System changes in the Pantanal (Brazil): lessons for wetland management

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Abstract

The Pantanal is a wetland of 245.000 km^2 in Brazil, Bolivia and Paraguay; it is a wet savannah with several larger river systems. It is a World Natural Heritage Site because of the diversity in fauna and flora. There is cattle breeding area since 200 years and it is an important area for tourism (fish and ecotourism).

There are changes occurring in rivers and savannahs in parts of the Pantanal, especially in the Rio Taquari catchment, with impact on fish populations and biodiversity. The process has also economic consequences. The question is then, what mitigating measures should be taken and in which context. The changes in the natural river process of erosion discharge and sedimentation are taking place in interaction with land use changes in the Planalto. This has an impact on the biodiversity, fish populations and the economy. A choice has to be made between short term repair for valid economic reasons or long term wetland management to secure the future of this important wetland. In that context one of the major questions is if this process is also affecting other rivers in the Pantanal.

Introduction

Land and water are dynamic. That becomes especially clear in wetland areas, where the interaction between water and land can be strong. Wetlands and the Pantanal ecosystem particularly deliver various services for society. Benefiting parties vary from local to international stakeholders. Loss of services as happened in the Taquari river system causes ecological change and societal damage. The causes of loss or gain can be natural or human. In this paper we will discuss the changes in ecosystem services of the Pantanal due to internal and external changes. The changes that are occurring in the Rio Taquari catchment has especially impact on fish populations and biodiversity. These changes can have a natural cause, but can also be caused by humans or a combination of both. An additional important question is if the process also occurs in other rivers in the Pantanal.

Although wetlands are a common landscape feature across all continents, there is an uneven distribution in specific types (see Wood and Van Halsema, 2008). Tropical wetlands as the Pantanal are rare and highly diverse. They are dynamic and its constituting elements can be stable, but also show chaotic behaviour changing between several equilibriums.

The Pantanal is the largest complex of savannah wetlands in the world and it is part of the Upper Paraguay River Basin (Fig. 1, UPRB). The UPRB comprises an area of 496,000km2, being 396,800km2 within the Brazilian borders and the remaining section in Bolivia and Paraguay (99,200km^2). The Brazilian section of UPBR can be divided into two main areas: floodplains or Pantanal and high plateaux or Planalto. The Pantanal is made up of large rivers, alluvial fans, lagoons, fossil dunes and isolated salt pans; it is a unique ecosystem with a very high biodiversity, which is seriously threatened (Alho et al., 1988, Lourival et al, 2009). It is a declared UNESCO World Natural Heritage Site. All three countries protect discontinuous areas as national parks and biosphere reserves. In Brazil most of the region is in private ownership and has the status of Biosphere reserve.

The Taquari River is a tributary of the Paraguay River. The lower reach of the Taquari runs through the Pantanal wetlands. The economy of the catchment is based cattle farming, professional fisheries, sport fisheries and ecotourism. At present nearly permanent inundation of an area of about 11,000km2 occurs in the sub-region of Paiaguás. Natural river processes, recent erosion in the Planalto and silting up in the Pantanal makes the river Taquari into an unstable dynamic system with economic and ecological impacts due to increasing flooding.

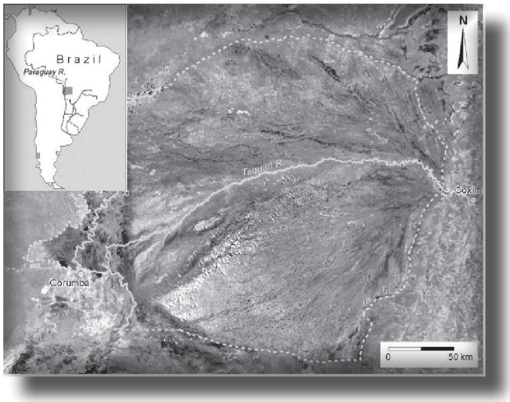

Fig. 1. Location of the Pantanal

Ecosystem functioning in the Pantanal

Climate in the Pantanal is tropical humid, with spatially variable yearly precipitation in the area roughly ranging from 1100 to 1800 mm (Galdino et al, 1997). Rainfall is markedly seasonal: December and January are the wettest months with average monthly precipitation well over 200mm in most of the area, whereas July and August are dry with average monthly precipitation mostly below 30mm. Temperatures are much less variable over the year. Average daily maximum temperatures are between 30 and 35° C all year round. Only during the dry season (June-August), average daily minimum temperatures drop slightly below 20°. The discharge of the Taquari is highly seasonal with mean peak discharge ~1100 m^3/s (Collischon et al., 2001).

The Taquari has built a huge megafan with a maximum radius of 250 km and an area of 49,000 km^2 (Makaske et al, 2010). It is a dynamic natural system with seasonal flooding. The rivers naturally form their bed through this flooding process, erosion, sedimentation and making new avulsions.

Since the 1970s there is an increase of the erosion rate in the high Taquari River basin (Oliveira et al., 1997). Deforestation and inadequate soil management for cattle ranching and some crop plantations are thought to be the causes (Godoy et al., 2002). The sedimentation in the main Taquari channel decreased the water transport capacity causing increasingly flood events in the flood season. In the upper part of the fan, floods from the Taquari only influence a restricted area because the river meanders in an incised bed bordered by terraces.

Downstream, in the recent distributary cone the marginal terraces disappear and the Taquari changed into a river with a distributary pattern. In this area there is a significant loss of water to the side floodplains. Galdino et al. (1997) showed that the water loss of the Taquari River to the floodplain is the cause of the foods in the recent distributary cone. The water of the Taquari looses energy when it spreads over the floodplain and the suspended sediments are deposited. This process of dissipation of the water flow loaded with sediments, forming avulsion complexes can be observed with satellite imagery (Assine, 2003, Makaske et al., 2010).

The Taquari water level is directly related to the rain in its drainage basin as a fast response way. However, between the Paraguay River peak flow and the peaks of rain and of the Taquari River, usually a time lag of some months can be observed. The floods of the Paraguay River influence the floods of the lower Taquari cone, making it longer and increasing the height of the floods. The Taquari flood wave that starts in December at the lower Taquari extends until April due to the rising water of the Paraguay River that blocks the Taquari waters, working like a dam (Hamilton, et al., 1995, Galdino et al., 1997).

The hydrograph of the Paraguay River at Ladário near the area where the Taquari merges with the Paraguay, shows that the water levels increased from 1974 to present, after the dry period of 1963 to 1973 and that the water levels before 1963 were lower than at present, suggesting the influence of climatic change in the floods of the lower Taquari cone (Soriano et al., 2001).

The aquatic system

The hypothesis, on which the ecosystem dynamics in tropical wetlands is based, is the Flood Pulse Concept. The Flood Pulse Concept (Junk et al 1989) states that the pulsing of the river discharge extending the river into the floodplain is the major force controlling biota in rivers with floodplains. The flood pulses control biota in three ways: directly by (1) facilitating migration of animals, indirectly by (2) enhancing primary production in the floodplain and by (3) habitat structuring. The floodplains provide important factors for driving ecological processes in the riverine ecosystem. During floods biota migrate both actively and passively between different habitats in the river floodplain system, where they feed (Wantzen et al 2001). The lateral exchanges between main channel and floodplain have an important impact on the biomass of the river system described in the River Continuum Concept. Fish move along their corridor in different speed and with different steps. The strong interaction between the river and the riparian ecosystems in its ecotone provide a huge exchange of energy, matter and nutrients. Networks of river corridors maintain the genetic exchange between populations.

In the Pantanal two different types of migrating species exist (Kawakami de Resende 2003, Box 1). Longitudinal migrating fish move upstream and downstream the river. They breed in the small rivers of the Planalto and feed downstream, in the rivers and floodplains in the period February to July. When the water level decreases in August/September they return to the river channel and if they are adult they swim upstream for spawning. Longitudinal migrating fish can swim 400 – 600 km. Network dispersion distances for most fishes are estimated at 2–3 km.

However, data on migration and the duration of stay are not known yet. These are important parameters for estimating population dynamics and reaction on the pattern changes. The aquatic ecosystem in the Pantanal is complex and there are many relations between species groups in different stages (Fig. 2).

Lateral migrating fish have their pathway from the river to the floodplains. During February to April they spawn eggs and larvae in the floodplain. In the dry season they go to the river.
It is not only the fish groups that are diverse; this also valid for the aquatic habitats that they use (Table 1). The most important habitat characteristics are water depth, flow velocity and the periodicity of the habitat. Baía is a shallow lake; the Vazante and Corixo are different temporary water streams.

Changes in fish population

From 1979 to 1983 the amount of fish caught in Taquari river basin ranged from 300 – 620 ton per year according to EMBRAPA data. Since 1994 fish catch was less than 100 ton per year and is now about 7% of the catches in 1980 and 5-6% of catches in the whole Pantanal in Mato Grosso do Sul, although it is the largest river (Tab. 2).

Before 1960 the floodplains became dry in the dry period and flooded during the wet season. With this flooding nutrients are introduced into the floodplain grasslands and forests, the feeding ground of small plant eating and detritivorous fish.

Due to sedimentation there is now a lack of flood pulse in the Taquari river basin, the river

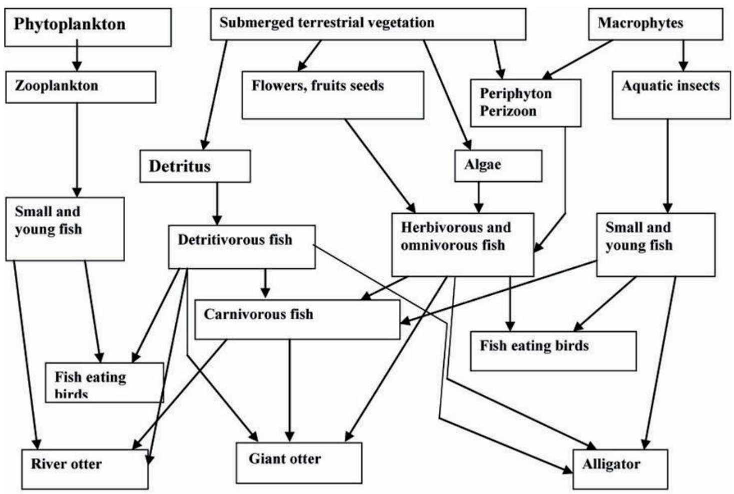

Fig. 2. Food network in the Pantanal wetlands (E. Kawakami de Resende)

macrophytes and a decline in nutrients and the amount of detritus in the floodplain. The number of detritivorous fish has strongly declined as did the number of fish feeding on fruit, flowers and plants.

Box 1

Longitudinal migratory piscivorous fish

Key species: Pintado; Group: Cachara, Dourado, Jau, Barbado, Jurupoca, Jurupesen. They feed on fish and migrate between the Planalto where they reproduce and the floodplains. In the Pantanal they forage in every water body that is connected to the river.

Longitudinal migratory omnivorous fish

Key species: Pacu, *Piaractus mesopotamicus*; Group: Pitaputanga

This group also migrates upstream to the Planalto for reproduction and downstream to the floodplain for feeding. They feed on animals, (especially) fruit, seeds, flowers and insects from the riparian vegetation and flooded pioneer and Cerrado vegetation.

Longitudinal migratory detritivorous fish

Key species: Curimbata, *Prochilodus lineatus*; Group: *Potamorhina squamoralevis*. This longitudinal migrating group feeds on detritus (decomposed organic matter), periphyton and perizoon coming from the temporary flooded terrestrial vegetation. The optimal habitat is in slow flowing shallow flooded vegetation (water depth < 1 m).

Floodplain spawners piscivorous fish

Key species: Piranha, *Pygocentrus nattereri*; Group: Dourado cachorro, Traira, Serrasalmus marginatus, Serrasalmus spilopleura, Pygocentrus natterei, Roeboides paranensis, Roeboides prognathus, Charax gibbosus, Acestrorhynchus pantaneiro, Hoplias malabaricus The floodplain spawners lay their eggs and larves in the floodplain. In the dry season they stay in lakes and some of them go to the main river channel.

Floodplain spawners detritivorous fish

Key species: Sairu, family Curimatidae; Group: Curimatopsis myersi, Curimatella dorsalis, Psectrogaster curviventris, Cyphocharox gillii. The group feeds on detritus and the optimal habitat is the connected lakes, oxbow lakes, corixos and flooded Savanna gramineo lenhosa.

Sedimentation also causes shifts in the corixos, the side channels and in the main river channel, which might result in barriers for migrating fishes. The restriction in movements has a direct impact on the breeding success and survival of young fish. This is expressed in the decline of catches in the river, as an important product both for professional fishing, but even more for sports fishing (Tab.2).

Tab. 1. Characteristics of water biotopes that are important fish habitat parameters

	Velocity of water flow	Water depth	Aquatic habitat	Vegetation
River/Rio	Fast	Deep	Permanent	+/-
Linked Baìa	Fast	Shallow	Permanent	+/-
Oxbow	Standing	Deep	Permanent	+
Isolated Baìa	Standing	Shallow	Permanent	+/-
Vazante	Moderate	Shallow	seasonal	+
Corixo	Moderate	Shallow/medium	seasonal	+
Flooded riparian vegetation	Moderate to standing	Shallow	seasonal	+
Grass savannah	Moderate to standing	Shallow	seasonal	+

Tab. 2. Fish catches in kg (period 1995-2000) in the Rio Taquari and totals of the Rio Miranda and Mato Grosso do Sul. The year 2000 was a year with low catches in nearly all rivers (Catella et al, 1998, 2002a, 2002b, Catella and Fernandes de Albuquerque 2000a, 2000b, Lopes de Ramires Campos et al 2000)

Year	Rio Taquari Professional catches (kg)	Rio Taquari Sport fishing catches (kg)	Rio Taquari total (kg)	Rio Miranda total (kg)	Mato grosso do Sul total (kg)
1995	5.254	61.817	67.071	251.848	1.269.431
1996	1.733	48.780	50.513	348.268	1.225.049
1997	13.448	45.632	59.080	363.913	1.453.383
1998	17.902	59.025	76.927	411.117	1.429.653
1999	11.539	67.471	78.010	375.128	1.411.478
2000	4.204	43.887	48.091	179.451	795.987

Causes and consequences of changes in wetlands

It has been concluded from measurements in the last decades that increase in sediment delivery from the Taquari catchment has caused increased aggradation in the river bed. Godoy et al. (2002) already reported increase of sedimentation in Taquari oxbow lakes on the upper fan around 1980. This increase runs parallel with a decrease in the natural vegetation cover in the Planalto from 96.2 % in 1977 to 42.5 % in 1991 (Godoy et al., 2002). In 1991 42.6% of the Planalto was grassland and 12.2% annual crops. In the early 1970s an increase of powerful overbank floods occurred due to a significant regional increase in precipitation from 1059 mm/yr annually in the period from 1960-61 to 1972-73, to 1347 mm/yr annually in the period from 1973-74 to 1992-93 (Galdino et al., 1997).

We conclude that critical conditions for an avulsion reached already during the relatively dry 1960s when the channel belt became substantially higher than the fan surface. This did not cause flooding, because of the low discharge and sandy bedload was stored in the channel. The sharp rise of Taquari peak flows in the early 1970s initially led to restoration of channel capacity by flushing out sandy bedload and speeding up levee construction. At the same time bank erosion increased leading to crevassing and finally to avulsion. A potential increase in sediment delivery from the Taquari catchment since ca. 1980 (Godoy et al., 2002), predominantly concerns fine suspended load in a first phase probably followed later by a pulse of coarse bedload (Makaske et al., 2010).

Conclusion

The changes that took place in the last decades in the Taquari river were result of an interaction of man induced changes and natural river processes. The impact of avulsions and the flooding on the Pantanal ecosystem can favourable for the river and wetland system as a whole, because it creates landscape diversity and rejuvenate physical parts of the ecosystem.

However, at present it also causes a decline of biodiversity and fish populations. This can be temporarily if the land management in the river catchment at the Planalto, where cattle breeding and arable crops have been introduced, is carried out in such a way that it is causing a decrease in sedimentation and restoration of the natural savannah regime on the longer run. It also is now an economic disaster for the people living in the Pantanal as their economic basis is disappearing. They cannot survive economically in geological cycles. This brings pressure on state and federal authorities to repair the changes and introduce river management in the Pantanal for short term success. This is the major threat for the long term survival of the wetland ecosystem of the Pantanal, especially if also other rivers might be affected by increased bedload and be threatened to collapse as well.

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