26 Human impacts and environmental problems in the Brazilian Pantanal

Ricardo B. Machado[1*], Mônica Barcellos Harris[2], Sandro M. Silva[3], and Mário B. Ramos Neto[1]

[1] Conservação Internacional, SAUS quadra 3, Ed. Business Center, sala 722, CEP: 70070-934 – Brasília, DF, Brazil

[2] Head of Programme - Business, Biodiversity and Ecosystem Service, UNEP World Conservation Monitoring Centre (UNEP-WCMC), 219 Huntingdon Road, Cambridge, CB3 0DL, UK

[3] Conservação Internacional, Rua Paraná, 32, Jardim dos Estados, CEP: 79021-220 – Campo Grande – MS, Brazil

[*] corresponding author: r.machado@conservation.org.br

Abstract

The Pantanal is the largest seasonal flooded region in the world and covers around 146,000 square kilometers in Brazil, Bolivia and Paraguay. Although the floodplain is relatively intact, with 76% of native habitat well preserved, the upper lands are heavily impacted by the expansion of agriculture and cattle raising. It is estimated that more than half of natural coverage was removed during the last 30 years. We used MODIS images in order to classify the fragmentation status of all micro-basins (5th order) on the region. Five landscape metrics (number of patches, mean patch size, mean distance to the next patch, total remaining area and a shape index) were used in a Principal Component Analysis (PCA) and the PCA scores were used to classify each micro-basin according to its fragmentation level. By overlapping threatened species distribution data, we identify four main regions (headstreams of Cuiabá, São Lourenço, Taquari and Miranda Rivers) with expressive concentration of species and worrying fragmentation level. We suggested that any conservation plan for the region should consider the natural interactions between lower parts (the Pantanal *per se*) and the highlands (the surrounding Cerrado). With deforestation, the implementation of huge infrastructure projects such as the Paraguay hydrovia and the construction of dams for energy generation can impact the natural flood pulse observed on the region. If add the expected near-future changes caused by climate change, the human impacts on the region can be very expressive.

Junk, W.J., Da Silva, C.J., Nunes da Cunha, C., Wantzen, K.M. (Eds) 2009
The Pantanal: Ecology, biodiversity and sustainable management of a large neotropical seasonal wetland, pp. 127-141.

26.1 Introduction

The Pantanal represents today, next to the Amazon, one of the regions with the largest populations of wildlife in South America. This condition is due to the good conservation status of native habitats, as the Brazilian portion of the Pantanal floodplain still maintains between 83% and 85% of its original vegetation cover (Harris et al. 2006). Nevertheless, the high plains (Planalto) that surrounds the Pantanal and integrate the Upper Paraguay River Basin (UPRB) is in a much different situation. Due to its topographic and edaphic characteristics, the high plains of the UPRB in 2004 only maintained just over half of its original vegetation cover (Harris et al. 2006).

Loss of habitat has been highlighted as one of the main threats to biodiversity in general (Myers 1986; Saunders et al. 1991; Laurance & Bierregaard JR 1997; Gaston et al. 2003), and the main threat to most vertebrates endangered to extinction (Baillie et al. 2004). Evaluate the status of natural ecosystems in one of the basic stages to define conservation strategies for the protection of biodiversity (Pressey et al. 1993; Margules & Pressey 2000; Pressey & Taffs 2001). The conservation actions suggested for the Pantanal region normally focus strictly on the floodplain and the high plains which are part of the same basin (UPRB) are considered separately. From the definition of priority areas for conservation (MMA 2002) to the adoption of development policies to the evaluation of potential effects of climate change (Marengo 2007) there is always a physical separation of the Pantanal floodplain from its headwaters. Although the Pantanal landscape is distinctly different from neighboring biomes, like the Cerrado, Chaco or the Amazon, the fauna and flora are totally shared with these natural regions (Prance & Schaller 1982). In addition to the biota, the high plains play an important role for the maintenance of hydrological processes observed in the region (Hamilton et al. 1995, 2002), thus, planning efforts, both environmental and developmental, must consider both regions.

Within this context, the aim of this work was to evaluate the fragmentation status of the UPRB (floodplain and high plains), identify the main environmental problems in the region, and suggest areas and priority action for environmental conservation and rehabilitation work.

26.1.1 Deforestation in the UPRB headwaters and floodplain

We evaluated the status of the native vegetation cover in the UPRB through a multivariate analysis using descriptive metrics of the fragmentation status. Initially we mapped the native vegetation cover remaining using MODIS images (product MOD13q) dated from four different periods in 2007: 7th April, 9th May, 10th June and 26th June. For each image, we used near infrared (NIR), mid wavelength infrared and the visible infrared (RED) bands, which were reprojected to Albers Equal Area Projection and preprocessed for the classification analysis. Initially we reclassified the negative values on MODIS images and, following the procedures provided by Mather (1987), we passed a 3 × 3 median filter to attenuate the effect of isolated pixels.

We carried out an unsupervised classification using the isocluster procedure with the programme IDRISI version Andes (Eastman 2006) for the initial creation of 30 classes. This was followed by manually grouping the classes generated into three: native areas, anthropogenic areas and water bodies. Landsat images from 2002 were used to support the identification of native and anthropogenic areas.

We used a watershed map to divide the Upper Paraguay River Basin into smaller planning units in order to analyze their fragmentation status. The watersheds, detailed up to 5th order streams, that was partly located in the high plains (areas dominated by Cerrado formation) and partly in low plains (areas dominated by Pantanal formation) were subdivided accordingly. Considering the subdivision, the final map analyzed was composed of a total of 367 watersheds. For each micro-watershed, we used the program Patch Analyst (Rempel 2006) to determine: total number of patches (NUMP), mean patch size (MPS), total native vegetation remaining (TLA), mean shape index (MSI), and mean nearest neighbor (MNN) (Table 26.1). A Principle Component Analysis (PCA) was then completed using the five variables selected to characterize the fragmentation status of the micro-watersheds. To this end, we selected the first component generated by the PCA and classified the micro-watersheds according to the score obtained for each of them. We compared the average values of the scores for the high plains and the floodplain using a Student's t-test. To identify key micro-watersheds requiring environmental conservation or management, the micro-watershed fragmentation map was cross referenced to the occurrence of threatened species (according to IUCN 2006 and the Brazilian Ministry for the Environment list for 2003 (MMA 2003; IUCN 2006).

26.2 Results and discussion

This work divided the Upper Paraguay River Basin in 367 micro-watersheds, with 217 located in the floodplain and 150 located in the high plains. The average vegetation cover found to be remaining for micro-watersheds located in the floodplain (N = 217, S.D. = 20%) was 86% and the minimum value was 18%. For the micro-watersheds located in the high plains (N = 150, S.D. = 21.4%), the average

Table 26.1 Variables used to describe the fragmentation status of the micro-watersheds in the Upper Paraguay River Basin (UPRB).

	Floodplain (Pantanal)				
	N	**Mean**	**Minimum**	**Maximum**	**S.D.**
MNN	217	234.7	0,0	2135,8	315,1
NUMP	217	11,7	1,0	150,0	23,6
MPS	217	16370,0	37,6	209254,0	26457,0
MSI	217	1,7	1.1	3,4	0,4
TLA	217	80.855	37,5	1.622.369	170.121,8
	Highlands (Cerrado)				
	N	**Mean**	**Minimum**	**Maximum**	**S.D**
MNN	150	496.4	0.0	2590.0	316.8
NUMP	150	85.2	1.0	796.0	138.8
MPS	150	1379.7	5.4	13443.0	1768.0
MSI	150	1.5	1.0	3.7	0.3
TLA	150	142.718	10,7	1.825.286	225.871,1

Observation: MNN = Mean Neighbor Nearest, NUMP = Number of patches, MPS = Mean patch size, MSI = Mean shape index, TLA = Total land area. For details on variables and its calculation, see McGarigal & Marks (1994)

value was 48% and the minimum 0%. Although the concept of fragment is associated with organisms, i.e., what is a fragment depends on how different organisms perceive it, in this study we considered as a fragment any set of contiguous pixels separated from other set of contiguous pixels by at least 250 meters, which is the resolution of the satellite images used. The results of the images classification indicates the existence of 13,073 fragments on the region, being 1,662 fragments on the floodplain (12.7%) and the rest (87.3%) on the highlands. The fragment average size is also quite different between the regions. While the mean patch size on floodplain is 7,765 hectares, on the highlands they have 901.2 hectares in average.

According to the Principal Component Analysis carried out, micro-watersheds can be clearly divided amongst very fragmented regions (located in the high plains) and regions with little fragmentation (located in the floodplain, Fig. 26.1). The first component generated by the PCA showed 42.4% variance of the original data, and the variables with the best negative correlation with this component were MSI (mean shape index) with -0.705 and MPS (mean patch size) with -0.537 and the variables with better positive correlation were NUMP (number of fragments) with 0.770 and TLA (total area remaining) with 0.681 (Table 26.2). These results suggest that micro-watershed located in the high plains are characterized to have fragments less clumped, higher in number and proportionally having less natural coverage than the floodplain. On the other hand, the fragments from the watersheds located on the floodplain are

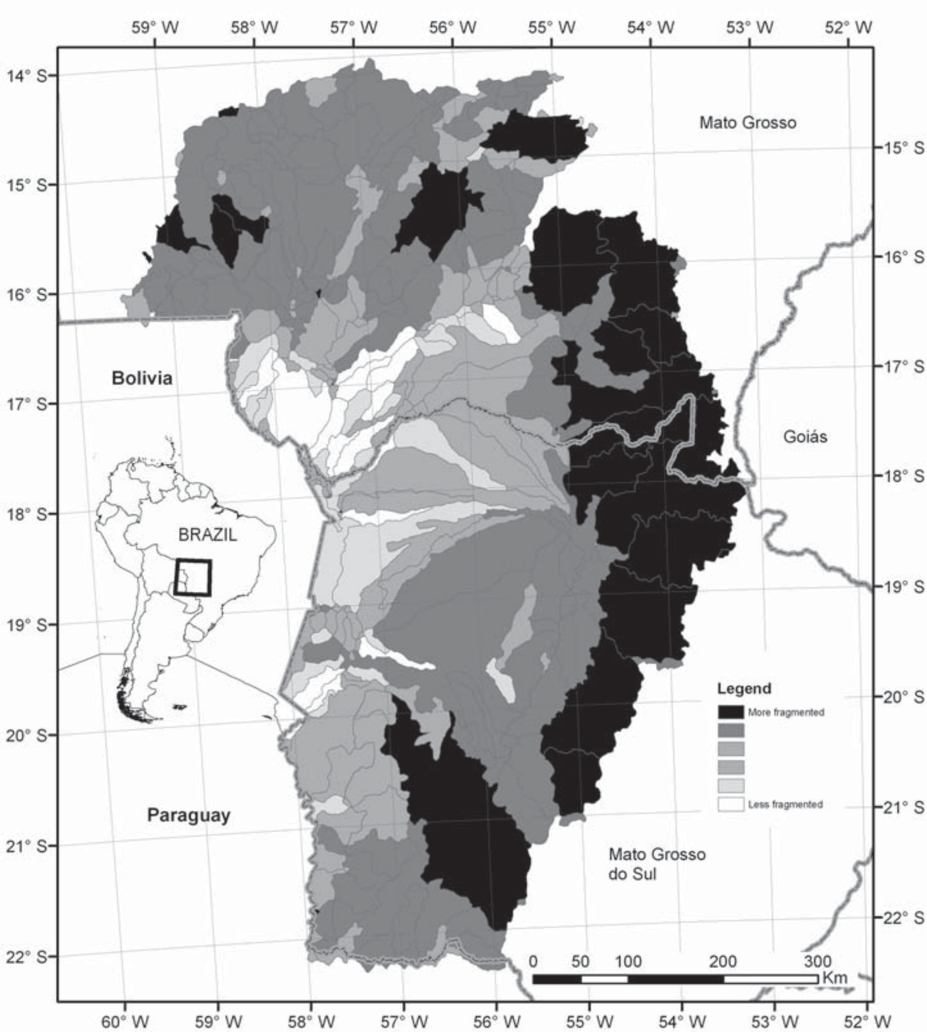

Fig. 26.1 Habitat fragmentation patterns in the micro-watershed of the Upper Paraguay River Basin (UPRB) based on the first component of a Principal Component Analysis-PCA (here grouped in five classes). The darker areas correspond to those in the worse fragmentation status. The values on the key refer to the scores of the first component generated by the PCA.

more regular (high area/perimeter ratio) and larger (Fig. 26.2). In fact, comparing the medium value of the scores for the micro-watersheds of the high plains and floodplain, there is a significant difference ($N = 367$, $t = 10.070$, $p < 0.0001$).

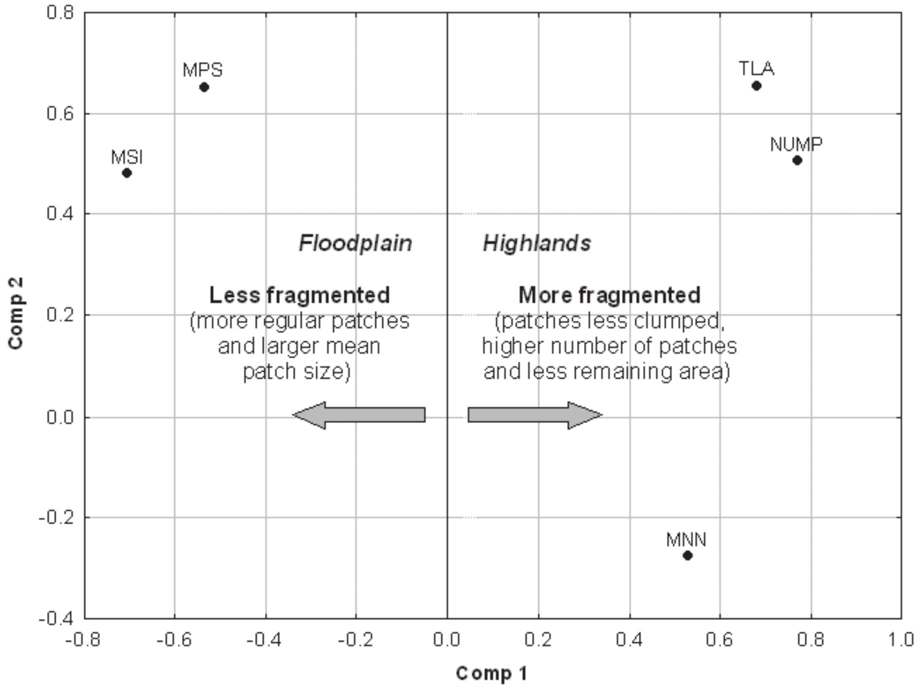

Fig. 26.2 Relation between the variables selected to characterize the fragmentation status of micro-watershed and the first two components generated. The variables considered to characterize each micro-watershed are MSI (mean shape index), MPS (mean patch size), MNN (mean nearest neighbor), TLA (total native vegetation remaining), and NUMP (number of patches).

Although the results of this mapping exercise are slightly different to those presented by Harris and collaborators (2006) for the same region, the overall occupation pattern and the removal of native vegetation registered are comparable. While the later suggested the removal of native vegetation in the floodplain and in the high plains was 17.5% and 63% respectively, this study estimated these to be 13.6% and 51.8% for the floodplain and high plains. Such variations can be due to the lack of ground truthing in both studies to support the unsupervised classifications used in both studies or even due to the difficulty in distinguishing similar targets such as non-native pasture land and grasslands. MODIS images have been used to monitor native vegetation cover in different regions of Brazil with good spatial and thematic precision (in terms of landuse classes that can be recognized).

In the Mato Grosso state, in a transition area of Cerrado and Amazon, Morton and collaborators (2006) used MODIS images to estimate the deforestation

Table 26.2 Correlation between the original variables and the first two components of the Principal Component Analysis (PCA) carried out.

	PCA Components	
Variables	**Comp1**	**Comp2**
MNN	0.35459	0.57714
NUMP	0.76819	-0.55114
MPS	-0.61201	-0.57621
MSI	-0.71530	-0.44425
TLA	0.65601	-0.68853
Explained variation	2.03241	1.64029
Total Prop.	0.40648	0.32806

Observation: MNN = Mean Neighbor Nearest, NUMP = Number of patches, MPS = Mean patch size, MSI = Mean shape index, TLA = Total land area. For details on variables and its calculation, see McGarigal & Marks (1994)

of the agriculture frontier between the years of 2001 and 2004. The results of this work were very similar to those obtained by the deforestation monitoring system known as PRODES, conducted by the Brazilian National Space Institute (INPE) (http://www.inpe.br/prodes). The authors highlighted that due to the large temporal frequency of the Earth, the MODIS images have an advantage for the characterization of targets which the reflectance alters over time, a similar conclusion demonstrated by Anderson et al. (2005). However, Morton et al. (2006) raised that in situations where environmental changes which take place in a short period of time may not be captured by MODIS images.

MODIS images with a 250 m resolution are very promising and allow for much superior differentiation when compared to other medium resolution images, even with the one kilometer resolution MODIS itself or with AVHRR/NOA. In 1998, a deforestation study for the Pantanal based on AVHRR/NOA images (Mantovani & Amaral 1998) did not present good results in terms of the ability to register deforestation. The authors concluded that only 20% of the areas mapped as deforestation using Landsat (N = 112) were registered by the AVHRR/NOA images used.

Nonetheless, both studies indicate that deforestation is rising in the UPRB, especially in the floodplain. One of the first studies to estimate the deforestation in the Pantanal floodplain was carried out by Silva and collaborators (1998), who indicated that deforestation represented 3.6% of the area of the floodplain in 1991. Later studies (Padovani et al. 2004; Harris et al. 2006 and this work) indicated a continuous rise in deforestation in the floodplain. This is in part led by the implementation of non-native pastureland as an alternative to increment the productivity of cattle ranching (Padovani et al. 2004). In the 1920s, the ruling productive system had a density of one cow for every 2.2 hectares (Wilcox 1992). With the Pantanal cattle ranching system continuous loss of competitive value compared to the same activity in the Cerrado, one of the options adopted by cattle ranchers has been the substitution of native vegetation of exotic grasses, such as *Braciaria* spp., which has considerably raised the density of cows per hectare, with some regions reaching one per hectare (Mourão et al. 2002).

Unplanned occupation, driven solely by the variations of the cattle market (low price market, less occupation; high price market, larger occupation) impacts the regions hydrological system, as described next, as well as the native species. According to the species occurrence records kept by Conservation International, in the region there are 65 species of vertebrates, terrestrial and aquatic of interest to conservation. These comprise species that are endemic to Brazil, species of restricted distribution and threatened and near threatened species (Table 26.3). All together, there are 34 threatened species, including one amphibian, two reptiles, 14 birds and 15 mammals. Cross referencing the species of interest for conservation occurrence data to the fragmentation of micro-watersheds indicated at least four regions, all of which were located in the high plains, as priority for the adoption of measures to either protect or manage the landscape.

The areas presented in Fig. 26.3 are the micro-watershed of the Upper Cuiabá River, the Upper São Lourenço River, Upper Taquari River and Upper Miranda River. Out of the four listed here, the headwaters of the Miranda River have the highest number of records for threatened species with 21 records, followed by Taquari (eight), Cuiabá (six) and São Lourenço (three) (Table 26.3). None of the threatened species were recorded for all micro-watersheds. The maned-wolf (*Chrysocyon brachyurus*) and the giant-anteater (*Myrmecophaga tridactyla*) were recorded in three out of the four micro-watersheds considered a priority in this study. Other 10 species (29.4% of the total) were recorded in two micro-watersheds and the remaining 22 threatened species (64.7% of the total) were recorded in only one micro-watershed.

The removal of native vegetation has caused serious environmental problems in the Pantanal, not only due to the reduction of habitat size available for native species, but mainly due to the impact in the dynamics of the hydrological system of the region. Changes in water course, siltation of rivers, loss or alterations in headwaters normal function are some of the problems arisen from deforestation (Harris et al. 2005). As shown by this study, a large number of headwaters of the rivers that drain the Pantanal are already impacted by the excessive occupation of anthropogenic activities (Fig. 26.4).

One of the most typical and didactical example of human impacts on rivers is the case of Taquari River. Taquari is one of the most important contributors

Table 26.3 Threatened or restricted range species recorded to Upper Paraguay River Basin (UPRB). Source: Conservation International.

Class	Order	Species	IUCN	MMA	Cuiabá	São Lourenço	Taquari	Miranda
Actinopterygii	Siluriformes	*Ancistrus formoso*		VU				x
Actinopterygii	Cyprinodontiformes	*Plesiolebias xavantei*	NT	VU	x			
Actinopterygii	Cyprinodontiformes	*Stenolebias bellus*						x
Amphibia	Anura	*Bufo ocellatus*					x	
Amphibia	Anura	*Bufo scitulus*						x
Amphibia	Anura	*Chiasmocleis albopunctata*	LC					x
Amphibia	Anura	*Chiasmocleis mehelyi*	DD					x
Amphibia	Anura	*Dendropsophus rubicundulus*	LC				x	
Amphibia	Anura	*Eleutherodactylus dundeei*	DD		x			
Amphibia	Anura	*Melanophryniscus fulvoguttatus*	LC					x
Amphibia	Anura	*Physalaemus albonotatus*	LC					x
Amphibia	Anura	*Physalaemus fuscomaculatus*	LC		x			x
Amphibia	Anura	*Pseudopaludicola ameghini*	EN	VU				x
Amphibia	Anura	*Scinax machadoi*	LC					x
Amphibia	Anura	*Scinax megapodius*	LC					x
Aves	Psittaciformes	*Alipiopsitta xanthops*	NT		x	x	x	x
Aves	Psittaciformes	*Anodorhynchus hyacinthinus*	EN	VU			x	x
Aves	Passeriformes	*Antilophia galeata*	LC					x
Aves	Passeriformes	*Basileuterus leucophrys*	LC		x	x		
Aves	Passeriformes	*Charitospiza eucosma*	NT		x			
Aves	Columbiformes	*Columbina cyanopis*	CR	CR	x			
Aves	Passeriformes	*Coryphaspiza melanotis*	VU	VU		x		

Class	Order	Species	IUCN	MMA	Cuiabá	São Lourenço	Taquari	Miranda
Aves	Passeriformes	*Culicivora caudacuta*	VU	VU		x		x
Aves	Caprimulgiformes	*Eleothreptus candicans*	EN	EM	x			
Aves	Falconiformes	*Harpyhaliaetus coronatus*	EN	VU		x	x	
Aves	Passeriformes	*Herpsilochmus longirostris*	LC		x		x	x
Aves	Passeriformes	*Hylocryptus rectirostris*	LC					x
Aves	Passeriformes	*Melanopareia torquata*	LC					x
Aves	Passeriformes	*Oryzoborus maximiliani*	NT	CR	x			
Aves	Galliformes	*Penelope ochrogaster*	VU	VU	x			
Aves	Passeriformes	*Pheucticus aureoventris*	LC					x
Aves	Passeriformes	*Phyllomyias reiseri*	LC					x
Aves	Passeriformes	*Polystictus superciliaris*	VU		x			
Aves	Passeriformes	*Poospiza cinerea*	NT		x			
Aves	Passeriformes	*Porphyrospiza caerulescens*	VU	VU			x	x
Aves	Passeriformes	*Saltator atricollis*	LC					x
Aves	Passeriformes	*Sporophila cinnamomea*	VU	EN				x
Aves	Passeriformes	*Suiriri islerorum*			x			
Aves	Passeriformes	*Synallaxis simoni*		VU	x			
Aves	Tinamiformes	*Taoniscus nanus*	VU	VU				x
Aves	Ciconiiformes	*Tigrisoma fasciatum*	LC	EN				x
Mammalia	Artiodactyla	*Blastocerus dichotomus*	VU	VU			x	x
Mammalia	Carnivora	*Chrysocyon brachyurus*	NT	VU	x		x	x
Mammalia	Rodentia	*Dasyprocta azarae*	VU				x	
Mammalia	Chiroptera	*Glyphonycteris behnii*	VU		x			

Class	Order	Species	IUCN	MMA	Cuiabá	São Lourenço	Taquari	Miranda
Mammalia	Chiroptera	*Histiotus velatus*	LC		x			
Mammalia	Carnivora	*Leopardus pardalis*	LC	VU			x	x
Mammalia	Carnivora	*Leopardus wiedii*	LC	VU				x
Mammalia	Chiroptera	*Lonchophylla dekeyseri*	VU	VU			x	x
Mammalia	Didelphimorphia	*Monodelphis kunsi*	EN					x
Mammalia	Xenarthra	*Myrmecophaga tridactyla*	NT	VU	x		x	x
Mammalia	Chiroptera	*Natalus stramineus*	LC				x	
Mammalia	Rodentia	*Oecomys mamorae*	LC					x
Mammalia	Artiodactyla	*Ozotoceros bezoarticus*			x			
Mammalia	Carnivora	*Panthera onca*	NT	VU	x			x
Mammalia	Xenarthra	*Priodontes maximus*	VU	VU			x	
Mammalia	Carnivora	*Pteronura brasiliensis*	EN	VU				x
Mammalia	Carnivora	*Puma concolor*	NT	VU			x	x
Mammalia	Carnivora	*Speothos venaticus*	VU	VU				x
Mammalia	Perissodactyla	*Tapirus terrestris*	VU				x	x
Mammalia	Didelphimorphia	*Thylamys macrurus*						x
Reptilia	Squamata	*Apostolepis intermedia*						x
Reptilia	Squamata	*Bronia bedai*						x
Reptilia	Testudines	*Geochelone denticulata*	VU					x
Reptilia	Testudines	*Podocnemis unifilis*	NT	VU	x			

IUCN – red list categories according to the list of the World Conservation Union (www.redlist.org)
MMA – red list categories according to the Brazilian legislation *Instrução Normativa no. 3 de 27/Maio/2003 do Ministério do Meio Ambiente*
CR – Threatened – Critically Endangered, EN – Threatened – Endangered, VU – Threatened – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data deficient.

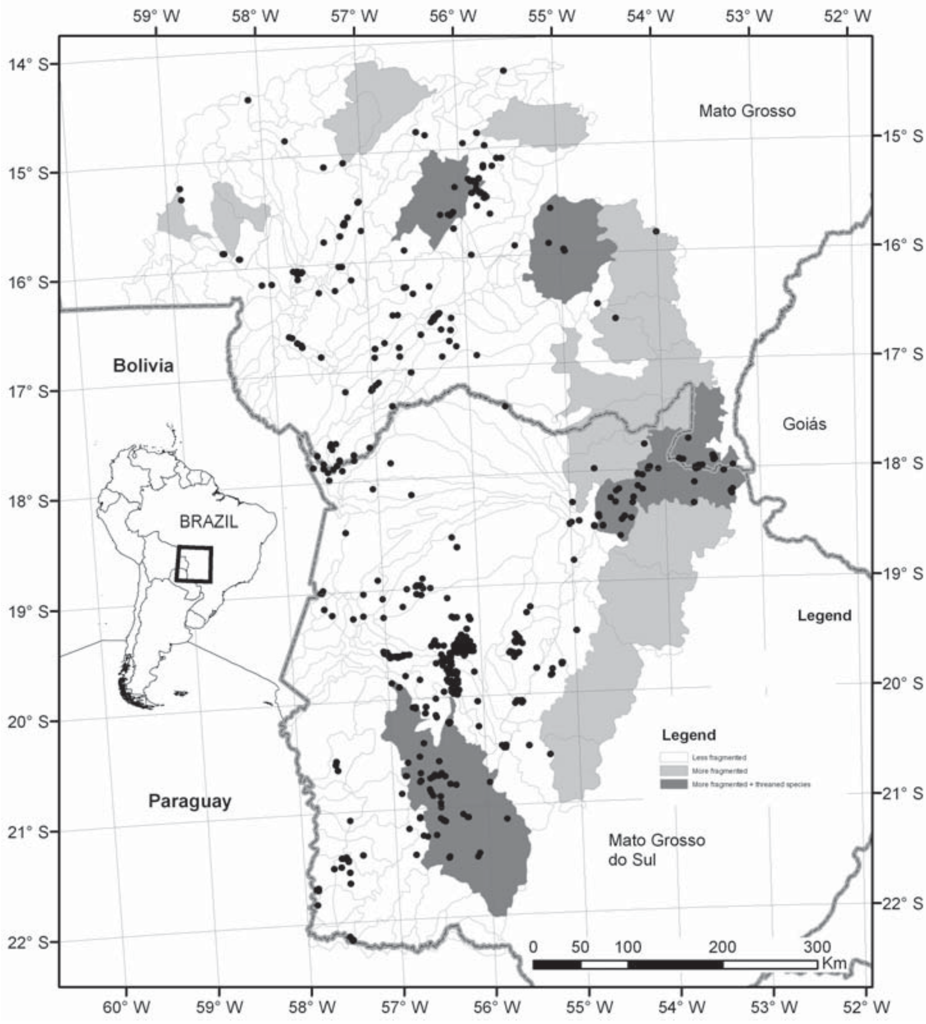

Fig. 26.3 Micro-watersheds considered as priorities (dark grey) for the rehabilitation of degraded areas and recovery of connection amongst fragments due to fragmentation status and occurrence of threatened species (represented by black dots in the map). From north to south and clockwise are the headwaters of the following micro-watersheds: Cuiabá River, São Lourenço River, Taquari River and Miranda River, respectively. Light grey areas represents micro-watersheds highly fragmented but with few records of threatened species. See Table 26.3 for the list of species considered.

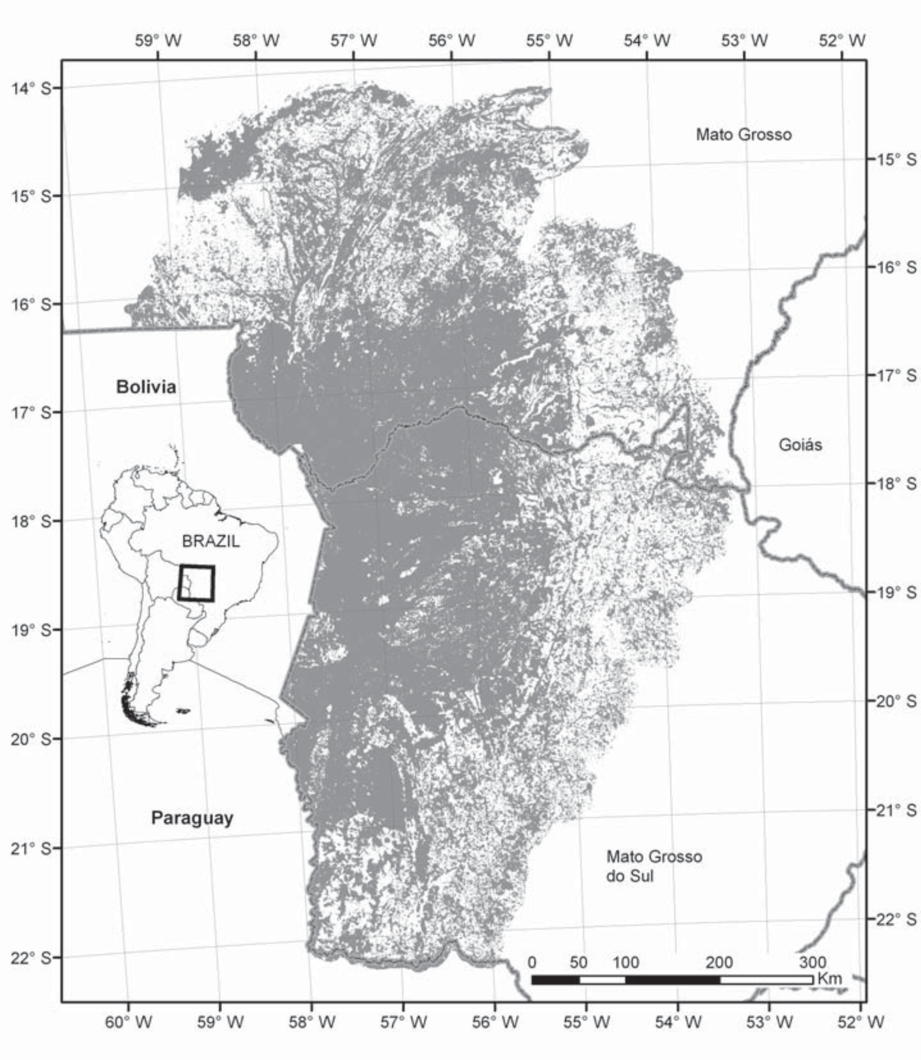

Fig. 26.4 Native vegetation cover remaining in the Upper Paraguay River Basin (UPRB) based on MODIS images from May 2007. The areas in white indicate where the native vegetation was removed in the UPRB.

on the right side of Paraguay River (C.A.B. Mendes, com. per.), covering approximately 3.3% of Pantanal's surface (Neves & Santos 2008). Although siltation process occurs naturally on Taquari River, human occupancy in the last years has considerably sped up the process leading to a critical situation (Godoy et al. 2002). Due to intense occupation of Taquari's headwaters and removal of its riparian vegetation, the river was transformed in a permanent swamp. As consequence, local human population had to move to other region, economic activities like cattle raising were heavily impacted and fishes stocks were reduced (Harris et al. 2005, Neves & Santos 2008).

26.2.1 Current situation and future threats

The Pantanal is subjected to many anthropogenic activities threat can cause profound changes to the region, if these are implemented without the adoption of measures to mitigate environmental impacts. As an alternative to the model of economic development based on soybean and cattle ranching, the Brazilian government is stimulating the development of mining, pig-iron and steel plants in the region of Corumbá (Carvalho et al. 2007). The energy demand to fuel these industries, based on charcoal, can impact the forest ecosystems locally and regionally, including the Chiquitanos dry forests in Bolivia, due to increasing demand for the production and consumption of charcoal. Currently native areas of Mato Grosso and Mato Grosso do Sul states, especially those located in the high plains are being converted into charcoal to fuel smelters in Minas Gerais state (Carvalho et al. 2007). According to the Brazilian Institute of Geography and Statistics, the state of Mato Grosso do Sul in 2006 was the largest producer of charcoal from native vegetation in the country (IBGE 2007). An increase pressure over remaining forests following the implementation of production plants in the floodplain will take place, if an effective policy promoting the production of charcoal from reforestation is not adopted. Also, an organization of the government's capacity to provide technical support and adequate enforcement of the sector is also needed (Carvalho et al. 2007).

In addition to the industrial expansion mentioned above, the region could also be highly affected by the implementation of an extensive infrastructure network of transport foreseen for South America. This refers to the development of a vast network of infrastructure projects (energy, transport and communication) in several regions of South America with the aim to promote the economic integration of several countries. The initiative was launched in 2000 during a South American presidential meeting in Brasilia, DF. In 2004, in the 6th meeting of the initiative, 31 priority projects were selected to be implemented by 2010 (Prado et al. 2006).

Although not selected as a priority, the development of the Paraguay River waterway is one of the integration options for countries in Mercosul. The water would aim to promote the transport of soya from Mato Grosso, connecting the region of Cáceres – MT to Nueva Palmira in Uruguay. The project foresees the lowering of the river bed and the straightening of some stretches to promote navigation of large shipment of grains and other products.

The environmental impacts resulting from the eventual implementation of the waterway would be extremely high for the Pantanal. Combined to deforestation of the headwaters, the changes foreseen for the Paraguay River would increase the flow of water in the region, which could lower the ability of the Pantanal to retain water during large natural flooding events. This increase in drainage in the Pantanal is likely to cause the region to remain flooded for less time than normal. In the short-term, activities like cattle ranching would expand to new drier areas. On the other hand, climatic changes foreseen for the region can contribute to worsen the smaller availability of water scenario in the Pantanal, which would have a negative impact in cattle ranching activities in the long-term. According to the prediction from climatic models used by the Intergovernmental Panel for Climate Change (IPCC) a reduction of 25%-50% in volume of water for the Pantanal region is foreseen (Marengo 2007). Thus, the combination of different scenarios (deforestation of the headwaters, implementation of large infrastructure projects, changes in the hydrological system due to climate change) could compromise the natural flooding dynamic in the Pantanal with disastrous effects for biodiversity and the economy of the region. If preventive and mitigation measures are not adopted for the conservation of the region, allied to an effective policy promoting the sustainable development of the UPRB, the continuous conversion of natural habitats will result in the loss of ecosystem services that maintain healthy population of several threatened species of animals, as well as in the loss of economic activities such as cattle ranching and navigation.

Another source of concern for the conservation of the Pantanal in the long-term is the implementation of hydropower and thermoelectric power plants. Currently nine hydropower plants of various sizes exist in the Upper Paraguay River Basin (Girard 2002). An additional of 22 are foreseen for the region, most of which would be located in the drop zones between the high plains and the floodplain. According to the author, the implementation of all the 22 hydropower plants foreseen would triple the generation of energy from hydropower in the region, and the negative impacts would be higher on the flood dynamics than on native habitats. Therefore, a depth analysis over the type, quantity and dimensions proposed for the region is required.

26.2.2 Main needs and opportunities for conservation

The Brazilian environmental legislation, specially the Forest Code (Brasil 1965) and the National System of Protected Areas (Brasil 2000), should provide the necessary basis for the protection of the Pantanal. The Forest Code emphasizes the need to maintain two types of elements: areas for permanent preservation (or APP) and legal reserves, corresponding to a 20% (minimum) of natural vegetation that must be left in any rural property in Brazil. The APPs includes all riparian vegetation, headstreams, altitudes above 1,800 meters, top of hills, and in areas with more than 45° of declivity. Especially on the case of riparian vegetation, the Law states that a range of 30 to 500 meters of natural vegetation must be maintained and this measure starts on the "river highest level". Observation and enforcement of this legislation would secure some the main features (i.e. gallery forests and headwaters) that are essential for maintaining this wetland. However, law enforcement alone will not solve the conservation problems of the region. Complementary some specific actions must be put in place in order to minimally ensure the maintenance of wildlife and the conspicuous ecological processes for region. Although Harris et al. (2005) had proposed several measures for the conservation of the region and in a complementary way, we suggest that the consideration of these proposals should be lead by the simple fact that the regions of the high plains and floodplain are intrinsically integrated and must be considered together, we here highlight some specific actions that must be implemented. One of the most important is to increase the protection level of natural vegetation in upper lands, especially on the basins that are also important contributors to the river system (such as upper Paraguay, upper Cuiabá, upper São Lourenço, upper Itiquira and upper Taquari). According to the map generated by our analysis, there area some conservation opportunities on upper Paraguay river (like the Serra do Amolar region), on upper Cuiabá (like some areas surrounding Chapada dos Guimarães National Park) and in upper São Lourenço. Unfortunately there are few conservation opportunities on Taquari and Itiquira regions, and for these two sitesit is crucial to develop and implement a program to restore degraded areas and contribute to reconnect natural fragments. Other measures that should be taken into consideration are the protection of some pristine areas in the floodplain, specially along the Negro River, near Pantanal Matogrossense National Park, and near Porto Murtinho on southern portion of Pantanal. Besides the adoption of some of these punctual proposals, one key aspect on the Pantanal´s conservation is that the region is composed by floodplain areas and highland areas. Without considering these two naturally integrated regions, any planning process will fail as the natural dynamic of the region will not be protected.

Some governmental actions, from the executive and legislative government arms, have disregarded this fundamental aspect. Three examples are described here. In 2006, a proposition for a new legislation, presented by the state deputy Pedro Teruel, bans deforestation in the Pantanal floodplain. This measure was a response to the increasing threat caused by conversion of native vegetation for charcoal production to fuel pig iron plants in Corumbá region. Although this can be considered an interesting measure, the initiative does not include important regions surrounding the floodplain that are responsible for maintaining the flood pulse, a concept proposed by W.J. Junk and collaborators (JUNK et al. 1989).

Another measure recently adopted by the Ministry for the Environment and Agriculture, equally geared towards the conservation of the Pantanal, and has been the prohibition of sugar cane plantations in the Pantanal floodplain. The mechanism for such restriction was the development of an ecological and economical zoning model, also partial in scope as it does not include the high plains in the surrounds of the region. If adopted, the measure will protect only the floodplain and will allow the expansion of biofuels affecting the Pantanal headwaters. As the edaphic conditions and the periodic flooding of the low plain are a natural inhibitor to sugar cane plantations in the flooding areas, we recommend that the zoning must be carried out encompassing the whole UPRB. In fact, a study carried out by the University of Campinas aiming to identify priority areas for the expansion of biofuels in Brazil has excluded all the Pantanal floodplain, although at least four regions were indicated in the high plains as important for sugar-cane plantations (LEITE et al. 2006). An analysis cross referencing important areas for the expansion of biofuels with priority areas for biodiversity conservation identifies a 40% overlap, suggesting that these could be impacted by expansion of sugar-cane plantations (MACHADO et al. 2006). With the increasing demand of biofuels due to international policies aiming to reduce greenhouse emissions, sustainability criteria (ROYAL SOCIETY 2008) need to be adopted to guarantee that the ecological and economical zoning of the region and incentives to certify the product could ally the development of the region and biodiversity conservation.

Finally, another example of an action that disregards the importance to integrate high plains and floodplain is the proposition to transform the Pantanal floodplain in an independent federal territory. This legislative proposition was made by the deputy Fernando Gabeira (Legislative decree No. 1.027/2003), who argued that the current Pantanal management action divided amongst two states (Mato Grosso and Mato Grosso do Sul) does not promote the conservation of the region and based on this view, the solution would be the creation of a single administrative unit led by the federal government. Independently of what should be the best administrative model for the Pantanal, led by a single federal government or split into two state governments, any policy aiming to guarantee the maintenance of the Pantanal will fail if the surrounding high plains are not considered.

26.3 Conclusions

The increase fragmentation of the Pantanal is of great concern, especially in the headwaters of the Paraguay River and its tributaries. In addition to the unplanned and excessive occupation in the high plains, large infrastructure projects and the lack of specific policies for the area represent an additional threat to the region. These two situations combined can compromise the flood pulse observed seasonally. These problems are likely to be aggravated by the potential future scenarios of water volume reduction due to climate change. Any policy planned for the promotion of rational occupation of the region must consider the floodplain areas as well as the high plains surrounding it. Some areas, however, deserve an especial attention for the implementation of conservation action and rehabilitation of degraded areas, there are the micro-watersheds of the Cuiabá, São Lourenço, Taquari and Miranda Rivers. In our study, these sites appeared as those with largest status of fragmentation and greatest concentration of records of threatened species.

References

Anderson LO, Shimabukuro YE, DeFries R, Morton DC, Espírito Santo FDB, Jasinsky E, Hansen MC, Lima A, Duarte V (2005) Utilização de dados multitemporais do sensor MODIS para o mapeamento da cobertura e uso da terra. In: Instituto Nacional de Pesquisas Espaciais (INPE) Anais XII Simpósio Brasileiro de Sensoriamento Remoto. pp 3443-3450

Baillie JEM, Bennun LA, Brooks TM, Butchart SHM, Chanson JS, Cokeliss Z, Hilton-Taylor C, Hoffmann M, Mace G, Mainka SA, Pollock CM, Rodrigues ASL, Stattersfield AJ, Stuart SN (2004) IUCN Red List of Threatened Species – a global species assessment. The IUCN Species Survival Commission, Cambridge, United Kingdom, 191 pp.

Brasil (1965) Lei 4.771 de 15 de setembro de 1965 - institui o novo Código Florestal Brasileiro. Diário Oficial.

Brasil (2000) Sistema Nacional de Unidades de Conservação da Natureza - SNUC. Lei 9.985 de 18 de julho de 2000.

Carvalho AP, Hübner DB, Figueiredo JC, Amorim PQR (2007) Impactos socioeconômicos e ambientais do complexo minero-siderúrgico de Mato Grosso do Sul – relatório de pesquisa. Escola de Administração de Empresas da Fundação Getúlio Vargas e Conservação Internacional, São Paulo, Brazil, 78 pp

Eastman JR (2006) IDRISI Andes – Guide to GIS and Image Processing. Clark Labs – Clark University, Worcester, United Kingdom, 284 pp

Gaston KJ, Blackburn TM, Goldewijk KK (2003) Habitat conversion and global avian biodiversity loss. Proceedings of the Royal Society of London, Series B: Biological Sciences 270:1293-1300

Girard P (2002) Efeito cumulativo das barragens no Pantanal. Instituto Centro Vida, Campo Grande – MS. Relatório Técnico não publicado, Campo Grande, Brazil, 28 pp

Godoy JM, Padovani CR, Guimarães RD, Pereira JCA, Vieira LM, Carvalho ZL, Galdino S (2002) Evaluation of the Siltation of River Taquari, Pantanal, Brazil, through ^{210}Pb Geochronology of Floodplain Lake Sediments. Journal of the Brazilian Chemical Society 13:71-77

Hamilton SK, Sippel SJ, Melack JM (1995) Inundations Patterns in the Pantanal wetland of South America determined from passive macrowave Remote Sensing. Hydrologie 137:1-23

Hamilton SK, Sippel SJ, Melack JM (2002) Comparison of inundation patterns among major South American floodplains. Journal of Geophysical Research 107:2-14

Harris MB, Arcangelo C, Pinto E, Camargo G, Ramos Neto MB, Silva SM (2006) Estimativa de perda de cobertura vegetal original na Bacia do Alto Paraguai e Pantanal brasileiro: ameaças e perspectivas. Natureza & Conservação 4:50-66

Harris MB, Tomas WM, Mourão G, Silva CJ, Guimarães E, Sonoda F, Fachim E (2005) Desafios para proteger o Pantanal brasileiro: ameaças e iniciativas em conservação. Megadiversidade 1:156-164

IBGE (Instituto Brasileiro de Geografia e Estatística) (2007) Produção da extração vegetal e da silvicultura 2006. IBGE-SIDRA – Base de Dados Agregados. Available at http://www.sidra.ibge.gov.br/

IUCN (2006) IUCN Red List of Threatened Species. Online publication: http://www.redlist.org (acessed 10th April 2006)

Junk, WJ, Bayley PB, Sparks, RE (1989) The flood-pulse concept in river –floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences, 106:110– 127

Laurance WF, Bierregaard JR RO (1997) Tropical Forest Remnants: ecology, management, and conservation of fragmented communities. The University of Chicago Press, Chicago, USA, 616 pp

Leite RCC, Leal MRLV, Cortez LAB (2006) Present Situation and Perspectives on Bioethanol in Brazil. I Seminário Fundação Brasileira para o Desenvolvimento Sustentável, Rio de Janeiro, RJ. pp 11-18

Machado RB, Paglia AP, Fonseca RL (2006) Áreas e paisagens prioritárias no Cerrado, Pantanal e Amazônia. I Seminário Fundação Brasileira para o Desenvolvimento Sustentável, Rio de Janeiro, RJ. pp 19-30

Mantovani ACM, Amaral S (1998) Avaliação preliminar da utilização de imagens AVHRR/NOAA na detecção de desmatamento no Pantanal. Pesquisa Agropecuária Brasileira 33 v. Especial: 1683-1690

Marengo JA (2007) Mudanças climáticas globais e seus efeitos sobre a biodiversidade – caracterização do clima atual e definição das alterações climáticas para o território brasileiro ao longo do século XXI. Biodiversidade 26:1-212

Margules CR, Pressey RL (2000) Systematic conservation planning. Nature 405:243-253

Mather PM (1987) Computer processing of remotely-sensed images. John Wiley & Sons, New York, USA, 284 pp

McGarigal K, Marks BJ (1994) Fragstats – spatial pattern analysis program for quantifying landscape strucuture – Version 2. Oregon State University, Oregon, USA, 134 pp

MMA (Ministério do Meio Ambiente) (2002) Biodiversidade brasileira: avaliação e identificação de áreas e ações prioritárias para conservação, utilização sustentável e repartição de benefícios da biodiversidade brasileira. MMA, Brasília, DF, Brazil, 404 pp

MMA (Ministério do Meio Ambiente) (2003) Lista das espécies da fauna brasileira ameaçada de extinção. Instrução Normativa no. 3 de 27th Mai 2003. MMA, Brasília, DF, Brazil

Morton DC, DeFries RS, Shimabukuro Y, Anderson LO, Arai E, Espírito Santo FDB, Freitas R, Morisette J (2006) Cropland expansion changes deforestation dynamics in the Southern Brazilian Amazon. Proceedings of the National Academy of Sciences 103:14637-14641

Mourão G, Coutinho M, Mauro RA, Tomas WA, Magnusson WE (2002) Levantamentos aéreos de espécies introduzidas no Pantanal: porcos ferais (porco monteiro), gado bovino e búfalos. Embrapa Pantanal, Corumbá, MS. Boletim de Pesquisa e Desenvolvimento 28:1-22

Myers N (1986) Tropical deforestation and a mega-extinction spasm. In: Soulé ME (ed) Conservation Biology: the science of scarcity and diversity. Ginauer Associates Inc. Publishers, Sunderland, United Kingdom, pp 349-409

Neves FAM, Santos AC (2008) Nem tudo são flores no Pantanal. Ciência Hoje 41:71-73.

Padovani CR, Cruz MLL, Padovani SLG (2004) Desmatamento do Pantanal Brasileiro para o ano 2000. IV Simpósio sobre Recursos Naturais e Socioeconômicos do Pantanal. pp X-*Y*

Prado PGP, Prado A, Freire I, Oliveira A, Passos F (2006) Projetos de infra-estrutura no Brasil e América do Sul – Relatório sobre a agenda de implementação consensual 2005-2010 da IIRSA e os projetos de infra-estrutura do Governo Brasileiro. Conservação Internacional, Brasília, DF, Brazil, 49 pp

Prance GT, Schaller GB (1982) Preliminary study of some vegetation type of the Pantanal, Mato Grosso, Brazil. Brittonia 34:228-251

Pressey RL, Humphries CJ, Margules CR, Vane-Wright RI, Williams PH (1993) Beyond opportunism – key principles for systematic reserve selection. Trends in Ecology & Evolution 8:124-128

Pressey RL, Taffs KH (2001) Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. Biological Conservation 100:355-376

Rempel R (2006) Patch Analyst 3.0. Centre for Northern Forest Ecosystem Research, Lakehead University Campus, Ontario, Canada [http://flash.lakeheadu.ca/~rrempel/patch/]

Royal Society (2008) Sustainable Biofuels: Prospects and Challenges. RS Policy Document, London United Kingdom, 90 pp

Saunders DA, Hobbs RJ, Margules CR (1991) Biological consequences of ecosystem fragmentation: a review. Conservation Biology 5:18-32

Silva JSV, Abdon MM, Silva MP, Romero HR (1998) Levantamento do desmatamento no Pantanal até 1990/91. Pesquisa Agropecuária Brasileira 33: 1739-1745

Wilcox R (1992) Cattle and Environment in the Pantanal of Mato Grosso, Brazil, 1870-1970. Agricultural History 66(2): 232-256