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Article

Overfishing or Over Reacting? Management of Fisheries in the Pantanal Wetland, Brazil

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Abstract

Historically, small-scale inland fisheries have been overlooked. Management practices based on industrial fishing, rarely take into account vital factors such as complex socio-environmental relations. This paper aims to help address this gap, contributing to a better understanding of small-scale inland fisheries. It uses the Pantanal wetland of Brazil as a case study, in which policymakers established restrictive fishing rules based on claims that local overfishing had caused numbers of recreational fishing tourists to decline. Through multiple regressions, participatory observation and mapping, this paper deconstructs the environmental narrative and uncovers the area's complex traditional system of use. The case study, firstly illustrates the adverse consequences of misconceived top-down fishing management practices and, how such environmental narratives may be deconstructed. Then it presents important aspects of customary management in inland floodplains fisheries, including high levels of mobility within a common property regime and unexploitable reserves. It concludes by analysing recently proposed categories of property regimes, identifying fundamental elements that must be taken into account in designing appropriate management policies in inland floodplain fisheries.

Keywords: The Pantanal, wetland, traditional fishermen, overfishing, tourism, natural reserves, rotational use, common property regime

INTRODUCTION

Industrial fishing has been part of the global conservation agenda since the beginning of the twentieth century, with much effort put into developing tools and techniques for accurate evaluation of the status, economic significance and best conservation practices of industrial fishing (Pauly et al. 2003; Norse et al. 2012; Watts et al. 2009; Costello et al. 2016). By contrast, small-scale fisheries have been largely overlooked. Catch statistics used to assess species stocks in artisanal fisheries are based on industrial practices; and normally do not take into account vital factors such as recreational fisheries and dispersed landings (Cowx et al. 2004). As a consequence, small-scale fisheries catches are thought to be greatly underreported (Welcomme et al. 2010; Cooke et al. 2016). Management practices are similarly based on industrial fisheries, largely on models of single species fished by one type of gear (Welcomme et al. 2006). This approach is disconnected from the complex realities of small-scale fisheries and inadequate to predict changes in fish species assemblages and local livelihoods (Welcomme 1999).

The lack of accurate conservation and management understanding of small-scale fisheries practices is even more evident in freshwater systems. Conservation practices focused on inland fisheries normally overlook fundamental ecological drivers, such as numbers and distributions of patches suitable for individual species and fish assemblages, their longitudinal connectivity and ecological variations through time (Parsons and Maguire 1996; Valley and Freeney 2013; Wilson et al. 2013). Moreover, local people in inland fisheries commonly adopt specialised dynamics of use, with high mobility, a

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variety of methods of production/extraction at different times and places, periods of intensive use in response to seasonal abundance, and flexible shifts in livelihoods (Abbott and Campbell 2009; Adger and Luttrell 2000). Their variety of use adds further complexity. For instance, overfishing leads not to single-species responses, but to fishing down: put simply, a decline in mean size of individuals and species in the assemblage (Welcomme et al. 2006). Conventional concepts of overfishing are thus difficult to apply in inland fisheries (Welcomme 1999).

Artisanal inland fishing plays a fundamental role in nutrition, livelihoods and poverty alleviation in the global south (Béné et al. 2016). For example, in Southeast Asia, the Mekong River encompasses six countries, maintains the world's largest inland fisheries, and supplies 50-80% animal protein for 65 million people regionally (Dugan et al. 2010). In the Brazilian Amazon floodplain, 84% of the households engage in fishing, representing 40% of local people's income (Almeida et al. 2002). Even in the drylands of sub-Saharan Africa, fish represent a fundamental part of local people's livelihoods and diets. In Senegal alone, the estimated annual value of fish from two of the three main rivers was between USD19 - 26 million (Kolding et al. 2016). Across the Lake Chad basin, fisheries provide 45% of the regional household income, amounting to USD 45.1 million per year (Young et al. 2012). Similarly, Lake Victoria produces about 1 million tonnes of fish per year (Kolding et al. 2014). Moreover, small-scale fisheries play a remarkable role in poverty alleviation through their capacity to absorb surplus labour and as an alternative protein supply when other sources fail (Béné 2009).

Abbott and Campbell (2009) document a telling example of this complexity and the potential for mismanagement in fisheries. In the Upper Zambezi River Floodplains, local people started to use government-issued mosquito nets for fishing. This method, used mostly to catch small fish, was widely seen as driving the area's fish stocks into decline. However, researchers uncovered a more complex situation. While the Zambian Government accused local fishers of using damaging fishing methods, local Zambian communities accused Namibian fishers of overfishing, and Zambian fishing lodge owners accused all non-tourist fishers of unsustainable practices. However, ecological research revealed that changes in fishing stocks were driven entirely by the biophysical effects of (variable) flooding events, therefore, local fishing practices were not leading to overuse, despite the mosquito nets.

The case of the Upper Zambezi River Floodplain highlights a further complexity found in many wetlands. Continual transitions between terrestrial drawdown and flooded states create a highly unpredictable system with unique features (Junk et al. 1989). Some argue that socio-ecological systems constantly facing environmental changes, such as floodplain fisheries, challenge established ideas of property regimes and sustainability (Moritz et al. 2013). Classical understanding of common property regimes see rules on use (property regimes) as leading to sustainability, and lack of rules (open access) to overexploitation (Behnke et al. 2016; Ostrom 2009). However, according to this view, in some systems, common pool resources are shared through an "ethos of open access" with no customary restriction on use, leading, nonetheless, it is suggested, to sustainability (Moritz et al. 2013; Moritz et al. 2014; Moritz et al. 2015). For example, in the Logone Floodplain, Cameroon says, "open access does not have to lead to a tragedy of the commons…in a sense, management of open access is not an oxymoron because there are clear rules about who has access to the common-pool grazing resources (all pastoralists) and who can be excluded (no one)." (Moritz et al. 2013:356), and more generally "management of open access is not limited to pastoral systems. There is evidence that other resource systems with open access to common-pool resources may also work as self-organizing systems" (Moritz et al. 2015: 62).

These concepts are yet poorly understood. Managers and policymakers worldwide commonly assume the same overfishing narrative that Abbott and Campbell (2009) challenged for the Zambezi River floodplain. Indeed, narratives are often strategically deployed to argue vested interests (Abbott and Campbell 2009; Homewood 1994). Claims of overfishing, bushmeat overhunting or desertification may be less evidence-based, than power plays by different interest groups (Robbins 2012). Scientific evidence to support or reject a specific claim offers one set of tools to deconstruct these narratives (Gray and Campbell 2009), in a fundamental step towards better local natural resources management and development (Neumann 2011). This is especially important for floodplain fisheries, on which millions of people depend but for which there is limited understanding of customary regimes, ecological drivers and impacts of use.

This paper examines a conflict regarding inland fisheries in the Pantanal wetland, whereby policymakers despite having no research-based evidence, accuse local people of overfishing and driving the drastic reduction in tourist numbers coming to the region for recreational fishing. Multivariate regression is first used to deconstruct the link between tourist numbers and local fishing. The Rotational Fishing System (RFS) maps onto the Pantanal's environmental characteristics, through customary management based on exclusion of outsiders, and reciprocity among residents. This is used to analyse Moritz's proposed concept of Management of Open Access (MOA). Management implications of unfishable reserves, unpredictable dynamics, and associated dynamics of reciprocity and territoriality are discussed.

MATERIAL AND METHODS

Study Site

The Pantanal is one of the world's biggest wetlands, encompassing 160 000 sq.km over three countries (Keddy et al. 2009). The annual flood pulse takes 3–4 months to pass from north to south, due to the slight gradient (2–3 cm/km north to south; 5–25 cm/km east to west) (Assine et al. 2006; Padovani 2010; Junk 2011).

The Pantanal catchment receives very variable precipitation: annual flood size and extent can range from 11,000-110,000 sq.km (Hamilton et al. 1996). The Annual Hydrologic Index (AHI) represents the sum of all daily Paraguay River water levels (in meters) measured at Ladário Port in each given year, capturing with great accuracy annual variation in flood size (Mourão et al. 2010).

The exact beginning and end of the flood period, and also its duration differ from year to year, with differences of more than one month between years in the timing of peak flood and dry periods in any site (Junk et al. 2011). For instance, in 2014, the flood reached its peak at a specific location 42 days before it did in 2012 at the same place, and was higher than the 2013 and 2012 floods (Brasil 2016).

Local fishermen, tourists and enforcement over fishing

Non-indigenous families have been established in the Western Border of the Pantanal for over 150 years (Neuburger and Silva 2011) deriving from intermarriage between ex-slaves, Paraguayans and remaining local indigenous families (Silva and Silva 1995). Living throughout the flooded areas, they undertake a variety of livelihoods, mainly focused on fishing, with some "pantaneiros" (swamp people) already recorded as selling salted fish in Corumbá city in the early nineteenth century (Silva 1986).

For the last 40 years, local fishermen have been under constant pressure to stop fishing, with decision-makers, environmentalists and local businessmen accusing them of overfishing (Silva 1986; Maymone 2015), some maintaining that there is no customary management that could promote sustainable use (Franco et al. 2013). Restrictive laws focused on single species and gears types have been imposed to reduce assumed impacts (Figure 1).

In Mato Grosso do Sul (MS), Southern Pantanal (Catella et al. 2014), three different laws were passed between 1983 and 1994 forbidding the use of all fishing nets. In the Northern Pantanal, Mato Grosso state (MT) banned fishing nets in 1987. At the same time, a new tourism fishing business emerged in the region, rapidly becoming one of the most important inputs into the local economy, generating an estimated USD 150 million per year (Girard and Vargas 2008). By 1999, in MS (the only state where they record annual data), 59,000 tourists per year were coming to fish in the region (Catella et al. 2014).

In face of the new restrictions, local fishermen were driven to seek alternative livelihoods in the nearby cities or locally (Amâncio et al. 2010), with many starting to work for the tourism trade, as guides to fishing spots (piloteiros) or bait suppliers (Catella et al. 2014). The small lungfish Tuvira (*Gymnotus sp.* 2-42cm) became the most important bait (50.1% of all bait gathered in the Pantanal in the 1990s: Moraes and Espinoza 2001). The Pantanal crab (*Dilocarcinus pagei* 5-10cm), represented 34.2% of the total bait gatherers' catch during the same period (Moraes and Espinoza 2001).

However, after a few years, tourism started to decline. In MS, numbers dropped to roughly 15,000 people/year by 2006 (Catella et al. 2014). Local companies claimed that there were no tourists because there were no fish, reviving the narrative of local small-scale commercial fishermen's overfishing. They supported tougher enforcement, especially for some big fish species and over the use of different fishing gears by local people (Catella et al. 2014). Meanwhile, policymakers established new

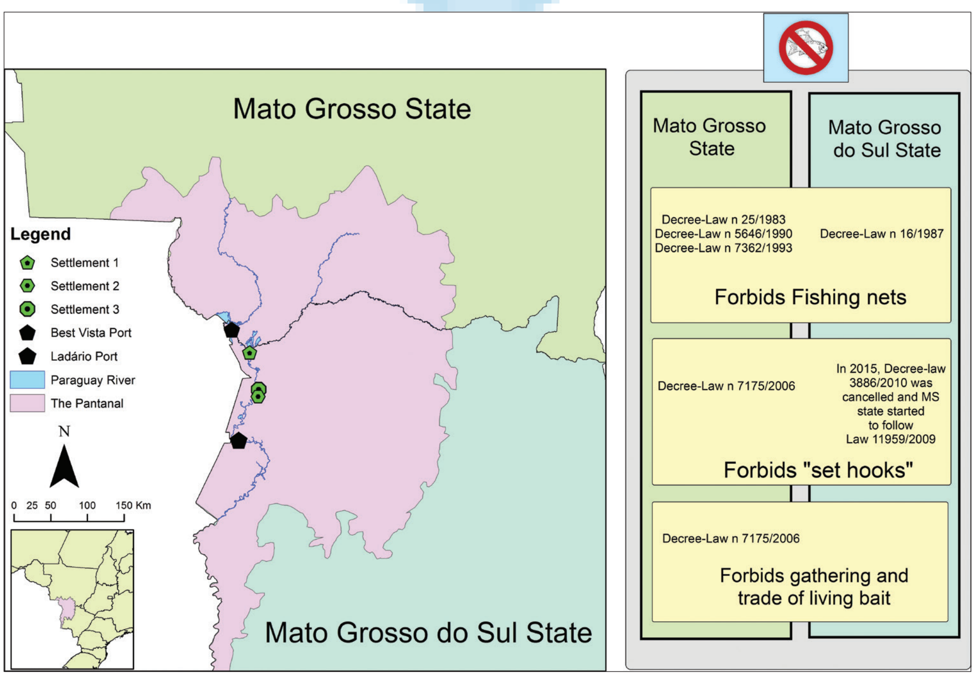

Figure 1
Location of the Pantanal and the states of Mato Grosso (MT) and Mato Grosso do Sul. The table on the right shows the different legislations for each state imposing restrictions on small-scale commercial fishing

fishing rules for all stakeholders. In both states, tourists saw a 5cm increase in minimum legal fish size for the two fish species tourists most commonly catch: Pacu (*Piaractus mesopotamicus*) in 2000 and Pintado (*Pseudoplatystoma fasciatum*) in 2006 (Catella et al. 2014). The tourist fish quota was reduced from 30kg to 25kg per person in 2000, to 12kg in 2002, to 0kg in 2003, then increased to 10kg in 2007 (Catella et al. 2014). Local fishermen were even more severely restricted, with the 2006 MT prohibition of "anzol de galho" (set hooks) and ban on gathering live bait (Catella et al. 2014). "Anzol de Galho" represents the most important fishing technique in the region, allowing fishermen to set several fishing gears at the same time. In 2014, the Brazilian Federal Supreme Court banned this technique throughout the Pantanal on the basis of the great damage it causes in supposedly already overexploited fishing stocks (Maymone 2015). Although this new law has not been fully implemented, legally, today, commercial fishermen in the Pantanal can only use line and hook; and those who continue to gather bait may only do so in the southern Pantanal (Catella et al. 2014; Maymone 2015) (Figure 1).

Data Collection and Analysis

One year of qualitative data collection was undertaken with local stakeholders in the Western Border of the Pantanal (April 2014 to March 2015). Today, around 600 people within 70 families live in this region (Amâncio et al. 2010), clustered in three main settlements (Figure 1). Field trips were undertaken in dry (April-June, 2014), flood (August – October 2014), and closed fishing seasons (November / 2014 – February – March[1] / 2015).

Participant observation in gathering bait, fishing, logging, collecting manioc, cooking and cleaning fish, helped understand local patterns of land tenure, access, and natural resource use.

Semi-structured interviews focusing on current and historical resource use were carried out using prints of new Brazilian Rapid Eye satellite images (5-metre resolution, 1:20 000 scale). All maps were printed on laminated paper, which people could draw on, easily erase, and then draw again. After each interview, pictures of locally-created maps were taken and information on the maps then erased.

In total, 45 fishermen were interviewed, the majority of them, from Settlement 1. Moreover, ten people from the tourism trade and ten scientists, NGOs and government institutions (involved in some degree with the western border of the Pantanal) were interviewed.

Lastly, two families agreed to use handheld GPS to record their daily activities and boat or canoe tracks. Individually-adapted versions of Sapelli software were installed in each GPS, allowing fishermen to record their geographic position, time and type of resource use during activities throughout the year (Lewis 2007). This produced a descriptive spatial analysis of use and mobility which are fundamental features of the local fishing system. Spatial environmental data were based on reference images from 2010 Landsat 5 TM satellite on a scale of 1:50 000 (Rosa et al. 2009).

To test whether overfishing drives tourist decline, the variance in MS tourist numbers (1994-2013) was analysed with respect to:

- Annual hydrologic index (AHI) from 1993 till 2012 calculated using the equation explained in Mourão et al. (2010) and data from (Brasil 2016) (a proxy for fish availability: Welcomme 1999)
- Increase in 5cm of the minimum legal fish size for Pacu (*Piaractus mesopotamicus*) in 2000 and for Pintado (*Pseudoplatystoma fasciatum*) in 2006; the two fish most commonly caught by tourists (Catella et al. 2014)
- Decrease in tourists' fish quotas from 30kg to 25kg in 2000, to 12kg in 2002, to 0kg in 2003, and its subsequent increase to 10kg in 2007 (Catella et al. 2014).

The first step in this analysis, tested for auto or partial correlation in tourist numbers among years. Individual tourists may have visited the Pantanal in consecutive years and been double-counted due to the visitor record system, which can bias the results of time series analyses (Metcalfe and Cowpertwait 2009).

The model established that tourist numbers coming to the Southern Pantanal was significantly autocorrelated for the first three years of the dataset (1994-1996). After this, each previous year explained no more than 17% of the variance in the number of tourists coming to the region, and was not a statistically significant influence. Moreover, there was no significant partial autocorrelation in any year. Based on this, all subsequent models were underpinned by the assumption that the possible double-count in the tourist numbers does not bias the results of time series analysis.

A nested model was then built, with a dependent variable number of tourists/year 1994-2013 (data for southern Pantanal); explanatory variables being minimum legal fish sizes, quotas for the same years and AHI for the previous year (Welcomme 1999) Backward simplification was used to find the best model (Calcagno and Mazancourt 2010). Then, to verify significant differences, all models were compared using analysis of variance. Finally, the residual distribution of the best model was verified, as a measure of goodness of fit. All analyses were carried out in R 3.2.3 (R Core Team 2015).

RESULTS

Drivers of change in the number of tourists among years

The best model explaining annual variation in tourist numbers considered changes in minimum legal size for Pacu and Pintado, and tourist quotas. Flood size did not emerge as an important explanatory variable. The best model explained 88.3% ($p = 1.14e\text{-}07$) of the variance in tourist numbers through the following formula:

Number of Tourists = 41726 + (-3,217.7) *(Pintado minimum size) + (-2,914.1) *(Pacu minimum size) + 295.0 *(Tourist quota)

In other words, for each increase of one centimetre in the minimum legal size of Pintado, there was a decrease of 3000 tourists. A comparable change in Pacu minimum legal size led to a further decrease of 3000 tourists and, finally, each kilo added to the tourist quota, increased the number of people coming to fish in the Southern Pantanal by almost 300. Fish availability as represented by flood size made no significant change to tourist numbers visiting the Pantanal.

Fishermen and customary management practices

In Settlement 1, three extended families comprised 22 nuclear families totalling 71 people. 95% informants identified as fishermen, 44% mainly gathering bait to sell to tourism companies and 56% catching large-bodied fish species to sell in city markets. Some switch between the two depending on demand for and quantity of fish and bait. With the support of grassroots human rights organisations, Settlement 1 created a formal association to have a say in government decisions. However, local informants said although the local association president is invited to participate in public discussions, such as fishing policies, she frequently does not go, due to the distance from the settlement to the city. Moreover, part of the group depends on bait trade and some avoid any argument with tourism companies, "to keep a good relationship with them" (informant 1). Therefore, most fishing legislation is established without consultation of fishermen.

Qualitative and quantitative data showed that fishermen, whether gathering bait or fishing, follow the flood pulse drawdown throughout the year. Figure 2 shows all points of use, boat tracks and zones collected during fishing and gathering bait activities in 2014 for Settlement 1. These is divided into three main phases (Figure 3).

However, according to local people, 2014 was atypical. Apparently, in 2012 and 2013 the fishing season did not finish around the settlement. Instead, there was a fourth phase: "in the last two years we finished the gathering season in Ranca Rabo Bay" (roughly 14 Km river distance south from settlement 1 – Figure 3, Informant 1). Areas around the settlement were already too dry by the end of 2012 and 2013 fishing seasons and fishers moved south to where the drawdown was still taking place. During 2014, areas took longer to dry out, so fishing did not move further south at the end of the fishing season.

In each of the 3-4 zones of the RFS, there is a continual turnover of fishing sites. People continually check whether new spots are worth fishing. People stay in each spot anywhere from 2 days to 2-3 weeks, depending on the flood and its site-specific consequences. Using the ecosystems types map produced by Rosa et al. (2009) (1:50 000 scale), 88 different bays and river channels were formally identified as in use. People constantly share information about good fishing or gathering spots in the following way–a group of fishermen or bait gatherers go to a fishing or bait gathering site while a few others try new areas. If someone finds a better place, s/he informs the others, and everyone moves there. This is constantly repeated during the fishing season. Throughout the year, this moving process creates 3-4 phases of the RFS along with a spread of sites within any one phase.

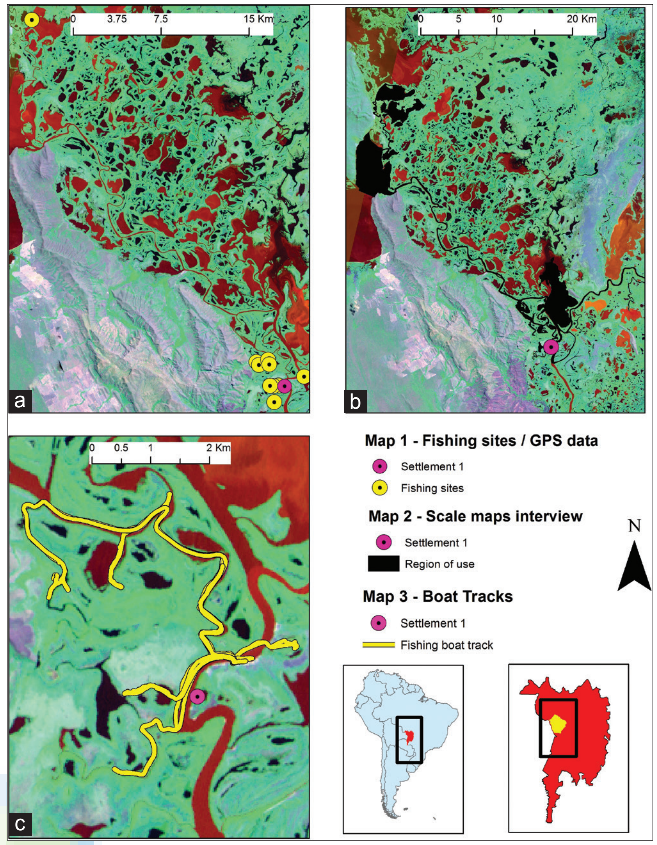

Figure 2
The three maps show the spatial data collected in Settlement 1 about fishing and gathering bait. Top left (a), data from handheld GPS. Top right (b), data from semi-structured interviews. Bottom (c), data from GPS trackers. Inset: location of the Pantanal in South America (left) and location of the study area in the Pantanal (right)

Information about good locations is shared during several ice tea drinking sessions held each day ("tereré"). People tend to not hide such information, establishing a sense of reciprocity. During this study, some families received visitors for over five ice tea sessions/day primarily to discuss good fishing spots. Visiting other people's houses is a way to build trust and inspect their catch. The tea sessions are an adaptation for optimising resource use in the context of on-going change in natural resource distribution.

Customary and natural restrictions on fishermen resource use

The openness and reciprocity showed by Settlement 1 members towards co-residents does not extend to outsiders. People from all three settlements studied were very clear about boundaries that groups from other settlements need to respect: "my uncles from the North Pantanal came to the Settlement 1 […] after a week when fisher folks realised they were going to live here, people started to come and say they should leave […] there was no way to argue against it, they had to leave" (informant 1). The same sense of territory was conveyed by informant 21 from Settlement 2 talking about Settlement 3: "when I go

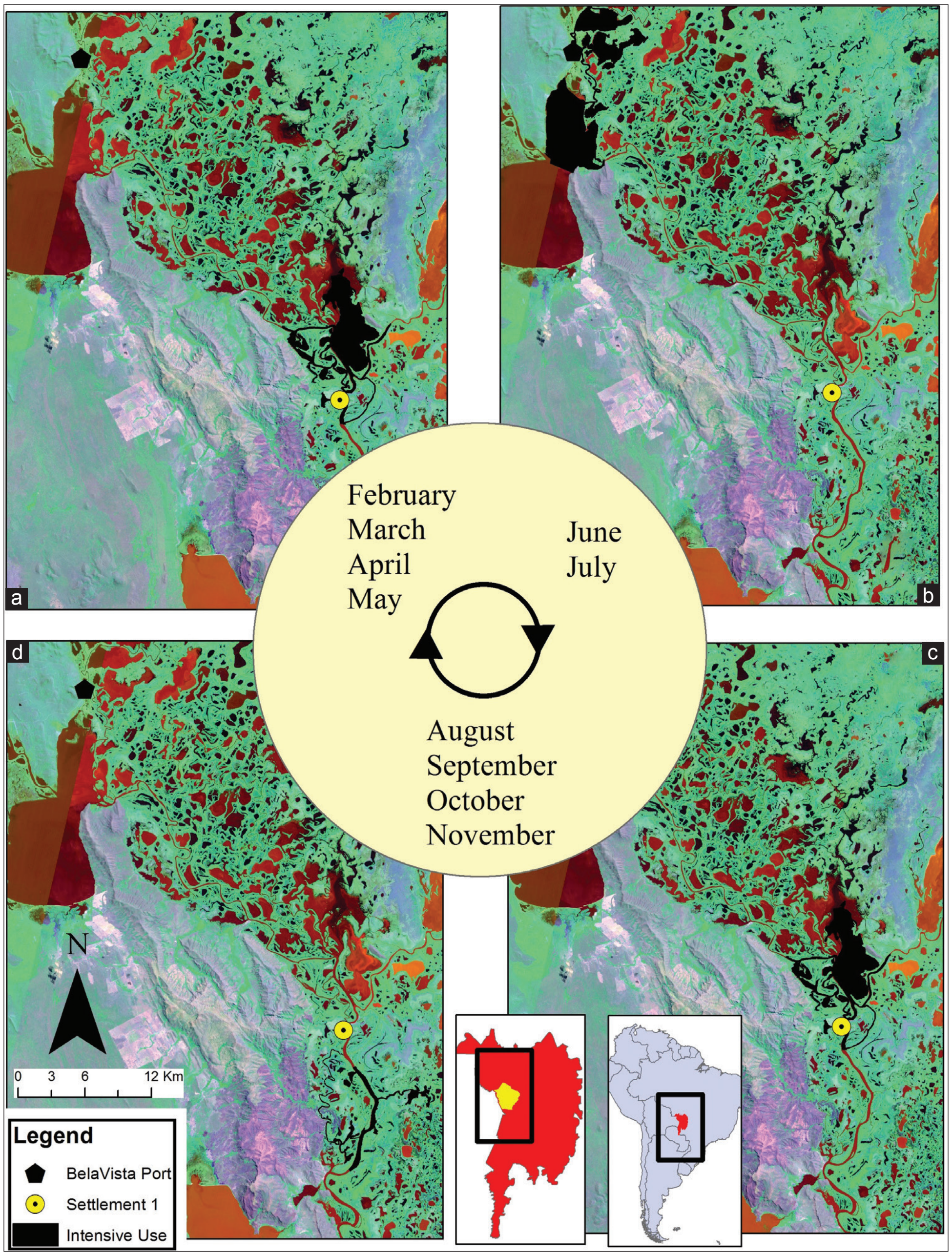

Figure 3
Fishing effort for Settlement 1. Fishing sites are shown in black. Clockwise from top left (a) February-May 2014. (b) June-July 2014. (c) August -November 2014. (d) October – November 2012-2013. Inset: location of the Pantanal in South America (right) and location of the study area in the Pantanal (left)

there to play football I feel like I am in the United States, they speak differently, behave differently, as soon as I finish I run back home".

Using satellite images from the region, it became clear that people tend to not recognise river channels and oxbow lakes from regions other than their own on the map. For instance, when Informant 19, from Settlement 3, saw a satellite image of his territory, he identified dozens of places of use, however, when shown a second map on the same scale but from Settlement 2, he drew a line with his finger and said "this is another group's area, I do not go there, I do not know the names". There are two possible explanations: either he really does not know these places or he professed a lack of knowledge through respect for the local rules. Either way, these boundaries, invisible to outsiders, are real and important for local people.

People from Settlement 1 were able to indicate on the maps what they call "their" area, and demarcate the limit beyond which someone from another settlement cannot fish. People included areas of man-made mounds, cemeteries, river shortcuts, and clean water sources. Figure 4 shows an approximation of what they drew, with some important caveats. First, the idea of fixed boundaries is not part of their understanding. Thus, depending on each year's flood, some places may be newly included within or excluded from their territory. Moreover, the shape was outlined by members of the three extended families living together in Settlement 1, which joined after conservation-induced displacement in the 1980s and 1990s caused by the Protected Areas being established (Chiaravalloti 2016). Therefore, this shape is at least, in part, a consequence of that management intervention. With all these caveats in mind, the area defined as Settlement 1's territory covers 33,651 ha, mostly water bodies and flooded vegetation (Figure 4).

Although restrictions on use are enforced and constantly reaffirmed between settlements, tourists who come to fish do not respect such boundaries. The tourism trade uses the entire floodplain area indiscriminately without regard to customary tenure and access arrangements. However, local people do not seek to restrain tourist use either, possibly due to their dependence on the bait economy.

Changes in connectivity between areas, through river channel changes or floating vegetation blocking off passages, are factored into people's livelihood adaptations. "Observing nature, you can see that it builds and destroys itself. The forest appears and disappears. It is how the Pantanal works" (Informant 10). Figure 5 illustrates such changes through a sequence of satellite images of the same bay near Settlement 1, taken in 2008, 2011 and 2013. In 2008, the bay in the right is open and connected with a second bay in the middle of the image. In 2011, it started to lose its connection with the middle bay. Finally, in 2013, a thick body of aquatic vegetation closed the link between them. After that local people ceased using the bay. A 2014 bait gatherer boat track shows it was still closed. Back in 2008, it was likely that they were using the bay for bait and fish. A similar process occurs in the river channel on the left side of the image. Between 2008 and 2013 the river channel becomes clogged, especially to the south. The main strategy when facing a blocked area is to find a new fishing spot nearby. This protects fish assemblages from use for a time, creating dynamic and flexible natural reserves in the Pantanal floodplain.

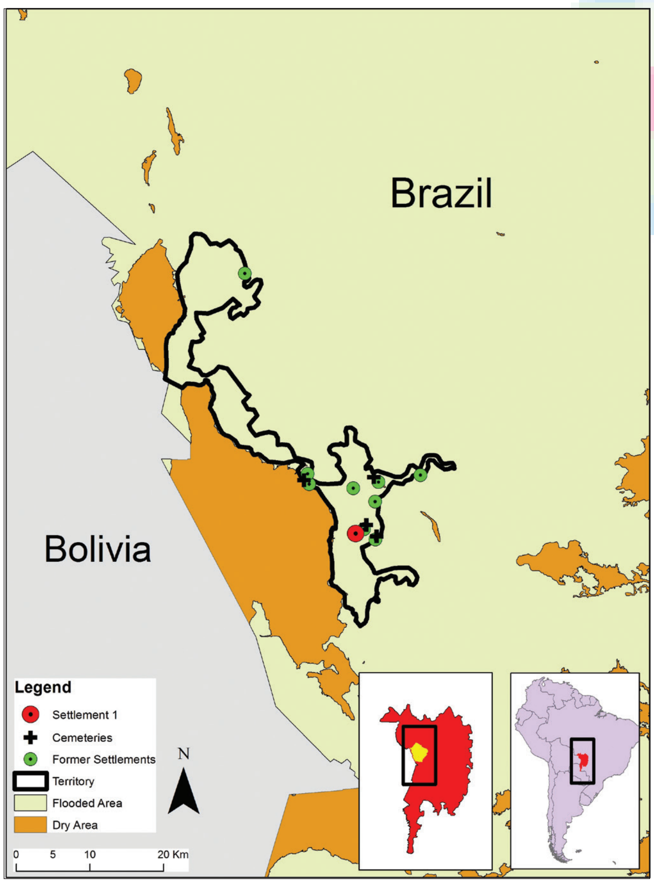

Figure 4
Territory defined by local people from Settlement 1. Inset: location of the Pantanal in South America (right) and location of the study area in the Pantanal (left)

DISCUSSION

Understanding small-scale inland fisheries better is fundamental to proposing management practices more in tune with local realities, and more likely to work. For many years, assessments of small-scale inland fish catches, their economic importance and any conservation efforts have simply replicated models derived from industrial marine practices for coastal areas. However, the two socio-ecological systems are very different, and tools created for one are unlikely to fit the other (Cochrane 2011; Kolding and Van Zwieten 2014; Cooke et al. 2016), leading potentially to suboptimal management practices and myopic views of environmental changes. Pantanal fishermen undertake a RFS structured by customary and natural restrictions, using local knowledge to adapt to unpredictable changes in resource distribution. Building on the assumption that Pantanal tourist numbers decreased because of overfishing, policymakers created restrictive laws. However, this study suggests the assumed link is misconceived. Variation in tourist numbers is instead primarily attributable to changing tourist fishing policies.

It is important to explore, in further detail, the idea of overfishing in small-scale inland fisheries. Though not directly assessed by this research, overfishing is an intrinsic part of the environmental narrative in the Pantanal and in many other small-scale inland fisheries (Allan et al. 2005). In the case of the Pantanal, no long-term or spatially extensive data exist on fishing in relation to fish production. Fish population studies using Maximum Sustainable Yield (MSY) calculated for individual species showed no damage to the stocks (Mateus et al. 2011). However, this method is ill-adapted to deal with the social-ecological complexities of multispecies inland fisheries (Lorenzen et al. 2016). In many inland systems, fishing pressure leads to replacement of larger by smaller individuals or a shift from long-lived to short-lived species (Allan et al. 2005; Castello et al. 2013), making it difficult to detect environmental impacts until collapse is underway (Welcomme 1999). In the face of such unpredictability, complexity and obstacles to evaluation and where, as a result, no robust understanding exists of fishing impacts on the whole fish assemblage, approaches to local sustainability should be based on fostering adaptive management through local-level

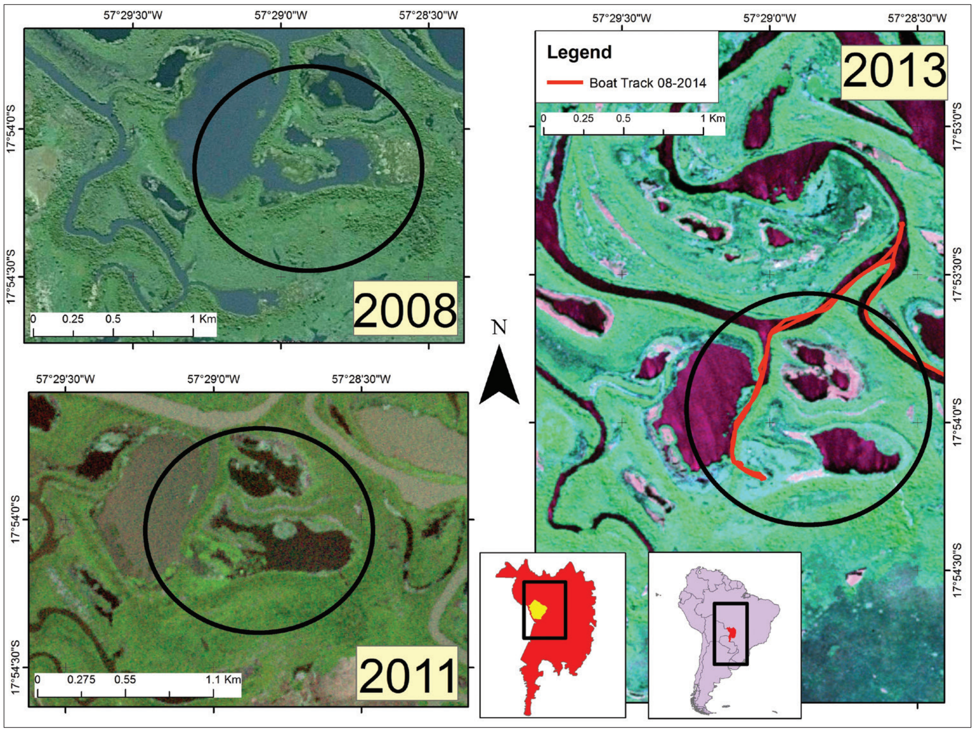

Figure 5
The three figures show images from the same bay and river channel near the Settlement 1 in 2008, 2011 and 2013. Inset: location of the Pantanal in South America (right) and location of the study area in the Pantanal (left)

self-governance and co-management, building on traditional ecological knowledge, and traditional governance structures (Cooke et al. 2016). In the Pantanal wetland, policymakers instead enforced top-down fishing restrictions targeting a few species, limiting the use of alternative gears by local people and denying local knowledge and management practices. This drove local fishermen to migrate out or seek alternative livelihoods locally and undermined the local economy, reducing almost tenfold the financial input of one of the most important businesses in the region (Moraes and Seidl 2000; Girard and Vargas 2008; Catella et al. 2014).

Setting up management rules and legislation to avoid local people's assumed environmental impacts, continually reappears around the developing world despite the frequent lack of scientific evidence (Abbott and Campbell 2009). For instance, Amazonian rainforest communities have been accused of depleting Brazil nut trees through commercialization of its nuts, justifying local people's displacement from their original areas (Peres et al. 2003). This view is contested by anthropologists showing that Brazil nut extractors help spread the seed and promote conservation of a tree in decline due to the Pleistocene Megafauna extinction (Shepard-Jr and Ramirez 2011). However, rigorous deconstruction of environmental narratives calls for rarely achievable long-term, large-scale research projects elucidating complex environmental drivers, pressures and multi-dimensional responses (Ostrom 2009). The approach used here looks at the link, not the in-depth biophysical details, and offers a simpler first step to analyse such narratives, requiring fewer data helping avoid the problematic consequences of poorly-conceived management practices.

While many agree that management practice should be based on traditional knowledge and use, there is little information on these customary use arrangements in small-scale inland fisheries (Adger and Luttrell 2000; Allan et al. 2005; Cooke et al. 2016; Dixon and Carrie 2016). This study goes some way to address that gap. It also contributes to the emergent debate on property regimes and sustainability in floodplains (Moritz et al. 2014).

Fishermen from Settlement 1 use drawdown areas as these emerge. Hence, they focus their fishing effort on regions where: 1) the big fish migrate from the floodplain to the main river and its channels 2) Tuvira (*Gymnotus* sp.) move to the floodplain and lakes and, and 3) Pantanal crabs (*D. pagei*) migrate to the aquatic macrophytes after having reached the end of their reproductive cycle on the riverbank (Resende 2011). This RFS is very similar to mobile systems used by other communities around the developing world, hailed as displaying sustainable management for Non-Timber Forest Products (Assies 1997), grazing (Kothari et al. 2013), fishing (Berkes 2006), agriculture (Sunderlin et al. 2005), and bushmeat hunting (Kümpel et al. 2009), in line with the biological principles of metapopulation dynamics (Hanski 1998). Ideally, mobile exploitation helps avoid exhaustion of natural resources and allows different species populations to recolonize the areas that have been used (Wilson et al. 2013).

A second important feature is that local people from the same settlement tend not to secure individual areas of use. They know that the distribution of resource is continually shifting, and that securing a specific area does not guarantee long-term income. Instead, local people uphold the idea that the floodplain is for public good and should have no boundaries, expressed through their constant 'fishing practices' sharing in tea drinking sessions. This constitutes a clear parallel with the paradox of pastoral land tenure (Fernandez-Gimenez 2002), whereby pastoralists need secure access to pasture and water, but also flexibility in resource use to deal with inter and intra-annual changes in local resource availability. Fernandez-Gimenez (2002) points out that high unpredictability calls for high levels of mobility and reciprocity. The same paradox extends to small-scale inland floodplain fisheries facing similar unpredictability, and management should take this into account.

In principle, the parallel with the paradox of land tenure, could place this socio-ecological system as a case of the newly-coined category Management of Open Access (MOA) (Moritz et al. 2013). MOA is argued to be the result of the interaction between movement and open access. This property regime leads users to adjust their distribution in relation to habitat quality so that each individual optimizes their own rate of acquisition of resources, leading to patterns of distribution proportional to resource availability; minimizing competition and maximizing access to and use of resources (Moritz et al. 2014). These authors make an analogue with the ecological theory of Ideal Free Distribution, the assumption that animals are free to go where they will do best and that they have complete information about resource availability (Kennedy and Gray 1993). The outcome is a sustainable socio-ecological system in balance with resource availability (Moritz et al. 2014; Xiao et al. 2015). However, for the Pantanal case study, besides reciprocity and mobile use, both sociocultural and biophysical restrictions shape local use and militate for sustainability. Each settlement has its own territory, with clear notions as to numbers of people allowed access, who controls use of specific spots and with whom each person shares information about such spots (Agrawal 2001). Moreover, the simple closing off of bays and river channel entrances by floating vegetation mats can turn water bodies into naturally unexploitable refuges for aquatic species. These natural no-take areas are postulated to be the main reason why Yacaré caiman (*Caiman yacare*) never faced any real extinction threat, even in the 1980s (Mourão et al. 2000), when at least 1 million animals were poached every year (David 1989). Some Yacaré caimans (*C. yacare*) were living in microhabitats that could not be effectively accessed, allowing them to reproduce, (Mourão et al. 1996). Then, in the wet season, animals from hard-to-hunt refuges dispersed into hunted areas, recolonising them and re-establishing a wider population. In East Africa, a comparable model was proposed to explain the sustainability of pastoralist societies around Lake Baringo. There, the lake's flood pulse created reserves that were [un]grazeable for several months each year, protecting the system as whole from overuse (Homewood 1994; Homewood and Rodgers 1988; Sullivan and Rohde 2002). Theoretical models showed how [un]grazeable reserves may underpin sustainability of grazing lands (Noy-Meir 1975). Fisheries in the Pantanal similarly incorporate no-take areas (unfishable reserves) created by biophysical landscape-level changes, blocking the river and oxbow lake entrances, protecting the whole floodplain from overfishing. This dynamic is likely to characterize other floodplain fisheries (Adger and Luttrell 2000) creating biodiversity refuges and guaranteeing socio-ecological sustainability. The Pantanal fishery described here is sustainable not because of the combination of open access and movement, but as a classical common property regime (Ostrom 2009) with region-specific features, in which excluding access by outsiders, while fostering free internal movement by residents, alongside the patch dynamics of fauna refuges, is likely to guarantee sustainable use.

Other studies seeking empirical evidence for MOA found similarly inconclusive results. Behnke et al. (2016) showed that, although pastoralists in Turkmenistan could be partly seen as MOA, historical and economic factors both shape movement and reciprocity. They argue that different historical property regime layers and ongoing interactions need to be taken into account. Beitl (2015) similarly, shows that Ecuador's Cockle Fishers share an ethos of open access among themselves, however, they quickly display a sense of territory and common property regime when their area is threatened by shrimp farmers. This suggest some socio-ecological systems may appear to operate as a MOA. However, when historical, economic, ecological and anthropological factors are considered, underlying Common Property Regime systems emerge, challenging the concept. This case study shows the importance of a nuanced understanding of property regimes, with sustainability due to multiple specific interacting factors, not to any specific property regime category (Dietz et al. 2003).

Environmental unpredictability, high levels of mobility and a great range of types of use are important drivers of sustainability in small-scale inland fisheries, especially on floodplains (Fernandez-Gimenez 2002; Abbott and Campbell 2009; Beitl 2015). Moreover, the paradox of land tenure in mobile resource use and the existence of flexible natural reserves created by biophysical processes as part of ecosystem dynamics is normally overlooked in management prescriptions. The Pantanal exemplifies a type of dynamic socio-ecological system, which calls for flexible tenure and access and adaptive management practices.

CONCLUSION

This paper has presented an in-depth and interdisciplinary analysis of environmental narratives and small-scale inland fisheries management. Statistical analysis deconstructs the claim that tourist numbers declined in the Pantanal due to local fishermen's impact on local fish stocks and pioneers an alternative approach to evaluating environmental narratives where in-depth data are lacking. Local fishermen's adaptive strategies of reciprocity and territoriality alongside, shifts biophysical restrictions in this dynamic ecosystem challenging the usefulness of the MOA concept. Finally, this paper highlights important ecological features of wetlands: flood pulse and naturally unexploitable refuges are fundamental to their socio-ecological sustainability. The hope is that these findings will help shape better future management policies in the Pantanal and other inland floodplain fisheries systems.

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NOTES

1. The closed fishing season ends in March for fishing and February for gathering bait.

REFERENCES

Abbott, J.G., and L.M. Campbell. 2009. Environmental histories and emerging fisheries management of the Upper Zambezi River Floodplains. *Conservation and Society* 7(2): 83–99.

Adger, W.N., and C. Luttrell. 2000. Property rights and the utilisation of wetlands. *Ecological Economics* 35: 75–89.

Agrawal, A. 2001. Common Property Institutions and Sustainable Governance of Resources. *World Development* 29(10): 1649–72.

Allan, J.D., R. Abell, Z. Hogan, C. Revenga, B.W Taylor, R. L Welcomme, and Kirk Winemiller. 2005. Overfishing of Inland Waters. *Bioscience* 55(12): 1041–51.

Almeida, O.T., K. Lorenzen, and D.G. McGrath. 2002. *Impact of Co-Management Agreements on the exploitation and productivity of Floodplain Lake Fisheries in the Lower Amazon.* Proceedings of the 9th Biennial Conference of the International Association for the Study of Common Property, no. 2: 12.

Amâncio, C.O.G., R. Amâncio, R. Toniazzo, D. Botelho, and L.A. Pellegrin. 2010. Caracterização Socioeconômica da Comunidade do Amolar, Sub-Região do Paraguai, Corumbá, MS. *Boletim de Pesquisa e Desenvolvimento* 92:1-6.

Assies, W. 1997. The extraction of non-timber forest products as a conservation strategy in Amazonia. *European Review of Latin American and Caribean Studies* 62: 33–53.

Assine, M.L., H.A. Macedo, J. C. Stevaux, I. Bergier, C.R. Padovani, and A. Silva. 2015. Avulsive Rivers in the Hydrology of the Pantanal Wetland. In: *Dynamics of the Pantanal Wetland in South America*. (eds. Bergier, I. and M.L. Assine). 1st edition. Pp. 83-110. New York: Springer.

Behnke, R., S. Robinson, and E.J. Milner-Gulland. 2016. Governing open access: livestock distributions and institutional control in the Karakum Desert of Turkmenistan. *Land Use Policy* 52 (March): 103–19.

Beitl, C.M. 2015. Mobility in the mangroves: catch rates, daily decisions, and dynamics of artisanal fishing in a coastal commons. *Applied Geography* 59: 98–106.

Béné, C. 2009. Are fishers poor or vulnerable? assessing economic vulnerability in small-scale fishing communities. *Journal of Development Studies* 45(6): 911–33.

Béné, C., R. Arthur, H. Norbury, E.H. Allison, M. Beveridge, S. Bush, L. Campling, et al. 2016. Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. *World Development* 79: 177–196.

Berkes, F. 2006. From community-based resource management to complex systems: the scale issue and marine commons. *Ecology and Society* 11(1): 45.

Brasil, Marinha do. 2016. Capitania fluvial do Pantanal. https://www.mar.mil.br/cfpn/. Accessed on March 2, 2016

Calcagno, V. and C. Mazancourt. 2010. Glmulti: an R package for easy automated model selection with (generalized) linear models. *Journal of Statistical Software* 34(12): 1–29.

Castello, L., D.G. Mcgrath, L.L. Hess, M.T. Coe, P.A. Lefebvre, P. Petry, M.N. Macedo, et al. 2013. The vulnerability of Amazon Freshwater Ecosystems. *Conservation Letters* 6(4): 217–29.

Catella, A.C., S.P. Albuquerque, F.L.R. Campos, and D.C. Santos. 2014. Sistema de Controle da Pesca de Mato Grosso Do Sul SCPESCA/MS - 20 - 2013. *Boletim de Pesquisa e Desenvolvimento* 127: 57.

Chiaravalloti, R.M. 2016. Is the Pantanal a pristine place? conflicts related to the conservation of the Pantanal. *Ambiente & Sociedade* 19(2): 305–8.

Cochrane, K.L., N.L. Andrew, and A.M. Parma. 2011. Primary fisheries management: a minimum requirement for provision of sustainable human benefits in small-scale fisheries. *Fish and Fisheries* 12(3): 275–88.

Cooke, S.J., E.H. Allison, T. D. Beard, R. Arlinghaus, A.H. Arthington, D.M. Bartley, I.G. Cowx, et al. 2016. On the sustainability of inland fisheries: finding a future for the forgotten. *AMBIO* 45(7): 753–764. doi:10.1007/s13280-016-0787-4.

Costello, C., D. Ovando, T. Clavelle, C.K. Strauss, R. Hilborn, M.C. Melnychuk, T.A. Branch, et al. 2016. Global fishery futures under contrasting management regimes. *PNAS* 113(18): 5125-5129. doi: 10.1073/pnas.1520420113.

Cowx, I. G., O. Almeida, C. Bene, R. Brummett, S. Bush, W. Darwall, J. Pittock, et al. 2004. Value of River Fisheries. In: *Proceedings of the second international symposium on the management of large rivers for fisheries*. Organised by FAO Regional Office for Asia and the Pacific. eds. Robin, L. Welcomme and T. Petr. Bangkok. Pp.1:1–20.

David, D. 1989. The first meeting for caiman conservation in the Pantanal. *Crocodile Specialist Group - IUCN* 8(3): 10–12.

Dietz, T., E. Ostrom, P. Stern. 2003. Struggle to govern the commons. *Science* 302(5652): 1907–1912. doi:10.1126/science.1091015.

Dixon, A. and R. Carrie. 2016. Creating local institutional arrangements for sustainable wetland socio-ecological systems: lessons from the 'Striking a Balance' project in Malawi. *International Journal of Sustainable Development & World Ecology* 23(1): 40–52.

Dugan, P.J., C. Barlow, A.A. Agostinho, E. Baran, G.F. Cada, Da. Chen, I.G. Cowx, et al. 2010. Fish migration, dams, and loss of ecosystem services in the Mekong Basin. *AMBIO* 39(4): 344–348. doi: 10.1007/s13280-010-0036-1.

Fernandez-Gimenez, M.E. 2002. Spatial and social boundaries and the paradox of Pastoral Land Tenure: a case study from postsocialist Mongolia. *Human Ecology* 30(1): 49–78. doi: 10.1023/A:1014562913014.

Franco, J.L.A., J.A. Drummond, C. Gentile, and A.I. Azevedo. 2013. Biodiversidade e ocupação humana do Pantanal Mato-Grossense: conflitos e oportunidades. 1st edition. Rio de Janeiro: Garamond.

Girard, P. and I. Vargas. 2008. Turismo, desenvolvimento e saberes no Pantanal: diálogos e parcerias possíveis. *Desenvolvimento e Meio Ambiente* 18: 61–76.

Gray, N.J., L.M. Campbell. 2009. Science, policy advocacy, and marine protected areas. *Conservation Biology* 23(2): 460–468.

Hamilton, S.K., S.J. Sippel, J.M. Melack. 1996. Inundation patterns in the Pantanal wetland of South America determined from passive microwave remote sensing. *Archiv fur Hydrobiol* 137(1): 1–23.

Hanski, I. 1998. Metapopulation dynamics. *Nature* 396 (November): 41–49.

Holt, F. L. 2005. The Catch-22 of conservation: indigenous peoples, biologists, and cultural change. *Human Ecology* 33(2): 199–215.

Homewood, K. 1994. Pastoralists, environment and development in East African rangelands. In: *Environment and population change*. (eds. Zaba,

B. and J. Clarke.). Pp. 311–22. Oxford, UK: Oxford University Press.

Homewood, K. and W. Rodgers. 1988. Pastoralism, conservation and the overgrazing controversy. In: *Conservation in Africa: people, policies and practices*. (eds. Anderson, D. and R. Grove). Pp: 111–28. Cambridge, UK: Cambridge University Press.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. In: *Proceedings of the International Large River Symposium* (ed. Dodge, D.P). Pp 110-127. Ontário: Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Junk, W.J., C.J.D.A. Silva, C.N. Cunha, and K. M. Wantzen. 2011. The Pantanal: ecology, biodiversity and sustainable management of a large neotropical wetland. 1st edition. Sofia-Moscow: Pensoft.

Keddy, P., L.H. Fraser, A.I. Solomeshch, W.J. Junk, D.R. Campbell, M.T.K. Arroyo, and C.J.R. Alho. 2009. Wet and wonderful: The world's largest wetlands are conservation priorities. *BioScience* 59(1): 39–51.

Kennedy, M. and R.D. Gray, 1993. Can ecological theory predict the distribution of foraging animals? a critical analysis of experiments on the Ideal Free Distribution. *Oikos* 68(1): 158–166.

Kolding, J., M. Modesta, O. Mkumbo, and P. Zwieten. 2014. Status, trends and management of the Lake Victoria Fisheries. In: *Inland fisheries evolution and management – case studies from four continents* (eds. Welcomme, R., J. Valbo-Jorgenson, and A. Halls). Pp. 49–62. Rome: FAO - Fisheries and Aquaculture Technical Paper.

Kolding, J. and P.A.M.V. Zwieten. 2014. Sustainable fishing of inland waters. *Journal of Limnology* 73(1 SUPPL): 132–48.

Kolding, J., P. Zwieten, F. van, Martin, F. Poulain. 2016. *Fisheries in the Drylands of Sub-Saharan Africa.* Rome: FAO –Fisheries and Aquaculture Circular 1118.

Kothari, A., P. Camill, and J. Brown. 2013. Conservation as if people also mattered: policy and practice of community-based conservation. *Conservation and Society* 11(1): 1–15.

Kümpel, N., E. J. Milner-Gulland, G.U.Y. Cowlishaw, and J. M. Rowcliffe. 2009. Assessing sustainability at multiple scales in a rotational bushmeat hunting system. *Conservation Biology* 24(3): 861–71.

Lewis, J. 2007. Enabling forest people to map their resources and monitor illegal logging in Cameroon. *Before Farming* 2: 1–7. doi:10.3828/bfarm.2007.2.3

Lorenzen, K., I. G. Cowx, R. E. M. Entsua-Mensah, N. P. Lester, J. D. Koehn, R. G. Randall, N. So, et al. 2016. Stock assessment in inland fisheries: a foundation for sustainable use and conservation. *Reviews in Fish Biology and Fisheries* 26(3): 405-440. doi:10.1007/s11160-016-9435-0.

Mateus, L. A. F., M. M. Vaz, and A. C. Catella. 2011. Fishery and fishing resources in the Pantanal. In: *The Pantanal: ecology, biodiversity and sustainable management of a large neotropical seasonal wetland* (eds. Junk, W.J., C.J. Silva, C. N. Cunha, and K.M. Wantzen.), 1st edition. Pp. 621–47. Sofia-Moscow: Pensoft.

Maymone, G. 2015. STF considera inconstitucional lei que permitia 'abusos' nos Rios de Mato Grosso do sul. http://www.correiodoestado.com.br/cidades/stf-considera-inconstitucional-lei-que-permitia-abusos-nos-rios-do/245405/. Accessed on June 2, 2016.

Metcalfe, A.V. and P.S.P. Cowpertwait. 2009. *Introductory time Series with R. Book*. New York, NY: Springer.

Moraes, A. and L. Espinoza. 2001. Captura e comercialização de iscas vivas em corumbá, MS. *Embrapa Pantanal: Boletim de Pesquisa* 21: 38.

Moraes, A.S. and A.F. Seidl. 2000. Perfil dos pescadores esportivos do sul do Pantanal. embrapa Pantanal: *Boletim de Pesquisa* 24: 43.

Moritz, M., P. Scholte, I.M. Hamilton, S. Kari. 2013. Open access, open systems: pastoral management of common-pool resources in the Chad Basin. *Human Ecology* 41(3): 351–365.

Moritz, M., I.M. Hamilton, Y.J. Chen, and P. Scholte. 2014. Mobile pastoralists in the Logone Floodplain distribute themselves in an ideal free distribution. *Current Anthropology* 55(1): 115–122.

Moritz, M., I.M. Hamilton, A.J. Yoak, P. Scholte, J. Cronley, P. Maddock, H. Pi. 2015. Simple movement rules result in ideal free distribution of mobile pastoralists. *Ecological Modelling* 305: 54–63.

Mourão, G., Z. Campos, M. Coutinho, and C. Abercrombie. 1996. Size Structure of illegally harvested and surviving Caiman *Caiman crocodilus yacare* in Pantanal, Brazil. *Biological Conservation* 75(95): 261–65.

Mourão, G., M. Coutinho, R. Mauro, Z. Campos, W. Tomás, and W. Magnusson. 2000. Aerial surveys of caiman, marsh deer and pampas deer in the Pantanal wetland of Brazil. *Biological Conservation* 92(5197): 175–83.

Mourão, G., W. Tomas, and Z. Campos. 2010. How much can the number of Jabiru Stork (Ciconiidae) nests vary due to change of flood extension in a large neotropical floodplain? *Zoologia (Curitiba, Impresso)* 27(5): 751–56.

Neuburger, M. and C.J. Silva. 2011. Riberinhos between ecological adaptation and modernisation. In: *The Pantanal: ecology, biodiversity and sustainable management of a large neotropical seasonal wetland* (eds. Junk, W.J., C.J. Silva, C. N. Cunha, and K. M. Wantzen.) Pp. 674–94. Sofia-Moscow: Pensoft.

Neumann, R.P. 2011. Political ecology III: theorizing landscape. *Progress in Human Geography*. 35(6): 843–850. doi:10.1177/0309132510390870

Norse, E.A., S. Brooke, W.W.L Cheung, M.R. Clark, I. Ekeland, R. Froese, K. M. Gjerde, et al. 2012. Sustainability of deep-sea fisheries. *Marine Policy* 36(2): 307–20.

Noy-Meir, I. 1975. Stability of grazing systems: an application of predator-prey graphs. *The Journal of Ecology* 63(2): 459.

Ostrom, E. 2009. A general framework for analysing sustainability of social-ecological systems. *Science* 325 (5939): 419–22.

Padovani, C.R. 2010. *Dinâmica espaço-temporal das inundações do Pantanal*. Ph.D. thesis. University of São Paulo, São Paulo, Brazil.

Parsons, L.S. and J.J. Maguire. 1996. Comments on chaos, complexity and community management of fisheries. *Marine Policy* 20(2): 175–176.

Pauly, D., J. Alder, E. Bennett, V. Christensen, P. Tyedmers, and R. Watson. 2003. The Future for Fisheries. *Science* 302(5649): 1359–61.

Peres, C., C. Baider, P. Zuidema, L.H.O. Wadt, K. Kainer, D.P Gomes-Silva, R. Salomão, et al. 2003. Demographic threats to the sustainability of Brazil nut exploitation. *Science* 302 (5653): 2112–14.

R Core Team. 2015. *R: a language and environment for statistical computing*. Vienna, Austria: The R Foundation for Statistical Computing Platform.

Resende, E. K. 2011. Ecology of fish. In: *The Pantanal: ecology, biodiversity and sustainable management of a large neotropical seasonal wetland* (eds. Junk, W.J., C.J. Silva, C. N. Cunha, and K. M. Wantzen). Pp. 469–523. Sofia-Moscow: Pensoft.

Robbins, P. 2012. *Political Ecology: A Critical Introduction*. 2nd edition. Oxford: Wiley-Braclwell.

Rosa, M.R., F.S. Rosa, N. Crusco, E.R. Rosa, J. Freitas, F. Paternost, V. Mazin. 2009. Monitoramento das Alterações da Cobertura Vegetal e Uso do Solo na Bacia do Alto Paraguai. Brasília: WWF-Brasil, Ecoa, Conservation International, Avina, SOS Pantanal.

Shepard-Jr, G.H. and H. Ramirez. 2011. 'Made in Brazil': human dispersal of the Brazil Nut (*Bertholletia excelsa*, Lecythidaceae) in ancient Amazonia. *Economic Botany* 65(January): 44–65. doi: 10.1007/s12231-011-9151-6.

Silva, M.V. 1986. *Mitos e verdades sobre a Pesca No Pantanal Sul-Mato-Grossense*. 1st edition. Campo Grande: FIPLAN.

Silva, C.J. and J.A.F. Silva. 1995. *No ritmo das Águas do Pantanal*. 1st edition. São Paulo: NUPAUB/USP.

Sullivan, S. and R. Rohde. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography* 29(12): 1595–1618.

Sunderlin, W.D., A. Angelsen, B. Belcher, P. Burgers, R. Nasi, L. Santoso, and S. Wunder. 2005. Livelihoods, forests, and conservation in developing countries: an overview. *World Development* 33(9): 1383–1402.

Valley, K. and R. Freeney. 2013. Reconciling spatial scales and sock structures for fisheries science and management. *Fisheries Research* 141: 1–2.

Vollan, B. and E. Ostrom. 2010. Cooperation and the commons. *Science* 330 (6006): 923–24.

Watts, M.E., I.R. Ball, R.S. Stewart, C.J. Klein, K. Wilson, C. Steinback, R. Lourival, et al. 2009. Marxan with zones: software for optimal conservation based land- and sea-use zoning. *Environmental Modelling & Software* 24(12): 1513–21.

Welcomme, R. L. 1999. A review of a model for qualitative evaluation of exploitation levels in multi-species fisheries. *Fisheries Management and Ecology* 6(1): 1–19.

Welcomme, R. L., K. O. Winemiller, and I. G. Cowx. 2006. Fish environmental guilds as a tool for assessment of ecological condition of rivers. *River Research and Applications* 22(3): 377–96.

Welcomme, R.L, I.G. Cowx, D. Coates, C. Béné, S. Funge-Smith, A. Halls, and K. Lorenzen. 2010. Inland capture fisheries. *Philosophical transactions of the Royal Society of B*. 365 (1554): 2881–96.

Wilson, J., A. Hayden, and M. Kersula. 2013. The governance of diverse, multi-scale fisheries in which there is a lot to learn. *Fisheries Research* 141 (April): 24–30.

Young, C., S. Sheridan, S. Davies, and A. Hjort. 2012. Climate change implications for fishing communities in the Lake Chad Basin. what have we learned and what can we do better? In: *FAO/Lake Chad Basin Commission Workshop*. eds. Young, C. S. Sheridan, S. Davies, and A. Hjort. N'Djamena, Chad. 18-10 November, 2011. Rome: FAO - Fisheries and Aquaculture Proceedings 25.

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