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LUCAS MACHADO NUNES

Threatened, rare, and functionally rare species of fish in the Upper Paraná River floodplain: ecological perspectives and conservation

Maringá
2023

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Dissertação apresentada ao Programa de Pós-Graduação em Ecologia de Ambientes Aquáticos Continentais do Departamento de Biologia, Centro de Ciências Biológicas da Universidade Estadual de Maringá, como requisito parcial para a obtenção do título de Mestre em Ecologia e Limnologia.
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Orientador: Prof. Dr. Luiz Carlos Gomes

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Espécies ameaçadas, raras e raras funcionais de peixes da planície de inundação do alto rio Paraná: perspectivas ecológicas e conservação

RESUMO

Entender como a perda de espécies está relacionada com o papel funcional em uma comunidade ou ecossistema é essencial. Explicar o porquê algumas espécies são mais suscetíveis a estarem ameaçadas do que outras é um objetivo da biologia da conservação. Além da perda de espécies, a perda de processos ecológicos que sustentam o ecossistema funcionando, pode ser a maior sequela. Para avaliar as espécies taxonomicamente raras, raras funcionais e ameaçadas, foram usados dados dos peixes coletados entre 2000 e 2019, através de redes de arrasto com tamanho de malhas variáveis, em seis pontos amostrais da planície de inundação do alto rio Paraná. Foi considerada a abundância das espécies por ponto de coleta, sendo que para o índice de raridade taxonômica foi necessário obter o alcance geográfico, especificidade de *habitat* e tamanho da população. Para estimar a raridade funcional foram usados onze traços funcionais para a composição de uma matrix de distância, junto com uma matriz de abundância relativa para obter "*Functional Uniqueness*" e *"Functional Restrictedness"*. O resultado foi uma lista de 58 espécies. 76% destas eram simultaneamente raras taxonomicamente e funcionalmente, quatro eram ameaçadas e 17 espécies eram exóticas para a região.

Palavras-chave: raridade taxonômica; raridade funcional; conservação de espécies; peixes de água doce.

Threatened, rare, and functionally rare species of fish in the Upper Paraná River floodplain: ecological perspectives and conservation

ABSTRACT

Understanding how the loss of a species is related to its functional role in a community or ecosystem is essential. To explain why some species are more prone to be endangered than others is a major goal of conservation biology. Beyond the loss of a species, the loss of ecological processes that sustain ecosystem functioning can be the most critical influence. To evaluate the threatened, taxonomical, and functional rare species, we used fish data from 2000 to 2019, collected from nine sampling points on the Upper Paraná River floodplain (the large rivers on the floodplain, Ivinheima, Baía and Paraná, and six lakes eventually connected to the rivers: Ventura and Patos lake (Ivinheima River), Guaraná and Fechada Lakes (Baía River), Ressaco do Pau Velho and Garças Lake (Paraná River). Fish were collected using gillnets with different size mesh, and the number of individuals caught as an estimation of abundance. We obtained geographic range, habitat specificity, and population size for the taxonomical rarity index. To estimate the functional rarity, we used eleven functional traits in the composition of a functional distance matrix, together with and relative abundance matrix to obtain Functional Uniqueness and Functional Restrictedness. The outcome was a 58 species list. 76% of the species shared taxonomical and functional rarity, four were endangered, and 17 species are considered exotic to the Upper Paraná River.

Keywords: taxonomical rarity; functional rarity; species conservation; freshwater fish.

SUMMARY

1 INTRODUCTION

Species dispersal and environmental heterogeneity play fundamental roles in the spatiotemporal biodiversity patterns (Herberich et al., 2023; Xia et al., 2023). While species vary in their dispersal ability, environmental patches vary in their level of isolation or connectedness and quality. Under low dispersal rates, local species interactions and other niche processes prevail, increasing the differences in composition between local communities when patches are heterogeneous (Mouquet & Loreau, 2002, 2003; Penha et al., 2017).

The primary selection of fish life strategies is the river dynamics, related to hydrological cycles of drought and flood, and continuous water flow (Agostinho et al., 2004; Röpke et al., 2017). The physicochemical alterations promoted by floods cause the biota to respond by morphological, anatomical, physiological, phenological, and/or ethological adaptations and produce characteristic community structures. Therefore, flooding causes perceptible alterations in biota and that biota display a defined reaction to flooding (Junk, 1989), favoring dispersal.

Rarity (here, taxonomic rarity) is widely used to assess extinction risk for conservation purposes. Rabinowitz (1981) proposed that rare species in a community could emerge from the combination of three parameters: geographic range, habitat specificity, and population size. The combination of these three characteristics defines seven forms of species rarity, with the rarest species having a small range, a high level of habitat specificity, and locally low abundance.

Concerning rare species, there is a common belief in the 'mass ratio hypotheses' (Grime, 1998). Traditionally using total biomass or productivity as a proxy for ecosystem functioning, where dominant species have strong effects while rare species have marginal influence (Shugart, 1984., Pastor & Post, 1986., Huston & Smith, 1986., Sala et al. 1996., Grime, 1997) However, the need to deal with ecosystem multifunctionality, resilience and/or resistance across time, and disturbances or dependence upon some keystone species, challenges this simplistic view (Power et al., 1996; Lyons et al., 2005; Violle et al., 2017).

Beyond the loss of species, there is a growing awareness that the loss of ecological processes that sustain ecosystem functioning can be the most critical outcome under accelerating global changes (Naeem et al., 2012). Rare species perform different functions in ecosystems, some being redundant with those of many other rare and common species, while others are unique (Violle et al., 2017). More recently, Violle et al. (2017), extended the scope of Rabinowitz's (1981) classification of rarity to incorporate further differences in functional traits among taxa, defining a new component – functional rarity. Better characterizing functional rarity goes beyond the issue of understanding why species are rare or common; it can also be key to better understanding the relationship between biodiversity and ecosystem functioning. Growing consensus suggests that biodiversity-ecosystem functioning (BEF) relationships are driven by the diversity of functions carried out by species and their individuals within an ecosystem (Hooper et al., 2005; Laughlin, 2014; Cadotte et al., 2015).

One major conservation tool at the species level is the Red List of the International Union for Conservation of Nature (IUCN), whose criteria to label the extinction risks, as vulnerable, endangered, and critically endangered, take into consideration: A) the decline rate of a species, estimating the current population size comparing with the past and projecting into the future; B) small range area and decline, when its geographical range is very restricted and when other factors suggest that it is at risk; C) small population size and decline, focuses on population that are numerically small and in continuing decline; D) very small population size, allows species to be listed as threatened without evidence that there has been, is, or will be a decline of some sort; E) unfavorable quantitative analysis, allows to use any kind of quantitative analysis for assessing the risk of extinction, which is compared with the extinction-risk thresholds within given time frame (Mace et al., 2008). Since the beginning of the century, the thematic of the loss of rare species in relation to the ecosystem has been focused on, and more recently the addition of functional traits to assess ecological data (Lyons et al., 2005; Hooper et al., 2005; Naeem et al., 2013; Cadotte et al., 2015; Leitão et al., 2016; Maciel, 2021;). Works exploring the functional rarity of fish are few, and are quite recent (Toussaint et al., 2016; Grenié et al., 2018; McLean et al., 2019; Fried et al., 2021; Murgier et al., 2021; Tóth et al., 2022; Trindade-Santos et al., 2022).

Given these aspects, this study aims to evaluate the taxonomically rare, the functionally rare, as well the threatened species. Considering the key species filtered in those criteria, thus, to comprehend the response of the more fragile species in front of an environment highly regulated by dams is essential for conservation purposes, and using this work as a tool to make decisions on when, where, and how to respond to threats affecting species, ecosystems, and the services they provide in a more centered manner.

2 METHODS

2.1 Study area

The Paraná River is the second longest river in South America (4.695 km), the 10th largest river in the world for water discharge, and the fourth in drainage area (2.8 x 10^6 km²) (Agostinho et al., 2008). The Upper Paraná River comprises approximately the first third of the Paraná River basin, and it lies completely within the Brazilian territory. The Upper Paraná River has a drainage area of 891,000 km², representing 10.5% of the total area (Agostinho et al., 2008).

The Upper Paraná River floodplain is a stretch of 480 km between the cities of Três Lagoas, Mato Grosso do Sul State, to Guaíra, Paraná State. After the closure of the Porto Primavera Dam in 1998, the floodplain (western margin of the Paraná River) was reduced to 230 km from the Porto Primavera Dam to the Upper part of the Itaipu Reservoir, which is one of the last stretches of the Paraná River with running waters. This stretch has high habitat heterogeneity and still maintains a great biodiversity of terrestrial and aquatic organisms (Agostinho et al., 2004a.; Agostinho et al., 2004b).

Despite the ecological importance of the floodplain, the Paraná River and its tributaries have more than 145 large dams, most of them in cascade. These reservoirs caused alterations in the annual flood regime of the Paraná River and its floodplain (Agostinho et al., 2005.; Agostinho et al., 2004; Sanches et al., 2006) but the flood pulse is still the main force function for the biota of the region. The flood period in the Paraná River usually occurs from November/December to April/May, while the low-water period coincides with the winter, between June and September. The occurrence of two or three annual flood pulses is quite common during periods of high water levels (Agostinho et al., 2009; Lima et al., 2017).

In the floodplain, the river has a wide-braided channel with a low slope and heavy accumulation of sediments on its bed, creating sandbanks and islands. There are also secondary but equally important channels, the Baía and Ivinheima rivers, and the lower courses of rivers entering on the right bank (e.g. Amambai, and Iguatemi rivers) forming a complex anastomosis in this stretch. The left margin of the river is steeper, and its tributaries have larger slopes (Paranapema, Ivai, and Piquiri rivers) with smaller floodplains (Figure 1).

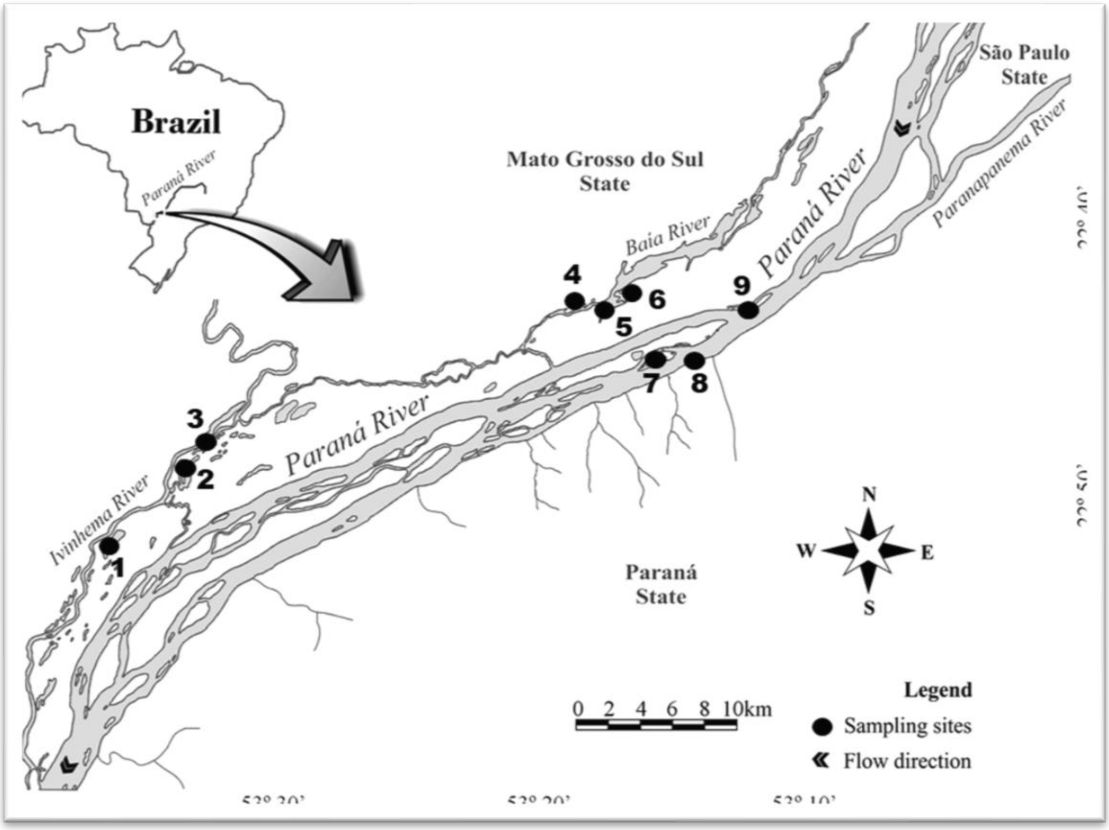

Figure 1. Map of the study area. 1= Ventura Lagoon, 2= Patos Lagoon, 3= Ivinhema River, 4= Guaraná Lagoon, 5= Baía River, 6= Fechada Lagoon, 7= Pau Véio Backwater, 8= Paraná River, 9= Garças Lagoon. Fonte: Andreotti et al. (2021)

2.2 Sampling

Sampling was conducted quarterly, from March 2000 until December 2019, in nine sampling sites, as follow: three including the large rivers on the floodplain, Ivinheima, Baía and Paraná, and six sampling sites on floodplain lakes connected or not to the rivers: Ventura and Patos Lagoon (Ivinheima River), Guaraná and Fechada Lagoon (Baía River), Ressaco do Pau Velho and Garças Lagoon (Paraná River) (Figure 1).

Fishes were collected using 20 m-long and 1.70 m-high gillnets with different mesh sizes (2.4 to 16 cm between opposite knots) that were exposed for 24 h and checked every 8 h, 16 h, and 22 h. Captured fish were anesthetized with 5% benzocaine and euthanized. All captured fish were identified according to Garavello (1979), Garavello and Britski (1987, 1988, 1990), Britski *et al*. (2007), Graça and Pavanelli (2002), and Ota *et al*. (2018). Because the fishing effort was the same for all samplings, I considered the number of individuals caught as an estimation of abundance.

2.3 Species sorting and analysis

For the definition of endangered species, were considered the Red Book of Threatened Brazilian Fauna: Vol. VI – Fishes (ICMBio, 2018), Portaria MMA 148/ 2022 and the IUCN Red List of Threatened Species (IUCN, 2022).

The taxonomic rare species were selected using a package in the R environment (R CoreTeam, 2023) introduced by Maciel (2021) called "rrindex". The idea behind the index follows the reasoning proposed by Rabinowitz (1981). The output of this package is a matrix with five columns, containing the following parameters for each species: species *(spp)*, the geographic range index (*gri*), habitat specificity index (*hsi*), the population size index (*psi*), and an average among them, the taxonomic rarity index *(rr)*. The "rrindex package" requires a series of inputs. The first one is a list with the name of the species as a factor, and the name of each species can appear in the list more than once. The second and third parameters are numeric vectors containing the information for latitude and longitude where species were registered. The fourth input is of the string type and represents the abundance of the species in a given area. The fifth input is a factor containing information on the type of habitat in which the species was collected. In this case, were used "rivi", "rpar", "rbai", to address each river and its two respective lakes temporally connected.

To quantify functional rarity, an R package named "funrar" was used, based on occurrence and trait data (R Core Team, 2023; Grenié et al., 2017). This package computes Functional Distinctiveness (Di), Functional Uniqueness (Ui), Taxon Scarcity (Si), and Taxon Restrictedness (Ri) using a species-by-site or community composition matrix with either the presence-absence or relative abundance of species, and a functional dissimilarity matrix. As emphasized by Violle et al. (2017), a species can be functionally distinct in a given community but not functionally unique in an entire region. In this regard, distinctiveness and scarcity are used to uncover local rarity; uniqueness and restrictedness are used regionally. In this work, I considered the floodplain on a regional scale. That is, were considered only uniqueness (Ui), and restrictedness (Ri). In addition, after applying these functions, I used a Spearman's correlation to check the relationship between these two indices separately. A Principal Coordinates Analysis (PCoA) was carried out to better visualize the functional dissimilarity of the species.

At the regional scale, Functional Uniqueness is relevant to assess the role of functional originality. It can represent how taxa depart from a regional pool due to specific biogeographical and evolutionary legacies and the index result varies from 0 to 1. Taxon restrictedness is an index used between 0 and 1. It tends to one when a species is present in fewer sites of the species-by-site matrix. To obtain the functional rarity, the average between Ui e Ri is calculated.

The functional traits used in this work were previously obtained through the works of Rodrigues et al. (2020) and Baumgartner et al. (2018), and they were considered to better characterize the species' functional role and response regarding the floodplain environment (Appendix B) (Winemiller et al., 2015; Villéger et al., 2017).

They are as follows:

Trophic category	detritivore, insectivore, piscivore, herbivore, omnivore, and planktivore (according to Hahn et al.,2004)
Position in the water column	benthopelagic, pelagic, and demersal (according to Graça e Pavanelli, 2007)
Body shape	fusiform, deep, laterally compressed, cylindrical, flattened, anguilliform (according to Graça e Pavanelli, 2007)
Crypsis	low, moderate, and extreme (according to Graça & Pavanelli, 2007; Calegari et al.,2013; Souza-Filho & Shibatta,2007. Deprá et al.,2015; Loboda et al.2015)
Standard length	(according to Costa & Soares,2015; Graça & Pavanelli, 2007; Deprá et al.,2015; Loboda et al.2015)
Eye position	lateral, dorsolateral, superior and inferior (according to Britski et al.,2007; Roberts, 2015; Varella,2011)
Mouth position	subterminal, terminal, inferior, superior, and lateral (according to Graça & Pavanelli, 2007; Castro et al.,20014; Britski et al.,2007; Marinho et al.,2008; Zarske et al.2008)
Diel activity	crepuscular, nocturnal and diurnal (according to Britski et al.,2007; Reis et al., 2003; Nakatani et al.,2001)
Fecundation and parental care	external fecundation with parental care, external fecundation without parental care, and internal fecundation (according to Nakatani et al., 2003; Suzuki et al., 2005; Graça & Pavanelli, 2007; Froese & Pauly, 2015)
Spawning	parceled, total (according to Nakatani et al., 2001; Suzuki et al., 2005; Graça & Pavanelli, 2007; Froese & Pauly, 2015)
Migration	migratory, sedentary (according to Graça & Pavanelli, 2007; Froese & Pauly, 2015)

For a more accurate result and concerning conservational purposes, only the species correctly identified were considered on the final list.

3 RESULTS

Four species matched one or more criteria established to define threatened species: *Aphyocheirodon hemigrammus, Brycon orbignyanus, Myloplus tiete,* and *Pseudoplatystoma corruscans.* Using the rarity metrics (Figure 2), the number of rare species found was 51 (33,5% of total species) (Appendix A). For they presented *rr* above average (*rr* = 0.36) measured for all species (n = 152).

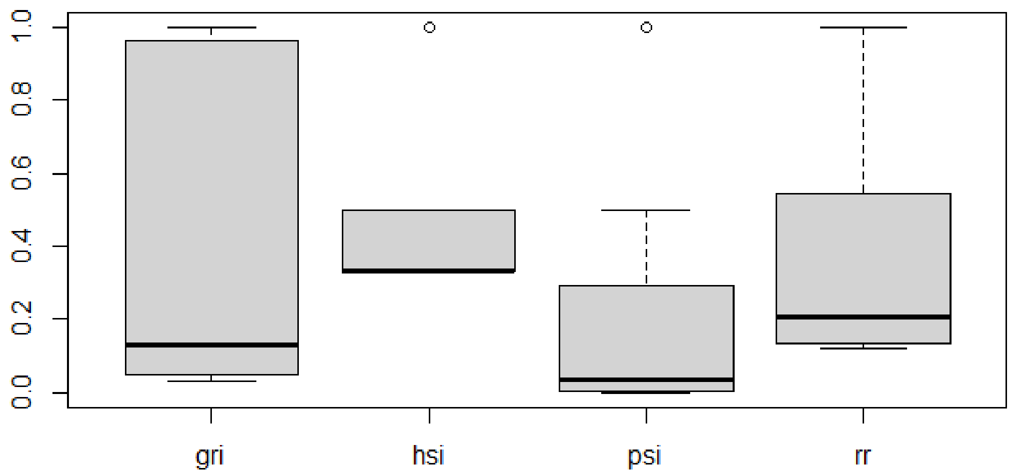

Figure 2. Boxplot showing the result of the rarity metrics for geographic range, habitat specificity, population size indices, and the average between them. (gri) = geographic range index, (his) = habitat specificity index, (psi) = population size index, and (rr) = rarity index

Among the 152 fish species registered, 127 species had trait information available. For each species, I calculated Functional Uniqueness and Taxon Restrictedness and averaged them by each species. Out of the 127 species, 44% (56) species were above the average (0.28) of functional rarity (Appendix C), but even so, the index for the rarest functionally species was only 0.66, *Farlowella hahni.* Despite of this value, the Functional Restrictedness for this species was 0.88, indicating that it occurred in a few sampling sites, and the Functional Uniqueness was 0.44, which means that its functional traits are shared with some other few species. In general, most species are functionally redundant, with low values of Functional Uniqueness, but 33% (42) of them are geographically restricted, present in just one sampling site (Figure 3). At the species level, Functional Uniqueness and Taxon Restrictedness were weakly inversely correlated (Spearman's rho= - 0.10, p=0.23). To better visualize the functional distance in contrast to the Functional Rarity Index, I made a PCOA. In which the position of the species is located differently than the index (**Figure *4***).

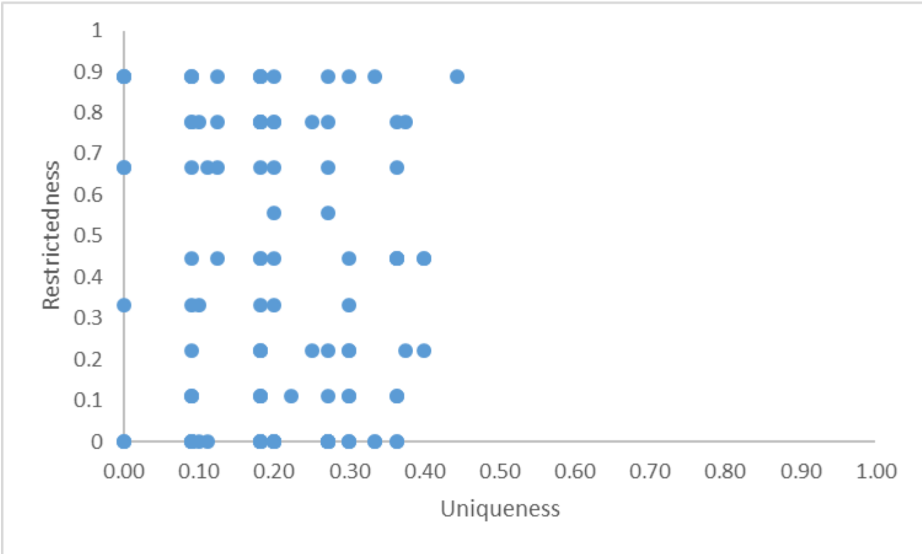

Figure 3. Taxon Restrictedness against Functional Uniqueness per species.

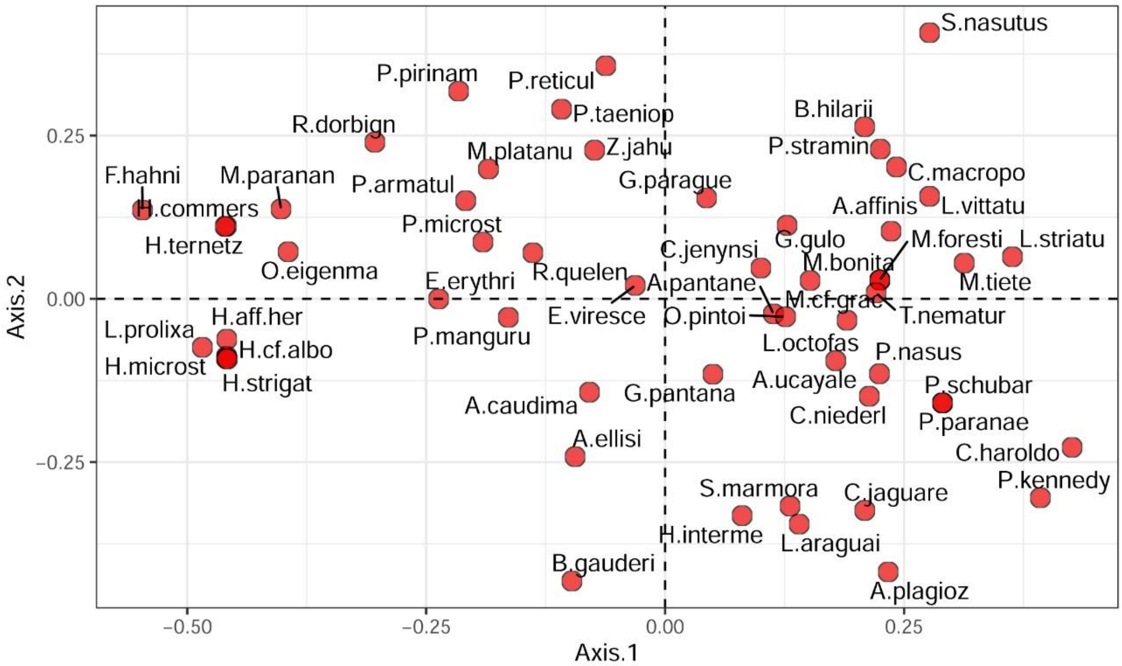

Figure 4. PCOA species scores showing the functional distance of the species.

Matching at least one of the three criteria, 58 species were ponted out (**Table *1***). For the species *Aphyocheirodon hemigrammus*, no functional trait was available. So, it is the only one without the metrics for functional and taxonomical rarity. 76% of the listed species (n=58, excluding the one cited above) shared taxonomical and functional rarity. 17 species are considered exotic to the Upper Paraná River according to Ota et al. (2018).

Table 1. Fish species and the respective criteria in which they fit. EN= endangered, VU= vulnerable, CR= critically endangered. * Alien species to the Upper Paraná River.

Species	Taxonomic Rarity Index	Functional Rarity Index	IUCN	Red Book	Portaria MMA Nº 148,07.07.22
Acestrorhynchus pantaneiro Menezes, 1992*	*0,36*	*31*			
Aequidens plagiozonatus Kullander, 1984	*0,73*	*0,45*			
Apareiodon affinis (Steindachner, 1879)	*0,49*	*0,51*			
Aphyocheirodon hemigrammus Eigenmann, 1915			VU	VU	
Apteronotus caudimaculosus Santana, 2003	*1*	*0,44*			
Apteronotus ellisi (Arámburu, 1957)	*0,69*	*0,44*			
Brachyhypopomus gauderio Giora, Malabarba, 2009*	*1*	*0,44*			
Brycon hilarii (Valenciennes, 1850)*	*0,43*	*0,47*			
Brycon orbignyanus (Valenciennes, 1850)	*0,16*	*0,13*		EN	CR
Catathyridium jenynsii (Günther, 1862)*	*0,19*	*0,31*			
Colossoma macropomum (Cuvier, 1818)*	*0,83*	*0,47*			
Crenicichla haroldoi Luengo, Britski, 1974	*0,83*	*0,5*			
Crenicichla jaguarensis Haseman, 1911	*0,44*	*0,39*			
Crenicichla nierderleinii Varella (2011)	*0,77*	*0,59*			
Eigenmannia virescens (Valenciennes, 1836)	*0,51*	*0,4*			
*Erythrinus erythrinus (Bloch, Schneider, 1801)**	*0,21*	*0,4*			
Farlowella hahni Meinken, 1937*	*1*	*0,66*			
Galeocharax gulo (Cope, 1870)	*0,21*	*0,42*			
Gymnotus pantanal Fernandes, Albert, Daniel-Silva, Lopes, Crampton, Almeida-Toledo, 2005	*0,22*	*0,31*			
Gymnotus paraguensis Albert, Crampton, 2003	*0,27*	*0,37*			
Hoplias intermedius (Günther, 1864)	*1*	*0,48*			
Hypostomus albopunctatus (Regan, 1908)	*0,55*	*0,43*			
Hypostomus cf. strigaticeps (Regan, 1908)	*0,23*	*0,37*			
*Hypostomus commersoni Valenciennes, 1836**	*0,54*	*0,43*			
Hypostomus hermanni (Ihering, 1905)	*0,76*	*0,43*			
*Hypostomus microstomus Weber, 1987**	*1*	*0,48*			
Hypostomus ternetzi (Boulenger, 1895)*	*1*	*0,48*			
*Laetacara araguaiae Ottoni, Costa, 2009**	*0,65*	*0,38*			
Leporellus vittatus (Valenciennes, 1850)	*0,7*	*0,53*			
Leporinus octofasciatus Steindachner, 1915	*0,66*	*0,47*			
Leporinus striatus Kner, 1858	*0,54*	*0,48*			
Loricaria prolixa Isbrücker, Nijssen, 1978	*0,24*	*0,42*			
Megalancistrus parananus (Peters, 1881)	*0,27*	*0,42*			
Megalonema platanum (Günther, 1880)	*0,66*	*0,51*			
Moenkhausia bonita Benine, Castro, Sabino, 2004	*1*	*0,53*			
Moenkhausia cf.gracilima Eigenmann, 1908	*1*	*0,53*			
Moenkhausia forestii Benine, Mariguela, Oliveira, 2009*	*1*	*0,53*			
Myloplus tiete (Eigenmann, Norris, 1900)	*0,57*	*0,43*			EN
Oligosarcus pintoi Campos, 1945	*0,75*	*0,58*			
Ossancora eigenmanni (Boulenger, 1895)*	*0,15*	*0,29*			
Parodon nasus Kner, 1859	*0,52*	*0,57*			
Piabarchus stramineus (Eigenmann, 1908)	*0,29*	*0,46*			
Pimelodella taenioptera Miranda-Ribeiro, 1914*	*0,54*	*0,47*			
Pimelodus microstoma Steindachner, 1877	*0,2*	*0,32*			
Pinirampus pirinampu (Agassiz, 1829)	*0,22*	*0,41*			
Platydoras armatulus (Valenciennes, 1840)*	*0,24*	*0,37*			
Psalidodon paranae (Eigenmann, 1914)	*0,83*	*0,44*			
*Psalidodon schubarti **	*0,51*	*0,33*			
Psellogrammus kennedyi (Eigenmann, 1903)*	*0,12*	*0,28*			

Pseudopimelodus mangurus (Valenciennes, 1835)	*0,56*	*0,57*			
Pseudoplatystoma corruscans (Spix, Agassiz, 1829)	*0,12*	*0,09*			VU
Pseudoplatystoma reticulatum Eigenmann, Eigenmann, 1889*	*0,5*	*0,47*			
Rhamdia quelen (Quoy, Gaimard, 1824)	*0,23*	*0,4*			
Rhinodoras dorbignyi Kner, 1855)	*0,32*	*0,48*			
Schizodon nasutus Kner, 1858	*0,12*	*0,4*			
Synbranchus marmoratus Bloch, 1795	*0,83*	*0,61*			
Triportheus nematurus (Kner, 1858)*	*0,68*	*0,54*			
*Zungaro jahu (*Ihering, 1898)	*0,51*	*0,52*			

4 DISCUSSION

Brycon orbignyanus was the most threatened species on the list (MMA,2022). And even so, it did not appear in any of the rarity indexes. Fact that can be explained since I used only the floodplain as a source of data. It is a migratory species, and the main threat is pollution, followed by the destruction of riparian vegetation, silting of rivers and dams in cascade. (ICMBio, 2018; Agostinho and Gomes, 2004). This species is very sensitive to environmental changes and requires an area with preserved riparian forests for food and consolidation of the reproductive process (Cecílio and Agostinho, 1997). With a loss of 97% of its extent of occurrence area, nowadays in Brazil, the Upper Paraná River (including its floodplain and some tributaries) is the last natural habitat for the species (ICMBio, 2018). Another migratory threatened species on the list is *Pseudoplatystoma corruscans* (VU-MMA, 2022). Whose main threats are damming, overfishing, and silting (Mello et al., 2009; Silva, 2015). *Aphyocheirodon hemigrammus* is endemic to the Upper Paraná River Basin. Found in low abundance in lentic water bodies, preferring marginal lakes (ICMBio,2018). *Myloplus tiete* is a riverine species, and its threat is related to the expansion of hydropower dams and introduction of invasive species such as *Cichla* spp (peackok bass) (Magallhães et al., 2019).

Rare species have become the focal species for conservation in the field of biodiversity conservation. In this sense, a simple approach like the "rrindex" used in this work can reduce the gap between science and decision-making. Another challenge is to try to understand how rarity can be associated with the risk of extinction. These questions have already been addressed using geographic range or population size as response variables. The index used here provides the ability to test this and other questions from the synthesis of three parameters (geographic range, habitat specificity, and population size) that are already recognized as important aspects of classifying rare species in a community of different taxa (Maciel, 2021).

At regional scale, Functional Uniqueness can represent how taxa depart from a regional pool due to specific biogeographical and evolutionary legacies and should then be estimated based on the whole site-species matrix (Grenié et al., 2017).

Some species such as *Farlowella hahni*, are non-native, which occurrence can be associated with the filling of the Itaipu Reservoir and the consequent inundation of the Sete Quedas Falls (Ota et.al. 2018). Therefore, despite its uniqueness, in the end, it doesn't match the conservational idea behind this work.

In general, except for *Farlowella hahni*, no other species in the final list has stood out from another. Whether by a high value for taxonomical rarity (max=0.83, *Synbranchus marmoratus, Psalidodon paranae,* and *Crenicichla haroldoi*), or high value for functional rarity (max= 0.61, *Synbranchus marmoratus*). It might be explained by the sampling methodology, being captured accidentally by a device not focused on fish of their size, morphology, life habits, and the redundancy of functions they possess amongst themselves. Knowing specifically the causes of rarity can predict in greater success the efforts for species preservation. Determining a boundary where rarity begins is a theme that has been already discussed by many authors (Dajoz,1983., Maitland,1985., Olden et al. 2008., leitão et al. 2016). As well as the fluctuation, similarity, diversity, and turnover (Cadotte et al., 2015; Baumgartner et al., 2018; Cantarute et al.,2018) of functional traits in some aspects, quite similar and the building blocks of the indexes I worked with here, I hoped that it would become clear the soft transition of one species to another considering the functional traits and the multi-factor aspect that encompasses the traditional taxonomic rarity. If rare species mainly support roles that are also played by common species, then we may expect mild consequences following their extinction. On the other hand, if rare species over-contribute to functional structure, then their extinction may lead to a harsh loss of ecological processes, as demonstrated by Pendleton et al. (2014) and Leitão et al. (2016) which showed that the loss of rare species may reduce the functional richness, specialization, and originality of assemblages more than expected under a random loss of species.

Progress in understanding how the loss of a species is related to its functional role in a community or ecosystem is essential. Studies showing the effects of species richness on ecosystem functioning are controversial. Ecosystem functions do not saturate at low species richness, many studies show positive effects of biodiversity on function (Oliver et al., 2015; Gonzalez et al., 2020; Moi et al., 2021), while others do not (Schwartz et al.,2000; Winfree et al., 2015). It is not yet clear how results from small-scale BEF experiments can be scaled up to larger spatial scales relevant to conservation. Although, realistic patterns of species extinction can result in BEF effects different from those predicted by random-loss experiments (Schwartz et al., 2000; Srivastava & Vellend, 2005).

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APPENDIX A - Taxa filtered by sampling methodology in which we applied the rarity index. the result, rr. in crescent order. Spp = species, gri = geographic range index, hsi= habitat specificity index, psi= population size index, rr= rarity index.

spp	gri	hsi	psi	rr
A.affinis	0,985156	0,5	0,00157	0,495575
A.caudima	1	1	1	1
A.crassip	0,290121	0,333333	0,00813	0,210528
A.ellisi	1	1	0,076923	0,692308
A.inermis	0,261433	0,333333	0,011765	0,202177
A.lacustr	0,237675	0,333333	0,000685	0,190565
A.militar	0,217876	0,333333	0,0625	0,20457
A.osteomy	0,201121	0,333333	0,0008	0,178418
A.pantane	0,5092	0,5	0,1	0,369733
A.plagioz	0,86206	1	0,333333	0,731798
A.ucayale	0,343275	0,333333	0,111111	0,262573
Ast.lacus	0,163421	0,333333	0,000729	0,165828
B.gauderi	1	1	1	1
B.hilarii	0,30548	0,5	0,5	0,43516
B.orbigny	0,15381	0,333333	0,009804	0,165649
C.britski	0,145267	0,333333	0,006289	0,16163
C.callich	0,149102	0,333333	0,0625	0,181645
C.gariepi	0,130743	0,333333	0,111111	0,191729
C.haroldo	1	1	0,5	0,833333
C.jaguare	0,803856	0,5	0,021739	0,441865
C.jenynsi	0,124519	0,333333	0,125	0,194284
C.kelberi	0,11886	0,333333	0,002538	0,151577
C.macropo	0,99965	1	0,5	0,833217
C.modestu	0,113693	0,333333	0,022222	0,156416
C.nagelii	0,108957	0,333333	0,017544	0,153278
C.niederl	1	1	0,333333	0,777778
C.paranae	0,113687	0,333333	0,055556	0,167525
C.piquiti	0,100577	0,333333	0,021739	0,151883
Cichla sp	0,137056	0,333333	0,5	0,323463
Cichlaspp	1	1	1	1
Creni spp	1	1	1	1
Cyphocasp	1	1	1	1
E.erythri	0,124531	0,5	0,034483	0,219671
E.triline	0,090174	0,333333	0,004202	0,14257
E.viresce	0,963384	0,5	0,071429	0,511604
F.hahni	1	1	1	1
G.gulo	0,132441	0,5	0,018182	0,216874
G.inaequi	0,087168	0,333333	0,006135	0,142212
G.pantana	0,084357	0,333333	0,25	0,222563
G.parague	0,117566	0,5	0,2	0,272522
G.sveni	0,079245	0,333333	0,001389	0,137989

spp	gri	hsi	psi	rr
G.sylvius	0,076914	0,333333	0,018868	0,143039
Gymnotspp	0,074717	0,333333	0,038462	0,148837
H.aff.her	0,804194	0,5	0,5	0,601398
H.ancistr	0,079199	0,333333	0,018868	0,1438
H.argenti	0,070679	0,333333	0,008333	0,137448
H.cf.albo	0,98898	0,5	0,166667	0,551882
H.cf.iher	0,352383	0,333333	0,05	0,245239
H.cochlio	0,068819	0,333333	0,010309	0,137487
H.commers	0,804194	0,5	0,333333	0,545843
H.hermann	1	1	0,5	0,833333
H.interme	1	1	1	1
H.littora	0,067055	0,333333	0,000825	0,133738
H.mbigua	0,065378	0,333333	0,002375	0,133696
H.microst	1	1	1	1
H.misione	0,085113	0,333333	0,5	0,306149
H.oremacu	0,062265	0,333333	0,006536	0,134045
H.orthono	0,060818	0,333333	0,000828	0,13166
H.platyrh	0,059435	0,333333	0,003226	0,131998
H.regani	0,341972	0,333333	0,003155	0,226153
H.strigat	0,354196	0,333333	0,02	0,235843
H.ternetz	1	1	1	1
H.unitaen	0,058115	0,333333	0,004902	0,132117
Hopli sp2	0,056852	0,333333	0,002183	0,130789
Hopli spp	0,055642	0,333333	0,002188	0,130388
Hypos spp	0,064168	0,333333	0,018519	0,138673
I.labrosu	0,053371	0,333333	0,001698	0,129467
L.araguai	0,95476	0,5	0,5	0,651587
L.frideri	0,052304	0,333333	0,001022	0,128887
L.lacustr	0,051278	0,333333	0,001253	0,128622
L.octofas	0,98898	0,5	0,5	0,662993
L.pectora	0,054951	0,333333	0,009709	0,132664
L.platyme	0,049343	0,333333	0,000304	0,12766
L.prolixa	0,343275	0,333333	0,055556	0,244055
L.rostrat	0,054928	0,333333	0,016129	0,134797
L.striatu	0,98898	0,5	0,142857	0,543946
L.vittatu	1	1	0,111111	0,703704
Leporispp	1	1	1	1
Lorica sp	0,053936	0,333333	0,014286	0,133852
M.aff.int	0,0467	0,333333	0,000437	0,126824
M.bonita	1	1	1	1
M.cf.grac	1	1	1	1
M.foresti	1	1	1	1
M.gra/bon	0,804194	0,5	1	0,768065
M.lippinc	0,045881	0,333333	0,002976	0,127397
M.macroce	0,04509	0,333333	0,025	0,134474

spp	gri	hsi	psi	rr
M.obtusid	0,044326	0,333333	0,012048	0,129902
M.paranan	0,354196	0,333333	0,125	0,270843
M.piavuss	0,043587	0,333333	0,003861	0,126927
M.platanu	0,98898	0,5	0,5	0,662993
M.tiete	0,985156	0,5	0,25	0,578385
O.eigenma	0,047552	0,333333	0,090909	0,157265
O.pintoi	1	1	0,25	0,75
P.amandae	0,048663	0,333333	0,1	0,160665
P.ambrose	0,042181	0,333333	0,000635	0,125383
P.armatul	0,344051	0,333333	0,043478	0,240288
P.avanhan	0,045092	0,333333	0,033333	0,137253
P.cf.falk	0,354196	0,333333	0,019608	0,235712
P.corrusc	0,041512	0,333333	0,005263	0,126703
P.fasciat	0,974978	0,333333	0,011494	0,439935
P.galeatu	0,040863	0,333333	0,000438	0,124878
P.gracili	0,044005	0,333333	0,04	0,139113
P.granulo	0,039625	0,333333	0,002237	0,125065
P.kennedy	0,043051	0,333333	0,011236	0,129207
P.lineatu	0,03846	0,333333	0,00052	0,124104
P.maculat	0,037902	0,333333	0,003436	0,124891
P.manguru	0,98898	0,5	0,2	0,562993
P.mes-hib	0,338376	0,5	0,166667	0,335014
P.mesopot	0,037361	0,333333	0,012346	0,12768
P.microst	0,041845	0,333333	0,25	0,208393
P.mysteri	0,036323	0,333333	0,009615	0,126424
P.nasus	0,98898	0,5	0,1	0,52966
P.ornatus	0,040704	0,333333	0,03125	0,135096
P.paranae	1	1	0,5	0,833333
P.pirinam	0,34376	0,333333	0,01	0,229031
P.reticul	0,95476	0,5	0,071429	0,50873
P.schubar	0,967821	0,5	0,083333	0,517051
P.squamos	0,035341	0,333333	0,002079	0,123585
P.stramin	0,041027	0,5	0,333333	0,291454
P.taeniop	0,804194	0,5	0,333333	0,545843
Pimel spp	0,3393	0,5	0,333333	0,390878
Pimelodsp	1	1	1	1
Pon e vir	0,376598	0,5	0,090909	0,322502
Potamo sp	0,057018	0,5	1	0,519006
Pseudo sp	0,38908	0,5	1	0,629693
R.aspera	0,036324	0,333333	0,00369	0,124449
R.descalv	0,034411	0,333333	0,001008	0,122918
R.dorbign	0,38908	0,5	0,1	0,329693
R.hahni	0,033964	0,333333	0,03125	0,132849
R.quelen	0,309751	0,333333	0,058824	0,233969
R.vulpinu	0,033529	0,333333	0,003906	0,12359

spp	gri	hsi	psi	rr
S.altopar	0,033105	0,333333	0,047619	0,138019
S.borelli	0,032691	0,333333	0,000828	0,122284
S.brasili	0,03353	0,333333	0,006536	0,124467
S.brevipi	0,032287	0,333333	0,000809	0,122143
S.geryi	1	1	1	1
S.hilarii	0,032692	0,333333	0,012987	0,126337
S.insculp	0,031894	0,333333	0,000786	0,122004
S.lima	0,031509	0,333333	0,017241	0,127361
S.macruru	0,034082	0,333333	0,029412	0,132276
S.maculat	0,030768	0,333333	0,002092	0,122064
S.margina	0,03041	0,333333	0,00025	0,121331
S.marmora	1	1	0,5	0,833333
S.nasutus	0,03598	0,333333	0,005556	0,124956
Satanopsp	0,030061	0,333333	0,001815	0,121736
Schizo sp	1	1	1	1
Steindasp	1	1	1	1
Steindspp	0,3393	0,5	0,166667	0,335322
T.nematur	1	1	0,0625	0,6875
T.paragua	0,029386	0,333333	0,000904	0,121208
Trache sp	0,02906	0,333333	0,25	0,204131
Z.jahu	0,98898	0,5	0,058824	0,515935

APPENDIX B – Fish species whose functional traits were available**.**

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
A.affinis	Detritivore	Benthopelagic	Fusiform	Low	93.3	Lateral	Subterminal	Crepuscular	EFNP	Parceled	Sedentary
A.caudima	Insectivore	Benthopelagic	Fus/Lat.compressed	Low	NA	Dorsolateral	Terminal	Nocturnal	EFPC	NA	NA
A.crassip	Piscivore	Benthopelagic	Deep	Extreme	172.3	Lateral	Terminal	Diurnal	EFPC	Parceled	Sedentary
A.ellisi	Insectivore	Benthopelagic	Fus/Lat.compressed	Low	175	Dorsolateral	Terminal	Nocturnal	EFPC	Parceled	Sedentary
A.inermis	Piscivore	Pelagic	Deep	Moderate	212	Lateral	Terminal	Nocturnal	IF	Total	Sedentary
A.lacustr	Piscivore	Benthopelagic	Fusiform	Low	150	Dorsolateral	Terminal	Diu/Noc/Cre	EFNP	Parceled	Sedentary
A.militar	Piscivore	Pelagic	Fusiform	Low	202	Lateral	Terminal	Nocturnal	IF	Total	Sedentary
A.osteomy	Insectivore	Pelagic	Fusiform	Low	191	Lat/Inf	Terminal	Nocturnal	IF	Parceled	Sedentary
A.pantane	Piscivore	Benthopelagic	Fusiform	Low	147	Dorsolateral	Terminal	Diurnal	EFNP	Parceled	Sedentary
A.plagioz	Herbivore	Benthopelagic	Deep/Lat.compressed	Moderate	103	Lateral	Terminal	Diurnal	EFPC	Parceled	NA
A.ucayale	Piscivore	Pelagic	Fusiform	Moderate	290	Lateral	Terminal	Nocturnal	IF	Total	Sedentary
Ast.lacus	Omnivore	Pelagic	Deep	Low	79.9	Lateral	Terminal	Diurnal	EFNP	Parceled	Sedentary
B.gauderi	Insectivore	Benthopelagic	Fus/Lat.compressed	Moderate	NA	Dorsolateral	Terminal	Nocturnal	EFPC	Parceled	Sedentary
B.hilarii	Omnivore	Benthopelagic	Deep	Low	288.9	Lateral	Terminal	Crepuscular	EFNP	Total	Migratory
B.orbigny	Insectivore	Benthopelagic	Fusiform	Low	270	Lateral	Terminal	Crepuscular	EFNP	Total	Migratory
C.britski	Insectivore	Benthopelagic	Deep	Moderate	130	Lateral	Terminal	Diurnal	EFPC	NA	Migratory
C.callich	Insectivore	Demersal	Fusiform	Low	120	Dorsolateral	Terminal	Nocturnal	EFPC	Total	Sedentary
C.gariepi	Piscivore	Benthopelagic	Fusiform	Moderate	27.7	Superior	Terminal	Nocturnal	EFPC	Parceled	Sedentary

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
C.haroldo	Omnivore	Benthopelagic	Fusiform	Moderate	110	Lateral	Terminal	Diurnal	NA	NA	NA
C.jaguare	Omnivore	Benthopelagic	Fusiform	Moderate	101.4	Lateral	Terminal	Diurnal	EFPC	NA	Sedentary
C.jenynsi	Insectivore	Demersal	Deep/Laterally.compressed	Extreme	107.6	Lateral	Terminal	Nocturnal	EFNP	Parceled	NA
C.kelberi	Piscivore	Benthopelagic	Deep	Moderate	190	Dorsolateral	Terminal	Diurnal	EFPC	Total	Sedentary
C.macropo	Omnivore	Benthopelagic	Deep	Low	250	Lateral	Terminal	Diurnal	EFNP	Total	Migratory
C.modestu	Detritivore	Benthopelagic	Deep	Low	80	Lateral	Terminal	Diul/Noc	EFNP	Total	Sedentary
C.nagelii	Detritivore	Benthopelagic	Fusiform	Low	130	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
C.niederl	Insectivore	Benthopelagic	Fusiform	Low	145.5	Lateral	Terminal	Diurnal	EFPC	NA	Sedentary
C.paranae	Piscivore	Benthopelagic	Deep	Moderate	110	Dorsolateral	Terminal	Diurnal	EFPC	Parceled	Sedentary
C.piquiti	Piscivore	Benthopelagic	Deep	Moderate	240	Dorsolateral	Terminal	Diurnal	EFPC	Parceled	Sedentary
E.erythri	Piscivore	Demersal	Fusiform/Cylindrical	Low	93	Dorsolateral	Terminal	Diurnal	EFPC	Total	Sedentary
E.triline	Insectivore	Benthopelagic	Fus/Dee	Moderate	212	Dorsolateral	Terminal	Crepuscular	EFPC	Total	NA
E.viresce	Insectivore	Benthopelagic	Fusiform	Extreme	275	Dorsolateral	Subterminal	Crepuscular	EFNP	Parceled	Sedentary
F.hahni	Planktivore	Demersal	Flattened	Low	130	Dorsolateral	Inferior	Cre/Noc	EFPC	NA	NA
G.gulo	Piscivore	Benthopelagic	Deep	Low	200	Lateral	Sub/Ter	Crepuscular	EFNP	Continuous	Sedentary
G.inaequi	Insectivore	Benthopelagic	Fusiform	Moderate	134	Ventrolateral	Superior	Nocturnal	EFPC	Parceled	Sedentary
G.pantana	Omnivore	Benthopelagic	Fusiform	Moderate	NA	Ventrolateral	Superior	Nocturnal	IF	Total	Sedentary
G.parague	Omnivore	Benthopelagic	Fusiform	Low	240	Ventrolateral	Superior	Crepuscular	IF/EFPC	Total	Sedentary
G.sveni	Invertivore	Demersal	Deep	Low	150	Lateral	Terminal	Diurnal	EFPC	NA	Sedentary
G.sylvius	Invertivore	Benthopelagic	Fusiform	Low	175.4	Ventrolateral	Superior	Nocturnal	EFPC	Total	Sedentary

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
H.aff.her	Detritivore	Demersal	Deep	Moderate	NA	Dorsolateral	Inferior	Crepuscular	EFPC	Total	Sedentary
H.ancistr	Detritivore	Demersal	Deep	Extreme	140	Dorsolateral	Inferior	Noc/Cre	EFPC	Total	Sedentary
H.cf.albo	Detritivore	Demersal	Deep	Moderate	210	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.cochlio	Detritivore	Demersal	Deep	Moderate	230	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.commers	Detritivore	Demersal	Deep	Low	255	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.interme	Piscivore	Pelagic	Fus/Cyl	Moderate	277.2	Lateral	Terminal	Cre/Noc	EFPC	Parceled	Sedentary
H.littora	Invertivore	Demersal	Fusiform	Low	133.4	Lateral	Terminal	Cre/Noc	EFPC	Parceled	Sedentary
H.mbigua	Piscivore	Pelagic	Fus/Cyl	Moderate	260	Lateral	Terminal	Cre/Noc	EFPC	Parceled	Sedentary
H.microst	Detritivore	Demersal	Deep	Moderate	165	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.oremacu	Invertivore	Pelagic	Fusiform	Moderate	405	Ventrolateral	Terminal	Diu/Noc	EFNP	Parceled	Sedentary
H.orthono	Omnivore	Pelagic	Fusiform	Low	137	Lateral	Terminal	Diu/Cre	EFNP	Total	Sedentary
H.platyrh	Piscivore	Demersal	Fusiform	Moderate	470	Superior	Terminal	Cre/Noc	EFNP	Total	Migratory
H.regani	Detritivore	Demersal	Deep	Moderate	170	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.strigat	Detritivore	Demersal	Deep	Moderate	150	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.ternetz	Detritivore	Demersal	Deep	Low	210	Dorsolateral	Inferior	Cre/Noc	EFPC	Total	Sedentary
H.unitaen	Omnivore	Benthopelagic	Fus/Cyl	Moderate	150.2	Dorsolateral	Terminal	Diu/Noc	EFPC	NA	Sedentary
Hopli.sp2	Piscivore	Pelagic	Fus/Cyl	Low	250	Lateral	Terminal	Cre/Noc	EFPC	Parceled	Sedentary
I.labrosu	Invertivore	Benthopelagic	Fusiform	Moderate	200	Dorsolateral	Subterminal	Cre/Noc	EFNP	Parceled	Sedentary
L.araguai	Insectivore	Benthopelagic	Deep	Moderate	32.6	Lateral	Terminal	Diurnal	EFPC	NA	NA

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
L.frideri	Omnivore	Benthopelagic	Fusiform	Low	189.2	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
L.lacustr	Omnivore	Benthopelagic	Deep	Low	210	Lateral	Terminal	Diu/Noc/Cre	EFNP	Parceled	Sedentary
L.octofas	Omnivore	Benthopelagic	Deep	Moderate	148.9	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
L.pectora	Invertivore	Benthopelagic	Fusiform	Moderate	100	Dorsolateral	Terminal	Nocturnal	EFPC	NA	Sedentary
L.platyme	Detritivore	Demersal	Flattened	Low	210	Superior	Inferior	Diu/Noc/Cre	EFPC	Parceled	Sedentary
L.prolixa	Herbivore	Demersal	Flattened	Moderate/Extreme	230.5	Dorsolateral	Inferior	Diu/Noc/Cre	EFPC	NA	Sedentary
L.rostrat	Detritivore	Demersal	Flattened	Low	250	Superior	Inferior	Diu/Noc/Cre	EFPC	Parceled	Sedentary
L.striatu	Insectivore	Benthopelagic	Fusiform	Moderate	69.2	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	NA
L.vittatu	Insectivore	Benthopelagic	Fusiform	Low	200	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
M.aff.int	Invertivore	Pelagic	Fusiform	Low	68.4	Lateral	Terminal	Diu/Noc	EFNP	Parceled	Sedentary
M.bonita	Insectivore	Pelagic	Lat. compressed	Low	28.-.44	Lateral	Terminal	Diu/Noc	EFNP	Parceled	Sedentary
M.cf.grac	Insectivore	Pelagic	Deep	Low	39.7	Lateral	Terminal	Diu/Noc	EFNP	Parceled	Sedentary
M.foresti	Herbivore	Pelagic	Lat. compressed	Low	30.6	Lateral	Terminal	Diu/Noc	EFNP	Parceled	Sedentary
M.lippinc	Herbivore	Pelagic	Deep/Lat.compressed	Low	149.3	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
M.macroce	Omnivore	Benthopelagic	Deep	Moderate	470	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Migratory
M.obtusid	Omnivore	Benthopelagic	Fusiform	Low	190.8	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Migratory
M.paranan	Detritivore	Demersal	Deep	Low	205	Dorsolateral	Inferior	Diu/Noc/Cre	EFPC	Total	Sedentary
M.piavuss	Omnivore	Benthopelagic	Fusiform	Low	190.8	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Migratory
M.platanu	Piscivore	Demersal	Fusiform	Low	340	Dorsolateral	Terminal	Nocturnal	NA	NA	NA

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
M.tiete	Herbivore	Benthopelagic	Deep/Lat.compressed	Low	135	Lateral	Terminal	Diu/Noc/Cre	EFNP	NA	Sedentary
O.eigenma	Insectivore	Demersal	Deep	Extreme	82.9	Dorsolateral	Terminal	Cre/Noc	NA	NA	NA
O.pintoi	Invertivore	Pelagic	Deep	Extreme	68.4	Lateral	Terminal	Cre/Noc	EFNP	Parceled	Sedentary
P.amandae	Piscivore	Demersal	Flattened	Extreme	380	Superior	Inferior	Diu/Noc	IF	NA	Sedentary
P.ambrose	Detritivore	Demersal	Deep	Low	395	Dorsolateral	Inferior	Crepuscular	EFPC	Parceled	Sedentary
P.armatul	Invertivore	Demersal	Deep	Low	132.9	Dorsolateral	Terminal	Nocturnal	EFNP	NA	Sedentary
P.avanhan	Invertivore	Demersal	Fusiform	Low	125	Dorsolateral	Terminal	Cre/Noc	EFNP	Total	Sedentary
P.cf.falk	Piscivore	Demersal	Flattened	Extreme	NA	Superior	Inferior	Diu/Noc	IF	NA	Sedentary
P.corrusc	Piscivore	Demersal	Fusiform	Low	675	Superior	Subterminal	Cre/Noc	EFNP	Total	Migratory
P.galeatu	Omnivore	Pelagic	Deep	Extreme	165	Dorsolateral	Terminal	Nocturnal	IF	Parceled	Sedentary
P.gracili	Insectivore	Demersal	Fusiform	Moderate	120	Dorsolateral	Terminal	Cre/Noc	EFNP	Total	Sedentary
P.granulo	Omnivore	Demersal	Deep	Extreme	600	Superior	Terminal	Nocturnal	EFNP	Parceled	Migratory
P.kennedy	Herbivore	Benthopelagic	Deep/Lat.compressed	Moderate	30.5	Lateral	Terminal	Diurnal	NA	NA	NA
P.lineatu	Detritivore	Benthopelagic	Deep/Lat.compressed	Moderate	495.2	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Migratory
P.maculat	Omnivore	Demersal	Deep	Moderate	180	Dorsolateral	Terminal	Crepuscular	EFNP	Parceled	Migratory
P.manguru	Detritivore	Demersal	Fusiform/Deep	Moderate	180	Superior	Terminal	Crepuscular	NA	NA	NA
P.mesopot	Herbivore	Demersal	Deep/Lat.compressed	Low	498	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Migratory
P.microst	Omnivore	Demersal	Deep	Moderate	140	Dorsolateral	Terminal	Crepuscular	EFNP	Total	Sedentary
P.mysteri	Omnivore	Demersal	Deep	Low	90.4	Dorsolateral	Terminal	Crepuscular	EFNP	Total	NA
P.nasus	Planktivore	Benthopelagic	Fusiform	Moderate	102.5	Lateral	Subterminal	Cre/Noc	EFNP	Parceled	Sedentary
P.ornatus	Omnivore	Demersal	Deep	Low	208	Dorsolateral	Terminal	Crepuscular	EFNP	Total	Migratory

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
P.paranae	Insectivore	Pelagic	Fus/Lat.compressed	Moderate	NA	Lateral	Terminal	Diurnal	EFNP	NA	Sedentary
P.pirinam	Piscivore	Demersal	Deep	Extreme	620	Dorsolateral	Terminal	Crepuscular	EFNP	Total	Migratory
P.reticul	Piscivore	Demersal	Fusiform	Moderate	580	Superior	Subterminal	Cre/Noc	EFNP	Total	Migratory
P.schubar	Insectivore	Pelagic	Fus/Lat.compressed	Moderate	NA	Lateral	Terminal	Diurnal	EFNP	NA	Sedentary
P.squamos	Piscivore	Pelagic	Deep	Low	330	Dorsolateral	Terminal	Nocturnal	EFNP	Parceled	Sedentary
P.stramin	Insectivore	Pelagic	Fusiform	Low	70	Lateral	Terminal	Crepuscular	EFNP	Total	Sedentary
P.taeniop	Insectivore	Demersal	Fusiform	Low	130	Dorsolateral	Terminal	Cre/Noc	EFNP	Total	Sedentary
R.aspera	Detritivore	Demersal	Deep	Low	360	Dorsolateral	Inferior	Crepuscular	EFNP	Total	Migratory
R.descalv	Insectivore	Benthopelagic	Deep	Low	88.8	Lateral	Terminal	Cre/Noc	EFNP	Parceled	Sedentary
R.dorbign	Invertivore	Demersal	Deep	Low	135.5	Dorsolateral	Subterminal	Nocturnal	EFNP	NA	Sedentary
R.hahni	Insectivore	Benthopelagic	Fus/Lat.compressed	Moderate	700	Dorsolateral	Terminal	Nocturnal	EFPC	Parceled	Sedentary
R.quelen	Piscivore	Demersal	Fusiform	Extreme	163.2	Dorsolateral	Terminal	Cre/Noc	EFNP	Parceled	Sedentary
R.vulpinu	Piscivore	Pelagic	Fusiform	Low	480	Dorsolateral	Superior	Cre/Noc	EFNP	Total	Migratory
S.altopar	Herbivore	Benthopelagic	Fusiform	Low	282	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
S.borelli	Herbivore	Benthopelagic	Fusiform	Low	207.5	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
S.brasili	Piscivore	Benthopelagic	Deep	Moderate	500	Lateral	Terminal	Diurnal	EFNP	Total	Migratory
S.brevipi	Detritivore	Benthopelagic	Fusiform	Moderate	105.8	Lateral	Terminal	Diu/Noc/Cre	EFNP	NA	Sedentary
S.hilarii	Piscivore	Benthopelagic	Deep	Moderate	170	Lateral	Terminal	Diurnal	EFNP	Total	Migratory
S.insculp	Detritivore	Pelagic	Fusiform	Moderate	90	Lateral	Terminal	Diu/Noc/Cre	EFNP	Total	Sedentary
S.lima	Piscivore	Demersal	Fusiform	Low	487	Lateral	Subterminal	Cre/Noc	EFNP	Total	Migratory

spp	Trophic category	Position in the water column	Body shape	Crypsis	Standard length (mm)	Eye position	Mouth position	Diel activity	Fecundation and parental care	Spawning	Migration
S.macruru	Insectivore	Benthopelagic	Fusiform	Moderate	625	Dorsolateral	Terminal	Crepuscular	EFPC/EFNP	Parceled	Sedentary
S.maculat	Piscivore	Pelagic	Deep/Lat.compressed	Moderate	157.2	Lateral	Terminal	Diu/Noc/Cre	EFPC	Parceled	Sedentary
S.margina	Piscivore	Pelagic	Deep/Lat.compressed	Moderate	160.2	Lateral	Terminal	Diu/Noc/Cre	EFPC	Parceled	Sedentary
S.marmora	Herbivore	Benthopelagic	Anguiliform	Moderate	273.2	Lateral	Terminal	Cre/Noc	EFPC	NA	Sedentary
S.nasutus	Herbivore	Pelagic	Fusiform	Low	160	Lateral	Subterminal	Diu/Noc/Cre	EFNP	Total	Sed/Mig
Satanop.sp	Detritivore	Benthopelagic	Deep	Extreme	150	Dorsolateral	Terminal	Diurnal	EFPC	Parceled	Sedentary
T.nematur	Insectivore	Benthopelagic	Deep	Low	102	Lateral	Terminal	Diurnal	EFNP	NA	Sedentary
T.paragua	Invertivore	Demersal	Deep	Moderate	125	Dorsolateral	Subterminal	Nocturnal	EFNP	Parceled	Sedentary
Trache.sp	Omnivore	Pelagic	Deep	Moderate	98.2	Dorsolateral	Terminal	Nocturnal	IF	NA	Sedentary
Z.jahu	Piscivore	Demersal	Deep	Moderate	800	Dorsal	Terminal	Cre/Noc	EFNP	Total	Migratory

APPENDIX C – Functional rarity index results.

spp	Uniqueness	Restrictedness	Functional rarity
M.obtusid	0.00	0	0
M.piavuss	0	0	0
R.hahni	0	0	0
C.piquiti	0.09090909	0	0.045454545
H.mbigua	0.09090909	0	0.045454545
L.platyme	0.09090909	0	0.045454545
S.altopar	0.09090909	0	0.045454545
S.borelli	0.09090909	0	0.045454545
S.maculat	0.09090909	0	0.045454545
S.margina	0.09090909	0	0.045454545
P.mysteri	0.1	0	0.05
C.britski	0.11111111	0	0.055555555
A.lacustr	0.18181818	0	0.09090909
C.kelberi	0.18181818	0	0.09090909
Hopli.sp2	0.18181818	0	0.09090909
L.frideri	0.18181818	0	0.09090909
M.macroce	0.18181818	0	0.09090909
P.corrusc	0.18181818	0	0.09090909
S.lima	0.18181818	0	0.09090909
M.lippinc	0.2	0	0.1
P.ambrose	0.2	0	0.1
P.galeatu	0.2	0	0.1
R.descalv	0.2	0	0.1
S.brevipi	0.2	0	0.1
S.insculp	0.2	0	0.1
T.paragua	0.2	0	0.1
H.cochlio	0.09090909	0.1111111	0.101010095
L.rostrat	0.09090909	0.1111111	0.101010095
S.brasili	0.09090909	0.1111111	0.101010095
A.crassip	0.27272727	0	0.136363635
Ast.lacus	0.27272727	0	0.136363635
B.orbigny	0.27272727	0	0.136363635
H.oremacu	0.27272727	0	0.136363635
H.orthono	0.27272727	0	0.136363635
L.lacustr	0.27272727	0	0.136363635

spp	Uniqueness	Restrictedness	Functional rarity
M.aff.int	0.27272727	0	0.136363635
P.lineatu	0.27272727	0	0.136363635
P.maculat	0.27272727	0	0.136363635
P.mesopot	0.27272727	0	0.136363635
Satanop.sp	0.27272727	0	0.136363635
A.militar	0.18181818	0.1111111	0.14646464
H.ancistr	0.18181818	0.1111111	0.14646464
H.platyrh	0.18181818	0.1111111	0.14646464
G.inaequi	0.3	0	0.15
G.sveni	0.3	0	0.15
H.littora	0.3	0	0.15
C.paranae	0.09090909	0.2222222	0.156565645
P.amandae	0	0.3333333	0.16666665
L.pectora	0.22222222	0.1111111	0.16666666
E.triline	0.33333333	0	0.166666665
H.unitaen	0.33333333	0	0.166666665
A.osteomy	0.36363636	0	0.18181818
R.vulpinu	0.36363636	0	0.18181818
C.modestu	0.27272727	0.1111111	0.191919185
A.inermis	0.18181818	0.2222222	0.20202019
P.avanhan	0.18181818	0.2222222	0.20202019
P.gracili	0.18181818	0.2222222	0.20202019
G.sylvius	0.3	0.1111111	0.20555555
P.squamos	0.3	0.1111111	0.20555555
H.regani	0.09090909	0.3333333	0.212121195
P.ornatus	0.1	0.3333333	0.21666665
C.callich	0.25	0.2222222	0.2361111
I.labrosu	0.36363636	0.1111111	0.23737373
P.granulo	0.36363636	0.1111111	0.23737373
R.aspera	0.27272727	0.2222222	0.247474735
C.nagelii	0.18181818	0.3333333	0.25757574
C.gariepi	0.3	0.2222222	0.2611111
S.macruru	0.3	0.2222222	0.2611111
Trache.sp	0.2	0.3333333	0.26666665
S.hilarii	0.09090909	0.4444444	0.267676745
P.kennedy	0.125	0.4444444	0.2847222
O.eigenma	0.375	0.2222222	0.2986111

spp	Uniqueness	Restrictedness	Functional rarity
C.jenynsi	0.4	0.2222222	0.3111111
A.pantane	0.18181818	0.4444444	0.31313129
A.ucayale	0.18181818	0.4444444	0.31313129
G.pantana	0.3	0.3333333	0.31666665
P.microst	0.2	0.4444444	0.3222222
P.cf.falk	0	0.6666667	0.33333335
P.schubar	0	0.6666667	0.33333335
G.parague	0.3	0.4444444	0.3722222
P.armatul	0.2	0.5555556	0.3777778
H.strigat	0.09090909	0.6666667	0.378787895
L.araguai	0.11111111	0.6666667	0.388888905
C.jaguare	0.125	0.6666667	0.39583335
E.erythri	0.36363636	0.4444444	0.40404038
E.viresce	0.36363636	0.4444444	0.40404038
R.quelen	0.36363636	0.4444444	0.40404038
S.nasutus	0.36363636	0.4444444	0.40404038
P.pirinam	0.27272727	0.5555556	0.414141435
G.gulo	0.4	0.4444444	0.4222222
L.prolixa	0.4	0.4444444	0.4222222
M.paranan	0.18181818	0.6666667	0.42424244
M.tiete	0.2	0.6666667	0.43333335
H.cf.albo	0.09090909	0.7777778	0.434343445
H.commers	0.09090909	0.7777778	0.434343445
H.aff.her	0.1	0.7777778	0.4388889
A.caudima	0	0.8888889	0.44444445
A.ellisi	0	0.8888889	0.44444445
B.gauderi	0	0.8888889	0.44444445
P.paranae	0	0.8888889	0.44444445
A.plagioz	0.125	0.7777778	0.4513889
P.stramin	0.27272727	0.6666667	0.469696985
B.hilarii	0.18181818	0.7777778	0.47979799
C.macropo	0.18181818	0.7777778	0.47979799
L.octofas	0.18181818	0.7777778	0.47979799
P.reticul	0.18181818	0.7777778	0.47979799
P.taeniop	0.18181818	0.7777778	0.47979799
L.striatu	0.2	0.7777778	0.4888889
R.dorbign	0.2	0.7777778	0.4888889

spp	Uniqueness	Restrictedness	Functional rarity
H.interme	0.09090909	0.8888889	0.489898995
H.microst	0.09090909	0.8888889	0.489898995
H.ternetz	0.09090909	0.8888889	0.489898995
C.haroldo	0.125	0.8888889	0.50694445
M.platanu	0.25	0.7777778	0.5138889
A.affinis	0.36363636	0.67	0.51515153
Z.jahu	0.27272727	0.7777778	0.525252535
L.vittatu	0.18181818	0.8888889	0.53535354
M.bonita	0.18181818	0.8888889	0.53535354
M.cf.grac	0.18181818	0.8888889	0.53535354
M.foresti	0.18181818	0.8888889	0.53535354
T.nematur	0.2	0.8888889	0.54444445
P.nasus	0.36363636	0.7777778	0.57070708
P.manguru	0.375	0.7777778	0.5763889
O.pintoi	0.27272727	0.8888889	0.580808085
C.niederl	0.3	0.8888889	0.59444445
S.marmora	0.33	0.8888889	0.611111115
F.hahni	0.44444444	0.8888889	0.66666667