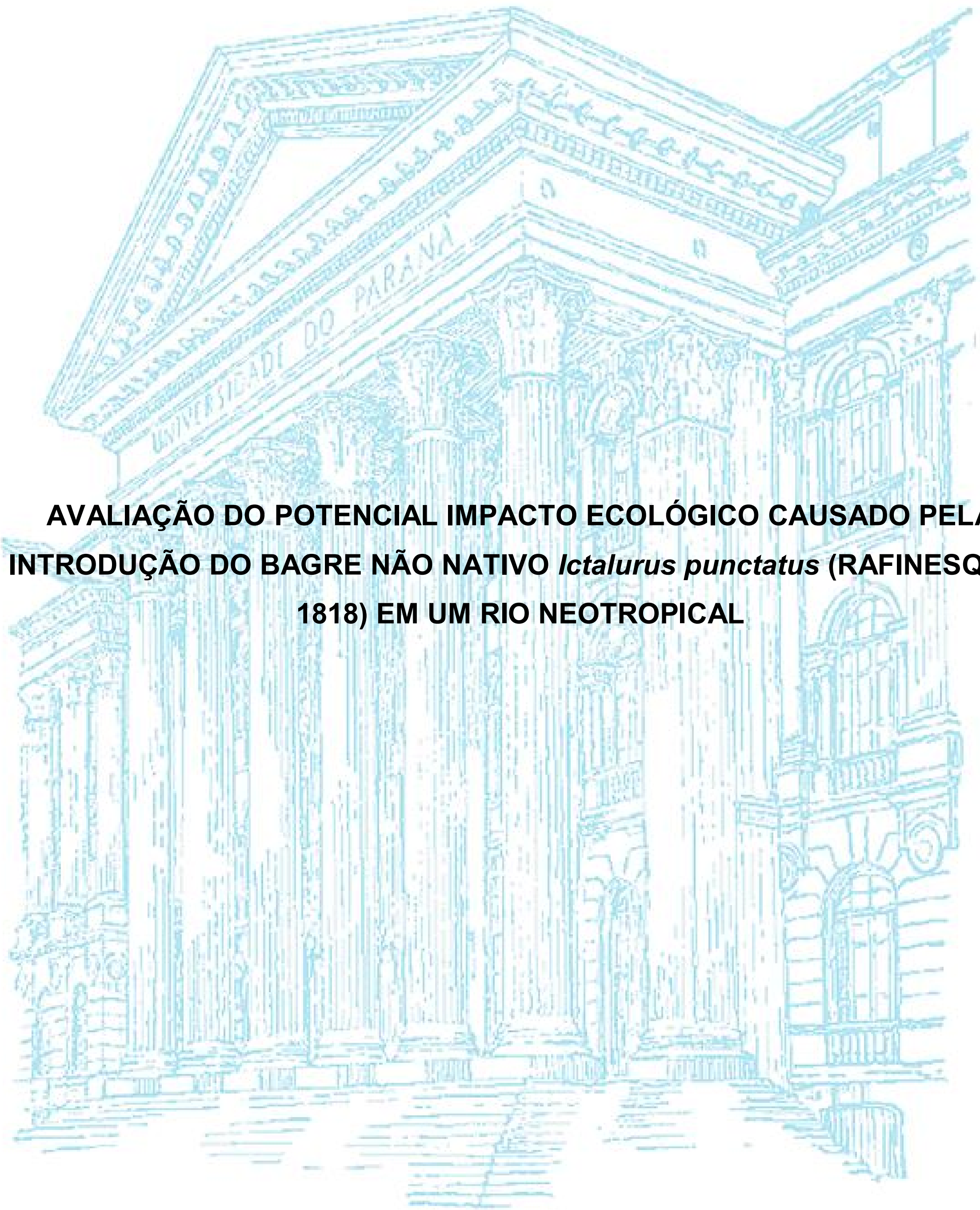
UNIVERSIDADE FEDERAL DO PARANÁ

PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA E CONSERVAÇÃO

LARISSA FARIA



AVALIAÇÃO DO POTENCIAL IMPACTO ECOLÓGICO CAUSADO PELA INTRODUÇÃO DO BAGRE NÃO NATIVO *Ictalurus punctatus* (RAFINESQUE, 1818) EM UM RIO NEOTROPICAL

CURITIBA

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Dissertação apresentada como requisito parcial à obtenção do grau de Mestre em Ecologia e Conservação, no Curso de Pós-Graduação em Ecologia e Conservação, Setor de Ciências Biológicas, da Universidade Federal do Paraná.

Orientador: Prof. Dr. Jean Ricardo Simões Vitule

CURITIBA
2018

Universidade Federal do Paraná. Sistema de Bibliotecas.
Biblioteca de Ciências Biológicas.
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Faria, Larissa
Avaliação do potencial impacto ecológico causado pela introdução do bagre não nativo *Ictalurus punctatus* (Rafinesque, 1818) em um rio Neotropical. / Larissa Faria. – Curitiba, 2018.
55 f.: il. ; 30cm.

Orientador: Jean Ricardo Simões Vitule
Dissertação (Mestrado) - Universidade Federal do Paraná, Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

1. Água doce. 2. Conservação. 3. Bagre (Peixe). I. Título II. Vitule, Jean Ricardo Simões. III. Universidade Federal do Paraná. Setor de Ciências Biológicas. Programa de Pós-Graduação em Ecologia e Conservação.

CDD (20. ed.) 597.52

MINISTÉRIO DA EDUCAÇÃO
SETOR CIÊNCIAS BIOLÓGICAS
UNIVERSIDADE FEDERAL DO PARANÁ
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
PROGRAMA DE PÓS-GRADUAÇÃO ECOLOGIA E CONSERVAÇÃO

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Os membros da Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em ECOLOGIA E CONSERVAÇÃO da Universidade Federal do Paraná foram convocados para realizar a arguição da dissertação de Mestrado de **LARISSA FARIA** intitulada: **Avaliação do potencial impacto ecológico causado pela introdução do bagre não nativo Ictalurus punctatus (Rafinesque, 1818) em um rio Neotropical.** , após terem inquirido a aluna e realizado a avaliação do trabalho, são de parecer pela sua APROVAÇÃO no rito de defesa.

A outorga do título de mestre está sujeita à homologação pelo colegiado, ao atendimento de todas as indicações e correções solicitadas pela banca e ao pleno atendimento das demandas regimentais do Programa de Pós-Graduação.

Curitiba, 08 de Março de 2018.

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A todas as mulheres corajosas deste mundo.

Especialmente à minha avó Mari, *in memoriam*.

AGRADECIMENTOS

À Universidade Federal do Paraná, por me acolher por mais dois anos como sua aluna, e por ser a minha segunda casa.

Ao Programa de Pós-Graduação em Ecologia e Conservação, na figura de seus professores e funcionários sempre dispostos a ensinar e auxiliar.

À CAPES, pela bolsa de estudos sem a qual a realização desta empreitada pelo título de mestra não seria possível.

Ao meu orientador Jean Ricardo Simões Vitule, por toda sua dedicação e confiança no meu trabalho. Obrigada por acreditar em mim mais do que eu mesma e me inspirar a buscar o meu melhor sempre.

À banca, professor Dr. André Padial e professora Dra. Mhairi Alexander, por aceitarem o convite prontamente e disponibilizarem um pouco do seu tempo para contribuir com este trabalho.

Aos meus colegas do Laboratório de Ecologia e Conservação, que sempre estiveram a postos quando eu precisei e que tornaram o dia-a-dia mais divertido com sua companhia. Obrigada especialmente ao Thiago, ao Gustavo e ao Matheus por toda a ajuda!

Às aquiculturas que doaram os peixes para a realização deste trabalho, sem os quais nada disso seria possível.

À minha família, principalmente à minha mãe Adriane que esteve sempre comigo, me dando todo o apoio necessário para que eu conseguisse concluir mais essa etapa. Nem todas as palavras do mundo são suficientes para agradecer tudo que você faz por mim!

Aos meus amigos por todo o companheirismo, principalmente Carol e Ton, que compartilharam esse período comigo. Ter vocês ao meu lado durante o mestrado foi um verdadeiro presente.

E finalmente, ao Alexandre, que me encontrou no meio dessa jornada, tornando-a mais leve! Obrigada por estar sempre ao meu lado acreditando no meu sucesso.

RESUMO

Os ecossistemas aquáticos de água doce da região Neotropical apresentam uma enorme riqueza de espécies de peixes, abrigando inúmeras espécies endêmicas. O Rio Guaraguaçu está inserido nesta região, sendo o maior rio da planície litorânea do Paraná e um importante componente do complexo estuarino LAGAMAR, área chave para conservação da Mata Atlântica. Devido a alterações de habitat, poluição da água e introdução de espécies não nativas, a fauna de pequenos peixes deste rio encontra-se ameaçada. O bagre-do-canal (*Ictalurus punctatus)* é uma espécie de peixe não nativa presente no Rio Guaraguaçu e este trabalho buscou avaliar seu potencial impacto ecológico sobre as espécies nativas. Espécies não nativas são conhecidas por causar impacto através de consumo superior de recursos, ameaçando a fauna nativa devido à predação. Uma das formas de quantificar seu impacto é comparar a resposta funcional (RF) da espécie não nativa (combinada com sua abundância/biomassa na natureza) a uma espécie nativa análoga. Portanto, aplicou-se neste trabalho a abordagem de resposta funcional comparativa (RFC) e a métrica de Impacto Potencial Relativo (IPR) para identificar os potenciais impactos da introdução de *I. punctatus* no Rio Guaraguaçu. O bagre nativo jundiá (*Rhamdia quelen*) foi escolhido como espécie nativa análoga. A espécie de presa escolhida foi o peixe de pequeno porte *Mimagoniates microlepis* utilizada como um indicador do impacto de *I. punctatus* sobre uma espécie congênere, simpátrica e sintópica ameaçada de extinção (*Mimagoniates lateralis*) que ocorre no Rio Guaraguaçu. Experimentos de RF foram realizados utilizando cinco densidades iniciais de presa (2, 5, 10, 20, e 30 indivíduos). O tipo de RF e seus parâmetros associados, taxa de ataque (*a*) e tempo de manuseio (*h*), foram estimados e comparados entre as espécies. A métrica IPR foi calculada utilizando dados de amostragens no Rio Guaraguaçu (abundância total, biomassa e captura por unidade de esforço - CPUE) obtidos da literatura. Ambas as espécies apresentaram RF Tipo II. Os intervalos de confiança das curvas estimadas se sobrepõem, porém, *I. punctatus* apresentou um *h* menor e uma taxa máxima de consumo maior (1/*h*T). Considerando a abundância total no ecossistema de estudo, um IPR < 1 foi obtido, o que indica que o bagre não nativo não representa impacto superior às presas quando comparado com seu análogo nativo. Quando utilizando dados de CPUE, porém, foi obtido um IPR > 1 indicando o impacto superior de *I. punctatus*. Dessa forma é possível afirmar que *I. punctatus* representa um impacto superior às presas nativas quando comparado com o nativo análogo, devido à um consumo mais eficiente e CPUE maior em campo. *Ictalurus punctatus* pode atingir tamanho corporal superior ao de *R. quelen* quando adulto, logo, um aumento no seu efeito *per capita* é esperado, aumentando seu impacto. Fica claro, a partir destes resultados, que aquiculturas utilizando espécies não nativas devem ser banidas e que a abundância de *I. punctatus* controlada, para evitar futuros impactos negativos sobre espécies endêmicas do Rio Guaraguaçu.

Palavras-chave: Água doce. Conservação. Efeitos ecológicos. Invasões biológicas. Predador-presa. Siluriformes. Utilização de recursos.

ABSTRACT

Freshwater ecosystems of the Neotropical region present a huge richness of fish species sheltering many endemic species. The Guaraguaçu River is located in this region, being the largest river of the coastal plain of Paraná state and an important component of the LAGAMAR estuarine complex, a key area for conservation of Atlantic Forest. Due to habitat alterations, water pollution and introduction of non-native species, the fauna of small fish species of this river is threatened. The channel catfish (*Ictalurus punctatus*) is one of the non-native species present in the Guaraguaçu River, and this work aimed to evaluate its potential ecological impacts. Non-native species are known to cause impacts through superior consumption of resources, threatening the native fauna by predation. A way of quantifying their impact is to compare the functional response (FR) of the non-native species (combined with its abundance/biomass in the field) to an analogue native species. Therefore, the comparative functional response (CFR) approach and the Relative Impact Potential (RIP) metric were used here to identify the potential impacts of the introduction of *I. punctatus* in the Guaraguaçu River. The South American silver catfish (*Rhamdia quelen*) was selected as the native comparator. The prey species chosen was the blue tetra *Mimagoniates microlepis* used here as a proxy of the impact of *I. punctatus* on a sympatric and syntopic endangered congeneric species (*Mimagoniates lateralis*) that occurs in Guaraguaçu River. Functional response experiments were performed using five initial densities of prey (2, 5, 10, 20, and 30 individuals). The FR type and its associated parameters attack rate (*a*) and handling time (*h*) were estimated and compared between species. The RIP metric was calculated using data from sampling in the Guaraguaçu River (total abundance, biomass and capture per unit effort - CPUE), obtained from literature. Both species presented a Type II FR. The confidence intervals of the estimated FR curves overlapped, but *I. punctatus* had a lower *h* and a higher maximum feeding rate (1/*h*T). Using the total abundance a RIP < 1 was found, which indicates that the non-native species does not represent superior impact to the native prey when compared to its native analogue. However, using CPUE data, a RIP > 1 was obtained, indicating that *I. punctatus* has superior impact. In this regard is possible to state that *I. punctatus* represents a superior impact to native prey when compared with the native analogue species, due to more efficient consumption and higher CPUE in the field. *Ictalurus punctatus* can reach bigger sizes than *R. quelen* when adult, so an increase in its *per capita* effect is expected, increasing its impact. It is clear, from the results that aquacultures using non-native species should be banned and the abundance of *I. punctatus* must be controlled in order to avoid future impacts on endemic species of Guaraguaçu River.

Key-words: Biological invasions. Conservation. Ecological effects. Freshwater. Predator-prey. Resource use. Siluriformes.

SUMÁRIO

APRESENTAÇÃO

Os ecossistemas aquáticos de água doce na Região Neotropical apresentam uma grande riqueza de espécies de peixes, com elevado endemismo devido à sua história de isolamento geológico e biótico (LUNDBERG et al., 2000; ABBEL et al., 2008; LÉVÊQUE et al., 2008; ALBERT; PETRY; REIS, 2011). Dentro desta região, a Floresta Atlântica é um importante *hotspot* de biodiversidade abrigando um grande número de peixes, especialmente de pequeno porte, que ocorre exclusivamente nas bacias costeiras deste bioma (MYERS et al., 2000; ABILHOA et al., 2011). Inserido na Floresta Atlântica, o Rio Guaraguaçu é o maior rio da planície litorânea do Paraná e um importante componente do complexo estuarino do LAGAMAR, apresentando uma imensa variedade de habitats e abrigando muitas espécies endêmicas de peixes de pequeno porte ameaçadas de extinção, tais como *Mimagoniates lateralis*, *Spintherobolus ankoseion* e *Scleromystax macropterus* (ABILHOA; DUBOC, 2004; MACHADO; DRUMMOND; PAGLIA, 2008; VITULE, 2008; ABILHOA et al., 2011). Impactos antropogênicos como a destruição e alteração de habitat, poluição da água e introdução de espécies não nativas estão entre as principais ameaças a estas espécies (DUDGEON et al., 2006; ABILHOA et al., 2011).

Dentro deste contexto, a introdução de espécies não nativas é uma das principais causas de perda de biodiversidade global e de importantes serviços ecossistêmicos, sendo responsável por grandes prejuízos econômicos e ecológicos (VITOUSEK et al., 1996; MACK et al., 2000; LOCKWOOD et al., 2007). Especificamente, a introdução de predadores pode devastar comunidades nativas, através da extinção de espécies de presas e, sendo consequentemente uma das causas da homogeneização biótica (MCKINNEY; LOCKWOOD, 1999; MACK et al., 2000; BELLARD et al., 2015). Dado a relevância de espécies não nativas para a biodiversidade e economia, um dos principais desafios em ecologia é a capacidade de prever os impactos do estabelecimento destas espécies em ecossistemas fora da sua área de distribuição (PARKER et al., 1999; MACK et al., 2000; RICCIARDI et al., 2013).

A maioria dos métodos utilizados para prever impactos é bastante subjetiva e pouco eficaz, pois se baseiam no histórico de invasão ou na análise de características funcionais, dados que muitas vezes são contexto-dependentes ou não estão disponíveis para todas as espécies (MACK et al., 2000; RICCIARDI, 2003; GARCÍA-BERTHOU, 2007; LOCKWOOD; HOOPES; MARCHETTI, 2007; HAYES; BARRY, 2008; KULHANEK et al., 2011; VITULE et al., 2012). Informações úteis sobre o potencial impacto de espécies não nativas podem ser obtidas pela comparação da resposta funcional destas com a resposta funcional de espécies nativas de níveis tróficos similares e/ou análogos a elas, uma vez que uma propriedade comum de espécies não nativas é o consumo superior dos recursos disponíveis (PARKER et al., 1999; DICK et al., 2013; SALO et al., 2007; PAOLUCCI et al., 2013). Essa abordagem quantifica o impacto diferencial de espécies não nativas, sendo mais objetiva e preditiva quando comparada a outros métodos disponíveis (BOLLACHE et al., 2008; DICK et al., 2014; 2017a).

A resposta funcional (RF) é a relação entre a densidade de recurso e a taxa de consumo deste recurso por um consumidor (HOLLING, 1959a; JULIANO, 2001). Existem três tipos principais de RF (HOLLING, 1959a; FIGURA 1) e a forma e magnitude da RF podem informar se o predador irá regular, estabilizar ou desestabilizar a população de presas através do consumo (MURDOCH; OATEN, 1975; DICK et al., 2014).

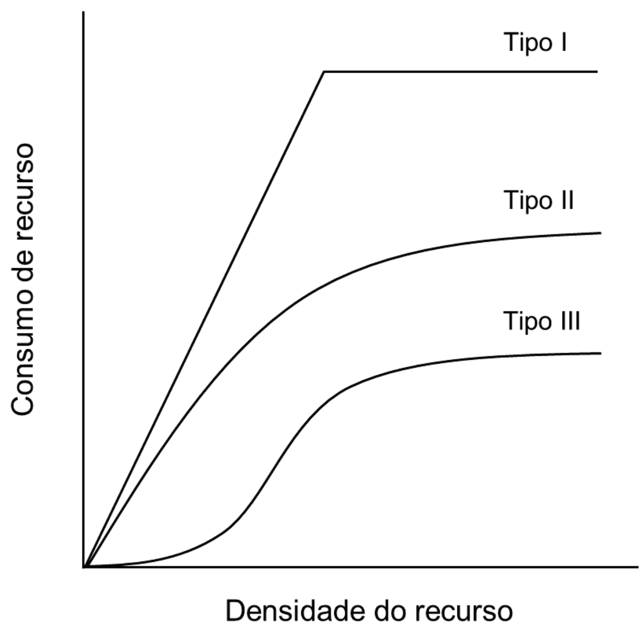

FIGURA 1. CURVAS REFERENTES AOS TRÊS TIPOS DE RESPOSTA FUNCIONAL IDENTIFICADOS POR HOLLING, 1959a.

Respostas funcionais do Tipo I são exclusivas de organismos filtradores que possuem um tempo de manuseio pequeno e uma taxa máxima de procura por recurso constante em todas as densidades (HOLLING, 1959a; JESCHKE; KOPP; TOLLRIAN, 2004) não se aplicando, portanto a relações predador-presa. A RF do Tipo II é mais comum na natureza e tende a desestabilizar a população de presas, já que estas não conseguem "escapar" da predação mesmo em baixas densidades, e podem ser completamente consumidas, chegando à extinção (SINCLAIR et al., 1998; JULIANO, 2001). Já na RF Tipo III, as presas possuem um risco de mortalidade menor em baixa densidade, portanto, esse tipo de RF fornece estabilidade à dinâmica predador-presa, mantendo a população de presas viável abaixo de um limiar de densidade (MURDOCH; OATEN, 1975; JULIANO, 2001).

Se a espécie não nativa apresentar uma RF superior às espécies nativas análogas presentes na comunidade, é provável que a população de presas sofra uma grande redução devido ao aumento na taxa de predação, consequentemente refletindo-se em impacto ecológico (DICK et al., 2014). Portanto, a comparação da RF é um método eficaz para prever o potencial impacto de uma espécie não nativa na comunidade em que foi introduzida. O poder preditivo da RF pode ser aumentado considerando-se ainda a abundância e biomassa das espécies na natureza. Dick et al. (2017b) propuseram uma métrica, chamada Impacto Potencial Relativo (IPR), para avaliar o impacto de uma espécie não nativa em relação à uma espécie comparável nativa, utilizando a taxa máxima de consumo (1/*h*T) obtida experimentalmente e dados de abundância e biomassa coletados em campo.

Dado o potencial da metodologia descrita acima, em prever o impacto de espécies não nativas, ela foi aplicada neste trabalho para avaliar o impacto ecológico da introdução do bagre-do-canal (*Ictalurus punctatus*) no Rio Guaraguaçu. O bagre-do-canal é uma das espécies não nativas presentes neste rio há mais de 10 anos (VITULE; UMBRIA; ARANHA, 2005; VITULE, 2008). Esta espécie é onívora e generalista, e tem sua dieta baseada principalmente em invertebrados e peixes de pequeno porte, sendo considerada uma invasora de alto impacto (BAILEY; HARRISON JR., 1948; TYUS; NIKIRK, 1990; TOWNSEND; WINTERBOURN, 1992). O bagre-do-canal pode atingir tamanho corporal muito superior ao das espécies nativas presentes na região (JACKSON, 2004), tornando-se uma ameaça potencial às espécies de peixes ameaçadas de extinção que ocorrem no Rio Guaraguaçu.

Sendo assim, a presa nativa *Mimagoniates microlepis* que é bastante abundante na bacia do Rio Guaraguaçu e muito similar, simpátrica e sintópica à outra espécie do mesmo gênero ameaçada de extinção (*M. lateralis*) (ABILHOA; DUBOC, 2004; BRAGA; ARANHA; VITULE, 2008; MACHADO; DRUMMOND; PAGLIA, 2008; MENEZES; WEITZMAN, 2009; VITULE 2008) foi utilizada para prever o impacto do bagre-do-canal sobre espécies de presa de pequeno porte. O objetivo é avaliar o impacto desta espécie para que novas estratégias de controle da mesma e de conservação das espécies ameaçadas presentes no rio sejam criadas. Este objetivo vem de encontro às diretrizes da Estratégia Nacional para Espécies Exóticas Invasoras no Brasil (CONABIO, 2009) e do Programa Estadual para Espécies Exóticas Invasoras do Estado do Paraná (IAP, 2008) no âmbito de geração de conhecimento científico para elaboração de planos ou medidas de ação para erradicação, contenção, controle e monitoramento de espécies não nativas.

Há uma grande lacuna de estudos sobre impactos de espécies não nativas na região tropical, principalmente no continente sul-americano, com poucos estudos utilizando abordagens experimentais (PYSEK et al., 2008; LÖVEI; LEWINSOHN, 2012; SPEZIALE et al., 2012; JUNQUEIRA, 2013; FREHSE et al., 2016). De fato, realizando uma busca nas bases Web of Science e Scopus, utilizando palavras-chave para resposta funcional, espécies não nativas e impacto (“functional response*" AND inva* OR introduc* OR "non$native" OR alien OR exotic AND impact*) foram encontrados apenas seis estudos publicados na América do Sul e nenhum no Brasil, até Janeiro de 2018. Nós acreditamos que a abordagem utilizada aqui pode ser uma alternativa rápida e eficaz para avaliar o impacto potencial de espécies não nativas na região, e que pode ser amplamente replicada, diminuindo essa lacuna de conhecimento.

ASSESSING THE IMPACTS OF THE CHANNEL CATFISH (*Ictalurus punctatus*) INTRODUCTION IN A HIGHLY DIVERSE NEOTROPICAL RIVER USING THE COMPARATIVE FUNCTIONAL RESPONSE APPROACH[1]

[1]Formatado segundo as normas do periódico *Aquatic Conservation: Marine and Freshwater Ecosystems*

Assessing the impacts of the channel catfish (*Ictalurus punctatus*) introduction in a highly diverse Neotropical river using the Comparative Functional Response approach

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Abstract

1. Non-native species are known to cause impacts through superior consumption of resources, threatening resident communities by predation. The functional response (FR) combined with the abundance/biomass of a non-native species can be compared to a native analogue and used to quantify its impact on native prey.

2. Here the comparative functional response approach (CFR) was applied to identify the potential impacts of the introduction of the non-native channel catfish (*Ictalurus punctatus*) in a Neotropical river. *Rhamdia quelen* was used as the native comparator and the prey species used was the small fish *Mimagoniates microlepis*, in five initial densities. The FR type and its associated parameters attack rate (*a*) and handling time (*h*) were estimated and compared between species. The Relative Impact Potential (RIP) metric was calculated using total abundance, biomass and capture per unit effort (CPUE) field data from literature.

3. Both species presented a Type II FR. The confidence intervals of the estimated FR curves overlapped, although *h* was lower for *I. punctatus* resulting in a higher maximum feeding rate (1/*h*T). Using CPUE data a RIP > 1 was calculated, which indicates that the non-native species represents a superior impact to prey when compared to its native analogue.

4. Despite the overlap of FR curves, *I. punctatus* represents a superior impact to native prey, due to a higher consumption efficiency and CPUE in the field. Additionally, *I. punctatus* can reach bigger sizes when adult compared to *R. quelen* which may increase its *per capita* effect. Finally, in a conservation perspective the

abundance of *I. punctatus* should be controlled and its cultivation should be banned in order to avoid future impacts on endemic species.

KEYWORDS

biological invasions, conservation, ecological effects, freshwater, predator-prey, resource use, Siluriformes

1. INTRODUCTION

Non-native species are considered the second major cause of global biodiversity loss, being one of the main drivers of species extinction (Bellard, Cassey, & Blackburn, 2016; Clavero & García-Berthou, 2005; Vitousek, D'Antonio, Loope, & Weestbrooks, 1996). Predation by non-native species, among other factors, can devastate native prey populations once non-native predators are known to have a superior consumption of available resources (Paolucci, MacIsaac, & Ricciardi, 2013; Salo, Korpimäki, Banks, Nordström, & Dickman, 2007; Simberloff & Vitule, 2014). Additionally, native prey frequently do not have effective anti-predator behaviour due to a lack of shared evolutionary history with the new predator (Cox & Lima, 2006; Simberloff & Vitule, 2014). These mechanisms can explain the establishment success of non-native predators and their negative impact in the recipient community, as declines in abundance of native populations and decreased diversity of the region (Gallardo, Clavero, Sánchez, & Vilà, 2016; Latini & Petrere-Jr, 2004; Sharpe, De León, González & Torchin, 2017; Simberloff et al., 2013; Trumpickas, Mandrak, & Ricciardi, 2011). In this regard, to predict and quantify impacts of non-native species is of great importance for conservation of biodiversity, although there is still no standard method for doing it (Kumschick et al., 2015; Parker et al., 1999; Ricciardi, Hoopes, Marchetti, & Lockwood, 2013).

Recently, Dick, Alexander, et al. (2017) claimed that the comparative functional response (CFR) approach "can unify invasion ecology" by providing a measurable trait of non-native species and their interactions with resources, that predicts its ecological impact. This framework is based on the comparison of the functional responses (FR) of non-native and trophically analogous native species, where the difference in the FR magnitude can predict and quantify the relative impacts of the non-native species (Dick et al., 2014). The functional response is the function of consumption rate by resource density (Holling, 1959b). There are three types of FR: an increasing linear relationship between resource density and consumption until a threshold of satiation (Type I); a decelerating rate of consumption that reaches an asymptote at higher densities (Type II); and an S-shaped curve where the consumption rate first accelerates at low densities and then decelerates towards satiation (Type III) (Holling, 1959b). The FR type of the predator can have direct effects on the stability of the prey population; Type II FR has destabilizing effects with consumption constant even at low densities, whereas Type III has stabilizing effects with a refuge of predation at low densities (Oaten & Murdoch, 1975; Sinclair et al., 1998).

As FR measures the *per capita* effect of a non-native species, this measure can be combined with the abundance of the species in the field in a single metric called the Relative Impact Potential (RIP), in order to enhance the predictive power of the method (Dick, Laverty, et al., 2017). To enable a judicious selection of trophic links to assess the ecological impacts of introduced species, a framework based on foraging theory and CFR was proposed by Penk et al. (2017). This framework consists of three steps: (1) Map potential interaction partners of the focal species; (2) Screen interaction partners in the recipient community (*i.e.* abundant species, keystone species and/or species of conservation importance); and (3) Quantify interaction strengths using FR experiments (Penk et al., 2017).

These methods were employed to assess the potential impacts of a non-native species, the channel catfish (*Ictalurus punctatus*), which is found over 10 years in an Atlantic Forest basin (Occhi et al., unpublished data; Vitule, 2008; Vitule, Umbria, & Aranha, 2005). This species is native from North America and is currently introduced in South America, Europe and Asia for aquaculture and sport fishing purposes (Cruz-Spindler, Leal, Lehmann, & Schulz, 2012; Daga, Debona, Abilhoa, Gubiani, & Vitule, 2016; Elvira, 2001; Kottelat & Freyhof, 2007; Matsuzaki et al., 2011; Mejía Mojica, Paredes Lira, & Beltrán López, 2013; Zanatta, Ramos, da Silva, Langeani, & Carvalho, 2010). The species was first introduced in Brazil in 1971 and may have spread through accidental escapes from aquaculture cages (Orsi & Agostinho, 1999; Welcomme, 1988). *Ictalurus punctatus* is an omnivorous generalist species that preys mainly on vegetation, insects and fish, and a nocturnal forager that uses a variety of habitats with preference for shallow warm waters (Bailey &

Harrison Jr., 1948; Braun & Phelps, 2016; Hill, Duffy, & Thompson, 1995; Jordan, Neumann, & Schultz, 2004; Kottelat & Freyhof, 2007; Tyus & Nikirk, 1990). *Ictalurus punctatus* is monogamous and temperature is the primary factor that influences they spawning which occurs once a year, usually during the spring and early summer (Lang, Romaire, & Tiersch, 2003; Wellborn, 1988). They have high fecundity (approximately 10,000 - 20,000 eggs per female) and present parental care with the male guarding the nest (Tatarenkov, Barreto, Winkelman, & Avise, 2006; Wellborn, 1988). The species also has the ability to tolerate salinity and use estuaries as bridges for dispersion to adjacent basins (Gutierre, Vitule, Freire, & Prodocimo, 2014). These characteristics place the *I. punctatus* as a potentially invasive species, being a threat to the native community through competition and predation of native species (Matsuzaki et al., 2011; Townsend & Winterbourn, 1992; Troca & Vieira, 2012).

The Guaraguaçu River is located in the Atlantic Forest which is one of the global hotspots of biodiversity and thus of great conservation value (Myers, Mittermeier, Mittermeier, da Fonseca, & Kent, 2000), especially for small-bodied fish species (Abilhoa, Braga, Bornatowski, & Vitule, 2011; Vitule, Braga, & Aranha, 2008). This river is the largest one of the Paraná coastal plain and shelters a high level of endemism, with many small fish species reported into the national and regional lists of threatened species such *as Mimagoniates lateralis*, *Spintherobolus ankoseion* and *Scleromystax macropterus* (Abilhoa & Duboc, 2004; Machado, Drummond, & Paglia, 2008). Therefore, the presence of *I. punctatus* in the Guaraguaçu River could increase the threat to these endangered species that already suffer the impacts of habitat alterations and water pollution in the region (Abilhoa et al., 2011; Vitule, Freire, & Simberloff, 2009; Vitule et al., 2005).

Knowing the FR type and the rate of predation is of fundamental importance to conservation management, once these data can be used to predict the degree of predator control needed to keep the endangered population of prey viable (Sinclair et al., 1998). Therefore, a prey of the resident community that is of great conservation importance was chosen in order to evaluate the potential impact of the *I. punctatus* in the Guaraguaçu River. In this regard, the potential negative impacts of *I. punctatus* predation on *M. lateralis* populations were assessed. A congeneric and sympatric species which is more abundant was used as a proxy prey species (*Mimagoniates* *microlepis*) in the FR experiments in order to predict the impact of the *I. punctatus* predation on other endangered small-bodied fish.

Based on species traits and the available invasion history of *I. punctatus* (Townsend & Winterbourn, 1992), and considering its taxonomic distinctiveness within the recipient community (Ricciardi & Atkinson, 2004), we hypothesized that *I. punctatus* represents an impact to the community through superior consumption of small stream fishes. Given the research deficit about non-native species impacts in South American countries (Bellard & Jeschke, 2016; Speziale, Lambertucci, Carrete, & Tella, 2012; Vitule, Freire, Vazquez, Nuñez, & Simberloff, 2012), we aim to contribute to the understanding of the impacts of introduced predators in the Neotropical region, where biodiversity is rich and threatened; and therefore research and conservation measures are needed (Lowry et al., 2013; Myers et al., 2000).

2. METHODS

2.1 Species used

The channel catfish *I. punctatus* is an omnivorous species that feeds mainly on insects and small fishes (Bailey & Harrison Jr., 1948; Tyus & Nikirk, 1990). Thus, as a prey model for the experiments a small fish was selected, the blue tetra (*M. microlepis*) that is congeneric of *M. lateralis,* a threatened species according to the national and local lists of endangered species (Abilhoa & Duboc, 2004; Machado et al., 2008; MMA, 2014). Both Mimagoniates species occur in the Guaraguaçu River and are representatives of the subfamily Glandulocaudinae characterized by small stream fishes (Braga, Vitule, & Aranha, 2007; Braga, Aranha, & Vitule, 2008; Braga, Braga, & Vitule, 2013; Menezes & Weitzman, 2009; Vitule, 2008). Therefore, to avoid using an endangered species in the predation experiments, *M. microlepis* was chosen as a proxy for *M. lateralis.* Once these species are of the same subfamily, sympatric and syntopic they are very similar; and the experimental results can be extrapolated to the endangered species using the more abundant congeneric as a proxy.

FRs of the non-native *I. punctatus* were compared with a resident consumer, the South American silver catfish (*Rhamdia quelen*), popularly known in the region as 'jundiá'. This species is also a representative of the order Siluriformes, and is native in the region of interest. As others catfishes of the family, it is nocturnal and omnivorous (Gomes, Golombieski, Gomes, & Baldisserotto, 2000). *Ictalurus punctatus* and *R. quelen* have many similarities in their anatomic digestive systems with the same food habits (Piedras, Pouey, & Moraes, 2006) which make of *R. quelen* the perfect resident comparator for *I. punctatus* in the FR experiments.

2.2 Experimental design

The experimental protocol (Fig. S1) was submitted and approved by the Ethics Commission on the Use of Animals of the Biological Sciences Department of the Federal University of Paraná (CEUA/BIO UFPR – Certificate nº1027). Juveniles of predator fish species (*I. punctatus* and *R. quelen*) were obtained in local aquaculture farms and stored in tanks of 300L in the lab. Each species was kept in a different tank with constant aeration and filtration for acclimation during 30 days. Fishes of the prey species (*M. microlepis*) were collected in the field using gill nets. They were kept in an 80L aquarium, with constant aeration and filtration, and were also acclimated for 30 days. The temperature in the lab was kept around 22-26°C with a natural light regime. During the acclimation period predators were fed every 48h with sausage to standardize prior experience.

Experiments were performed in 10L opaque plastic boxes (35 x 20 x 25 cm) with constant aeration. Individuals of predator species were randomly selected one day prior to use and placed in the experimental aquariums for 24h acclimation. They were reused in two more trials with different initial densities. Predators ($n = 9$ per species) were size-matched with respect to total length (*R. quelen*: 16.39 cm ±1.15 and *I. punctatus*: 16.83 cm ±2.14; t-test, $t = -0.55$, df = 16, $p = 0.59$). After the acclimation period, they were held without food for 72h to standardize hunger levels. Predators were then presented with the prey at five initial densities (2, 5, 10, 20, and 30 individuals), with at least five replicates per density. Preys were also size matched with respect to total length by visual selection (~3cm). Experiments were initiated at 14:00 and prey consumption was recorded after 24h. Controls were three replicates of each initial density of preys in the absence of predators.

2.3 Statistical analysis

The FR type was determined from a logistic regression of prey density by the proportion of consumed prey, as proposed by Juliano (2001). A negative first order term indicates a Type II FR, while a positive first order term followed by a negative second order term indicates a Type III FR (Pritchard, Paterson, Bovy, & Barrios-O'Neill, 2017). Functional response curves and the parameters attack rate (*a*) and handling time (*h*) were modelled through Maximum Likelihood Estimation (Bolker, 2008) with the Rogers' random predator equation that considers the depletion of prey without replacement along the experimental period (Rogers, 1972):

$$N_e = N_0 \{1 - \exp [a (N_e h - T)]\} \quad (1)$$

where N_e is the number of prey consumed, N_0 is the initial density of prey, *a* is the attack rate, *h* is the handling time and T is the experimental period, given in days. The attack rate (*a*) is the instantaneous capture rate*, i.e.* the rate at which the consumer encounters resource items per unit of resource density; and the handling time (*h*) is the time spent capturing and consuming the prey item (Brose, 2010; Holling, 1959a; Jeschke, Kopp, & Tollrian, 2002). The *h* was used to estimate the maximum feeding rate (1/*h*T), which represents the FR curve asymptote. To compare the FR of each species, the parameters *a* and *h* were compared between predators using the indicator variables method, as the following equation:

$$0 = N_0 - N_0 \exp \{[a + Da(j)] \{h + Dh(j)] (N_e) - T\}\}-N_e \quad (2)$$

where j is an indicator variable that takes value 0 for *R. quelen* and 1 for *I. punctatus*. The parameters D*a* and D*h* estimate the differences between the predators in the value of the parameters *a* and *h*, respectively. If these parameters are significantly different from zero, thus the two species differ significantly in the corresponding parameters (Juliano 2001). To visualise the uncertainty around the fitted functional responses 95% confidence intervals were constructed by bootstrapping (n=2000) data around FR curves. If confidence intervals do not overlap, it can be stated that species FRs are different (Paterson et al., 2015). Analyses were carried in R v. 3.4.1 (R Core Team, 2015) using the 'frair' package (Pritchard et al., 2017) at 0.05 significance.

The Relative Impact Potential (RIP) metric was calculated using the following equation, according to proposed by Dick, Laverty, et al. (2017):

$$RIP = \left(\frac{FR_{non\text{-}native}}{FR_{native}}\right) X \left(\frac{AB_{non\text{-}native}}{AB_{native}}\right) \quad (3)$$

where FR is the estimated maximum feeding rate (1/*h*T) and AB is the field abundance/biomass of the species. When RIP < 1, the non-native species is predicted to have less impact than the native equivalent; when RIP = 1, there is no impact above that driven by native equivalents; whereas RIP > 1 indicates a likely non-native ecological impact (Dick, Laverty, et al., 2017). Data of total abundance and biomass used are from samples collected in Guaraguaçu River using different fishing gears, and were obtained from literature (Vitule, 2008; Table S1). As data from different methods of capture and of different fishing efforts were compiled (Table S1), the capture per unit effort (CPUE) was calculated to standardize these differences, as the number of fishes captured divided by the number of fish hooks or area of gill nets multiplied by fishing effort in hours.

3. RESULTS

No prey deaths were recorded in control replicates, thus prey mortality in experimental trials was attributed to predation. Both species obtained a negative first-order term from logistic regressions, indicating a Type II FR (Table 1, Fig. 1). Parameter estimates of the FR model were all significant (Table 1). The attack rate did not differ between species (D*a*= -0.646, z= -0.447, *p*= 0.655), but the handling time was significantly lower for *I. punctatus* (D*h*= 0.053, z= 2.209, *p*< 0.05), and thus a higher maximum feeding rate was obtained (Table 1).

Table 1. Linear coefficient (lc) from logistic regressions and functional response parameters estimates for both species preying on *Mimagoniates microlepis* (*a* attack rate, *h* handling time, 1/*h*T maximum feeding rate). SE standard error. **p* < 0.05.

Predator	lc	*a*	SE	*h*	SE	1/*h*T
Rhamdia quelen	-0.0779*	2.809*	1.013	0.159*	0.021	6.3
Ictalurus punctatus	-0.0781*	3.456*	1.029	0.106*	0.012	9.4

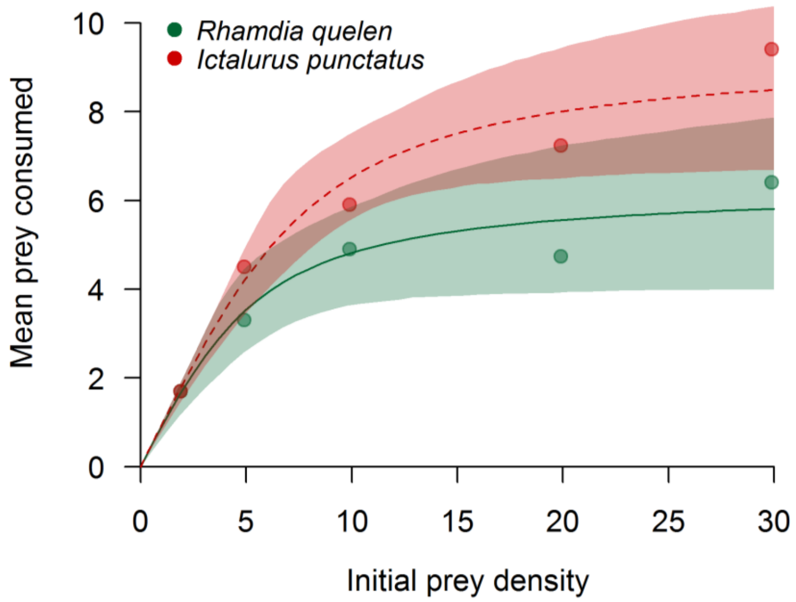

Figure 1. Type II Functional Response curves for *Ictalurus punctatus* (dashed line) and *Rhamdia quelen* (solid line) preying on *Mimagoniates microlepis*. Points indicate mean consumption per density. Shading represents bootstrapped (n=2000) 95% confidence intervals for each species.

The RIP calculated using field data on total abundance did not demonstrate superior impact of the non-native species (RIP < 1, Table 2). Considering biomass the impact of *I. punctatus* is considered similar to the native species *R. quelen* (RIP ≈ 1, Table 2). However, using CPUE data, *I. punctatus* shows superior impact (RIP > 1, Table 2).

Table 2. Calculated Relative Impact Potential (RIP) for *Ictalurus punctatus* when compared with *Rhamdia quelen* preying on *Mimagoniates microlepis*. AB total abundance, CPUE capture per unit effort. Data of abundance and biomass from Vitule, 2008.

	AB	Biomass (g)	CPUE
Ictalurus punctatus	30	27692	0.05
Rhamdia quelen	112	38985	0.035
RIP	**0.399**	**1.059**	**2.131**

4. DISCUSSION

There is little information about the impacts of *I. punctatus* in regions where it is non-native despite it was widely introduced for aquaculture and sport fishing purposes worldwide (FAO, 2004; Vitule et al., 2009; Savini et al., 2010). The introduction of the *I. punctatus* in a highly diverse Neotropical river is cause of great concern once this region is known as the richest realm regarding freshwater fishes, characterized by a great abundance of endemic and small species (Lindsey, 1966; Abell et al., 2008; Lévêque, Oberdorff, Paugy, Stiassny, & Tedesco, 2008). Besides threatened by habitat destruction and water pollution, these endemic species also face the danger of predation by introduced large-bodied fishes, such *I. punctatus* (MacRae & Jackson, 2001; Dudgeon et al., 2006; Vitule et al., 2009; Abilhoa et al., 2011).

To quantify and predict the impacts of non-native species is of fundamental importance for conservation, because such data is needed in order to create plans for management and control of non-native species. The CFR approach and the RIP metric have been proved to be a great tool for predicting the impact of existing and emerging high impact non-native species (Alexander, Dick, Weyl, Robinson, & Richardson, 2014; Dick, Alexander, et al., 2017; Dick, Laverty, et al., 2017; Laverty et al., 2017). Thus, in developing countries with deficient data about non-native species impacts, such as Brazil, the application of this approach is a good alternative (Lövei et al., 2012; Nuñez & Pauchard, 2010).

Using the CFR approach, evidences that the *I. punctatus* represents an impact to the native small fish prey were found. Despite the overlap of FR curves of *I. punctatus* and its native comparator (Fig. 1), it is apparent that *I. punctatus* preys more on *M. microlepis*, with a significant lower handling time, resulting in a higher maximum feeding rate (Table 1). Lower *h* and consequently higher 1/*h*T due to faster rates in processing prey can explain the superior impact of invaders (Alexander, Dick, et al., 2014). So, even if the superior impact of *I. punctatus* cannot be stated by differences in FR curve’s magnitude, differences in their associated parameters suggest that *I. punctatus* inflict superior impact to the native community.

The native species *R. quelen* is more abundant in the Guaraguaçu River, which results in a lower relative impact of the non-native species (Table 2). However, using data standardized as CPUE a different result emerged, with *I. punctatus* presenting a higher CPUE, and thus a superior impact when compared to *R. quelen* (Table 2). To use only the FR gives a modest predictive power of non-native species impacts because a low FR can be compensated by higher abundance in the field, resulting in greater impact when compared with the native analogue; hence the combination of FR with field abundance yields more accurate predictions (Laverty et al., 2017). The results obtained here, of a greater RIP using CPUE field data, are sufficient to justify the need of management and control of *I. punctatus* population in the Guaraguaçu River. As discussed by Simberloff (2003b) early interventions may be successful in avoiding non-native species impacts, and in this case there are enough evidences to motivate the immediate action to keep *I. punctatus* at low population levels.

Additionally, as the phenomenon of time lags in invasions is very common, it is not possible to be sure that a species that is causing no visible harm now will stay harmless in the future (Crooks, 2005; Essl et al., 2011; Strayer, Eviner, Jeschke, & Pace, 2006). That is why decisions about the control of non-native species based solely on its current perceived impact and not on its origin are very risky (Simberloff & Vitule, 2014). Furthermore, the impact of a non-native species is not always proportional to its density (Byers et al., 2002). Negative effects of *Pseudorasbora parva* on its prey were found even at low densities of *P. parva* (Jackson, Ruiz-Navarro, & Britton, 2015). So, caution must be taken when stating that the impact of a non-native species will be greater in higher abundance as approximations of density-impacts are frequently inaccurate and even at low densities the non-native species can have robust negative effects (Jackson et al., 2015; Thiele, Kollmann, Markussen, & Otte, 2010).

Relatedly, *I. punctatus* can reach bigger sizes when adult compared to *R. quelen,* so it is logical to anticipate an increased *per capita* effect with increased body size, and this feature may influence the FR results in practice. *Ictalurus punctatus* reaches its sexual maturity at 30 – 37.5 cm in length, whereas *R. quelen* generally matures at 13.4 – 17.5 cm length (Gomes et al., 2000; Jackson, 2004; Shephard & Jackson, 2005). Also, the maximum length reported for *R. quelen* was 47.4 cm and for *I. punctatus* 132 cm (Froese & Pauly, 2017), almost a three-fold difference. In the experiments this factor was controlled and juveniles of similar body size were used, but in a real situation in the field the scenario might be different. The body size seems to be more important for foraging behaviour than ontogeny in fishes and the stomach capacity of the *I. punctatus* increases in a great rate with increased body length (Gosch, Pope, & Michaletz, 2009; Miller, Crowder, Rice, & Binkowski, 1992). Predator body size influences most aspects of its feeding behaviour and there are allometric relationships between body size and the FR parameters, with increases in *a* and decreases in *h* as predator size increases (Brose, 2010; González-Suárez et al., 2011; Miller et al., 1992; Vucic-Pestic, Rall, Kalinkat, & Brose, 2010). For instance, native and non-native predatory rates of size-matched amphipods (*Dikerogammarus villosus* and *Gammarus pulex*) were similar and the superior impact of the invasive *D. villosus* was only evident when using larger individuals in the experiments to represent natural sizes in the field (Taylor & Dunn, 2017). Therefore, size matters in the prediction of non-native species impacts and this is a factor that should always be taken into consideration (Taylor & Dunn, 2017). In the field different size classes are present, and the results using standardized lengths might be conservative (Dodd et al., 2014; Laverty et al., 2017). Taken this into account here, the different body sizes of adults of both species can be determinant to decouple the obtained FR curves; with *I. punctatus* likely having a superior response in comparison to *R. quelen*.

Differences in their biomass also corroborate the argument that the bigger sizes attained by *I. punctatus* will likely result in a superior impact. The mean biomass of *R. quelen* specimens captured in Guaraguaçu River is 348.1 g (total biomass divided by total abundance, Table 2) while for *I. punctatus* it is 923.1 g, more than twice of the native species. This difference, along with a RIP = 1 considering biomass, despite the lower total abundance of *I. punctatus* (Table 2), is evidence of *I. punctatus* bigger sizes in the field. Thus it can be expected that the *per capita* effect of *I. punctatus* is indeed superior to that of *R. quelen*. As discussed by Anderson et al. (2016) neither predator species nor size alone can predict consistently the FR type and its associated parameters, so both predator identity and size should be considered to fully assess the potential ecological impacts of a non-native species on invaded communities (Guo, Sheath, Trigo, & Britton, 2017).

Another thing that comes to attention is the similar responses of *I. punctatus* and *R. quelen* to the prey used, suggesting that these species may have niche overlap and might be competing or sharing resources in the field. The interspecific competition between native and non-native species can lead to changes in habitat selection, decreased growth rate and survival, with negative impacts for the native population (Blanchet, Loot, Grenouillet, & Brosse, 2007; Britton, Cucherousset, Grey, & Gozlan, 2011). Additionally, *I. punctatus* may be superior when competing for food with species that have a narrow diet breadth, impacting many native species through competition (Matsuzaki et al., 2011). In the Hudson River (USA), outside its native range, *I. punctatus* seems to displace the native white catfish (*Ameirus catus*) mainly because it has a great flexibility on habitat use according to feeding opportunity (Jordan et al., 2004). As highlighted by Dick, Alexander, et al. (2017), the CFR approach can, besides predicting the potential impact of non-native species on native prey, reveal some competitive interactions with the resident predators, and the competition between *R. quelen* and *I. punctatus* deserves further investigations.

Both species presented a Type II FR when exposed to *M. microlepis*, which means prey are consumed even at low densities leading to destabilizing effects on prey population (Holling 1959a; Murdoch & Oaten, 1975; Sinclair et al., 1998). This feature may be a matter of concern once a relevant species of prey, very similar to an endangered one was used, which classification is often based on population size (Sinclair et al., 1998; IUCN, 2012). It can be expected that the small-bodied endangered fish species present in this particular river may suffer predation pressure of *I. punctatus* in a similar manner of *M. microlepis*. Justification for conservation of smaller species that are non-commercial and not attractive to the angling community is difficult, increasing the challenge for conservation, although they are the most at risk of extinction (Cambray, 2003; Kopf, Shaw, & Humphries, 2017; Liu, Comte, & Olden, 2017; Olden, Hogan, & Zanden, 2007; Todd et al., 2017). Additionally, many tropical freshwater fish species are not evaluated on the official IUCN Red List, which would help to bring attention to their conservation (Arthington, Dulvy, Gladstone, & Winfield, 2016; Darwall & Freyhof, 2016; Vitule et al., 2017).

Furthermore, the historical and socio-cultural aspects of South American countries can contribute to a reduced concern about non-native species, impairing the conservation efforts for controlling them (Speziale et al., 2012). Also, species that do not present visible harm (mainly economic) are less prone to have their impacts studied and management plans applied (Junqueira, 2013; Simberloff, 2003a; Frehse, Braga, Nocera, & Vitule, 2016). Education and communication of scientific results about invasive species impacts are the key to solve this problem and increase the awareness about the issue, contributing to manage non-native species more effectively (Azevedo-Santos et al., 2015; Cambray, 2003; Gozlan, Burnard, Andreou, & Britton, 2013; Novoa, Dehnen-Schmutz, Fried, & Vimercati, 2017; Rodewald, 2012; Vitule, 2009). Eradication and control of non-native species are frequently costly and impractical in larger areas, but an alternative is the construction of barriers to avoid the arrival of the species in certain areas (Cambray, 2003; Hulme, 2006; Leprieur et al., 2009; Vilà et al., 2010). In the case of Guaraguaçu River, and more broadly of the Neotropical region, education of local population combined with communication of research results to stakeholders are good starting points for reducing impacts of introduced species. Also areas where *I. punctatus* is still not present (or abundant) can be mapped and contained in order to preserve endangered small-bodied endemic fishes and the creation of new protected areas in the region is highly needed.

Along with that, the cultivation of the *I. punctatus* should be truly banned in the area, in order to reduce its spreading in natural water bodies. It is widely known that propagule pressure plays a fundamental role on the successful establishment and permanency of non-native species, contributing to its continuous impact (Kolar & Lodge, 2001; Ruesink, 2005). The juveniles of *I. punctatus* used in these experiments were obtained from local aquaculture. Aquaculture is recognized as the major pathway of introduction of freshwater invasive species (Naylor, Williams, & Strong, 2001; Casal, 2006; Gozlan, 2008) and in Brazil most of aquaculture production is based on non-native species (Lima Junior, Pelicice, Vitule, & Agostinho, 2012; Vitule, 2009). There are many fish-farming in Paraná state that cultivate and sell fry of *I. punctatus* despite a normative of the Environmental Institute of Paraná (IAP) that classified this species as Category I, which has its "*transportation, breeding, release or translocation, cultivation, propagation, commercialization, donation or intentional acquisition prohibited by any means*" (IAP, 2015). Besides that, the production of *I. punctatus* continues to increase with risk of escapes from aquaculture ponds being constant in Neotropical streams, representing a high propagule pressure (Forneck, Dutra, Zacarkim, & Cunico, 2016; Lima Junior et al., 2012; Vitule et al., 2009). This failed attempt to ban the introduction of *I. punctatus* in Paraná could be responsible for the worsened conservation status of many endemic fishes and is directly in conflict with the Aichi Targets of the Convention on Biological Diversity (Lima Junior et al., 2018; Pelicice et al., 2017; Vitule et al., 2009). Besides, the introduction of non-native catfishes in Brazil is paradoxical, once the Neotropical region has a great richness of Siluriformes that are valued for food and sport fishing (Abilhoa et al., 2011; Lévêque et al., 2008; Ota *et al.* 2015; Vitule, Skóra & Abilhoa, 2012). These native Siluriformes could readily replace non-native species and should have their production promoted (Cambray, 2003; Vitule et al., 2009).

As with any experimental study, there are some limitations that may be considered. A possible bias in the FR experiment results is that omnivores tend to present a Type II FR when exposed to a single type of prey (Murdoch & Oaten, 1975). For example, the presence of an alternative food changed the FR results of amphipods *D. villosus* and *G. pulex* and the superior consumption of the invasive *D. villosus* disappeared when it was presented with an alternative non-animal food (Médoc, Thuillier, & Spataro, 2017). So, for opportunistic omnivores, such as *I. punctatus*, the presence of an alternative food item might change its FR (Médoc et al., 2017) and this is a feature that should be tested in the future. Another limitation is the consideration of only variable densities of prey, instead of also considering predator-density dependence (Médoc & Spataro, 2015; Skalski & Gilliam, 2001). If conspecific predators compete interfering in each other's consumption, or if they cooperate, may be reflected in their real FR; in the first case, the impacts predicted by CFR may be overestimated, while in the latter they may be underestimated (Médoc & Spataro, 2015). The predator dependence importance on FR also remains to be tested for *I. punctatu*s.

There are other context dependencies that may influence in the FR of non-native predators. The synergistic effects between climate change and invasions have been studied in the last years, revealing some insightful consequences of warming climate and altered precipitation patterns over the dispersion of non-natives (Diez et al., 2012; Dukes & Mooney, 1999; Walther et al., 2009). However, it is known that warmer temperatures can also increase the consumption rate of ectothermic species such as fishes, magnifying their impact on native preys (Rahel & Olden, 2008). Indeed, many studies revealed that the temperature directly changes the FR and its associated parameters, reflecting in lower *h* and higher *a* as the temperature increases (Pellan, Médoc, Renault, Spataro, & Piscart, 2016; Rall et al., 2012; South, Dick, McCard, Barrios-O'Neill, & Anton, 2017). Therefore, temperature is another factor that should be considered in future research about impacts of non-native species in a changing climate reality.

A different context that may alter FR results, through altered predator behaviour, is habitat complexity (Alexander, Dick, O'Connor, Haddaway, &

Farnsworth, 2012; Barrios-O'Neill, Dick, Emmerson, Ricciardi, & MacIsaac, 2015). In some cases, habitat complexity can change the FR from Type II to Type III, if the complexity acts as a refuge for preys in low density, and habitat simplification is expected to increase the impact of a non-native species (Alexander, Kaiser, Weyl, & Dick, 2015). However, the opposite may also be true if habitat complexity contributes to predation of ambush predators, resulting in a higher consumption rate in the presence of habitat structuring (Santos, García-Berthou, Hayashi, & Santos, 2013). This context-dependency factor may also be an important feature to be tested in the FR of *I. punctatus*, once the Guaraguaçu river is invaded by the African signalgrass (*Urochloa arrecta*), a macrophyte that increases habitat complexity but also promotes homogenization due to the displacement of native macrophytes (Michelan, Thomaz, Mormul, & Carvalho, 2010; Thomaz, Ribeiro, & Cunha, 2010; Vitule, Umbria, & Aranha, 2006).

The present study is important once there are few research publications about the impact of non-native species in megadiverse developing countries; and in Brazil few studies about it are performed in an experimental fashion (Bellard et al., 2016; Frehse et al., 2016; Junqueira, 2013; Lövei & Lewinsohn, 2012; Nuñez & Pauchard, 2010; Pyšek et al., 2008). To our knowledge, this is the first study using the CFR approach to evaluate the impacts of a non-native species in Brazil. The CFR approach provides a valuable assessment of the potential impacts of non-native species and can be performed elsewhere in a very simple fashion (Dick et al., 2014, Dick, Alexander, et al., 2017). We expect that this work stimulate other Brazilian researchers to use this framework in their studies about non-native species.

Negative impacts from aquatic invaders are in general difficult to detect, especially because aquatic species are not easily observed, often experience time lags and interact synergistically with other disturbances, having indirect effects on the native biodiversity and ecosystem services (Crooks, 2005; Dudgeon et al., 2006; Gallardo et al., 2016; Lima Junior et al., 2018; Vitule, 2009; Vitule, Freire, et al., 2012). Therefore, we cannot wait for the impacts to be visible in order to start confronting them and the CFR approach can be a useful tool in this endeavour (Alexander, Dick, et al., 2014; Dick et al., 2014; Simberloff & Vitule, 2014). *Ictalurus punctatus* represents a negative impact in a highly diverse Neotropical river and measures should be taken if we want to preserve and discover all the diversity that remains to be known.

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SUPPORTING INFORMATION

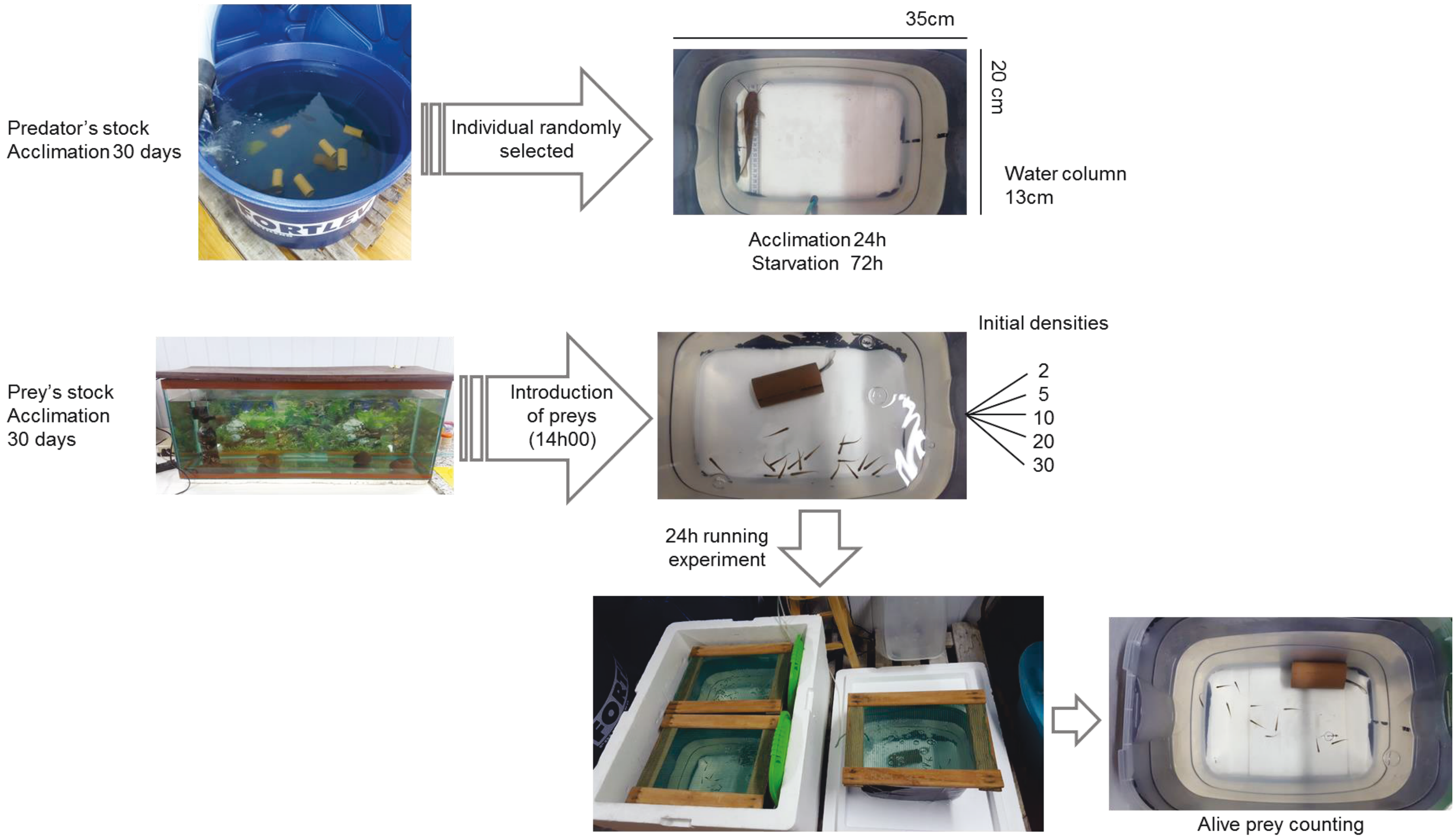

Figure S1. Experimental protocol used to obtain FR curves of *Ictalurus punctatus* and *Rhamdia quelen* preying on *Mimagoniates microlepis*.

Table S1. Field data on total abundance (n), capture per unit effort (CPUE) and total biomass (in grams) of *Ictalurus punctatus* and *Rhamdia quelen* captured in 17 standardized samples, between 2005 and 2007, using different fishing gears. Data from Vitule, 2008.

Fishing gear	Effort	n	CPUE	Biomass (g)
Ictalurus punctatus				
Longline	3 longlines of 10m with 10 fish hooks, 1500hrs	8	0.000178	9312
Gill net 20mm mesh size	Gill net of 30x1.70m, 1500hrs	5	6.54E-05	1069
Gill net 40mm mesh size	Gill net of 30x1.70m, 1500hrs	4	5.23E-05	2075
Gill net 60mm mesh size	Gill net of 30x1.70m, 1500hrs	1	1.31E-05	740
Fishing rod	4 anglers, aprox. 60hrs	12	0.05	14496
Rhamdia quelen				
Longline	3 longlines of 10m with 10 fish hooks, 1500hrs	40	0.000889	14106
Gill net 20mm mesh size	Gill net of 30x1.70m, 1500hrs	31	0.000405	8133
Gill net 40mm mesh size	Gill net of 30x1.70m, 1500hrs	33	0.000431	14768
Fishing rod	4 anglers, aprox. 60hrs	8	0.033333	1978

CONSIDERAÇÕES FINAIS

O Rio Guaraguaçu é um importante rio da costa brasileira, abrigando uma diversidade enorme de espécies de peixe de pequeno porte, porém, a introdução de espécies não nativas de predadores de grande porte, como o bagre-do-canal, ameaça esta diversidade. Acreditamos que os resultados obtidos aqui são suficientes para demonstrar a necessidade de monitoramento e controle desta espécie devido ao seu potencial impacto ecológico sobre as populações de espécies ameaçadas de extinção presentes no rio.

Avaliar e prever o impacto de espécies não nativas não é uma tarefa trivial em ecologia. A metodologia da Resposta Funcional Comparativa vem se mostrando uma boa ferramenta para isso, dentro é claro, de algumas limitações. Em um país de dimensões continentais como o Brasil, e com um alto número de espécies não nativas introduzidas, esta abordagem pode ser bastante útil para avaliar rapidamente o impacto de espécies não nativas em diferentes ecossistemas. Considerando os resultados obtidos neste trabalho, percebe-se a necessidade de estudar de maneira mais aprofundada os impactos ecológicos da introdução de espécies em ambientes aquáticos continentais, dentro de todos os contextos possíveis. Este trabalho serve de pontapé inicial para esta tarefa e ainda há muito a ser feito neste campo, porém, espera-se que ele sirva de exemplo para próximas pesquisas.

A conservação de espécies no Brasil continua sendo um grande desafio e para enfrentá-lo a comunicação de resultados científicos deve ser amplamente divulgada para que seja aplicada de maneira eficaz. Este trabalho chama a atenção para o problema do cultivo de espécies não nativas no país, o que certamente traz mais impactos negativos à biodiversidade do que positivos à economia. Esperamos que através da comunicação com tomadores de decisão e educação da população consigamos conscientizar sobre os problemas causados por espécies não nativas para que estes atores se tornem aliados no combate à introdução de espécies e à degradação da diversidade local.

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ANEXO

Ministério da Educação
UNIVERSIDADE FEDERAL DO PARANÁ
Setor de Ciências Biológicas
Comissão de Ética no Uso de Animais
(CEUA)

Nº 1027

CERTIFICADO

A Comissão de Ética no Uso de Animais do Setor de Ciências Biológicas da Universidade Federal do Paraná (CEUA/BIO – UFPR), instituída pela Resolução Nº 86/11 do Conselho de Ensino Pesquisa e Extensão (CEPE), de 22 de dezembro de 2011, **CERTIFICA** que os procedimentos utilizando animais no projeto de pesquisa abaixo especificado estão de acordo com a Diretriz Brasileira para o Cuidado e a Utilização de Animais para fins Científicos e Didáticos (DBCA) estabelecidas pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA) e com as normas internacionais para a experimentação animal.

STATEMENT

The Ethics Committee for Animal Use from the Biological Sciences Section of the Federal University of Paraná (CEUA/BIO – UFPR), established by the Resolution Nº 86/11 of the Teaching Research and Extension Council (CEPE) on December 22nd 2011, **CERTIFIES** that the procedures using animals in the research project specified below are in agreement with the Brazilian Guidelines for Care and Use of Animals for Scientific and Teaching purposes established by the National Council for Control of Animal Experimentation (CONCEA) and with the international guidelines for animal experimentation.

PROCESSO/PROCESS: 23075.160195/2016-43

APROVADO/APPROVAL: 18/10/2016 – R.O. 09/2016

TÍTULO: Resposta funcional de peixes nativos do rio Guaraguaçu – PR considerando-se a estruturação de habitat causada por uma gramínea invasora

TITLE: Functional response of native and nonnative fishes of Guaraguaçu river – PR considering the habitat structuration promoted by an invasive grass

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