICS

The Pantanal is a wetland region located in the center of South America, in western Brazil's upper Paraguay River basin - latitude 15° 30'-22° 30' south and longitude 54° 45'- 58° 30' west - (Figure 1). The greater upper Paraguay basin is an area of 361,666 km^2, within which the land ranging 200-1,200 meters above sea level is considered as highland or plateau and the flatland between 80 and 150 meters is the floodplain, called the Pantanal, which occupies an area of 138,183 km^2 representing about 38% of the Basin (ANA 2005).

Figure 1. The Upper Paraguay River Basin showing (in dark black) in western Brazil the flatland which is the Pantanal, mainly in Brazil, but touching Bolivia to west and Paraguay to south, with influence of the *Cerrado* biome of central Brazilian territory. (Source: ANA 2005).
Figura 1*. Bacia do Alto Paraguai (em preto) na porção rebaixada do oeste do Brasil, que é o Pantanal, principalmente no Brasil, mas tocando a Bolívia na porção oeste e o Paraguai na porção sul, com influência do bioma Cerrado do Brasil Central. (Fonte: ANA 2005).*

The Pantanal is a sedimentary basin, a mosaic of alluvial fans of Pleistocene origin. The geological characteristics include elevations named Xingu Complex and Rio Apa Complex, representing the Brazilian Crystalline Complex, whose substrate reflects the different geological events. The plains are sediments deposited during the Quaternary, which are markedly sandy, with restricted areas of clay and organic deposits. The relief of the whole Upper Paraguay River Basin has been recognized in three units: (1) the flood plain which is the Pantanal, (2) the adjacent residual elevations plus the depressions and (3) the highlands.

The uplands, including the mountains, tables, hills, plateaus, depressions and other forms of relief, surround the Pantanal, such as *Chapada dos Parecis* and *Chapada dos Guimarães*, in the north, going in the west-east direction; the hilly plateaus located in the east portion (*Chapada de Emas* and others), distributed in north south direction; and in the south, going in the east-west direction, like the *Planalto da Bodoquena* and others (Figure 2).

The major rivers feeding the Pantanal are (from north to south): Paraguay, Bento Gomes, Cuiabá, São Lourenço-Itiquira, Taquari, Negro, Aquidauana-Miranda, Nabileque and Apa (Figure 2). The Paraguay River originates in Brazilian territory, on the plateau *Chapada dos Parecis* in Mato Grosso State, and then heads southwards receiving important tributaries along its course. It joins the Paraná River in southern Brazil and they united, flow into the La Plata River. The tributaries of the Paraguay River are slow moving when they meet the flatland and have coves with adjacent flood land. They periodically overflow their banks. The maze of fluctuating water levels, nutrients and wildlife forms a dynamic ecosystem. The flooding occupies about 80% of the whole Pantanal. In contrast, during the dry season, most of the flooded areas stay dry, when the water returns to the riverbeds (ANA 2005, Alho 2005a).

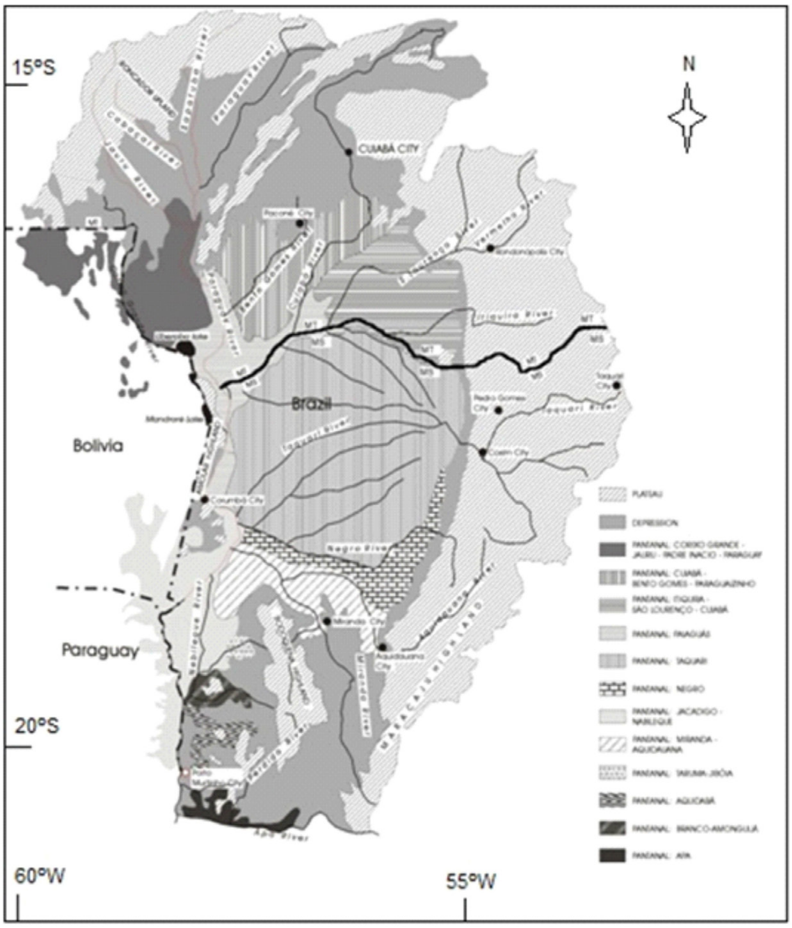

Figure 2. The Upper Paraguay River Basin encompasses an area if 362,374 km² in Brazil, with the Pantanal (147,000 km², which is an alluvial floodplain of accumulated sediments with altitudes varying from 80 to below 200 m), surrounded by the plateaus of old rocks with altitudes ranging from above 200 to 1,000 m, comprising about 59% of the Upper Paraguay Basin. The river system has their springs in the plateaus (source: ANA 2005).
Figura 2*. A Bacia do Alto Paraguai compreende uma área de 362.374 km² no Brasil, com o Pantanal (147.000 km²), o qual é uma planície aluvial de sedimentos acumulados, com altitudes variando de 80 a menos de 200 m), rodeado por planalto de rochas antigas, com altitudes variando entre 200 e 1.000 m, compreendendo cerca de 59% da Bacia do Alto Paraguai. O sistema fluvial tem suas cabeceiras no Planalto. (Fonte: ANA 2005).*

The Pantanal is mainly formed by the tributaries from the left margin of the Paraguay River, in Brazil, with its western border following that of Brazil itself, touching Bolivia to the north and Paraguay to the south. The streams and rivers on these highlands are most prevalent where rainfall is abundant in the wet season (annual average precipitation is 1,400 mm, varying between 800 and 1,600mm). In the plateaus small brooks flow into small rivers, which flow into large ones. The large rivers are shaped largely by terrain, velocity of the water, levels of dissolved oxygen, nutrient loads, temperature and type of riverbed (ANA 2005, Alho 2005a).

The floodplain inundated for a large part of the year, plus the presence of physical, chemical and principally biological characteristics, allow the Pantanal to qualify technically as well as politically as a true wetland. Common diagnostic features of wetlands are hydric soil and hydrophytic vegetation. Elements of the local flora and fauna are good indicators of the Pantanal wetland (Alho 2005a, 2008, Scremin-Dias *et al.* 2011). The water retained on its plain determines the cycle and shape of the environment as a typical wetland. These features are present except where specific human intervention has disrupted nature, which in the case of the Pantanal is not always obvious.

Thus, three major factors characterize the Pantanal wetland: water, substrate and biota. The hydrological phenomenon is evident in the region. The substrate feature is a result of the geomorphologic and climatic evolutions, which support recurrent and sustained saturation. A representative biota arises from species of flora and fauna specifically adapted to the local flooding cycles. Then, indicators for the three factors (water, substrate and biota) can be easily identified (Alho 2005a, Junk *et al.* 2006).

INTERACTING NON-LIVING AND LIVING ENTITIES THROUGH ECOSYSTEM PROCESSES

The rainy season, with most rain falling in the region between November and March, but with variations between the northern and the southern regions of the Pantanal, varies annually from 1,200 to 1,300 mm across the region and in some years can reach 2,000 mm. Rainfall is more intensive in the northern uplands than in the south. The relationship among slope/soil/water/vegetation cover/fauna, is significant in differentiating the Pantanal plains, with an average altitude of 80 to 150 meters, from their surrounding plateaus with altitudes varying from 200 to 1,200 meters. The Pantanal is located in a climatic dry area. Annual rainfall in the highlands is generally above 1,200 mm, which produces a rapid response in the drainage basin. Water finds reduced runoff on the plains, flooding the region. Depressions retain water volume, forming small temporary lakes and ponds (*baías*) or flooding the permanent ones. During low water times the retained water volume does not return to the river-bed to be drained, but remains where it is and evaporates or infiltrates the soil (Alho 2005a).

The rainfall level on the plains is from 800 to 1,200 mm and potential evaporation is 1,300 to 1,600 mm, and so the hydric balance is negative. Evaporation of water from the land is greater than the volume of water received through precipitation. The Pantanal is considered an enormous evaporation "window". The retention of water on the plains reaches 30 to 60%, transforming the Pantanal into a wetland. In the north flooding occurs from March to April and from July to August in the south (Alho 2005a). Therefore, the Pantanal inundation relies upon the rainfall on the surrounding plateaus and on the rivers that have their springs up there.

In addition to the annual variation in rainy and dry seasons, there are periodic floods and droughts recorded in the literature (Alho & Silva 2012). The levels of the Paraguay River are influenced by several different factors from micro to macro scales. The variation in the river level depends mainly upon the regional climatic (precipitation) characteristics. The level of a river is an indicator of two important features: (1) drainage and (2) size of its river-bed, including the adjacent inundated area (Alho 2005a).

A study using a scanning multichannel microwave radiometer to reveal flood patterns in the Pantanal showed maximum flooding occurring as early as February in the northern sub-regions and as late as June in the south, as a result of the delayed drainage of the region (Hamilton *et al*. 1996). An area near of 110,000 km^2 was inundated annually during nine years of observation, between 1979 and 1987. It means that 80% of the Pantanal may be flooded. An average area of 53,000 km^2 is inundated annually and monthly estimates of the total area inundated range from 11,000 to 110,000 km^2.

The hydrological station located at Ladário (near the city of Corumbá) measures the level of the Paraguay River in the Pantanal for more than a century, from 1900 up to 2012. Annual and pluri-annual variations on degree of flooding can be detected. Flooding is seasonal, but it also varies throughout the plain, because of the gentle gradients. The flood period tends to be delayed after the rains on the uplands because of the slow passage of floodwaters through the floodplains. Most of the area is flooded by the overflow from the rivers, but some specific areas flood with local rainfall. During the high water level, the flow moves slowly through depressions locally known as "*corixos*" or along shallow water paths, "*vazantes*". After receiving the contribution of its tributaries in Brazilian territory, the Paraguay River at Ladário presents two flood cycles. The first is influenced by the rivers Aquidauana, Miranda, Negro, and Taquari, with floods in February and March. The second is influenced by the discharge of the upper Paraguay River from April to June (Alho & Silva 2012).

Historical records of the Paraguay River's level at Ladário, showed the maximum flood levels reaching about four meters from 1900 to 1960, but two meters from 1960 to 1972. During this period (1960-1972) people occupied a large portion of the non-flooded area for diverse uses. However, since 1973 the levels have risen again to around five meters (Alho 2005a). Daily records on the level of the Paraguay River at Ladário, analyzed from January 1900 to June 1995, have shown the following results: (1) significant variability was detected between years (that is, there is a permanent annual variability), (2) significant variability exists at intervals of 2 to 5 years, not stationary; that is, a transient variability was observed within the period interval, (3) significant variability occurs at intervals from 10 to 11 years, not plainly stationary; that is, a persistent variability within a 10 year interval (Sá *et al*. 1998).

Contact of the river water with the floodplain results in depletion of dissolved oxygen oversaturation of carbon dioxide, and methane, loss of suspended sediments, and reduced export of nitrogen and phosphorus. Oxygen depletion and associated chemical changes are most marked when river water first contacts the floodplain (Hamilton *et al.* 1997).

LIVING ATTRIBUTES

As a wetland ecosystem, the Pantanal is characterized by an indistinct and ever-changing boundary between water and land. A variety of habitats is present, offering clear seasonality in food production and other ecological resources, and so a great number of animals can thrive with minimal competition. The ever-changing patterns of floating vegetation, annual plants, solid ground and open water provide ample niches for a wide range of plants and animals (Alho 2005a, Alho *et al.* 2011, Pott *et al.* 2011b, Scremin-Dias *et al.* 2011).

Every year many parts of the Pantanal change from terrestrial into aquatic habitats. From May to October the land dries out and grasslands and scattered pools appear. The most striking aspect of the Pantanal is its curious combination of hydric and xeric vegetation growing side by side. Several case studies carried out throughout the Pantanal support the relationship between flooding patterns and nutrient and life cycles with different emphases on: (a) seasonal succession of aquatic macrophyte vegetation communities (Prado *et al*. 1994); (b) arboreal communities (Schessl 1997, Cunha 1998, Cunha & Junk, 2000, Scremin-Dias *et al.* 2011); (c) structure and dynamics of young trees (Almeida 1998); (d) production of fruits by the palm *Bactris glaucescens* (Ferreira 2000); (e) aquatic habitats, limnology, water chemistry, primary production and morphological patterns (Silva & Esteves 1993, 1995, Heckman 1994, Kretzchmar *et al*. 1993, Hardoim & Heckman 1996, Heckman 1997).

Plants

Opportunistic plant species can rapidly respond to the water regimen, occupying an available space. This is the case for *Pontederia cordata* and *P. lanceolata,* which are able to grow as soon as their rhizomes feed on the water of a new flood season. Grasses that appear dead during high water suddenly grow, occupying all the space available, during the dry season. Dormant seeds "wake up" and germinate, covering the ground of dry lagoons. Some temporal species such as *Momordica charantia,* alternate with bamboo species in covering the ground of the gallery forest. A large part of the area is flooded only during the height of the rainy season, and much non-flooded higher ground is interspersed throughout the region.

Diversity of aquatic macrophytes in the Pantanal varies from the smallest (*Wolffia brasiliensis*) to the largest hydrophyte, *Victoria amazonica*. There are at least 280 species of aquatic macrophytes in the Pantanal considering various degrees of dependence on water. The most numerous families are Poaceae (26), Cyperaceae (19), Fabaceae (15), Onagraceae (15) and Pontederiaceae (12), and the best represented genera are *Ludwigia* (15), *Bacopa* (12), *Utricularia* (11), *Nymphaea* (7), and *Polygonum* (7) (Pott *et al.* 2011a). Considering only the Pantanal plain, 1,863 species of phanerogams were listed, legumes being the most numerous (240 spp.), followed by more than 200 grasses (Pott & Pott 1999). The list could be updated to nearly 2,000 species (Pott & Pott 2009). The most numerous families are Fabaceae (240), Poaceae (212), Malvaceae (98), Cyperaceae (92), Asteraceae (87), Rubiaceae (62), Myrtaceae (45), Convolvulaceae (41), and the best represented genera are *Paspalum* (35), *Cyperus* (29), *Ipomoea* (24), *Panicum* (22), *Eugenia* (20), *Ludwigia* (19), *Mimosa* (18) and *Rhynchospora* (18) (Pott & Pott 1999), with a prominence of herbaceous species, around 1,000, due to their adaptation to floodable areas, largely occupied by amphibious and grassland habitats.

The central position of the Pantanal in South America has allowed the encounter among distinct phytogeographic provinces, which are Amazonia to the North, the *Cerrado* to the East, the Atlantic Forest to the South, and the Bolivian and Paraguayan Chaco to the West, favoring a great variety of vegetation types. There are various degrees of *Cerrado* cover:

more than 70% in the sub-regions of *Aquidauana, Barão de Melgaço* and *Paiaguás* (central and Eastern part of the Pantanal); between 40 and 50% in the sub-regions of *Cáceres, Nhecolândia* and *Miranda*; and 10% in the sub-region of *Poconé*), whereas *Cerrado* vegetation is absent in the sub-regions of *Nabileque* and Paraguay – with dominance of Chaco and Amazonian vegetation, respectively, and a synthesis of vegetation types is given by Pott *et al.* 2011b.

Aquatic plants respond well to the flood dynamics (Pott *et al.* 2011a). Many shallowly flooded grasslands dry up and the seasonal aquatics disappear, among them even perennials, such as *Pontederia parviflora* and *Sagittaria guayanensis*, as do small annuals like *Bacopa* spp. and *Echinodorus tenellus*. A difference is that in the Pantanal there is a stronger wet and dry cycle, whereas on the upper watershed the flood pulse is much lower, even where there is 50-100% more rainfall. Here soils remain waterlogged or with a high water table all year round, fed by ground water in the dry season, flowing over an impermeable layer of laterite, making the water ferruginous, or over basalt or sandstone. Plant distribution in *cerrado* wet grassland and *vereda* is related to ground-water level (Meirelles *et al*. 2002), yet in the Pantanal the water table may fall below two meters in the dry season, hence above-ground water level in the wet is a more important factor. In parts of the Pantanal landscape these changes in dry phase and aquatic phase are more pronounced, reflected in a high proportion of opportunistic therophytes (Schessl 1999), and on intermediate ground between floodless and deep flooded stretches. *Vereda* soils are more organic and peaty, acting like a water storing sponge. These soils are organosoils and gleysoils (Ramos *et al*. 2006). The soils in the Pantanal, even though hydromorphic too, vary from pure sand to heavy clay, but due to the very flat landscape, in the dry period the water table reaches the surface only in depressed parts, for example in ponds and water courses.

Frequent and unusual pluri-annual flooding events recorded in the Pantanal have been responsible for the sudden colonization of different trees in seasonally flooded open areas (Alho & Silva 2012). During the occurrence of longer dry and wet successive periods, two trends have been observed: (1) during longer dry events some woody plant colonize the seasonally flooded open fields, which usually are covered by herbaceous vegetation; (2) during longer wet events, flood tolerant trees, mainly the *cambará* tree *Vochysia divergens*, form homogeneous plots of expanding riparian forest. This tree can form mono-specific stands, known locally as *cambarazais*. These have become locally common due to long-term flooding of old field areas.

Invertebrates

Biological productivity in the region involves primary productivity, in which living organisms form energy-rich biomass from energy inorganic materials such as nutrients in the habitats through photosynthesis, and secondary production through consumption within the trophic chain. The diversity of benthonic macroinvertebrates (zoobenthos such as decapods, molluscs, oligochaetes, insect larvae which feed upon microorganisms and algae) were estimated in 70 taxa (Takeda *et al.* 2000). Zoobenthos are important in the food chain because they serve as food for fish, birds, mammals and other animal groups. Ostracoda (aquatic crustacea) and Nematoda (free living non-parasitic roundworms) are the two most abundant groups. Crustacean diversity (shrimps and crabs) is represented by 10 species and the shrimp *Macrobrachium amazonicum* and the crabs *Dilocarcinus pagei, Sylviocarcinus australis, Trichodactylus borellianus* and *Valdivia camerani* are found in surveys (Magalhães 2000; Junk *et al.* 2006). These decapod crustaceans play important role in ecological processes of the Pantanal's aquatic ecosystem since they participate in the trophic chain as herbivores, predators, decomposers and are prey for fish and other animal groups.

Fish

Fish resources are important, both ecologically and socially. Britski *et al*. 2007 listed 269 species for the Pantanal. However, survey performed in the Negro River region of the Pantanal showed that 19% of the species collected are believed to be new to science (Willink *et al*. 2000). This list does not include species living in the upper river habitats. The number of fish species increases from the headwaters (plateau upland region or *planalto)* to the base of the drainage (Pantanal).

Because of the great variety of feeding and reproductive niches for fish, the Pantanal harbors high species diversity and abundance (Britski *et al.* 2007) and species exhibit different strategies to exploit the temporal ecological resources. Fish feeding strategy changes as a function of the seasonal variation. A study carried out in ten marginal lagoons formed along the Cuiabá River in the Pantanal, covering three hydrological cycles (beginning and ending of the dry season and beginning of the flooding season) has shown eight different feeding guilds: insectivore, herbivore, omnivore, zooplanktivore, planktivore, detritivore, benthivore and iliophage – which varied spatially and temporarily (Ximenes *et al.* 2011). The results of this study suggest that spatial and temporal variation in the composition of the guilds can be related to many factors, such as alterations in the composition of the community (37 species sampled), where new species can contribute to the different trophic guilds; and the exploration of more abundant resources in certain seasons of the year favoring the presence of some guilds only in some periods (Ximenes *et al.* 2011).

Thus, a complex trophic relationship is shown as a result of seasonal offer of feeding resources. Three distinct phases can be distinguished in the fish cycle in relation to the water regime in the Pantanal (PRODEAGRO 1997):

1. Flood season, a period of continuous rain with inundation of the plains, occurring from October to April. First, in the "piracema" type of migration the fish schools move upstream at the beginning of the rainy season. Later, migratory fish leave the riverbed and move into the adjacent flooding areas searching for food. Reproduction occurs at the beginning of the rainy season when a schooling behavior known as "rodada" is observed. Therefore, the "rodada" occurs at the end of the migratory trip known as "piracema".
2. Drainage season, a period coinciding with the end of the rainy season from April to May. Fish disperse from flooded areas to the riverbed and permanent ponds or lagoons. This fish movement is known as "lufada". During this period fish are pursued and caught by natural predators.
3. Dry season, running from June to October. Fish start organizing schools for reproductive migration (piracema). Sedentary species face low levels of dissolved oxygen in the shallow water and some stay dormant in the mud during the dry season. Thus, flooding cycle is determinant for migration and successful reproduction.

Fishing is of fundamental social-economic importance for local people (Catella 2004, 2007). In addition, fishing for sport is one of the incentives to bring tourists to the region. Fish resources in the Pantanal have been recognized according to their multiple uses as (Catella 2007): a fundamental biotic component of the ecosystem, supporting the local biodiversity and being part of it; food for subsistence and income of local people; of interest for sport fishing; a genetic resource; an ornamental resource.

For example, the Cuiabá River is the main source of commercial fish for the Cuiabá city, although some fish sold locally comes from the Paraguay River (Mateus *et al.* 2004). Catch consisted mainly of migratory species, and large catfishes represented 70% of the landed fish, among which "pintado" was the most abundant.

Study has shown a relatively high value of recreational fishing in the Pantanal in comparison to similar studies conducted in other parts of the world (Shrestha *et al.* 2002).

Herpetofauna

During the rainy season the region presents vigorous populations of amphibians, due to the expansion of favorable habitats. About half of the anuran species in the Pantanal lives in trees (Junk *et al.* 2006). Some species, such as the spotted-tree-frog *Hypsiboas punctatus,* show association with permanent bodies of water (rivers and ponds) and others, such as the purple-barred-tree-frog *Hypsiboas raniceps*, the green-leaf-frog *Scinax acuminatus*, the yellow-and-black-tree-frog *Scinax fuscovarius,* tolerate droughts but population suddenly grows when flooding comes, usually October to May. Frogs are also more vocal during this period. The tiny clicking-frog *Pseudis limellum* lives on floating vegetation and vocalizes also by day.

The occurrence of species within the sub-regions of the Pantanal varies according the local species composition and distribution, depending on the influence of the nearby biomes such as the Chaco, the Cerrado and the Amazonia. Among the snakes of the northern sub-region of Poconé, for example, Strüssmann & Sazima (1993) observed that the most abundant species are *Eunectes notaeus, Helicops leopardinu* and *Hydrodynastes cf strigilis.* While the southern sub-region of Nhecolândia presented different species composition with *Leptodeira annulata, Liophis typhlus* and *Lystrophis mattogrossensis,* snakes common throughout the Brazilian Cerrado. The same pattern is observed for amphibians, but with difference on local abundance, which is more remarkable in the Pantanal for these species.

Seasonal variations in diet and foraging behavior as well in kinds of habitats and caiman densities of the Pantanal's crocodilian *Caiman crocodilus yacare* has been documented for the region (Coutinho & Campos 1996). A relationship between rainfall, nesting habitat and fecundity of the Pantanal's caiman has been pointed out (Campos & Magnusson 1995). Terrestrial activities of caimans, exhibiting coordinated movement during the dry season in the Pantanal, have been reported (Campos *et al.* 2005).

Avifauna

The Pantanal bird abundance and diversity are greatly influenced by regional hydrology. Most waterfowl species exhibit synchronized reproduction, where huge colonies of birds such as wood stork (*Mycteria americana*) egrets (snowy egret *Egretta thula*, great white egret *Casmerodius albus* and the capped heron *Pilherodius pileatus*) and others such as the spoonbill *Ajaia ajaja* concentrate in nesting sites in the gallery forest, during the dry season, to take advantage of the seasonal resources available. It has been observed a strong association between breeding guilds and water level, mainly during the dry season.

The breeding colonies are formed by hundreds of nesting birds following a pattern of species breeding at the same site or in designated trees. There is a strong relation between nesting behavior exhibited by the bird species and seasonal variation of the water level. The birds take advantage of concentrations of fish and invertebrates in ponds. The concentration of birds in colonies allows concentration of nutrients due to dropping feces, prey and hatchlings on the ground which, in turn, attracts predators such as caimans, anacondas, wild foxes and others (Gwynne *et al*. 2010). As a result the shallow water of the dry season presents locally high turbidity, elevated levels of nitrogen and phosphate forms, as well as modified dissolved levels of oxygen.

Two waves of breeding species are already recognized in the same trees: a white colony and a black colony. In the sub-region of *Barão de Melgaço*, during the dry season, in the period of July to October, the white colony is established in a few selected trees of the Cuiabá River gallery forest, in the *Porto da Fazenda*, nearby ponds and flooded areas, with 600 nests concentrated in a single nesting site. This white colony is composed first by hatchlings of the wood-ibis *Mycteria americana*, followed in lower numbers by hatchlings of the egrets *Ardea alba* and *Egretta thula*, and finally by hatchlings of the spoonbill (*Platalea=Ajaia ajaja*). The black colony is composed of the cormorant *Phalacrocorax brasilianus=olivaceus,* followed by the anhinga *Anhinga anhinga*,and the white-necked heron *Ardea cocoi.*

Colonial reproduction is successful in having many pairs of eyes to remain vigilant in the frequent presence of predators. The principal flying predators are: the crested caracara hawk *Caracara=Polyborus plancus*, the great black hawk *Buteogallus urubitinga* and the black vulture *Coragyps atratus.* Both female and male storks incubate and take care of the hatchlings. They feed the young about six times a day during the first three weeks. The parents catch prey in shallow waters (15-50cm deep): mainly fish, molluscs, crustaceans, amphibians, reptiles, and insects. The colonial nesting site is active every year and the young storks born there return 3-4 years later, as adults, to reproduce in the same nesting site.

High densities of black-bellied-tree-duck *Dendrocygna autumanalis*, white-faced-tree-duck *Dendrocygna viduata,* the Brazilian duck *Amazonetta brasiliensis*, and the Muscovy duck *Cairina moschata* are observed. Other common birds are the southern screamer *Chauna torquata*, and macaws, including the hyacinth macaw *Anodorhynchus hyacinthinus*.

Study carried out in the Pantanal on jabiru (*Jabiru micteria*) shows that there is a clear linkage between the flooding regimen of the Pantanal and the availability of food for the adult jabirus to raise their young (Antas 1992; Antas & Nascimento 1996; Oliveira 1997). The birds need low water, especially in lagoons and ponds, in order to obtain the food they can catch with their specialized beak. The preferred food is "*mussum*" fish (*Symbranchus marmoratus*), which can stay dormant and encapsulated in the mud throughout the dry season, to swim again when the water arises in the rainy season. The jabiru is a specialist in detecting and catching the dormant fish in the muddy bed of the drying pond.

Jabirus are rarely present in the Pantanal during the flooding season. They migrate to higher grounds to still unknown sites. Unusual rain and flooding occurred during the nesting season (dry season) of 1992. In the *Nhecolândia* sub-region, the hatching success was zero, from 70 nests monitored by "Projeto Tuiuiú" in July, that is, no young were seen that year. On the Taquari River, an area of 600km along the river was surveyed and 62 nests monitored in the same year. Only one chick was born. Apparently, the incubating behavior of the parents depends upon the availability of food for the birds, which depends upon the flooding regimen. Reproductive success varies with the flooding schedule (Antas 1992, Antas & Nascimento 1996, Oliveira 1997).

In 1995 (September-October), while conducting fieldwork in *Cáceres* sub-region, in the *Ecological Reserve of Taiamã*, and *Porto Murtinho* sub-region, one of the authors (C. Alho) observed a successful nesting season for jabirus. Dozens of nests were seen with three young in each nest and no abnormal flooding was reported for that season. The young jabirus are ready to leave the nests in October-November, coinciding with the period of the lowest water.

Different flooding patterns have different impacts on nesting activities. For example, the unusual flooding in July-August 1992 in the *Taquari* area suggests that reproductive activities in that area occurred later than those in the region of *Aquidauana* and *Miranda* (Antas 1992, Antas & Nascimento 1996, Oliveira 1997). The production of young was normal in the *Aquidauana/Miranda* area and no chicks were born in the *Taquari* area, due to the abnormal local flooding in that sub-region. The study reports that the stork *Mycteria americana* also exhibited nest abandonment behavior due to flooding cycles at Rio Vermelho. The preferred trees for jabiru nests are: *piúva* (*Tabebuia ochracea*) 55%; *manduvi* (*Sterculia striata*) 31%; dead trees 12%; *para-tudo* (*Tabebuia insignis*) 1%, and others 1%.

In the Pantanal occur annually about 40 migratory bird species mainly that arrive from the northern hemisphere (Nunes & Tomas 2008). There are inter-American migratory routes connecting bird movement to the Pantanal. During the dry season, from May to October, the migrant birds from North America fly over the Pantanal and the resident aquatic birds are more visible, concentrated in retained waters in ponds and depressions. It is evident that the seasonal change in the region is a key factor affecting migrants and resident birds and other ecological interactions (Keast & Morton 1980).

Wild mammals

Studies on capybaras show that the use of habitats varies seasonally within the Pantanal (Alho *et al*. 1989). Jaguar is identified as one important capybara predator. During the dry season, capybaras spend the night in the forest. In the early morning they leave the forest to graze on the grassland. During the rainy season, the capybaras also spend the night in the forest, but in the morning usually emerge and go directly to the water or to grazing areas. Use of aquatic vegetation and forest vegetation in their diet at that time increases significantly, since few grazing areas remain above water level.

Many aspects of the behavior and ecology of the capybara are affected by seasonal fluctuations in the amount of available food. Some preferred food items that are richer in protein tend to be more seasonal than poorer food items. There is a period of the year, from June until November, when the standing crop on lower areas susceptible to flooding is abundant and is consumed by capybaras. During the remainder of the year the presence of these food items is very scarce. Thus, the times of food abundance and scarcity are predicted by the flooding pattern (Alho 2005a).

Group sizes and social structure influence capybara social behavior. As soon as male sub-adults begin to reach sexual maturity, the dominant males exclude some from the social groups. The group size increases from the beginning (rainy season) to the middle of the year (dry season). During the floods the groups subdivide and are largely confined to the forest patches, while in the dry season more animals are observed feeding on the pasture of the grassland. During the latter, there are younger in the group (Alho

2005a). Capybara groups have larger home ranges and core areas during the dry season than during the rainy season, a change associated with a reduction in grassland area due to flooding.

Higher densities of other mammal species occur during the dry season (August and September), when there is a considerable expansion of terrestrial habitats, mainly seasonally flooded grassland, due to the shrinking-and-expansion of habitats related to the flooding pulse (Mamede & Alho 2006).

Among the five primate species that occur in the Pantanal (*Cebus libidinosus, Mico melanurus, Alouatta caraya, Callicebus donacophilus* and *Aotus azarae*: Alho *et al.* 2011), the howler monkey *Alouatta caraya* inhabits the canopy of riparian forests of the Pantanal. This arboreal monkey is a generalist herbivore; it eats new shoots, leaves, flowers and fruits, altering the components and their proportions in its diet depending on the phenological peaks in the riparian forest productivity (Alho and Silva, 2012).

Study using the line-transect method examined the distribution of densities and metabolic biomass of medium to large-sized non volant mammals in forest, *cerrado* (=savanna) and floodplain habitats, in an area with low anthropogenic influence, in the central area of the Brazilian Pantanal during a prolonged drought season (Desbiez *et al*. 2010). Results suggest that population fluctuations of certain mammal species are closely associated with water due to the drought. Results from this study showed that mammal assemblages varied between landscape habitats. Forested landscapes have the highest densities of mammals and are the most important in terms of relative energy consumption. In addition, frugivore mammals were found to have higher energy consumption than browser/grazers across the three landscapes sampled; most fruits are produced in forested areas stressing their importance. Sightings of pampas deer *Blastocerus dichotomus* (N=384) and capybara *Hydrochoerus hydrochaeris* (N=82) occurred almost exclusively in open habitats, while those of agouti *Dasyprocta azarae* (N=446) and howler monkey *Alouatta caraya* (N=117) occurred almost exclusively in closed habitats. The study concludes that forested landscapes have the highest densities of medium to large-sized mammals, are the most important landscape in terms of relative energy consumption and harbor the highest proportion of mammals from different trophic guilds. Certain species, or sets of species, characterized each landscape. Higher densities of pampas deer, feral pig and capybara characterized the floodplain. Higher densities of white-lipped peccary, collared peccary, howler monkeys and agoutis characterized the forest.

The marsh deer *Blastocerus dichotomus* is the largest deer in South America, with males reaching a height of up to 115 cm. It occurs over a wide area: northern Argentina, Paraguay, Bolivia, southeast Peru, and Brazil (Amazonia, *Cerrado*, part of Southern Brazil, and the Pantanal). It is listed as an endangered species but it occurs at high population densities in the Pantanal (Schaller & Vasconcellos 1978; Tomás & Salis 2000).

All vegetation communities in which marsh deer have been observed (Tomás & Salis 2000) are frequently flooded during the wet season (most habitats are formed by aquatic plants). These floristic communities occupy about 18% of the open habitats and 12.8% of the whole *Nhecolândia* ranch during the flood season, while the marshland, totally flooded, is completely occupied by aquatic vegetation (floating mats, *Eichhornea*, *Nymphaea, Reussia* and other plants). The vegetation type most used by marsh deer is *Andropogon* grassland and other open areas is dominated by *Pontederia, Scleria, Nymphaea, Eleocharis, Thalia, Axonopus, Oryza, Nymphoides* and *Luziola* communities. Marsh deer select about 35 plant species, mainly aquatic plants. *Pontederia cordata* (including both flowers and leaves), *Thalia geniculata* (mainly flowers), *Nymphaea* spp., *Aeschynomene sensitiva*, *A. fluminensis, Discolobium pulchellum, Reussia,* spp. *Leersia hexandra* and others are frequently eaten by marsh deer.

According to Tomás & Salis (2000), the ecological density (the density in suitable habitats such as marshlands) is 3.12 deer/km^2. In other areas the estimated density is 0.73 deer/km^2. Other estimates range from 0.09 deer/km^2 (low flooding habitats) to 0.38 deer/km^2 (highly inundated habitats), for dry season surveys. Seasonal flooding causes significant variation in the population distribution and density. During the dry season, deer prefer the boundary between the flooded areas and the drained range of the marshland. During the flood season the animals are dispersed.

Local diversity and number of individuals of small mammals also rely on the offering resources and behavioral specialization to habitat components.

At small scale specialized species are able to exploit the spatial and temporal variation of the habitat heterogeneity, including microhabitat components (Lacher & Alho 1989, Alho *et al.* 2011). Community differences appear to be a function of local mosaic factors. Among small mammals, like marsupials and rodents, there are habitat generalists occurring in more than three types of habitat (pan-habitat species) and habitat specialists, showing a high degree of fidelity to habitat (Alho 2005b, Alho *et al.* 2011). It is common to find small mammal species with a preference for arboreal or forested habitats or for open habitats within the same study area. In the semi-decidous forest habitats, surrounded by open savanna habitats, woodland-dwelling genera such as *Cerradomys* and *Oligoryzomys* occur within a few meters of transition zone-habitat dwellers such as *Clyomys* and *Trichomys*. The genus *Oligoryzomys* also occur in both open and forested habitats.

Microhabitat use among small mammals in the Pantanal shows that two genera of Cicretidae rodents – *Oligoryzomys* (with two species occurring in the Pantanal: *O. chacoensis* and *O.microtis)* and *Cerradomys (C. subflavus)* – are more generalized in their use of microhabitats than are two Echimyidae species - *Clyomys laticeps* and *Trichomys pachyurus* (referred to as *T. apereoides* in some publications, but recognized as a distinct species based on chromosomal differentiation; Bonvicino & Lacher 2008). *Oligoryzomys* species are broad habitat generalist at the "Nhecolândia" sub-region of the Pantanal. *Cerradomys subflavus* selects the savanna patch of arboreal vegetation, *capão de cerrado,* microhabitat. Both *Clyomys* and *Trichomys* were restricted to their transition microhabitat. Although both genera overlap in the same microhabitat, competition is avoided since *Trichomys* is scansorial while *Clyomys* is fossorial (Lacher & Alho 1989). In general the transition between arboreal habitats and open areas are selected by *Trichomys pachyurus* (Carmignotto 2004).

Studies carried out in habitats surrounding the Pantanal, on plateaus of *Chapada dos Guimarães*, Mato Grosso State, pointed out that the combination of vegetation type and substrate structured the community of 19 terrestrial species of small mammal into several smaller communities with little faunal overlap (Lacher & Alho 2001). This study showed that most species were captured in only one or two of the qualitative habitat types (wet field, dirt savanna field, *cerrado* or savanna field, savanna=*cerrado*, valley forest, gallery forest and wet forest). There were open habitat species completely absent from forest, and forest species that were captured only in forest habitats. Cluster analysis of 19 species studied confirmed the separation made by qualitative classification of habitats based on plant species composition and other habitat characteristics. The results for habitat associations of small mammal species determined by cluster analysis of soil and vegetation structural characteristics (independently of plant species composition) generated five fairly distinct clusters. The first five axes extracted by the analysis approach accounted: (1) separated the flat sites with low vegetation and no trees from forested capture sites; (2) separated habitats on the basis of substrate: rocky versus non-rocky; (3) separated capture sites in the rocky slope habitat from the forested fringe of the slope habitat dominated by bamboo; (4 and 5) more difficult to interpret, but they were included because they both accounted for more than five percent of the total variance among capture sites. In general, most of the variations among traps or capture stations were attributable to the distinction between forested and unforested sites with different substrates and slope.

The gallery forest cluster grouped the same set of species that had previously been assigned to gallery forest (*Neacomys spinosus*, *Hylaeamys megacephalus*, *Nectomys squamipes*, *Oecomys bicolor*, *Proechimys longicaudatus*, and *Caluromys philander*), confirming the earlier analysis. The cluster analysis also grouped the six species that had previously been associated with wet campo (*Oligoryzomys microtis* — occurring at the Cerrado-Amazonia contact zone, *Oligoryzomys nigripes* (=*eliurus*), *Cerradomys subflavus* species group, *Necromys lasiurus*, *Monodelphis domestica*, and *Marmosa murina)*. The grouping of species was essentially the same whether it was done qualitatively by habitat type or by a quantitative analysis of structural aspects of the vegetation and substrate of the habitat (Lacher & Alho 2001). Small mammals are more specialized regarding to habitat requirements, and so they are able to exploit different parts of the habitat mosaics of the Pantanal.

In conclusion small mammals in the Pantanal habitats exhibit different patterns of population increase and reproductive activity, with fluctuations between the dry and wet seasons, depending upon availability of ecological resources (food, reproductive niche and space). Wild mammals respond to seasonal shrinking-and-expansion of habitats due to flooding regime of the Pantanal with highest abundance of species observed during the dry season (August and September), when there is a considerable expansion of terrestrial habitats, mainly seasonally flooded grassland (Mamede & Alho 2006).

ENVIRONMENTAL THREATS

If on one hand the flow regime is crucial for the diversity of habitats in the Pantanal, favoring its biodiversity, as we highlighted with several study cases, on the other hand man activities have caused environmental disturbances which negatively affect the natural ecosystem. Physical characteristics such as local geomorphology of the Upper Paraguay River Basin, with the upper land where the river springs are located and the Pantanal floodplain seasonally flooded, are determinant attributes of the natural system influencing natural habitats and the local biodiversity. Considering the co-evolution of nonliving and living components of the ecosystems, biotic portion has evolved strategies (morphological, physiological and behavioral characteristics) to adapt to seasonal change.

There has been growing evidences that Pantanal biodiversity has been affected by altered flow regimes. Some of these disturbances are results of direct action on river flow, such as the installation of small hydroelectric plants, other are indirect influences associated with land use changes, such as deforestation on highlands in river springs.

While flow alteration has been identified as an important factor in relation to habitat quality and biodiversity conservation, the present situation in the Pantanal is even more complicated by other environmental disturbances (Alho 2005a, Alho & Sabino 2011).

DEFORESTATION

Conversion of natural vegetation into pasture and agricultural crops has been drastic during the last decades, mainly on highlands. A study monitoring changes in vegetation and land use in the Brazilian part of the Upper Paraguay River Basin, (with a total area of 368,640 km²), considering the period from 2002 to 2008, showed that the region has been suffering the consequences of the expansion in cattle ranching and agricultural activities, especially in the highland region (CI + ECOA + AVINA + SOS Pantanal + WWF- Brazil 2009). This study points out that while the Pantanal maintains 86.6% of its natural vegetation, the surrounding upland plateaus (*planaltos*) have kept only 41.8% of their original vegetation cover. During the short period from 2002 to 2008, the Brazilian side of the Upper Paraguay River Basin lost 4% of its vegetation on the plateaus and 2.4% in the floodplain (the Pantanal). Data for 2008 show that cattle ranching are responsible for 11.1% of vegetation conversion in the Pantanal and 43.5% in the upland plateaus. Up to 2008, the Pantanal had lost 12.1 % of its original forest cover, a comparatively low figure in the modern world. However, at the current rate of forest loss, the natural vegetation of the Pantanal will have been totally destroyed by 2050, if no measures are taken to combat this trend.

RIVER FLOW ALTERATION BY HYDROELECTRIC PLANTS

It is noteworthy that three quarters of these enterprises involve small hydropower plants (PCH, from Portuguese acronym), located or planned for the same river, together resulting in an important impact. Even small power-plants, which may not form a reservoir, can change the discharge of nutrients and suspended matter and hence the cycling of nutrients in affected water bodies (Calheiros *et al*. 2009, Fernandes *et al.* 2009). Furthermore, the presence of the physical barrier in the form of a dam is known to prevent the movement of migratory fish species during the spawning season, affecting fish production in the medium and long term. All these changes and negative impacts on the water ecology of each sub-basin forming the Pantanal should be assessed simultaneously, in terms of the integrated area of the Upper Paraguay River Basin, prior to installing such projects (Calheiros *et al*. 2009).

INTRODUCTION OF EXOTIC SPECIES

Land use and human occupation within the natural habitats of the Pantanal have facilitated introduction of invasive species of plants and animals, including domestic species. Exotic species threaten regional biodiversity because they modify ecological community structure, alter natural habitats and affect local biodiversity. An international organization, the International Union for Conservation of Nature (IUCN), and the Brazilian government identify invasive species as the third most important threat to biodiversity, following habitat loss and direct effect on species. In addition, exotic species carry pathogens or may function as vectors or reservoirs for diseases that affect regional biota (Alho *et al.* 2011).

Natural pastures of the Pantanal are mainly formed by species such as *Axonopus purpusii, Mesosetum loliiforme* and *Panicum laxum* covering the open fields and sandy soils of the floodplain. Other plant species forming homogeneous fields are present, such as the legume *Desmodium barbatum* and the *fura-bucho* genus *Paspalum*. Since these fields of natural pasture remain submerged during the wet season, cattle ranchers are introducing exotic grassland species on the higher ground of the Pantanal. Cultivated pastures have been expanding rapidly in the floodplain to compete with the ranchers located in the upper *Cerrado* plateaus surrounding the Pantanal. Two exotic species dominate such pastures: *Urochloa decumbens* (formely *Brachiaria decumbens*) and *Urochloa humidicola* (former *Brachiaria humidicola*). They aggressively cover the ground and have been widely used to convert natural vegetation into cultivated pastures (Alho & Silva 2012).

WILD FIRE

Fire is a major threat. Ranchers in the Pantanal set fire to the vegetation during the dry season as a “management” technique to “clear” the vegetation not used by cattle. The fire is initially started in the grassland but due to open areas, dry vegetation and wind, the fires often spread to savannas, woodland and forest (Alho 2005a). Removal of natural vegetation eliminates food and shelter, especially for forest-dwelling wildlife and epiphytic plants. Deforestation also increases erosion since most elevated areas have sandy soil that is easily blown or washed away by rain.

OVERFISHING

Deforestation also affects fish, since migration may be influenced by terrestrial habitat disturbances, mainly gallery forests and seasonally flooded fields. In the “*piracema*” – a kind of migration – the schools of fish move upstream at the beginning of the rainy season. Other migratory fish species leave the riverbed and move into the adjacent flooding areas searching for food.

Species of large fish such as jaw characins (*Salminus brasiliensis*), spotted surubim (*Pseudoplatystoma corruscans*), barred surubim (*Pseudoplatystoma fasciatum*), streaked prochilod (*Prochilodus lineatus*), “piraputanga” (*Brycon hilarii*) and threespot leporinus (*Leporinus friderici*) are some of the most remarkable Pantanal ichthyofauna. This is due, in part, to the size of these large fish species that are valuable for professional and amateur fishing (Catella 2004). Less evident and less known, but no less important, are the small fish species, which are up to 15 cm in length. Without the small characins, small catfish and small armored catfish, many large species could not exist: small species support aquatic food-chains, or are food-chain links, and essentially are fish whose biological richness is yet to be adequately evaluated, especially in the headwaters of the Pantanal (Sabino & Prado 2006).

There is evidence of overfishing in some large fish species (Garcia 2006), a major threat hanging over the water system of the Pantanal, which may adversely affect the flood pulse of the plain. Study carried out on fishing resources of the Cuiabá River has shown that commercial fish catches are smaller than those recorded in previous years and the distribution of species abundance has changed (Mateus *et al.* 2004).

About 70% of the water of the Pantanal wetland originates in the northern part of the basin, and the Cuiabá River, forming the main tributary of the Pantanal, contributes with 40% of the water system (PCBAP 1997). Consequently, the information that 75% of all 115 dam projects planned for the Upper Paraguay basin (BAP) are in the northern region, in Mato Grosso State (ANEEL 2010), gives a glimpse of a disturbing scenario since all these developments may change the hydrodynamics and floods in the wetland plain (Girard 2002). A simple change in the regime of droughts and floods in this biome has already produced worrying results, since the main trigger for the reproduction of fish is the rise in river level with the first rains. Consequently, changes in this pattern negatively affect the reproductive cycle. When the fish run into an insuperable obstacle and a lake, their reproductive cycle is not completed because spawning occurs in the upper river (Godinho *et al*. 2009).

When dams are installed, conservation of the fish fauna, particularly migratory species, requires that connectivity is restored between the river channel and its flood areas (wetlands). Additionally, there are eco-hydrological studies which would be required in each river to assess the flow rates, in the flood period, timing of the spawning migration period and to ensure the survival of juvenile forms of fish (Calheiros *et al*. 2009).

WATER POLLUTION AND ENVIRONMENTAL CONTAMINANTS

The introduction of toxins and other contaminants to the Pantanal is an undesirable trend in habitat quality, since it affects valuable wildlife and fish resources as well as the quality of associated natural resources, including surface and ground water. The introduction of pollutants to ecosystems results in changes in an interrelated series of variables or processes that can affect the structure and function of the ecosystem in the short or long term.

Alho & Vieira (1997) point out that unregulated gold mining has contaminated Pantanal habitats with mercury. Fish samples showed high percentages of contamination (Cuiabá and Bento Gomes rivers) with mercury beyond the levels allowed by international standards for contamination. Bird species, which feed on fish, like the olivaceous cormorant *Phalacrocorax olivaceu*, the limpkin *Aramus guarauna* and the snail-kite *Rosthramus sociabilis* were also contaminated.

In addition, untreated sewage from most urban areas and deposit of solid waste are usually dejected into rivers (Alho 2005a).

UNSUSTAINABLE TOURISM

Tourism, if well planned and regulated, provides an excellent alternative economy for the region. There is a booming tourist trade in the Pantanal. Unfortunately, most of this tourism is predatory. Tour groups may invade areas that should be preserved (e. g., waterfowl nesting grounds or rookeries), sport fishing groups may over-fish, in general spreading litter, particularly in illegal camp sites in gallery forest, where these fishermen leave signs of their predatory presence. Numerous tourist hotel boats throughout the Pantanal do not treat waste properly and spread solid waste on their way (Alho 2005a). It has been observed that many small rural hotels called "pousadas" are flourishing with commercial success in the Pantanal. However, the activity needs improvement to achieve a better balance between recreation and conservation. Much current "pousada" establishments in the region have negative impacts on nature, such as deforestation, erosion and pollution, with disposal of untreated sewage and garbage, with consequent water contamination.

MINING

Gold mining in Poconé region and exploitation of other minerals, especially in the northern portion of the upper land, cause erosion, siltation and pollution of water including by environmental contaminants such as mercury, among other disturbances (Alho 2005a).

INFRASTRUCTURE

Large cargo convoys navigate through the Paraguay and other rivers in the Pantanal and, because of their length, these vessels sometimes touch and damage the river banks, in addition to causing other damage such as oil spills and waste (Alho 2005a).

Some official and private roads constructed in the Pantanal dam the waters blocking the normal flow. There are significant data showing the impact of traffic on roads crossing areas of rich and abundant wildlife. One study conducted by Fisher (1997) points out the dramatic impact of road killings on several species of wildlife along the road BR-262, crossing the Pantanal from Campo Grande to Corumbá; in the state of Mato Grosso do Sul. From May 1966 to November 1997, this author registered 1,402 animals killed by cars, including birds, reptiles, anphibians and mammals belonging to a total of 84 species. Among those species six were officially declared endangered, such as the marsh deer *(Blastocerus dichotomus*), the manned wolf (*Chrysocyon brachyurus)*, two wild cats (*Felis pardalis*), and (*Panthera onca*), the otter (*Lontra longicaudis*) and the giant anteater (*Myrmecophaga tridactyla*). The study showed a rate of road death up to 105 kills/month, 3 per day along that road. The average number of vehicles running on that road is 1,800/day.

Depending on the alterations that the road makes to the natural environment, these roads may function as barriers for the wildlife. In some cases the roads function as a place of attraction for the animals, especially during the flooding season. In fact, on some roads crossing the Pantanal it is common to see animals resting on the roads, mainly capybaras. Another problem is that in some places the road crosses a gallery forest that goes along the river, which is usually a corridor for medium and large mammals. This interruption in the gallery forest forces animals to cross the road. The road going from Santo Antônio de Leverger to Barão de Melgaço, in the state of Mato Grosso, interrupted some drainage channels, impeding fish migration from river to flooded grounds and vice-versa (Alho 2005a).

LACK OF INSTITUTIONAL STRENGTH AND LAW ENFORCEMENT

The fragile institutional basis, the need for management policies and the lack of skilled personnel are identified as important elements contributing to environmental degradation. Thus, three elements need to be strengthened to improve participatory management: (a) knowledge of the decision-makers in the Pantanal's hydrological resources; (b) skill of the stakeholders in participating; and (c) motivation of the local residents to participate in social decisions. A recent federal law on hydrological resources (Law 9433/1977) encourages participatory management through specific committees.

CONCLUDING REMARKS

One of the most relevant challenges for the Pantanal is to meet the growing demand for social and economic development, mainly cattle ranching, agriculture, urban growth and tourism, while conserving biodiversity and providing essential ecosystem services for water quality, landscape integrity and wildlife protection.

Large wetlands like the Pantanal perform many essential ecosystem services – in addition to the intrinsic importance of the maintenance of biodiversity, carbon storage, flood control, fish production, and aquifer recharge, among others – services that have increasingly important global consequences (Keddy *et al.* 2009). The Brazilian biodiversity is recognized as one of the most expressive in the terrestrial biosphere and plays an important role to human well-being and health, providing basic products and ecosystem services. The products or goods from natural ecosystems include pharmaceutical material, food such as fishery, timber, and many others (Alho 2012).

In addition to its intrinsic value (nature working as it is; species are the product of a long history of continuing evolution by means of ecological processes, and so they have the right to continued existence), biodiversity also plays a fundamental role as ecosystem services in the maintenance of natural ecological processes. The economic or utilitarian values of biodiversity rely upon the dependence of man on biodiversity; products that nature can provide: wood, food such as fishery, fibers to make paper, resins, chemical organic products, genes as well as knowledge for biotechnology, including medicine and cosmetic sub-products. It also encompasses ecosystem services, such as climate regulation, reproductive and feeding habitats for commercial fish, some organisms that can create soil fertility through complex cycles and interactions, such as earthworms, termites and bacteria, in addition to fungi responsible for cycling nutrients like nitrogen, phosphorus and sulfur and making them available to plant absorption. These services are the benefits that people indirectly receive from natural ecosystem functions (air quality maintenance, regional climate, water quality, nutrient cycling, reproductive habitats of commercial fish, etc.) with their related economic values (Alho 2008).

These challenges for the Pantanal conservation and sustainable use of its natural resources are aligned with the development of new economic paradigms and environmental issues, which require – in addition to scientific knowledge and new technologies – innovative business models and new human attitudes that valorize the natural capital and induce cultural changes.

AKNOWLEDGEMENTS: We are grateful to Dr. Erich Fischer (Universidade Federal de Mato Grosso do Sul), for his encouragement and help in preparing this manuscript. Celina Alho helped to draft this article.

REFERENCES

ALHO, C.J.R. 2005a. The Pantanal. *In:* Lauchlan H. Fraser; Paul A. Keddy. (Org.). *The World's Largest Wetlands - Ecology and Conservation*. New York, USA: Cambridge University Press, v. único, p. 203-271.

ALHO, C.J.R. 2005b. Intergradation of habitats of non-volant small mammals in the patchy Cerrado landscape. *Arquivos do Museu Nacional do Rio de Janeiro*, 63: 41-48.

ALHO, C.J.R. 2008. Biodiversity of the Pantanal: response to seasonal flooding regime ant to environmental degradation. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 68, (4)(Suppl.):957-966.

ALHO, C.J.R. 2011. Biodiversity of the Pantanal: its magnitude, human occupation, environmental threats and challenges for conservation. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 71, (1)(Suppl.):229-232.

ALHO, C.J.R. 2012. Importância da biodiversidade para a saúde humana: uma perspectiva ecológica. *Estudos Avançados*(USP) 26(74):151-165.

ALHO, C.J.R. & SABINO, J. 2011. A conservation agenda for the Pantanal's biodiversity. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 71, (1)(Suppl.): 327-335.

ALHO, C.J.R. & VIEIRA, L.M. 1997. Fish and wildlife resources in the Pantanl wetlands of Brazil and potential disturbances from the release of environmental contaminants. Environmental Toxicology and Chemistry. Vol 16, Nº 1:71-74.

ALHO, C.J.R; CAMARGO, G. & FISCHER, E. 2011a. Terrestrial and aquatic mammals. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 71, (1)(Suppl.): 297-310.

ALHO, C.J.R.; CAMPOS, Z.M.S. & GONÇALVES H.C., 1989, Ecology, Social Behavior, and Management of the Capybara (*Hydrochaeris hydrochaeris*) in the Pantanal of Brazil, pp. 163-194. *In: Advances in Neotropical Mammalogy*, edited by K.H. Redford & J.F. Eisenberg. University of Florida, Gainesville, Sandhill Crane Press.

ALHO, C.J.R; MAMEDE, S.; BITENCOURT, K. & BENITES, M. 2011. Introduce species in the Pantanal: implications for conservation. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 71, (1)(Suppl.): 321-325.

ALHO, C.J.R. & SILVA, J.S.V., 2012. Effects of Severe Floods and Droughts on Wildlife of the Pantanal Wetland (Brazil) - A Review. *Animals 2*: 591-610; http://dx.doi.org/10.3390/ani2040591 . Available: http://www.mdpi.com/2076-2/2/4/591/

ALMEIDA, N.N. 1998. *Estrutura e dinâmica de uma comunidade de plântulas em uma floresta sazonalmente inundável no Pantanal de Poconé, MT.* Master Thesis, Universidade Federal de Mato Grosso, Instituto de Biociências, Cuiabá, Brazil, 93 pp.; supervised by Fernando Roberto Martins.

ANA – AGÊNCIA NACIONAL DE ÁGUAS. 2005. *Strategic Action Program for the Integrated Management of the Pantanal and the Upper Paraguay River Basin*. Brasília, DF: ANA/GEF/PNUMA/OEA, 315 p. ISBN 859827604-9.

ANEEL – AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA, 2010. Ministério de Minas e Energia. *Quadro de acompanhamento de autorizações das PCH's.* Disponível em: <http://www.aneel.gov.br/aplicacoes/autorizacoes/default_aplicacao_acompanhamento.cfm?IDACOMPANHAMENTOTIPO=4>. Acesso em: 2 January.2012.

ANTAS, P.T.Z. 1992. Projeto Tuiuiú. Relatório Consolidado das Atividades de 1992. Unpublished Report CEMAVE, IBAMA. Brasília

ANTAS, P.T.Z. & NASCIMENTO, I.L.S. 1996 Tuiuiú: sob os céus do Pantanal. Brasília: SEMAVE e Monsanto, 1996. 169p.

BONVICINO, C. & LACHER, T. 2008. *Thrichomys pachyurus*. *In*: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 21 January 2012.

BRITSKI, H.A.; SILIMON K.Z.S. & LOPES B.S. 2007. Peixes do Pantanal. Brasília, EMBRAPA, 230p.

BUNN, S.E. & ARTHINGTON, A.H. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management* 30 (4): 492-507.

CALHEIROS, D.; ARNDT, E.; RODRIGUEZ, EA. & SILVA, M.C.A., 2009. Influências de Usinas Hidrelétricas no Funcionamento Hidro-Ecológico do Pantanal Mato-Grossense – Recomendações. *Embrapa - Documento 102*. Acesso em 23 January 2012 http://www.cpap.embrapa.br/publicacoes/online/DOC102.pdf

CAMPOS, Z. & MAGNUSSON, W. 1995. Relationship between rainfall, nesting habitat and fecundity of *Caiman crocodilus yacare* in the Pantanal - Brazil. *Journal of Tropical Ecology*, v.11, p. 351-358.

CAMPOS, Z.; COUTINHO, M. & MAGNUSSON, W.E. 2005. *Terrestrial Activity of Caiman in the Pantanal, Brazil.* Copea (3): 626-634.

CARMIGNOTTO, A.P. 2004. *Pequenos mamíferos terrestres do bioma Cerrado: padrões faunísticos locais e regionais*. Doctoral thesis. São Paulo: Universidade São Paulo. 404 p.

CATELLA, A.C. 2004. *A pesca no Pantanal Sul: situação atual e perspectivas*. Corumbá: Embrapa Pantanal, Série Documentos, v. 48.

CATELLA, A.C. 2007. Uso plural dos recursos pesqueiros como estratégia para sua conservação. *In*: Congresso Brasileiro de Produção de Peixes Nativos de Água Doce, 1.; Encontro de Piscicultores de Mato Grosso do Sul, 1., Dourados. *Anais***.** Dourados: Embrapa Agropecuária Oeste; Corumbá: Embrapa Pantanal, 2007. CD-ROM.

CI + ECOA + AVINA + SOS Pantanal + WWF- Brasil. 2009. *Monitoramento das alterações da cobertura vegetal e uso do solo na Bacia do Alto Paraguai Porção Brasileira.* Available: http://assets.wwfbr.panda.org/downloads/mapacoberturabaciaaltopara-guai_estudocompleto.pdf. Accessed on January 23, 2012.

COUTINHO, M. & CAMPOS, Z. 1996. Effect of Habitat and Seasonality on the Densities of Caiman in Southern Pantanal, Brazil. *Journal of Tropical Ecology,* Vol. 12(5):741-747.

CUNHA, C.N. 1998.*Comunidades arbustivo-arbóreas de capão e de diques marginais no Pantanal de Poconé-MT: Caracterização e análise de gradiente.* Unpublished Doctoral Thesis. Universidade Federal de São Carlos, Brasil. 150 pp.

CUNHA, C.N. & JUNK, W.J. 2000. Distribution of woody plant communities along the flood gradient in the Pantanal of Poconé, Mato Grosso, Brazil. *The Millenium Wetland Event*. Quebec, Canada. August 6-12. Abstracts: 194.

DESBIEZ, A.L.J.; BODMER, R.E.B.; and TOMAS, W.M. 2010. Mammalian Densities in a Neotropical Wetland Subject to Extreme Climatic Events. *Biotropica* 42(3): 372–378

FERNANDES, R.; AGOSTINHO, A.A.; FERREIRA, E.A.; PAVANELLI, C.S.; SUZUKI, H.I.; LIMA, D.P. & GOMES, L.C. 2009. Effects of the hydrological regime on the ichthyofauna of riverine environments of the Upper Paraná River Floodplain. *Brazilian Journal of Biology*, v. 69, n. 2. (suppl.), p. 669-680.

FERREIRA, A.R. 2000. *A influência do pulso de inundação na produção de frutos de Bactris glaucescens. Drude, no município de Barão de Melgaço, Pantanal mato-grossense, Mato Grosso, Brazil.* Unpublished Master Thesis. Universidade Federal do Mato Grosso, Instituto de Biociências. Cuiabá. 43 pp.

FISCHER, W.A. 1997. *Efeitos da BR-262 na mortalidade de vertebrados silvestres: síntese naturalística para a conservação da região do Pantanal-MS.* Dissertação de Mestrado, Universidade Federal de Mato Grosso do Sul, Campo Grande-MS. 44 pp.

GARCIA, I.C.B. 2006. *Influência da pesca seletiva sobre o comprimento médio de maturação em população de Dourado (Salminus brasiliensis), Piraputanga (Brycon hilarii) e Curimbatá (Prohilodus lineatus) no Rio Miranda.* Unpublished Thesis, Mestrado em Ecologia e Conservação – Universidade Federal de Mato Grosso do Sul - UFMS, Campo Grande, 46p.

GIRARD, P. 2002. *Efeito cumulativo das barragens no pantanal: mobilização para conservação das áreas úmidas do Pantanal e Bacia do Araguaia*. Campo Grande, MS: Instituto Centro Vida, 28 p. Relatório. Disponível em: <http://www.riosvivos.org.br/dowloads/Efeito_cumulativo_barragens_Pantanal.pdf>. Acesso em 25 January 2012.

GODINHO, A.L.; LAMAS, I.R. & GODINHO, H.P. 2009. Reproductive ecology of Brazilian freshwater fishes. *Env. Biol. Fish*, v. 87, p. 143-162.

GWYNNE, J.A.; RIDGELY, R.S.; TUDOR, G. & ARGEL, M. 2010. *Aves do Brasil: Pantanal e Cerrado*. Wildlife Conservation Society. Editora Horizonte. São Paulo. 322p.

HAMILTON, S.K., SIPPEL, S.J. & MELACK, J.M. 1996. Inundation patterns in the Pantanal wetland of South America determined from passive microwave remote sensing. *Arch. Hydrobiol*. 137:1-23.

HAMILTON, S.K.; SIPPEL, S.J.; CALHEIROS, D.F. & MELACK, J.M. 1997. An anoxic event and biogeochemical effects of the Pantanal wetland on the Paraguay River. *Limnology and Oceanography,* 42(2):257-272.

HARDOIM, E.L. & HECKMAN, C.W. 1996. The seasonal succession of biotic communities in wetlands of the tropical wet-and-dry climatic zone: IV. The free-living Sarcodines and Ciliates of the Pantanal of Mato Grosso, Brazil. *Int. Revue ges. Hydrobiol.* 81(3):367-384.

HECKMAN, C.W. 1994. The seasonal succession of biotic communities in wetlands of the tropical wet-and-dry climatic zone: I. Physical and chemical causes and biological effects in the Pantanal of Mato Grosso, Brazil. *Int. Revue ges. Hydrobiol.* 79(3):397-421.

HECKMAN, C.W. 1997. Ecosystems dynamics in the Pantanal of Mato Grosso, Brazil. *Verh. Int. Verein. Limnol.* 26:1343-1347. Stuttgart.

JUNK, W.J. 1993. *Wetlands of tropical South America*. Pages 679-739. In: D. Whigham *et al.* (eds.), Wetlands of the World: inventory, ecology, and management. V.1 Kluwer.

JUNK, W.J.; CUNHA, C.N.; WANTZEN, K.M.; PETERMANN, P.; STRÜSSMANN, C.; MARQUES, M.I. & ADIS, J. 2006. Biodiversity and its conservation in the Pantanal of Mato Grosso, Brazil. *Aquatic Sciences* 68 (2006): 278–309.

KEAST, A. & MORTON, E. (eds.) 1980. Migrant birds in the Neotropics. Ecology, behavior, distribution and conservation. Smithsonian Institution. Washington. 576 pp.

KEDDY, P.A.; FRASER, L.H.; SOLOMESHCH; A.I.; JUNK, W.J.; CAMPBELL, D., ARROYO; T.K. & ALHO, C.J.R. 2009**.** Wet and Wonderful: The World's Largest Wetlands are Conservation Priorities. *BioScience*, Volume 59 (1): 39-51.

KRETZCHMAR, A.U.; FERREIRA, S.A.; HARDOIM, E.L. & HECKMAN, C.W. 1993. *Peak growth of the Asplanchna sieboldi (Leydig 1854) Rotifer aggregation in relation to the seasonal wet-and-dry cycle in the Pantanal, Mato Grosso, Brazil.* In: B. Gopal; A. Hillbricht-Ilkowska & R.G. Wetzel (eds.): Wetlands and ecotones: Studies on land-water interactions. National Institute of Ecology. New Delhi. Pp 293-301.

LACHER Jr., T.E. & ALHO, C.J.R. 1989. Microhabitat Use Among Small Mammals in the Brazilian Pantanal. *J. Mamm.* 70(2):396-401.

LACHER Jr., T.E. & ALHO, C.J.R. 2001. Terrestrial small mammal richness and habitat associations in an Amazon forest-Cerrado contact zone. *Biotropica*, Storrs, 33(1):171-181.

MAGALHÃES, C. 2000. *Diversity and abundance of decapod crustaceans in the Rio Negro basin, Pantanal, Mato Grosso do Sul, Brasil*. Chapter 5. In: P.W. Willink; B. Chernoff; L.E. Alonso; J.R. Montambault & R. Lourival (eds.). A biological assessment of the aquatic ecosystems of the Pantanal, Mato Grosso do Sul, Brasil. RAP Bulletin of Biological Assessment 18. Conservation International, Washington, DC.

MAMEDE, S.B. & ALHO, C.J.R. 2006. Response of wild mammals to seasonal shrinking-and-expansion of habitats due to flooding regime of the Pantanal, Brazil. *Revista Brasileira de Biologia=Brazilian Journal of Biology* 66(4): 991-998.

MATEUS, L.A.; PENHA, J.M.F. & PETRERE, M. 2004. Fishing resources in the rio Cuiabá basin, Pantanal do Mato Grosso, Brazil. *Neotropical Ichthyology* 2 (4):217-227.

MEIRELLES, M.L.; OLIVEIRA, R.C.; SANTOS, A.R. & CORREIA, J.R. 2002. *Espécies do estrato herbáceo e profundidade do lençol freático em áreas úmidas do Cerrado.* Planaltina: Embrapa Cerrados. 19 p. (Boletim de Pesquisa e Desenvolvimento, Embrapa Cerrados, no. 25).

NUNES, A.P & TOMAS, W.M. 2008. *Aves migratórias e nômades ocorrentes no Pantanal.* Embrapa Pantanal, Corumbá, MS, 124 p. ISBN 978-85-98893-13-6.

OLIVEIRA, D.M.M. 1997. Sucesso reprodutivo e conservação de tuiuiú *Jabiru mycteria* (Aves: Cinoniidae) no Pantanal de Poconé, Mato Grosso. Unpublished Master Thesis. Universidade Federal de Mato Grosso. Instituto de Biociências. Cuiabá. 68 pp.

PCBAP – *Plano de Conservação da Bacia do Alto Paraguai*. 1997. 3 volumes, 7 t. illustr., maps. V. 1 – Metodologia do Plano de Conservação para a Bacia do Alto Paraguai. V. 2 – Diagnóstico Ambiental da Bacia do Alto Paraguai; t. 1 - Meio Físico; t. 2 – Hidrossedimentologia; t.3 – Meio Biótico; t. 4 – Sócio-economia de Mato Grosso; t. 5 – Sócio-economia de Mato Grosso do Sul; t. 6 – Aspectos Jurídicos e Institucionais de Mato Grosso; t, 7 – Aspectos Jurídicos e Institucionais de Mato Grosso do Sul. V. 3 – Análise Integrada e Prognóstico da Bacia do Alto Paraguai. Programa Nacional do Meio Ambiente, Ministério do Meio Ambiente, Brasília.

POTT, A. & POTT, V.J. 1999. Flora do Pantanal – listagem atual de fanerógamas. *In:* Anais do Simpósio sobre Recursos Naturais e Sócio-Econômicos do Pantanal, Manejo e Conservação, 2, 1996. Corumbá: Embrapa Pantanal. p. 297-325.

POTT, A. & POTT, V.J. 2009. Vegetação do Pantanal: fitogeografia e dinâmica. *Anais 2.º Simpósio de Geotecnologias no Pantanal.* Corumbá: Embrapa Informática Agropec./INPE, p. 1065-1076.

POTT, V.J.; POTT, A.; LIMA, L.C.P.; MOREIRA, S.N. & OLIVEIRA, A.K.M. 2011a. Aquatic macrophyte diversity of the Pantanal wetland and upper basin. *Revista Brasileira de Biologia- Brazilian. Journal of Biology*, 71, (1)(Suppl.): 255-263.

POTT, A.; OLIVEIRA, A.K.M.; DAMASCENO-JUNIOR, G.A. & SILVA, J.S.V. 2011b. Plant diversity of the Pantanal wetland. *Revista Brasileira de Biologia - Brazilian. Journal of Biology*, 71, (1)(Suppl.): 265-273.

PRADO, A.L.; HECKMAN, C.W. & MARTINS, F.R. 1994. The seasonal succession of biotic communities in wetlands of the tropical wet-and-dry climatic zone: II. The aquatic macrophyte vegetation in the Pantanal of Mato Grosso, Brazil. *Int. Revue Ges. Hydrobiol*. 79(4):569-589.

PRODEAGRO. 1997. Projeto de Desenvolvimento Agroambiental do Estado de Mato Grosso. Governo do Estado de Mato Grosso. Cuiabá. Paper in digital format (CD). Meio Biótico.

RAMOS, M.V.V.; CURI, N.; MOTTA, P.E.F.; VITORINO, A.C.T.; FERREIRA, M.M. & SILVA, M.L.N. 2006. Veredas do triângulo Mineiro: solos, água e uso. *Ciência Agrotécnica* vol. 30, no. 2, p. 283-293.

SÁ, L.D.A.; SAMBATTI, S.B.M. & GALVÃO, G.P. 1998. Ondeleta de Morlet aplicada ao Estudo da variabilidade do nível do rio Paraguay em Ladário, MS. *Pesq. Agropec*. Brasil., Brasília, 33 (Número Especial): 1775-1785.

SABINO, J. & PRADO, P.I. 2006. Vertebrados: Síntese do Conhecimento da Diversidade Biológica do Brasil. *In:* T.M. Lewinsohn. (Org.). Avaliação do Estado do Conhecimento da Diversidade Brasileira. 1 ed. Brasília: Ministério do Meio Ambiente, v. II, p. 55-143

SCHALLER, G.B. & VASCONCELOS, J. 1978. A marsh deer sensus in Brazil. *Oryx,* 14:345-351.

SCHESSL, M. 1997. *Flora und vegetation des nördlichen Pantanal von Mato Grosso, Brasilien*. Unpublished Doctoral Thesis. University Ulm, Martina-Galunder-Verlag, Wiehl, Germany. 276 pp.

SCHESSL, M. 1999. Floristic composition and structure of floodplain vegetation in the Northern Pantanal of Mato Grosso, Brazil. *Phyton*, vol. 39, no. 2, p. 303-336.

SCREMIN-DIAS, E.; LORENZ-LEMKE, A.P. & OLIVEIRA, A.K.M. 2011. The floristic heterogeneity of the Pantanal and the occurrence of species with different adaptive strategies to water stress. *Revista Brasileira de Biologia = Brazilian. Journal of Biology*, 71, (1)(Suppl.): 275-282.

SRESTHA, R.K.; SEIDL, A.F.; & MORAES, A.S. 2002. Value of recreational fishing in the Brazilian Pantanal: a travel cost analysis using count data models. *Ecological economics* 42:289-299.

SILVA, J.S.V. 1991. Aplicações de técnicas de sensoriamento remoto e sistema de informação geográficas na avaliação da dinâmica de inundação no Pantanal. Unpublished Master thesis. INPE, São José dos Campos. Available at www.inpe.br/biblioteca

SILVA, J. D.V. & ABDON, M.M. 1998. Delimitação do Pantanal Brasileiro e suas sub-regiões. *Pesq. Agropec. Bras.*, Brasília, 33 (Número Especial): 1703-1711.

SILVA, C.J. & ESTEVES, F.A. 1993. Biomass of three macrophytes in the Pantanal of Mato Grosso, Brazil. *International Journal of Ecology and Environmental Sciences* 19:11-23.

SILVA, C.J. & ESTEVES, F.A. 1995. Dinâmica das características limnológicas das baías Porto de Fora e Acurizal (Pantanal de Mato Grosso) em função da variação do nível da água. *Oecologia Brasiliensis*, 1:47-60.

STRÜSSMANN, C. & SAZIMA, I. 1993. The snake assemblage of the Pantanal at Poconé, western Brazil: faunal composition and ecological summary. *Studies of Neotropical Fauna Environments* 28: 157-168.

TAKEDA, A.; PEREIRA, M.C.F. & BARBOSA, F.A.R. 2000. Zoobenthos survey of the Pantanal, Mato Grosso do Sul, Brasil. *In:* Philip W. Willink, Barry Chernoff, Leeanne E. Alonso, Jensen R. Montambault & Reinaldo Lourival (eds.). 2000. A biological assessment of the aquatic ecosystems of the Pantanal, Mato Grosso do Sul, Brasil. RAP *Bulletin of Biological Assessment* 18. Conservation International, Washington, DC.

TUBELIS, D.P. & TOMÁS, W.M. 2002. *Caracterização da avifauna da planície do Pantanal. Indicadores da magnitude da diversidade e abundância de vertebrados silvestres do Pantanal num mosaico de hábitats sazonais.* EMBRAPA. Publicado em meio digital: Centro de Pesquisa Agro-Pecuária da EMBRAPA, Corumbá, MS.

TOMÁS, W.M.; SALIS, S. M. 2000. Diet of the marsh deer (*Blastocerus dichotomus)* on the Pantanal wetland, Brazil. *Stud. Neotrop. Fauna Environ. 35*, 165-172.

VINSON, M.R. & HAWKINS, C.P. 1998. Biodiversity of stream insects: variation at local, basin and regional scales. *Annual Review of Entomology*, n.43, p.271-293.

WANTZEN, K.M. & JUNK, W.J. 2000. *The importance of stream-wetland-systems for biodiversity: a tropical perspective.* In: GOPAL, B.; JUNK, W.J.;DAVIS, J.A. (Eds.) Biodiversity in wetlands: assessment, function and conservation. Leiden: Backhuys Bublishers, v.1, p.11-34.

WILLINK, P.W.; CHERNOFF, B.; ALONSO, L.E.; MONTAMBAULT, J.R.; & LOURIVAL, R. (eds.). 2000. A biological assessment of the aquatic ecosystems of the Pantanal, Mato Grosso do Sul, Brasil. RAP *Bulletin of Biological Assessment* 18. Conservation International, Washington, DC.

XIMENES, L.Q.L.; MATEUS, L.A.F. & PENHA, J.M.F. 2011. Variação temporal e espacial na composição de guildas alimentares da ictiofauna em lagoas marginais do Rio Cuiabá, Pantanal Norte *Biota Neotrop.* 11(1):205-215.

Submetido em 03/05/2012
Aceito em 10/12/2012