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The return of giant otter to the Baniwa Landscape: A multi-scale approach to species recovery in the middle Içana River, Northwest Amazonia, Brazil

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ABSTRACT

Commercial hunting for the 20th century international fur trade was responsible for the collapse of giant otter populations throughout Amazonia. Some thirty years after the wildlife trade was outlawed, giant otter populations have begun to show signs of recovery. The Baniwa indigenous people from the Upper Rio Negro region of Brazil have witnessed the recovery of otter populations in areas where they had been wiped out by hunting. To evaluate the giant otter recovery process, we identified local and landscape variables contributing to the re-establishment of the species throughout Baniwa territory. We conducted transect sampling in lakes and streams in search of direct and indirect signs of giant otter occurrence. During surveys, we recorded three local variables, and through radar and satellite image, obtained six landscape variables in buffers of 250 m, 500 m and 1000 m. Using generalized linear models we identified the 250 m buffer as the most suitable scale within which to study giant otter habitat use. Connectivity between shallow and elongated waterbodies were the most reliable landscape indicators of otter population presence on the middle Içana River. Our results highlight the importance of small and connected water bodies to species recovery, a fact that should be taken into consideration in the creation of protected areas and local resource management plans. With this study we hope to contribute to the advancement of giant otter conservation strategies, as well as to an increased role for indigenous people in managing their territory and resources towards more effective biodiversity conservation.

1. Introduction

The giant otter (*Pteronura brasiliensis*) was the species most impacted by commercial hunting for the international fur trade during the mid-20th century in Amazonia (Antunes et al., 2016). High prices for their pelts (Antunes et al., 2014) as well as intrinsic biological and ecological characteristics, such as low reproductive rate and strong social organization (Pimenta et al., 2018), contributed to a low resilience which drove giant otter populations to collapse throughout the Central Amazon (Antunes et al., 2016). The species has long been considered locally extinct in many areas within its historical range (Carter and Rosas, 1997; Duplaix et al., 2015; Pimenta et al., 2018). Some thirty years after the prohibition of hunting and trade in wild animal products by national and international law, giant otter populations began to show signs of recovery in Colombia (Díaz and Sánchez, 2002), Peru (Recharte and Bodmer, 2009; Groenendijk et al., 2014) and Brazil (Rosas et al., 2007; Leuchtenberger and Mourão, 2008; Ribas et al., 2012; Leuchtenberger et al., 2013; Lima et al., 2014).

Reoccupation of hunted-out areas after local extinction occurs via the migration of individuals from metapopulations resident in refuge areas through source-sink dynamics (Joshi and Gadgil, 1991). Such refuge areas need to be sufficiently remote to be mostly free of human pressure, and contain populations close to carrying capacity (Novaro et al., 2000). The dispersal of individuals from an established population to a new area, via migration, depends on the capacity of the species for movement between habitats through the landscape (Metzger and Décamps, 1997; Schenck et al., 2003). Consequently, the way in which habitats are distributed within a landscape has implications for connectivity, and therefore, for its suitability for a given species (Lyra-Jorge et al., 2010).

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Variations in population patterns (e.g. abundance, density, encounter rate) in particular habitats may provide a way to assess species response to different landscape structures and configurations (Lyra-Jorge et al., 2010). These different conformations define the habitat requirements necessary for species establishment, and reflect a population's demographic potential, as well as the individuals' ability to move through the landscape (Metzger and Décamps, 1997; Uezu et al., 2005). High quality habitats tend to be used more than degraded ones (Garshelis, 2000). This reflects matrix permeability, and is directly related to the maintenance of the flow of individual animals (Taylor et al., 1993) - a factor essential to species persistence (Metzger and Décamps, 1997; Uezu et al., 2005; Umetsu and Pardini, 2007).

Habitat selection by a species can vary at both spatial and temporal scales. However, an erroneous or arbitrary choice of scale can result in false inferences concerning the influence of the landscape on habitat selection by a species (Chambers et al., 2016). A multiple-scale approach can help avoid such errors when analyzing the strength of the relationship between species and habitat use (Thompson and McGarigal, 2002; Grand et al., 2004; Gaillard et al., 2010; Mateo-Sánchez et al., 2013), and provide a better understanding of the role of landscape in ecological relations and processes (Neel et al., 2004; Cushman et al., 2008). In this context, variations in local characteristics of habitats occupied by giant otters (Duplaix et al., 2015) suggest some flexibility in relation to microhabitat aspects. Moreover, variations in the reported sizes of giant otter home ranges (Duplaix et al., 2015) makes it difficult to assess the appropriate scale at which to study landscape requirements for the species.

On the other hand, there is a consensus concerning giant otter dependence on healthy riverine ecosystems, such that the species is recognized as a strong indicator of environmental quality (Barnett et al., 2000). As an apex predator, the giant otter regulates its prey populations (Treves and Karanth, 2003). In consequence, their disappearance may have impacts at several trophic levels (Gittleman, 2001), which makes the giant otter a key species for the conservation of wetlands. Floodplains comprise some 30% of Amazonia, and are among the world's most threatened ecosystems (Darwall et al., 2008; Junk et al., 2014). Expansion of human occupation and exploitation of forest resources has long contributed to the degradation of these environments (Agostinho et al., 2005), representing major threats to giant otter population recovery. For this reason, the species remains classified as "Endangered" on the IUCN Red List (Groenendijk et al., 2015a). A knowledge of giant otter habitat requirements, from local to landscape scale, is crucial for maintaining viable populations and for making conservation decisions that are appropriate to both the species and the habitats it occupies.

The Upper Rio Negro remains the most well-preserved region in the Amazon, and as part of the northern Rio Negro basin, may harbor one of the largest populations of giant otters in South America (Duplaix et al., 2015). The region is also home to over twenty distinctive indigenous groups, some 10% of Brazil's indigenous cultural and linguistic diversity, who, through their political organizations and partnerships with Nongovernmental Organizations (NGOs) have developed innovative strategies for social development and sustainable management of their territories (Cabalzar and Ricardo, 2006). However, the Rio Negro basin has been targeted for large-scale development projects, including mining operations and hydroelectric dams. Laws currently under debate in the Brazilian congress such as PL 3729/2004, and the proposed constitutional amendment 215 (PEC 215/2010), would deregulate the process of environmental licensing for such projects, weaken indigenous peoples' constitutionally guaranteed land rights, and loosen the rules restricting the exploitation of resources in different categories of protected areas (Ferreira et al., 2014; Fearnside, 2016). Such policy changes would threaten both the biological and cultural diversity of the region.

The Baniwa indigenous people, who inhabit the Içana River in São Gabriel da Cachoeira municipality, Upper Rio Negro, Amazonas, Brazil, persuaded by outsiders, hunted otters and other commercially valuable species from the mid-1950s until the late 1970s, leading to a collapse of otter populations near their settlements (Pimenta, 2016; Pimenta et al., 2018). In recent decades, the Baniwa have witnessed the recovery of otter populations in areas where these animals had been wiped out by hunting. The Baniwa welcome the recovery of otter populations as a sign of general ecological health, especially with regard to fish stocks. The return of the giant otters was partly responsible for awakening within the Baniwa people an awareness of the need for a fishing management plan for the region: the use of lakes and streams need to be regulated in a way that guarantees the Baniwa's fish stocks, while avoiding damage to the giant otter's recovery process. Using the giant otter as an indicator of fish stock resources, we seek to generate information to support the Baniwa people's fishing management plan by identifying, at multiple scales, the essential environmental elements necessary for the reestablishment of giant otter populations. We hope this contribution will advance conservation strategies for otter species and Amazonian wetlands more generally, while also supporting indigenous peoples in their community-based management and conservation strategies.

2. Methods

2.1. Study area

The upper Rio Negro is located in the northwest Amazon within the Brazilian municipalities of Barcelos, Santa Isabel do Rio Negro and São Gabriel da Cachoeira, along the border with Colombia and Venezuela. The region is home to a tremendous diversity of indigenous peoples, including some twenty ethnic groups speaking languages belonging to five distinctive cultural-linguistic families (Cabalzar and Ricardo, 2006). The Baniwa people belong to the Arawakan language family and have inhabited the Içana River Basin for centuries (Wright, 2005). The Içana River Basin originates in Colombia, but most of its 696 km length occurs in Brazilian territory. Here, the Içana River runs through the Indigenous Land of the Upper Rio Negro receiving water from several tributaries (including the Aiari, Cuiari, Piraiauara and Cubate rivers), until it joins the Rio Negro (Cabalzar and Ricardo, 2006).

At its source, the Içana is a white water river, but changes color to reddish and black after receiving waters from its tributaries. This variation in the composition of its waters, soil type and human habitation history creates a diverse mosaic of landscapes and vegetation types (Shepard et al., 2004). The region has many micro-ecosystems with diverse ecological characteristics, including areas of savannah-like open forest, known in Portuguese as *campinarana* or *caatinga* (in Baniwa, *hamáliani*), upland *terra-firme* (*éedzawa*), seasonally flooded blackwater forests (*igapó* in Portuguese; *álape* in Baniwa), and secondary forests (*capoeira*; *heñame*) (Abraão et al., 2010). Our study area on the middle Içana consisted mostly of nutrient-poor sandy soils with seasonally flooded igapó forests interspersed with numerous lakes and small streams relatively abundant in fish (Shepard et al., 2004). Within the so-called "lakes region" there are some 65 km of river, along which ten Baniwa communities are currently distributed. We visited nine of these communities during the research period in 2015.

2.2. Survey of giant otter occurrence

We surveyed a total of 150 km of waterways, including 19 lakes (97.3 km) and 16 small streams (52.6 km), once each, during 22 consecutive days at the beginning of the low-water period, which is when giant otters are restricted to such permanent watercourses. Because the species is diurnal, we conducted field sampling between 6 am and 6 pm (Groenendjik et al., 2005). We traveled along the whole margin of the water body in search of direct (e.g. sightings of groups or individuals) and indirect (e.g. footprints, latrines, burrows and lay-up sites) signs of otter presence at a maximum speed of 10 km/h (Yoccoz et al., 2001;