Environmental accounting of natural capital and ecosystem services for the Aquidauana River, Southern Pantanal, Brazil

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ABSTRACT

The main objective of this work is to evaluate the natural capital and ecosystem services of the Aquidauana River and the role of the Giant otter (*Pteronura brasiliensis*) as a flag species to change adverse realities, based on system ecology and emergy synthesis. First, a system diagram was constructed to organize the thinking and the relationships between components and pathways of exchange and resource flow. The second step was to construct the emergy synthesis tables of flows directly from the diagrams. Finally, emergy indices were calculated in order to summarize and relate emergy flows of the economy with those of the environment. Quantities of stored emergy of environmental resources are calculated from the sum of the emergy of all inputs, and then multiplied them by the time it takes to accumulate the storage. To calculate the emergy of economic storages, all inputs of energy, materials, and labor to produce them were summed. For the evaluation of renewable inputs to the Aquidauana River, solar energy, rainfall, runoff, river geopotential, transport of phosphorous, and wind annual averages were used. Main services with market values provided by the Aquidauana River are information, water supply, tourism, and fish harvest.

Keywords: Emergy; System Ecology; Giant otter; Economic Evaluation

1. INTRODUCTION

The main objective of this work is to evaluate the natural capital and ecosystem services of the Aquidauana River and the role of the Giant otter (*Pteronura brasiliensis*) as a flag species to change adverse realities, based on system ecology and emergy synthesis. The application of emergy synthesis (Odum, 1983; 1996) aims to evaluate natural capital and environmental services, including economic costs and benefits, and societal and environmental non-market assets and values at the Aquidauana River.

Emergy represents the available energy required to make a product or service, and its unit is the emjoule. It also measures the work to produce goods and services, expressed in emdollars (UNEP, 2012). It is used to evaluate Aquidauana River processes related to geological, hydrologic, ecological, and economic components. Major inputs from the human economy and from the environment are integrated applying emergy methods to approach public policy and environmental management.

Emergy analysis is also used to establish values for endangered species such as the Giant otter, on a common baseline. The emdollars are defined for each item of the system as a measure of the money that circulates in the local economy as a result of the flow of emergy. It is calculated by first determining the emergy of the flow and then converting to emdollars using a standard conversion factor.

At the end of the project, we hope to provide sound scientific knowledge about the Pantanal that will lead to a better understanding of the role of the Aquidauana River in a sustainable partnership of community and nature, facilitating interdisciplinary research wetland-related resource management issues. The otter is analyzed within this context, as a flag species to change adverse realities.

The Giant otter's home ranges can vary from 8 km in Equador (Utreras, 2005) to 32 km in Guiana (Laidler, 1984). Evangelista and Rosas (2011) in a study in Xixuaú Reserve (Roraima, Brazil) found home range varying from 4.6 to 10.4 km. These data consider only the linear distance along the river. In the Brazilian wetland, Pantanal, a surveyed conducted from 2000 to 2011 revealed that Giant otter's groups are distributed in linear territories that range from 5.1 to 26 km (Tomas et al, 2015). In the Pantanal of MS, Brazil, the Aquidauana river stands out as a region where Giant otter populations can be more easily observed and studied in the wild. For example, Thomas et al (2000) observed ninety individuals in a study conducted in Aquidauana and Miranda rivers, with an average of one group per 11 km of river.

The Giant otter was common in almost all tropical and subtropical Brazilian rivers. Currently, its presence is restricted to isolated areas of Brazil, Peru, and Guyana (Groenendijk et al, 2005). The Giant otter is a species considered endangered by the Convention on International Trade in Endangered

Species of Wild Fauna and Flora (CITES) (of which Brazil is a signatory), the US Endangered Species Act (USESA), and also by the International Union for Conservation of Nature (IUCN). In Brazil, the species used to have a wide distribution, from the Rio Grande do Sul to the Amazon (Reis et al, 2006). Currently, it is believed that the species is extinct in Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Santa Catarina, and the Rio Grande do Sul. Therefore, its conservation status is critical and must be addressed transparently, through education and social mobilization, so that the situation can be reversed.

1.1 The Study Area - Aquidauana City and Aquidauana River.

Aquidauana has a population of about 45.000 inhabitants, with a density of 2,65 density inhabitants/Km^2, covering an area of 16.958.496 square kilometers (IBGE, 2010). Figure 1 shows the urban area of Aquidauana and part of the river from a Sino-Brazilian satellite image of Earth Resources (CBERS), of July 30, 2008, courtesy of the National Institute for Space Research (INPE).

Figure 1. The study area, Aquidauana City on the top, Anastácio city below, and the Aquidauana river crossing both cities.

Main services with market values provided by the Aquidauna River system are research, water supply, and fish harvest. The main economic activities are related to fishing, agriculture and cattle farms. However, these activities are not in balance. About 10.000 hectares are used for agriculture. On the other hand, livestock occupies an area of nearly 1 million ha of native pasture. The Gross Domestic Product (GDP) of Aquidauana is R$ 398.906,580 ($127.891,56) resulting in a per capita GDP of R$ 8.622,02 ($2.764,27) (IBGE, 2010) and a Human Development Index (HDI) average of 0,757 (UNDP, 2011).

The Aquidauana River has it source in the mountain range of Maracaju and meanders slowly north-westward for 1.200 km to the Miranda River. It is part of the Paraguay's watershed that drains an area of 1,1 million of km^2

including not only the Brazilian states of Mato Grosso and Mato Grosso do Sul, but also Argentina, Paraguay, and Bolivia. It belongs to the Pantanal wetland and it is under influence of the monomodal flood pulse (Junk et al 2006) (Figure 2).

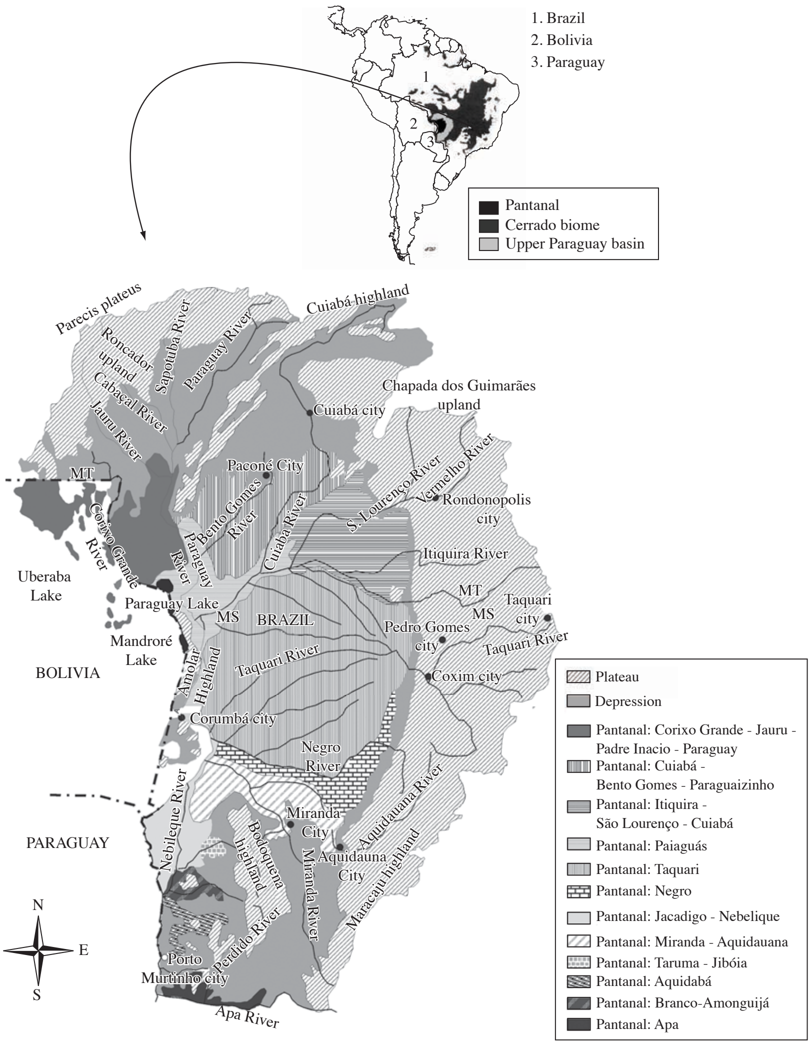

Figure 2. Map of the water shed of Pantanal, Brasil. Data source: Alho (2008).

The Brazilian Pantanal corresponds to an area of 140.000 km^2. The Aquidauana river belongs to the Miranda basin that shows an area of 35.000 km^2. The region receives an insolation of 6,57x10^9 J/m^2/yr (Atlas Solarimétrico do Brasil, 2000) with an annual average temperature of 25,4^{o}C and total annual precipitation of 1.175,00 mm (Soriano and Galdino, 2002). The annual average wind speed is 5,04 m/s (Amarante et al 2001). The annual water discharge of the Aquidauana River is 3.110,16 cfs.

The history of fishing in the Aquidauana River is marked by conflicts of interests and a strong decrease of capture over the last 18 years. There are two types of main fishing groups active in the area: professional and amateur. The last census shows that there are 74 professional and 578 amateur fishermen registered to the Aquidauana River (Catella et al, 2014). The total fish catch is quite different between the two groups. In 2013, total fish captured by professional fishermen was 6.840 kg while the total from the amateur group was 3.710 kg. Total capture from the amateur group has been consistently higher since 2007. However, in general, the total fish captured for both groups decreased substantially from 1997 to 2013 (Figure 3).

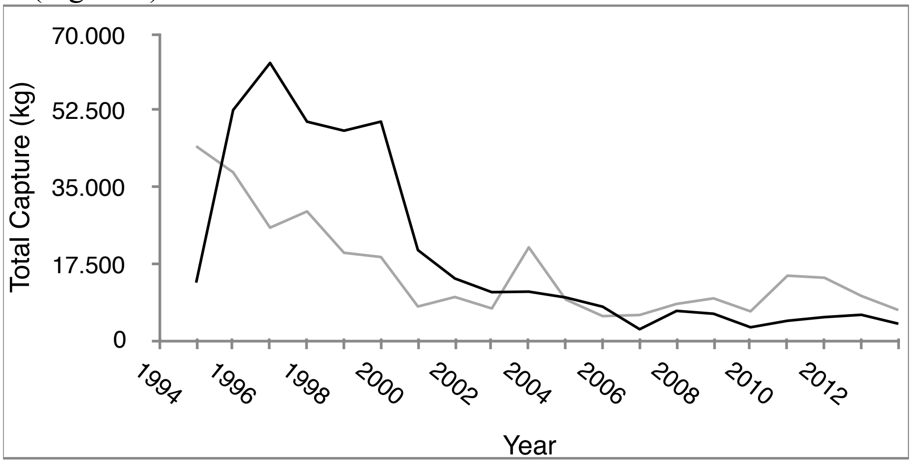

Figure 3. The professional (bold line) and amateur (grey line) fishing trend in the Aquidauana River from 1994 to 2013. Data source: Catella et al, 2013.

This decrease in fishing can be associated to the loss of flooding area since 1998, resulting in a decreasing on the average depth of the Aquidauana River to 4,44 m, therefore reducing available habitat for fish (Catella et al, 2014). This situation affected the tourism of the region as the number of amateur fishermen also decreased with the fish. However, not only natural causes affect the fishing in the Aquidauana River. From 1994 up to the present several public policies were implemented such as the control of fish catch, prohibition of certain types of fishing gear, definition of a closed fishing period, and the increase of minimum size of capture for some species.

Apart from fish, biodiversity data for Aquidauana River area is scarce. Available data indicate that 263 fish species can be found in the Pantanal (Britiski et al, 1999). A total of 41 anuran species (frogs and toads) and 24 reptile species (one turtle, seven lizards, fifteen snakes and one caiman) were recorded so far (Junk et al, 2006). The Pantanal as a whole (210.000 km^2) present 152 species of mammals (Tomas et al, 2010), 44 species of amphibians and 127 of reptiles (Strussmann et al, 2011).

In this research, the river stretch of approximately 120 km long was sampled, starting upstream of the Aquidauana and Anastacio cities, and ending downstream near a place called Fazenda São José (Figura 4). Several dredges perform commercial extraction of riverbed sand in areas close to cities. There are several cattle farms and animals that often have access to the river banks. Sewage launch sites can be seen along the river, near the town center. Throughout the study area, can be observed the presence of several condominiums and fishing support structures, focused on fishing tourism activity.

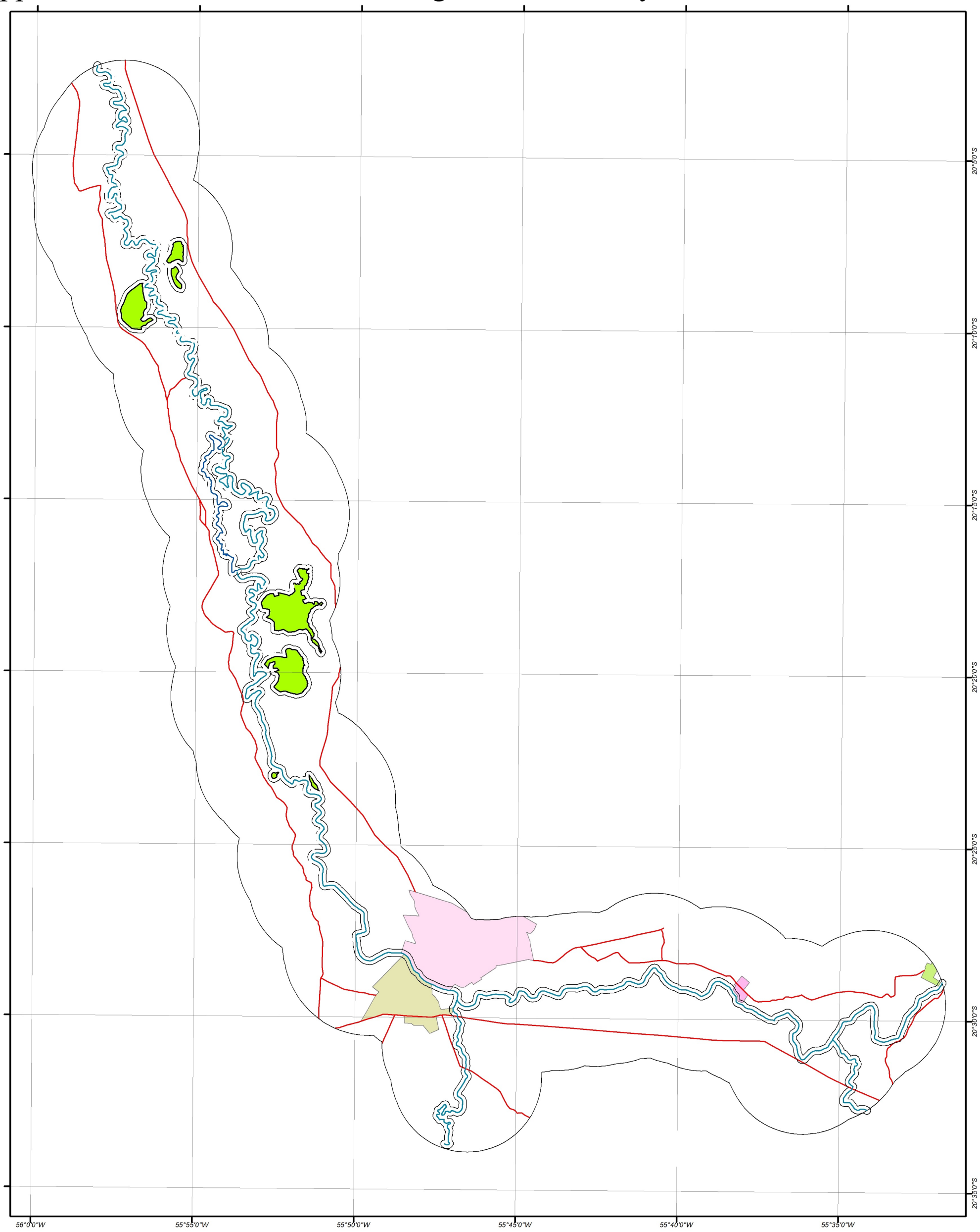

Figure 4. Location of the study area. Preliminary zoning of the Aquidauana River and the buffer zone. Aquidauana city is the pink patch, Anastácio city is grey. Green patches are bays along the river.

Two lagoons located at the right margin of the river (Baia Grande and Baia dos Jacarés, with 5,3 and 3,0 km² respectively) and some oxbow lakes that form small bays along the river were included in the study area. These were selected by the ease of access by water and to represent places frequented by Giant otters.

2. METHODS

In the present work, the emergy of a Giant otter represents the necessary evolution emergy of the species. It includes the natural selection process transmitted through the genetic information. This emergy is the potential environmental work that would be lost if the species go extinct. In order to estimate the emergy, the average turnover time of species (Weir, 2007) is defined as 3 million years and a total number of 10 million species is used (Campbell and Brown, 2012).

The Giant otter's home range taken into account is 2,4 Km^2 based on Utreras (2005), Laidler (1984), Evangelista and Rosas (2011), Tomas et al (2015), and Thomas et al (2000). This viable population home range area comprises 0,000016% of the total distribution area of the species (IUCN, 2015). The emergy of the species is multiplied by these values to obtain an estimate of the emergy embodied in the Giant otter inhabiting the Aquidauana River System (ARS) according to the equation below (Campbell and Brown, 2012).

*Endangered Giant otter = #of species * % of total pop in ARS * emergy required to develop species*

To place the value of the Giant otter in perspective, emergy synthesis of the main storages and ecological processes in the Aquidauana River are calculated. In addition, flows of purchased inputs, goods, fuel, and electricity were also evaluated. This includes the flows of renewable and nonrenewable inputs, purchased inputs and exports from the system.

First, a <u>system diagram</u> was constructed to organize the thinking and the relationships between components and pathways of exchange and resource flow. It is an overview of the system, combining different sources of information and organizing the efforts. The second step was to construct the <u>emergy synthesis tables of flows</u> directly from the diagrams. It accounts for the annual flows of material, energy, and information that support the system.

Finally, <u>emergy indices</u> are calculated in order to summarize and relate emergy flows of the economy with those of the environment. Quantities of stored emergy of environmental resources are calculated from the sum of the emergy of all inputs and then multiplied by the time it takes to accumulate the storage. The required time is estimated from the literature. To calculate the emergy of economic storages, all inputs of energy, materials, and labor to produce them were summed. The objective is to be able to predict the economic and environmental viability.

For the evaluation of renewable inputs to the Aquidauana River, annual averages of solar energy, rainfall, runoff, stream geopotential, wind, and transport of phosphorus in the water column, were used. Transformities and specific emergies are calculated for biodiversity and endangered species. They are calculated by first quantifying all the emergy used in making the product or service, and dividing by the energy of the product or service. The units can be in sej/J if the product is divided by the energy or sej/g if the emergy of the product is divided by the mass. Emdollar is a measure of the money circulating in the economy as a result of the emergy flow. The emdollar is obtained by dividing the total emergy driving the economy by the economy's Gross Domestic Product (GDP).

The Aquidauana River services are based on the energy evaluation, expressed as emergy, and converted to emdollars, in order to compare with economic values such as fish harvest, recreation, and information produced. Socioeconomic data about the municipality were obtained from the IBGE's website (Brazilian Institute of Geography and Statistics) and UNDP (United Nations Development Program). Educational information were obtained from the IDEB - Basic Education Development Index. Analysis of the HDI (Human Development Index) and other financial indicators about Brazil were accessed on the World Bank database.

The analysis of fishing is based on published data from the study area together with interviews and informal meeting with fishermen, owners of hotels, and staff from the local Aquidauana fishermen association. These data are further rearranged and recalculated in order to be able to compare tourist and professional fishing, to a potential wildlife watching. The wildlife watching is focused on the Giant otter as a flag-species.

The economic, social, physical, and biological existent data and information, are organized in a Geographic Information System (GIS) database. Environmental and socioeconomic thematic maps started with the zoning of land-use in a 10 km strip along each side of the Aquidauana River.

An estimated average price of fish from Aquidauana River is based on prices from Ceasa, the main Brazilian fresh food market located in São Paulo. For each fish price, 40% was subtracted in order to get a more realistic value for what is paid to the local fishermen at the Aquidauana River. Main fishes considered for this analysis were the Pacu (*Piaractus mesopotamicus*), Pintado (*Pseudoplatystoma corruscans*), Piranha (*Pigocentrus nattereri*), and Dourado (*Salminus brasiliensis*).

Navigation of the main course of the river was made in medium and small vessels with an outboard of 40hp and 15hp, respectively, at a constant speed of 10-15 km/h. The bays along the river that were not open to the river, were accessed by a small boat equipped with an electric motor. The bay perimeter was covered as slowly as possible (about 3 to 5 km/h), with stops at strategic points (observation points) with variable duration from 1 to 4 hours.

During the samples, individuals and groups of Giant otters, signs of the presence of the species, as latrines, dens, resting areas and marking, were recorded and georeferenced. The method used was the one based on a search for vestiges, and direct observations of Pteronura (Groenendjik et al, 2005). When an animal was sighted, the behavior was recorded, as well as the geographic coordinates and environmental variables. A Bushnell 8x30 binocular with integrated digital camera, and a Sony DCR-SX45 camcorder with 70x optical zoom were used to register the throat spots for the photo-identification of the individual and the group.

The data was organized in Excel and Numbers spreadsheets, and the basic descriptive statistical analyzes were performed by R statistic (R Development Core Team, 2009). The geographical coordinates of the records were plotted on GIS QGIS 2.2 for vector analysis.

3. RESULTS

The results of this analysis for the Giant otter and the Aquidauana River include the emergy synthesis of the main ecological processes. Figure 5 represents the system diagram for the Aquidauana River System in the study area. Components for Aquidauana System are organized as renewable, nonrenewable sources, landscape, the Giant otter, research, and assets. The image represents a key factor in the region, as it is based on tourism. Closely related to the image, surface water, fish, Giant otter, and biodiversity are of paramount importance since most of the touristic attractions are in the river.

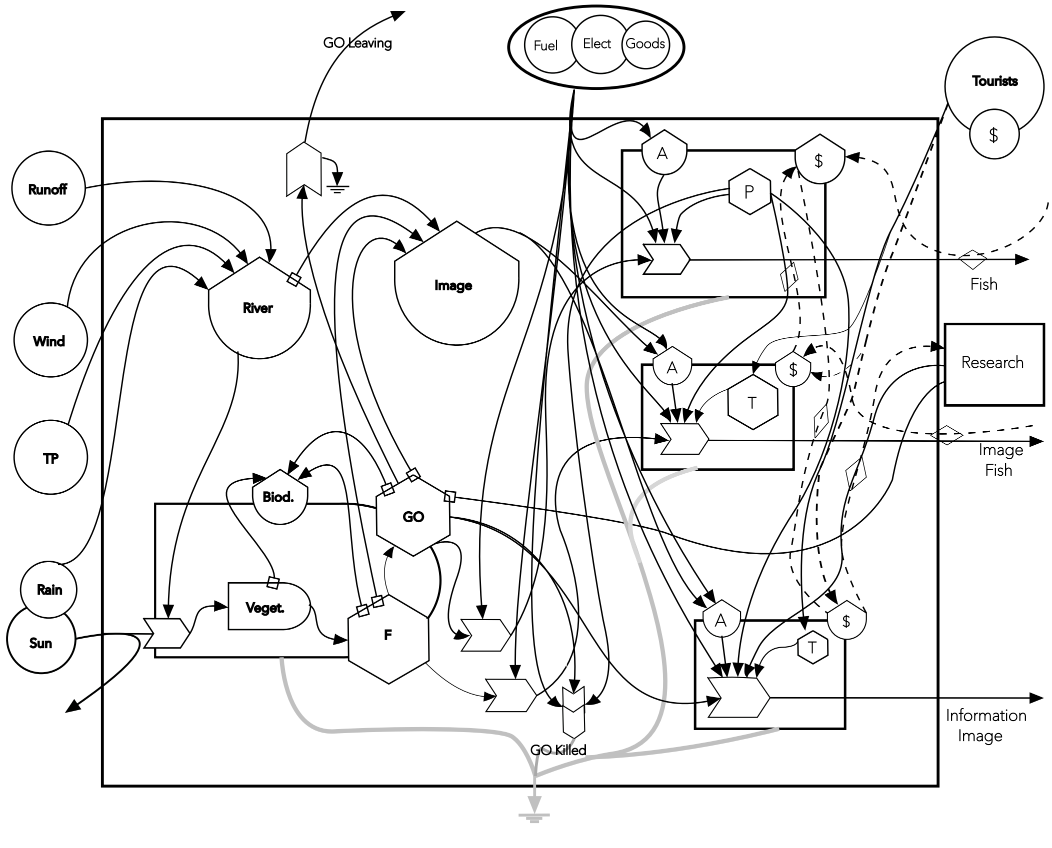

Figure 5. System diagram of the study area, Aquidauana River exhibiting the connections within the ecosystem, professional and touristic fishing, wildlife watching with the Giant otter as a flag species, in providing ecosystem services.

Table 1 summarizes the emergy evaluation of the Aquidauana River, listing the driving energies, monetary inflows and outflows, and exports of the system. Footnotes that detail data, sources, and calculations can be found in Appendix 1. Referring to Table 1, the total renewable emergy is 5,99E+21 seJ year^{-1}, equivalent to ^{em}\$1,8 billion. The total purchased inputs is 1,14E+18 (^{em}\$335 thousand). Electricity for the touristic fishing is 67% of the total inputs.

Table 1. Emergy evaluation of the flows supporting the Aquidauana River.

Note[a]	Item	Quantity	Emergy Intensity (seJ/unit)	Solar Emergy ($x10^{18}$ seJ)	EmDollars (xE6)
Renewable Resources					
1	Sunlight, J	1,92E+20	1,00E+00	191,63	56,36
2	Rain, J	1,93E+17	3,10E+04	5.991,91	1.762,33
3	Wind, J	1,10E+17	2,45E+03	269,88	79,38
4	TP in river, J	5,11E+14	2,00E+06	1.021,47	300,43
5	TP out river, J	1,28E+15	2,00E+06	2.553,66	751,08
6	River, geopotential, J	2,84E+10	1,85E+03	0,00	0,00
7	Runoff, J	1,89E+17	5,19E+01	9,79	2,88
Total renewable				5.991,91	1,76E+03
Purchased Inputs					
9	Goods professional fishing (equipments), g	2,46E+07	1,13E+10	0,28	0,08
10	Goods amateur fishing (equipments), g	1,92E+08	1,13E+10	2,17	0,64
11	Fuel (professional fishermen), J	6,22E+04	1,11E+05	0,00	0,00
12	Fuel (amateur fishermen), J	4,86E+05	1,11E+05	0,00	0,00
13	Electricity professional fishing, J	3,35E+11	2,92E+05	0,10	0,03
14	Electricity amateur fishing, J	2,61E+12	2,92E+05	0,76	0,22
Total Purchased				1,14	0,34
Exports					
15	Information (research), hrs	3,14E+04	2,35E+14	7,38	2.169.948,53
16	Water, chemical potential, J	2,26E+14	8,1E+04	18,27	5.373.113,81
17	Water, geopotential, J	3,13E+14	4,7E+04	14,72	4.329.483,07

18	Surface water supply, J	2,38E+13	8,10E+04	1,93	567.021,92
19	Fishing, professional, J	1,17E+13	1,68E+07	196,18	57.698.996,31
20	Fishing, tourist, J	6,33E+12	1,68E+07	106,40	31.295.586,06
21	Wildlife watching (image exported with tourists), J	3,43E+09	1,50E+07	22,20	6.530.160,00
Total exports				367,08	107.964.309,70

[a] Foot notes to Table 1 can be found in Appendix 1

The emergy value of fishing (professional and touristic) using the natural resources of the Aquidauana River is quite significant, equivalent to about ^{em}\$89 million. On the other hand, the emergy value of exports from the Aquidauana River is 367,08 seJ/year with an emdollar value of ^{em}\$108 million. The largest exports are fishing (professional and touristic) followed by wildlife watching, chemical, and geopotential energy in the water.

Table 2 exhibits the natural capital of the Aquidauana River, within the study area. Footnotes that detail data, sources, and calculations can be found in Appendix 2. Natural capital stocks are separated from cultural capital and endangered species to highlight their differences, both in function and magnitude. Ecosystem services are generated from natural capital, while cultural and endangered species capital are used by humans to manage, and appreciate ecosystems. The total emergy of natural capital was 6,89E+15 seJ translating into about ^{em}\$2,04 thousand, whereas the total emergy of cultural capital was 782,25E+20 seJ or about ^{em}\$230 thousand. The Giant otter as an endangered species accounts to ^{em}\$2,29E+7.

Table 2. Emergy in natural, cultural and endangered species capital of Aquidauana River System.

Note[a]	Item	Quantity	Emergy intensities (seJ/unit)	Solar emergy (x10^{10}seJ)	EmDollars (^{em}\$)
Natural capital					
1	Surface Water, J	1,54E+10	8,10E+04	124.443,54	366,01
2	Riparian Forest, J	5,74E+10	3,62E+04	207.788,00	611,16
3	Vegetation of high fields, J	6,40E+09	3,62E+04	23.177,73	68,17
4	Vegetation of low fields, J	2,37E+09	3,62E+04	8.595,01	25,28
5	Savannah, J	8,98E+10	3,62E+04	325.122,38	956,24
Total natural capital				689.126,66	2.026,86
Cultural capital					

Note[a]	Item	Quantity	Emergy intensities (seJ/unit)	Solar emergy ($x10^{10}$ Sej)	EmDollars ($x10^{3}$ ^{em}$)
6	Value of Indian Artifacts, J	4,14E+15	1,89E+07	7.822.503.440.230,7	23.007.363.059,5
Endangered species capital					
Note[a]	Item	Quantity	Emergy intensities (seJ/unit)	Solar emergy (seJ)	EmDollars (^{em}$)
7	Value of *Pteronura braziliensis*, # of ind.	1	7,78E+19	7.780.000.000,00	22.882.352,94
National Emergy Money Ratio (EMR) sej/$ (Total emergy Used/GDP)				3,40E+12	
[a] Notes to Table 2 can be found in Appendix 2.					

Table 3 lists some of the ecosystem services provided by the Aquidauana River based on provisioning and cultural values. Of the services with provisioning values, professional and tourist fishing had the largest emergy values, combined totaling about 91% of the provisioning services or ^{em}$89 million, while their economic value totaled $408 thousand. In all cases, except the water supply, the emdollar value of the service exceeded the economic value. The economic value of water supply is about 13 times higher than emdollars value. Scientific information generated by research results in about ^{em}$2 million. Thus, the total emdollar value of provisioning services was ^{em}$98,3 million, while the computed monetary values totaled $8.5 million, the largest of which was water supply ($7,6 million).

Table 3. Emergy, emdollar, and economic value of services of the Aquidauana River System.

Note[a]	Item	Emergy value	EmDollars[a]	Economic value
Provisioning services				
1	Research	7,38E+18	2.169.948,53	468.000,00
2	Water supply	1,93E+18	567.021,92	7.607.368,42
3	Fishing Professional	1,96E+20	57.698.996,31	46.264,80
4	Fishing Tourist	1,06E+20	31.295.586,06	361.365,60
5	Wildlife watching (image exported with tourists)	2,22E+19	6.530.160,00	23.025,72
Total Provisioning Services, yr			98.261.712,81	8.506.024,54
Cultural Services				

6	Scientific information, hrs	7,38E+18	2.169.948,53
Total	*Cultural Services, yr*		2.169.948,53

*Emdollar are calculated by dividing emergy in column 3 by 3.4E+12 sej/$, the average ratio of emergy to money in the Brazilian economy.

[a] Notes to Table 3 can be found in Appendix 3.

Part of the Giant otter's diet is *Piractus mesopotamicus* (Pacu), *Pigocentrus nattereri* (Piranha-vermelha; Red piranha), and *Brycon hilarii* (Piraputanga) (Rojas, 2009). These species are part of the main fishing resources in the Aquidauana River (Catella et al, 2014). Therefore, it can be expected that with a reduction of the fish resource, conflicts between fishermen and Giant otters might get worse, as the perception fishermen have related to the decrease of the resources often does not express the reality. In fact, a public policy such as the closed period of fishing and catch quotas, together with water quality, pollution and climate change can affect the fishing income. However, for many fishermen, these facts are not clear and not well understood.

The monthly income average of the fishermen from Aquidauana River is a minimum wage which is today US$ 207,37, resulting in a yearly income of 2.488,42 American dollars. If the income would rely only on professional fishing it would be about 171,50 American dollars per fishermen per year, which represents 6,89% of the yearly income. The difference is obtained through the service provided as a guide for tourist fishermen. Assuming that the professional fisherman is paid for at least 1 trip per week during the 8 months of the year, plus 12 extra trips during September, October, and November, a period of the maximum catch of tourist fishing (Catella et al, 2014) the yearly income can be about 2.315,79 American dollars.

The Brazilian Pantanal is visited by 150 thousand tourists per year resulting in approximately US$14.250,00 revenue (Araujo et al, 2005). The most successful tourist program is Bonito, 79 miles far from Aquidauana. According to Portal Brasil (http://www.brasil.gov.br/turismo/2015/08/bonito-ms-recebe-r-102-milhoes-do-turismo-no-primeiro-semestre), from January to July 2015, Bonito had 85,7 thousand visitors with an income of 25 million American dollars. Considering that a well-organized wildlife watching in Aquidauana, based on a Conservation Tourism, could get 10% of these number, this would result in 8.500,00 visitors per year. Estimating a spent of 100 American dollars per day and an average stay of 3 to 5 days, the result would be about 3.400.000,00 American dollars per year, 2,5% of the actual Aquidauana GDP.

Fishermen, through the local fishermen association, MS Z-07, can be trained in order to work with another kind of public, interested in the local culture and wildlife, instead of fishing. Well prepared guides, easy and safe access to the river, as well as silent motors, are important ingredients of a successful business plan based on observation of mammals and birds. Tours and lodges that offer an opportunity for wildlife watching are becoming more common, but the great majority are apart from the community, located in big cattle farms.

Part of this work was to map the Giant otter groups living in the Aquidauana River, especially the ones near Aquidauana and Anastacio cities. From March to November 2014, 53 expeditions along the 120 km study area in Aquidauana River were conducted, totaling 66 days of fieldwork and 350 hours of observation. Altogether 2.770 km were covered, including bays and meanders as Acogo, Corrente, Baía Grande and Baía dos Jacarés.

Thirty-four direct observations of Giant otters were made, all of them from 7:00 to 17:00 hs, 15 in the bays along the river and 17 in the river. The average number of observed individuals per event ranged between 1 and 9 (Mean=3,6 ± 1,9). Forty-six locations with Giant otters indirect signs such as dens, campsites, trails, resting and marking sites were also recorded. The density of the presence of the species was 0,38 per kilometer.

A general index of 0,05 records per kilometer of the river was obtained. The records in the bays were considered for the calculation since they are located along the river. On average, 57,2% (±12,8) of the records were made in the river and 42,78% (±12,8) in the bays. A *T-test* was applied in order to compare the presence of Giant otter groups on the river and bays. It obtained a *p*-value of 0,112 which suggests that there is no significative difference when comparing records from river and bays, with a confidence of 95%.

Ten different groups of Giant otters were identified in the study area, but only 5 could be sighted more than once. In addition, on thirteen occasions (38% of sightings) it was not possible to observe the throat marks and, consequently, it was not possible to identify the group. Therefore, individuals observed on these occasions were not used for density calculations. The density calculation was done in two different forms, considering only the observations made in the main course of the river and the other including the bays. The only published study on the same study area (Tomas et al, 2000) did not include bays and meanders, so the data presented here can be compared.

Only one of the groups observed within a bay was also observed in the river. It is possible that groups found in the bays remain longer in these places, moving little to the main watercourse. This suggest that bays along the Aquidauana River can have a greater ecological importance in the preservation of the Giant otter in the area.

Euclidean distance was calculated in meters, between locations of dens and sightings of Giant otter groups until the urban center of Aquidauana and Anastácio. For this, the geographic coordinates of the bridge (Ponte Nova), were considered which connects the center of the two municipalities. Although the Euclidean distance does not take into account the landscape elements, like the meandering of the river, it reflects the closest distance from reality once the course of the river moves away from the urban area to the northwest. Table 4 shows the coordinate locations of the 10 groups, the number of individuals for each group, and the distances from Aquidauana bridge.

Table 4. Location of the identified Giant otter groups in the Aquidauana River.

Local	ID_Group	X	Y	N_ind	Bridge (m)
Frigo Bay	1	621072	7735557	3	4.585,09
Frigo Bay	1	621072	7735557	3	4.585,09
River	1	621024	7739355	3	6.576,08
River	2	613871	7765542	5	33.085,66
River	2	613883	7765689	6	33.219,01
River	2	614740	7764268	6	31.588,97
River	2	614334	7762203	1	29.807,58
River	2	614785	7764273	6	31.578,29
Little Bay	3	609926	7774590	6	42.946,68
Little Bay	3	609926	7774590	6	42.946,68
Little Bay	3	609828	7774455	8	42.856,83
River	4	616933	7747320	2	15.376,23
River	5	616225	7751210	3	19.061,15
Current Bay	6	619383	7742334	8	9.903,66
Big Bay	7	618740	7755375	4	21.875,64
Big Bay	7	619125	7753820	4	20.278,42
Big Bay	7	618768	7755559	4	22.041,92
Taquaruçu River	8	627234	7732596	2	2.605,83
Taquaruçu River	8	627345	7732272	2	2.927,67
River	9	619431	7741169	2	8.988,90
Frigo Bay	10	621303	7735227	3	4.298,26
Frigo Bay	10	621297	7734963	2	4.272,95

Following Table 4, Figure 6 presents the spatial distribution of identified groups within the study area. It is important to notice that groups 1, 8 and 10 are close to Aquidauna City, with distances ranging from 2,6 to 6,5 km. Two of these groups are in a near bay, and the other one is in the Taquaruçu River, a close tributary of the Aquidauana. They can be important in the case of conservation tourism, representing an important economic alternative to the locals. However, social mobilization strategies must be applied in order to implement a safe management program that ensures the protection of the species and a sustainable long-term business for the community.

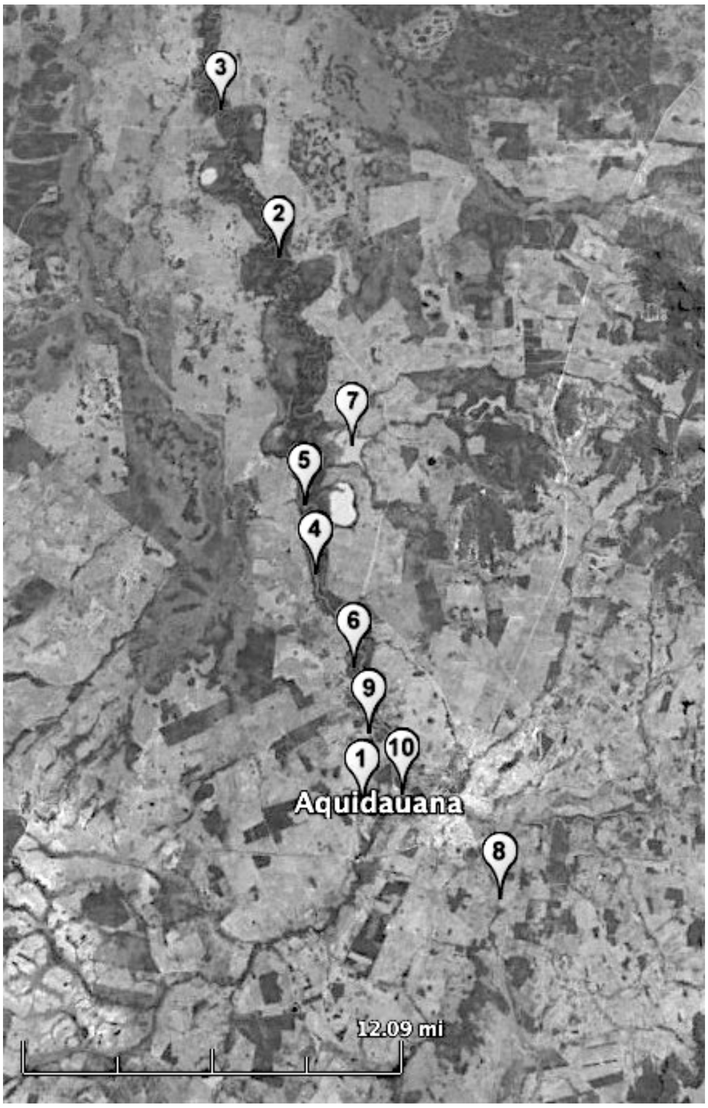

Figure 6. Giant otter groups locations in the Aquidauana River, MS. Ten groups were identified along 120 km of river and bays.

The distance matrix was generated by vector analysis of distance between points calculated by QGIS software. On average, the distance between the points of Giant otters occurrences and the urban center was 22,7 km (± 14,5), with a minimum of 1,1 km (Figure 7). Identifying the 10 groups and distributing them linearly along the 120 km of the river resulted in 1 group of Giant otter for each 12 km. This is in agreement to a census based on one expedition of 18 days, along 324 km of river, from Aquidauana City to Passo do Lontra, that found one group of the species for each 10.8 km (Tomas, et al, 2000).

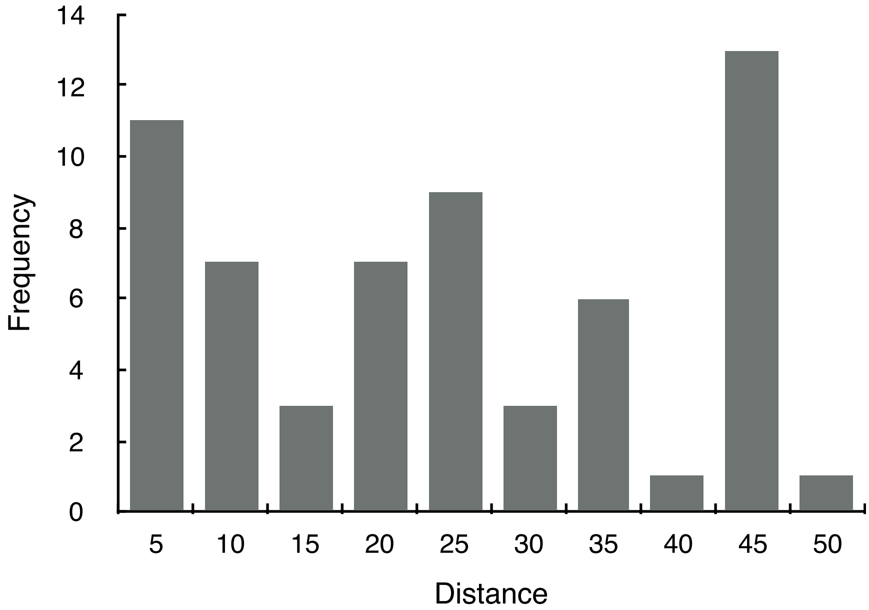

Figure 7. Histogram frequencies of Euclidean distances observed between the Giant otter groups and the urban center of the study area.

Published papers do not mention or describe the horizontal movements of the *Pteronura brasiliensis*. However, during the present field study, it was common to observe the species walking along the margins and on the banks of the river. It was also found that the bays located along the Aquidauana river are equally frequented. It is possible to say that the species can walk considerable distances from the river to inland, in order to reach a bay or another water course. It is important to take into account that during the high flood pulse it can be difficult to define the river main course in many areas. During this period the species can travel away from the main course, which makes them more difficult to be sighted.

In order to perform the emergy calculations, the home range of the Giant otter is defined in square kilometers, considering 12 km extension and 10 km width. The 10 km width is an average estimation taking into account the bays, inland and the legal reserve of 100 meters for each margin of the river.

The nearest bay where the species is found is the Acogo, next to which a slaughterhouse is located. In fact, many Giant otters sightings are within 5 km from the center of Aquidauana City. However, most encounters did not last for more than a few minutes, as the animals would quickly swim away and be out of sight. Reports from locals indicate that they are often harassed by people, or simply by the noise of the boats.

As expected, the dry season favored to obtain records of Giant otters presence, which reinforces the importance of conducting a more intense monitoring at this time of year. Most of the direct observations of Giant otters were made downstream of Aquidauana city. In August, for the first time, it was recorded a couple of Giant otters upstream of the bridge connecting the two cities (Aquidauana and Anastácio). This shows the importance of long-term monitoring of Giant otters populations in the study area, because the sites used by the species can vary throughout the year, according to the seasonal dynamics of flood pulse in the region.

4. DISCUSSION

The Aquidauana River is dominated by its renewable base energy. Within the system, there is a significant storage of phosphorous that contributes to a large export of fishing, professional and touristic. Fishing, professional and touristic, accounts for 86% of the total exports. Wildlife watching, as a potential activity, and water chemical potential are the next most important export from the Aquidauana River, totaling 11% of total exports. While there is a Federal University in the city (UFMS) and a regional research facility (Embrapa), where a large number of scientists and researchers are engaged in the generation of information, its emergy value represents only 2% of total exports.

Natural Capital Resources are shown in Table 2, dominated by savannah vegetation (47%), riparian forest (30%), and surface water (18%). Of particular interest is Indigenous artifacts, and *Pteronura brasiliensis* as cultural and endangered species, respectively. If these two were to be included in the assets, they would account for about 99.99% of the natural capital resources.

The Aquidauana River provides multiple ecosystem services (Table 3) totaling ^{em}\$ 98.3 million for market value services and ^{em}\$ 2.2 million for non-market value service (service information). The largest market value services are professional and touristic fishing (^{em}\$ 89 million). When compared to dollar value, the output services is about 11.5 times larger.

Evaluating the flows of energy, materials, and information supporting the Aquidauana River, it is possible to provide a different approach, away from the one that Odum (1996) defined as a receiver value system, based on a human-centered framework, value to humans, willingness-to-pay (WTP) process. The approach adopted here takes into account flows of energy, material, and information, and is defined as a donor value system (Campbell and Brown, 2012).

In this study, both natural capital and ecosystem services are valued in terms of emergy, which represents the energy used to produce a product or service. Table 3 shows the difference between monetary and emdollar values. The higher emdollar value, compared to dollar value, reflects the large benefit that society receives from underpriced fishing and wildlife. It should be considered the uncertainty in the data, related to spatial computing of renewable inputs, as well as assumptions related to fish prices and a number of species. However, it is quite clear that, even with more refined data, based on the large differences found, values of fishing and species will still be extremely important resources within the Aquidauana River system.

The Aquidauana River system cannot be treated or managed singly. It is part of the most important Brazilian wetland, the Pantanal, a highly productive ecosystem. The amount of phosphorous through the study area account for 24% of the renewable resources, equivalent to em$751 billion. Any changes in flows of energy and nutrient cycling within the ecosystem can be disastrous. It is believed that one of the main impacts resulting from the designed dams for the upper Pantanal would be a change in nutrients. For example, a study conducted in the Correntes River shows that retention of phosphorous (28%), total solids (23%), and nitrate (14%) caused by a local dam could affect the whole productivity of downstream floodplains (Fantin-Cruz, 2015). Another study carried out at Proto Primavera reservoir at the Paraná river, revealed that 70% of the total phosphorous was prevented to reach the floodplain area (Roberto et al, 2009).

This are bad news for a biome that is among the most productive ecosystems on Earth. Commercially harvested fish, tourism and biodiversity are directly related to the quality and size of the Pantanal, as it provides spawning grounds, nurseries, shelter, and food for fish, birds, and other wildlife as the Giant otter, a highly endangered species. It is possible to say that this regional richness depends on Pantanal habitats, promoted by rivers, lakes and flood-pulse. The calculated Giant otter value, for example, is based on the emergy required for its evolution along time, and registered in its genetic information. Therefore, the value of the endangered species represents the loss of this entire environmental service if the species is extinct.

The storage and flux of P among the vegetation biomass and animal biodiversity, and how this varies within the Pantanal, with and without the Giant otters, remains to be determined. The effects of nutrient retention and storage on trophic cascade can be of important economic dimension. Riparian forest and the Giant otter, for example, represent important assets to the Pantanal. Just the riparian forest, within the study area, accounted to em$611 thousands and *Pteronura brasiliensis* to em$22.895.176,00. Whatever the scenario is, the absence of a top predator as the Giant otter would lead to a dramatic ecosystem simplification followed by a number of extinctions, causing severe harm to many other organisms and to the economy. The conflict situation among fishermen and Giant otter in the Aquidauana River is alarming, when people tend to relate the decrease in fish to the presence of the species. As well noted by Miller et al (2001), past policies driven by paradigms such as this continue to play a stronger role than scientific information. As a result, species like the *Pteronura brasiliensis*, with low biological resilience, tend to decline drastically.

On the other hand, there could be a window of opportunity. The presence of Giant otter groups near the city could represent the beginning of a Community Based Conservation Tourism Program. With the proper social mobilization program together with economic/environmental education and training, local people could be empowered. Local government would be responsible for coordinating a public policy with the different stakeholders involved. If the community could see the economic and social benefits, with a better quality of life, it could be co-responsible for projects of conservation of the Giant otter and the biodiversity as a whole.

At the moment, the data reveal that the Aquidauana PIB value is highly influenced by cattle farm. However, when these numbers are analyzed together with the HDI, it seems that cattle farm result in income concentration. On the other hand, the results based on emergy reveal that the greater assets are the Indian culture and the Giant otter. A public policy on conservation tourism, based on these two assets could promote a better social justice. Society today evaluates the reality from the receiver's point of view, ie only gives importance to what it receives, which can be easily detected. Society does not see or does not give importance to the origin of producing the natural resources used by it. This reveals a major problem for environmental conservation, which can be, at least in part, reversed by social mobilization and conservation tourism, supported by a well planned public policy.

ACKNOWLEDGEMENTS

This work could not have been possible without the support of the Institute Ekko Brazil and the Petrobras Environmental Program. The author is also indebted to Prof. Mark Brown, responsible for the invitation to work as a Research Visitor at the Center for Wetlands at the University of Florida, from 2015 to 2016. Discussions with Prof. Brown, and doctoral students under his supervision, were of enormous help and support for this work.

APPENDIX 1

Notes do Table 1. Emergy evaluation of the flows supporting the Aquidauana River.

Sunlight

Annual energy = (Avg. Total Annual Insolation J/yr)(Area)(1-albedo)

Insolation, $J/m^2/yr$ =	6,57E+09	Atlas Solarimétrico do Brasil, 2000
Area, m^2 =	3,56E+10	
Albido =	1,8E-01	Brown and Campbell, 2007
Annual energy, J/yr =	1,92E+20	
UEV, seJ/J=	1,00E+00	Odum, 2000

Rain

Annual energy =volume*1000kg/m^3*4940J/kg

Rain (m/yr)=	1,1	ANEEL, 2015
Area (m^2)=	3,56E+10	
Volume, m^3=	3,91E+10	
Runoff coeff.=	6,00E-01	
Annual energy =	1,93E+17	
UEV, seJ/J=	3,10E+04	Odum et al, 2000

Wind kinetic energy

Area =	3,56E+10	
Density of Air =	1,30E+00	
Avg. annual wind velocity =	5,04E+00	Amarante et al, 2001
Geostrophic wind =	8,40E+00	
Drag Coeff. =	2,00E-03	
Energy (J) =	(area)(air density)(drag coefficient)($velocity^3$)	
Energy (J) =	(_ m^2)(1.3 kg/m^3)(1.00 E-3)(___mps)(3.14 E7 s/yr	
Energy(J) =	1,10E+17	
Transformity, sej/J=	2,45E+03	Odum, 2000

TP in river

(volume, cfs)(P, mg/l)(0.02831m^3/f^3)(3.1536E+7sec/yr)((1E-3g/mg)(1E+6L/m^3))

volume, cfs=	3,11E+03	Carvalho et al, 2000
P, mg/l=	1,84E+02	
densidade, m^3/f^3=	2,83E-02	
sec/yr=	3,15E+07	

g/mg=	1,00E-03	
L/m^3=	1,00E+06	
Average TP mass=	5,11E+14	

TP out river

(volume, cfs)(P, mg/l)(0.02831m^3/f^3)(3.1536E+7sec/yr)((1E-3g/mg)(1E+6L/m^3))

volume, cfs=	3,11E+03	Carvalho et al, 2000
P, mg/l=	4,60E+02	
densidade, m^3/f^3=	2,83E-02	
sec/yr=	3,15E+07	
g/mg=	1,00E-03	
L/m^3=	1,00E+06	
Average TP mass=	1,28E+15	

Stream, geopotential (J.yr^{-1})

Stream, geopotential (J.yr^{-1}) = (flow volume)(density)(dh)(gravity)

flow, cfs=	1,84E+02	Carvalho et al, 2000
density=	0,028317	
dh, m=	700	Brandt-Williams, 1999)
gravity=	7000000	
Annual energy=	1,94E+16	

Runoff, J

Volume, m^3/yr=	3,91E+10	
J/g=	4,82E+00	
J/Cal=	1,00E+06	
Energy/yr=	1,89E+17	
Transformity, sej/J=	5,19E+01	Brandt-Williams, 2000) Newnans Lake (p. 81)

Machinery and Equipments

Total investment, $=	1,11E+03	Cardoso and Freitas, 2006
Unit Emergy Value, sej/$=	1,90E+12	Brown and Campbell, 2007
Canoa, g=	7,50E+04	estimated
motor, g=	1,50E+04	estimated
avg. mass, g/vehicle=	9,00E+04	
avg. mass total, g/vehicle=	6,66E+06	
avg. vehicle lifespan, yrs=	2,00E+01	estimated
# Professional Fishermen Aquidauana=	7,40E+01	Catella et al, 2014

# Amateur Fishermen Aquidauana=	5,78E+02	Catella et al, 2014

use per yr= mass*#motorboats/avg life

Professional goods use per yr=	2,46E+07	
Amateur goods use per yr=	1,92E+08	
Transformity, sej/J=	1,13E+10	

Fuel, J per expedition

(litros * 0,35 J/l)

Energy J/l=	3,50E-01	
Liters/fisherman/day=	1,50E+01	
Liters/total/Professional fishermen/day=	1,11E+03	
Liters/total/Amateur fishermen/ day=	8,67E+03	
# days=	1,60E+02	
Liters/total/Professional fishermen/yr=	1,78E+05	
Liters/total/Amateur fishermen/ yr=	1,39E+06	
Litros R$=	5,33E+05	
Litros $=	1,67E+05	
Professional Fishermen Annual energy, J=	6,22E+04	
Amateur Fishermen Annual energy, J=	4,86E+05	
Emergy per unit input	1,11E+05	Odum, 1996

Professional Fishing Electricity, J

Annual energy=KWh*3,6E+06 J/KWh

Conversion=	3,60E+06	
KWh/person/month =	1,57E+02	
ofessional Fishermen KWh/year=	9,29E+04	
Annual energy =	3,35E+11	
Transformity=	2,92E+05	Brown and Campbell, 2007

Amateur Fishing Electricity, J

Annual energy=KWh*3,6E+06 J/KWh

Conversion	3,60E+06	
KWh/person/month =	1,57E+02	Infomoney, 2016 www.infomoney.com.br
Amateur Fishermen KWh/year=	7,26E+05	
Annual energy =	2,61E+12	
Transformity=	2,92E+05	Brown and Campbell, 2007

Annual production of information

# of papers=	39	Google Academico, results for 2015
average time spent, hours/paper=	8,05E+02	
research hours, hours/yr=	3,14E+04	
Transformity, sej/J=	2,35E+14	

Water, Chemical Potential

Total export Aquidauana River, m^3/yr=	4,57E+07	Oliveira and Ferreira, 2003
Density, kg/m^3=	1000	
Heat capacity, J/kg=	4940	
Chemical Potential=	volume total (m3/yr) * density * heat capacity	
Chemical Potential=	2,26E+14	
Transformity, sej/J=	8,1E+04	Odum, 2000

Water, Geopotential

Total export Aquidauana River, m^3/yr=	4,57E+07	Oliveira and Ferreira, 2003
Elevation, m=	49	
Density, kg/m^3=	1000	
Gravity, m/s^2=	9,8	
Geopotential, J=	volume*avg elevation*density*gravity	
Geopotential, J=	2,19E+13	
Transformity, sej/J=	4,70E+04	Odum, 2000

Surface Water

Volume, m^3=	4.818.000,00	Santos et al, 2009
Density, kg/m^3=	1000	
Gibbs Free energy of water, J/kg=	4940	
Energy (J) =	volume*density*Gibbs	
Energy, J=	2,38E+13	
Transformity, sej/J=	8,10E+04	

Fishing, Professional

Total fish caught, g=	6.840.600,00	Catella et al, 2014
Total fish caught, kg=	6.840,60	
Total fish caught per person/yr, kg=	92,44	
Average price kg fish, $=	1,86	assume Ceasa price minus 40% for the price at the producer
Total income fishing per person/yr, $=	171,50	
avg. mass, g/fish=	4,54E+02	assume avg weight, kg=0.45

energy content, J/g=	1,88E+04	4.5Cal/G*4187 J/cal
energy fish caught, J=	Tot fish * avg. mass * energy content * 0.2	
energy fish caught, J=	11.677.177.824.	assume 20% dry weight
Transformity, sej/J=	1,68E+07	
# fishermen=	74	
monthly income, $=	207,37	assume 1 minimum salary/month, Anjos et al, 2010
Yearly income, $=	2.488,42	
Fishing, Tourist		
Total fish caught, g=	3.710.300,00	Catella et al, 2014
Total fish caught, kg=	3.710,30	
Total fish caught per person, kg=	6,42	
avg. mass, g/fish=	4,54E+02	assume avg weight, kg=0.45
energy content, J/g=	1,88E+04	4.5Cal/G*4187 J/cal
energy fish caught, J=	Tot fish * avg. mass * energy content * 0.2	
energy fish caught, J=	6.333.630.512.0	assume 20% dry weight
Transformity, sej/J=	1,68E+07	
# fishermen=	578	
# of days/year=	44	assume 1 trip per week during 8 months of the year + 12 extra trips during Sept/Oct/Nov
price/day trip, $=	52,63	estimated day trip of 200.00 Brazilian Reals, Dollar at 3.8 Reais
income year/fishermen, $=	2.315,79	
Total income/yr, $=	2.487,29	
Wildlife watching (Image exported with tourists)		
Pantanal, visits/yr=	85.000,00	Araujo et al, 2005
Aquidauana, visits/yr=	8.500,00	
ıe in Pantanal, total hours/person=	120,00	
Average spent day/tourist	100,00	
Total spent/tourist=	400,00	
Total spent year=	3,40E+06	
ːism time in Pantanal, total hours=	10.200.000,00	
ːism fishing in Pantanal, visits/yr=	13.856,00	Catella et al, 2014
olunteers 2014 (Otter Project - Santa Catarina), #=	76	
olunteers 2014 (Otter Project - Santa Catarina), $=	12.832,67	
ːovolunteer total hours stay 2014=	7.870,00	
ıverage stay, hours ecovolunteer=	103,55	
Avg. energy/hr, kcal/hr=	1,04E+02	

total energy expenditure=kcal/hr*hrs*4186J/Kcal

total energy expenditure, J/yr=	1,48E+12
Transformity, sej/J=	1,50E+07

APPENDIX 2

Notes to Table 2. Emergy in natural capital of Aquidauana River System.

Surface Water, J

energy, J=	volume*1000kg/m^3*4940J/kg	
volume, m^3=	3,11E+03	
water density, kg/m^3=	1,00E+03	
Gibbs free energy of water, J/kg=	4,94E+03	
energy, J=	1,54E+10	

Riparian Forest, J

mass, kcal/g=	m^3*kg/m^3*1000g/kg	
Average height, m=	12	Damasceno-Junior et al, 2005
Quantity, m^2=	159.450,02	
Quantity, m^3=	1.913.400,	
Weight, kg/m^3=	30	
mass, kcal/g=	5,74E+10	
Transformity, sej/J=	3,62E+04	

Vegetation of high fields, J

mass, kcal/g=	m^3*kg/m^3*1000g/kg	
Average height, m=	6,700	Soares and Oliveira, 2009
Quantity, m2=	191.125,02	
Quantity, m^3=	1.280.537,	
Weight, kg/m^3=	5	
mass, kcal/g=	6,40E+09	
Transformity, sej/J=	3,62E+04	

Vegetation of low fields, J

mass, kcal/g=	m^3*kg/m^3*1000g/kg	
Average height, m=	6,70	Silva et al, 2001
Quantity, m2=	70.875,00	
Quantity, m^3=	474.862,5	
Weight, kg/m^3=	5	
mass, kcal/g=	2,37E+09	
Transformity, sej/J=	3,62E+04	

Savannah, J

mass, kcal/g=	m^3*kg/m^3*1000g/kg	
Average height, m=	9,00	Abode and Silva, 2008
Quantity, m2=	453.600,0	
Quantity, m^3=	4.082.400,	

Weight, kg/m^3=	22	
mass, kcal/g=	8,98E+10	
Transformity, sej/J=	3,62E+04	

Information Indians on Aquidauana

Energy of Population, J=	population*J/yr/Indian*year	
# of indians MS (population)=	73295	IBGE, 2010
# of indians Aquidauana (population)=	5714	
J/yr/Indian (energy per capita), J/yr=	1896.32 Cal/day*365 d/yr * 4186 J/Cal	
Consumo Cal/day=	1896,32	Gondi, 2007
Days/yr=	365	
J/Cal=	4186	
J/yr/Indian (energy per capita), J/yr=	2,90E+09	
Yrs to develop information, #=	2,5E+02	
Energy, J=	4,14E+15	
Transformity, sej/J=	1,89E+07	

Value of *Pteronura braziliensis*, # of ind.

# of species*% of viable population in distribution area*em. required to dev.	
Endangered/Threatened Species, #=	1,00E+00
Viable population area to the otter distribution area estimated, %=	6,60E-05
emergy per species, sej/species=	4,75E+24
Emergy in Pteronura braziliensis=	7,78E+19
Transformity, sej/J=	2,26E+22

National Emergy Money Ratio (EMR) sej/$ (Total emergy Used/GDP)	3,40E+12

Appendix 3.

Notes to Table 3. Emergy, emdollar, and economic value of services of the Aquidauana River System.

Research

Emergy of UFMS/Aquidauana and Embrapa - MS engaged in research activities

Number of staff=	156	estimated: 4 persons/paper, 39 papers
Emergy/person=	4,704E+17	
Emergy (sej)=	7,33824E+19	

Economic costs of research (Salary)

Dollar costs=	468.000,00	estimated salary $3000/person

Water supply

a. Emergy value of surface water

Emergy, sej=	1,93E+18	

b. Dollar value

Price, $/m^3$=	1,58	Sanesul, MS, 2015
Volume of water, m^3=	4.818.000,00	
Dollar value, $=	7.607.368,42	

Fishing Professional

a. Emergy of fish harvested

Emergy, sej=	1,96E+20	

b. Estimated dollar expenditure for fishing

# of professional fishing=	74,00	
Expenditure/fisher, $=	625,2	Cardoso and Freitas, 2006
Total expenditures, $=	46.264,80	

Fishing Tourist

a. Emergy of fish harvested

Emergy (sej)=	1,06E+20	

b. Estimated dollar expenditure for fishing

Numbers persons fishing (sej)=	578,00	
Expenditure/fisher, $=	625,2	
Total expenditures, $=	361.365,60	

Wildlife watching (image exported with tourists)

Emergy of ecovolunteers

Number of wildlife watchers=	76,00
Expenditure/ecovolunteer, $=	302,97
Total expenditures, $=	23.025,72

Emergy (sej)=	2,22E+19

Scientific information

Annual production of information

# of papers=	39	Google Academico, results for 2015
average time spent, hours/paper=	8,05E+02	
research hours, hours/yr=	3,14E+04	
Transformity, sej/J=	2,35E+14	

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