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INFLUÊNCIA DE VARIÁVEIS ANTRÓPICAS E AMBIENTAIS SOBRE A DISTRIBUIÇÃO DE ARIRANHAS (*PTERONURA BRASILIENSIS*) EM UMA ÁREA PROTEGIDA DE USO SUSTENTÁVEL NA AMAZÔNIA ORIENTAL

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Sinopse: Este trabalho teve como objetivo avaliar e relacionar as principais variáveis antrópicas e ambientais que influenciam a ocorrência e a distribuição espacial e temporal de ariranhas (*Pteronura brasiliensis*) em uma Unidade de Conservação de Uso Sustentável na Amazônia oriental.

Palavras-chave: Mustelidae, Fatores antrópicos, sazonalidade, Unidades de Conservação, Amazônia.

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"É um rio encantado o Araguari, o Araguari, o Araguari..." (Osmar Júnior)

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RESUMO

Impactos antropogênicos que afetam a distribuição e a ecologia de ariranhas estão bem documentados, porém pouco se sabe sobre os fatores que afetam a distribuição atual das espécies. Nosso objetivo foi determinar a importância relativa de fatores ambientais (níveis sazonais dos rios) e antrópicos (presença de casas, barcos e redes de pesca) sobre a distribuição de ariranhas em torno de uma área protegida de uso sustentável na Amazônia oriental brasileira. Realizamos um total de 6.836,1 km de censo com barco motorizado a fim de georreferenciar os locais de observações diretas e vestígios indiretos da espécie ao longo de 150 km nos rios Araguari e Falsino, na Floresta Nacional do Amapá, estado do Amapá, Brasil. Para entender a importância dos fatores em diferentes escalas espaciais, realizamos as análises utilizando os dados resumidos em duas escalas espaciais: 50 km do rio, "zonas dos rios" e 5,1 km "seções dos rios". Nossos resultados mostraram contrastes nos padrões espaciais e temporais das detecções diretas e indiretas de ariranhas. No entanto, as perturbações antrópicas foram os determinantes mais importantes para presença de ambos os sinais diretos e indiretos, com detecções raras de ariranhas nos 40 km de rio mais próximos a cidade adjacente. As ariranhas estavam presentes no curso principal dos rios ao longo de todo o ciclo anual (níveis altos, decrescente, baixo e crescente) e as observações diretas da espécie se relacionaram positivamente com o número de redes de pesca ao longo do rio. Nossos resultados sugerem considerável sobreposição espacial e temporal entre as ariranhas e as atividades dos pescadores locais, desta forma os fatores quantificados neste estudo devem ser considerados para a gestão eficaz da área de proteção a fim de minimizar os conflitos homem-natureza em regiões de rápido desenvolvimento econômico e social.

Palavras-chave: Mustelidae; Fatores antrópicos; Sazonalidade; Unidades de Conservação; Amazônia.

ABSTRACT

Historic anthropogenic impacts affecting the distribution and ecology of Giant otters are well documented, however little is known regarding the factors affecting the current distribution of the species. Our objective was to determine the relative importance of temporal (seasonal river levels), and anthropogenic (presence of houses, boats and fishing nets) factors on the distribution of Giant otters around a sustainable-use protected area in the eastern Brazilian Amazon. We conducted a total of 6836.1 km of motorized boat surveys to record locations of both direct observations and indirect signs of Giant otters along 150 km Araguari and Falsino River, in National Forest of Amapá, Amapá State, Brazil. To understand the importance of the factors at different spatial scales we conducted analysis using data summarized at two spatial scales: 50 km river "zones" and 5.1 km river sections. Our results showed contrasting spatial and temporal patterns resulting from direct and indirect signs. However, anthropogenic disturbances were the most important determinants of the presence of both direct and indirect signs, with Giant otters rarely detected within 40 km of the nearest town. Giant otters were present in the waterways throughout the annual water cycle (high, decreasing, low and increasing river levels), with direct observations positively related with the number of fishing nets present in the waterways. Our results suggest considerable spatial and temporal overlap between Giant otters and the activities of local fishers which must be considered for the effective management of conservation conflicts in this rapidly developing region.

Keywords: Mustelidae; Anthropic factors; Seasonality; Protected Area; Amazon.

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INTRODUÇÃO GERAL

O aumento da população humana e os consequentes impactos antropogênicos associados têm levado um número cada vez maior de populações animais a persistir em ambientes perturbados. No entanto, atividades humanas podem interferir significativamente na fauna silvestre, alterando o comportamento natural (Silva e Best, 1996; Duplaix, 2002; Thomas *et al.*, 2003; Rees *et al.*, 2005), sucesso reprodutivo (De la Torre *et al.*, 2000; Arrojo e Razin, 2006) e a fisiologia de muitos organismos (Romero e Wikelski, 2002).

Além disso, o avanço da população humana para áreas cada vez mais remotas tem aproximado cada vez mais homens e animais silvestres, o que pode resultar em conflitos (Redpath *et al.*, 2013), que atuam de forma aditiva e sinergética as perturbações antrópicas. Nesse estudo, conflitos são definidos como situações que ocorrem entre duas partes com opiniões divergentes sobre objetivos de conservação, ou quando espécies silvestres causam impactos sobre humanos (Redpath *et al.*, 2013). A maioria dos conflitos de conservação estão comumente associados à danos econômicos causados pela fauna à atividades humanas como a pesca, a aquicultura (Gómez e Jorgenson, 1999; Recharte *et al.*, 2008; Kloskowski, 2011; Barbieri *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012) ou a pecuária (Michalski *et al.*, 2006). Em comunidades ribeirinhas, espécies piscívoras, como os botos (Silva e Best, 1996; Loch *et al.*, 2009), jacarés (Peres e Carkeeka, 1993), lontras (Barbieri *et al.*, 2012), e ariranhas (Michalski *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012) são comumente acusados de comprometerem a produtividade pesqueira, podendo sofrer represarias diretas da população humana local (Gómez e Jorgenson, 1999; Recharte *et al.*, 2008; Loch *et al.*, 2009).

Adicionalmente, uma série de estudos também demonstrou que vertebrados sofrem efeitos diretos da variação do ambiente (Norris *et al.*, 2011; Di Bitteti *et al.*, 2013). Elevação, temperatura e pluviosidade estão diretamente ligados à estruturas de comunidades e ao comportamento de espécies. Para vertebrados aquáticos e semiaquáticos pode-se destacar o efeito dos níveis do rios, no qual muitas espécies acompanham a variação sazonal do ambiente e podem se deslocar para o interior de planícies alagadas, bem como expandir suas áreas de vida em épocas mais cheias do rio (Duplaix, 1980; Utreras *et al.*, 2005; Leuchtenberger *et al.*, 2013).

O aumento do número e da extensão de Áreas Protegidas (APs) na Amazônia brasileira tem auxiliado na redução das taxas de desmatamento nesse bioma (Soares-Filho *et al.*, 2010; Nepstad *et al.*, 2011). No entanto, a quantidade de Unidades de Conservação (UC) da categoria de uso sustentável, formalmente criadas pelo governo, tem sido maior do que as reservas de proteção integral (Peres, 2011). Desde 1991, aproximadamene 63,1 milhões de hectares de novas UCs de uso sustentável foram criadas na Amazônia brasileira, representando 51,5% da área total de áreas protegidas (excluindo terras indígenas) (Peres, 2011; Figura 1). Além disso, mesmo em áreas protegidas, perturbações crípticas podem estar ocorrendo sob o dossel da floresta (Peres *et al.*, 2006; Wilkie *et al.*, 2011). Isso pode ser especialmente verdadeiro em áreas protegidas de uso sustentável, que permitem alguma forma de uso humano. Interações negativas e conflitos entre moradores e a fauna silvestre têm sido observadas em várias reservas de uso sustentável na Amazônia ao longo dos anos (Peres e Carkeeka, 1993; Silva e Best, 1996; Silveira e Thorbjarnarson, 1999; Loch *et al.*, 2009; Dickman, 2010; Rosas-Ribeiro *et al.*, 2012).

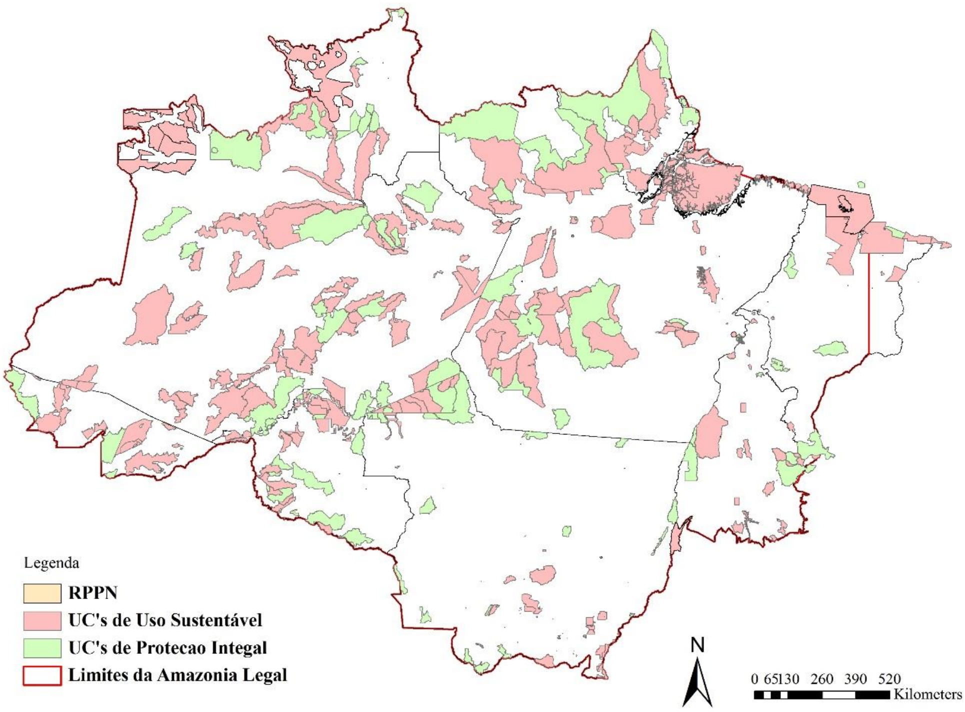

Figura 1: Mapa dos limites da Amazônia Legal indicando a localização das Unidades de Conservação particulares (RPPN’s), de uso sustentável (incluindo as terras indígenas) e de proteção integral na Amazônia brasileira.

Animais piscívoros, como as ariranhas - *Pteronura brasiliensis* (Zimmermann, 1780); Carnivora: Mustelidae: Lutrinae, são constantemente envolvidos em conflitos com humanos. As ariranhas são mamíferos semiaquáticos, endêmicos e os maiores representantes da família na América do Sul, chegando a comprimentos e pesos máximos em torno de 1,8 m e 30,0 kg, respectivamente (Duplaix, 1980; Carter e Rosas, 1997; Rosas *et al.*, 2009). É encontrada em partes das bacias dos rios Orinoco, Amazonas, Paraguai e Paraná (Duplaix, 1980). No Brasil, restringe-se à bacia amazônica e ao Pantanal, com populações criticamente ameaçadas nos estados de São Paulo e do Paraná (Rosas, 2008; Reis *et al.*, 2011). Desde 2000, esta espécie é classificada como "em perigo de extinção" na Lista Vermelha da IUCN de Espécies Ameaçadas (Duplaix *et al.*, 2008) e estudos visando a sua conservação são prioritários, por se tratar de uma espécie-chave, reguladora de cadeias tróficas.

Figura 2: Registros diretos e indiretos da espécie *Pteronura brasiliensis* na Floresta Nacional do Amapá. A) Grupo de ariranhas visualizado no rio Araguari; B) Latrina ativa na entrada de um igarapé no Rio Araguari; C) Fezes frescas em uma latrina ativa no rio Falsino; e D) Pegada recente na margem do Rio Falsino. (Fotos: Isabel Oliveira)

As ariranhas são animais territorialistas (Ribas e Mourao, 2004; Leuchtenberger e Mourao, 2009) e sociais que vivem em grupos de três a doze indivíduos (Duplaix, 1980; Carter e Rosas, 1997). Esta espécie utiliza certos tipos de planícies para a construção de seus acampamentos e latrinas, locais utilizados para a marcação de território com urina e fezes, e preferem pescar em águas rasas, associadas a igarapés (Duplaix, 1980; Duplaix, 2002) (Figura 2).

Até a década de 1970, as ariranhas foram amplamente caçadas até a quase extinção de suas populações naturais, devido ao comércio internacional de peles (Duplaix, 1980; Carter e Rosas, 1997). Atualmente, a principal ameaça à espécie é o rápido aumento da população ribeirinha e do nível de exploração dos recursos pesqueiros (Duplaix, 2002), sendo fatores como o uso de redes de pesca, a mineração e a poluição dos rios causas de mortalidade de indivíduos (Carter e Rosas, 1997; Duplaix, 2002). A sobre-exploração das margens e o constante fluxo de barcos em determinadas áreas do rio provocam o afugentamento de grupos e o consequente abandono de suas áreas de vida (Staib e Schenck, 1994; Duplaix, 2002; Rosas *et al.*, 2007) (Figura 3).

Até o momento, existem vários estudos focando no conflito entre ribeirinhos e ariranhas (Gómez e Jorgenson, 1999; Zucco e Tomás, 2004; Recharte *et al.*, 2008; Michalski *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012), bem como estudos avaliando aspectos da biologia e ecologia dessa espécie (Rosas *et al.*, 1999; Ribas e Mourao, 2004; Utreras e Pinos, 2003; Utreras *et al.*, 2005; Rosas *et al.*, 2007; Leuchtenberger e Mourao, 2009; Rosas *et al.*, 2009; Cabral *et al.*, 2010; Leuchtenberger *et al.*, 2012). Porém, a literatura ainda é carente em relação a estudos que avaliem simultaneamente os efeitos espaciais e temporais de variáveis ambientais e antrópicas sobre as populações de ariranhas na Amazônia. Além disso, com o crescimento do número de unidades de proteção de uso sustentável na Amazônia brasileira, estudos que avaliem e quantifiquem quais são os principais fatores que afetam as populações de ariranhas e quais são seus limiares são de extrema relevância.

Figura 3: Atividades humanas am ambientes aquáticos que podem influênciar diretamente as ariranhas. A) Residências ribeirinhas; B) fluxo de barcos a motor; C) redes de pesca; e D) Dragas para a mineração de areia no leito do rio. (Fotos: Isabel Oliveira)

Para entender melhor os efeitos dos impactos humanos sobre a biodiversidade em UCs de uso sustentável utilizaremos a ariranha (*Pteronura brasiliensis*) como objeto de estudo. Desta forma, este estudo pretende responder as seguintes questões: 1) Quais os efeitos das interferências antrópicas (e.g., residências de ribeirinhos, redes de pesca e embarcações) na ocorrência e na distribuição espacial e temporal dos grupos de ariranhas em uma área protegida de uso sustentável? e 2) Qual o efeito da sazonalidade (i.e., níveis dos rios) na ocorrência e distribuição espacial e temporal de ariranhas na região? Portanto, os resultados deste estudo irão gerar dados quantitativos sobre os efeitos de perturbações antrópicas e suas interações com sazonalidade que podem auxiliar o manejo de áreas de uso sustentável a fim de reduzir conflitos entre humanos e ariranhas nos neotrópicos.

OBJETIVOS

Objetivo Geral

Avaliar como variáveis ambientais e antrópicas influenciam a distribuição espacial e temporal dos grupos de ariranhas (*Pteronura brasiliensis*) em uma reserva de desenvolvimento sustentável da Amazônia Oriental.

Objetivos Específicos

1. Analisar a influência da distribuição espacial de de residências de ribeirinhas, presença de barcos e redes de pesca sobre a distribuição espacial de grupos de ariranhas;

2. Analisar os efeitos temporais da presença de barcos e de redes de pesca sobre a distribuição de grupos de ariranhas;

3. Analisar a influência da variação do nível do rio sobre a distribuição espacial e temporal de ariranhas;

4. Avaliar a importância relativa das variáveis antrópicas e ambiental (residências, barcos, redes de pesca e nível do rio) e suas interações sobre a distribuição espacial e temporal de ariranhas.

CAPÍTULO 1

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Determinants of giant otter sightings along waterways in the northern Brazilian Amazon

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Short title: Giant otter sightings in Amazonia

Abstract

Historic anthropogenic impacts affecting the distribution and ecology of Giant otters are well documented, however little is known regarding the factors affecting the current distribution of the species. Our objective was to determine the relative importance of temporal (seasonal river levels), and anthropogenic (presence of houses, boats and fishing nets) factors on the distribution of Giant otters around a sustainable-use protected area in the eastern Brazilian Amazon. We conducted a total of 6836.1 km of boat surveys to record locations of both direct and indirect Giant otter sightings along 150 km of waterways. To understand the importance of the factors at different spatial scales we conducted analysis using data summarized at two spatial scales: 50 km river "zones" and 5.1 km river sections. Our results showed that anthropogenic disturbances were the most important determinants of the presence of both direct and indirect signs, with Giant otters rarely detected within 40 km of the nearest town. Giant otters were present in the waterways throughout the annual water cycle (high, decreasing, low and increasing river levels), with direct observations positively related with the number of fishing nets present in the waterways. Our results suggest considerable spatial and temporal overlap between Giant otters and the activities of local fishers which must be considered for the effective management of conservation conflicts in this rapidly developing region.

Keywords: *Pteronura brasiliensis*; Mustelidae; Amazon; Anthropic influence; Species records.

Introduction

Human population growth and the associated anthropogenic effects have led to the disturbance of increasing numbers of animal habitats. Human activities may significantly interfere with wild fauna, altering the natural behaviour (Silva & Best, 1996; Duplaix, 2002), reproductive success (De la Torre *et al.*, 2000; Arrojo & Razin, 2006), and physiology of many organisms (Romero & Wikelski, 2002).

The encroachment of human populations into increasingly remote areas has reduced the distance between humans and wild animals. This process may result in conflicts (Redpath *et al.,* 2013) that additively and synergistically contribute to the effect of the anthropogenic disturbances. Most conservation-related conflicts are the result of economic impacts caused by wild fauna to human activities, such as fishing, aquaculture (Gómez & Jorgenson, 1999; Recharte *et al.*, 2008; Kloskowski, 2011; Barbieri *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012), or livestock farming (Michalski *et al.*, 2006). In riverside communities, piscivorous species such as fresh-water dolphins (Silva & Best, 1996; Loch *et al.*, 2009), alligators (Peres & Carkeeka, 1993), otters (Barbieri *et al.*, 2012; Michalski *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012) are often blamed for the reduced productivity of fishing activities and may therefore suffer direct retaliation from the local human population (Gómez & Jorgenson, 1999; Recharte *et al.,* 2008; Loch *et al.*, 2009).

The giant otter (*Pteronura brasiliensis*, Zimmerman, 1780) is the largest member of the Mustelidae family in South America (Duplaix, 1980; Carter & Rosas, 1997; Rosas *et al.*, 2009). These large (adults can weigh over 30 kg and reach a total length of approximately 1.8 m (Carter & Rosas, 1997) piscivorous semi-aquatic mammals are often involved in confrontations with humans (Gómez & Jorgenson, 1999; Recharte *et al.*, 2008; Michalski *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012). Due to the complexity of their social system (Carter & Rosas, 1997; Ribas & Mourao, 2004; Davenport, 2010) and extensive spatial requirements (Carter & Rosas, 1997) giant otters are sensitive to a variety of anthropogenic perturbations including: deforestation surrounding waterways (Duplaix, 2002; Michalski *et al.*, 2006; Rosas *et al*, 2007), tourism/traffic of watercraft (Staib & Schenck, 1994; Duplaix, 2002), the number of fishing nets (Utreras *et al.*, 2005; Rosas *et al.*, 2007), river pollution, and the exploitation of fishing resources (Carter & Rosas, 1997; Duplaix, 2002). These sensitivities coupled with historic decimation of populations mean that giant otters have been designated as "endangered" since 2000 (Duplaix *et al.*, 2008).

The Amazon basin harbours the largest remaining populations of giant otters (Carter & Rosas, 1997). Brazil governs approximately 60% of Amazon forests, and the Brazilian government has invested heavily in establishing protected areas across Amazonia (Peres, 2011). Although the number and size of Amazonian protected areas has increased in recent decades (Soares-Filho *et al.*, 2010; Nepstad *et al.*, 2011), the area accounted for by sustainable-use protected areas exceeds the area represented by more completely protected units (51.5% of the total area) (Peres, 2011). Sustainable-use protected areas allow for some forms of human use, which may lead to conflicts between humans and endangered species, such as the giant otter (Michalski *et al.*, 2012; Rosas-Ribeiro *et al.*, 2012). Therefore, studies that assess the influence of human interference contribute essential information for the effective management and conservation of endangered species.

To assess the effects of human activity and seasonal variables on giant otter (*Pteronura brasiliensis*) populations in sustainable-use protected areas, we sought to answer the following questions: 1) What are the effects of anthropogenic interference (e.g., riverside homes, fishing nets, and boats) on the occurrence and spatial and temporal distribution of giant otter sightings? 2) What is the effect of seasonality (i.e., river water level) on the occurrence and spatial and temporal distribution of giant otter sightings in a sustainable-use protected area?

Material and methods

Study area

We collected data between March 2011 and June 2013 in the area surrounding the National Forest of Amapá (0º 55' N, 51º 35' W) on the Araguari and Falsino rivers (Figure 1). The National Forest (Floresta Nacional - FLONA) is a sustainable-use Protected Area located in the centre of the Amapá state in the extreme north of the eastern Brazilian Amazon; the forest has an area of approximately 412,000 hectares (ICMBio, 2012). Between 2010 and 2012, the rainy season in the region encompassed the months of February, March, and April and was characterised by an average monthly precipitation of 275.7 ± SD 99.1 mm (range 422.0 – 44.8 mm); during the dry season (September to November), the monthly average precipitation was 59.6 ± SD 36.4 mm (range 145.8 – 12.0 mm) (ANA, 2013).

Giant otter sampling

Giant otter sightings were obtained from a total of 272 km of rivers (river length measured via GPS) surrounding the National Forest of Amapá. Diurnal (8am to 5pm) river based surveys were conducted using a 9-m-long motorised aluminium boat with a 25 HP engine at an average speed of 10.8 ± SD 2.8 km/h (range 20.0 – 2.0 km/h) (Groenendijk *et al.*, 2005). The sampling area was divided into three zones: 1) Porto Grande town – FLONA headquarters, Araguari river (51 km); 2) FLONA headquarters – Mutum river, Araguari river (128 km); and 3) FLONA headquarters – Grande Waterfall, Falsino river (93 km) (Figure 1).

We designated visual encounters of giant otters as "direct" sightings; "indirect" sightings consisted of observations of otter activity, such as territory markings (e.g., latrines, camp sites, and dens) and tracks (e.g., footprints and scratches) (Duplaix, 1980; Groenendijk *et* *al.*, 2005). Only recent sightings classified according to the criteria described by Groenendijk *et al.* (2005) were considered in our study.

Seasonal and anthropogenic variables

To quantify whether and how seasonal and anthropogenic variables influence the spatial and temporal distribution of giant otter sightings, we selected one seasonal variable (river water level) and three anthropogenic variables (location of homes, boats, and fishing nets) as previous studies have reported that these variables influence giant otter populations (Gómez & Jorgenson, 1999; Duplaix, 2002; Rosas-Ribeiro *et al.*, 2012).

Records of anthropogenic activities were georeferenced along the rivers during the giant otter sampling; more specifically, we chose to record the positions of watercraft (e.g., motorised and non-motorised boats), fishing nets, and homes of local people.

We obtained data on river water levels (daily river level values) from the virtual database of the National Water Agency (Agência Nacional das Águas – ANA) – *http://hidroweb.ana.gov.br*. The active data collection station (Capivara station – 30080000, 3º 49' N, 54º 29' W) closest to the study site is located within the Protected Area and has data available through September 2012.

Data analysis

To examine the spatial and temporal distributions of the direct and indirect giant otter sightings, we organised the analyses along a hierarchy of scales. First, on a coarse scale, we compared the detection frequency of the three sampling zones (Table 1). We also counted the number of homes (n = 39), boats (n = 263), trawl nets (n = 39), and fishing nets (n = 144) in each zone to characterise the human activities in the region. On a more granular scale, we divided the rivers into equal-length sections within each zone. We obtained the length of the sections using an objective *bandwidth* selection method (Hengl, 2009) and Berman and Diggle's (1989) algorithm (Supplemental material 1). From the *bandwidth* selection calculation, we obtained an optimal bandwidth (i.e. separation distance) of any value greater than 456.00 m. The Araguari and Falsino rivers were then divided into 39 5.1-km-long sections (10, 15, and 14 sections, zones 1, 2, and 3 respectively). This value was chosen as it is likely to be at a useful scale for management actions and also provided a minimum of 10 sections per zone.

We used generalised linear models (GLM, family = binomial) to examine the influence of the anthropogenic and seasonal variables on the number of direct and indirect giant otter sightings within each section. The responses of direct and indirect sightings were modelled separately, and expressed as the proportion of section samples (i.e. times visited) with a sighting. In other words the sighting rate per section was modelled as a function of the anthropogenic and seasonal variables. To control for differences in sample effort per section, the GLMs were weighted by the total km surveyed within each river section.

Preliminary analyses showed a strong correlation between the number of boats and the number of homes per river section (Spearman correlation $r = 0.67$, $P < 0.001$). We therefore excluded "boats" from the GLM analysis as previous studies have shown that riverside people in the region usually stay close (<500 m) to their homes when fishing (Norris & Michalski, 2013). For this analysis, we therefore retained the number of homes and the number of nets found in each section as anthropic variables. This analysis combined data from multiple visits of the river sections to control the large number of zero responses in the model (zero-inflation problem). The river level was included as a categorical variable (high or low) as if the river water level influences the distribution of giant otters, we would expect to detect this effect when comparing the most contrasting seasons. Subsequently, to select the most parsimonious variables (i.e., the variables that "best" explained the occurrence of giant otter sightings), we used the AIC selection criterion with the *stepwise* algorithm (R "step" function).

We used generalised additive models (GAM) to assess the effect of seasonal variations of the river on the number of direct and indirect giant otter sightings. Thus, we analysed the number of direct and indirect giant otter sightings, the presence of boats and nets per daily sampling effort (km travelled), and the daily variation in river parameters (quotas in cm) during the study period.

Subsequently, we used Spearman correlations to analyse the associations between the water level of the river, the number of direct and indirect giant otter sightings, and the human activities in the region during the sampling period (Ranta *et al.*, 1998).

Results

Sightings in the zones

We performed 19 field campaigns providing a total of 125 sampling days and 6,836.1 km of otter surveys between March 2011 and June 2013. During the sampling period, we recorded 39 direct and 241 indirect giant otter sightings (Table 1). Few sightings occurred in the Porto Grande – Headquarters section (zone 1) (one direct sighting and one indirect sighting), thus confirming a clear separation in the number of sightings when compared with zones 2 (FLONA Headquarters – Mutum river section) and 3 (FLONA Base – Grande Waterfall section).

The three zones were characterised by different anthropogenic disturbance levels, with the human influence being substantially greater in zone 1, followed by zones 2 and 3 (Figure 2). This difference in anthropic impacts was reflected in the giant otter sightings with giant otters effectively absent from zone 1, whereas zones 2 and 3 (less impacted) accounting for 99.6% (n = 241) and 97.4% (n = 38) of the indirect and direct sightings, respectively (Table 1). Giant otters were sighted during all periods of the hydrological cycle in zones 2 and 3 and there was no evidence of any significant difference in sighting rates between the two zones (Wilcoxon signed rank test, $P > 0.30$ for both direct and indirect sightings).

Sightings in the river sections

Variation in the number of direct and indirect sightings was explained by the seasonal (water level) and anthropogenic (numbers of homes and fishing nets) variables ($P < 0.0001$, Table 2). The number of riverside homes was negatively associated with the number of direct and indirect giant otter sightings, whereas the number of fishing nets was positively associated with the number of direct sightings and negatively associated with the number of indirect sightings (Table 2). The number of direct sightings was not significantly related to the river water level ($P = 0.619$), with the best model retaining the number of homes ($P < 0.01$) and fishing nets ($P = 0.016$). In contrast, variation in the number of indirect sightings was explained by both seasonal and anthropogenic variables. The number of indirect sightings increased when the river level was lowest ($P < 0.0001$).

Seasonality of the sightings

The number of direct (GAM, F = 5.168, $P = 0.02$, deviance explained = 83%) and indirect giant otter sightings (GAM, F = 36.4, $P = 0.096$, deviance explained = 99.7%) varied non-linearly over time (Figure 3). The number of watercraft (GAM, F = 4.233, $P = 0.05$, deviance explained = 40.7%) did not vary with the season; however, there was a pronounced non-linear variation in the number of fishing nets by season (GAM, F = 6.41, $P = 0.011$, deviance explained = 85.9%).

We compared the seasonal variation in sightings and watercraft traffic in zones 2 (Araguari river) and 3 (Falsino river) (Figure 4). In the Araguari river, there was no significant variation in the number of direct sightings over time; in contrast, the number of indirect sightings did vary over time (GAM, F = 4.621, *P* = 0.007, deviance explained = 83.1%). Neither the number of direct nor indirect sightings varied with time in the Falsino river.

These zones are located in the immediate vicinity of the protected area, and 99.2% of the direct and indirect giant otter sightings occurred in these zones. The water level of the river and the number of indirect giant otter sightings in zone 2 were negatively correlated (S = 795.65; r = - 0.7487; *P* = 0.0021); no such correlation was observed for the number of direct sightings. In zone 3, the water level of the river tended to be negatively correlated with the number of indirect sightings (S = 680.99, r = - 0.4967, *P* = 0.0708).

The number of boats on the river did not vary with season in either zone. The number of fishing nets in the Araguari river (zone 2) did not vary with the season (S = 275.21; r = 0.3951; *P* = 0.162); on the Falsino river (zone 3), the number of fishing nets was negatively correlated (S = 809.38; r = - 0.7788; *P* = 0.001) with the monthly water level of the river (Figure 4).

Discussion

A variety of environmental and anthropogenic factors affect the spatial and temporal distribution of large carnivorous animals. Our study shows that the incidence of giant otter sightings is directly related to anthropogenic factors around protected waterways.

Sightings in the different zones

The area comprising the National Forest of Amapá and its surroundings is characterised by three zones with different levels of anthropogenic disturbance. Considerably fewer giant otters were sighted in the zone with the greatest level of human activity (only one direct sighting). Only eight families live within the protected area (Michalski *et al.*, 2012), and the impact of human activity is less pronounced in the protected area than in zone 1 despite the constant flow of motorised boats near the homes in the protected area. Human activity at the river edges in the vicinity of the protected area tends to drive away groups of otters (Duplaix, 2002) but does not completely prevent the animals from visiting this area, as a considerable number of indirect sightings occurred in zone 2. The greatest number of otter sightings occurred in zone 3, the most preserved region, confirming that direct and indirect sightings occur more frequently in better preserved areas (Duplaix, 2002; Rosas *et al.*, 2007).

We observed no changes in the number of direct giant otter sightings by season in zones 2 and 3; however, the number of indirect sightings did vary by season. Field ecological studies of giant otters are usually conducted in the drier seasons (Utreras *et al.*, 2005; Rosas *et al.*, 2007; Lima *et al.*, 2012), as groups are generally less frequently observed during rainy seasons and/or seasons characterised by high river water levels. The low detection rates in the main river courses during the flood season may also be associated with the fact that individual animals tend to move through the narrower streams into the floodplains in the forest interior in search of food and/or shelter (Lima *et al.*, 2012; Leuchtenberger *et al.*, 2013).

Sightings in the sections

Giant otters choose certain types of plains on which to build their dens and establish latrines and prefer to forage in specific parts of the river (Duplaix, 1980; Carter & Rosas, 1997; Duplaix, 2002; Lima *et al.*, 2012). These sites are associated with areas that are less disturbed by human activity (Duplaix, 2002; Rosas *et al.*, 2007). The visitation of different areas (even areas with limited human activity) by these species may also depend on the noise level of the environment, as these mammals are easily scared away by the presence of motorised boats (Staib & Schenck, 1994; Duplaix, 2002). Direct and indirect sightings of this species decreased or disappeared as the number of homes and watercraft traffic increased.

We observed a weak positive association between the number of direct sightings and the presence of fishing nets. Net fishing in the Amazon occurs in sites with weaker currents, such as the smaller water courses where nets can be used more easily and efficiently (Cardoso & Freitas, 2007). The spatial overlap of the fishing sites of humans and giant otters explains the positive association between these two variables and may account for the conflicts between the species that were observed in other areas (Gómez & Jorgenson, 1999; Recharte *et al.*, 2008; Rosas-Ribeiro *et al.,* 2012). In contrast, an opposite trend between the direct and indirect sightings regarding the fishing nets, may indicate that individuals are found in these areas but do not remain for long periods in the fishing area due to human influence and behaviour of avoidance.

When analysing the combined effects of the anthropogenic variables and seasons on direct giant otter sightings, we noted that the best model does not include the river water level. Thus, the river sections where giant otters were most likely to be sighted were those that had few or no homes and where net fishing was conducted. The season (high or low water) weakly influenced the number of indirect sightings but no influence on direct sightings, suggesting that seasonal effects are weak compared to the impacts of human activities.

As predicted by the model, the number of indirect sightings was associated with the season, with the most sightings being recorded during the drier period (between June and November). It seems likely that indirect sightings of these animals are more easily encountered during the drier season because sand banks, rocks, and use areas such as latrines, living areas, and dens are more exposed and more easily detectable (Duplaix, 1980; Groenendijk *et al.*, 2005). Therefore, to maximise the number of indirect sightings along the main course of the river, sections with little or no human activity on the edges should be monitored; in addition, censuses should be taken during the drier seasons.

Seasonality of sightings

Amphibious predators such as giant otters may change the areas they frequent to adapt to seasonal changes in the river water level and prey availability (Duplaix, 1980; Lima *et al.*, 2012). We observed a non-linear seasonal variation in the number of direct sightings; however, sighting rates were not directly correlated with the river water level. A recent radio-telemetry study conducted in the Pantanal reported changes in the partial or total movement of some giant otter groups with season and the expansion of their habitat ranges in different seasons, however other groups showed no seasonal variation (Leuchtenberger *et al.*, 2013). Therefore, it seems likely that different giant otter groups have different responses to seasonal changes (Evangelista & Rosas, 2011). Our data show that if present, giant otters (as shown by both direct and indirect sightings) will be present throughout the year along a particular river.

Although we found temporal variation in giant otter sightings there was no evidence of a relevant biologically relationship with water level. Although our GAM analysis showed that there were subtle differences in the temporal patterns of direct and indirect sightings, generally both sighting types showed similar patterns. For example over 18 months of surveys both types of sightings showed less variation in the less impacted zone 3 (Falsino river) compared with zone 2 (Araguari). This finding suggests that even low levels of anthropic impacts such as fishing may modulate the occurrence of giant otters. Fishing in this region also follows a seasonal pattern and tends to be negatively correlated with the water levels of the river; in contrast, watercraft traffic tends to be constant throughout the year. Factors such as precipitation, river levels, and the closed seasons of various fish species determine the commercial fishing season in the Amazon region (Cardoso & Freitas, 2007). We found no relationship between net fishing seasonality and the frequency of either direct or indirect giant otter sightings, which suggests that encounters and therefore human-otter conflicts will be generally related to spatial rather than temporal factors.

In the two zones where > 99% of the direct and indirect giant otter sightings occurred, the numbers of sightings varied differently with the flow of the river. In the Araguari river (zone 2), where human activity is greater, the number of indirect sightings varied with time, with more sightings occurring during the drier and/or water level transition periods. However, the number of direct sightings did not vary with river flow in the most preserved study area (zone 3). The lower level of disturbance and the consequent low number of people in the region may have contributed to the use of all of the flooded areas in zone 3 by this species. Because giant otters are opportunistic predators and prefer to hunt in the shallow waters of smaller streams (Duplaix, 1980; Carter & Rosas, 1997), the use of the main course of the river, even during the flood season, may be associated with the need of the animals to move into areas with more available prey. Therefore, the number of sightings of these animals in areas with a lower level of human activity does not depend on the season.

Implications for species monitoring and management

The likelihood of encountering giant otter groups is directly related to the intensity of human activity in the potential home range of this species. Even in environments where abundant food is available, the over-exploitation of the river edges and the constant traffic of watercraft can drive this species away. Sites where fishermen place fishing instruments may favour direct encounters with these groups but tend to preclude indirect observations of this species. Direct and indirect sightings vary seasonally and may be influenced by the degree of preservation of the sites. We conclude that otter sightings and observations of the degree of influence of human activities on the likelihood of otter sightings are more likely to occur during the drier seasons. Therefore, our results may aid in coordinating and promoting the sustainable management of activities such as eco-tourism and commercial fishing that depend on this type of sighting to minimise the threat posed to this carnivore by human activity.

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Tables

Table 1: Sampling effort and number of direct and indirect sightings in the three sampling zones of the National Forest of Amapá (Zone 1 – Porto Grande-Headquarters sections; zone 2 – Headquarters-Mutum River section; zone 3 – Headquarters-Grande Waterfall section) during the annual periods with different river water levels (high, decreasing, low, and increasing) for the sampling months between March 2011 and June 2013.

Zone	Total km	Direct (per km)		Indirect (per km)	
1: Porto Grande Total	**1131.6**	**1**	**(0.0009)**	**1**	**(0.0009)**
High	373.4	0			0
Decreasing	287.0	0			0
Low	221.2	1	(0.005)	0	
Increasing	250.0	0		1	(0.004)
2: Araguari Total	**2793.9**	**16**	**(0.006)**	**116**	**(0.04)**
High	729.0	5	(0.007)	14	(0.02)
Decreasing	691.2	1	(0.001)	24	(0.03)
Low	1118.0	8	(0.007)	65	(0.06)

Increasing	255.7	2	(0.007)	13	(0.05)
3: Falsino Total	**2910.6**	**22**	**(0.007)**	**124**	**(0.04)**
High	666.9	6	(0.009)	32	(0.05)
Decreasing	728.1	5	(0.007)	34	(0.05)
Low	1288.2	10	(0.008)	52	(0.04)
Increasing	227.4	1	(0.004)	6	(0.03)
Total	**6836.1**	**39**	**(0.006)**	**241**	**(0.04)**

Table 2: Influence of seasonal and anthropogenic variables on giant otter sightings in the National Forest of Amapá and its surroundings. The results of GLM models (coefficients associated with SE the in parenthesis) used to explain variation in giant otter sighting rates in 39 river sections (5.1 km/section) during the sampling period.

	Direct detections		**Indirect Detections**	
	Full	**Best**	**Full**	**Best**
[a] **Houses**	**-0.639 (0.079)	**-0.639 (0.079)	**-0.449 (0.029)	**-0.449 (0.029)
[b] **Nets**	*0.121 (0.050)	*0.119 (0.050)	**-0.109 (0.028)	**-0.109 (0.028)
Water level (low vs. high)	-0.057 (0.115)		**0.416 (0.059)	**0.416 (0.059)
Model AIC	1337	1335	3510	3510
Model significance	<0.0001	<0.0001	<0.0001	<0.0001
Model deviance explained (%)	16.12	16.10	25.2	25.2

Significance levels: *< 0.05 , ** < 0.0001

[a] number of riverside homes per section.

[b] number of fishing nets per section.

Figure legends

Figure 4: Location of the study area in the extreme north of the eastern Amazon. Polygon of the National Forest of Amapá (FLONA-AP) showing the sampled area and the division of the Araguari and Falsino rivers into three zones. Zone 1 (dark grey), a 51-km stretch of the Araguari river between the town of Porto Grande and the FLONA headquarters; zone 2 (medium grey), a 128-km stretch of the Araguari river between the FLONA headquarters and the Mutum River; and zone 3 (light grey), a 93-km stretch of the Falsino river between the FLONA headquarters and the Grande Waterfall.

Figure 5: Frequency distribution of the number of homes, boats, and fishing nets (counts per sampled km) in zones 1, 2 and 3 of the Araguari and Falsino rivers surrounding the National Forest of Amapá.

Figure 6: Temporal variation in the river water level and in the number of direct and indirect giant otter sightings per km of river surveyed around the National Forest of Amapá. The line represents the model tendency and the grey area shows the confidence interval.

Figure 7: Comparison of direct and indirect giant otter sightings, number of boats, and fishing nets with time and with river water levels in zones 2 (Araguari river) and 3 (Falsino river), which are in the immediate vicinity of the protected area in the National Forest of Amapá; weighting by sampling effort was conducted. The line represents the model tendency and the grey area shows the confidence interval.

Figures

Figure 4

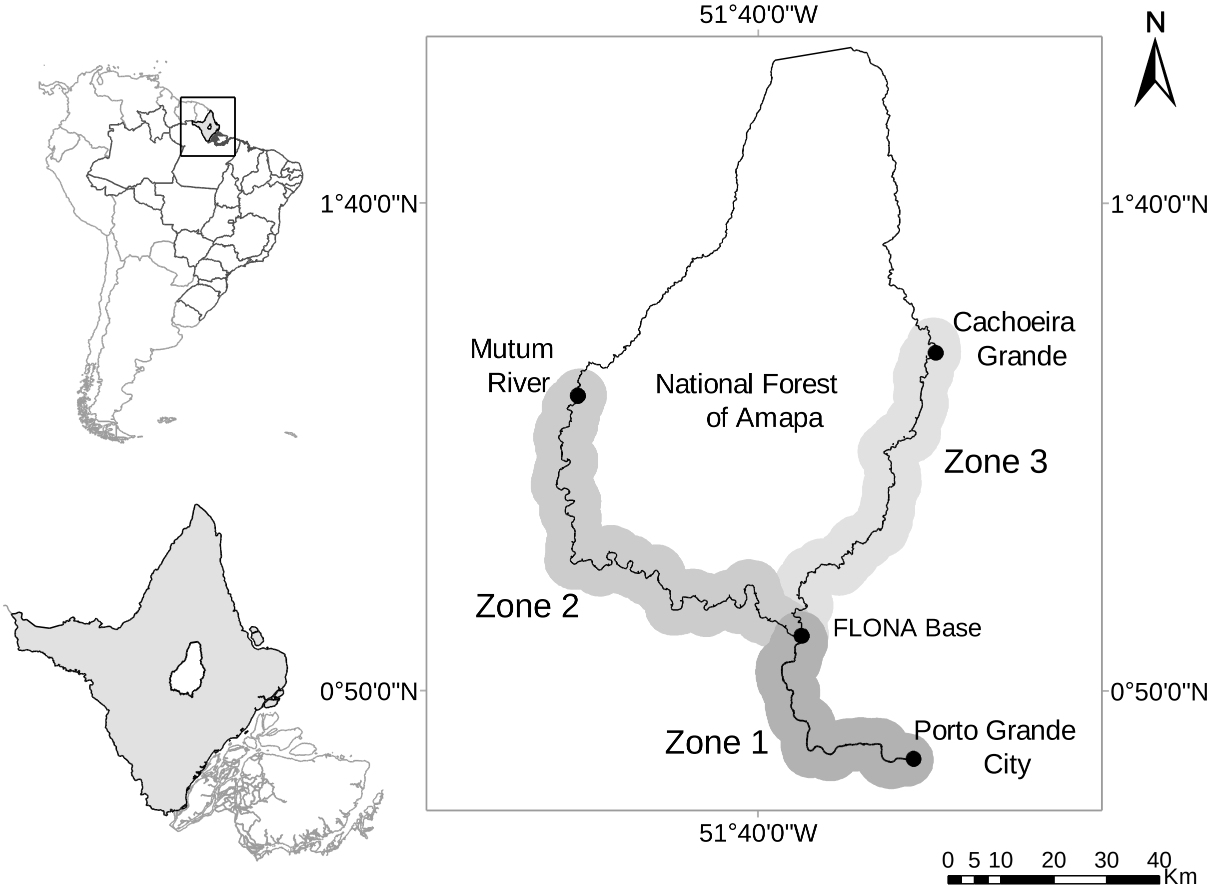


Figure 5

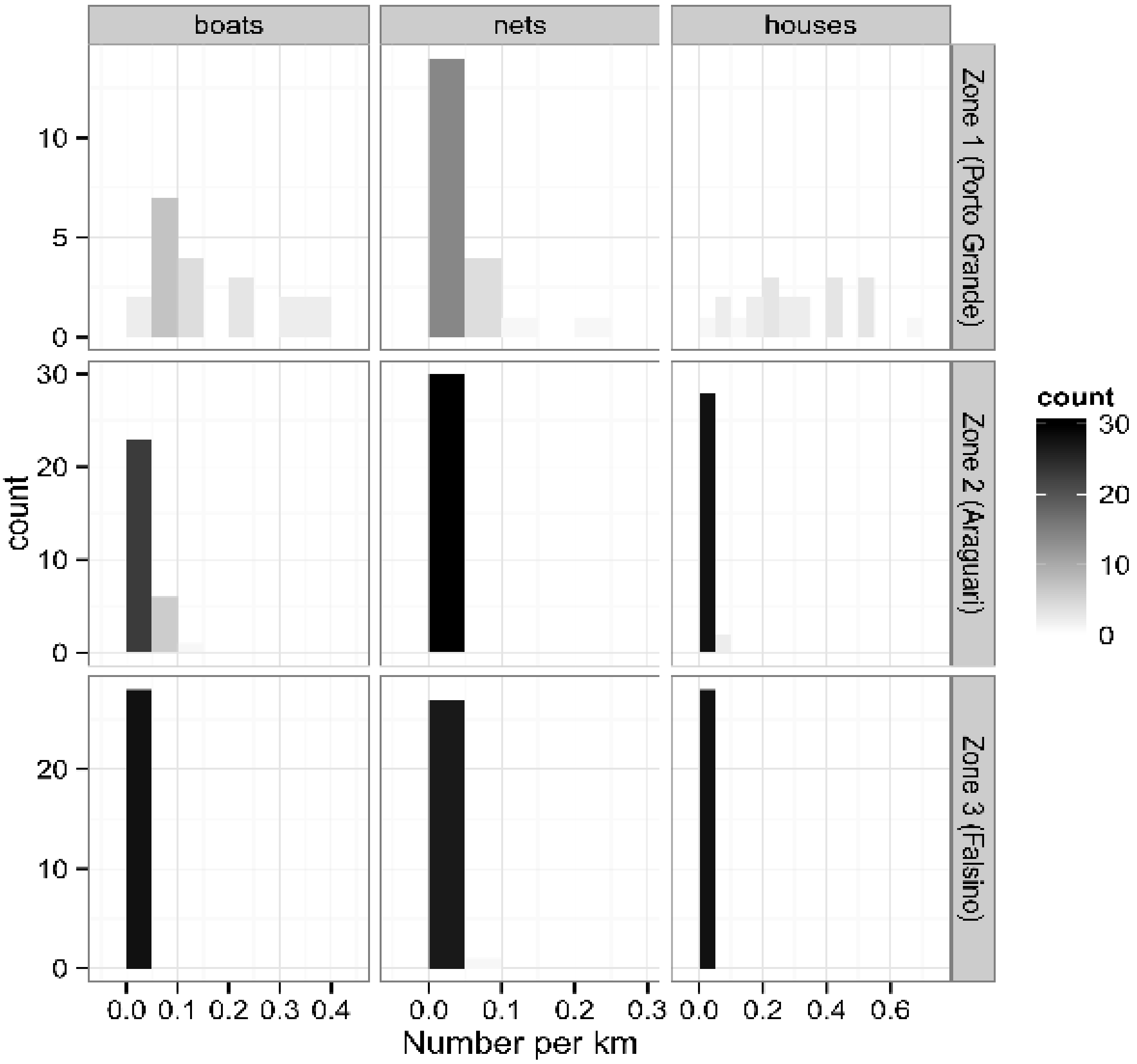

boats
nets
houses
Zone 1 (Porto Grande)
Zone 2 (Araguari)
Zone 3 (Falsino)
count
Number per km
0
5
10
20
30
0.0
0.1
0.2
0.3
0.4
0.6
count
30
20
10
0

Figure 6

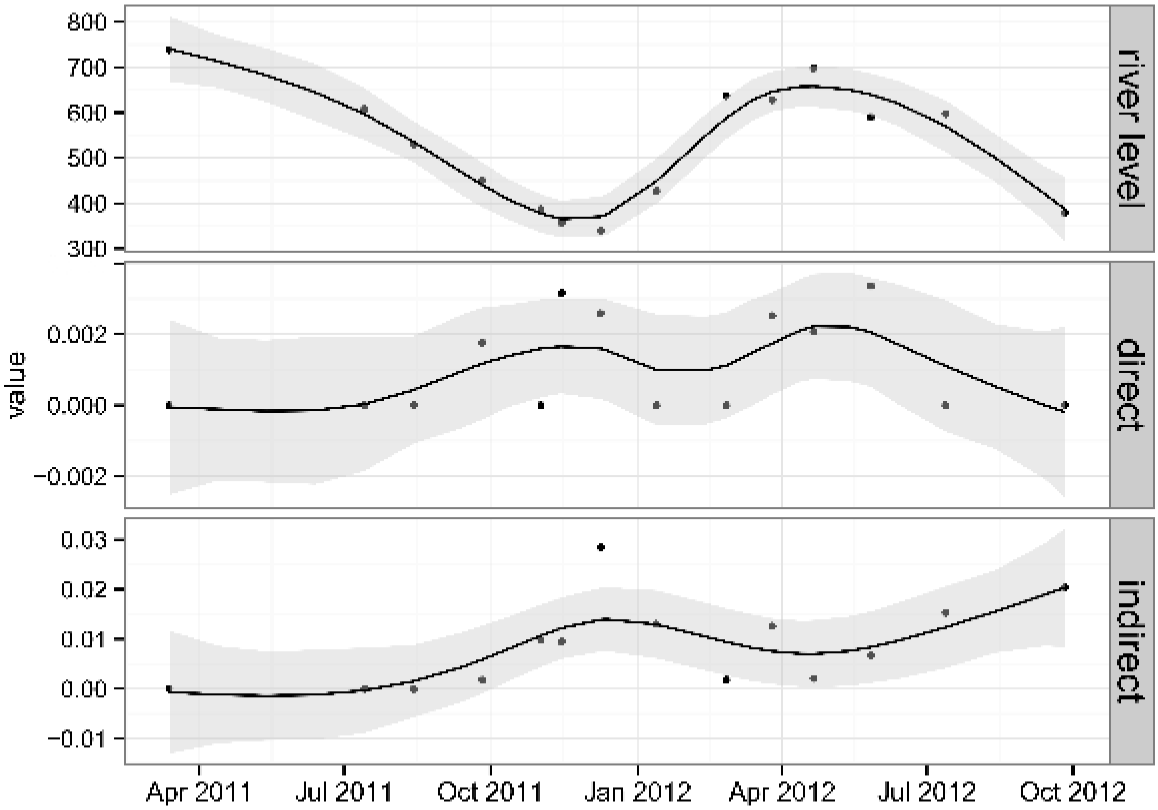
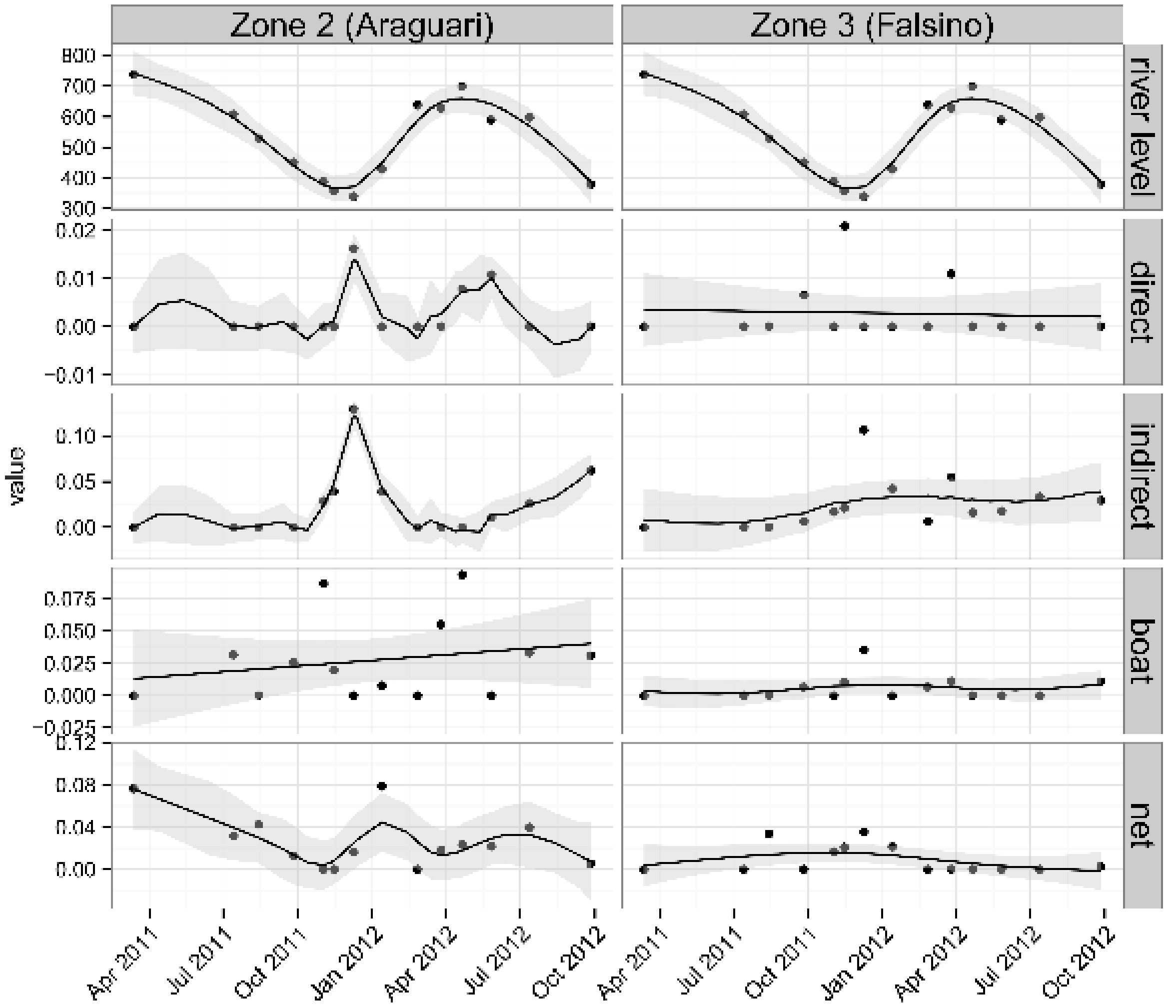

800
700
600
500
400
300
0.002
0.000
−0.002
0.03
0.02
0.01
0.00
−0.01
value
river level
direct
indirect
Apr 2011
Jul 2011
Oct 2011
Jan 2012
Apr 2012
Jul 2012
Oct 2012

Figure 7


Zone 2 (Araguari)
Zone 3 (Falsino)
river level
direct
indirect
boat
net
value
800
700
600
500
400
300
0.02
0.01
0.00
−0.01
0.10
0.05
0.00
0.075
0.050
0.025
0.000
−0.025
0.12
0.08
0.04
0.00
Apr 2011
Jul 2011
Oct 2011
Jan 2012
Apr 2012
Jul 2012
Oct 2012

Supporting Information

1) *Bandwidth* selection

To objectively derive the length of the river sections, i.e. set the spatial resolution, we used a bandwidth selection approach (Hengl, 2009). This enables us to ensure that the spatial resolution adopted was adequate based on the sample size, distance between points and size of the study area (Fortin & Dale, 2005; Hengl, 2009).

Bandwidth selection looks for the smallest Mean Square Error (MSE) at the distances between sampled point pairs within a specified search radius. The bandwidth obtained (sigma-σ) therefore represents the distance between point pairs, and the optimal bandwidth can be obtained from that corresponding to the lowest MSE value. As such elevated MSE values at small values of sigma suggest that spatial dependence only occurs between very close point pairs (Hengl, 2009).

To obtain the bandwidth we used the algorithm of Berman & Diggle (1989). Calculations were based on the point pattern formed from direct observations (n = 35) and the areal study area derived from a 100 m buffer surrounding the surveyed river channels (Figure 1a). From this calculation we obtained an optimum bandwidth value of 456 meters, although based on the MSE values any bandwidth value above 456 seems suitable (Figure 1b).

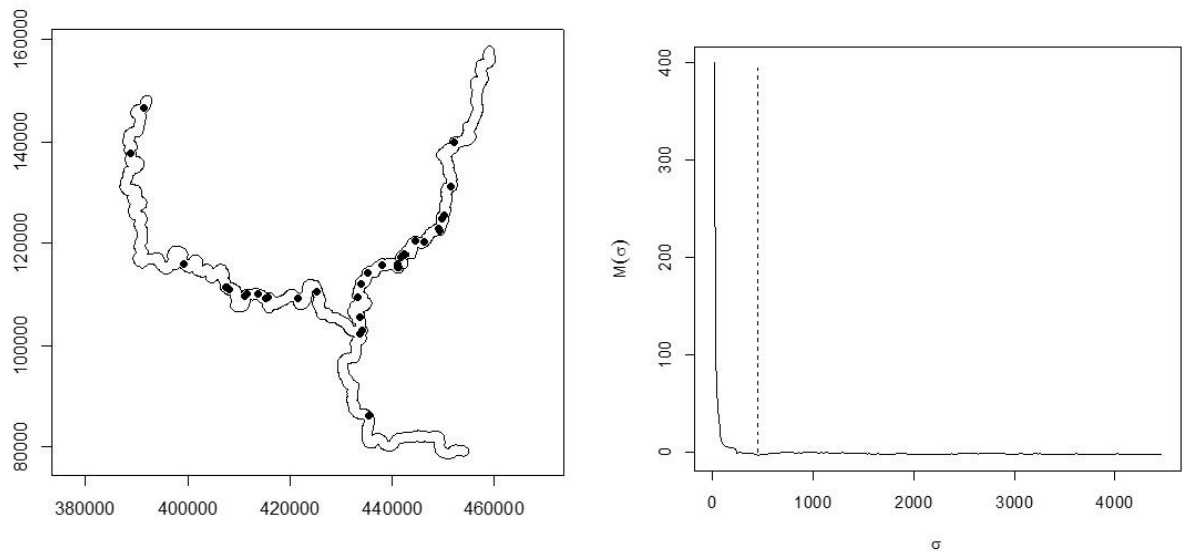


Figure 8: Objective derivation of river section length. a) Point pattern of *Pteronura brasiliensis* detections (direct observations, n = 35). b) Bandwidth selection using the method of Berman and Diggle (1989), dashed vertical line indicates optimal bandwidth.

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CONCLUSÃO

Os encontros com os grupos de ariranhas estão diretamente ligados a intensidade do uso humano em suas potenciais áreas de vida. A sobre-exploração das margens dos rios, para a construção de moradias, e o constante fluxo de barcos agiram negativamente sobre a espécie. Os locais utilizados por pescadores para a alocação de aparatos pesqueiros podem possibilitar o encontro direto com os grupos, porém tiveram efeitos negativos sobre a ocorrência de vestígios indiretos.

Observamos que as épocas de transição (nível crescente ou decrescente do rio) e a época mais seca são mais favoráveis para a visualização dos grupos e a para localização de rastros. Porém, para áreas mais conservadas e com baixo nível de perturbação antrópica, há visualização dos grupos independente da época sazonal. Os vestígios indiretos, sofrem efeito da detectabilidade de acordo com a sazonalidade, pois são mais comumente encontrados em épocas mais secas. A sazonalidade no uso de cursos hídricos principais é bastante evidenciada para as ariranhas, porém nosso estudo detectou que outros fatores, como o nível de perturbação antrópica, podem estar agindo conjuntamente e influenciando a ocorrência da espécie em determinadas seções do rio.

A identificação de áreas, mais preservadas e com menor influência antrópica, como as evidenciadas por este estudo, são propícias para a proteção dessa espécie semiaquática ameaçada de extinção, sendo de extrema importância para a gestão de unidades de uso sustentável. Portanto, este trabalho contribui com a dados que reforçam a importância de caraterísticas individuais de cada área protegida, para o manejo sustentável de atividades que dependam direta ou indiretamente dos encontros com ariranhas. Isto é especialmente relevante para atividades de pesca com redes, turismo ecológico e o uso de solo em margens do rio, que podem minimizar os impactos negativos sobre estes organismos.

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APÊNDICES

Ata da Aula de Qualificação

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Nível: MESTRADO
Orientador(a): FERNANDA MICHALSKI
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Título

"Influência de variáveis ambientais e antrópicas sobre a distribuição de ariranhas (Pteronura brasiliensis) em uma Área Protegida de Uso Sustentável na Amazônia Oriental brasileira"

BANCA JULGADORA

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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 20 dias do mês de março do ano de 2014, às 09:00 horas, no Auditório da Biblioteca do INPA, Campus I, INPA/Aleixo, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Adrian Paul Ashton Barnett** do Instituto Nacional de Pesquisas da Amazônia - INPA, o(a) Prof(a). Dr(a). **Renato Cintra Soares** do Instituto Nacional de Pesquisas da Amazônia - INPA e o(a) Prof(a). Dr(a). **Fabricio Beggiato Baccaro**, da Universidade Federal do Amazonas - UFAM, tendo como suplentes o(a) Prof(a). Dr(a). Wilson Roberto Spironello, do Instituto Nacional de Pesquisas da Amazônia - INPA, e o(a) Prof(a). Dr(a). Albertina Pimentel Lima do Instituto Nacional de Pesquisas da Amazônia – INPA, sob a presidência do(a) primeiro(a), a fim de proceder a arguição pública do trabalho de **DISSERTAÇÃO DE MESTRADO** de **ISABEL ALINE PEREIRA DE OLIVEIRA,** intitulado "Influência de variáveis antrópicas e ambientais sobre a distribuição de ariranhas (*Pteronura brasiliensis*) em uma Área Protegida de Uso Sustentável na Amazônia oriental", orientado pelo(a) Prof(a). Dr(a). Fernanda Michalski da Universidade Federal do Amapá – UNIFAP e coorientado pelo(a). Dr(a). Darren Norris da Universidade Federal do Amapá – UNIFAP.

Após a exposição, o(a) discente foi arguido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

- [x] APROVADO(A)
- [ ] REPROVADO(A)
- [x] POR UNANIMIDADE
- [ ] POR MAIORIA

Nada mais havendo, foi lavrada a presente ata, que, após lida e aprovada, foi assinada pelos membros da Comissão Examinadora.

Prof(a).Dr(a). Adrian Paul Ashton Barnett ____________________

Prof(a).Dr(a). Renato Cintra Soares ____________________

Prof(a).Dr(a). Fabricio Beggiato Baccaro ____________________

____
Coordenação PPG-ECO/INPA