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CARINE GOMES MORAES

Partição de nicho entre os mustelídeos *Lontra longicaudis* e
Pteronura brasiliensis no rio Xingu, Bacia Amazônica



BELÉM
2020

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Dissertação submetida ao programa de Pós-Graduação em Ecologia Aquática e Pesca da Universidade Federal do Pará como requisito para a obtenção do título de Mestra em Ecologia Aquática e Pesca.

Orientador: Dr. Marcelo C. Andrade

Coorientador: Prof. Dr. Tommaso Giarrizzo

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Ilustrações na capa e guarda-capas de I love otters 鍵条漆 @kagijourushi

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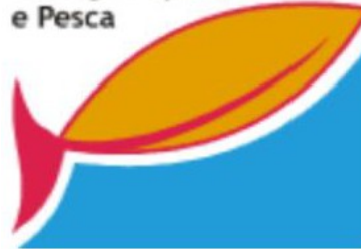
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*“Eu queria poder afagar uma fera terrível
Eu queria poder transformar tanta coisa impossível
Eu queria dizer tanta coisa que pudesse fazer eu ficar bem comigo
Eu queria poder abraçar meu maior inimigo.*

*Eu queria não ver tantas nuvens escuras nos ares
Navegar sem achar tantas manchas de óleo nos mares
E as baleias desaparecendo por falta de escrúpulos comerciais
Eu queria ser civilizado como os animais.*

*Eu queria não ver todo o verde da Terra morrendo
E das águas dos rios os peixes desaparecendo
Eu queria gritar que esse tal de ouro negro não passa de um negro veneno
E sabemos que por tudo isso vivemos bem menos.*

*Eu não posso aceitar certas coisas que eu não entendo
O comércio das armas de guerra, da morte vivendo
Eu queira falar de alegria ao invés de tristeza mas não sou capaz
Eu queria ser civilizado como os animais.*

*Não sou contra o progresso
Mas apelo pro bom-senso
Um erro não conserta o outro
Isso é o que eu penso.”*

O progresso, Roberto Carlos

*Ao meu maior presente de 2019,
meu sobrinho/afilhado Wylker.
Amo-te imensuravelmente.*

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RESUMO

Pteronura brasiliensis e *Lontra longicaudis*, pertencentes a subfamília Lutrinae. São espécies carnívoras que têm os peixes como a sua principal fonte alimentar, ocorrendo em simpatria na região Amazônica e Pantanal. O presente estudo evidencia a dieta dos dois mustelídeos no baixo rio Xingu em período pré-operação da Usina Hidrelétrica (UHE) Belo Monte. Supondo que mustelídeos coocorrem no mesmo ambiente mediante partição de nicho trófico, o objetivo do estudo é testar a hipótese de partição de nicho e o comportamento alimentar das espécies de mustelídeos levando em consideração os períodos hidrológicos não chuvoso e chuvoso no baixo rio Xingu. Além disso, comparar o consumo de peixes por parte desses mustelídeos com a disponibilidade dessas pressas, *i.e.*, abundância estimada da ictiofauna presente no rio. Para tal, amostras fecais das duas espécies foram coletadas nos períodos não chuvoso (ago/2012) e chuvoso (fev/2013), totalizando 216 amostras. Em laboratório as amostras foram secas, lavadas, triadas e identificadas utilizando literatura específica e/ou comparando com materiais presentes na coleção de peixes do Grupo de Ecologia Aquática (GEA) da Universidade Federal do Pará (UFPA). Para análises da diversidade e abundância dos peixes (*i.e.*, principal fonte alimentar), a ictiofauna foi amostrada simultaneamente nas mesmas áreas e períodos utilizando três conjuntos de redes de emalhar com sete redes cada (20 m x 2 m cada) e com tamanhos de malha entre 2 e 18 cm entre nós opostos. As redes foram armadas aleatoriamente nas áreas marginais do rio ao pôr do sol onde permaneceram por um período de 14 horas sendo verificadas a cada três horas para evitar perdas. Os resultados indicaram que as dietas dos mustelídeos são compostas primariamente por peixes, sendo os peixes da família Anostomidae (piaus e aracus) os mais consumidos por ambos os mustelídeos. A maior amplitude de nicho é apresentada pela espécie *Lontra longicaudis*. Análises utilizando o índice de Pianka indicaram uma maior sobreposição de nicho durante o período chuvoso. Apesar da alta sobreposição de nicho, o particionamento trófico entre as duas espécies de mustelídeos é facilitado devido a maior amplitude de nicho da *L. longicaudis*, que ajuda a evitar a

exclusão competitiva entre as espécies. Além disso, a variação sazonal intraespecífica não foi constatada no presente estudo.. A família de peixe Erythrinidae (traíras e jejus) apresentou eletividade positiva para ambos mustelídeos, no entanto, apresentam uma baixa representatividade nas capturas com redes de emalhar. Esses peixes apresentam pouca mobilidade, conseqüentemente maior vulnerabilidade aos predadores tais como os mustelídeos que são predadores oportunistas. A melhor compreensão sobre a diferença de nicho entre os mustelídeos apresentada no presente estudo pode contribuir com a mitigação do status de conservação atual de ambas espécies, pois pode auxiliar em propostas mais eficazes para conservação desses animais. Além disso, vale ressaltar que o presente estudo foi realizado durante a fase pré-operação da UHE Belo Monte, e acredita-se que com a sua construção os status de conservação das espécies tende a piorar. Por esses motivos, fazem-se necessários novos estudos sobre os efeitos de hidrelétricas (bem como a atividades mineradoras, construção de estradas, dentre outras) sobre a disponibilidade de recursos alimentares para esses carnívoros topo de cadeia, pois são de suma importância para a conservação como espécies-chave que garantirão a saúde das comunidades aquáticas.

Palavras-chave: Mamífero semi-aquático; Dieta; Nicho Trófico; Coexistência; Competição; Mustelídeo.

ABSTRACT

Pteronura brasiliensis and *Lontra longicaudis* both otters are carnivorous members of the subfamily Lutrinae with fish as their main food source, and co-occurring in the Amazon and Pantanal regions. The present study investigates the diet of both mustelids in the Lower Xingu River prior completion of Belo Monte Hydropower Plant (HPP). Under the theory of competitive exclusion two species must occupy separate niches. We hypothesize that the co-occurrence of both species within the same habitat is possible due to trophic niche partitioning or behavioral. The aim of the present study is to test the hypothesis that niche partitioning and feeding behavior, across the rainy and drought hydrologic seasons of the Lower Xingu River, separates these two mustelids species. To accomplish this, fish consumption was compared for each mustelid in regard to prey availability, i.e., abundance estimation of fish. Fish consumption was measured using fecal samples of both mustelids collected during drought (Aug/2012) and rainy (Feb/2013) seasons, totaling 216 samples. In the laboratory these samples were washed, dried, processed and identified based upon specific literature and/or comparison with materials in the collection of the Grupo de Ecologia Aquática (GEA) from Universidade Federal do Pará (UFPA). To analyze the diversity and abundance of fishes (the main food source of both mustelids), fish were sampled simultaneously in the same areas and periods of fecal sample collection using three gillnet sets (20 m long x 2 m height) and seven mesh size each (from 2 to 18 cm between knots). The gillnets were randomly placed at sunset, in areas of backwater at river banks, and remained in place for 14 hours, being checked every three hours to avoid fish losses. The outcomes suggest that mustelid diets are composed primarily of fishes in the family Anostomidae (Headstanders). The widest niche breadth is presented by *Lontra longicaudis*. Analysis using the Pianka index pointed to greater niche overlap during rainy season than during the drought season. Although the great niche overlap, trophic niche partitioning between both species is facilitated due to the greater niche breadth of *L. longicaudis*, which helps to avoid competitive exclusion between the two species. Both mustelids showed

positive selectivity for fish in the family Erythrinidae (Trahiras), however, this fish family had low catch rates in gillnet samplings. This anomalous result is likely due to the low mobility of Trahiras, a behavior which consequently results in greater vulnerability to opportunistic predators such as mustelids but low vulnerability to gill nets. The improved understanding of the niche differences between the mustelid species presented in this study can contribute to mitigating the current conservation status of both species by providing more effective ecological information for the conservation of these animals. In addition, it is important to mention that the present study was carried out prior completion of the Belo Monte HPP, and it is believed that construction of this dam has worsened the conservation status of both species. For these reasons, further studies are needed to understand the effects of hydropower – as well as mining activities, road constructions, among others – on the resources availability. Understanding the ecology and affect of anthropogenic change on these top predators is important for their conservation of both the mustelids and their aquatic communities, as keystone species their conservation ensure the health of their aquatic communities.

Keywords: Semi-aquatic mammal; Diet; Trophic niche; Coexistence; Competition; Mustelid.

1. INTRODUÇÃO GERAL

A família Mustelidae pertence à ordem Carnívora, apresentado ampla variação em tamanho e comportamento, acompanhado por variados estilos de vida, o que inclui espécies semi-fossoriais, fossoriais, semi-arbóreas, semi-aquáticas e aquáticas (Schutz & Guralnick, 2007; do Nascimento, 2014; Botton-Divet et al., 2017). Segundo do Nascimento (2014) o táxon é representado pelas oito subfamílias: Mustelinae, Ictonychinae, Helictidinae, Guloninae, Melinae, Mellivorinae, Taxidiinae e Lutrinae. Essa última subfamília é composta por 13 espécies, que ocorrem tanto em ambientes marinhos quanto de água doce (De Jong, 1987; Duplaix & Savage, 2018). Dessas 13 espécies, cinco estão ameaçadas de extinção de acordo com a Lista Vermelha da União Internacional para Conservação da Natureza e dos Recursos Naturais (IUCN) (Duplaix & Savage, 2018).

Na Amazônia são encontradas duas espécies de Lutrinae, a ariranha *Pteronura brasiliensis* (Zimmermann, 1780) (será mencionada a partir de então apenas como *Pteronura*) e a lontra *Lontra longicaudis* (Olfers, 1818) (a partir de então *Lontra*). A *Pteronura* está classificada como espécie “vulnerável” na lista brasileira (Instrução Normativa Interministerial 2012) e como “ameaçada” pela IUCN (Groenendijk et al., 2015; Leuchtenberger et al., 2018). Da mesma forma, a *Lontra*, embora não esteja na lista brasileira como espécie ameaçada (Instrução Normativa Interministerial 2012), é classificada como “quase ameaçada” pela IUCN (Rheingantz & Trinca, 2015; Rheingantz et al., 2018). O presente status de conservação dessas espécies deve-se à caça, principalmente ocorridas entre as décadas de 1950 a 1970 para utilização e comercialização de suas peles (Macdonald & Mason 1990; Carter & Rosas, 1997). No entanto, os grandes declínios populacionais são ocasionados atualmente pela perda de hábitat, como a depredação/destruição de rios e matas ciliares, mudanças estas que também causam reduções nas populações de peixes, que constituem a principal presa para esses mustelídeos (Muanis & Oliveira, 2011; Silva et al., 2013; Groenendijk et al., 2014; Rheingantz et al., 2014; Rheingantz & Trinca, 2015; Duplaix et al., 2015; Rheingantz et al., 2017a). Além disso, as frequentes mortes de animais devido a conflitos com pescadores,

também prejudica a situação desses mustelídeos (Rosas-Ribeiro et al., 2012; de Castro et al., 2014; Lima et al., 2014), agravando o status de conservação para ambas as espécies.

A *Pteronura* e a *Lontra* são espécies semi-aquáticas que coocorrem nos ambientes aquáticos da bacia amazônica e compartilham muitas semelhanças no comportamento alimentar e hábitat de preferência (Carter & Rosas, 1997; Dos Reis et al., 2011; Muanis & Oliveira, 2011; Silva et al., 2013) (Figura 1). As duas espécies desempenham um papel fundamental como predadores de topo na cadeia alimentar, atuando como controle das populações de presas, por esse motivo são bons indicadores ecológicos do bem-estar ambiental (Palmeirim et al., 2014; Duplaix et al., 2015; Trigila et al., 2015).



Figure 1: *Lontra longicaudis* alimentando-se de peixe no rio Xingu (Fonte: Pedro Rocha, 2019).

Pteronura é uma espécie endêmica da América do Sul, é o maior mustelídeo da família, atingindo comprimento máximo total de corpo de até 1,8 m, seu corpo é alongado e predominantemente marrom escuro e pode ser ainda distinguido por apresentar mancha marrom-

amarelada na garganta. Sua cauda é longa e achatada e as patas possuem membranas interdigitais facilitando na natação (Duplaix, 1980; Carter & Rosas, 1997). A *Pteronura* é diurna, uma espécie social, vivendo em grupos que incluem fêmeas, machos e filhotes (Figura 2) de diferentes idades (Carter & Rosas, 1997; Duplaix et al., 2015), são territorialistas, demarcando sua área com urina e latrinas comunitárias (Leuchtenberger & Mourão, 2009). Segundo Leuchtenberger (2018) a distribuição atual de *Pteronura* é conhecida para a Guiana Francesa, Guiana, Suriname, Bolívia, Colômbia, Brasil, Equador, Paraguai, Venezuela e Peru, e não há mais registros de populações na Argentina e Uruguai. A *Lontra* é caracterizada por sua coloração marrom e tamanho do corpo variando de 1,2 a 1,4 m, são animais diurnos, esquivos, geralmente solitários (Figura 3), formando grupos de acasalamento ou família compostos por fêmeas e machos, ou fêmeas e juvenis apenas durante a estação reprodutiva (Rodrigues et al., 2013; Rheingantz et al., 2014; Rheingantz et al., 2017b). Apresentam grande capacidade de adaptação em seu padrão de atividade, podendo se tornar crepuscular ou noturno, pode ser devido às mudanças nos padrões de atividades das presas, ou à presença humana (Rheingantz et al., 2016). A *Lontra* possui uma ampla distribuição geográfica que vai desde o Norte do México até a Argentina, ocorrendo em quase todo o continente sul-americano, exceto no Chile (Rheingantz et al., 2018).

Desse modo, as duas espécies ocorrem em simpatria em algumas regiões do Brasil, como na Amazônia e Pantanal (Silva et al., 2013). Alguns estudos têm mostrado que no caso de coocorrência, a partição de nicho ocorre entre as populações simpátricas, reduzindo a competição e permitindo a coexistência entre espécies de nicho semelhante (Papastamatiou et al., 2006; Gallagher et al., 2017). Além disso, o particionamento de recursos reduz os efeitos da exclusão competitiva entre espécies (May, 1974; Pianka, 1974; Di Bitetti et al., 2010; Wiens et al., 2010; Wang et al., 2015), que por sua vez, apresentam plasticidade alimentar adaptando seu comportamento devido à competição, e assim reduzindo a sobreposição de nicho entre espécies com comportamento alimentar similar (Punchard et al., 2000; Gotelli & McCabe., 2002; Araújo et al.,

2011). A partição de recursos ajuda a manter a estrutura da comunidade, o nicho dos organismos e suas relações ecológicas fundamentais, portanto, proporcionando equilíbrio ecológico entre as espécies (Krebs, 2001).



Figure 2: *Pteronura brasiliensis* com seu filhote, rio Xingu (Fonte: Daniel Villar, 2019).

Não se sabe até que ponto o comportamento alimentar e a posição trófica se sobrepõem entre essas espécies durante períodos com baixa disponibilidade de recursos. Pois a competição interespecífica é intensificada entre espécies de nicho semelhante quando a diversidade de recursos é reduzida (Andrade et al., 2019). Nesse sentido, a avaliação da dieta de uma espécie é importante para a compreensão das interações tróficas entre espécies coexistentes (Sih & Christensen, 2001; da Silva et al., 2017). Nesse caso, as espécies geralmente alteram seus padrões de atividade alimentar em resposta aos fatores ambientais, como o clima e a distribuição espaço-temporal de recursos (Groenendijk et al., 2014).



Figure 3: *Lontra longicaudis* as margens do rio Xingu (Fonte: Carson Jeffres, 2019).

Segundo Andrade et al. (2019) durante o período não chuvoso), geralmente ocorre a concentração de espécies em áreas geográficas menores, forçando predadores com nichos semelhantes a compartilhar recursos. Assim, as diferenças sazonais no comportamento alimentar entre mustelídeos ao longo do ano estão relacionadas, em grande parte, às diferenças na disponibilidade de presas mediadas pela sazonalidade (Leuchtenberger et al., 2013; Krpo-Ćetković et al., 2019). Já a estação chuvosa, apesar do aumento na disponibilidade de recursos para as espécies aquáticas, tende a ser um período onde os mustelídeos enfrentam maior dificuldade para encontrar suas presas devido à dispersão dos peixes no ambiente e a redução da sua capturabilidade (Cabral et al., 2010; Souza et al., 2013).

Assim, compreender a dinâmica de nicho da *Lontra* e da *Pteronura*, bem como a partição de nicho trófico desses grandes predadores torna-se imprescindível frente às frequentes modificações no ecossistema Amazônico. Principalmente para garantir a conservação de ambas as espécies em seu hábitat natural. Os efeitos antrópicos sobre essas populações podem ser irreversíveis, como por exemplo, alterações devido a construção de Usinas Hidrelétricas, que afeta diretamente o habitat de ambas as espécies. O presente estudo foi realizado em momento prévio à conclusão da Usina Hidrelétrica de Belo Monte, nos anos de 2012 e 2013, fornecendo assim uma compreensão essencial sobre a ecologia trófica dessas espécies antes da modificação ambiental provocada pela barragem.

Partindo do princípio que mustelídeos coexistam em harmonia mediante partição de nicho, isso é, as espécies diferem em suas dietas em determinado nível permitindo-os coocorrer em harmonia, o estudo fornecerá conhecimento sobre qual o nível de partição de nicho entre as duas espécies levando em consideração a variação sazonal do regime hidrológico sobre a dieta de cada espécie na região de estudo. Além disso, os resultados mostrarão a preferência alimentar de cada espécie de mustelídeo de acordo com a composição de peixes encontrados no ambiente nos dois períodos hidrológicos estudados. Espera-se que esse estudo forneça informações que auxiliem ações para a conservação dos mustelídeos.

2. OBJETIVOS

2.1. Geral

Avaliar a partição de nicho e o comportamento alimentar das espécies de mustelídeos *Lontra longicaudis* e *Pteronura brasiliensis* entre dois períodos hidrológicos no baixo rio Xingu.

2.2. Específicos

- Identificar a importância dos itens alimentares para cada uma das espécies de mustelídeos (*Lontra longicaudis* e *Pteronura brasiliensis*);
- Estimar amplitude de nicho e a especialização trófica de cada espécie com base na análise da dieta;
- Examinar as variações sazonais no comportamento alimentar das duas espécies entre dois períodos hidrológicos distintos (i.e não chuvoso vs chuvoso);
- Avaliar a seletividade de presas observando a preferência alimentar de cada uma das espécies de mustelídeos.

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Artigo¹

Feeding behavior and trophic niche partitioning between the Neotropical otter *Lontra longicaudis* and Giant otter *Pteronura brasiliensis* from the Xingu River, Amazon Basin

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Feeding behavior and trophic niche partitioning between the Neotropical otter *Lontra longicaudis* and Giant otter *Pteronura brasiliensis* from the Xingu River, Amazon Basin

Abstract. Niche partitioning occurs among coexisting populations to reduce effects of competitive exclusion among species of similar niche. The aim of the present study is to verify the trophic niche partitioning and the feeding behavior between two mustelids, the Giant otter and the Neotropical otter, through the dry and rainy hydrologic regimes of the Lower Xingu River. The outcomes suggest that the diets of both mustelids are composed primarily by fish of the family Anostomidae (Headstanders) the most consumed by both mustelids. Despite extensive niche overlap, our results indicate partitioning is facilitated by differences in niche breadth, with potential implications for conservation of both species in the case of declines in prey abundance and diversity. Both species inhabit an area recently impacted by completion of the Belo Monte Hydropower Plant, resulting in large changes to the hydrologic regime. Thus, these results provide a baseline for future understanding of the health of these mustelid populations, and provide important information for conservation efforts regarding the feeding behavior and co-occurrence of both species. The present study is the first to test the hypothesis of niche partitioning between these two mustelids outside a protected area in the Amazon.

Keywords. Aquatic mammal; Diet; Seasonal niche; Coexistence; Competition; Niche segregation.

Introduction

Many aquatic and semi-aquatic animals facultatively use the resources of several habitats within freshwater ecosystems (Schofield et al. 2018). This is particularly true in the Amazon region, where species shift resources, habitat, and behavior in response to seasonal cycles of flooding which often

drastically alter their riverine environment (Cabral et al. 2010; Rheingantz et al. 2011). In these cases, species often change their activity patterns in response to the environment factors such as weather and spatiotemporal distribution of resources (Daura-Jorge et al. 2005; Groenendijk et al. 2014; Fitzgerald et al. 2018). Low water periods, however, often concentrate species into smaller geographic areas, forcing species with similar niches to share resources (Andrade et al. 2019).

Theory predicts, and studies have shown, that in cases of this type of co-occurrence, niche partitioning occurs between the coexisting populations, reducing competition and allowing the coexistence between species of similar niche (Bonesi et al. 2004; Papastamatiou et al. 2006; Gallagher et al. 2017). In addition, resource partitioning reduces the effects of competitive exclusion among species (May 1974; Pianka 1974; Wiens et al. 2010). The species can adapt their behavior in response to competition, widening or narrowing its diet, reducing any niche overlap among coexistent species (Gotelli & McCabe 2002; Araújo et al. 2011). This balance of competition and resource partitioning helps to maintain community structure and the niche of the evolved organisms as fundamental ecologic relationships (Krebs 1999).

One example of seasonal shifts leading to sympatric habitat occupation of species occupying the same or similar niches occurs in Amazonian mustelids, whose habitats and species exploitation patterns shift with seasonal resource availability (Pardini 1998; Rheingantz et al. 2011; Leuchtenberger et al. 2015; Hernández-Romero et al. 2018). The Neotropical otter *Lontra longicaudis* (Olfers, 1818) (hereafter *Lontra*), and the Giant otter *Pteronura brasiliensis* (Zimmermann, 1780) (hereafter *Pteronura*), co-occur in the changing riverine environment of the Amazon basin and share great similarities in their feeding behavior and preferred habitat (Carter & Rosas 1997; dos Reis et al. 2011; Muanis & Oliveira 2011; Silva et al. 2013).

Both are semi-aquatic, carnivorous mammals of the family Mustelidae and subfamily Lutrinae, with fish as their main food source (Silva et al. 2013; Groenendijk et al. 2014). *Lontra* is characterized by its brown coloration and body size ranging from 1.2 to 1.4 meters. They are

elusive, diurnal, and generally solitary, forming mating or family groups composed of female and male, or female and juveniles, only during the breeding season (Rheingantz et al. 2014; 2017). *Pteronura* is the largest otter of the family, reaching a total body length up to 1.8 meters, its body is predominantly dark brown and can be further distinguished by a yellowish-brown patch on the throat. *Pteronura* is diurnal as well, but is a more social species than *Lontra*, living in groups that include females, males and pups (Carter & Rosas 1997; Duplaix et al. 2015). Both species also perform a fundamental role as top predators in the food chain, acting as a top-down control on prey populations, and for this reason their presence act as good ecological indicators of environmental welfare (Duplaix et al. 2015; Trigila et al. 2015).

Studies of habitat occupation and use by tropical mustelids during the different seasons of the year are still scarce, but it is believed that during the rainy season both species leave their dry season territories, or extend those territories towards wetlands looking for fishes (Carter & Rosas 1997; Leuchtenberger et al. 2013; 2015). Thus, seasonal differences in feeding behavior between mustelids throughout year are related largely to differences in prey availability (Leuchtenberger et al. 2013; Krpo-Ćetković et al. 2019). The rainy season, although a period of increasing resource availability for many aquatic Amazonian species, is a difficult period for otters to find prey due to prey dispersion into the environment (Fitzgerald et al. 2018; Leuchtenberger et al. 2015). It is unknown to what degree the feeding behavior and trophic position overlaps between these species during this low-resource period. Predators, such as otters, are typically generalists, feeding on a variety of prey and often exploiting the most energy rich resources (“optimal foraging theory” e.g. Charnov 1976; Costa 1993; Gallagher et al. 2017), with interspecific competition intensifying between species when resources are reduced (Andrade et al. 2019). In this sense, the diet evaluation of an organism is important for comprehension of the trophic interactions among coexistent species (Sih & Christensen 2001; da Silva et al. 2017). This is particularly true for top predators, which can affect the top-down population dynamics of the ecosystems in which they reside. Thus,

understanding the niche dynamics of *Lontra* and *Pteronura* is important in the theoretical context, as an example of niche partitioning in large predators, as well as from an ecosystem perspective within the Amazon region.

Characterizing the ecological dynamics of these species is important also because these mustelid species are heavily affected by anthropocentric actions. Both species are experiencing population declines through habitat loss, such as river depredation and removal of riparian forests, changes which are also causing reductions in fish populations and thus reductions in prey availability (Rheingantz et al. 2014; Duplaix et al. 2015; Rheingantz & Trinca 2015). These affects threaten the conservation status of both species. *Pteronura* is classified as a “vulnerable” species in Brazil (Instrução Normativa Interministerial 2012) and “endangered” by the International Union for Conservation of Nature (IUCN) (Groenendijk et al. 2015). Similarly, *Lontra*, while not listed on the Brazilian list of threatened species (Instrução Normativa Interministerial 2012), is classified as “near threatened” by the IUCN (Rheingantz & Trinca 2015).

Understanding niche dynamics between these species then, may be crucial for conservation of one or both of these species where they co-occur. This is particularly true given the environmental effects of Belo Monte Hydropower Plant (HPP) constructed in the Lower Xingu River, which directly impacts the habitat of both species in the Xingu basin. This study was conducted prior to the completion of the dam, providing the only available baseline understanding of the trophic dynamics of both species outside conservation units in Brazil.

We hypothesized that these mustelids coexist through trophic niche partitioning, despite clear overlap in feeding behavior, seasonal habitat use, and resources. Specifically, we hypothesized that differences in their diets allow them co-occur in the same area using similar prey. This study aims to: (i) characterize the feeding behavior of the mustelids between *Lontra* and *Pteronura* in the lower Xingu River; (ii) estimate the niche breadth and trophic specialization of each mustelid through diet analysis; (iii) identify the importance of alimentary items for each mustelid species;

and (iv) analyze the seasonal variations in the feeding behavior and prey selection of mustelid species between the rainy and dry seasons.

Methods

Study Area

The present study was carried out in the Xingu River, one of the largest tributaries on the right (Southern) bank of Amazon River, extending approximately 2,050 km (Andrade et al. 2019). The Xingu is a “clearwater” river (*sensu* Junk et al. 2011), with low concentrations of suspended material and nutrients, poor in phytoplankton, whose productivity is dependent on allochthonous sources such as alluvial forest on its islands and river margins (Camargo & Ghilardi 2009). The weather is characterized as tropical, warm, and humid with annual temperatures ranging from 25 to 27°C. Its waters show volumetric flow variations between 8,000 and 10,000 m³/s in the rainy season (between December and May), and 2,000 m³/s in the dry season (between June and November) (Camargo & Ghilardi 2009).

Sampling

The sampling area comprises around 300-km from upstream in the confluence of Iriiri River with Xingu River to the downstream around the city Senador José Porfirio (Fig. 4), encompassing the former area of the current constructed Belo Monte HPP. Collections of fecal samples of the two mustelids *Lontra* and *Pteronura* were performed in two hydrologic seasons, in August 2012 representing the dry season and February 2013 the rainy season. The sampling areas were traveled with the use of small motorized vessels, surveying the margins looking for traces of feces. Samples of *Lontra* generally are found on the rocks, tree trunks, and sand banks, or near to its burrow entrance. *Lontra* feces are cylindrical shaped and more consistent than the *Pteronura* feces (Kasper

et al. 2008; Silva et al. 2013). *Pteronura* feces are generally found in community latrines, scattered in the river banks ground where the species remove the vegetation along the margins of rivers (Carter & Rosas 1997). In the field, each collected sample was packaged in individual plastic jars, given an alphanumeric code identifying the place of collection, date and species (*Lontra* or *Pteronura*).

Diet Analysis

For diet analysis, fecal samples were washed individually in running water using a 1 mm mesh sieve which retained undigested food items in the feces which allow identification (e.g., scales, otoliths, bones, exoskeletons, teeth, fur, and others). These samples were then dehydrated in an oven at 60°C and examined under a ZEISS model Stemi DV4 stereoscope. The items were grouped and identified using specific literature and/or comparing with biological samples in the fish collection of the Grupo de Ecologia Aquática (GEA) at the Universidade Federal do Pará (UFPA).

Data Analysis

The importance of food resources A_i was evaluated through alimentary index according to (Kawakami & Vazzoler 1980):

$$A_i = (F_i * N_i) / \sum (F_i * N_i),$$

where F_i is the frequency of occurrence of the prey i and N_i is the numerical frequency of the prey i . The frequency of occurrence ($F_i\%$) is the relative frequency of occurrence of the prey i in relation to the number of analyzed samples, and the numerical frequency ($N_i\%$) represents the relative number of the prey i in relation to the total number of prey. In order to be conservative, multiple items such as scales of a particular fish in the same stomach were counted just as one fish of that group. The similarity in diet composition between mustelids was evaluated through a cluster

analysis using Bray-Curtis distance based on the matrix of the alimentary importance of the items found, and graphically represented with a *heatmap* (Clarke et al. 2014).

The niche breadth and niche overlap between species and between seasons were inferred based in the Levin's niche breadth (Krebs et al. 1999):

$$B = 1 / (\sum P_j^2),$$

where p is the proportion of specimens (mustelids) where the resource j was found. The niche overlap of species was calculated using Pianka's index with the null model based in the algorithm RA3 available in the R package EcoSimR v1.0 (Gotelli & Ellison 2013) and 9,999 Monte Carlo permutations.

To reveal feeding patterns of selection of the *Lontra* and *Pteronura*, a Principal Coordinate Analysis (PCo) was made with the Bray-Curtis dissimilarity matrix of diet data of the two mustelids between rainy and dry seasons, and potential differences tested as Permutational Multivariate Analysis of Variance (PERMANOVA) with 9,999 permutations in PRIMER v.7 (Clarke & Gorley 2015).

Resource Availability

The alimentary resource availability, more specifically fish availability since they are the majority of consumed prey resources in both mustelids (Silva et al. 2013), were estimated based on gillnet samples collected at the same sites and during the same periods which fecal samples were collected (data provided by Norte Energia S.A.). Three sets of seven gill nets were used, each set having net sizes between 2–18 cm of mesh. The nets were 20 m long and 2 m deep. Gillnets were set at random locations at twilight near the river margins (Fig. 4) and remained there for a 14 h period. Nets were checked every three hours to avoid losses by predation.

The potential selection of preys by the two mustelids was evaluated by the Ivlev's Electivity Index (E_i), performed as:

$$E_i = (r_i - n_i) \div (r_i + n_i),$$

where r_i is the percentage of particular prey item in the diet of mustelids, and n_i is the percentage of a particular family of collected fish by gillnets. The E_i 's values ranging from -1 to $+1$, where the negative values indicate a less accessible prey or rejection of them, zero indicates random feeding, and positive values indicate active search by preys (Strauss 1979).

Trophic connections between mustelid species

To evaluate the trophic connections between *Lontra* and *Pteronura*, and between the rainy and dry seasons, bipartite networks were created from the data. The bipartite networks represent the trophic linkages between the mustelids (consumers) and the food items (resources) using the package ‘*bipartite*’ (Dormann et al. 2008) in R (R Development Core Team, 2019).

To analyze the influence of seasons the trophic connections of the two mustelids were also calculated through two methods. Connectance (C) is calculated as the proportion of interactions in relation to all possible interactions (Dunne et al. 2002; Thompson et al. 2012). In this context, species with C near zero (0) are considered trophic specialists, while those near to one (1) are trophic generalists. Secondly, linkage density (D) was calculated for each species. Linkage density is the average number of linkages by species (Vermaat et al. 2009; Thompson et al. 2012), calculated by:

$$D = L/S,$$

where L is the number of links, and S is the number of knots.

Results

Overall, 216 fecal samples of mustelids were collected throughout the Lower Xingu River basin. Of these, for *Lontra* 56 were samples from the rainy and 114 from dry seasons. For *Pteronura*, 30 samples were collected from the rainy and 16 from dry seasons. For all samples we classified prey

to five large food groups: fish, crustacean, reptile, mammal, and gastropods. These five groups were made up of 16 item categories, the majority being fish families. The groups present in the sample were: Acestrorhynchidae, Ageneiosidae, Anostomidae, Characidae, Doradidae, Erythrinidae, Loricariidae, Pimelodidae, Pleuroceridae, Serrasalminidae (all fish families), aside from Crustacean, Gastropoda, Iguania, Mammalia, Lizard, and Serpent. We kept the groups Iguania, Lizard and Serpent separated rather than together in the higher taxa level Squamata to evidence specificity in diet of each mustelid.

Based in the alimentary index, *Lontra* fed most on the fish family Anostomidae and the Crustacea in both seasons. While *Pteronura* fed most on the fish families Acestrorhynchidae and Erythrinidae in the dry season and fed primarily of the fish families Anostomidae and Acestrorhynchidae during the wet season (Supporting Information). The similarity in diet between mustelid species was indicated by a dendrogram generated from the cluster analysis of the importance of each prey item (Fig. 5). The result revealed two distinct groups by similarity of alimentary importance: Group 1 (*Pteronura* in the dry and rainy seasons) and Group 2 (*Lontra* – in the dry and rainy seasons). Further, the analysis confirmed the result above, that *Pteronura* fed most on the fish family Acestrorhynchidae in the dry season and on the fish family Anostomidae in the rainy season. In contrast, *Lontra* showed high importance for the consumption in fish family Anostomidae in both periods.

The niche breadth analysis indicated that both mustelid species show wider niche in the rainy season than in dry, and *Lontra* showed wider niche breadth than *Pteronura* in both seasons (*Lontra*: $B_{\text{dry}} = 6.33$, $B_{\text{rainy}} = 7.24$; *Pteronura*: $B_{\text{dry}} = 2.71$, $B_{\text{rainy}} = 5.16$). The diet comparison using Pianka's index based in the niche breadth of species found low interspecific niche overlap in dry season ($O_{jk} = 0.28$) whereas niche overlap was high in the rainy season ($O_{jk} = 0.55$). In addition, the observed niche overlap was greater than that estimated by the null model (observed = 0.59 > estimated = 0.32). The diet comparisons between dry and rainy seasons did not find significant

statistical differences for *Lontra* (PERMANOVA, *Pseudo-F*: 0.53, $p=0.69$) neither for *Pteronura* (PERMANOVA, *Pseudo-F*: 0.86, $p=0.48$). The PCo explained 70.2% of the alimentary pattern in the first two axis (Fig. 6), 47.5% in the first axis and 22.7% in the second, unveiling two distinct groups, one corresponding to *Lontra*, whether in dry or rainy season, and other composed by *Pteronura*, whether in dry or rainy season (PERMANOVA, *Pseudo-F*: 16.81, $p<0.0001$). The results showed significance of the alimentary items only for two large groups, fish and crustacean. For both mustelids the majority of the significance was due to fish families Acestrorhynchidae, Anostomidae, Characidae, Erythrinidae, Loricariidae and Serrasalminidae, and also to the group Crustacea, which is composed mostly of freshwater crabs (Supporting Information).

Overall 4,498 fish specimens belonging to 10 taxonomic orders, 33 families and 168 species were collected during the sampling with gillnets in both seasons. From those, 2,028 fish of 30 families were collected in dry season, and 2,470 fish of 27 families in rainy season. The relative abundance of eight fish families which were also found in the mustelids diet was evaluated regarding to its relative abundances of the same families sampled in the environment by gillnets. The Ivlev's electivity index (E_i) showed greater preference for particular fish families (Supporting Information) for both mustelids. *Lontra* in the dry season actively feed (positively selected) on five fish families; while randomly feed (negatively selected) on three families. Conversely, in rainy season *Lontra* positively choose seven fish families showed negative preference during this season (Fig. 7). *Pteronura* actively feed on four fish families in the dry season as represented by electivity index; showing also negative preference for four families in this season. On the other hand, seven families showed positive preference in the rainy season; and only the family Loricariidae showed negative preference during this season (Fig. 7).

The results suggested high trophic connection between mustelids ($C_{dry} = 0.86$; $C_{rainy} = 0.79$), suggesting opportunistic and generalist behavior in resource choice for both species. In the fig. 8 the bipartite net represents the predator-prey interactions of the mustelids and their food resources. The

horizontal bars in the top represent the niche breadth of each mustelid in its respective season. The horizontal bars in the bottom represent the resource availability for mustelids of the respective prey. The linkages are different, thickness represents the importance of each prey for the mustelid in determined season being the wider linkage more important and narrower less important.

Discussion

Several prior studies have suggested that seasonal changes shape the feeding behavior of these mustelid species, mainly due to changes in prey availability (e.g., Pardini 1998; Rheingantz et al. 2011; Leuchtenberger et al. 2015; Krpo-Ćetković et al. 2019). However, our study did not find differences in mustelids' diet within each species between seasons. Diet comparisons between the two mustelid species showed lower niche overlap during the dry season. This may be explained by the high availability of a variety of resources in the environment during this low-water season, allowing each mustelid to access the prey of its preference (Silva et al. 2013).

The highest niche overlap occurred in the rainy season, likely owing to the greater dispersion of food resources (e.g., fishes) into flooded riparian areas, resulting in lower capturability by the mustelids and, thereby, forcing both predators feed on the most accessible, abundant, and similar prey. However, despite the niche overlap, the trophic partitioning between the two mustelids was facilitated by the wider niche breadth of *Lontra*. This niche breadth presumably avoids competitive exclusion between species, providing niche differentiation among species and optimizing their coexistence (Schirmer et al. 2020). This supports the hypothesis of resource partitioning between *Pteronura* and *Lontra* through niche distinction. The same mechanism has been recorded for other mustelid species, for example the Eurasian otter *Lutra lutra* and the American mink *Mustela vison* (Bonesi et al. 2004). In this example, *M. vison* broadened its diet and consumed greater proportions of birds and mammals in the presence of *L. lutra*.

The feeding behavior and prey choice of both *Pteronura* and *Lontra* in the present study is consistent with optimal foraging theory (MacArthur & Pianka 1966). Generally, these animals are opportunistic predators, actively seeking the most vulnerable or most abundant prey in the environment, this includes fishes of the family Anostomidae (Headstanders), the main food resource for both mustelids in this study. These fish form large schools with multiple species of similar morphology (Sidlauskas & Birindelli 2018), as well as the fishes of the family Acestrorhynchidae (Smallscale pike characins; the second most consumed food resource of *Pteronura*). Both fish families are pelagic fishes and represents a larger portion of the biomass found in Amazonian aquatic environments (Garavello & Britski 2003; Menezes 2003).

While benthic fishes, with low mobility and consequently greater vulnerability to predators (Armbruster et al. 2018), make up a significant part of each species diet the two mustelid do not prey equally on all benthic species. Fishes of the family Loricariidae (Plecos) are consumed in abundance by *Lontras*, while the fishes of the family Erythrinidae (Trahiras), which are composed of sedentary species (Oyakawa & Mattox 2018) were more commonly consumed by *Pteronura*.

Since the mustelids utilize the terrestrial environment, performing feeding, reproduction, shelter building, and other activities on river banks (Alarcon & Simões-Lopes 2003), crustaceans (freshwater crabs) have been shown to be an important group in the diet of *Lontra* in some studies (Rheingantz et al. 2011; Quintela et al. 2012), but less important in others (Silva et al. 2013; Souza et al. 2013). Our study indicated that crustaceans made up a significant part of the diet of *Lontra*, and was a key differentiator between the diets of the two species. Crustaceans were rarely found in the diet of *Pteronura*.

The comparison of diet and prey availability from gillnet captures found that from the eight fish families analyzed, *Lontra* showed feeding preference for five of those fish families during the dry season, and seven during rainy season. Silva et al. (2013) suggest that both mustelids a preference for prey with low mobility. That is, fish with reduced escape ability, such as the fishes of

the family Erythrinidae. In our study this family showed positive selectivity and was consumed in abundance for both mustelids. However, this family was also poorly represented in gillnet captures, potentially biasing these results. This result, however, is likely due to the methodology used, since gillnets are most suitable for catching more active, pelagic fishes (Mesquita et al. 2019). The consumption of other food items such as Iguania, Pleuroceridae, mammalia (small rodents) and lizards, have been reported in previous studies on diet of mustelids (Silva et al. 2013; Souza et al. 2013; Krpo-Ćetković et al. 2019). Even though these prey appeared in the present study, they were less important in diet for both mustelids, appearing mainly in the rainy season. This is explained by weather conditions of rainy season which makes the main prey capturability difficulted (i.e., fishes) for both mustelids (Pardini 1998) and supports the finding that both species are forced to broaden their niche during the rainy season.

Beyond facilitating their co-occurrence ecologically, understanding the niche differences between the *Lontra* and *Pteronura* may provide important insights useful for mitigating the poor current conservation status of both species. Understanding the biological and ecological needs of each species help ensure the most effective measures for conservation of these animals in their natural environment. We saw that, while both mustelids exhibit generalist feeding behavior, *Pteronura* have a narrower niche when compared to *Lontra*. This suggests that *Pteronura* may be more sensitive than *Lontra* to environmental changes such as fragmentation and habitat loss, which causes decrease resource availability. In fact, this lack of niche breadth may be one reason for the status of *Pteronura* as a “Threatened” species while *Lontra* is only listed as “Near Threatened” species according to IUCN.

Our results indicate that *Pteronura* would suffer more severely in conditions of low resource availability, especially decreases in fish diversity and abundance. Despite often displaying generalist feeding behavior, the diet of *Pteronura* is nonetheless more specialized to fish consumption than *Lontra*. This scenario of decreased fish diversity and habitat fragmentation

(which is known to decrease species diversity) was predicted as a result of the construction of the Belo Monte HPP (Sabaj Pérez 2015). This indicates that *Pteronura* may be more heavily affected by the changes the Belo Monte dam complex has brought to the Xingu River. However, despite these threats, strategies for the conservation of mustelids in the region are lacking (Groenendijk et al. 2015; Rheingantz & Trinca 2015).

The present study is the first to test the hypothesis of niche partitioning between these two mustelids outside a protected area in the Amazon. These mustelids with generalist feeding behavior which co-occur in the Lower Xingu River diminish niche overlap by distinction in their diets during the dry season. However, niche overlap occurs during the rainy season when food is comparatively scarce. In this context our study provides critical baseline information on the feeding behavior and niche partitioning of both mustelid species prior to the completion of the Belo Monte HPP.

Evidence from our analysis indicates that *Pteronura* may be the most impacted by the predicted fish diversity loss after construction of HPP, a question which should be investigated by future studies.

Both species are top predators of major importance for nature conservation and are keystone species within their aquatic communities. Understanding their ecology, both before and after anthropogenic impacts on their populations, is critical to their conservation.

Supporting Information

Prey items' indices (Appendix S1), prey items' significance (Appendix S2), Ivlev's index of electivity (Appendix S3).

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Fig. 4. Sites of fecal sampling of *Lontra longicaudis* and *Pteronura brasiliensis* and gillnets sampling collected in dry (August 2012) and rainy (February 2013) seasons throughout the Xingu River basin.

Fig. 5. Cluster analysis and heatmap showing the similarity in diet of the two mustelid species *Pteronura brasiliensis* and *Lontra longicaudis* between seasons of dry (Aug/2012) and rainy (Feb/2013) from Xingu River basin. P.D (*P. brasiliensis* – Dry); P.R (*P. brasiliensis* – Rainy); L.D (*L. longicaudis* – Dry); L.R (*L. longicaudis* – Rainy).

Fig. 6. First two axes of the principal coordinates analysis (PCo) based on diet contents of the two mustelids (P) *Pteronura brasiliensis* and (L) *Lontra longicaudis*, during dry (Aug/2012) and rainy (Feb/2013) seasons in the Xingu River basin.

Fig. 7. Prey electivity of fishes by the two mustelids (*Lontra longicaudis* and *Pteronura brasiliensis*) from Xingu River basin during seasons of dry (Aug/2012) and rainy (Feb/2013).

Fig. 8. Bipartite network diagram representing the predator-prey interactions between *Lontra* and *Pteronura*. Predators are represented above by the two mustelids *Pteronura* and *Lontra* from seasons of dry (Aug/2012) and rainy (Feb/2013); and prey are represented below. The bar width of predators represents the niche breadth and the bar width of prey is the level of importance to the diet of both mustelids.

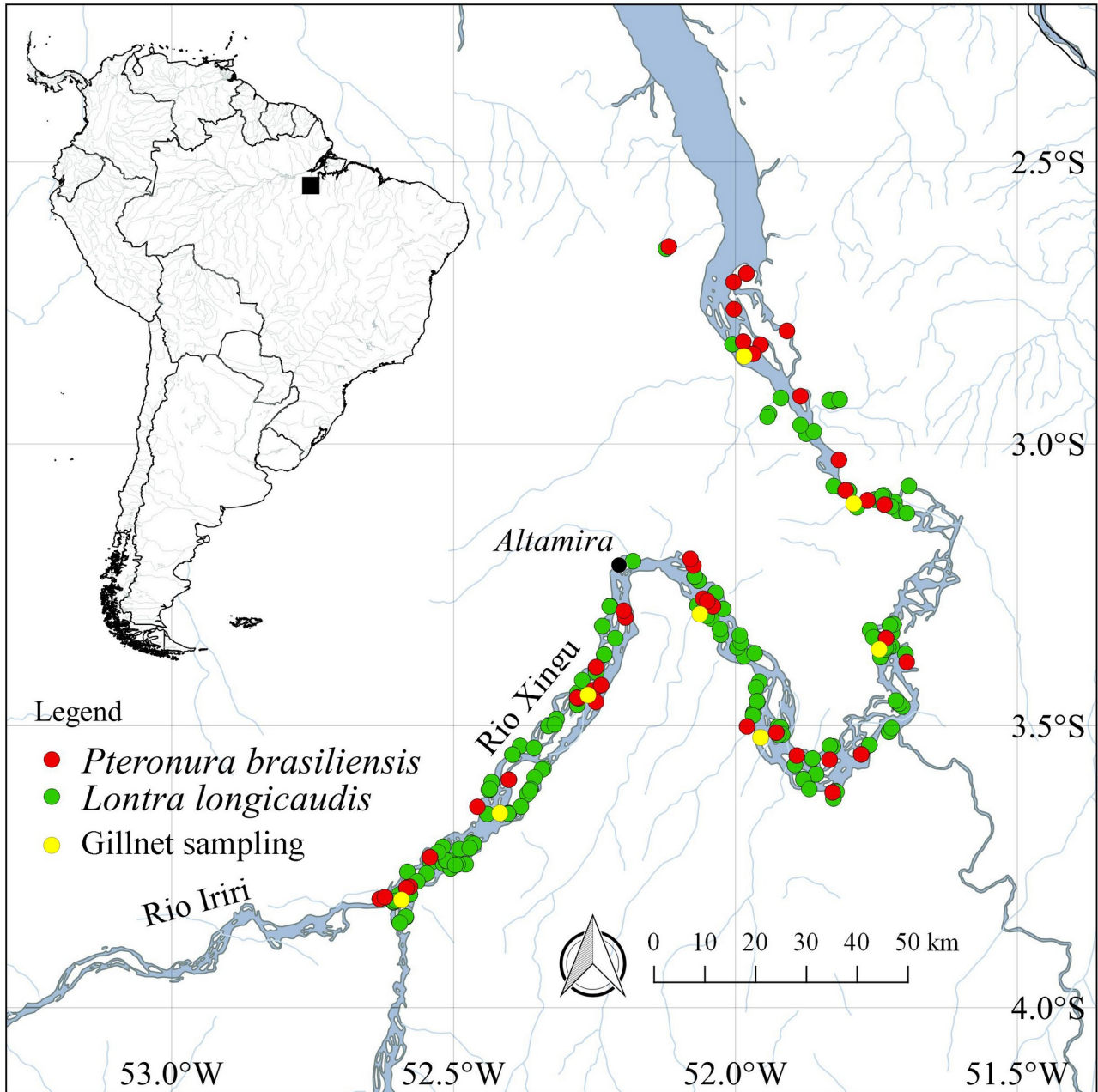


Figure 4: Sites of fecal sampling of *Lontra longicaudis* and *Pteronura brasiliensis* and gillnets sampling collected in dry (August 2012) and rainy (February 2013) seasons throughout the Xingu River basin.

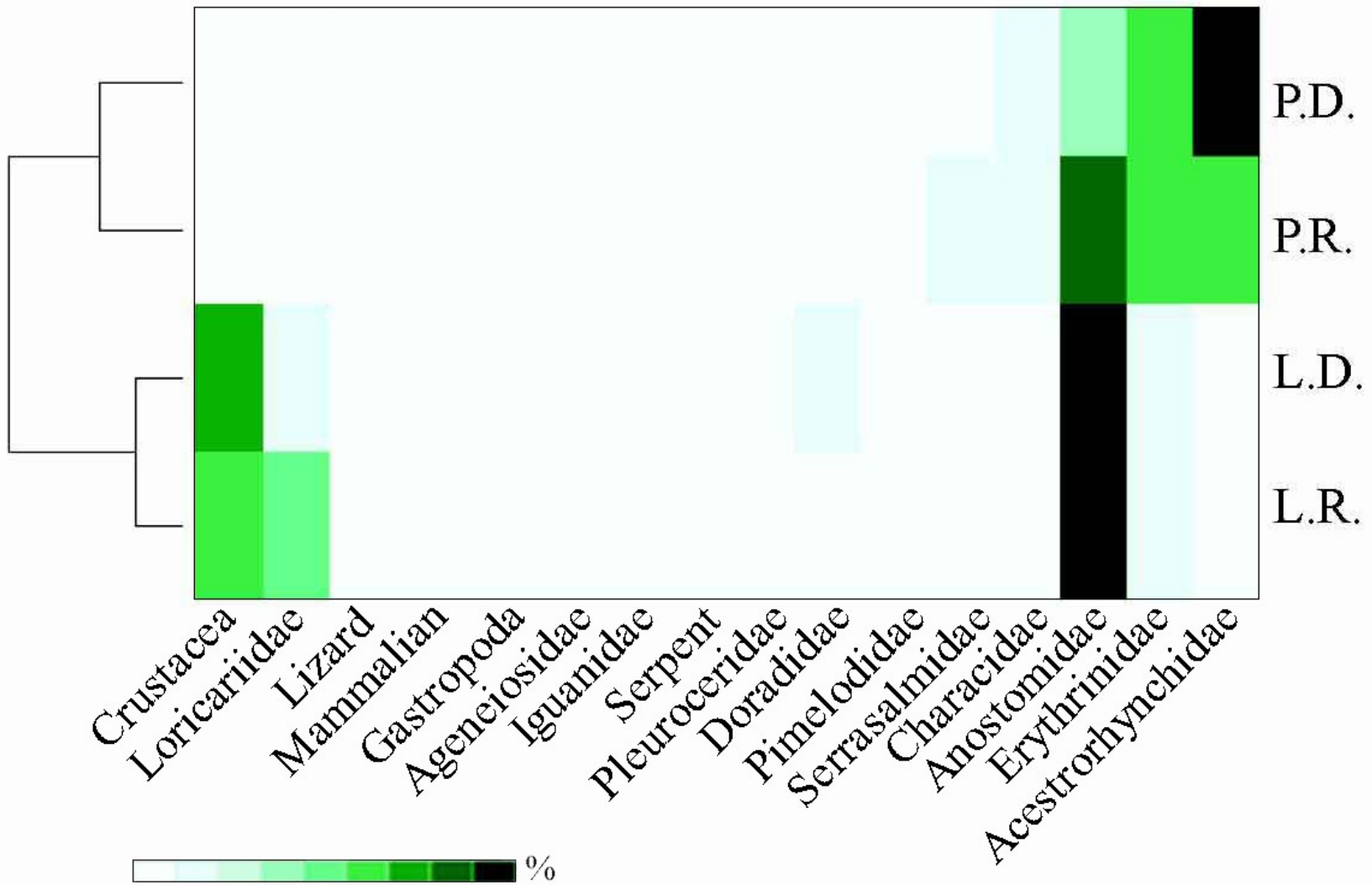


Figure 5: Cluster analysis and heatmap showing the similarity in diet of the two mustelid species *Pteronura brasiliensis* and *Lontra longicaudis* between seasons of dry (Aug/2012) and rainy (Feb/2013) from Xingu River basin. P.D (*P. brasiliensis* – Dry); P.R (*P. brasiliensis* – Rainy); L.D (*L. longicaudis* – Dry); L.R (*L. longicaudis* – Rainy).

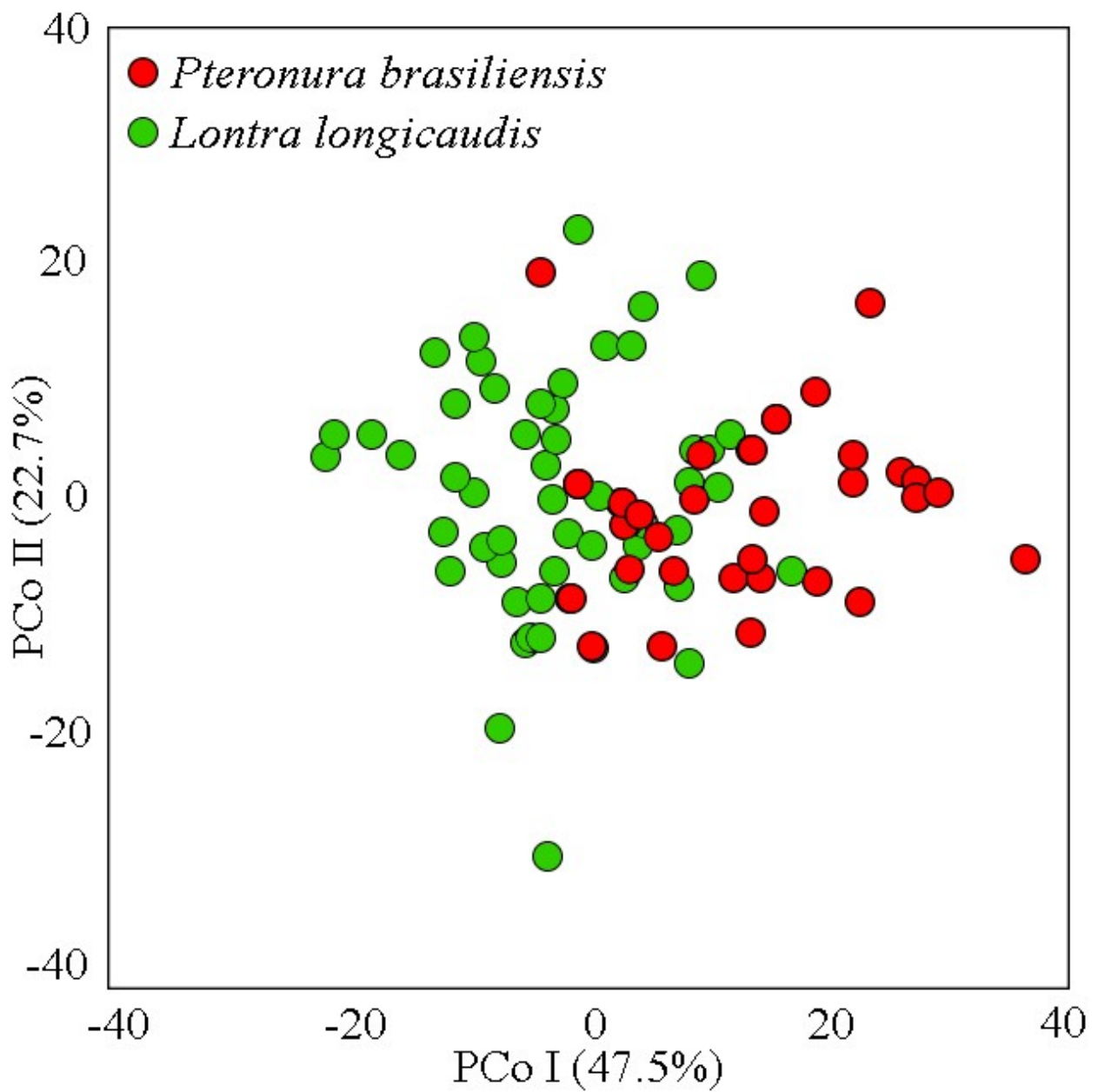


Figure 6: First two axes of the principal coordinates analysis (PCo) based on diet contents of the two mustelids (P) *Pteronura brasiliensis* and (L) *Lontra longicaudis*, during dry (Aug/2012) and rainy (Feb/2013) seasons in the Xingu River basin.

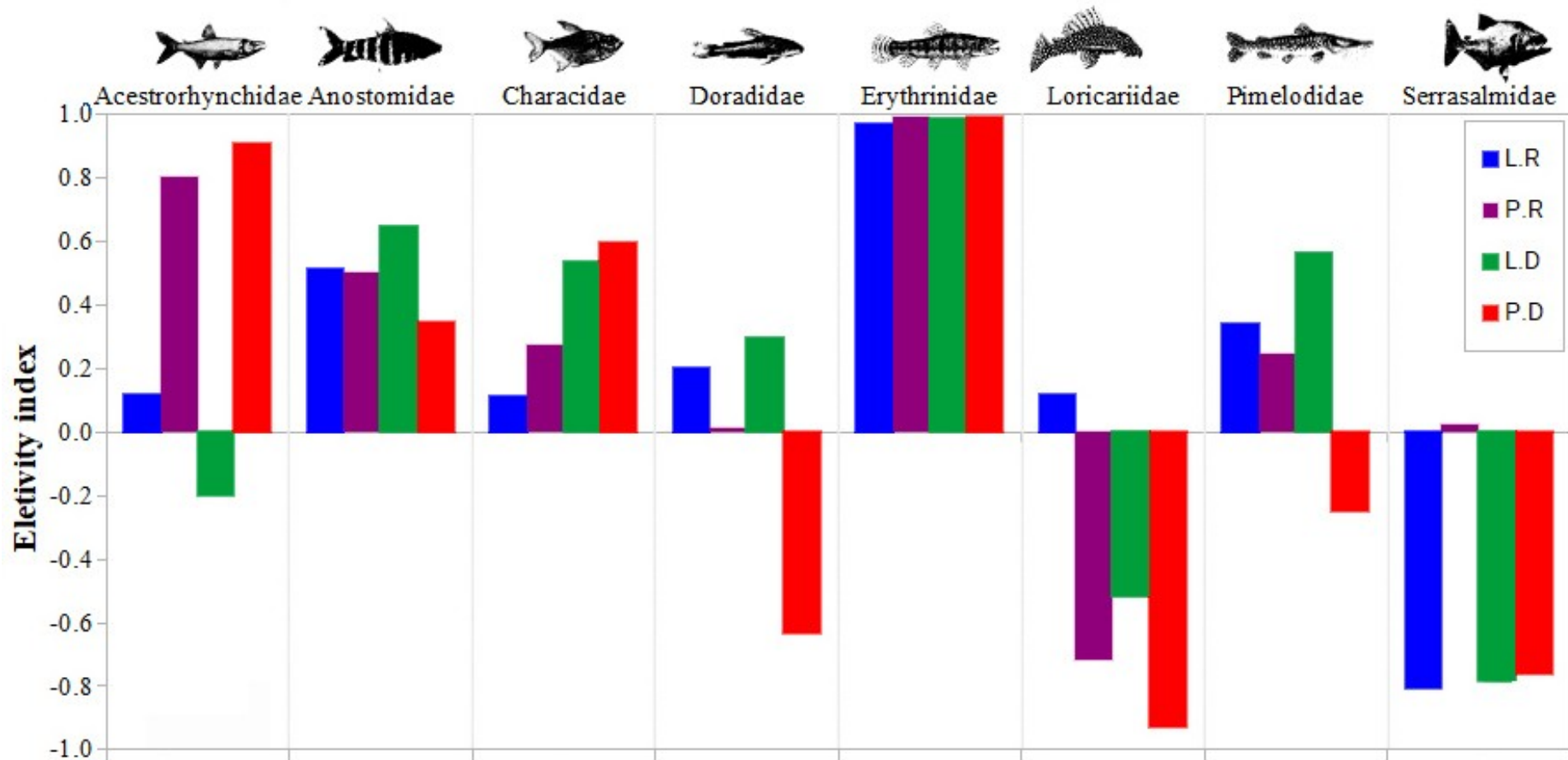


Figure 7: Prey electivity of fishes by the two mustelids (*Lontra longicaudis* and *Pteronura brasiliensis*) from Xingu River basin during seasons of dry (Aug/2012) and rainy (Feb/2013).

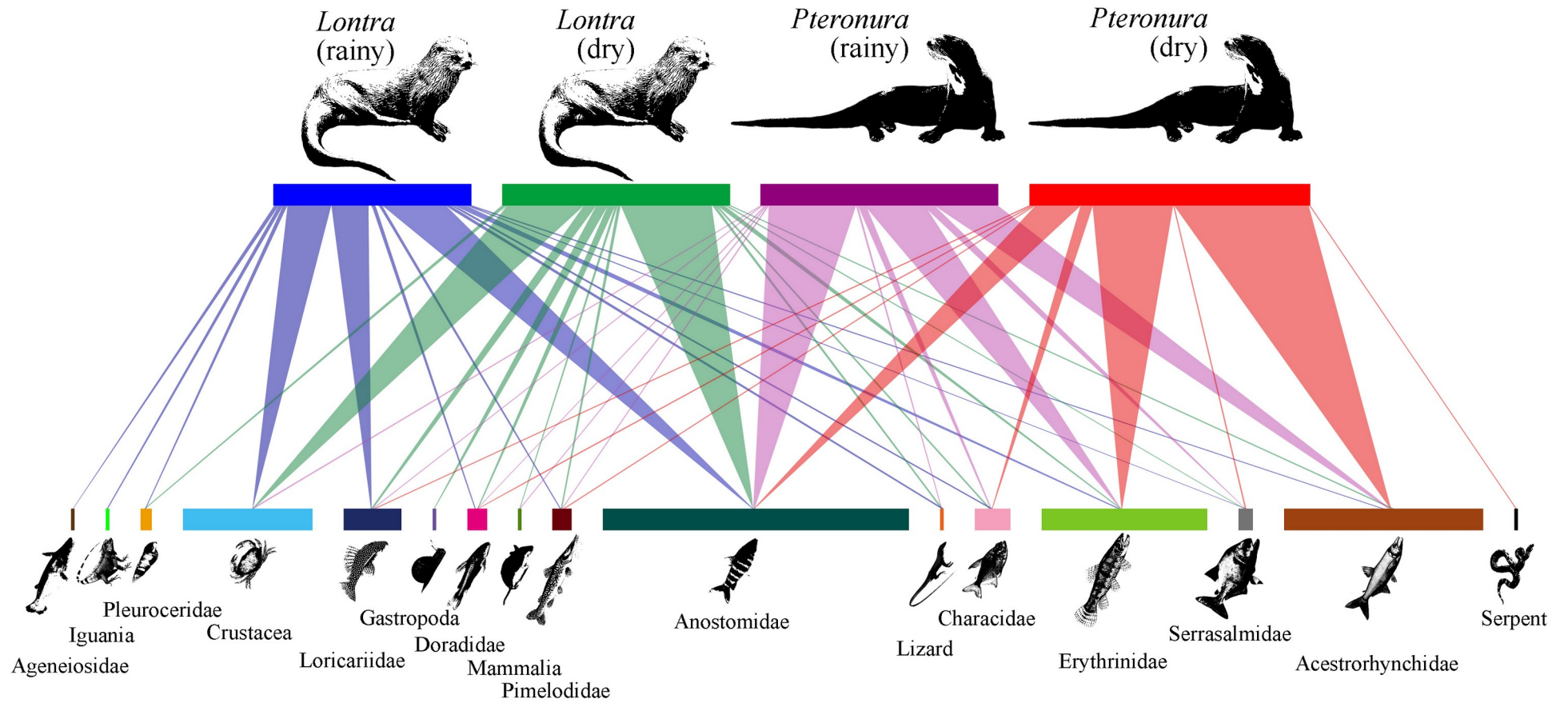


Figure 8: Bipartite network diagram representing the predator-prey interactions between *Lontra* and *Pteronura*. Predators are represented above by the two mustelids *Pteronura* and *Lontra* from seasons of dry (Aug/2012) and rainy (Feb/2013); and prey are represented below. The bar width of predators represents the niche breadth and the bar width of prey is the level of importance to the diet of both mustelids.

Feeding behavior and trophic niche partitioning between the Neotropical otter *Lontra longicaudis* and Giant otter *Pteronura brasiliensis* from the Xingu River, Amazon Basin

Supporting information

Appendix S1. Frequency of occurrence (Fo%), numeric frequency (Ni%) and alimentary index of prey items found in the fecal samples of the two mustelids (*Lontra longicaudis* and *Pteronura brasiliensis*) during the dry (August 2012) and rainy (February 2013) seasons in Xingu River basin.

Groups	Fo%				Ni%				Ai%			
	L.D	P.D	L.R	P.R	L.D	P.D	L.R	P.R	L.D	P.D	L.R	P.R
Acestrorhynchidae	5.4	60	2.6	43.8	3.8	27.2	1.8	55.3	9.6	432.6	2.3	922.3
Ageneiosidae	1.8	-	-	-	0.8	-	-	-	0.6	-	-	-
Anostomidae	50	110	52.6	75	21.2	20.4	26.1	11.7	503.3	594.9	684	332.9
Characidae	12.5	43.3	10.5	37.5	5.3	7.4	4.9	5.8	31.5	85.2	25.5	83.2
Crustacea	41.1	3.3	46.5	-	17.4	0.6	23	-	339.6	0.5	532.5	-
Doradidae	12.5	13.3	17.5	6.3	4.5	3.1	8	1	27	10.9	69.6	2.3
Erythrinidae	17.9	60	18.4	68.8	9.8	25.3	10.6	21.4	83.5	403.1	97.4	559.4
Gastropoda	-	-	0.9	-	-	-	0.4	-	-	-	0.2	-
Iguania	1.8	-	-	-	0.8	-	-	-	0.6	-	-	-
Loricariidae	41.1	13.3	21.9	6.3	14.4	1.9	8.8	1	280.6	6.6	96.6	2.3
Mammalia	-	3.3	4.4	-	-	0.6	1.3	-	-	0.5	2.9	-
Pimelodidae	16.1	23.3	17.5	6.3	5.3	4.3	5.8	1	40.4	26.8	50.2	2.3
Pleuroceridae	7.1	-	3.5	-	15.2	-	7.1	-	51.4	-	12.4	-
Lizard	1.8	10	0.9	-	0.8	1.9	0.4	-	0.6	4.9	0.2	-

Serrasalminae	1.8	36.7	3.5	12.5	0.8	7.4	1.8	1.9	0.6	72.1	3.1	9.2
Serpent	-	-	-	6.3	-	-	-	1	-	-	-	2.3

L.D (*Lontra longicaudis* – Dry); P.D (*Pteronura brasiliensis* – Dry); L.R (*Lontra longicaudis* – Rainy); P.R (*Pteronura brasiliensis* – Rainy).

Appendix S2. First two principal component analysis axes (PC I, II) and the significant prey items for the two mustelids (*Lontra longicaudis* and *Pteronura brasiliensis*) during seasons of dry (Aug/2012) and rainy (Feb/2013) from Xingu River basin.

Prey items	PC I	PC II	r^2	<i>P</i> -value
Acestrorhynchidae	0.75	0.66	0.59	0.0001
Ageneiosidae	-0.81	-0.59	<0.01	0.5765
Anostomidae	0.34	-0.94	0.60	0.0001
Characidae	0.66	-0.75	0.11	0.0001
Crustacea	-0.58	0.81	0.28	0.0001
Doradidae	-0.06	-1.00	0.02	0.1056
Erythrinidae	0.90	0.44	0.69	0.0001
Gastropoda	-0.54	0.84	0.02	0.0986
Iguania	-0.54	0.84	0.02	0.0950
Loricariidae	-0.63	0.78	0.19	0.0001
Mammalia	-0.44	-0.90	<0.01	0.5934
Pimelodidae	0.16	-0.99	0.05	0.0074
Pleuroceridae	-0.95	0.32	0.08	0.0115

Lizard	0.71	-0.70	0.02	0.0852
Serrasalmidae	0.73	-0.68	0.13	0.0002
Serpent	0.77	-0.64	0.01	0.1335

Appendix S3. Calculated Ivlev's index of electivity for the eight fish families as prey for the two mustelids (*Lontra longicaudis* and *Pteronura brasiliensis*) during seasons of dry (Aug/2012) and rainy (Feb/2013) from Xingu River basin.

Fish families	L.R.	P.R.	L.D	P.D
Acestrorhynchidae	0.12	0.80	-0.20	0.91
Anostomidae	0.51	0.50	0.64	0.35
Characidae	0.11	0.27	0.53	0.60
Doradidae	0.20	0.01	0.30	-0.63
Erythrinidae	0.97	0.99	0.98	0.99
Loricariidae	0.11	-0.72	-0.52	-0.93
Pimelodidae	0.34	0.24	0.56	-0.25
Serrasalmidae	-0.81	0.02	-0.78	-0.77

