UNIVERSIDADE FEDERAL DO RIO DE JANEIRO

ESPÉCIES DE PEIXES COMO INDICADORES DA QUALIDADE DA ÁGUA EM BACIAS COSTEIRAS DO SUDESTE BRASILEIRO

VICTOR DE BRITO

Rio de Janeiro
2018

ESPÉCIES DE PEIXES COMO INDICADORES DA QUALIDADE DA ÁGUA EM BACIAS COSTEIRAS DO SUDESTE BRASILEIRO

Victor de Brito

Dissertação apresentada ao Programa de Pós-Graduação em Ciências Biológicas (Zoologia), Museu Nacional, da Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do título de Mestre em Ciências Biológicas (Zoologia)

Orientador: Prof. Dr. Paulo Andreas Buckup

Banca examinadora:

_____
Prof. Dr. Paulo Andreas Buckup (Presidente)

_____
Prof. Dra. Erica Maria Pellegrini Caramaschi

_____
Prof. Dra. Christina Wyss Castelo Branco

_____
Prof. Dr. Marcelo Ribeiro de Britto

_____
Prof. Dr. Ricardo Campos da Paz

Rio de Janeiro
Julho/ 2018

Estudo realizado no Setor de Ictiologia, Departamento de Vertebrados, Museu Nacional, Universidade Federal do Rio de Janeiro

Orientador: Prof. Dr. Paulo Andreas Buckup - Museu Nacional, Universidade Federal do Rio de Janeiro

Ficha catalográfica

DE BRITO, Victor.

Espécies de Peixes como Indicadores da Qualidade da Água em Bacias Costeiras do Sudeste Brasileiro/ Victor de Brito. Rio de Janeiro: UFRJ/ MN, 2018.

xxiv, 128f.: il.; 29,7 cm.

Orientador: Paulo Andreas Buckup

Dissertação (Mestrado). UFRJ /MN/Programa de Pós-graduação em Ciências Biológicas (Zoologia), 2018.

Referências Bibliográficas: xxiii-xxv; 40-49; 77-88.

1.Bioindicação. 2. Ictiofauna. 3. Bacias Costeiras. 4. Rio Piraí. 5. Rio Guapiaçu. 6. Rio Macaé. I. Buckup, Paulo Andreas. II. Universidade Federal do Rio de Janeiro, Museu Nacional. III. Dissertações.

Dedico este trabalho à minha mãe, Cecilia, e meus avós, Maria do Carmo (*in memoriam*) e Ary, por terem me dado todo o apoio necessário para que eu chegasse aqui.

Agradecimentos

Agradeço à Universidade Federal do Rio de Janeiro, seus professores e funcionários, por me proporcionar a estrutura necessária ao desenvolvimento da pesquisa e à minha formação como Mestre em Ciências Biológicas (Zoologia).

Ao professor e orientador Dr. Paulo Andreas Buckup, pela orientação, desde a graduação, suas correções e incentivos.

À professora Dra. Érica P. Caramaschi por concelhos desde o início da elaboração desta dissertação, acolhimento em seu laboratório e participação no processo de avaliação.

Aos professores do Setor de Ictiologia do Museu Nacional e amigos Dr. Marcelo Ribeiro de Britto e Dr. Cristiano Moreira, pelas dúvidas sanadas, momentos de conversa e companheirismo.

Aos professores Dr. Ricardo Campos da Paz e Dra. Christina Wyss Castelo por Branco fazerem parte do processo de avaliação deste trabalho.

Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento do Pessoal de Nível Superior - CAPES, Associação Amigos do Museu Nacional (SAMN), The Nature Conservancy, representada por Paulo Petry e Anita Diderichsen, Agência da Bacia do Rio Paraíba do Sul – AGEVAP e Comitê Guandu pelo financiamento desta pesquisa, através de projetos coordenados por P. A. Buckup.

A todos os companheiros de pesquisa que me ajudaram nessa caminhada acadêmica.

Aos meus amigos e companheiros de trabalho do Museu Nacional Sérgio Santos, Roberta Fonseca, Giovana Vignoli (que está no Canadá), Emanuel Neuhaus, Igor Santos, Cecilia Gomes, Evandro Malanski, Karina Carvalho, Ricardo Dias, Gustavo Ferraro, Décio Ferreira, e Gabriel Araújo. Vocês tornam o laboratório em um ambiente alegre sem perder o profissionalismo acadêmico.

Aos meus amigos Leonam Carvalho, Iago Duarte, Renan Souza, Felipe Demani, Jonathan Sienkiewicz, Micaela Locke, Flavia Lutterbach, Nathália Dias, Letícia Santos, Tito Lopes, Lennon Madeira, Thiago Luiz, João Felizardo e Yuri Pilon pelos momentos de alegria após estressantes dias de trabalho e estudo.

À minha namorada Patricia, por toda paciência, compreensão, carinho e amor. Obrigado por estar ao meu lado e fazer parte da minha vida. Te amo!

Agradeço à minha família por todo apoio e incentivo, especialmente aos meus avós Maria do Carmo (*in memoriam*) e Ary de Brito, que fizeram parte integral minha formação como pessoa.

Agradeço à minha mãe, Cecilia Inez da Silva de Brito que me apoiou incondicionalmente em todas as horas, desde o início da minha carreira acadêmica, superando a distância e a saudade.

E a todos que direta ou indiretamente fizeram parte da minha formação, o meu muito obrigado!

RESUMO GERAL

Espécies de Peixes como Indicadores da Qualidade da Água em Bacias Costeiras do Sudeste Brasileiro

Victor de Brito

Orientador: Prof. Dr. Paulo Andreas Buckup

Resumo da Dissertação submetida ao Programa de Pós-Graduação em Ciências Biológicas (Zoologia) do Museu Nacional, Universidade Federal do Rio de Janeiro - UFRJ, como parte dos requisitos necessários à obtenção do título de Mestre em Ciências Biológicas (Zoologia).

O desenvolvimento de técnicas de avaliação da qualidade da água baseada na ictiofauna permite o monitoramento da qualidade ambiental de rios costeiros da Mata Atlântica. O presente estudo teve como objetivo desenvolver índices taxonômicos de bioindicação (TIs) para avaliação da qualidade da água em drenagens costeiras do Sudeste Brasileiro. As avaliações foram realizadas através do levantamento da ictiofauna em 40 pontos de coleta nos rios Guapiaçu, Macaé e alto Piraí. Os TIs baseiam-se no grau de sensibilidade de 78 espécies de peixes à impactos ambientais negativos. Valores de TIs foram correlacionados positivamente com outros dois índices ambientais, indicando que os TIs são ferramentas adequadas para o monitoramento ambiental. Este estudo também resultou na lista comentada da ictiofauna da região de cabeceira do rio Piraí, a drenagem com maior número de amostras.

Palavras-chave: Bioindicação; Ictiofauna; Bacias Costeiras; Rio Piraí; Rio Guapiaçu; Rio Macaé.

Rio de Janeiro

Julho de 2018

GENERAL ABSTRACT

Fish Species as Indicators of Water Quality in Coastal Rivers of Southeastern Brazil

Victor de Brito
Orientador: Prof. Dr. Paulo Andreas Buckup

Abstract da Dissertação submetida ao Programa de Pós-Graduação em Ciências Biológicas (Zoologia) do Museu Nacional, Universidade Federal do Rio de Janeiro - UFRJ, como parte dos requisitos necessários à obtenção do título de Mestre em Ciências Biológicas (Zoologia).

The development of techniques for the evaluation of water quality based on ichthyofauna allows the monitoring of environmental quality in coastal rivers of the Atlantic Forest. The present study aimed to develop taxonomic indexes of bioindication (TIs) for the evaluation of water quality in coastal drainages of the Southeastern Brazil. The evaluations were performed through the sampling of the ichthyofauna in 40 sampling points in rivers Guapiaçu, Macaé and upper Piraí. The TIs were based on the level of sensitivity of 78 fish species to negative environmental impacts. Values of TIs were correlated positively with two other environmental indexes, indicating that the TIs are adequate tools for the environmental monitoring. This study also resulted in the annoted checklist of the ichthyofauna from the headwaters of the Piraí river, the drainage with highest number of samples.

Key-words: Bioindication; Ichthyofauna; Coastal Drainages; Piraí river; Guapiaçu river; Macaé river.

Rio de Janeiro
Julho de 2018

Índice Geral

Resumo Geral ix

General Abstract x

Índice de Figuras xiii

Índice de Tabelas xvi

Índice de Anexos xix

Introdução Geral xxi

Referência Bibliográfica xxiii

Apresentação 1

Capítulo I - Development of Biotic Indexes for Assessment of Water Quality in Coastal Rivers of Southeastern Brazil 2

Introduction 3

Materials and methods 5

Study areas 5

Sampling methods 8

Taxonomic Index development 11

Species scores 11

Taxonomic Index calculation 15

Taxonomic Index performance 16

MMI calculation 16

Environmental Index (EI) calculation and indexes correlation 17

Results 18

Fish fauna and sampling 18

Taxonomic indexes 20

Metric selection and MMI results 28

Correlation among indexes 33

Discussion 37

References 40

Capítulo II - The fish fauna of the upper Piraí drainage, a transposed mountain river system in southeastern, Brazil 50
Introduction 51
Methods 52
Study Area. 52
Sampling. 53
Results 54
Discussion 75
References 77
Anexos 89

Índice de Figuras

Capítulo I

Figura 1 - Upper Piraí river drainage and sampling sites. Geographic coordinates and altitude of the sites are listed in Table 1.....6

Figura 2 - Guapiaçu river basin, indicating the sampling sites. Geographic coordinates and altitude of the sites are listed on Table 1……...7

Figura 3 - Macaé river basin, indicating the sampling sites. Geographic coordinates and altitude of the sites are listed on Table 1…….8

Figura 4 - Species accumulation curves for the Macaé river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1)……19

Figura 5 - Species accumulation curves for the upper Piraí river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1)……19

Figura 6 - Species accumulation curves for the Guapiaçu river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1)……....20

Figura 7 - Taxonomic index values obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season)…….24

Figura 8 - Taxonomic index values obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season)…….24

Figura 9 - Taxonomic index values obtained for sampling sites in the Macaé river basin in June 2017 (dry season)……...……..25

Figura 10 - Taxonomic index values obtained for sampling sites in the Macaé river basin in November 2017 (rainy season)……...……..25

Figura 11 - Taxonomic index values obtained for sampling sites in the upper Piraí drainage in June 2009 (dry season)……..……..26

Figura 12 - Taxonomic index values obtained for sampling sites in the upper Piraí drainage in September 2010 (dry season)…….……26

Figura 13 - Taxonomic indices values obtained for sampling sites in the upper Piraí drainage in July 2015 (dry season).……..……27

Figura 14 - Taxonomic index values obtained for sampling sites in the upper Piraí drainage in April 2016 (rainy season).…….……27

Figura 15 - EI values in correlation with TI1, TI2 and MMI..……...……37

Capítulo II

Figura 1 - Map of the upper Piraí river drainage, indicating the collecting sites along the streams Coutinhos (C), Papudos (P), Parado (A), Passa Quatro (Q) and Rio das Pedras (R), and the main channel Piraí (I). Geographic coordinates and altitude of the sites are listed on Table 1.…….……52

Figura 2 - Fish species collected in upper Piraí river drainage. **A.** *Astyanax giton*, MNRJ 37986, 63.56 mm SL. **B.** *Hypomasticus mormyrops*, MNRJ 46698, 128.6 mm SL. **C.** *Astyanax intermedius*, MNRJ 43805, 77.2 mm SL. **D.** *Hoplias malabaricus*, MNRJ 43830, 70.8 mm SL. **E.** *Astyanax* sp. aff. *scabripinnis*, MNRJ 36427, 71.8 mm SL. **F.** *Characidium lauroi*, MNRJ 43823, 57.3 mm SL. **G.** *Brycon opalinus*, MNRJ 47259, 116.6 mm SL. **H.** *Characidium vidali*, MNRJ 43807, 66.6 mm SL. **I.** *Oligosarcus hepsetus*, MNRJ 43812, 63.1 mm SL.……66

Figura 3 - Fish species collected in upper Piraí river drainage. **A.** *Trichomycterus macrophthalmus*, MNRJ 43760, 52.4 mm SL. **B.** *Imparfinis minutus*, MNRJ 43770, 83.4 mm SL. **C.** *Trichomycterus mariamole*, MNRJ 36525, 58.72 mm SL. **D.** *Pimelodella lateristriga*, MNRJ 43888, 39.7 mm SL. **E.** *Trichomycterus nigroauratus*, MNRJ 38003, 48.8 mm SL. **F.** *Rhamdia quelen*, MNRJ 43889, 98.6 mm SL. **G.** *Scleromystax barbatus*,

MNRJ 46722, 66.1 mm SL, male. **H.** *Scleromystax barbatus*, MNRJ 46722, 57.62 mm SL, female.……..68

Figura 4 - Fish species collected in upper Piraí river drainage. **A.** *Harttia carvalhoi*, MNRJ 43816, 78.1 mm SL. **B.** *Harttia loricariformis*, MNRJ 43773, 42.1 mm SL. **C.** *Hemipsilichthys gobio*, MNRJ 43868, 75.3 mm SL. **D.** *Hemipsilichthys papillatus*, MNRJ 46657, 53.7 mm SL. **E.** *Hypostomus affinis*, MNRJ 43824, 62.6 mm SL. **F.** *Hypostomus luetkeni*, MNRJ 47007, 112.8 mm SL. **G.** *Neoplecostomus microps*, MNRJ 43808, 87 mm SL. **H.** *Pareiorhina rudolphi*, MNRJ 46835, 65.9 mm SL. **I.** *Rineloricaria* sp. cf. *R. lima*, MNRJ 43826, 76.3 mm SL.……71

Figura 5 - Fish species collected in the upper Piraí river drainage. **A.** *Gymnotus pantherinus*, MNRJ 43827, 172.5 mm SL. **B.** *Australoheros* sp., MNRJ 43780, 50.3 mm SL. **C.** *Phalloceros harpagos*, MNRJ 43828, 34.2 mm SL, female. **D.** *Crenicichla lepidota*, MNRJ 43779, 85.9 mm SL. **E.** *Phalloceros harpagos*, MNRJ 43828, 25.3 mm SL, male. **F.** *Geophagus brasiliensis*, MNRJ 43778, 64.2 mm SL. **G.** *Poecilia reticulata*, MNRJ 43763, 36.8 mm SL, female. **H.** *Oreochromis niloticus*, MNRJ 37964, 96.56 mm SL. **I.** *Poecilia reticulata*, MNRJ 43763, 19.2 mm SL, male.…….....……75

Índice de Tabelas

Capítulo I

Tabela 1 - Sampling sites and their geographic coordinates and altitudes……..9

Tabela 2 - Score assigned for each attribute. ……11

Tabela 3 - Abiotic variables and criteria used to attribute grades for calculation of the environmental index (EI)…….……18

Tabela 4 - Score obtained for sampled species based on their ecological attributes, following the categories defined in methodology (Table 2). The catalog number of voucher specimens are listed in (Appendix 16) Legend: RD - Restricted geographic distribution; LA - Limited to Atlantic Forest; WD - Widely distributed; AS - Exotic species; SN - Sensitive; IT - Intermediate; TL - Tolerant; IN - Invertivore; HB -Herbivore; PS - Piscivore; OM - Omnivorous; DT - Detritivore; BT - Benthic; HD - Hider; MW – Mid-water; CH - Characiformes; SL - Siluriformes; GY - Gymnotiformes; OO - Other orders……..….20

Tabela 5 - Candidate metrics and result of selection based on tests of range, responsiveness and redundancy. Legend: failed range test - 1; failed responsiveness test - 2; failed redundancy test - 3; used in MMI calculation - ✓……...28

Tabela 6 - MMI values obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season)…….32

Tabela 7 - MMI results obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season)…… ……..……...32

Tabela 8 - MMI results obtained for sampling sites in the Macaé river basin in June 2017 (dry season)…… …….……32

Tabela 9 - MMI results obtained for sampling sites in the Macaé river basin in November 2017 (rainy season)…… …….……32

Tabela 10 - MMI results obtained for sites in the upper Piraí drainage in July 2015 (dry season)…… …….33

Tabela 11 - MMI results obtained for part of the sites in the upper Piraí drainage in April 2016 (rainy season)……..……33

Tabela 12 - Abiotic attributes obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI……...33

Tabela 13 - Abiotic attributes obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI...34

Tabela 14 - Abiotic attributes obtained for sampling sites in the Macaé river basin in June 2017 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI…….....……34

Tabela 15 - Abiotic attributes obtained for sampling sites in the Macaé river basin in November 2017 (rainy season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI…….....35

Tabela 16 - Abiotic attributes obtained for sampling sites in the upper Piraí drainage in July 2015 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI……...35

Tabela 17 - Abiotic attributes obtained for sampling sites in the upper Piraí drainage in April 2016 (rainy season), and resulting environmental index based on grades defined by

criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm-1) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI…….36

Capítulo II

Tabela 1. Geographic coordinates from the sampling sites in the Upper Piraí river drainage, Rio de Janeiro State, Brazil……..……53

Tabela 2. List of the freshwater fishes of upper Piraí river drainage and catalog numbers of voucher specimens……...……56

Índice de Anexos

Capítulo I

Anexo 1. Trophic guilds of native species……...89

Anexo 2. Metric values obtained in sampling sites in the Guapiaçu river in August 2016 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5…….…….92

Anexo 3. Metric values obtained in sampling sites in the Guapiaçu river in December 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5…….……95

Anexo 4. Metric values obtained in sampling sites in the Macaé river in June 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5……..…. 97

Anexo 5. Metric values obtained in sampling sites in the Macaé river in November 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5…….……99

Anexo 6. Metric values obtained in sampling sites in the upper Piraí river drainage in July 2015 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5……..……...101

Anexo 7. Metric values obtained in sampling sites in the upper Piraí river drainage in April 2016 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5……..……...104

Anexo 8. Species collected in the Guapiaçu river in August 2016……..…109

Anexo 9. Species collected in the Guapiaçu river in December 2017…….111

Anexo 10. Species collected in the Macaé river in June 2017……..…..113

Anexo 11. Species collected in the Macaé river in November 2017…….…..115

Anexo 12. Species collected in the upper Piraí river drainage in June 2009……..……..117

Anexo 13. Species collected in the upper Piraí river drainage in September 2010…..…118

Anexo 14. Species collected in the upper Piraí river drainage in July 2015……119

Anexo 15. Species collected in the upper Piraí river drainage in April 2016……..120

Anexo 16. Catalog numbers of voucher specimens. The collected specimens that were not catalogued in the Ichthyology Collection of the Museu Nacional (MNRJ) until the present day were associated with the field number of their respective sampling site (PAB). Information about the specimens can be retrieved from the database of the Ichthyology Collection of the Museu Nacional with the field number when they are calagued……..122

Introdução Geral

A Mata Atlântica é o segundo maior bioma da América do Sul, abrigando uma das maiores taxas de riqueza e endemismo da Terra (Galindo-Leal & Câmara, 2003; Riberio et al., 2009). Devido a impactos ambientais de natureza antrópica, apenas 16% da sua cobertura original está preservada em trechos reduzidos e isolados (Alexandrino et al., 2017). Bacias hidrográficas que abastecem grandes centros urbanos brasileiros são diretamente afetadas pela fragmentação da Mata Atlântica, uma vez que a redução da vegetação ripária é uma das principais fontes de impacto ambiental nos corpos d'água (Cetra & Ferreira, 2016).

A integridade das comunidades de organismos fornece uma medida direta das condições ambientais dos corpos d'água e, consequentemente, seu estado de preservação (Cetra & Ferreira, 2016). O estudo da ictiofauna pode ser utilizado no monitoramento ambiental de rios, uma vez que peixes acumulam os efeitos do estado de conservação do habitat, sendo impossível detectar grande parte dos fatores que impactam negativamente a integridade biótica através de avalições físico-químicas da qualidade da água (Karr, 1981; Araújo, 1998; Jaramillo-Villa & Caramaschi, 2008). Inicialmente proposto por Karr (1981), índices bióticos que avaliam a qualidade ambiental baseados na ictiofauna são amplamente aplicados para monitorar sistemas aquáticos (Jaramillo-Villa & Caramaschi, 2008). Nos Estados Unidos, tais índices têm sido adotados por agências de gestão de recursos hídricos como principal meio para avaliar o estado biológico de rios e lagos (USEPA, 2013). Na Europa, o monitoramento biológico se tornou obrigatório a partir da implementação da "Water Framework Directive" (European Commission, 2000), e índice que avaliam a qualidade ambiental baseados na ictiofauna constituem-se como uma ferramenta útil para guiar ações de restauração e manejo de sistemas aquáticos (Hering et al., 2006). Contudo, em países em desenvolvimento, como o Brasil, o uso de índices bióticos ainda não é adotado na maioria dos programas de monitoramento ambiental, apesar de diversos estudos realizados nessa área nos últimos anos (Araújo, 1998; Araújo et al., 2003; Ferreira & Casatti, 2006; Petesse et al., 2016; de Carvalho et al., 2017).

A medição de variáveis físicas e químicas da água é uma estratégia amplamente utilizada para analisar a qualidade ambiental, porém essa técnica possui desvantagens. Normas e limites para contaminantes específicos baseados em testes de toxidez aguda não levam em consideração a variação geoquímica natural que ocorre em contaminantes,

como metais (Thurston, 1979). Além disso, esse tipo de análise não considera o efeito sinergético de diversos contaminantes ou os efeitos subletais em aspectos biológicos das espécies, como reprodução ou crescimento. O monitoramento de variáveis de qualidade da água, como matéria orgânica dissolvida, temperatura, pesticidas e metais pesados, geralmente falha em detectar eventos pontuais, de curta duração, que podem ser fundamentais para a medição de impactos biológicos (Karr, 1981). Finalmente, é impossível medir todos os fatores que impactam a integridade biótica, sendo questionável parte da literatura sobre poluentes químicos que define padrões de qualidade para organismos aquáticos (Araújo, 1998). Consequentemente, o impacto causado por alterações no curso de rios, degradação ou perda de habitats, a criação de barreiras artificiais e a utilização da água para geração de energia não podem ser detectados em análises físico-químicas, não refletindo a saúde dos organismos que habitam rios e lagos.

Apesar dessas dificuldades para medir e interpretar fatores físicos e químicos, a qualidade de um sistema aquático pode ser avaliada pelo grau em que a água deste meio pode ser utilizada para fins benéficos para o ser humano, como cosumo e recreação. Neste contexto, a capacidade desse ambiente em sustentar uma comunidade biológica saudável é um dos melhores indicadores de qualidade da água (Karr, 1981). Comunidades biológicas podem refletir o estado de conservação de um ambiente, uma vez que elas são sensíveis a diversos tipos de mudanças em seus habitats (Karr, 1981). Diversos grupos taxonômicos têm sido propostos como indicadores de qualidade ambiental, porém existem diversas vantagens para o uso de peixes como base de índices bióticos (Araújo, 1998; Dias et al., 2005). Um dos principais benefícios é a existência de dados sobre o ciclo de vida de várias espécies de diferentes níveis tróficos (omnívoros, herbívoros, insetívoros, planctívoros, carnívoros), representando uma dieta tanto de origem aquática quanto terrestre. Peixes também ocupam o topo da cadeia alimentar em diversos ambientes aquáticos, fato esse que permite uma análise integrada do seu ambiente, o que não ocorre com outras espécies que podem ser usadas como indicadores ambientais, como diatomáceas e invertebrados. Trabalhos taxonômicos e guias de identificação de espécies permitem a identificação da maioria das espécies coletadas nos corpos d'água estudados. Por fim, situações críticas, como mortalidade de peixes, podem ser comunicadas pelo público em geral, o que pode chamar a atenção para alterações nas condições de qualidade de água dos ambientes.

A partir dessa base teórica foi criado o projeto "Espécies de Peixes como Indicadores da Qualidade da Água em Bacias Costeiras do Sudeste Brasileiro", que tem

como objetivo desenvolver índices que avaliam a qualidade ambiental baseados no levantamento da ictiofauna de bacias costeiras do sudeste brasileiro.

Referência Bibliográfica

Alexandrino, E. R., Buechley, E. R., Karr, J. R., Ferraz, K. M. P. M. de B., Ferraz, S. F. de B., Couto, H. T. Z. do, & Şekercioğlu, Ç. H. (2017). Bird based Index of Biotic Integrity: Assessing the ecological condition of Atlantic Forest patches in human-modified landscape. *Ecological Indicators*, *73*, 662–675.

Araújo, F. G. (1998). Adaptação do índice de integridade biótica usando a comunidade de peixes para o rio Paraíba do Sul. *Revista Brasileira de Biologia*, *58*(4), 547–558.

Araújo, F. G., Fichberg, I., Pinto, B. C. T., & Peixoto, M. G. (2003). A Preliminary Index of Biotic Integrity for Monitoring the Condition of the Rio Paraiba do Sul, Southeast Brazil. *Environmental Management*, *32*(4), 516–526.

Bennion, H., & Battarbee, R. (2007). The European Union Water Framework Directive: Opportunities for palaeolimnology. *Journal of Paleolimnology*.

Cetra, M., & Ferreira, F. C. (2016). Fish-based Index of Biotic Integrity for wadeable streams from Atlantic Forest of south São Paulo State, Brazil. *Acta Limnologica Brasiliensia*, *28*(e22).

de Carvalho, D. R., Leal, C. G., Junqueira, N. T., de Castro, M. A., Fagundes, D. C., Alves, C. B. M., Pompeu, P. S. (2017). A fish-based multimetric index for Brazilian savanna streams. *Ecological Indicators*, *77*(January), 386–396.

Dias, A. C. M., Castelo Branco, C. W., & Guimarães Lopes, V. (2005). Estudo da dieta natural de peixes no reservatório de Ribeirão das Lajes, Rio de Janeiro, Brasil. *Acta Scientiarum - Biological Sciences*, *27*(4), 355–364.

Ferreira, C. D. P., & Casatti, L. (2006). Integridade biótica de um córrego na bacia do Alto Rio Paraná avaliada por meio da comunidade de peixes. *Biota Neotropica*, *6*(3),

Galindo-Leal, C., & Câmara, I. G. (2003). Atlantic Forest hotspots status: an overview. In *The Atlantic Forest of south america: biodiversity status, threats, and outlook* (pp. 3–11).

Hering, D., Feld, C. K., Moog, O., & Ofenböck, T. (2006). Cook book for the development of a Multimetric Index for biological condition of aquatic ecosystems: Experiences from the European AQEM and STAR projects and related initiatives. *Hydrobiologia*, *566*(1), 311–324.

Jaramillo-Villa, U., & Caramaschi, É. P. (2008). Índices De Integridade Biótica Usando Peixes De Água Doce: Uso Nas Regiões Tropical E Subtropical. *Oecologia Australis*, *12*(3), 442–462.

Karr, J. R. (1981). Assessment of Biotic Integrity Using Fish Communities. *Fisheries*, *6*(6), 21–27.

Petesse, M. L., Siqueira-Souza, F. K., de Carvalho Freitas, C. E., & Petrere, M. (2016). Selection of reference lakes and adaptation of a fish multimetric index of biotic integrity to six amazon floodplain lakes. *Ecological Engineering*, *97*, 535–544.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, *142*(6), 1141–1153.

THURSTON, R. V. (eds.) A review of the EP Red Book. Quality criteria for water. American Fisheries Society, Bethesda, 1979.

USEPA. (2013). *National Rivers and Streams Assessment 2008–2009: a collaborative survey*. *EPA/841/D-13/001*. Washington: Office of Wetlands, Oceans and Watersheds and Office of Research and Development.

Apresentação

Os resultados apresentados nesta dissertação foram obtidos através da análise de dados relativos ao projeto de pesquisa sobre o uso de espécies de peixes como indicadores da qualidade ambiental de bacias costeiras do sudeste brasileiro. Os dois capítulos desenvolvidos foram redigidos em inglês seguindo formatação de revistas científicas.

No Capítulo 1, intitulado "Development of Biotic Indexes for Assessment of Water Quality in Coastal Rivers of Southeastern Brazil", foi descrito o desenvolvimento de índices ambientais em bacias costeiras sudeste brasileiro. Este capítulo seguiu a formatação da revista "Ecological Indicators".

No Capítulo 2, intitulado "The fish fauna of the upper Piraí drainage, a transposed mountain river system in southeastern, Brazil", foi descrita a identificação da ictiofauna da região de cabeceira do rio Piraí, drenagem com maior número de amostragens para realização deste trabalho. Este capítulo seguiu a formatação da revista "Checklist".

Capítulo I

Development of Biotic Indexes for Assessment of Water Quality in Coastal Rivers of Southeastern Brazil

1. Introduction

Evaluation of environmental quality in freshwater systems can be performed through the study of aquatic organisms present in those habitats. The integrity of communities of organisms provides a direct measure of the environmental condition of water bodies and, consequently, their state of preservation state (Cetra & Ferreira, 2016). Among aquatic organisms used as indicators of habitat integrity, fishes are commonly targeted due to their capacity to reflect different sources of degradation in rivers and streams (Karr, 1981; Araújo, 1998; Jaramillo-Villa & Caramaschi, 2008). Initially proposed by Karr (1981), indexes that quantify water quality based on the integrity of fish communities are well stablished and widely applied in official environmental monitoring programs of freshwater systems in North America (USEPA, 2009, 2013) and Europe (European Commission, 2000).

Among available methodologies to evaluate environmental quality in freshwater systems based on fish communities, Multimetric Indexes (MMIs) have been traditionally applied in various ecosystems in Brazil (Araújo, 1998; Araújo et al., 2003; Ferreira & Casatti, 2006; Petesse et al., 2016; Chen et al., 2017; de Carvalho et al., 2017). These indexes are based on metrics, that are measurable characteristics of the ecology of a community (e.g. taxonomic richness, habitat use, trophic composition, health and abundance of individuals) (Barbour et al., 1998; Jaramillo-Villa & Caramaschi, 2008). However, the application of MMIs to evaluate biotic integrity can be challenging and present difficulties in the tropical region (Jaramillo-Villa & Caramaschi, 2008). First, MMIs assess the environmental quality of streams comparing metrics values in sampled sites with reference values of biotic integrity. These reference values are established by assessing minimally degraded stream sites. However, pristine reference sites are scarce in biomes heavily impacted by human occupation (Terra et al., 2013). In addition, variation of longitudinal gradient affects the composition of fish communities in freshwater drainages (Almeida & Cetra, 2016). Therefore, a large number of reference sites must be used to account for longitudinal variation. Second, for the development of MMIs, metrics must be selected based on their responsiveness to stressors and its capacity to discriminate between optimal and degraded sites (Barbour et al., 1998). However, methodologies for metric selection often include series of complex statistical tests that

are not practical for extensive application of MMIs in the evaluation of environmental quality.

Development of simple methodology for assessment of aquatic systems environmental quality is an alternative to the use of MMIs, allowing the examination of large number of sites with relatively low cost and effective application (Barbour et al., 1998; Miserendino & Pizzolón, 1999). Evaluation of biotic integrity using taxa score systems have been developed to facilitate the application of biotic indexes in monitoring programs of water quality worldwide (Barbour et al., 1998; Miserendino & Pizzolón, 1999; Capítulo et al., 2001; Ofenböck et al., 2010; Paisley et al., 2014). This methodology is based on scores attributed to different taxa, according to their degree of sensitivity to negative environmental impacts (Czerniawska-Kusza, 2005). Therefore, taxa with great sensitivity to negative impacts have high scores, whereas tolerant taxa have low scores. The environmental quality is quantified by the average value of the scores in a sampled site. In contrast with MMIs, indexes that use score systems do not require sampling of pristine reference sites and can be easily adapted for extensive use in biomonitoring programs (Chessman, 1995).

In Brazil, the adaptation of indexes using taxa score systems can provide alternative tools for simple assessment of environmental impacts in threatened aquatic systems, such as coastal drainages in the Atlantic Forest. In the last decade, few studies adapted indexes to evaluate environmental quality of coastal drainages in the Atlantic Forest from southeastern Brazil based on fish assemblages (Terra et al., 2013; Cetra & Ferreira, 2016). Such limited number of studies devoted to assess biotic integrity demonstrates the need for development of simple methodologies for continuous environmental monitoring in this threatened ecosystem.

The Atlantic Forest is the second largest biome in South America, hosting one of the highest rates of species diversity and endemism on Earth (Galindo-Leal & Câmara, 2003; Ribeiro et al., 2009). Due to the negative impact of anthropic activities, only 16% of the original extension is preserved in reduced and isolated patches (Alexandrino et al., 2017). The largest remaining extension of this ecosystem is present along the mountain chain of Serra do Mar. The coastal drainages of the Atlantic Forest supply water to important urban areas in Eastern Brazil and host highly diverse and threatened fish fauna (Abilhoa et al., 2011). These drainages are separated by mountain ranges of the eastern margin of the Brazilian crystalline shield (Ribeiro, 2006). Due to extensive human occupation along the coast, these drainages are directly affected by the fragmentation of

the Atlantic Forest, since the reduction of riparian vegetation is a major source of environmental impact in freshwater systems (Cetra & Ferreira, 2016).

The absence of studies that reflect ecological conditions of coastal drainages in remaining segments of Atlantic Forest, impairs development and application of environmental recovery and protection plans (Hughes et al., 2000). Therefore, the constant evaluation of coastal streams is necessary to understand and create effective plans to recover ecosystems from negative impacts. Aiming to develop simple methodology to evaluate environmental quality of coastal drainages from southeastern Brazil based on fish fauna surveys, in the present work, two indexes using taxa score system, Taxonomic Indexes (TIs), were applied and compared with Multimetric Index (MMI), in three freshwater systems at Serra do Mar, the Upper Piraí, Guapiaçu and Macaé river basins.

2. Materials and methods

2.1. Study areas

The coastal drainages sampled in the present study drain the mountain chain of Serra do Mar. This geological formation extends for 1,000 km between the Rio de Janeiro state, in the northern extremity, and the north of Santa Catarina state, in the southern border, with the highest point reaching 2,263 m of altitude (Almeida & Carneiro, 1998). The climate is warm and humid, with two well-defined seasons: a rainy season from October to March, and a dry season from April to September, an average annual temperature of 22 ºC, and mean annual precipitation of approximately 1700 mm (SEMADS, 2001).

The Piraí river is one of the most important drainages of the Guandu river system. It is located within the boundaries of the municipalities of Rio Claro and Barra do Piraí, Rio de Janeiro state, southeastern Brazil (Figure 1). The Piraí river was originally a major right-bank tributary of the Paraíba do Sul river basin, but since the begging of the 20th century it was artificially diverted to the coastal Guandu river system, which supplies water to approximately 9 million people in the metropolitan area of Rio de Janeiro. The Upper Piraí drainage is composed by streams that flow from the northern face of the mountain system of Serra do Mar and drain the Biodiversity Corridor Tinguá-Bocaina (BCTB) (Paiva & Coelho, 2015). The BCTB connects Atlantic Forest fragments delimited by the Tinguá Biologic Reserve, on the central region of Rio de Janeiro, and the National Park of Serra da Bocaina, on the southern coast of the state.

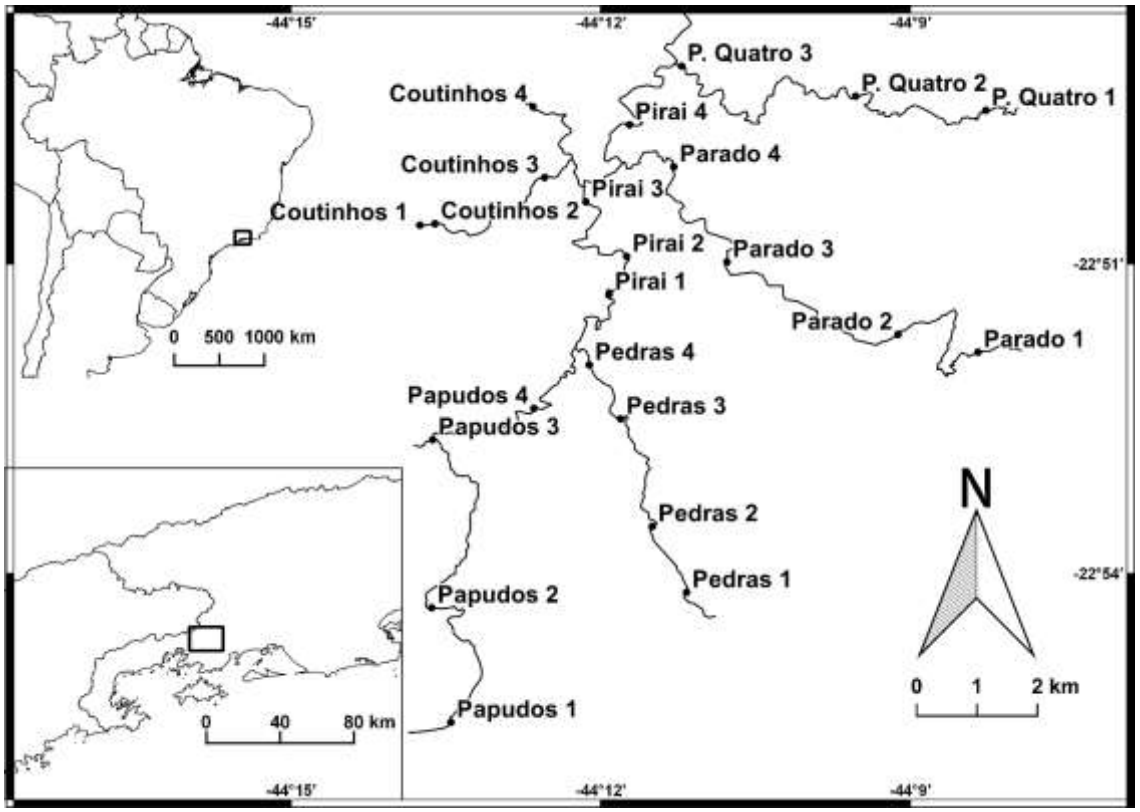

Figure 1. Upper Piraí river drainage and sampling sites. Geographic coordinates and altitude of the sites are listed in Table 1.

The Guapiaçu river is located in the northeastern portion of the Guanabara Bay region, crossing the municipalities of Cachoeiras de Macacu and Itaboraí, in the Rio de Janeiro Metropolitan Region (Figure 2). It is a right bank tributary of the Macacu river. The Macacu, together with the Guapimirim and Caceribu river basins comprise the Guapi-Macacu freshwater system, which supplies water to approximately 2.5 million people in the state of Rio de Janeiro (Oliveira et al., 2011). The Guapiaçu headwaters are located in the stretch of Serra do Mar denominated Serra dos Órgãos, and it is locally encompassed by the Três Picos State Park, Guapiaçu Ecological Reserve (REGUA) and Ecological Station of Paraíso. In contrast with the preserved slopes of highlands, the lower course of the Guapiaçu river crosses areas characterized by the presence of agricultural and cattle-raising properties, and the Petrochemical Complex of Rio de Janeiro (COMPERJ) (Pereira et al., 2012).

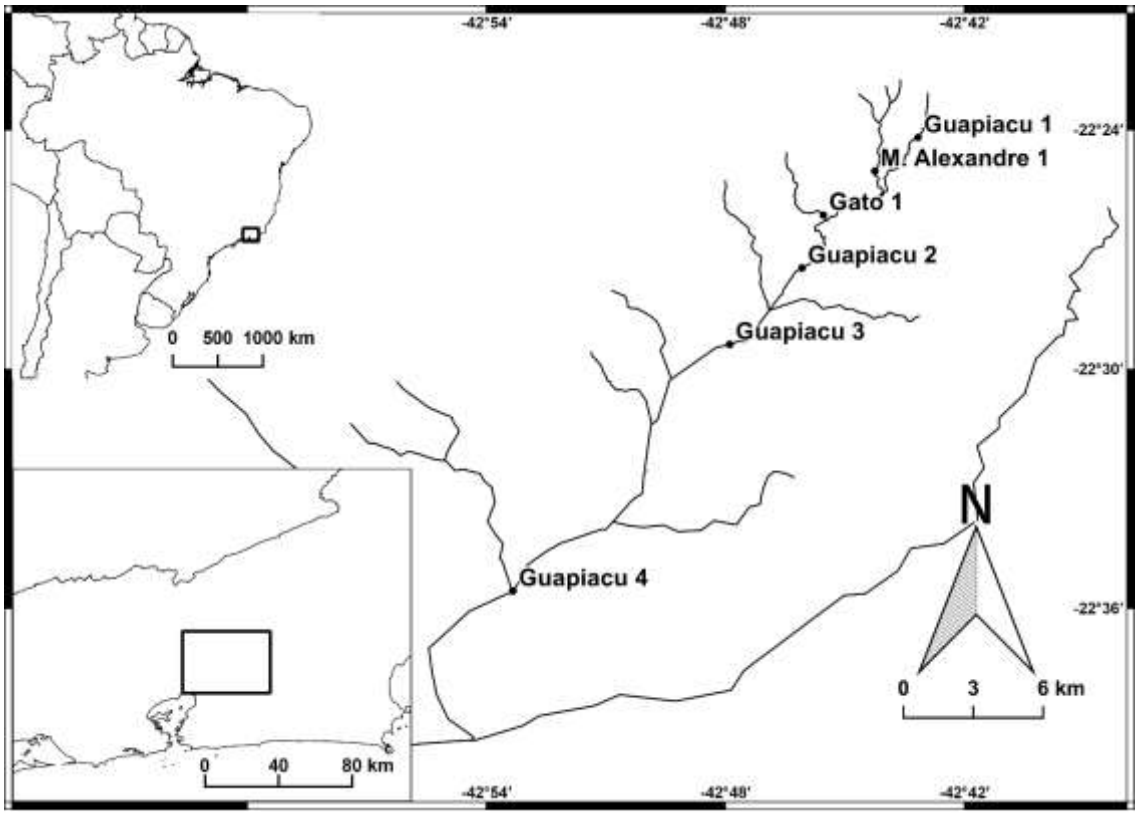

Figure 2. Guapiaçu river basin, indicating the sampling sites. Geographic coordinates and altitude of the sites are listed on Table 1.

The Macaé river (Figure 3) is the largest coastal river with complete drainage in the state of Rio de Janeiro (Brito, 2007). This river basin is comprised within the municipalities of Nova Friburgo, Casimiro de Abreu and Macaé, supplying water to approximately 300,000 people. Similarly to the Guapiaçu drainage, the upland portion of the Macaé river follows through fragments of the Atlantic Forest partially protected by natural reserves, e.g. State Environmental Protection Area of Macaé de Cima. As many coastal drainages in Brazil, the lower stretch of the Macaé river is marked by alterations on its original course, mainly through straightening by artificial channels, dredged to prevent floods (Assumpção, 2009). Agricultural and cattle raising properties are also present on the medium/lower course.

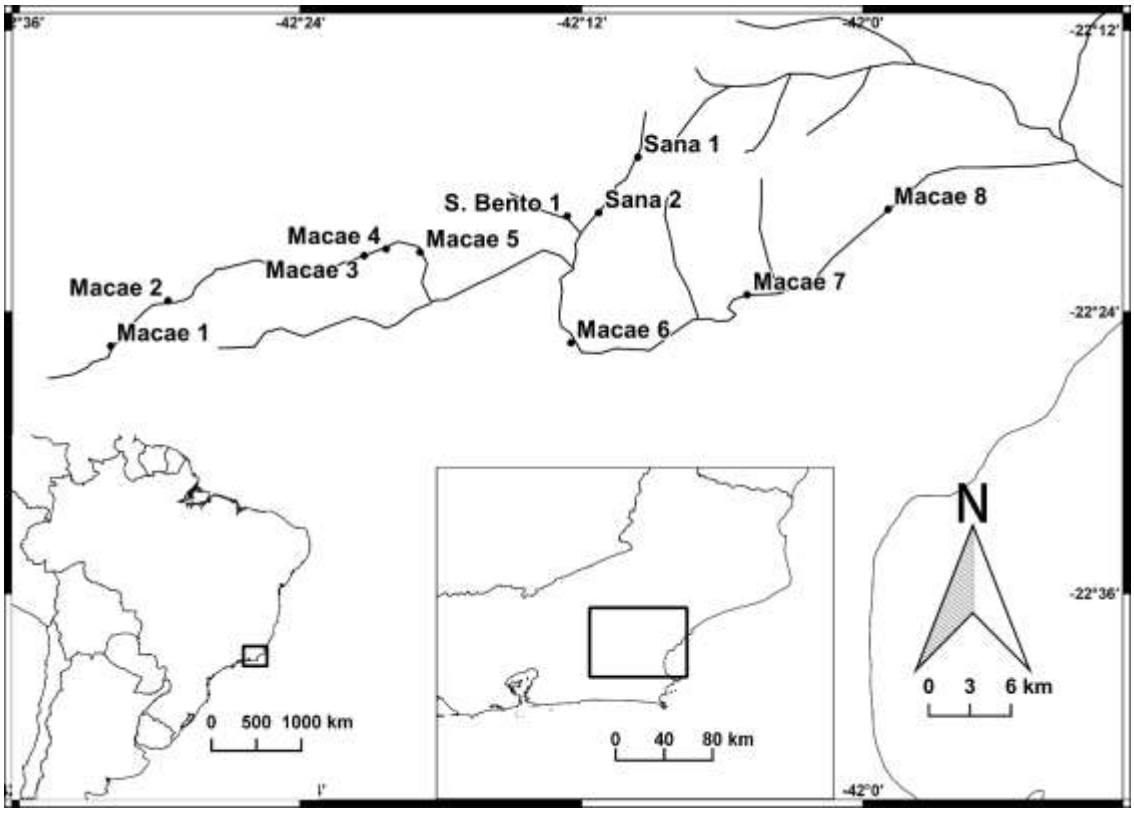

Figure 3. Macaé river basin, indicating the sampling sites. Geographic coordinates and altitude of the sites are listed on Table 1.

2.2. Sampling methods

Fish were collected in 40 sampling sites along main river courses in the three drainages targeted in this study: six in the Guapiaçu river drainage, 11 in the Macaé drainage, and 23 in the upper Piraí drainage (Table 1). In order to account for seasonal variation in fish fauna, samplings were conducted during eight expeditions, in rainy and dry seasons: June 2009, September 2010, July 2015 and April 2016 at the Piraí river drainage; August 2016 and December 2017 at the Guapiaçu river drainge; and June 2017 and November 2017 at the Macaé river drainage. The sampling sites were selected in order to cover a wide range of habitats, from the alluvial plain of the streams to the high-mountain rapids. Each site was surveyed during one hour of exhaustive sampling activity by a team of five ichthyologists with prior experience in stream fish capture methods. Fishing equipment included beach seines (2, 3, 5 and 15 m long, 4 mm nylon mesh), dip nets with metal handles (40 x 90 cm basket area, 2 mm plastic mesh), casts nets (12 mm mesh size). An acoustic amplifier of electric signals was used detect specimens of the order Gymnotiformes hidden in marginal vegetation and rocks. At each site, all available habitats were explored with active sampling techniques commonly used in freshwater

streams (Uieda & Castro, 1999). The techniques used to explore all possible microhabitats included manual seining along the margins, midwater trawls in pools and puddles, kicking through riffles and runs, scroll of rocks and gravel with fixed nets downstream, blockage of runs followed by water and substrate agitation towards a fixed net, and cast net throws in pools deeper than 50 cm.

Measurements of pH, conductivity and temperature of superficial water were taken prior to the fish sampling activities. Visual estimations of the type of substrate and presence of riparian vegetation were recorded for each sampling site. The relative coverage of type of landscape category was recorded as percentages. Observations related to prevailing or recent events causing major changes in environmental quality were also recorded. Most of the collected specimens were fixed in 10% formalin solution in the field and transferred to 70% ethanol after sorting in the laboratory. The remainder specimens were preserved in anhydrous ethanol for molecular studies. Individuals were identified at the lowest taxonomic level possible and deposited in the Ichthyology Collection of the Museu Nacional (MNRJ), Universidade Ferderal do Rio de Janeiro. The taxonomic classification of the species followed Nelson et al. (2016). In order to test sampling efficiency, sample-based species accumulation curves, including 95% confidence intervals, and one non-parametric richness estimators, Chao 1, were generated for all drainages using the software EstimateS v9.1.0 (Chao & Chiu, 2016; Colwell, 2013).

Table 1. Sampling sites and their geographic coordinates and altitudes.

Basin	**Site**	**Latitude (S)**	**Longitude (W)**	**Altitude (m)**
Upper Piraí	Coutinhos 1	22° 50' 37"	44° 13' 45"	610
	Coutinhos 2	22° 50' 37"	44° 13' 36"	582
	Coutinhos 3	22° 50' 10"	44° 12' 33"	537
	Coutinhos 4	22° 49' 28"	44° 12' 39"	572
	Passa Quatro 1	22° 49' 31"	44° 08' 16"	712
	Passa Quatro 2	22° 49' 22"	44° 09' 32"	622
	Passa Quatro 3	22° 49' 05"	44° 11' 13"	513
	Papudos 1	22° 55' 27"	44° 13' 27"	1002
	Papudos 2	22° 54' 20"	44° 13' 38"	951
	Papudos 3	22° 52' 42"	44° 13' 38"	571
	Papudos 4	22° 52' 24"	44° 12' 39"	563

Basin	Site	Latitude (S)	Longitude (W)	Altitude (m)
	Parado 1	22° 51' 51"	44° 08' 21"	1050
	Parado 2	22° 51' 41"	44° 09' 07"	976
	Parado 3	22° 50' 59"	44° 10' 46"	561
	Parado 4	22° 50' 03"	44° 11' 17"	545
	Pedras 1	22° 54' 11"	44° 11' 10"	842
	Pedras 2	22° 53' 33"	44° 11' 30"	786
	Pedras 3	22° 52' 30"	44° 11' 48"	576
	Pedras 4	22° 51' 59"	44° 12' 07"	554
	Piraí 1	22° 51' 18"	44° 11' 55"	555
	Piraí 2	22° 50' 56"	44° 11' 45"	548
	Piraí 3	22° 50' 24"	44° 12' 09"	535
	Piraí 4	22° 49' 39"	44° 11' 43"	519
Guapiaçu	Guapiaçu 1	22° 24' 11"	42° 43' 10"	328
	Guapiaçu 2	22° 27' 28"	42° 46' 05"	26
	Guapiaçu 3	22° 29' 23"	42° 47' 53"	21
	Guapiaçu 4	22° 35' 34"	42° 53' 20"	9
	Gato 1	22° 26' 08"	42° 45' 33"	33
	Manoel Alexandre 1	22° 25' 02”	42° 44' 15”	168
Macaé	Macaé 1	22° 25' 27"	42° 32' 05"	1034
	Macaé 2	22° 23' 31"	42° 29' 39"	920
	Macaé 3	22° 21' 37"	42° 21' 16"	679
	Macaé 4	22° 21' 19"	42° 20' 20"	642
	Macaé 5	22° 21' 27"	42° 18' 54"	609
	Macaé 6	22° 25' 19"	42° 12' 27"	54
	Macaé 7	22° 23' 16"	42° 04' 57"	25
	Macaé 8	22° 19' 38"	41° 58' 56"	12
	São Bento 1	22° 19' 55"	42° 12' 37"	352
	Sana 1	22° 17' 25"	42° 09' 36"	395
	Sana 2	22° 19' 47"	42° 11' 16"	288

2.3. Taxonomic Index development

2.3.1. Species scores

Scores attributed to species ranged from -1 to 10, according to their degree of sensitivity to negative environmental impacts. The scores were based on ecological attributes commonly used for development of biotic integrity indexes: geographic distribution, level of tolerance, trophic guild, habitat and taxonomic group) (dos Santos & Esteves, 2015; de Carvalho et al., 2017; Terra et al., 2013) (Table 2). In this study, data on species attributes was gathered from literature, expert consultation and personal observation in field. Characteristics of the genus or family were considered when information was not available for a species. Minimum and maximum scores of each attribute were stablished to ensure that the sum of scores did not exceed -1 and 10. Justification for the inclusion of these attributes in the calculation of the TIs is described below.

Table 2. Score assigned for each attribute.

Category	**Attribute**	**Score**
Geographic distribution	Restricted geographic distribution	2
	Limited to Atlantic Forest	1
	Widely distributed	0
	Exotic species	-1
Level of tolerance to	Sensitive	2
environmental	Intermediate	1
disturbance	Tolerant	0
Trophic guild	Invertivore, herbivore or piscivore	2
	Omnivorous	1
	Detritivores	0
Habitat	Benthic or Hider	2
	Mid-water	0
Taxonomic group	Characiformes, Siluriformes or Gymnotiformes	2
	Others	0

2.3.1.1. Geographic distribution

The range of geographic distribution of fish species is commonly used in biodiversity assessments to indicate their level of sensitivity to environmental disturbance

(Nogueira et al., 2010; IUCN, 2012). In order to classify species sensitivity to environmental degradation according to their geographic distribution, four categories were defined: *restricted distribution*, *limited to Atlantic Forest*, *widely distributed* and *exotic species.* In this study, the limits of distributions were obtained in public databases and published studies with distributions of fish species (e.g. Buckup et al., 2007; Eschmeyer et al., 2018; GBIF.org, 2018; Nogueira et al., 2010).

The classification of species in the *restricted distribution* category followed Nogueira et al. (2010), who compiled a list of species with known distributions not exceeding 10.000 km^2. Those taxa are extremely vulnerable to shifts in environmental quality due to the narrow association to their natural habitat. The geographic restriction also results in small population size. Species with small population size are more susceptible to environmental changes caused by anthropic activities. In addition, the rescue effect, process in which immigrating individuals of the same species decrease extinction risk of a target population, is less likely to occur with species with highly restricted distributions (Gärdenfors et al., 2001).

Species with geographic distribution *limited to Atlantic forest* are defined as those with geographic ranges exceeding 10.000 km^2, which do not occur outside the limits of the Atlantic Forest biomes. Although these species have wider geographic distribution, their occurrence restricted to a set of ecological conditions present in Atlantic forest biomes demonstrate their sensitivity to changes in habitat. The third category, *widely distributed* species, includes species that can occur in multiple biomes along the Neotropical Region. Their broad distribution is usually related to increased dispersal potential, adaptability to different types of habitats and great resiliency to environmental changes caused by negative man-made impacts.

Differently from the other three categories, *exotic* species do not occur naturally in the sampled basin, reflecting their capacity to tolerate a wide range of ecological conditions. Exotic organisms are usually more successful in negatively affected systems or where native species population are depleted (Ross, 1991). Although the establishment of some exotic species demand good environment conditions, e.g. *Oncorhynchus mykiss*, their presence is a direct indication of human interference in the local aquatic environments and their introduction affects negatively the structure of native fish assemblages (Ross, 1991; Lazzarotto & Caramaschi, 2009). Thus, exotic species received the lowest and definitive score of -1.

2.3.1.2. Level of tolerance to environmental disturbance

This attribute indicates how tolerant a species is to environmental disturbance caused by a stressor (Hering et al., 2006). In most biotic indexes, species are divided in two groups: *tolerant* and *intolerant/sensitive*. Although an objective methodology for classification of the level of sensitivity of species does not exist yet, this kind of classification have been extensively applied in different studies based on expert judgment or coarse *a posteriori* estimates (Terra et al., 2013; dos Santos & Esteves, 2015). In this study, the species tolerance was classified in three categories, following Hughes et al. (1998): *tolerant*, *intermediate* and *sensitive*.

Tolerant species are resilient to environmental disturbance, being able to tolerate a wide range of conditions including highly polluted or modified habitats (Karr et al., 1986). These species usually benefit from conditions where other common species are not able to persist (Terra et al., 2013). *Intermediate* species are negatively affected by environmental disturbance, but are usually able to resist to small variations on habitat integrity and can be present in mildly to moderately disturbed areas, not struck by heavy environmental damage. In contrast, *sensitive* species are highly susceptible to minor environmental disturbance, and most of their population is isolated in small numbers in preserved areas and absent in disturbed sites. Those species usually appear as threatened in the Red Book of the Brazilian Fauna (ICMBio, 2016) or in regional species surveys, due to their vulnerability.

2.3.1.3. Trophic guild

Disturbance in environmental quality may degrade food resources. Thus, trophic structure of fish communities may be used as an indicator of aquatic degradation (Karr, 1981; Oberdorff & Hughes, 1992). Species were classified according to their trophic guild: *invertivore*, *herbivore*, *piscivore*, *omnivore* and *detritivore*. Extensive literature was used to determine the diet composition and classification of every species (Appendix 1). When information about the food source of a species was not available, information about congeneric taxa was used to establish their trophic guild category.

Invertivorous species have their diet composed mainly by invertebrate animals. Those species are affected by reduction in population of invertebrate prey, which results from degradation of riparian vegetation or sewage discharge (Ferreira & Casatti, 2006; Karr, 1981). Another group directly affected by reduction of riparian vegetation is the one composed by *herbivorous* species, which have their diet composed mostly by vegetal matter originated from marginal vegetation. *Piscivorous* species are long lived, k-

strategist predators of other fish species, which are affected by physical and chemical changes in the environment, including bioaccumulation of toxic substances and oxygen depletion (Petesse et al., 2016). These carnivorous species contribute to the regulation of fish communities and their abundance decreases with high environmental degradation (e.g. hypoxic conditions) (Anjos et al., 2008). Due to their relatively higher sensitivity to ecological stressors, invertivores, herbivores and piscivores species received the highest scores related to trophic guilds.

Omnivorous taxa have plastic diets composed by items of animal and vegetal source. They are very adaptable to changes in food sources, and the proportion of *omnivorous* organisms in a community tend to increase with habitat degradation (Karr, 1981). Although *omnivorous* species are adaptable to shifts in diet composition, they are still affected by decrease in food variety related to degradation of river systems (Gomiero et al., 2008). Due to their intermediate sensitivity to ecological stressors, omnivorous species received medium scores related to trophic guilds. *Detritivore* species feed largely on organisms and organic matter associated with debris and sediment. These fishes can support higher intake of organic matter in aquatic systems, with some species benefiting from sewage plumes (Henriques et al., 2013). Thus, detritivore species received the lowest scores related to trophic guilds.

2.3.1.4. Habitat

The position of a species in the water column can reflect its vulnerability to alterations on the habitat. *Benthic* species are the ones that occupy the bottom of the streams and are usually heavily affected by structural changes of the habitat and water quality (Oberdorff & Hughes, 1992). Due to their limited mobility and high dependence on the substrate, the number of these species was expected to decline in response to alteration or loss of benthic habitat (McCormick et al., 2001; Terra et al., 2013). Similar to benthic species, *hider* species are also susceptible to changes in the substrate. Species in this category have cryptic habits related to marginal vegetation and availability of lodges in riverbanks. Therefore, their occurrence is positively correlated with preservation of riparian forest and habitat complexity. On the other hand, *mid-water* species are not considered as highly affected by habitat alterations, including high sediment loads, as benthic species (Bozzetti & Schulz, 2004). Thus, species that are not susceptible to changes in river substrate are more abundant in degraded habitats.

2.3.1.5. Taxonomic group

Characiformes and *Siluriformes* are the most representative orders of fishes in freshwater systems of the Atlantic Forest (Abilhoa et al., 2011), so it is expected that fish communities in coastal drainages southeastern Brazil are composed mainly by individuals of those orders. In relation to water quality, diversity and richness of Characiformes and Siluriformes species tend to decline with negative anthropic impact, giving more space to members of more tolerant taxa, (Ferreira & Casatti, 2006). *Gymnotiformes* species are usually present in substrate interstices or among aquatic macrophytes and marginal plant roots (Bizerril & Primo, 2001). Therefore, the presence of Gymnotiformes in an ecosystem is strictly connected to preservation of riparian vegetation and habitat complexity. Due to relatively higher correlation of Characiformes, Siluriformes and Gymnotiformes species with least degraded coastal drainages of the Atlantic Forest, these orders received the highest scores in the present category. In contrast, the percentage of other representative orders of tropical streams, such as Cichliformes, Synbranchiformes and Gobiiformes, tend to increase in degraded environments (Casatti et al., 2009). Thus, other orders, besides Characiformes, Siluriformes and Gymnotiformes, received the lowest score.

2.3.2. Taxonomic Index calculation

Using the scores obtained for each species, two TIs were developed in this study. The first index, TI1, represents the average of the species scores in a sampling site. Hence, TI1 was calculated by the sum of scores of all species present in the samples (SR) divided by the species richness of the samples (R):

$$TI1 = {(\sum SR)}/{R}$$

The second index, TI2, was created to account for the relative abundance of each species in the sample. TI2 was calculated by the sum of the abundance of species (A_o) divided by the total abundance in the sample (A_t), multiplied by the species score (SR). Thus, TI 2 represents the medium species score, weighted by the relative abundance:

$$TI2 = \sum \left(\left[{A_o}/{A_t} \right] \times SR \right)$$

Environmental conditions were classified as *acceptable* when TI values were higher than 6, *partially degraded* with TIs between 6 and 5, and if the results were lower than 5 the quality on sampling site was considered *degraded*. When classification of environmental conditions in a stretch of freshwater system was incongruent between TIs, both indexes were considered in the ecological evaluation, because the disparity of results may indicate different aspects of the fish community integrity.

2.4. Taxonomic Index performance

In order to compare the two proposed taxonomic indexes with traditionally applied methodology of biotic integrity evaluation, a multimeric index, adapted from dos Santos & Esteves (2015), was calculated.

2.4.1. MMI calculation

In order to select the metrics that better reflect ecological components of the sampled fish communities, three statistical tests were applied in 102 metrics adapted from de Carvalho et al. (2017). These metrics reflect measurable characteristics of the ecology of the fish communities sampled in the present study (Table 12 Table 17).Tests were applied sequentially and metrics that failed in one of these tests were not considered for further evaluation.

First, the *range test* was used to select metrics that are able to differentiate ecological conditions between sites (Whittier et al., 2007). If the range of values of a metric is small, or most of their values are identical, then the metric is unlikely to reflect environmental conditions of different sites. Thus, metrics were not considered for the second test if they presented equal values in more than 75% of the time (Whittier et al., 2007). Second, the *responsiveness test* was applied to select metrics that had significant correlation with abiotic variables (pH, conductivity, temperature of superficial water, substrate diversity, riparian vegetation cover, margin alterations). Correlation among metrics and variables was calculated through Spearman rank correlation coefficient using the 'Hmisc' package in the software R v3.4.4 (Harrell, 2018; R Core Team, 2018). Metrics that displayed two or more significant correlations with water and habitat variables according to P-test ($P < 0.05$) were selected for the third test (McCormick et al., 2001). Third, the *redundancy test* evaluate the redundancy among metrics. Only metrics that did not contain information that was redundant with other selected metrics were included in the final MMI. Redundancy was estimated by a correlation matrix among metric values. Metrics were considered redundant if the Spearman correlation

coefficients between pair of metrics were greater than 0.70 (Whittier et al., 2007). In the case of redundant pairs, the metrics with highest number of redundant correlations were selected (McCormick et al., 2001).

As described by dos Santos & Esteves (2015), the values of metrics were scaled from 1 to 10 based on reference values of environmental conditions. The reference values were determined by the relation of metrics with environmental disturbance. Thus, if a metric value decreased with environmental degradation (M_α), the reference value is the highest one, and the metric scaling was determined by the division of the observed value (O) by the reference value (V):

$$M_\alpha = (O/V) \times 10$$

When the metric's value increased with degradation (M_β), the reference value is the lowest one above zero. In this case, the metric scaling was determined by the division of the reference value (V) by the observed value (O):

$$M_\beta = (V/O) \times 10$$

The final MMI value was calculated by the sum of scaled metrics for each sampling site. Environmental conditions were classified at each sampled site was classified as *acceptable* when the resulting sum of metrics was higher than 80% of the maximum MMI, *partially degraded* if represented 60 to 80% of the maximum value, and *degraded* if lower than 60% (dos Santos & Esteves, 2015). MMI were not calculated for the first two samplings of upper Piraí, because physiochemical water and habitat variables necessary for the selection of candidate metrics were not registered.

2.4.2. Environmental Index (EI) calculation and indexes correlation

It is expected that indexes of biotic integrity can reflect changes in variables related to environmental quality. In order to compare the performance of the indexes developed in this study, they were correlated with an environmental index (EI) developed by Araújo et al. (2003). The EI was used to quantify variation of abiotic variables related to water quality (pH, conductivity and temperature) and physical habitat structure (substrate diversity, riparian vegetation and margin alterations) measured at each sampling site (Table 3). These variables were graded 1, 3 or 5, according to their relation to environmental condition, with the grades indicating poor (1), intermediate (3) or close to ideal conditions (5) (Table 3). The EI was calculated by summing the grades attributed

to each variable. The relationships among the EI and TI1, TI2 and MMI were examined through the calculation of the Spearman Rank correlation coefficient.

Table 3. Abiotic variables and criteria used to attribute grades for calculation of the environmental index (EI).

	Grades and criteria		
Variables	**1**	**3**	**5**
pH	<4 or >9.1	4–6 or 8–9	6.1–7.9
Conductivity (µS cm^{-1})	>100 or <20	-	20–100
Temperature (◦C)	>28	-	<28
Substrate diversity (rocks, sand, silt)	1 type	2 types	3 types
Riparian vegetation cover	None	Sparse	Common
Margin alterations	Common	Little	None

3. Results

3.1. Fish fauna and sampling

In total, 13,222 individuals of 78 fish species belonging to 22 families and nine orders were collected in the studied streams (Appendix 8 to 15). Among the captured species, 11 occurred on the three sampled basins, 20 were shared between Guapiaçu and Macaé, three occurred in the Macaé and Piraí, and two in the Guapiaçu and Piraí. Thirteen species were found exclusively in Guapiaçu sites, 13 in the Macaé, and 16 in headwaters of the Piraí. According to the species accumulation curves, the number of captured species presented a stabilization tendency in the Macaé (Figure 4) and upper Piraí (Figure 5) river basins, whereas the Guapiaçu curve did not reach stabilization (Figure 6). The estimated species richness in Macaé, Chao 1 = 47.1, and upper Piraí, Chao 1 = 33.5, were inside the 95% confidence interval of observed values of richness, 47 and 32 species in Macaé and Upper Piraí, respectively. In the Guapiaçu drainage, the estimated species richness, Chao 1 = 55.3, was higher than the 95% confidence interval of observed values of richness, 46 species.

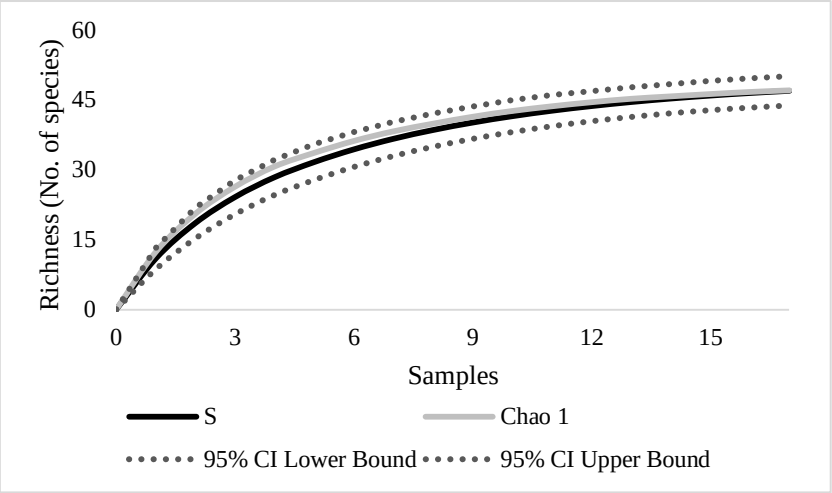

Figure 4. Species accumulation curves for the Macaé river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1).

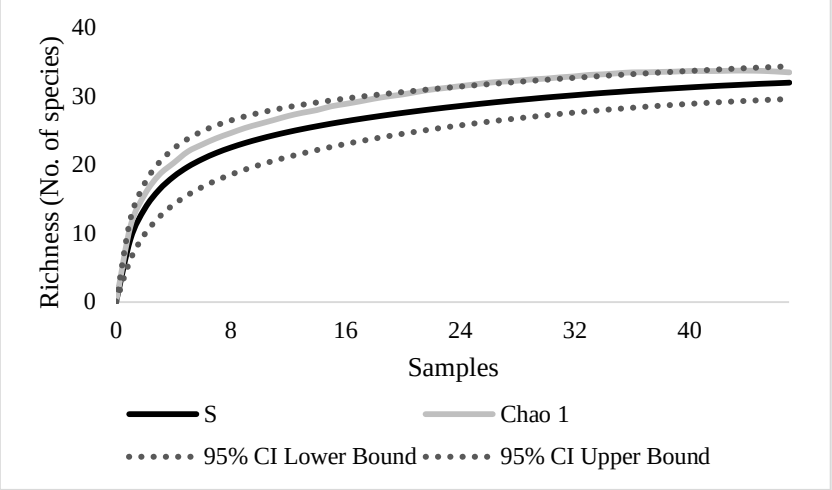

Figure 5. Species accumulation curves for the upper Piraí river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1).

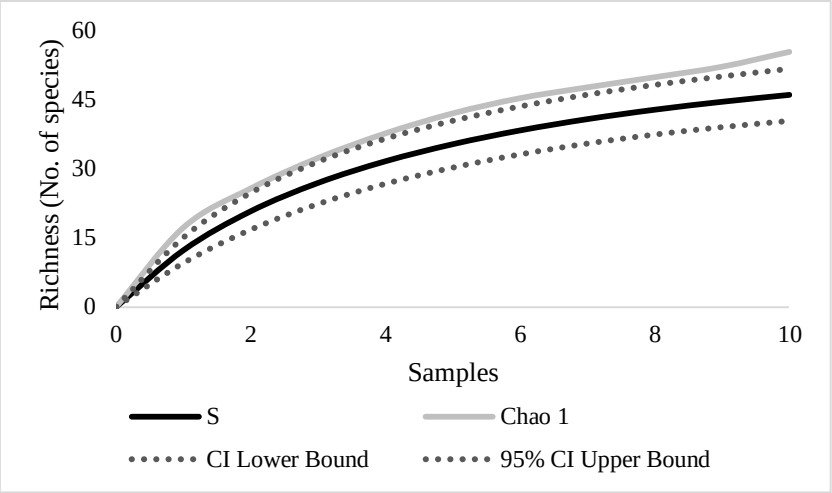

Figure 6. Species accumulation curves for the Guapiaçu river drainage based on species richness (S), with upper and lower bounds of 95% confidence intervals (CI), and richness estimator (Chao 1).

3.2. Taxonomic indexes

The attributes of the 78 species and the resulting scores are listed in Table 4.

Table 4. Score obtained for sampled species based on their ecological attributes, following the categories defined in methodology (Table 2). The catalog number of voucher specimens are listed in (Appendix 16) Legend: RD - Restricted geographic distribution; LA - Limited to Atlantic Forest; WD - Widely distributed; AS - Exotic species; SN - Sensitive; IT - Intermediate; TL - Tolerant; IN - Invertivore; HB -Herbivore; PS - Piscivore; OM - Omnivorous; DT - Detritivore; BT - Benthic; HD - Hider; MW – Mid-water; CH - Characiformes; SL - Siluriformes; GY - Gymnotiformes; OO - Other orders.

Species	**Geographic distribution**	**Tolerance**	**Trophic guild**	**Habitat**	**Taxonomic group**	**Score**
Microcambeva barbata	RD	SN	IN	BT	SL	10
Microglanis nigripinnis	RD	SN	IN	BT	SL	10
Pareiorhina rudolphi	RD	SN	HB	BT	SL	10
Acentronichthys leptos	LA	SN	IN	BT	SL	9
Characidium lauroi	RD	IT	IN	BT	CH	9
Characidium sp.	RD	IT	IN	BT	CH	9

Species	**Geographic distribution**	**Tolerance**	**Trophic guild**	**Habitat**	**Taxonomic group**	**Score**
Characidium sp. aff. *vidali*	RD	IT	IN	BT	CH	9
Characidium vidali	RD	IT	IN	BT	CH	9
Imparfinis minutus	RD	IT	IN	BT	SL	9
Neoplecostomus granosus	LA	SN	IN	BT	SL	9
Rhamdioglanis transfasciatus	RD	IT	IN	BT	SL	9
Trichomycterus immaculatus	RD	IT	IN	BT	SL	9
Trichomycterus macrophthalmus	RD	IT	IN	BT	SL	9
Trichomycterus mariamole	RD	IT	IN	BT	SL	9
Trichomycterus nigroauratus	RD	IT	IN	BT	SL	9
Characidium sp. aff. *interruptum*	RD	SN	IN	MW	CH	8
Hemipsilichthys papillatus	RD	SN	DT	BT	SL	8
Neoplecostomus microps	LA	IT	IN	BT	SL	8
Pareiorhaphis garbei	RD	SN	DT	BT	SL	8
Pimelodella lateristriga	LA	IT	IN	BT	SL	8
Rineloricaria sp. 2	RD	SN	DT	BT	SL	8
Trichomycterus zonatus	LA	IT	IN	BT	SL	8
Astyanax sp. aff. *scabripinnis*	RD	SN	OM	MW	CH	7
Brycon opalinus	RD	SN	OM	MW	CH	7
Bryconamericus ornaticeps	RD	IT	IN	MW	CH	7
Bryconamericus sp. aff. *tenuis*	RD	IT	IN	MW	CH	7
Characidium interruptum	LA	SN	IN	MW	CH	7
Eigenmannia sp. gr. *trilineata*	WD	IT	IN	HD	GY	7
Gymnotus carapo	WD	IT	IN	HD	GY	7
Gymnotus pantherinus	WD	IT	IN	HD	GY	7
Hemipsilichthys gobio	LA	SN	DT	BT	SL	7
Hypomasticus mormyrops	LA	IT	HB	MW	CH	7
Kronichthys heylandi	LA	SN	DT	BT	SL	7
Mimagoniates microlepis	LA	SN	IN	MW	CH	7
Scleromystax barbatus	LA	IT	OM	BT	SL	7

Species	**Geographic distribution**	**Tolerance**	**Trophic guild**	**Habitat**	**Taxonomic group**	**Score**
Ancistrus multispinis	LA	IT	DT	BT	SL	6
Astyanax hastatus	RD	IT	OM	MW	CH	6
Astyanax sp. 2 gr. *fasciatus*	RD	IT	OM	MW	CH	6
Harttia carvalhoi	LA	IT	DT	BT	SL	6
Harttia loricariformis	LA	IT	DT	BT	SL	6
Hisonotus notatus	LA	IT	DT	BT	SL	6
Hypostomus luetkeni	LA	IT	DT	BT	SL	6
Oligosarcus hepsetus	LA	IT	PS	MW	CH	6
Parotocinclus maculicauda	LA	IT	DT	BT	SL	6
Rineloricaria sp. 1	LA	IT	DT	BT	SL	6
Rineloricaria sp. cf. *lima*	LA	IT	DT	BT	SL	6
Schizolecis guntheri	LA	IT	DT	BT	SL	6
Astyanax giton	LA	IT	OM	MW	CH	5
Astyanax intermedius	LA	IT	OM	MW	CH	5
Astyanax lacustris	LA	IT	OM	MW	CH	5
Astyanax sp.	LA	IT	OM	MW	CH	5
Astyanax taeniatus	LA	IT	OM	MW	CH	5
Hypostomus affinis	LA	TL	DT	BT	SL	5
Microphis lineatus	WD	IT	IN	HD	OO	5
Australoheros sp.	LA	IT	IN	MW	OO	4
Cyphocharax gilbert	LA	IT	DT	MW	CH	4
Hoplias malabaricus	WD	TL	PS	MW	CH	4
Pseudophallus mindii	WD	IT	OM	HD	OO	4
Rhamdia quelen	WD	TL	PS	MW	SL	4
Symbranchus marmoratus	WD	TL	PS	HD	OO	4
Eleotris pisonis	WD	TL	OM	DT	OO	3
Hyphessobrycon bifasciatus	WD	TL	OM	MW	CH	3
Trachelyopterus striatulus	WD	TL	OM	MW	SL	3
Awaous tajasica	WD	TL	DT	DT	OO	2

Species	**Geographic distribution**	**Tolerance**	**Trophic guild**	**Habitat**	**Taxonomic group**	**Score**
Cichlasoma sp.	WD	TL	IN	MW	OO	2
Crenicichla lacustris	WD	TL	PS	MW	OO	2
Crenicichla lepidota	WD	TL	PS	MW	OO	2
Geophagus brasiliensis	WD	TL	OM	MW	OO	1
Phalloceros harpagos	LA	TL	DT	MW	OO	1
Phalloceros tupinamba	LA	TL	DT	MW	OO	1
Poecilia vivipara	WD	TL	OM	MW	OO	1
Apistogramma sp.	AS					-1
Hyphessobrycon eques	AS					-1
Oncorhynchus mykiss	AS					-1
Oreochromis niloticus	AS					-1
Poecilia reticulata	AS					-1
Pyrrhulina australis	AS					-1
Trichopodus trichopterus	AS					-1

The taxonomic indexes calculated for the sampling sites varied from 1 to 9, with average values of 5.96 for TI 1 and 5.27 for TI 2. In the Guapiaçu drainage, the average values were 6.11 for TI 1, and 6.59 for TI 2 (Figure 7 and Figure **8**). Values of TI presented direct correlation to longitudinal gradient. The sampling sites with higher elevation in the Guapiaçu drainage (Guapiaçu 1, Manoel Alexandre 1 and Gato 1) were the ones that obtained the highest values of TIs. In those three sites, the environmental condition was classified as acceptable by both indexes. The lowest values for TI 1, and TI 2 were obtained in Guapiaçu 4, which was classified as degraded. The classification of the environmental condition in the sites Guapiaçu 2 and 3 varied from degraded to acceptable, with maximum value of 6.2 and minimum of 4.5.

Seasonally, results of TI values did not vary significantly from dry to rainy season in the Guapiaçu river. The biggest change in environmental quality was observed in Guapiaçu 3, which had lower results of TI 1 and TI 2 during the rainy season (Figure 8).

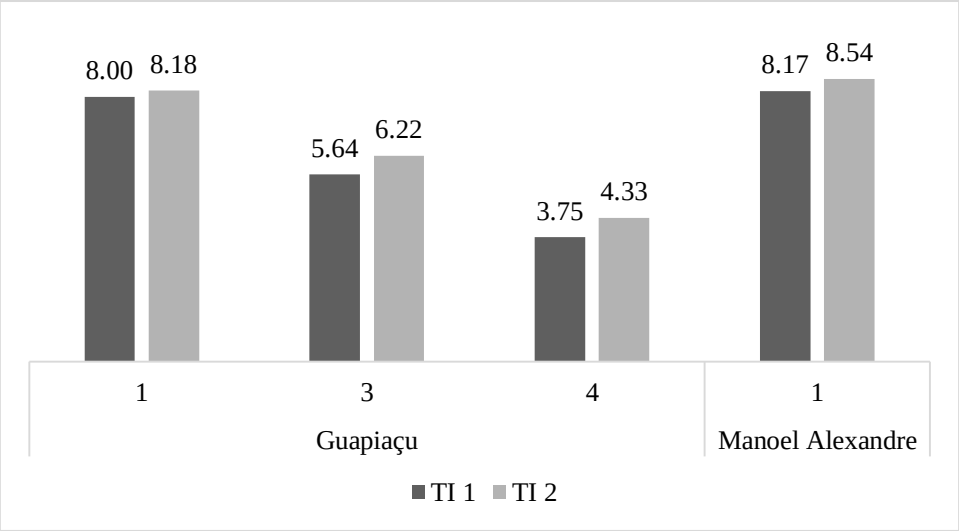

Figure 7. Taxonomic index values obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season).

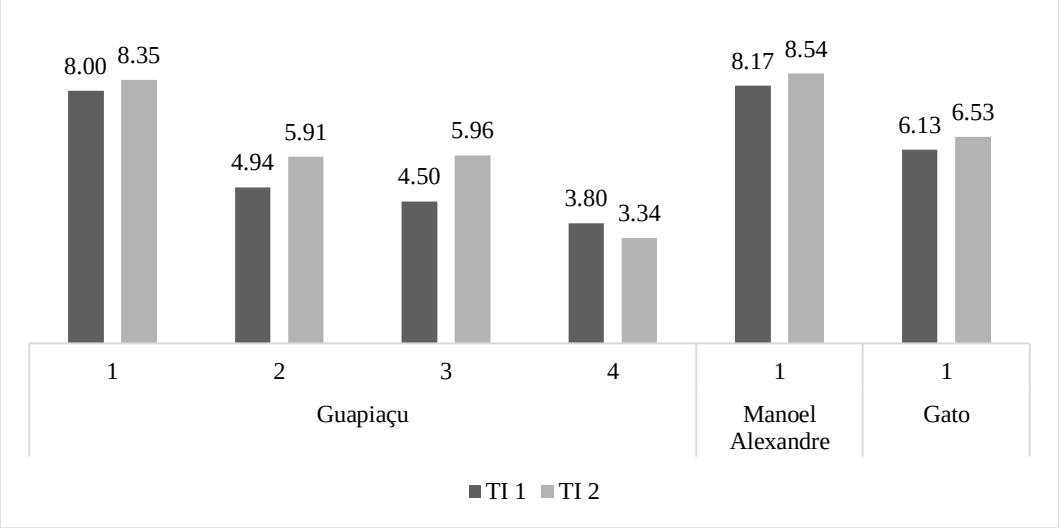

Figure 8. Taxonomic index values obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season).

In the Macaé basin, the average results were 6.05 for TI 1 and 5.54 for TI 2 (Table 9Table 10). Similar to the results in Guapiaçu drainage, the best values of water quality were observed in the highest sampling site. Although the general trend in values of TI were related to longitudinal changes, some sampling sites in the upper reaches of the Macaé basin (Macaé 2, Sana 2) presented relatively lower values. Among the sites sampled in the rainy and dry seasons, Macaé 1 and 4 had their environmental condition classified as acceptable by the two indexes. Macaé 3, São Bento 1 and Sana 1 also presented TI results above 6, but only in one instance. The values of TI 1 and TI 2 indicate the lowest environmental condition of the basin in Macaé 6 and 7, which were the only

sites classified as depleted twice by both indexes. Little variation was registered from the first to the second collection event, maintaining a similar overall profile of environmental quality along the basin. The most significant variation occurred on TI 2 result of São Bento 1, increasing from 4.53 to 7.90

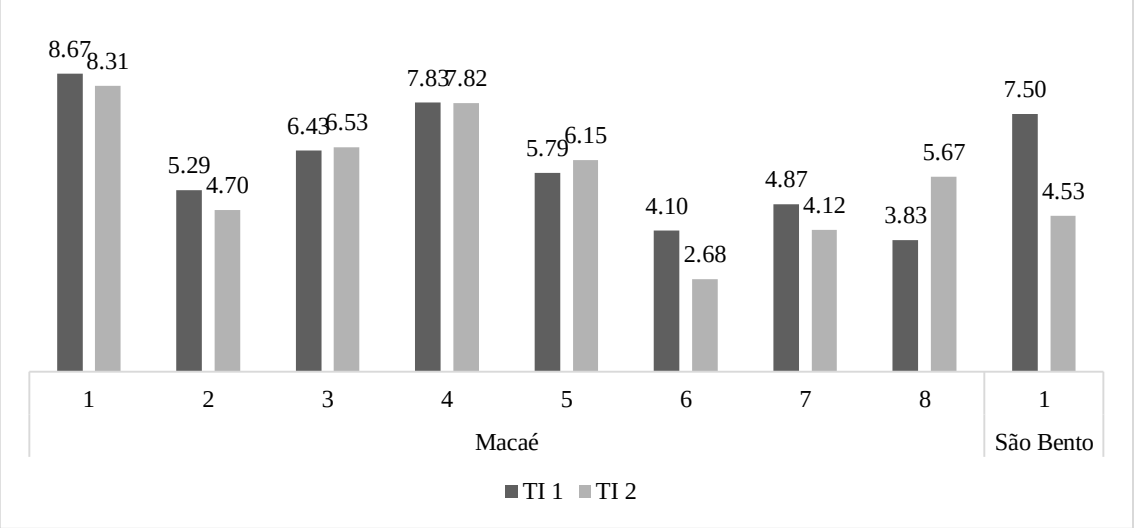

Figure 9. Taxonomic index values obtained for sampling sites in the Macaé river basin in June 2017 (dry season).

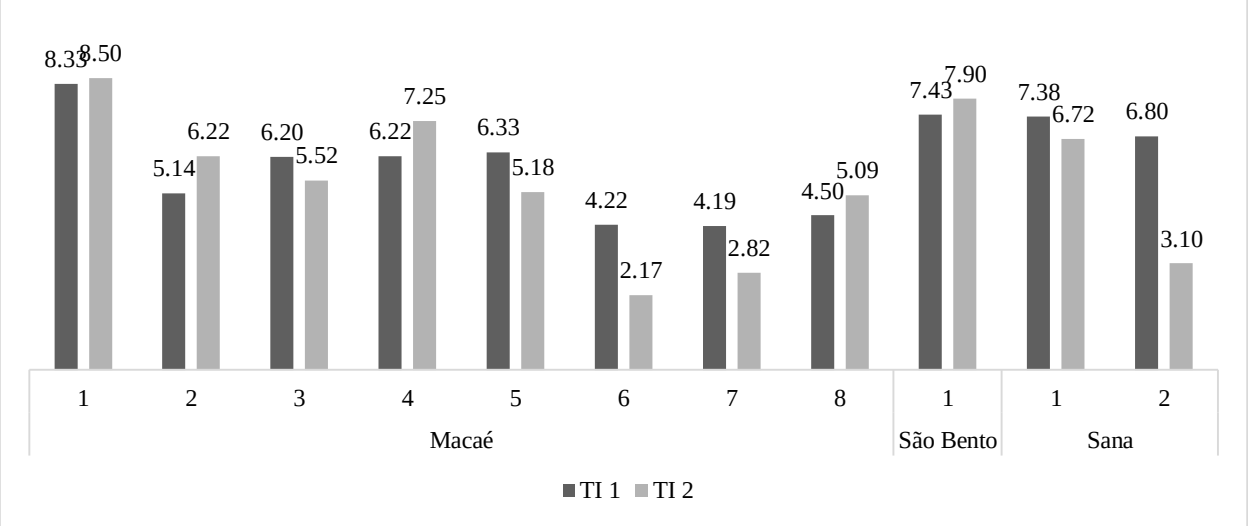

Figure 10. Taxonomic index values obtained for sampling sites in the Macaé river basin in November 2017 (rainy season).

In the upper Piraí drainage, the average integrity index values were 6.12 for TI 1 and 4.99 for TI 2. Among the sites, only Pedras 3 had its environmental condition classified as acceptable by the TI 1 and TI 2 on every occasion. The highest values of TI were observed in the upper Piraí drainage during the dry season in September 2010. In the upper Piraí drainage, most of the values of TI 1 and TI 2 were above six in the Rio

das Pedras and Papudos streams. On the other hand, the lowest result of TIs in all sampled sites were obtained in the Parado river.

Regarding temporal variation, on the ten sites sampled three times (Papudos 2, 3, 4; Piraí 1, 2, 3; Rio das Pedras 1, 2, 3, 4), small variation was observed on values of the taxonomic indices. The average values of TI 1 obtained on the first sampling in those sites were 6.35, followed by 6.51 on the second sampling, and 6.12 on the last. For TI 2, average values on the first sampling were 5.74, followed by 5.92 on the second sampling, and 5.33 on the last one. Among those sites, the greatest temporal variation in TI values occurred in Papudos 2, where TI 1 and TI 2, respectively, varied from 5.25 and 6.00 on the first sampling, to 9.00 and 8.20 on the second time, to 5.75 and 5.59 on the last sampling.

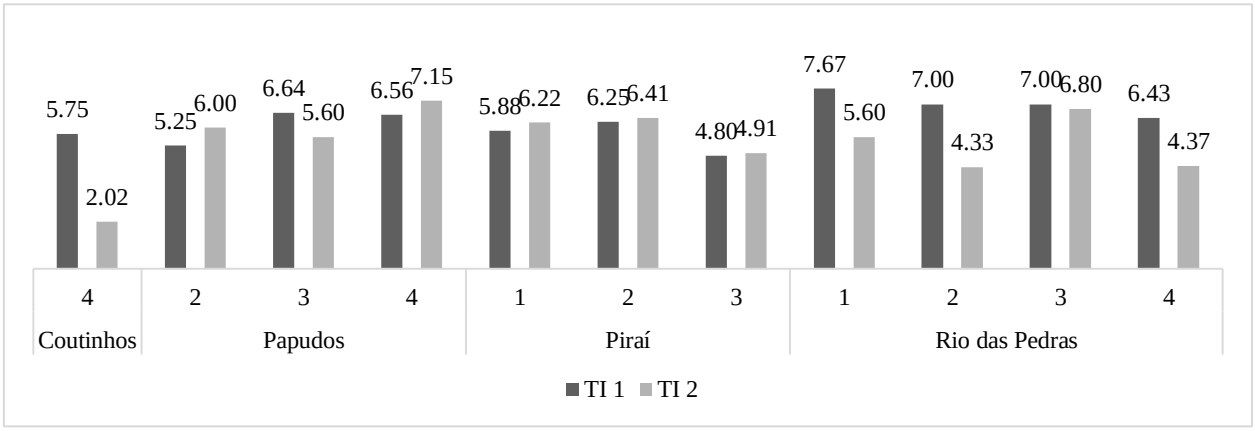

Figure 11. Taxonomic index values obtained for sampling sites in the upper Piraí drainage in June 2009 (dry season).

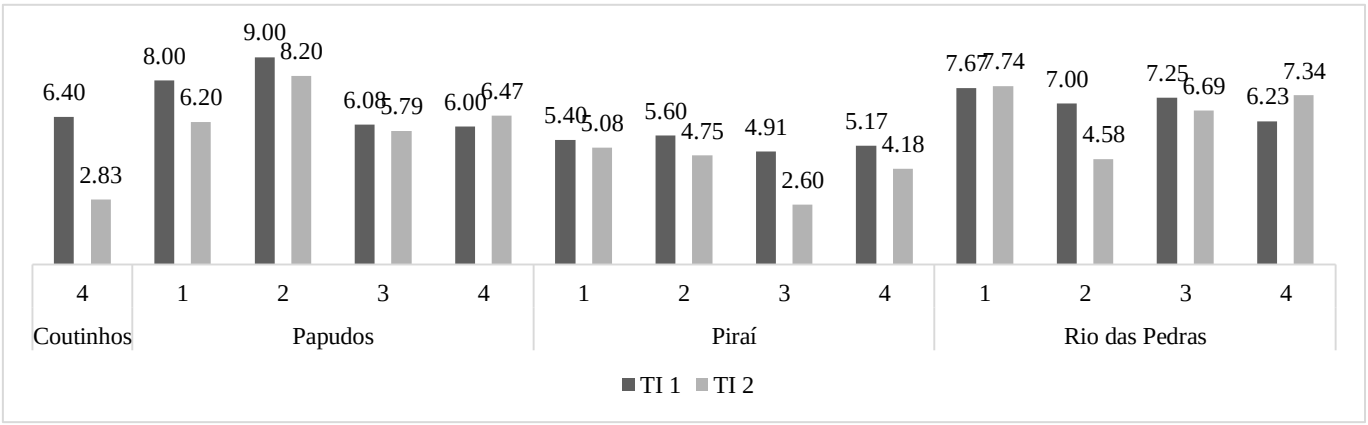

Figure 12. Taxonomic index values obtained for sampling sites in the upper Piraí drainage in September 2010 (dry season).

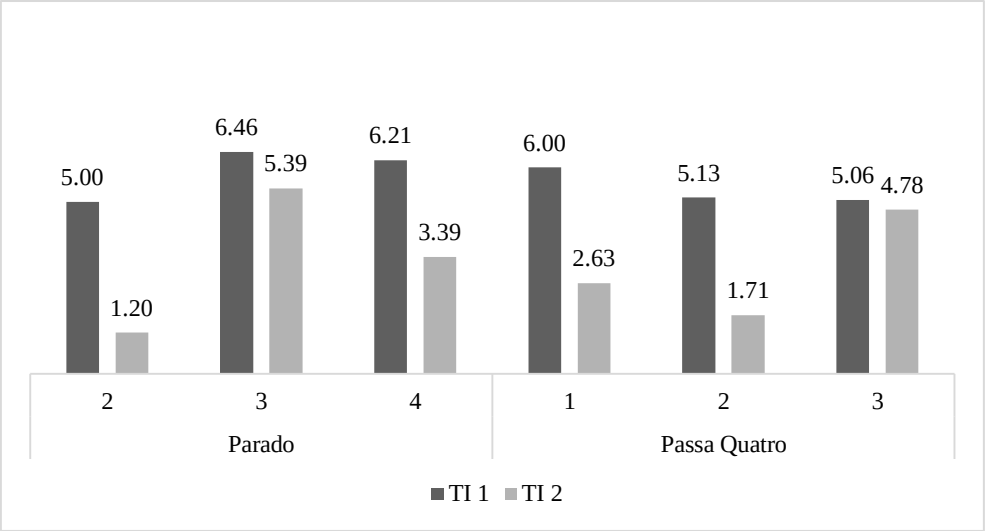

Figure 13. Taxonomic indices values obtained for sampling sites in the upper Piraí drainage in July 2015 (dry season).

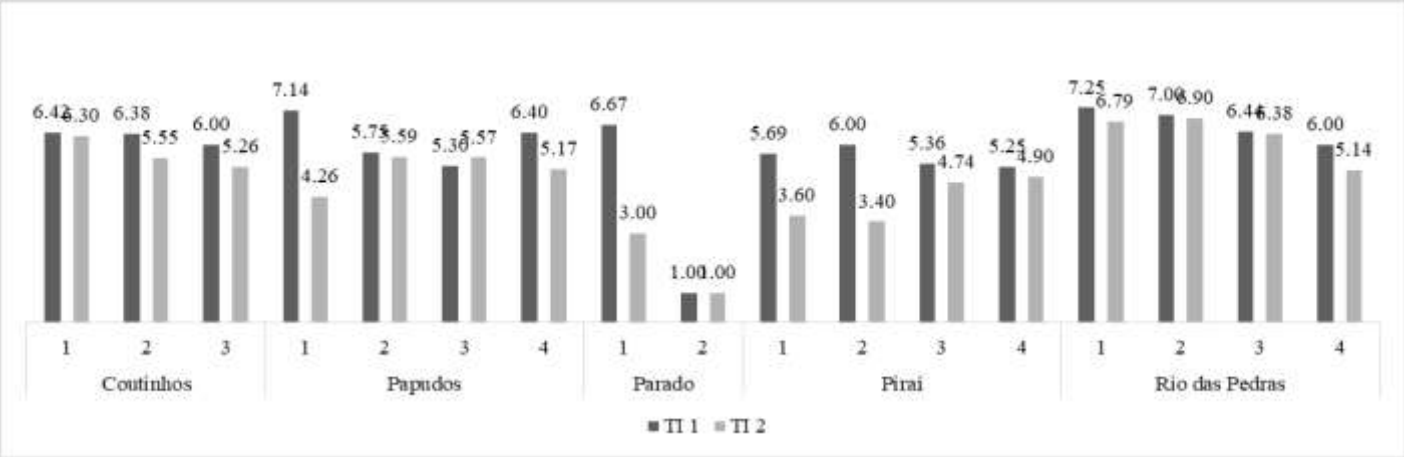

Figure 14. Taxonomic index values obtained for sampling sites in the upper Piraí drainage in April 2016 (rainy season).

3.3. Metric selection and MMI results

Metric screening resulted in the exclusion of 91 candidate metrics: 45 were eliminated in the range test, 25 in the responsiveness test and 21 in the redundancy test (Table 5).

Table 5. Candidate metrics and result of selection based on tests of range, responsiveness and redundancy. Legend: failed range test - 1; failed responsiveness test - 2; failed redundancy test - 3; used in MMI calculation - ✓.

Metric		**Failed Test**
1	Richness	3
2	Abundance of individuals	2
3	Number of orders	✓
4	% species of Characiformes & Siluriformes	3
5	% species of Characiformes	2
6	% individuals of Characiformes	2
7	% species of Siluriformes	3
8	% individuals of Siluriformes	2
9	% species of Gymnotiformes	3
10	% individuals of Gymnotiformes	3
11	% species of Salmoniformes	1
12	% individuals of Salmoniformes	1
13	% species of Gobiiformes	1
14	% individuals of Gobiiformes	1
15	% species of Cichliformes	✓
16	% individuals of Cichliformes	3
17	% species of Cyprinodontiformes	2
18	% individuals of Cyprinodontiformes	2
19	% species of Synbranchiformes	1
20	% individuals of Synbranchiformes	1
21	% species of Anabantiformes	1
22	% individuals of Anabantiformes	1
23	% species of Syngnathiformes	1
24	% individuals of Syngnathiformes	1
25	Numbers of families	3

26	% species of Crenuchidae	2
27	% individuals of Crenuchidae	2
28	% species of Erythrinidae	1
29	% individuals of Erythrinidae	1
30	% species of Anostomidae	1
31	% individuals of Anostomidae	1
32	% species of Curimatidae	1
33	% individuals of Curimatidae	1
34	% species of Lebiasinidae	1
35	% individuals of Lebiasinidae	1
36	% species of Characidae	2
37	% individuals of Characidae	2
38	% species of Trichomycteridae	✓
39	% individuals of Trichomycteridae	2
40	% species of Callichthyidae	1
41	% individuals of Callichthyidae	1
42	% species of Loricariidae	✓
43	% individuals of Loricariidae	2
44	% species of Auchenipteridae	1
45	% individuals of Auchenipteridae	1
46	% species of Heptapteridae	2
47	% individuals of Heptapteridae	2
48	% species of Pseudopimelodidae	1
49	% individuals of Pseudopimelodidae	1
50	% species of Gymnotidae	3
51	% individuals of Gymnotidae	3
52	% species of Sternopygidae	1
53	% individuals of Sternopygidae	1
54	% species of Salmonidae	1
55	% individuals of Salmomidae	1
56	% species of Eleotridae	1
57	% individuals of Eleotridae	1
58	% species of Oxudercidae	1

59	% individuals of Oxudercidae	1
60	% species of Cichlidae	3
61	% individuals of Cichlidae	3
62	% species of Poeciliidae	✓
63	% individuals of Poeciliidae	2
64	% species of Synbranchidae	1
65	% individuals Synbranchidae	1
66	% species of Osphronemidae	1
67	% individuals of Osphronemidae	1
68	% species of Syngnathidae	1
69	% individuals of Syngnathidae	1
70	Dominance	2
71	Diversity (Shannon Index)	3
72	Diversity (Simpson Index)	3
73	% common species (+50% of streams)	✓
74	% individuals of common species (+50% of streams)	3
75	Number of trophic categories	3
76	% detritivores species	3
77	% detritivores individuals	2
78	% invertivorous species	✓
79	% invertivorous individuals	2
80	% omnivorous species	3
81	% omnivorous individuals	2
82	% piscivorous species	✓
83	% piscivorous individuals	3
84	% herbivorous species	1
85	% herbivorous individuals	1
86	% benthic species	3
87	% benthic individuals	2
88	%mid-water species	2
89	%mid-water individuals	2
90	% hider species	3
91	% hider individuals	3

92	% Poecilia reticulata	1
93	% tolerant species	✓
94	% tolerant individuals	✓
95	% intermediate species	✓
96	% intermediate individuals	2
97	% sensitive species	2
98	% sensitive individuals	2
99	% native species	1
100	% native individuals	1
101	% exotic species	1
102	% exotic individuals	1

The remaining 11 metrics were selected for the calculation of MMI (Appendix 2 to 7). Five of those 11 metrics represented the taxonomic composition of the ictiofauna (number of orders, % species of Cichliformes, % species of Trichomycteridae, % species of Loricariidae, % species of Poeciliidae), one indicates species rarity (% common species (+50% of streams)), two were related to trophic structure (% invertivorous species, % piscivorous species), and three to level of tolerance (% tolerant species, % tolerant individuals and % sensitive species).

The MMI values varied between 15.6 and 81.49, with medium value of 49.27, across the sampled sites (Tables 6 to 11). The highest values of MMI were recorded on the two samplings in Guapiaçu 1 site. Along with Guapiaçu 1, the sites M. Alexandre 1, Macaé 1 and Macaé 4 were the only sites that registered acceptable environmental conditions. Environmental quality in sampling sites was classified as partially degraded in three sites in the Guapiaçu drainage, seven in Macaé and seven in Upper Piraí. According to the MMI, the most degraded environmental conditions were observed in Parado 2. Three sites in the Guapiaçu drainage, seven in the Macaé and 14 in the upper Piraí were considered degraded at least once.

Table 6. MMI values obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season).

	Guapiaçu			M. Alexandre
	1	3	4	1
MMI	80.67	53.84	48.36	79.66
% highest MMI	99%	66%	59%	98%

Table 7. MMI results obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season).

	Guapiaçu				M. Alexandre	Gato
	1	2	3	4	1	1
MMI	81.49	35.89	40.82	35.70	60.32	53.66
% highest MMI	100%	44%	50%	44%	74%	66%

Table 8. MMI results obtained for sampling sites in the Macaé river basin in June 2017 (dry season).

	Macaé								S. Bento
	1	2	3	4	5	6	7	8	1
MMI	66.06	48.77	44.38	76.96	46.81	37.62	54.05	42.45	42.90
% highest MMI	81%	60%	54%	94%	57%	46%	66%	52%	53%

Table 9. MMI results obtained for sampling sites in the Macaé river basin in November 2017 (rainy season).

	Macaé								S. Bento
	1	2	3	4	5	6	7	8	1
MMI	74.08	51.09	50.09	47.58	53.35	28.42	40.90	42.11	53.62
% highest MMI	91%	63%	61%	58%	65%	35%	50%	52%	66%

	Sana	
	1	2
MMI	56.11	50.94
% highest MMI	69%	63%

Table 10. MMI results obtained for sites in the upper Piraí drainage in July 2015 (dry season).

	Parado			P. Quatro		
	2	3	4	1	2	3
MMI	47.53	54.89	55.28	46.46	39.96	34.74
% highest MMI	58%	67%	68%	57%	49%	43%

Table 11. MMI results obtained for part of the sites in the upper Piraí drainage in April 2016 (rainy season).

	Coutinhos			Papudos				Parado	
	1	2	3	1	2	3	4	1	2
MMI	54.28	47.70	51.36	52.62	47.68	37.66	47.17	46.70	15.62
% highest MMI	67%	59%	63%	65%	59%	46%	58%	57%	19%

	Piraí				Pedras			
	1	2	3	4	1	2	3	4
MMI	43.97	48.36	37.16	35.78	50.66	49.60	40.63	46.84
% highest MMI	54%	59%	46%	44%	62%	61%	50%	57%

3.4. Correlation among indexes

Values of abiotic atributes mesuared in sampling points are listed bellow. Those values were used to calculate the environmental index (EI).

Table 12. Abiotic attributes obtained for sampling sites in the Guapiaçu river basin in August 2016 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	pH	Cond	Temp	Sub	Veg	Marg	EI
Guapiaçu 1	6.8	78	20	1	Sparse	Little	22
Guapiaçu 3	6.37	130	24	1	None	Common	14
Guapiaçu 4	6.55	173	25	1	None	Common	14
Manoel Alexandre 1	6.7	72	18	2	Common	Little	26

Table 13. Abiotic attributes obtained for sampling sites in the Guapiaçu river basin in December 2017 (rainy season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	pH	Cond	Temp	Sub	Veg	Marg	EI
Guapiaçu 1	6.25	52	20	1	Sparse	Little	22
Guapiaçu 2	7.62	80	26	2	Sparse	Common	22
Guapiaçu 3	7.19	102	26	1	None	Common	14
Guapiaçu 4	7.4	117	23.5	1	None	Common	14
Manoel Alexandre 1	7.2	50	21	2	Common	Little	26
Gato 1	6.89	56	23	2	Sparse	Little	24

Table 14. Abiotic attributes obtained for sampling sites in the Macaé river basin in June 2017 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	pH	Cond	Temp	Sub	Veg	Marg	EI
Macaé 1	7.95	28	15	1	Sparse	Little	20
Macaé 2	7.9	36	15.5	3	Sparse	Common	22
Macaé 3	8.32	97	16	2	None	Common	18
Macaé 4	8.22	57	16	3	Common	Little	26
Macaé 5	7.86	69	16	2	Sparse	Little	24
Macaé 6	8.04	80	21	2	None	Common	18
Macaé 7	7.8	94	22	1	None	Common	18
Macaé 8	6.85	106	21	1	None	Common	14

São Bento 1	8.22	70	16.5	2	Common	None	26

Table 15. Abiotic attributes obtained for sampling sites in the Macaé river basin in November 2017 (rainy season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	**pH**	**Cond**	**Temp**	**Sub**	**Veg**	**Marg**	**EI**
Macaé 1	6.5	37	16	1	Sparse	Little	22
Macaé 2	6.83	43	18.5	3	Sparse	Common	24
Macaé 3	6.9	69	20.5	2	None	Common	20
Macaé 4	7.7	74	22	3	Common	Little	28
Macaé 5	7.86	86	22	2	Sparse	Little	24
Macaé 6	7.7	107	26	2	None	Common	16
Macaé 7	7.63	120	26	1	None	Common	14
Macaé 8	7.31	121	26	1	None	Common	14
São Bento 1	7.75	86	20	2	Common	None	28
Sana 1	7.69	117	22	2	Sparse	Little	20
Sana 2	7.45	124	22.3	2	Sparse	Little	20

Table 16. Abiotic attributes obtained for sampling sites in the upper Piraí drainage in July 2015 (dry season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	**pH**	**Cond**	**Temp**	**Sub**	**Veg**	**Marg**	**EI**
Parado 2	7.4	35	18	1	Common	Little	20
Parado 3	7.45	46	22	3	None	Common	22
Parado 4	7.04	52	23	2	None	Common	20
Passa Quatro 1	6.9	102	20	2	None	Common	16
Passa Quatro 2	7.78	117	22	2	None	Common	16
Passa Quatro 3	7.64	129	23	3	None	Common	18

Table 17. Abiotic attributes obtained for sampling sites in the upper Piraí drainage in April 2016 (rainy season), and resulting environmental index based on grades defined by criteria described in Table 3. Legend: Potential of hydrogen - pH; Conductivity (µS cm^{-1}) - Cond; Temperature (◦C) - Temp; Substrate diversity (rocks, sand, silt) - Sub; Riparian vegetation cover - Veg; Margin alterations - Marg; Environmental index - EI.

Site	pH	Cond	Temp	Sub	Veg	Marg	EI
Coutinhos 1	8	78	21	3	Sparse	Little	24
Coutinhos 2	7.38	50	20	2	Common	None	28
Coutinhos 3	8.7	89	21	3	Sparse	Little	24
Papudos 1	7.8	35	18	3	Sparse	Little	26
Papudos 2	7.84	37	18.5	3	Common	None	30
Papudos 3	6.8	48	20	3	None	Common	22
Papudos 4	6.6	54	23	3	Sparse	Little	26
Parado 1	8.6	44	19	2	Common	None	26
Parado 2	8.6	44	19	1	Common	Little	22
Piraí 1	8.2	80	24.5	2	None	Common	18
Piraí 2	6.7	82	24	3	None	Common	22
Piraí 3	7.3	86	25	2	None	Common	20
Piraí 4	6.9	86	21	3	Sparse	Little	26
Rio das Pedras 1	8.08	56	20	2	Sparse	Little	22
Rio das Pedras 2	7.5	64	22	3	Sparse	Little	26
Rio das Pedras 3	6.84	71	22	3	None	Common	22
Rio das Pedras 4	7.9	71	23	2	None	Common	18

The three indexes demonstrated positive correlation with the EI (Figure 15), with TI 1 having the highest correlation ($r_s = 0.571$; $P = 7*10^{-6}$), followed by TI 2 ($r_s = 0.412$; $P = 0.002$) and MMI ($r_s = 0.325$; $P = 0.001$). The higher values of correlations presented by TIs, demonstrated greater capacity of those indexes to reflect changes in abiotic varables.

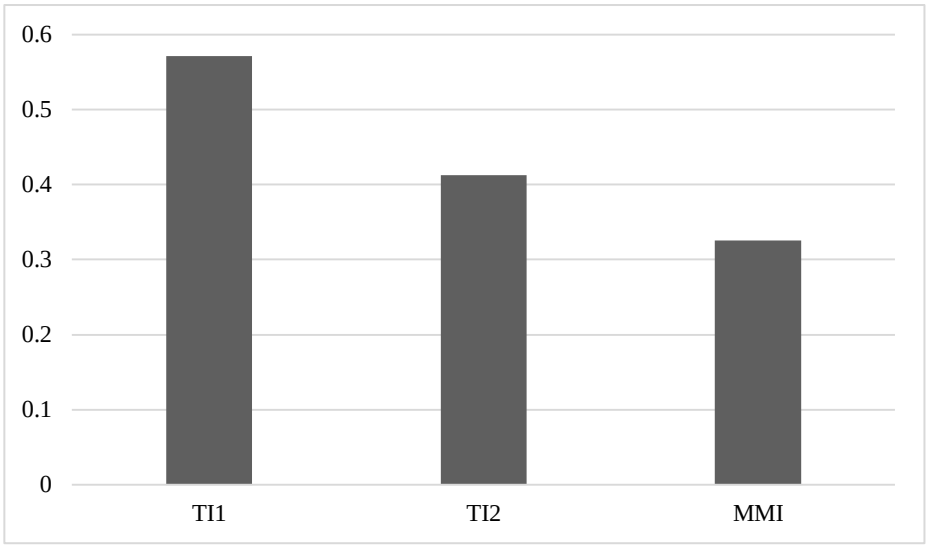

Figure 15. EI values in correlation with TI1, TI2 and MMI.

4. Discussion

The accumulation curves indicated differences in sampling sufficiency among the sampled drainages. The stabilization tendency of the species accumulation curves of the Macaé and upper Piraí drainages suggested that increase in sampling is unlikely to increase the number of collected species. However, the profile of the species accumulation curves of the Guapiaçu drainage indicates that more sampling would likely result in greater number of species collected. The species accumulation curve did not reach an asymptote in the Guapiaçu drainage, reflecting the lower number of samplings compared to the other two drainages, but richness estimator indicates that the inventory represented a high percentage of the hypothetical total of species (83%) in the Guapiaçu drainage. Therefore, the sampling effort in the three studied basins was adequate to represent the fish community of these freshwater systems, which is a requirement pointed by Karr (1981) to assess the biotic integrity of aquatic environments based on fish fauna.

The higher correlation between the taxonomic indexes and the EI support their use as proxies for environmental conditions without the need for extensive statistical screening of a large number of environmental metrics. Methodologies that demand lower effort facilitate the intensive application of biotic integrity indices in the evaluation of environmental quality by professionals and researchers who are not familiar with this type of evaluation. Thus, using the methodology proposed here, one can evaluate the environmental quality of multiple sites in coastal drainages of Southeastern Brazil by updating the scores attributed to species with information from taxa recorded in the targeted streams.

The methodology for calculating taxonomic indices developed here does not require the selection of reference sites. A limitation of studies that use MMI methodology in heavily impacted areas is the absence of pristine reference sites to calibrate selected metrics (Terra et al., 2013). The great majority of the Atlantic Forest has been devastated by human occupation and most the rivers that drain this biome cross urban or rural areas. Thus, it is a hard task to find undisturbed sites that can be used as a reference for environmental monitoring in the Atlantic Forest. Most of the remnant areas are protected as conservation units, which creates additional limitations for the use of reference sites in MMI methodologies. The great majority of preserved areas in coastal drainages of southeastern Brasil are located in headwaters, and the reference values for metrics obtained in preserved segments in those areas may not be applicable as reference values for preserved areas in different stretches of the rivers. Because the composition of fish fauna varies naturally across the altitude gradient of coastal rivers, pristine sites in upland regions cannot be used as reference for biotic integrity in lowland segments.

Another aspect of the methodology developed here is the possibility to evaluate the effect of species abundance. Unlike TI 1, the TI 2 allows for the evaluation of the environmental influence in the relative abundance. For instance, in the sampling of Parado and Passa Quatro (Figure 13), the results of TI 2 reflect the dominance of species resilient to negative impacts (e.g. *Phalloceros harpagos* and *Poecilia reticulata*) which is not reflected in the faunal composition alone, because these species are ubiquitous. However, results of TI 2 are more susceptible to variation in sampling sufficiency than TI 1. Therefore, standardized sampling methodology in all sampling points is a requirement for adequate application of Taxonomic Indexes.

All indexes demonstrated a direct relation betweenvariation in longitudinal gradient and biotic integrity. Overall, environmental conditions in sampling sites located near the headwaters were not classified as degraded. The fish comunities of these sampling sites (e.g. Guapiaçu 1, Macaé 1) were usually composed by species that indicate acceptable environmental conditions (e.g. *Pareiorhaphis garbei*, *Characidium spp.* and *Trichomycterus spp.*). On the other hand, lower stretches of the sampled rivers demonstrated fish fauna composed by a greater number of species that indicated lower environmental quality (e.g. *Geophagus brasiliensis*, *Poecilia spp.* and *Pyrrhulina australis*).

Some factors related to the history of human occupation in coastal drainages of Rio de Janeiro state are fundamental to understand this longitudinal gradient in habitat

health. First, lowland areas surrounding rivers were always targeted by extensive occupation by human-related activities, including farming and industrial activities that heavily degrade the health of riverine ecosystems. Agriculture and cattle raising properties occupy most of the margin of the rivers in this study, causing environmental damages such as reduction of riparian vegetation, erosion, and contamination of water by chemical substances. Large chemical industries are present near the Guapiaçu river mouth, where the Petrochemical Complex of Rio de Janeiro (Comperj) is installed. This petrochemical industries demanded huge infrastructure changes in the surrounding area, increasing demand for freshwater usage, and may release heavy loads of pollutants when the complex reaches its full potential, processing 450,000 barrels of crude oil a day (Siciliano et al., 2016).

Second, all three basins suffered artificial changes in the original river course in the lower regions. In the lower stretches of the Guapiaçu and Macaé rivers, straightening of river channels were made in order to prevent flooding, thus reducing the river habitat complexity, and increasing the current speed, resulting in homogenization of the river bed and increase in sedimentation of particulate matter (Assumpção, 2009; Pereira et al., 2012). In the Piraí river, the diversion of its original course by a system of artificial dams, tunnels and a water pumping station created a artificial barriers to fish migration, isolating and reducing populations of species that depend on migration flows for their natural life cycle.

Third, human occupation in mountain slopes and highland areas is scarcer than in lowland regions, which limits the impacts of human occupation to sites near the lower course of the river. Although there is some impacts in highland areas (e.g. abandoned damn in site Macaé 2), most of remaining Atlantic Forest in Rio de Janeiro state are located in mountain ranges. Some of those patches are part of natural reserves, in which the highest scores for environmental quality were registered by all three indexes: the sampling points Manoel Alexandre 1 and Macaé 1 are inside the buffer area of the RPPN Guapiaçu Ecological Reserve (REGUA) and the Statewide Environmental Protection Area of Macaé de Cima, respectively. In addition, the streams with better biotic integrity in the Upper Piraí basin, Rio das Pedras and Papudos, are target areas of a project for gallery forest restauration (Paiva & Coelho, 2015).

5. Conclusions

The taxonomic indexes developed in the present study demonstrated a simple and practical way to quantify environmental quality based on biotic integrity. The high

correlation among TI 1, TI 2 and environmental variables demonstrate that those index are able to reflect negative impacts along coastal drainages of Southern Brazil. This methodology also proved to be an alternative to the use of multimetric indexes, eliminating some of the limitations associated with the need to test and select environmental metrics. The development of simple methods, such as those proposed here, to monitor the ecological status of freshwater basins that are under human-induced impact is necessary in order to mitigate further depletion and create effective conservational plans.

References

Abilhoa, V., Braga, R. R., Bornatowski, H., & Vitule, J. R. S. (2011). Fishes of the Atlantic Rain Forest Streams : Ecological Patterns and Conservation. *Changing Diversity in Changing Environment*, 259–282. https://doi.org/www.intechopen.com

Alexandrino, E. R., Buechley, E. R., Karr, J. R., Ferraz, K. M. P. M. de B., Ferraz, S. F. de B., Couto, H. T. Z. do, & Şekercioğlu, Ç. H. (2017). Bird based Index of Biotic Integrity: Assessing the ecological condition of Atlantic Forest patches in human-modified landscape. *Ecological Indicators*, *73*, 662–675. https://doi.org/10.1016/j.ecolind.2016.10.023

Almeida, F. F. M., & Carneiro, C. D. R. (1998). Origem e evolução da Serra do Mar. *Revista Brasileira de Geociências*, *28*(2), 135–150. Retrieved from http://www.sbgeo.org.br/pub_sbg/rbg/vol28_down/2802/2802135.pdf

Almeida, R. S., & Cetra, M. (2016). Longitudinal gradient effects on the stream fish metacommunity. *Natureza & Conservação*, *14*(2), 112–119. https://doi.org/10.1016/j.ncon.2016.10.001

Andreata, J. V. (2012). Reprodução e alimentação de algumas espécies de peixes da lagoa rodrigo de freitas, Rio de Janeiro. *Oecologia Australis*, *16*(3), 501–524. https://doi.org/10.4257/oeco.2012.1603.11

Anjos, M. B., De Oliveira, R. R., & Zuanon, J. (2008). Hypoxic environments as refuge against predatory fish in the Amazonian floodplains. *Brazilian Journal of Biology*, *68*(1), 45–50.

Araújo, F. G. (1998). Adaptação do índice de integridade biótica usando a comunidade de peixes para o rio Paraíba do Sul. *Revista Brasileira de Biologia*, *58*(4), 547–558. https://doi.org/10.1590/S0034-71081998000400002

Araújo, F. G., Fichberg, I., Pinto, B. C. T., & Peixoto, M. G. (2003). A Preliminary Index

of Biotic Integrity for Monitoring the Condition of the Rio Paraiba do Sul, Southeast Brazil. *Environmental Management*, *32*(4), 516–526. https://doi.org/10.1007/s00267-003-3003-9

Araújo, F. G., Pinto, B. C. T., & Teixeira, T. P. (2009). Longitudinal patterns of fish assemblages in a large tropical river in southeastern Brazil: Evaluating environmental influences and some concepts in river ecology. *Hydrobiologia*, *618*(1), 89–107. https://doi.org/10.1007/s10750-008-9551-5

Assumpção, A. P. (2009). *Retificação De Canais Fluviais No Baixo Curso Da Bacia Do Rio Macaé (RJ) – Uma Abordagem Geomorfológica*. Universidade Federal do Rio de Janeiro.

Azevedo, R. S. (2011). *Ecologia alimentar de Characidium vidali Travassos , 1967 no Rio Macaé (RJ) revelada através de quatro ferramentas complementares*. Universidade Federal de Juiz de Fora.

Barbour, M. T., Gerritsen, J., Snyder, B. D., & Stribling, J. B. (1998). Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, Second Edition. *US Environmental Protection Agency Office of Water Washington DC*, *2nd*, 339. https://doi.org/EPA 841-B-99-002

Bizerril, C. R. S. F., & Primo, P. B. S. (2001). *Peixes de águas interiores do estado do Rio de Janeiro*. Rio de Janeiro: FEMAR - SEMADS.

Bozzetti, M., & Schulz, U. H. (2004). An index of biotic integrity based on fish assemblages for subtropical streams in southern Brazil. *Hydrobiologia*. https://doi.org/10.1007/s10750-004-5738-6

Braga, F. M. de S., & Gomiero, L. M. (2009). Alimentação de peixes na microbacia do Ribeirão Grande, Serra da Mantiqueira oriental, SP. *Biota Neotropica*, *9*(3), 207–212. https://doi.org/10.1590/S1676-06032009000300021

Brazil-Sousa, C., Marques, R. M., & Albrecht, M. P. (2009). Segregação alimentar entre duas espécies de Heptapteridae no Rio Macaé, RJ. *Biota Neotropica*, *9*(3), 31–37. https://doi.org/10.1590/S1676-06032009000300002

Brito, M. F. G. (2007). *Atividade reprodutiva dos peixes do rio Macaé (RJ) em função do gradiente longitudinal*. Universidade Federal do Rio de Janeiro.

Buckup, P. . A., Menezes, N. . A., & Ghazzi, M. S. (2007). *Catálogo das Espécies de Peixes de Água Doce do Brasil*. (P. . A. Buckup, N. . A. Menezes, & M. S. Ghazzi, Eds.). Rio de Janeiro, Brasil: Museu Nacional.

Carolina, A., & Castelo, C. (2005). Estudo da dieta natural de peixes no reservatório de

Ribeirão das Lages, Rio de Janeiro, Brasil, (1986), 355–364. https://doi.org/10.4025/actascibiolsci.v27i4.1270

Casatti, L., de Ferreira, C. P., & Carvalho, F. R. (2009). Grass-dominated stream sites exhibit low fish species diversity and dominance by guppies: An assessment of two tropical pasture river basins. *Hydrobiologia*, *632*(1), 273–283. https://doi.org/10.1007/s10750-009-9849-y

Castro, R. M. C., & Casatti, L. (1997). The fish fauna from a small forest stream of the upper Paraná River basin, southeastern Brazil. *Ichthyological Exploration of Freshwaters*, *7*(4), 337–352.

Cetra, M., & Ferreira, F. C. (2016). Fish-based Index of Biotic Integrity for wadeable streams from Atlantic Forest of south São Paulo State, Brazil. *Acta Limnologica Brasiliensia*, *28*(e22). https://doi.org/10.1590/S2179-975X1216

Chao, A., & Chiu, C. (2016). Nonparametric Estimation and Comparison of Species Richness. In *eLS* (pp. 1–11). Chichester, UK: John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470015902.a0026329

Chen, K., Hughes, R. M., Brito, J. G., Leal, C. G., Leitão, R. P., de Oliveira-Júnior, J. M. B., … Zuanon, J. (2017). A multi-assemblage, multi-metric biological condition index for eastern Amazonia streams. *Ecological Indicators*, *78*, 48–61. https://doi.org/10.1016/j.ecolind.2017.03.003

Chessman, B. C. (1995). Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. *Austral Ecology*, *20*(1), 122–129. https://doi.org/10.1111/j.1442-9993.1995.tb00526.x

Colwell, R. K. (2013). EstimateS: Statistical estimation of species richness and shared species from samples. Retrieved from http://purl.oclc.org/estimates

Corrêa, M. D. O. D. A., & Uieda, V. S. (2007). Diet of the ichthyofauna associated with marginal vegetation of a mangrove forest in southeastern Brazil. *Iheringia. Série Zoologia*, *97*(4), 486–497. https://doi.org/10.1590/S0073-47212007000400020

Coutinho, A. B., Aguiaro, T., Branco, C. W. C., Albuquerque, E. F., & Souza Filho, I. F. (2000). Alimentação de *Hyphessobrycon bifasciatus* Ellis, 1911 (Osteichthyes, Characidae) na Lagoa Cabiúnas, Macaé, RJ. *Acta Limnologica Brasiliensia*.

Czerniawska-Kusza, I. (2005). Comparing modified biological monitoring working party score system and several biological indices based on macroinvertebrates for water-quality assessment. *Limnologica*, *35*(3), 169–176.

https://doi.org/10.1016/j.limno.2005.05.003

de Carvalho, D. R., Leal, C. G., Junqueira, N. T., de Castro, M. A., Fagundes, D. C., Alves, C. B. M., Pompeu, P. S. (2017). A fish-based multimetric index for Brazilian savanna streams. *Ecological Indicators*, *77*(January), 386–396. https://doi.org/10.1016/j.ecolind.2017.02.032

de Souza Braga, F. M., Gomiero, L. M., & Souza, U. P. (2008). Aspectos da reprodução e alimentação de Neoplecostomus microps (loricariidae, neoplecostominae) na microbacia do Ribeirão Grande, serra da Mantiqueira oriental (Estado de São Paulo). *Acta Scientiarum - Biological Sciences*, *30*(4), 455–463. https://doi.org/10.4025/actascibiolsci.v30i4.301

Dias, T. S., & Fialho, C. B. (2011). Comparative dietary analysis of *Eurycheilichthys pantherinus* and *Pareiorhaphis hystrix*: two Loricariidae species (Ostariophysi, Siluriformes) from Campos Sulinos biome, southern Brazil. *Iheringia. Série Zoologia*, *101*(1–2), 49–55. https://doi.org/10.1590/S0073-47212011000100006

dos Santos, F. B., & Esteves, K. E. (2015). A Fish-Based Index of Biotic Integrity for the Assessment of Streams Located in a Sugarcane-Dominated Landscape in Southeastern Brazil. *Environmental Management*, *56*(2), 532–548. https://doi.org/10.1007/s00267-015-0516-y

Eschmeyer, W. N., Fricke, R., & van der Laan, R. (2018). CATALOG OF FISHES: GENERA, SPECIES, REFERENCES. Retrieved January 25, 2018, from http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp

Esguicero, A. L. H., & Arcifa, M. S. (2010). Biology and population features of a rare species of Pseudopimelodidae from the Upper Parana River Basin. *Biota Neotropica*, *10*(3), 161–167. https://doi.org/10.1590/s1676-06032010000300018

European Commission. (2000). Directive 2000/60/EC of the European Parlament and Council, establishing a framework for Community action in the field of water policy. *Official Journal of the European Union*, *L327*, 1–72.

Ferreira, C. D. P., & Casatti, L. (2006). Integridade biótica de um córrego na bacia do Alto Rio Paraná avaliada por meio da comunidade de peixes. *Biota Neotropica*, *6*(3), 1–25. https://doi.org/10.1590/S1676-06032006000300002

Galindo-Leal, C., & Câmara, I. G. (2003). Atlantic Forest hotspots status: an overview. In *The Atlantic Forest of south america: biodiversity status, threats, and outlook* (pp. 3–11). https://doi.org/10.1007/s10980-005-1788-z

Gärdenfors, U., Hilton-Taylor, C., Mace, G. M., & Rodríguez, J. P. (2001). The Application of IUCN Red List Criteria at Regional Levels. *Conservation Biology*, *15*(5), 1206–1212. https://doi.org/10.1111/j.1523-1739.2001.00112.x

GBIF.org. (2018). GBIF Home Page. Retrieved January 25, 2018, from https://www.gbif.org

Gomes, A. D., Correia, T. G., & Moreira, R. G. (2010). Fatty acids as trophic biomarkers in vitellogenic females in an impounded tropical river. *Fish Physiology and Biochemistry*, *36*(3), 699–718. https://doi.org/10.1007/s10695-009-9345-3

Gomiero, L., Manzatto, A., & Braga, F. (2008). The role of riverine forests for food supply for the omnivorous fish *Brycon opalinus* Cuvier, 1819 (Characidae) in the Serra do Mar, Southeast Brazil. *Brazilian Journal of Biology*, *68*(2), 321–328. https://doi.org/10.1590/S1519-69842008000200013

Gonçalves, C. da S., & Cestari, C. (2013). The use of an Atlantic Forest stream by the catfish Scleromystax barbatus (Quoy & Gaimard, 1824). *Neotropical Biology and Conservation*, *8*(3), 115–120. https://doi.org/10.4013/nbc.2013.83.01

Gurgel, H. C. B., & Canan, B. (1999). Feeding of six fish species in Jiqui Lagoon, eastern coast of Rio Grande do Norte, Brazil. *Acta Scientiarum. Biological Sciences*, *21*(2), 243–246.

Gurgel, H. D. C. B., Almeida, R. G. De, Barbieri, G., & Vieira, L. J. S. (1998). Dieta de *Crenicichla lepidota* Heckel, 1840 (Perciformes, Cichlidae) da lagoa Redonda, Nísia Floresta/RN. *Acta Scientiarum. Biological Sciences*, *20*(0), 191–194. https://doi.org/10.4025/actascibiolsci.v20i0.4472

Harrell, F. E. J. (2018). Hmisc: Harrell Miscellaneous. Retrieved from http://biostat.mc.vanderbilt.edu/Hmisc

Henriques, S., Pais, M. P., Batista, M. I., Costa, M. J., & Cabral, H. N. (2013). Response of fish-based metrics to anthropogenic pressures in temperate rocky reefs. *Ecological Indicators*, *25*, 65–76. https://doi.org/10.1016/j.ecolind.2012.09.003

Hering, D., Feld, C. K., Moog, O., & Ofenböck, T. (2006). Cook book for the development of a Multimetric Index for biological condition of aquatic ecosystems: Experiences from the European AQEM and STAR projects and related initiatives. *Hydrobiologia*, *566*(1), 311–324. https://doi.org/10.1007/s10750-006-0087-2

Hughes, R. M., Kaufmann, P. R., Herlihy, A. T., Kincaid, T. M., Reynolds, L., & Larsen, D. P. (1998). A process for developing and evaluating indices of fish assemblage integrity. *Canadian Journal of Fisheries and Aquatic Sciences*, *55*(7), 1618–1631.

https://doi.org/10.1139/f98-060

Hughes, R., Paulsen, S., & Stoddard, J. (2000). EMAP-Surface Waters: a multiassemblage, probability survey of ecological integrity in the USA. *Hydrobiologia*, *422/423*(3), 429–443. https://doi.org/10.1023/A:1017029107669

IUCN. (2012). *IUCN Red List Categories and Criteria: Version 3.1* (Vol. Second edi). Gland: IUCN.

Jaramillo-Villa, U., & Caramaschi, É. P. (2008). Índices De Integridade Biótica Usando Peixes De Água Doce: Uso Nas Regiões Tropical E Subtropical. *Oecologia Australis*, *12*(3), 442–462. https://doi.org/10.4257/oeco.2008.1203.06

Karr, J. R. (1981). Assessment of Biotic Integrity Using Fish Communities. *Fisheries*, *6*(6), 21–27. https://doi.org/10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2

Karr, J. R., Fausch, K. D., Angermeier, P. L., Yant, P. R., & Schlosser, I. J. (1986). Assessing biological integrity in running waters: A method and its rationale. *Illinois Natural History Survey Special Publication 5*, *5*(August), 28. Retrieved from http://limnoreferences.missouristate.edu/assets/limnoreferences/Karr_et_al._1986.pdf

Lazzarotto, H., & Caramaschi, É. P. (2009). Introdução da truta no Brasil e na bacia do rio Macaé, estado do Rio de Janeiro: histórico, legislação e perspectivas. *Oecologia Brasiliensis*, *13*(04), 649–659. https://doi.org/10.4257/oeco.2009.1304.08

Leitão, R. P., Caramaschi, É. P., & Zuanon, J. (2007). Following food clouds: feeding association between a minute loricariid and a characidiin species in an Atlantic Forest stream, Southeastern Brazil. *Neotropical Ichthyology*, *5*(3), 307–310. https://doi.org/10.1590/S1679-62252007000300011

Livro vermelho da fauna brasileira ameaçada de extinção. (2016). Brasilia: ICMBio.

Mazzoni, R., & Costa, L. D. S. da. (2007). Feeding ecology of stream-dwelling fishes from a coastal stream in the Southeast of Brazil. *Brazilian Archives of Biology and Technology*, *50*(4), 627–635. https://doi.org/10.1590/S1516-89132007000400008

Mazzoni, R., Marques, P., Rezende, C., & Iglesias-Rios, R. (2012). Niche enlargement as a consequence of co-existence: a case study. *Brazilian Journal of Biology*, *72*(2), 267–274. https://doi.org/10.1590/S1519-69842012000200006

Mazzoni, R., & Rezende, C. (2009). Daily feeding activity of *Bryconamericus microcephalus* (Characiformes, Characidae) from Córrego Andorinha, Ilha Grande - RJ. *Brazilian Journal of Biology*, *69*(2), 381–384. https://doi.org/10.1590/S1519-

69842009000200021

McCormick, F. H., Hughes, R. M., Kaufmann, P. R., Peck, D. V., Stoddard, J. L., & Herlihy, A. T. (2001). Development of an Index of Biotic Integrity for the Mid-Atlantic Highlands Region. *Transactions of the American Fisheries Society*, *130*(5), 857–877. https://doi.org/10.1577/1548-8659(2001)130<0857:DOAIOB>2.0.CO;2

Miserendino, M. L., & Pizzolón, L. (1999). Rapid Assessment of River Water Quality Using Macroinvertebrates: A Family Level Biotic Index for the Patagonic Andean Zone. *Acta Limnologica Brasiliensia*.

Moraes, M. B. de, & Braga, F. M. de S. (2011). Biologia populacional de *Imparfinis minutus* (Siluriformes, Heptapteridae) na microbacia do Ribeirão Grande, serra da Mantiqueira oriental, Estado de São Paulo. *Acta Scientiarum. Biological Sciences*, *33*(3), 301–310. https://doi.org/10.4025/actascibiolsci.v33i3.6591

Nelson, J. S., Grande, T. C., & Wilson, M. V. H. (2016). *Fishes of the World* (5th ed.). Hoboken: John Wiley & Sons.

Nogueira, C., Buckup, P. A., Menezes, N. A., Oyakawa, O. T., Kasecker, T. P., Ramos Neto, M. B., & da Silva, J. M. C. (2010). Restricted-Range Fishes and the Conservation of Brazilian Freshwaters. *PLoS ONE*, *5*(6), e11390. https://doi.org/10.1371/journal.pone.0011390

Oberdorff, T., & Hughes, R. M. (1992). Modification of an index of biotic integrity based on fish assemblages to characterize rivers of the Seine Basin, France. *Hydrobiologia*, *228*, 117–130.

Ofenböck, T., Moog, O., Sharma, S., & Korte, T. (2010). Development of the HKHbios: A new biotic score to assess the river quality in the Hindu Kush-Himalaya. *Hydrobiologia*, *651*(1), 39–58. https://doi.org/10.1007/s10750-010-0289-5

Oliveira, R. B. S., Baptista, D. F., Mugnai, R., Castro, C. M., & Hughes, R. M. (2011). Towards rapid bioassessment of wadeable streams in Brazil: Development of the Guapiaçu-Macau Multimetric Index (GMMI) based on benthic macroinvertebrates. *Ecological Indicators*, *11*(6), 1584–1593. https://doi.org/10.1016/j.ecolind.2011.04.001

Ottoni, F. P., & Katz, A. M. (2017). Feeding Ecology of the Genus *Australoheros* (Teleostei: Cichlidae: Cichlinae) Based on Examined Specimens and Literature Information. *Boletim Do Laboratório de Hidrobiologia*, *27*(2017), 13–18.

Paisley, M. F., Trigg, D. J., & Walley, W. J. (2014). Revision of the biological monitoring working party (BMWP) score system: Derivation of present-only and abundance-

related scores from field data. *River Research and Applications*, *30*(7), 887–904. https://doi.org/10.1002/rra.2686

Paiva, R. F. da P. de S., & Coelho, R. C. (2015). O Programa Produtor de Água e Floresta de Rio Claro/RJ enquanto ferramenta de gestão ambiental: o perfil e a percepção ambiental dos produtores inscritos. *Desenvolvimento e Meio Ambiente*, *33*, 51–62. https://doi.org/10.5380/dma.v33i0.36702

Pereira, P. da S., Fernandes, L. A. C., Oliveira, J. L. da M., & Baptista, D. F. (2012). Avaliação da integridade ecológica de rios em áreas do zoneamento ecológico econômico do complexo hidrográfico Guapiaçu-Macacu, RJ, Brasil. *Ambiente e Agua - An Interdisciplinary Journal of Applied Science*, *7*(1), 157–168. https://doi.org/10.4136/ambi-agua.762

Perrone, E. C., & Vieira, F. (1991). Habito alimentar de *Eleotris pisonis* (Teleostei: Eleotrididae) na região estuarina do rio Jucu, Espírito Santo, Brasil. *Revista Brasileira de Biologia*, *51*(4), 867–872.

Petesse, M. L., Siqueira-Souza, F. K., de Carvalho Freitas, C. E., & Petrere, M. (2016). Selection of reference lakes and adaptation of a fish multimetric index of biotic integrity to six amazon floodplain lakes. *Ecological Engineering*, *97*, 535–544. https://doi.org/10.1016/j.ecoleng.2016.10.046

R Core Team. (2018). R: A language and environment for statistical computing. *R Foundation for Statistical Computing*. Vienna, Austria. Retrieved from http://www.r-project.org/

Ribeiro, A. C. (2006). Tectonic history and the biogeography of the freshwater fishes from the coastal drainages of eastern Brazil: An example of faunal evolution associated with a divergent continental margin. *Neotropical Ichthyology*, *4*(2), 225–246. https://doi.org/10.1590/S1679-62252006000200009

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, *142*(6), 1141–1153. https://doi.org/10.1016/j.biocon.2009.02.021

Rodrigues Capítulo, A., Tangorra, M., & Ocón, C. (2001). Use of benthic macroinvertebrates to assess the biological status of Pampean streams in Argentina. *Aquatic Ecology*, *35*(2), 109–119. https://doi.org/10.1023/A:1011456916792

Rodrigues, D. (2013). *Ecologia trófica das principais espécies de peixes do Rio Paraíba do sul na área de influência do aproveitamento hidrelétrico Simplício durante o*

período pré – represamento. Universidade Federal de Juiz de Fora.

Ross, S. T. (1991). Mechanisms structuring stream fish assemblages: are there lessons from introduced species? *Environmental Biology of Fishes*, *30*, 359–368. https://doi.org/10.1007/BF02027979

SEMADS. (2001). *Bacias hidrográficas e rios fluminenses - síntese informativa por macroregião*. Rio de Janeiro: Planágua.

Siciliano, A. M., Silva, C. E. F. C., & Corrêa, S. M. (2016). Ozone forming potential at Rio de Janeiro petrochemical complex, Brazil. *Revista Virtual de Quimica*, *8*(3), 1004–1019. https://doi.org/10.5935/1984-6835.20160071

Souza, U. P., Ferreira, F. C., Carmo, M. A. F., & Braga, F. M. S. (2015). Feeding and reproductive patterns of *Astyanax intermedius* in a headwater stream of Atlantic Rainforest. *Anais Da Academia Brasileira de Ciências*, *87*(4), 2151–2162. https://doi.org/10.1590/0001-3765201520140673

Terra, B. D. F., Hughes, R. M., Francelino, M. R., & Araújo, F. G. (2013). Assessment of biotic condition of atlantic rain forest streams: A fish-based multimetric approach. *Ecological Indicators*, *34*, 136–148. https://doi.org/10.1016/j.ecolind.2013.05.001

Uieda, V. S., & Castro, R. M. C. (1999). Coleta e Fixação de Peixes de Riacho. *Oecologia Brasiliensis*, *6*, 1–22.

USEPA. (2009). *National Lakes Assessment: a collaborative survey of the Nation's lakes. EPA 841/R-09/001*. Washington: Office of Wetlands, Oceans and Watersheds and Office of Research and Development.

USEPA. (2013). *National Rivers and Streams Assessment 2008–2009: a collaborative survey. EPA/841/D-13/001*. Washington: Office of Wetlands, Oceans and Watersheds and Office of Research and Development.

Whittier, T. R., Hughes, R. M., Stoddard, J. L., Lomnicky, G. A., Peck, D. V., & Herlihy, A. T. (2007). A Structured Approach for Developing Indices of Biotic Integrity: Three Examples from Streams and Rivers in the Western USA. *Transactions of the American Fisheries Society*, *136*(3), 718–735. https://doi.org/10.1577/T06-128.1

Wolff, L. L., Carniatto, N., & Hahn, N. S. (2013). Longitudinal use of feeding resources and distribution of fish trophic guilds in a coastal Atlantic stream, southern Brazil. *Neotropical Ichthyology*, *11*(2), 375–386. https://doi.org/10.1590/S1679-62252013005000005

Zuanon, J., Bockmann, F. A., & Sazima, I. (2006). A remarkable sand-dwelling fish assemblage from central Amazonia, with comments on the evolution of

psammophily in South American freshwater fishes. *Neotropical Ichthyology*, *4*(1), 107–118. https://doi.org/10.1590/S1679-62252006000100012

Capítulo II

The fish fauna of the upper Piraí drainage, a transposed mountain river system in southeastern, Brazil

Introduction

The Brazilian Atlantic Forest is the second largest biome in the South America, with one of the highest rates of species richness and endemism of the planet (Galindo-Leal and Câmara 2003, Ribeiro et al. 2009). Due to environmental impacts originated from human activities, only 16% of the original forest is preserved in reduced and isolated patches (Ribeiro et al. 2009, 2011). Freshwater streams in southeastern Brazil are directly affected by the degradation of the Atlantic Forest, as their headwaters are located in these few remaining patches of forest, and the reduction of the riparian vegetation is one of the main sources of environmental impact in water bodies (Cetra and Ferreira 2016). Systematic surveys of fish communities that inhabit these streams are necessary to reduce knowledge gaps about biodiversity and the state of conservation of the Atlantic Forest (Buckup et al. 2014).

The upper Piraí river drainage (Figure 1) is a former tributary of the Paraíba do Sul river basin that has been artificially diverted to the Guandu river system through a complex system of tunnels and pumps to generate electric power and water for the metropolitan area of Rio de Janeiro. The Piraí river drains the Biodiversity Corridor Tinguá-Bocaina (BCTB) (Paiva and Coelho, 2015). The BCTB connects Atlantic Forest fragments delimited by the Tinguá Biologic Reserve, on the central region of Rio de Janeiro, and the National Park of Serra da Bocaina, on the southern coast of the state. The BCTB is one of the most important priority areas for the preservation of the Atlantic Forest biodiversity due to its location at the most critical point of fragmentation of the largest continuous area of this biome in the Serra do Mar (Vilar et al. 2012). In the present study, we surveyed the ichthyofauna from Upper Piraí drainage in order to provide an annotated checklist of freshwater fish species occurring in the study area. This study is part of a long term program to monitor the effects of forest restoration in the Guandu river system (Vilar et al. 2012, Castello Branco 2015), and it is a geographically expanded and updated inventory of fish species carried in previous studies (Buckup et al. 2014).

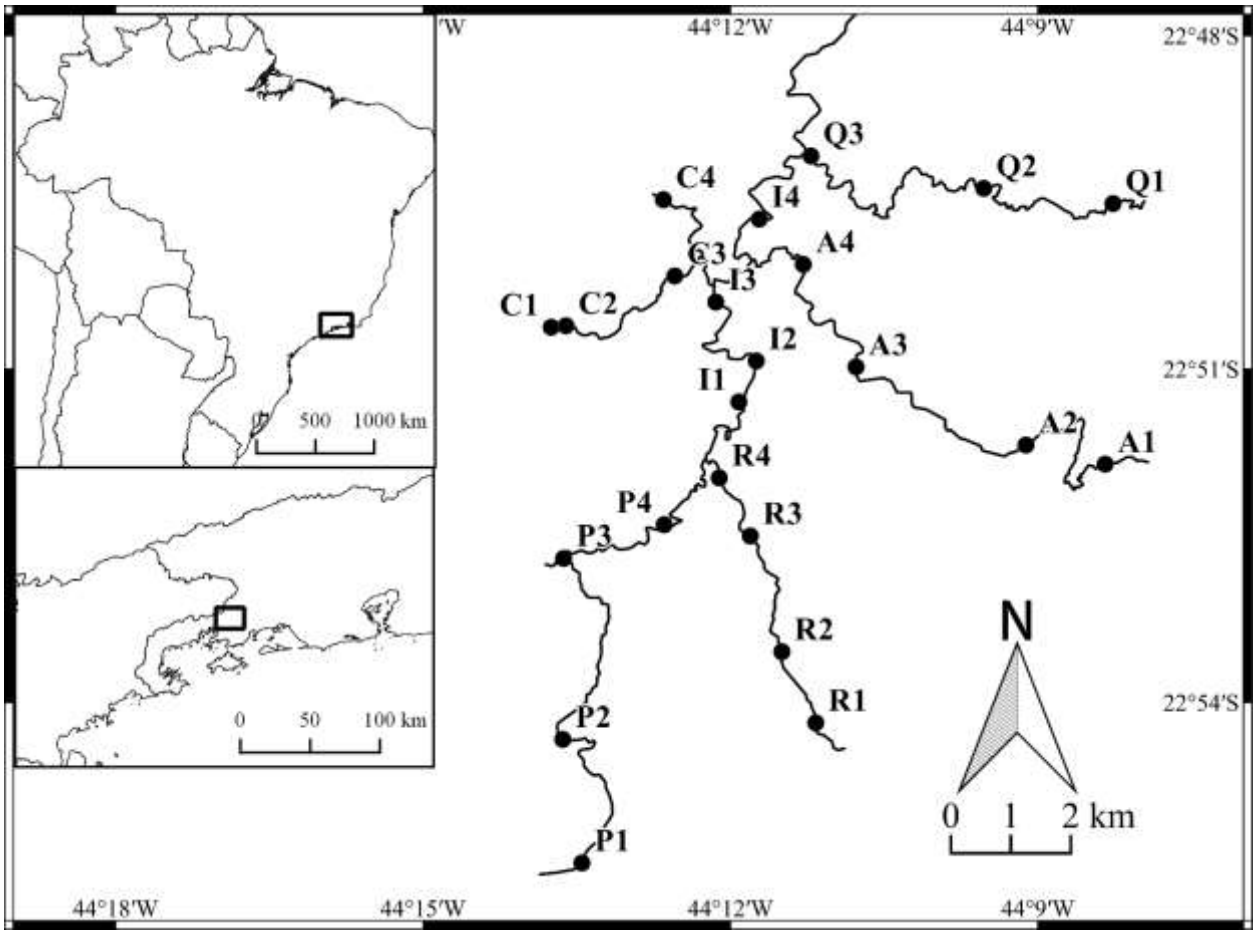

Figure 1. Map of the upper Piraí river drainage, indicating the collecting sites along the streams Coutinhos (C), Papudos (P), Parado (A), Passa Quatro (Q) and Rio das Pedras (R), and the main channel Piraí (I). Geographic coordinates and altitude of the sites are listed on Table 1.

Methods

Study Area. The Piraí river drainage is located within the boundaries of the municipalities of Rio Claro and Barra do Piraí, Rio de Janeiro state, southeastern Brazil. The Piraí river was originally a major right-bank tributary of the Paraíba do Sul river, but since the beginning of the 20th century it has been artificially diverted to the coastal Guandu river basin, in the Rio de Janeiro Metropolitan Region. The headwaters of the Piraí drainage is composed by streams that flow from the northern face of the mountain system of Serra do Mar. This mountain chain has an extension of 1.000 km between Rio de Janeiro state, in the northern extremity, and north of Santa Catarina state, in the southern border (Almeida and Carneiro 1998).

Sampling. Fish were collected in 23 sampling sites along six streams, Coutinhos, Papudos, Parado, Passa Quatro and Rio das Pedras, and the main channel of the upper Piraí river drainage (Table 1, Figure 1) in four expeditions between the years of 2009 and 2016, under collecting permit 12129, issued by the Instituto Chico Mendes de Conservação da Biodiversidade. The sampling sites were selected in order to cover a wide range of habitats, from the alluvial plain of the streams to the high-mountain rapids. Each site was surveyed during one hour of exhaustive sampling activity by a team of five ichthyologists with prior experience in stream fish capture methods. Fishing equipment included beach seines (2, 3, 5 and 15 m long, 4 mm nylon mesh), dip nets with metal handles (40 x 90 cm basket area, 2 mm plastic mesh), casts nets (12 mm mesh size). An acoustic amplifier of electric signals was used detect specimens of the order Gymnotiformes hidden in marginal vegetation and rocks. Most of the collected specimens were fixed in 10% formalin solution and transferred to 70% ethanol after 48 hours. Part of the specimens were preserved in anhydrous ethanol for DNA-sequencing studies. The examined specimens were deposited in the ichthyological collection of the Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ). Standard length, abbreviated as SL, was measured to the base of the middle caudal-fin rays.

Table 1. Geographic coordinates from the sampling sites in the Upper Piraí river drainage, Rio de Janeiro State, Brazil.

Stream	Site	Latitude (S)	Longitude (W)	Altitude (m)
Coutinhos	C1	22° 50' 37.4"	44° 13' 45"	610
	C2	22° 50' 36.6"	44° 13' 36.3"	582
	C3	22° 50' 09.7"	44° 12' 32.6"	537
	C4	22° 49' 28.5"	44° 12' 39.3"	572
Papudos	P1	22° 55' 26.6"	44° 13' 27"	1002
	P2	22° 54' 19.9"	44° 13' 38.2"	951
	P3	22° 52' 42.2"	44° 13' 37.7"	571
	P4	22° 52' 24"	44° 12' 38.8"	563
Parado	A1	22° 51' 51.3"	44° 08' 20.6"	1050
	A2	22° 51' 41"	44° 09' 07,1"	976
	A3	22° 50' 58.8"	44° 10' 46.5"	561
	A4	22° 50' 03.5"	44° 11' 17.4"	545

Passa Quatro	Q1	22° 49' 30.6"	44° 08' 16"	712
	Q2	22° 49' 22.4"	44° 09' 31.7"	622
	Q3	22° 49' 04.9"	44° 11' 12.9"	513
Piraí	I1	22° 51' 17.7"	44° 11' 55.1"	555
	I2	22° 50' 55.6"	44° 11' 44.9"	548
	I3	22° 50' 23.8"	44° 12' 08.6"	535
	I4	22° 49' 39"	44° 11' 43.2"	519
Rio das Pedras	R1	22° 54' 11"	44° 11' 10.1"	842
	R2	22° 53' 32.6"	44° 11' 29.9"	786
	R3	22° 52' 30.1"	44° 11' 48.4"	576
	R4	22° 51' 58.7"	44° 12' 06.6"	554

Results

In this study, 7,860 fish specimens of 32 species belonging to 24 genera and 12 families were collected in the upper Piraí river drainage (Table 2). Among the river sections that comprise the sampled drainage, the main channel of the Piraí river had the higher species richness, with 22 species. The number of species captured in the other five streams varied between 18 in Coutinhos, Passa Quatro e Rio das Pedras, and 17 in Papudos e Parado. Bottom-inhabiting catfishes were the most diverse taxonomic group, including 16 species of Siluriformes (50%), followed by nine Characiformes (28%), four Cichliformes (13%), two Cyprinodontiformes (6%) and one Gymnotiformes (3%). The most diverse families were the Loricariidae with nine species (28%), the Characidae and Cichlidae, with four species (13%) each, and the Trichomycteridae and Heptapteridae, with three species (9%) each.

Phalloceros harpagos was the most abundant species, with 2,437 specimens (31.1%), followed by *Astyanax intermedius* with 1,597 (20.4%), *Neoplecostomus microps* with 676 (8.6%), *Pareiorhina rudolphi* with 553 (7.1%), *Geophagus brasiliensis* with 497 (6.4%) and *Characidium lauroi* with 444 (5.7%). These six species combined represented 79.3% of all specimens collected in all sampled sites. Some species were notably rare in the samples, including *Astyanax* sp. aff. *A. scabripinnis, Hemipsilichthys gobio,* and *Hypostomus luetkeni* which were represented by one specimen each. The three most abundant species were also the most widely distributed along the Upper Piraí drainage, with *P. harpagos* absent only in one site (C2), *N. microps* absent in two sites (A1, A2), and *A. intermedius* absent in three sites (A1, A2, R1). *Trichomycterus*

nigroauratus, *G. brasiliensis* and *T. macrophthalmus* were also widely distributed, having been present in 18, 16 and 14 sites, respectively.

Table 2. List of the freshwater fishes of upper Piraí river drainage and catalog numbers of voucher specimens.

	Sites																					Catalog number (number of exemplars)
Taxon	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
CHARACIFORMES																								
Anostomidae																								
Hypomasticus mormyrops																			X			X	X	MNRJ 46698 (3), MNRJ 47001 (2), MNRJ 47012 (1), MNRJ 47256 (1)
Crenuchidae																								
Characidium lauroi		X					X	X								X	X			X	X	X	X	MNRJ 36451 (3), MNRJ 36458 (3), MNRJ 36472 (32), MNRJ 36486 (1), MNRJ 36508 (50), MNRJ 36518 (6), MNRJ 37977 (1), MNRJ 38019 (26), MNRJ 38032 (13), MNRJ 38039 (10), MNRJ 38045 (25), MNRJ 43748 (39), MNRJ 43759 (5), MNRJ 43806 (18), MNRJ 46650 (8), MNRJ 46668 (73), MNRJ 46690 (25), MNRJ 46702 (20), MNRJ 47260 (29)
Characidium vidali	X		X								X	X		X	X	X	X					X	X	MNRJ 36457 (1), MNRJ 36471 (1), MNRJ 36497 (1), MNRJ 36507 (10), MNRJ 38018 (69), MNRJ 38031 (13), MNRJ 43758 (37), MNRJ 43767 (1), MNRJ 43807 (7), MNRJ 43821 (3), MNRJ 46636 (2), MNRJ 46822 (3), MNRJ 47023 (1), MNRJ 47261 (14)
Bryconidae																								
Brycon opalinus																						X	X	MNRJ 38022 (3), MNRJ 46701 (1), MNRJ 47259 (25)

Table 2. *Continued.*

Taxon	Sites																						Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
Characidae																								
Astyanax giton																X	X	X	X				X	MNRJ 37834 (1), MNRJ 37835 (20), MNRJ 37974 (5), MNRJ 37986 (2), MNRJ 38021 (5), MNRJ 50819 (1), MNRJ 50820 (2)
Astyanax intermedius	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X		X	X	X	MNRJ 36459 (15), MNRJ 36473 (21), MNRJ 36487 (21), MNRJ 36498 (29), MNRJ 36510 (81), MNRJ 36519 (51), MNRJ 36524 (22), MNRJ 37954 (5), MNRJ 37965 (28), MNRJ 37978 (34), MNRJ 38020 (51), MNRJ 38033 (42), MNRJ 38040 (19), MNRJ 38053 (10), MNRJ 38087 (31), MNRJ 43749 (79), MNRJ 43755 (58), MNRJ 43766 (74), MNRJ 43805 (16), MNRJ 43820 (15), MNRJ 46631 (20), MNRJ 46643 (95), MNRJ 46689 (23), MNRJ 46699 (10), MNRJ 46713 (15), MNRJ 46791 (11), MNRJ 46813 (92), MNRJ 47002 (14), MNRJ 47014 (6), MNRJ 47257 (91)
Astyanax sp. aff. *scabripinnis*							X																	MNRJ 36427 (1)
Oligosarcus hepsetus		X	X				X	X			X				X	X	X	X	X			X	X	MNRJ 36460 (2), MNRJ 36474 (2), MNRJ 36488 (1), MNRJ 36499 (5), MNRJ 36509 (3), MNRJ 37966 (2), MNRJ 37979 (1), MNRJ 38023 (3), MNRJ 38034 (16), MNRJ 38052 (2), MNRJ 43768 (6), MNRJ 43812 (6), MNRJ 46644 (1), MNRJ 46700 (5), MNRJ 46714 (13), MNRJ 46792 (21), MNRJ 46814 (1), MNRJ 47003 (15), MNRJ 47015 (9), MNRJ 47258 (2)
Erythrinidae																								
Hoplias malabaricus												X				X	X		X					MNRJ 38051 (1), MNRJ 43830 (1), MNRJ 46802 (1), MNRJ 47013 (1)

Table 2. *Continued.*

Taxon	Sites																						Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
SILURIFORMES																								
Trichomycteridae																								
Trichomycterus macrophthalmus	X		X				X	X			X	X	X	X	X	X	X	X				X	X	MNRJ 36467 (1), MNRJ 36478 (4), MNRJ 36494 (16), MNRJ 36504 (12), MNRJ 36513 (4), MNRJ 37957 (5), MNRJ 43750 (22), MNRJ 43760 (27), MNRJ 43772 (13), MNRJ 43813 (2), MNRJ 43832 (1), MNRJ 46640 (8), MNRJ 46795 (1), MNRJ 46825 (1)
Trichomycterus mariamole				X	X												X			X	X			MNRJ 36452 (2), MNRJ 36520 (1), MNRJ 36525 (2), MNRJ 38047 (1), MNRJ 38088 (3), MNRJ 47024 (1)
Trichomycterus nigroauratus		X	X	X	X	X	X	X	X	X	X	X	X			X	X			X	X	X	X	MNRJ 36453 (11), MNRJ 36468 (3), MNRJ 36477 (3), MNRJ 36512 (2), MNRJ 37968 (5), MNRJ 38025 (3), MNRJ 38035 (2), MNRJ 38041 (7), MNRJ 38046 (2), MNRJ 38091 (1), MNRJ 43719 (5), MNRJ 43754 (1), MNRJ 43814 (2), MNRJ 43833 (2), MNRJ 46645 (3), MNRJ 46669 (11), MNRJ 46694 (1), MNRJ 46712 (2), MNRJ 46796 (2), MNRJ 46824 (1), MNRJ 46834 (6), MNRJ 47025 (1), MNRJ 47026 (1), MNRJ 47253 (13)
Callichthyidae																								
Scleromystax barbatus																		X						MNRJ 46722 (4)

Table 2. *Continued.*

Taxon	Sites																						Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
Loricariidae																								
Harttia carvalhoi	X		X				X	X			X	X				X	X	X	X			X	X	MNRJ 36461 (3), MNRJ 36480 (9), MNRJ 36501 (3), MNRJ 36515 (2), MNRJ 37969 (5), MNRJ 38026 (15), MNRJ 38036 (3), MNRJ 38057 (1), MNRJ 43816 (2), MNRJ 43823 (4), MNRJ 46641 (2), MNRJ 46826 (1), MNRJ 47022 (2)
Harttia loricariformis		X	X				X	X							X							X	X	MNRJ 36514 (1), MNRJ 38037 (1), MNRJ 43773 (4), MNRJ 46646 (2), MNRJ 46706 (4), MNRJ 46827 (1), MNRJ 47262 (1)
Hemipsilichthys gobio						X																		MNRJ 36448 (1)
Hemipsilichthys papillatus					X											X								MNRJ 36482 (1), MNRJ 46657 (1)
Hypostomus affinis	X		X									X			X	X		X	X				X	MNRJ 36502 (1), MNRJ 37958 (1), MNRJ 38062 (1), MNRJ 43781 (1), MNRJ 43824 (3), MNRJ 46632 (1), MNRJ 46710 (1), MNRJ 46723 (4), MNRJ 46803 (1), MNRJ 46820 (1), MNRJ 46821 (1)
Hypostomus luetkeni																			X					MNRJ 47007 (1)
Neoplecostomus microps	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	MNRJ 36431 (23), MNRJ 36442 (13), MNRJ 36449 (8), MNRJ 36454 (6), MNRJ 36462 (17), MNRJ 36481 (27), MNRJ 36489 (14), MNRJ 36516 (27), MNRJ 36521 (8), MNRJ 36526 (1), MNRJ 37960 (4), MNRJ 37971 (9), MNRJ 37983 (8), MNRJ 37993 (34), MNRJ 38008 (20), MNRJ 38013 (13), MNRJ 38017 (21), MNRJ 38028 (47), MNRJ 38038 (15), MNRJ 38043 (17), MNRJ 38049 (9), MNRJ 38089 (6), MNRJ 43751 (21), MNRJ 43761 (43), MNRJ 43774 (10), MNRJ 43808 (38), MNRJ 43825 (118), MNRJ 46633 (11), MNRJ 46647 (8), MNRJ 46653 (20), MNRJ 46662 (18), MNRJ 46691 (3), MNRJ 46708 (18), MNRJ 46785 (6), MNRJ 46797 (2), MNRJ 46816 (14), MNRJ 47006 (4), MNRJ 47017 (5), MNRJ 47254 (10), MNRJ 47263 (12)

Table 2. *Continued.*

Taxon	Sites																					Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
Pareiorhina rudolphi					X	X			X											X	X			MNRJ 36455 (72), MNRJ 36522 (24), MNRJ 38012 (1), MNRJ 38016 (7), MNRJ 38042 (64), MNRJ 38048 (112), MNRJ 46652 (34), MNRJ 46670 (141), MNRJ 46692 (58), MNRJ 46835 (40)
Heptapteridae																								
Imparfinis minutus	X						X	X				X			X	X	X	X	X			X	X	MNRJ 36464 (2), MNRJ 36476 (5), MNRJ 36491 (1), MNRJ 36511 (1), MNRJ 37956 (1), MNRJ 37967 (2), MNRJ 37980 (2), MNRJ 37990 (1), MNRJ 38024 (3), MNRJ 38056 (2), MNRJ 43770 (5), MNRJ 43822 (3), MNRJ 46637 (2), MNRJ 46703 (5), MNRJ 46721 (1), MNRJ 46788 (1), MNRJ 46793 (6), MNRJ 47004 (3)
Pimelodella lateristriga	X		X				X				X	X					X	X	X				X	MNRJ 36434 (1), MNRJ 36465 (1), MNRJ 36492 (1), MNRJ 38055 (4), MNRJ 43815 (1), MNRJ 43831 (1), MNRJ 46639 (1), MNRJ 46704 (2), MNRJ 46715 (4), MNRJ 46823 (1)
Rhamdia quelen	X		X				X	X							X	X	X	X					X	MNRJ 36433 (1), MNRJ 36466 (7), MNRJ 36475 (3), MNRJ 36493 (1), MNRJ 36500 (1), MNRJ 37955 (1), MNRJ 37981 (4), MNRJ 37991 (1), MNRJ 43769 (2), MNRJ 46638 (2), MNRJ 46660 (4), MNRJ 46705 (2), MNRJ 46716 (2), MNRJ 46789 (1), MNRJ 46794 (5), MNRJ 46815 (1), MNRJ 47016 (3)
GYMNOTIFORMES																								
Gymnotidae																								
Gymnotus pantherinus	X	X	X				X	X			X	X			X	X	X	X	X					MNRJ 37961 (1), MNRJ 38054 (9), MNRJ 43777 (2), MNRJ 43809 (11), MNRJ 43827 (4), MNRJ 46635 (6), MNRJ 46648 (2), MNRJ 46663 (4), MNRJ 46718 (2), MNRJ 46786 (9), MNRJ 46799 (8), MNRJ 46828 (2), MNRJ 47008 (1), MNRJ 47019 (2)

Table 2. *Continued.*

Taxon	Sites																							Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
CYPRINODONTIFORMES																								
Poeciliidae																								
Phalloceros harpagos	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	MNRJ 36437 (29), MNRJ 36446 (1), MNRJ 36450 (2), MNRJ 36456 (84), MNRJ 36469 (3), MNRJ 36483 (11), MNRJ 36495 (4), MNRJ 36505 (15), MNRJ 36517 (5), MNRJ 36523 (70), MNRJ 36527 (84), MNRJ 37962 (55), MNRJ 37972 (5), MNRJ 37984 (4), MNRJ 37997 (36), MNRJ 38010 (1), MNRJ 38029 (1), MNRJ 38044 (136), MNRJ 38050 (43), MNRJ 38059 (16), MNRJ 38090 (67), MNRJ 43722 (199), MNRJ 43752 (417), MNRJ 43762 (294), MNRJ 43775 (40), MNRJ 43811 (34), MNRJ 43828 (241), MNRJ 46642 (4), MNRJ 46655 (157), MNRJ 46664 (6), MNRJ 46671 (110), MNRJ 46693 (33), MNRJ 46711 (3), MNRJ 46719 (2), MNRJ 46800 (7), MNRJ 46818 (7), MNRJ 46836 (158), MNRJ 47009 (3), MNRJ 47020 (29), MNRJ 47231 (8), MNRJ 47255 (13)
Poecilia reticulata														X	X									MNRJ 43763 (266), MNRJ 43776 (1)
CICHLIFORMES																								
Cichlidae																								
Australoheros sp.															X				X					MNRJ 38060 (2), MNRJ 43780 (1)
Crenicichla lepidota															X				X					MNRJ 43779 (5), MNRJ 47010 (6)

Table 2. *Continued.*

Taxon	Sites																					Catalog number (number of exemplars)
	C1	C2	C3	C4	P1	P2	P3	P4	A1	A2	A3	A4	Q1	Q2	Q3	I1	I2	I3	I4	R1	R2	R3	R4	
Geophagus brasiliensis		X	X				X	X		X	X	X	X	X	X	X	X	X	X			X	X	MNRJ 36470 (38), MNRJ 36484 (7), MNRJ 36496 (3), MNRJ 36506 (3), MNRJ 37963 (14), MNRJ 37973 (16), MNRJ 37985 (4), MNRJ 37998 (1), MNRJ 38009 (5), MNRJ 38030 (5), MNRJ 38061 (10), MNRJ 43753 (11), MNRJ 43764 (53), MNRJ 43778 (20), MNRJ 43810 (17), MNRJ 43829 (57), MNRJ 46649 (2), MNRJ 46667 (2), MNRJ 46709 (40), MNRJ 46720 (31), MNRJ 46787 (37), MNRJ 46801 (67), MNRJ 46819 (3), MNRJ 47011 (16), MNRJ 47021 (30), MNRJ 47230 (1), MNRJ 47264 (4)
Oreochromis niloticus																X		X						MNRJ 36485 (3), MNRJ 37964 (3)

The taxonomic identification of the 32 species fish species collected in the study area are commented below. Although species listed here occur in other drainages, the diagnostic characters described next are limited to identify the set of species that occur in the upper Piraí drainage. These diagnoses might be useful for ichthyological studies in other drainages of the Paraíba do Sul river basin, but in that case, the occurrence of other species not listed in the upper Piraí have to be considered.

Order Characiformes

Family Anostomidae

Hypomasticus mormyrops (Steindachner, 1875) (Figure 1B)

This species, the only member of the family Anostomidae captured in the upper Piraí river drainage, is easily distinguished from other Characiformes by having a single series of three or four teeth in each pre-maxillary or dentary, arranged by length, in a step-like arrangement, with the front teeth being the longest (Garavello and Britski 2003).

Family Crenuchidae

Characidium lauroi Travassos, 1949 (Figure 1F)

Two species of *Characidium*, part of the group known as South American darters, were registered in upper Piraí. These species differ from other Characiformes in the study area by the presence of paired foramina located in the frontal bones, posterodorsally to the orbits (Buckup 2003). *Characidium lauroi* differs from its congener *C. vidali* by the presence small rounded dark marks below the lateral stripe, which are separated from the dorsal-lateral bars, and pigmentation bars on the caudal fin are usually absent or inconspicuous (Melo 2001, Buckup et al. 2014).

Characidium vidali Travassos, 1967 (Figure 1H)

Characidium vidali can be distinguished from *C. lauroi* by the presence of vertical polyhedric dark marks along the medium and inferior portion of the body and pigmentation bars on caudal fin evident and defined (Buckup et al. 2014).

Family Bryconidae

Brycon opalinus **(**Cuvier, 1819) (Figure 1G)

Brycon opalinus is the only species of Bryconidae registered in upper Piraí and it can be distinguished from other Characiformes in the study area by the following characters: two rows of dentary teeth, conical ones in internal series and multicuspidate on external series, three to four rows of pre-maxillary teeth, fifth infraorbital bone with similar width and height and obtuse to moderately tapered head shape (Lima 2017).

Family Characidae

Astyanax giton Eigenmann, 1908 (Figure 1A)

The genus *Astyanax* is currently defined by a combination of non-exclusive characters proposed by Eigenmann (1917), which includes two rows of premaxillary teeth, five teeth in the inner premaxillary series, complete lateral line, presence of the adipose fin, and lack of scales on the caudal fin (Bertaco and Lucena, 2006). Among the three species identified in the study area, *A. giton* is distinguished from its congeners by presenting the posterior extremity of pelvic fin surpassing the urogenital opening. A gradual variation of size on dentary teeth size and higher body height (approximately 41% SL) are also distinguishable features of this species in relation to *Astyanax intermedius* and *Astyanax* sp. aff. *scabripinnis* (Melo 2001).

Astyanax intermedius Eigenmann, 1908 (Figure 1C)

Astyanax intermedius differs from *A. giton* by the following characters: body depth smaller than 41% of SL and abrupt size reduction posterior to the fifth dentary teeth (Melo 2001). Also, in contrast with *A. giton*, the posterior extremity of pelvic fin in *A. intermedius* does not surpass the urogenital opening in this species. *A. intermedius* can be distinguished from *Astyanax* sp. aff. *scabripinnis*, by the presence of five cuspids in most dentary teeth and regular sized adipose fin.

***Astyanax* sp. aff. *scabripinnis* (**Jenyns, 1842) (Figure 1E)

This species was represented by a single individual, which belongs to *Astyanax scabripinnis* species complex, a non-monophyletic group roughly defined by the body deepest and heaviest in area proximate to middle of pectoral fins, head heavy and snout short and abrupt by tapering (Bertaco and Lucena, 2006). *Astyanax* sp. aff. *scabripinnis* is differentiated from *A. intermedius* by most dentary teeth with seven cuspids (vs. usually five cuspids in *A. intermedius*) and reduced adipose fin. *Astyanax* sp. aff. *scabripinnis*

differs from *A. giton* by the following characters: body depth smaller than 41% of SL and abrupt size reduction posterior to the fifth dentary teeth (Melo 2001)

Oligosarcus hepsetus (Cuvier, 1829) (Figure 1I)

This predatory fish species differs from other Characiformes in the upper Piraí river basin by the combination of following characters: presence of several conical teeth, elongated body, pointy snout, 60 to 75 perforated lateral-line scales and 23 to 28 scales from tip of occiput to dorsal-fin origin (Ribeiro and Menezes 2015).

Family Erythrinidae

Hoplias malabaricus (Bloch, 1794) (Figure 1D)

Differently from other Characiformes in upper Piraí, individuals of this species have cylindrical body, presence of caniniform teeth and absence of adipose fin (Oyakawa 2003). *Hoplias malabaricus* is a widespread species that exhibits significant morphological and genetic variation, which suggests that this taxa represents a species complex that requires taxonomic revision (Ferreira et al. 2007).

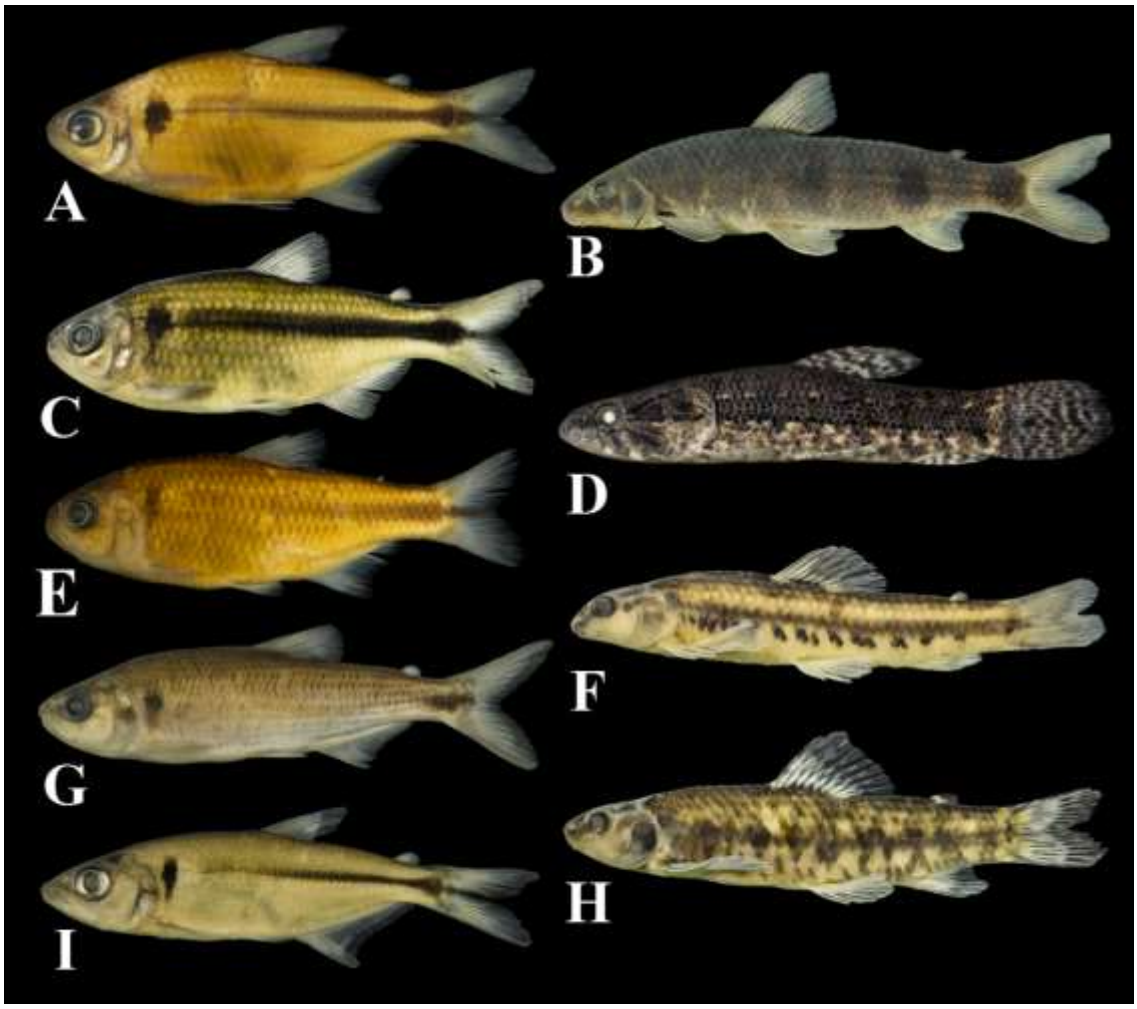

Figure 2. Fish species collected in upper Piraí river drainage. **A.** *Astyanax giton*, MNRJ 37986, 63.56 mm SL. **B.** *Hypomasticus mormyrops*, MNRJ 46698, 128.6 mm SL. **C.** *Astyanax intermedius*, MNRJ 43805, 77.2 mm SL. **D.** *Hoplias malabaricus*, MNRJ 43830, 70.8 mm SL. **E.** *Astyanax* sp. aff. *scabripinnis*, MNRJ 36427, 71.8 mm SL. **F.** *Characidium lauroi*, MNRJ 43823, 57.3 mm SL. **G.** *Brycon opalinus*, MNRJ 47259, 116.6 mm SL. **H.** *Characidium vidali*, MNRJ 43807, 66.6 mm SL. **I.** *Oligosarcus hepsetus*, MNRJ 43812, 63.1 mm SL.

Order Siluriformes

Family Trichomycteridae

Trichomycterus macrophthalmus Barbosa and Costa, 2012 (Figure 2A)

Trichomycterus macrophthalmus is part of a family of catfishes characterized by the presence of odontoids on opercular and interopercular bones in most of species, three pairs of barbels and absence of spine-locking mechanism on dorsal fin (de Pinna and

Wosiacki 2003). *Trichomycterus macrophthalmus* is the only species of the genus in the study area that is part of the *Trichomycterus travassosi* species complex. This species group is characterized by the colour pattern consisting of transverse dark bars crossing the dorsum, which can be fused with lateral marks in this species (Barbosa and Costa 2012). *Trichomycterus macrophthalmus* are also distinguished from *Trichomycterus mariamole* and *Trichomycterus nigroauratus* by the presence of nine pairs of ribs and diameter of eyes 13.2% to 14.6% the size of head length (HL) (Barbosa and Costa 2012).

Trichomycterus mariamole Barbosa and Costa, 2010 (Figure 2C)

Trichomycterus mariamole is distinguishable from congeneric species that occur in the upper Piraí drainage by the light yellow coloration with small circular brown marks on flanks, diameter of the eyes 9% to 11% the size of HL, opercular region of odontoids reduced and laterally placed, and seven pectoral fins (Barbosa and Costa 2010). *Trichomycterus mariamole* differs from *T. claudiae*, another species of the *T. brasiliensis* species group that occurs in the middle region of the Piraí drainage, by the short ill-defined stripe restricted to the anterior portion of the flank (vs. well defines stripe along the whole flank) and fewer interopercular odontodes (27-34 vs. 41-46).

Trichomycterus nigroauratus Barbosa and Costa, 2008 (Figure 2E)

Trichomycterus nigroauratus, the most abundant species of *Trichomycterus* in the study area, differs morphologically from *T. mariamole* and *T. nigroauratus* by the presence of golden spots on the snout and body, and broad (wider than long) metapterygoid bone (Barbosa and Costa 2008). Individuals of *T. nigroauratus* present ontogenetic variation of coloration, with juveniles exhibiting a black stripe along the lateral midline, and mature ones presenting stripes with irregular borders and dark stains that can cover the entire body in a homogeneous pattern (Buckup et al. 2014).

Family Callichthyidae

Scleromystax barbatus (Quoy & Gaimard, 1824) (Figure 2G, H)

Members of the family Callichthyidae are easily distinguished from other Siluriformes by presenting a double series of dermal plates along the body (Reis 2003). *Scleromystax barbatus* can be recognized by the conspicuous coloration pattern with large, dark brown blotches, often coalesced, on almost all dorsolateral body plates (Britto et al. 2016). This species also presents sexually dimorphic characters, such as, dorsal and

pectoral fins of males reaching, or almost reaching, the caudal peduncle, and well-developed odontoids inserted in fleshy tissue on a large area on the sides of the snout in fully grown males (Britto and Reis 2005).

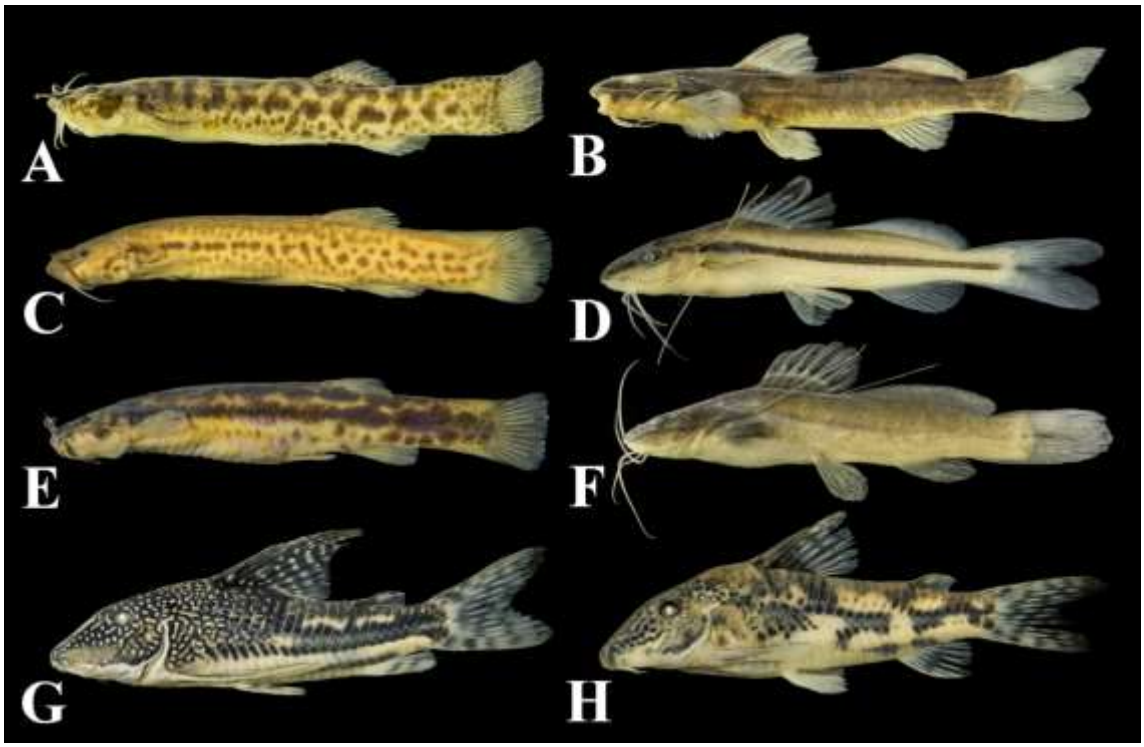

Figure 3. Fish species collected in upper Piraí river drainage. **A.** *Trichomycterus macrophthalmus*, MNRJ 43760, 52.4 mm SL. **B.** *Imparfinis minutus*, MNRJ 43770, 83.4 mm SL. **C.** *Trichomycterus mariamole*, MNRJ 36525, 58.72 mm SL. **D.** *Pimelodella lateristriga*, MNRJ 43888, 39.7 mm SL. **E.** *Trichomycterus nigroauratus*, MNRJ 38003, 48.8 mm SL. **F.** *Rhamdia quelen*, MNRJ 43889, 98.6 mm SL. **G.** *Scleromystax barbatus*, MNRJ 46722, 66.1 mm SL, male. **H.** *Scleromystax barbatus*, MNRJ 46722, 57.62 mm SL, female.

Family Loricariidae

Harttia carvalhoi Miranda Ribeiro, 1939 (Figure 3A)

Harttia carvalhoi belongs to a genus of suckermouth armored catfishes recognized by the absence of keels on the body plates, snout rounded in dorsal view, large plates surrounding the anal opening and abrupt narrowing of caudal peduncle (Boeseman 1971, Rapp Py-Daniel 1997). The two species of *Harttia* that occur in the study area can be distinguished by the pattern of plates in front of the anus: *Harttia carvalhoi* is

distinguished from *H. loricariiformis* by the absence of preanal plates (Langeani et al. 2001).

Harttia loricariformis Steindachner, 1877 (Figure 3B)

Differently from its congener, *Harttia loricariformis* presents two large and trapezoid preanal plates touching the small anterior plates (Langeani et al. 2001).

Hemipsilichthys gobio (Lütken, 1874a) (Figure 3C)

Individuals of the genus *Hemipsilichthys* are distinguished from other Loricariids from upper Piraí by the combination of the following characters (Reis et al. 2006): high preadipose keel, almost symmetrically bifid teeth, orbital diameter 8.6–16.9% of HL, and dorsal-fin membrane never in contact with the first preadipose plate. Among the congener species that occur in the study area, *Hemipsilichthys gobio* can be differentiated from *H. papillatus* by its rectangular or oval-shaped dorsal-fin spinelet, and by the orbital diameter 12.0–14.7% of HL (Reis et al. 2006).

Hemipsilichthys papillatus Pereira et al. 2000 (Figure 3D)

Hemipsilichthys papillatus is distinguishable from *H. gobio* by not having plates in the dorsal midline between the base of the dorsal fin and the adipose-fin, and presenting an orbital diameter 8.6–11.8% of HL (Reis et al. 2006).

Hypostomus affinis (Steindachner, 1877a) (Figure 3E)

The genus *Hypostomus* is one of the most species-rich groups of the Loricariidae family (Martins et al. 2014), and the identification of these species is usually based on regional taxonomic revisions. The two species of *Hypostomus* that occur in coastal drainages of Rio de Janeiro (*Hypostomus affinis* and *Hypostomus luetkeni*) were collected in upper Piraí river drainage. This genus is distinguished from other Loricariids in the study area by the dorsal fin with spine and seven branched rays, V-shaped spinelet present and locking mechanism functional (Buckup et al. 2014). Individuals of *Hypostomus affinis* can be distinguished *H. luetkeni* by the presence of one main post-supraoccipital plate and four lateral ridges on flanks (Mazzoni et al. 1994).

Hypostomus luetkeni (Steindachner, 1877b) (Figure 3F)

Hypostomus luetkeni can be distinguished from *H. affinis* by the presence of two or three plates in the main post-supraoccipital series and the absence of ridges on the flanks of the body (Mazzoni et al. 1994).

Neoplecostomus microps (Steindachner, 1877b) (Figure 3G)

Individuals of *Neoplecostomus microps* differ from other suckermouth armored catfishes occurring the Piraí river drainage by the presence of two or three conspicuous rows of enlarged and transversally flattened papillae posterior to the dentary teeth, and a conspicuous patch of small platelets covering the ventral surface of the body, between the insertions of the pectoral and pelvic fins, surrounded by naked areas (Langeani 1990).

Pareiorhina rudolphi (Miranda Ribeiro, 1911) (Figure 3H)

The species *Pareiorhina rudolphi* can be distinguished from other loricariids that occur in the upper Piraí river drainage by the absence of adipose fin, and the shape of caudal peduncle, which is flat dorsally, with a pair of dorso-lateral keels (Chamon et al. 2005).

Rineloricaria* sp. cf. *R. lima (Kner, 1853) (Figure 3I)

Specimens of *Rineloricaria* sp. cf. *R. lima*, are characterized morphologically by the dorsal-ventrally compressed body, presence of small dermic plates covering the ventral region between pectoral and pelvic fins, caudal peduncle length bigger than half of the SL, and presence of small barbell on lips junction (Buckup et al. 2014). Different from most of loricariids found at the study area, *Rineloricaria* sp. cf. *R. lima* occurs on sites with sand substrate. The genus *Rineloricaria* is one of the most diverse groups within the family Loricariidae, but the limits among species are not completely known. In this study we refer this species as *Rineloriaria* sp. cf. *R. lima* due to similarity of the specimens from the Piraí drainage with specimens of this genus collected in the Paraíba do Sul previously identified as *Rineloricaria* cf. *lima* by other authors (e.g. Fichberg 2008).

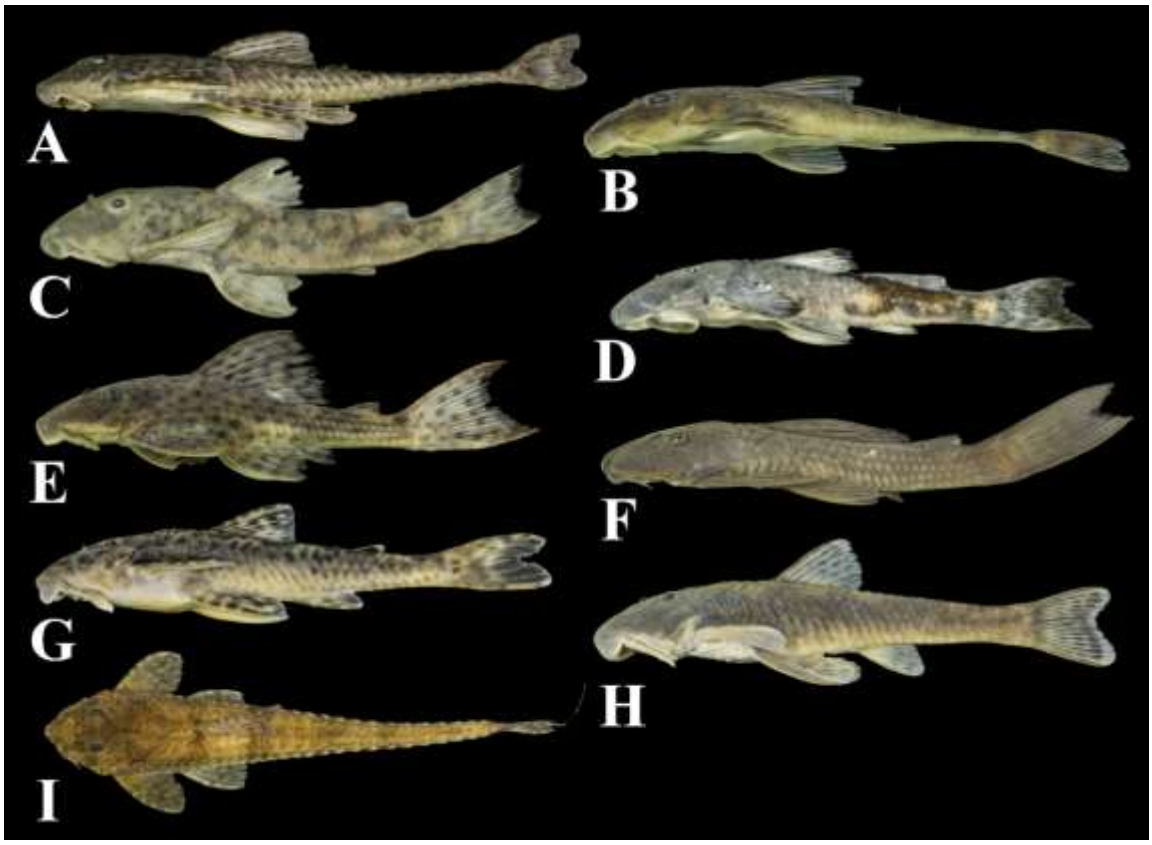

Figure 4. Fish species collected in upper Piraí river drainage. **A.** *Harttia carvalhoi*, MNRJ 43816, 78.1 mm SL. **B.** *Harttia loricariformis*, MNRJ 43773, 42.1 mm SL. **C.** *Hemipsilichthys gobio*, MNRJ 43868, 75.3 mm SL. **D.** *Hemipsilichthys papillatus*, MNRJ 46657, 53.7 mm SL. **E.** *Hypostomus affinis*, MNRJ 43824, 62.6 mm SL. **F.** *Hypostomus luetkeni*, MNRJ 47007, 112.8 mm SL. **G.** *Neoplecostomus microps*, MNRJ 43808, 87 mm SL. **H.** *Pareiorhina rudolphi*, MNRJ 46835, 65.9 mm SL. **I.** *Rineloricaria* sp. cf. *R. lima*, MNRJ 43826, 76.3 mm SL.

Family Heptapteridae

Imparfinis minutus (Lütken, 1874b) (Figure 2B)

Imparfinis minutus is part of the family Heptapteridae, which differs from the other two families of Siluriformes that occur on the study area by having naked skin (vs. presence of dermic plates in Loricariidae) and absence of odontoids on opercular and interopercular bones (vs. presence of odontoids in Trichomycteridae). *Imparfinis minutus* can be distinguished from the other species of Heptapteridae from the upper Piraí drainage by the shorter maxillary barbell, reaching the base of pectoral fin, lack of perforating spines on the pectoral and dorsal fins, eye diameter 11–15% of head length, without free

orbital margin, and dorsal lobe of the bifurcated caudal fin pointed and longer than inferior lobe.

Pimelodella lateristriga (Lichtenstein, 1823) (Figure 2D)

Individuals of *Pimelodella lateristriga* are easily distinguished from the other two species of Heptapteridae that occur in the upper Piraí river drainage by the presence of the following charaters: pectoral and dorsal fins with a sharply perforating spine, body with a dark midlateral stripe extending from the snout to the insertion of the median caudal-fin rays, and limits of eye well defined by a free orbital rim, especially pronounced anteriorly and dorsally (Slobodian et al. 2017).

Rhamdia quelen (Quoy and Gaimard, 1824) (Figure 2F)

Rhamdia quelen can be distinguished from *Imparfinis minutus* and *Pimelodella lateristriga* by the lateral line extending to the base of median caudal-fin rays, presence of a spine only on the pectoral fins, and long maxillary barbells extending beyond the pelvic fins (Buckup et al. 2014). *Rhamdia quelen sensu* Silfvergrip (1996) is considered a species complex with some forms being distinguished as distinct species in recent studies (Garavello and Shibatta 2016, Angrizani and Malabarba 2018).

Order Gymnotiformes

Family Gymnotidae

Gymnotus pantherinus (Steindachner, 1908) (Figure 4A)

The single species of Gymnotiformes registered in the area, *Gymnotus pantherinus*, is easily distinguishable from the other fish species from the upper Piraí river drainage by the anguilliform body, absence of dorsal, adipose and pelvic fins, and capacity to generate and detect electric fields (Albert 2001). This species can be differentiated from individuals of the species complex *Gymnotus carapo*, which also occur on river drainages of Rio de Janeiro state, by the coloration pattern, that includes vermiculated dark marks in *G. pantherinus* (vs. diagonal bands in *G. carapo* complex).

Order Cyprinodontiformes

Family Poeciliidae

Phalloceros harpagos Lucinda, 2008 (Figure 4C, E)

Species of the family Poeciliidae, have the pectoral fins inserted high on the body, pelvic fins that migrate anteriorly in males during growth and recessed supraorbital pores (Lucinda 2003). *Phaloceros harpagos* can be distinguished from *Poecilia reticulata*, the other poeciliid that occurs on the upper Piraí basin, by their sexual characters: males have a pair of gonopodial appendices with a small hook and females present urogenital papilla located between the anus and the base of first anal-fin ray (Lucinda 2008).

Poecilia reticulata Peters, 1859 (Figure 4G, I)

This species of guppy can be distinguished from *Phalloceros harpagos* by the absence of urogenital papilla in female individuals, and males presenting variation of conspicuous color pattern with dark blotches and lateral stripe, and absence of a pair gonopodial appendices.

Order Cichliformes

Family Cichlidae

***Australoheros* sp.** Říčan and Kullander, 2006 (Figure 3B)

The cichlids from the upper Piraí river drainage are distinguishable from fishes of other orders by a series of spines followed by soft rays on the dorsal fin and lateral line divided in two separated portions. The genus *Australoheros* is diagnosed by the low scale count on lateral series (less than 25), scales on chest of comparable size to flank scales, low number of vertebrae (13 + 13-14), breeding coloration with interruption of abdominal bars in the mid-dorsal part, and presence of xanthophore dots at the base of the caudal fin in juveniles (Říčan and Kullander 2006). A single individual was collected in the area, and this specimen does not match the description of other species of *Australoheros* in recent taxonomic studies of the group in southeastern Brazil (Ottoni and Costa 2008, Ottoni 2012). The reduced geographic representation of these studies suggests that an extensive revision of the genus is required for adequate identification of the population from the Piraí drainage.

Crenicichla lepidota Heckel, 1840 (Figure 3D)

Crenicichla lepidota, known as a 'pike cichlid', differs from the other species of cichlids in the study area by the elongated body shape, with SL four times or more the body depth. This species is distinguishable from individuals of the *Crenicichla lacustris* species group, the congener taxa that also occur in river drainages of Rio de Janeiro, by

the presence of an humeral ocellus located between the pectoral fin and lateral line (vs. absence of ocellus in *C.* gr. *lacustris*) and absence of dots on the surface of the head and along the body (vs. presence of dots in *C.* gr. *lacustris*) (Kullander 1981, 1982).

Geophagus brasiliensis (Quoy and Gaimard, 1824) (Figure 3F)

The genus *Geophagus* is distinguished from other cichlids in upper Piraí by the naked anterior half of cheek, discontinuous lip folds, and presence of a large dark brown or black spot on the middle of the side, the midlateral spot (Kullander 1998). *Geophagus brasiliensis* also differs from *Oeochromis niloticus*, an introduced cichlid species that occurs on the upper Piraí river drainage, by the presence of a fleshy lobule on the superior branch of first branchial arch, an arched black stripe that extends from the pre-dorsal region to the pre-opercle, through the eye, and the absence of a dark spot on the posterior extremity of the opercle (Buckup et al. 2014).

Oreochromis niloticus (Linnaeus, 1758) (Figure 3H)

This species differs from the other cichlids from the study area by the combination of the following characters: deep body shape (vs. elongated body in *Crenicichla lepidota*), anal-fin with three spines (vs. six or more spines in *Australoheros* sp.), and presence of dark spot on the posterior extremity of the opercle (vs. absence in *Geophagus brasiliensis*). *Oreochromis niloticus* also differs from *G. brasiliensis* by the absence of the fleshy lobule on the superior branch of first branchial arch and absence of the black stripe on the head. The Nile tilapia differs from another widely introduced species of African cichlid present in Brazilian rivers, *Coptodon rendalli*, by the caudal-fin with prominent transversal stripes (vs. absence of stripes in *C. rendalli*) and 13 or more rakers in the inferior branch of the first gill arch (vs. 12 or less in *C. rendalli*) (Vieira et al. 2015).

Figure 5. Fish species collected in the upper Piraí river drainage. **A.** *Gymnotus pantherinus*, MNRJ 43827, 172.5 mm SL. **B.** *Australoheros* sp., MNRJ 43780, 50.3 mm SL. **C.** *Phalloceros harpagos*, MNRJ 43828, 34.2 mm SL, female. **D.** *Crenicichla lepidota*, MNRJ 43779, 85.9 mm SL. **E.** *Phalloceros harpagos*, MNRJ 43828, 25.3 mm SL, male. **F.** *Geophagus brasiliensis*, MNRJ 43778, 64.2 mm SL. **G.** *Poecilia reticulata*, MNRJ 43763, 36.8 mm SL, female. **H.** *Oreochromis niloticus*, MNRJ 37964, 96.56 mm SL. **I.** *Poecilia reticulata*, MNRJ 43763, 19.2 mm SL, male.

Discussion

In this study, the prevalence of Siluriformes and Characiformes in the composition of the fish assemblage follows the observed composition pattern of Atlantic Forest streams (e.g. Sarmento-Soares et al. 2007, Ferreira and Petrere 2009, Camilo et al. 2015) and in most Neotropical freshwater systems (Lowe-McConnell 1999, Abilhoa et al. 2011). This dominance is partially explained by the great number of species of these two orders in the Neotropical region and the range of adaptations that allow them to inhabit a wide variety of environments (Reis et al. 2016).

The number of collected species was higher in the lowest stretches of the upper Piraí basin than in its headwaters. According to the River Continuum Concept (Vannote

et al. 1980), the composition and structure of ichthyofauna in freshwater streams is directly related to altitude. Thus, high altitude stretches with comparatively lower temperature, high dissolved oxygen and fast flowing waters tend to have lower species richness than downstream sites with decreasing slope, increasing temperature and high availability of pools. However, anthropogenic impacts also contribute to richness variation in coastal drainages in the Atlantic Forest (Camilo et al. 2015). Higher availability of organic matter caused by sewage discharge into water bodies and changes in substrate increase the number of generalist species resilient to environmental degradation in lower stretches of freshwater drainages.

Among the widespread species in the study area, the high number of individuals of *Phalloceros harpagos* present is correlated with the capacity of poecilids to colonize a wide range of habitats and tolerate different levels of environmental quality (Araújo et al. 2009). The second most abundant species in upper Piraí drainage, *Astyanax intermedius*, is a typical opportunistic strategist characterized by the capacity of rapid population turnover and colonisation (Souza et al. 2015). This wide trophic adaptability combined with the characteristic phenotypic plasticity of the genus *Astyanax*, allow this species to inhabit several headwater basins (Ornelas-García et al. 2008, Matoso et al. 2013, Souza et al. 2015). In addition, *Astyanax* and *Trichomycterus* were the most speciose genera in the study area, represented by three species each. Individuals of *Trichomycterus claudiae* (Barbosa and Costa 2010) were not registered in the upper Piraí drainage. This species was expected to occur in the sampled drainage due to the proximity of its type locality.

Two species collected in the upper Piraí drainage are listed in the red book of Brazilian fauna threatened by extinction (ICMBio 2016): *Brycon opalinus*, present in the lower reaches of Rio das Pedras stream, and *Hemipsilichthys gobio*, collected in the second highest sampling site of the Papudos stream. *B. opalinus*, known as 'pirapitinga', is considered a vulnerable species due to commercial exploration and environment degradation, and its distribution is restricted to preserved tributaries of Paraíba do Sul and Doce basins headwaters (Gomiero and Braga 2007, ICMBio 2016). *H. gobio* is considered an endangered species due to habitat reduction and fragmentation (ICMBio 2016). The distribution of this species is limited to highly oxygenated cold waters of fast flowing tributaries of the Paraíba do Sul river basin. The presence of these two threatened species indicates that existence of preserved stretches in the upper Piraí drainage, which are natural refuges for endangered fauna.

Two non-native species were registered in four sampling sites along the study area: *Poecilia reticulata* was captured in the lowest points of the Passa Quatro stream, and *Oreochromis niloticus* occurred in two sites of the main channel of upper Piraí. *P. reticulata* is an exotic poecilid species originated from Venezuela, widely introduced along the Americas due to its predation on mosquito larvae (Santos, 1958). *O. niloticus*, known as 'Nile tilapia', is an invasive cichlid species originated from Africa that is widely cultivated in tanks and net cages in Brazil, and were probably introduced by escapes from pisciculture (Orsi and Agostinho 1999). Regarding environmental conditions, invasive species are usually more successful in negatively affected systems or where native species population are depleted (Leidy et al. 2011). Therefore, the introduction and population establishment of invasive species in the study are is related to environmental depletion of the medium-lower reach of the Passa Quatro stream and the main channel of upper Piraí.

Among the 32 species surveyed in this study, eight were not present in the first survey of the Piraí headwaters (Buckup et al. 2014): *Hypomasticus mormyrops*, *Hoplias malabaricus*, *Scleromystax barbatus*, *Hemipsilichthys gobio*, *Hypostomus luetkeni*, *Poecilia reticulata*, *Australoheros* sp. and *Crenicichla lepidota*. In addition to the increase of diversity, some species were captured in significant numbers only in the recent surveys (e.g. *Brycon opalinus*). The higher richness and abundance of the ichthyofauna in the upper Piraí river drainage correlates with the consolidation of recent conservation programs implemented in the study area to recover riparian forest (Castello-Branco 2015). Thus, the record of these eight species not previously captured in the area demonstrates the importance of continuous surveys in freshwater systems, in order to increase the knowledge on the distribution and impact of human activity on fish assemblages present on Atlantic Forest remnants.

References

Albert JS (2001) Species diversity and phylogenetic systematics of american knifefishes (Gymnotiformes, Teleostei). Miscellaneous Publications, Museu of Zoology, University of Michigan 190: 1–140.

Abilhoa V, Braga RR, Bornatowski H, Vitule JRS (2011) Fishes of the Atlantic Rain Forest streams: ecological patterns and conservation. In: Grillo O, Venora G (Eds) Changing diversity in changing environmental. InTech, Rijeka, 259–282. http://dx.doi.org/10.5772/1835

Almeida FFM, Carneiro CDR (1998) Origem e evolução da Serra do Mar. Revista Brasileira de Geociências 28 (2), 135–150.

Angrizani RC, Malabarba LR (2018) Morphology and molecular data reveal the presence of two new species under *Rhamdia quelen* (Quoy & Gaimard, 1824) (Siluriformes: Heptapteridae) species complex. Zootaxa 4388 (1): 44-60. http://dx.doi.org/10.11646/zootaxa.4388.1.3

Araújo FG, Peixoto MG, Pinto BCT, Teixeira TP (2009) Distribution of guppies *Poecilia reticulata* (Peters, 1860) and *Phalloceros caudimaculatus* (Hensel, 1868) along a polluted stretch of the Paraíba do Sul river, Brazil. Brazilian Journal of Biology 69 (1): 41–48. http://dx.doi.org/10.1590/S1519-69842009000100005

Barbosa MA, Costa WJEM (2008) Description of a new species of catfish from the upper rio Paraíba do Sul basin, south-eastern Brazil (Teleostei: Siluriformes: Trichomycteridae) and re-description of *Trichomycterus itatiayae*. aqua, International Journal of Ichthyology 14 (4): 175-186.

Barbosa MA, Costa WJEM (2010) Seven new species of the catfish genus *Trichomycterus* (Teleostei: Siluriformes: Trichomycteridae) from southeastern Brazil and redescription of *T. brasiliensis*. Ichthyological Exploration of Freshwaters 21 (2): 97-122.

Barbosa MA, Costa WJEM (2012) *Trichomycterus macrophthalmus* (Teleostei: Siluriformes: Trichomycteridae), a new species of catfish from the Paraíba do Sul river basin, southeastern Brazil. Vertebrate Zoology 62 (1): 79-82.

Bertaco VA, Lucena CAS (2006) Two new species of *Astyanax* (Ostariophysi: Characiformes: Characidae) from eastern Brazil, with a synopsis of the *Astyanax scabripinnis* species complex. Neotropical Ichthyology 4 (1): 53–60. http://dx.doi.org/10.1590/S1679-62252006000100004

Bloch ME (1794) Naturgeschichte der ausländischen Fische. Vol. 8. Auf Kosten des Verfassers und in Commission bei dem Buchhändler Hr. Hesse, Berlin, 174 pp. https://dx.doi.org/10.5962/bhl.title.63303

Boeseman M (1971) The “combtoothed” Loricariinae of Surinam, with reflections on the phylogenetic tendencies within the family Loricariidae (Siluriformes, Siluroidei). Zoologische Verhandelingen 116: 1-56.

Britto MR, Reis RE (2005) A new *Scleromystax* species (Siluriformes: Callichthyidae) from coastal rivers of southern Brazil. Neotropical Ichthyology 3 (4): 481–488. http://dx.doi.org/10.1590/S1679-62252005000400005

Britto MR, Fukakusa CK, Malabarba LR (2016) New species of *Scleromystax* Günther, 1864 (Siluriformes: Callichthyidae) - extending the meridional distribution of genera endemic to the Atlantic Forest. Neotropical Ichthyology 14 (3): 1–10. http://dx.doi.org/10.1590/1982-0224-20150158

Buckup PA (2003) Family Crenuchidae (South American darters). In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 87-95.

Buckup PA, Britto MR, Souza-Lima R., Pascoli JC, Villa-Verde L, Ferraro GA, Salgado FLK, Gomes JR (2014) Guia de Identificação das Espécies de Peixes da Bacia do Rio das Pedras Município de Rio Claro, RJ. The Nature Conservancy, Rio de Janeiro, 144 pp.

Camilo GS, Terra BDF, De Araújo FG (2015) Ichthyofauna from the Parque Nacional da Serra dos Órgãos and its surrounding areas, Rio de Janeiro state, Brazil. Check List 11 (4): 1696. https://dx.doi.org/10.15560/11.4.1696

Castello-Branco MR (2015) Pagamentos por Serviços Ambientais: da teoria à prática. ITPA, Rio Claro, 188 pp.

Cetra M, Ferreira FC (2016) Fish-based Index of Biotic Integrity for wadeable streams from Atlantic Forest of south São Paulo State, Brazil. Acta Limnologica Brasiliensia 28 (22). http://dx.doi.org/10.1590/S2179-975X1216

Chamon CC, Aranda AT, Buckup PA (2005) *Pareiorhina brachyrhyncha* (Loricariidae: Siluriformes): a new species of fish from the Paraíba do Sul slope of Serra da

Mantiqueira, southeastern Brazil. Copeia 2005 (3): 550-558. http://dx.doi.org/10.1643/CI-04-276R

Cuvier G (1819) Sur les poissons du sous-genre *Hydrocyon*, sur deux nouvelles especes de Chalceus, sur trois nouvelles especes de Serrasalmes, et sur l'*Argentina glossodonta* de Forskahl, qui est l'*Albula gonorhynchus* de Bloch. Mémoirs du Museum D'Historie Naturelle 5: 351–379.

Cuvier G (1829) Le Règne Animal, distribué d'après son organisation, pour servir de base à l'histoire naturelle des animaux et d'introduction à l'anatomie comparée. Edition 2. Deterville, Paris, xv + 406 pp. https://dx.doi.org/10.5962/bhl.title.49223

De Pinna MCC, Wosiacki W (2003) Family Trichomycteridae (Pencil or parasitic catfishes). In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 270-290.

Eigenmann CH (1908) Preliminary descriptions of new genera and species of tetragonopterid characins. (Zoölogical Results of the Thayer Brazilian expedition.). Bulletin of the Museum of Comparative Zoology 52 (6): 91-106.

Eigenmann CH (1917) The American Characidae. Part 1. Memoirs of Museum of Comparative Zoology 43: 1-102. https://dx.doi.org/10.5962/bhl.title.49183

Ferreira IA, Bertollo LAC, Martins C (2007) Comparative chromosome mapping of 5S rDNA and 5SHindIII repetitive sequences in Erythrinidae fishes (Characiformes) with emphasis on the *Hoplias malabaricus* 'species complex'. Cytogenetic and Genome Research, 118 (1): 78-83. https://dx.doi.org/10.1159/000106445

Ferreira FC, Petrere M (2009) The fish zonation of the Itanhaém river basin in the Atlantic Forest of southeast Brazil. Hydrobiologia 636 (1): 11–34. https://dx.doi.org/10.1007/s10750-009-9932-4

Fichberg I (2008) Relações filogenéticas das espécies do gênero *Rineloricaria* BLEEKER, 1862 (Siluriformes, Loricariidae, Loricariinae). PhD thesis,

Universidade de São Paulo, São Paulo, 162 pp. https://dx.doi.org/10.11606/T.41.2008.tde-17022009-115207

Galindo-Leal C, Câmara IG (2003) Atlantic Forest hotspots status: an overview. In: Galindo-Leal C, Câmara IG (Eds). The Atlantic Forest of South America: Biodiversity Status, Threats and Outlook. CABS and Island Press, Washington, 3-11. https://dx.doi.org/10.1086/425812

Garavello JC, Britski HA (2003) Family Anostomidae. In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 71–84.

Garavello JC, Shibatta OA (2016) Reappraisal of R*hamdia branneri* Haseman, 1911 and *R. voulezi* Haseman, 1911 (Siluriformes: Heptapteridae) from the rio Iguaçu with notes on their morphometry and karyotype. Neotropical Ichthyology 14 (1): e140111. http://dx.doi.org/10.1590/1982-0224-20140111

Gomiero LM, Braga FMS (2007) Reproduction of Pirapitinga do Sul (*Brycon opalinus* Cuvier, 1819) in the Parque Estadual da Serra do Mar-Núcleo Santa Virgínia, São Paulo, Brazil. Brazilian Journal of Biology 67 (3): 541–549. https://dx.doi.org/10.1590/S1519-69842007000300021

Heckel JJ (1840) Johann Natterer's neue Flussfische Brasilien's nach den Beobachtungen und Mittheilungen des Entdeckers beschrieben (Erste Abtheilung, Die Labroiden). Annalen des Wiener Museums der Naturgeschichte 2: 325-471.

ICMBio (2016) Brazil Red Book of Threatened Species of Fauna. Executive Summary. Eighth Edition. MMA, Brasília, 76 pp.

Jenyns L (1842) Part IV: Fish. In: Darwin C (Eds) The Zoology of the Voyage of H.M.S. Beagle, Under the Command of Captain Fitzroy, R.N., During the Years 1832 to 1836. Smith, Elder and Co., London, 1–172. https://dx.doi.org/10.5962/bhl.title.14216

Kner R (1853) Die Panzerwelse des K.K. Hof-naturalien-Cabinetes zu Wien. I. Abtheilung, Loricarinae. Denkschriften der Kaiserlichen Akademie der

Wissenschaften in Wien, Mathematisch-Naturwissenschaftliche Classe 6: 65-98. https://dx.doi.org/10.5962/bhl.title.12577

Kullander SO (1981) Cichlid fishes from the La Plata basin. Part I. Collections from Paraguay in the Museum d'Histoire naturelle de Geneve. Revue Suisse Zoologie 88: 675-692.

Kullander SO (1982) Cichlid fishes from the La Plata basin. Part III. The *Crenicichla lepidota* species group. Revue Suisse Zoologie 89: 627-661

Kullander SO (1986) Cichlid fishes of the Amazon river drainage of Peru. Swedish Museum of Natural History, Stockholm, 431 pp.

Kullander SO (1998) A phylogeny and classification of the Neotropical Cichlidae (Teleostei: Perciformes). In: Malabarba LR, Reis RE, Vari RP, Lucena ZM, Lucena CAS (Eds) Phylogeny and Classification of Neotropical Fishes. Edipucrs, Porto Alegre, 461–498.

Kullander SO, Lucena CAS (2006) A review of the species of *Crenicichla* (Teleostei: Cichlidae) from the Atlantic coastal rivers of southeastern Brazil from Bahia to Rio Grande do Sul States, with descriptions of three new species. Neotropical Ichthyology 4 (2): 127–146. http://dx.doi.org/10.1590/S1679-62252006000200001

Langeani F (1990) Revisão do gênero *Neoplecostomus* Eigenmann & Eigenmann, 1888, com a descrição de quatro novas espécies do sudeste brasileiro (Ostariophysi, Siluriformes, Loricariidae. Comunicação Do Museo de Ciências Da PUCRS, Série Zoológica, Porto Alegre, 3: 3–31.

Langeani F, Oyakawa OT, Montoya-Burgos JI (2001) New species of *Harttia* (Loricariidae, Loricariinae) from the Rio São Francisco basin. Copeia, 2001, 136–142. http://dx.doi.org/10.1643/0045-8511(2001)001[0136:NSOHLL]2.0.CO;2

Leidy RA, Kristina CY, Carlson SM (2011) Persistence of native fishes in small streams of the urbanized San Francisco Estuary, California: acknowledging the role of

urban streams in native fish conservation. Aquatic Conservation: Marine and Freshwater Ecosystems 21: 472–483. https://dx.doi.org/10.1002/aqc.1208

Lichtenstein MHC (1823) Verzeichniss der Doubletten des zoologischen Museums der Königl. Universität zu Berlin, nebst Beschreibung vieler bisher unbekannter Arten von Säugethieren, Vögeln, Amphibian und Fishen. T. Trautwein, Berlin, x + 118 pp. https://dx.doi.org/10.5962/bhl.title.40281

Lima FCT (2017) A revision of the cis-andean species of the genus *Brycon* Müller & Troschel (Characiformes: Characidae). Zootaxa 4222 (1): 1-189. https://dx.doi.org/10.11646/zootaxa.4222.1.1.

Linnaeus C (1758) Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Tomus I. Editio decima. Laurentii Salvii, Hol- miae, 824 pp. https://dx.doi.org/10.5962/bhl.title.542

Lowe-McConnell RH (1999) A fauna de peixes neotropical. In: Lowe-McConnell RH (Eds) Estudos ecológicos de comunidades de peixes tropicais. Edusp, São Paulo, 129–168.

Lucinda PHF (2003) Family Poeciliidae. In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 555–581.

Lucinda PHF (2008) Systematics and biogeography of the genus *Phalloceros* Eigenmann, 1907 (Cyprinodontiformes: Poeciliidae: Poeciliinae), with the description of twenty-one new species. Neotropical Ichthyology 6 (2): 113-158. https://dx.doi.org/10.1590/S1679-62252008000200001

Lütken CF (1874a) Ichthyographiske bidrag. I. Nogle nye eller mindre fuldstaendigt kjendte Pandsermaller, isaer fra det nordlige Sydamerica. Videnskabelige Meddelelser fra den Naturhistoriske Forening i Kjøbenhavn, Aaret 1873 (13–14): 202–220.

Lütken CF (1874b) Siluridae novae Brasiliae centralis a clarissimo J. Reinhardt in provincia Minas-geraës circa oppidulum Lagoa Santa, praecipue in flumine Rio das Velhas et affluentibus collectae, secundum caracteres essentiales, breviter descriptae. Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlinger 1874 (1): 29-36.

Martins FO, Langeani F, Zawadzki CH (2014) A new spiny species of *Hypostomus* Lacépède (Loricariidae: (Loricariidae: Hypostominae) from thermal waters, upper rio Paraná basin, central Brazil. Neotropical Ichthyology 12 (4): 729–736. http://dx.doi.org/10.1590/1982-0224-20140035

Matoso DA, Silva M da, Artoni RF, Torres RA (2013) Molecular taxonomy and evolutionary hypothesis concerning *Astyanax fasciatus* (Characiformes, Characidae) from Vila Velha State Park and Tibagi and Iguaçu Rivers. Genetics and Molecular Research 12 (1): 631–638. https://dx.doi.org/10.4238/2013.March.7.1

Mazzoni R, Caramaschi U, Weber C (1994) Taxonomical revision of the species of *Hypostomus* Lacépède, 1803 (Siluriformes, Loricariidae) from the Lower rio Paraiba do Sul, State of Rio de Janeiro, Brazil. Revue Suisse de Zoologie 101 (1): 3-18. https://dx.doi.org/10.5962/bhl.part.79897

Melo FAG (2001) Revisão taxonômica das espécies do gênero *Astyanax* Baird e Girard, 1854, (Teleostei: Characiformes: Characidae) da região da serra dos Orgãos. Arquivos do Museu Nacional do Rio de Janeiro 59: 1-46.

Melo MRS (2001) Sistemática, filogenética e biogeografia do grupo *Characidium lauroi* Travassos, 1949 (Characiformes, Crenuchidae). Master dissertation, Universidade Federal do Rio de Janeiro, Rio de Janeiro, 95pp.

Miranda Ribeiro, A (1911) Fauna brasiliense. Peixes. Tomo IV (A) [Eleutherobranchios Aspirophoros]. Arquivos do Museu Nacional do Rio de Janeiro, 16 (4): 1504.

Miranda Ribeiro, P (1939) Sobre o genero *Harttia*, Steind. (Peixes: Loricariidae). Boletim Biológico (Nova série) 4 (1): 11-13.

Ornelas-García CP, Domínguez-Domínguez O, Doadrio I (2008) Evolutionary history of the fish genus *Astyanax* Baird & Girard (1854) (Actinopterygii, Characidae) in Mesoamerica reveals multiple morphological homoplasies. BMC Evolutionary Biology 8: 340. https://dx.doi.org/10.1186/1471-2148-8-340

Orsi ML, Agostinho AA (1999) Introdução de espécies de peixes por escapes acidentais de tanques de cultivo em rios da bacia do rio Paraná, Brasil. Revista Brasileira de Zoologia 16: 557–560. https://dx.doi.org/10.1590/S0101-81751999000200020

Ottoni FP (2012) Three new species of *Australoheros* from southeastern Brazil, with taxonomic notes on *Chromys oblonga*, *Heros autochton* and *H. jenynsii* (Teleostei: Labroidei: Cichlidae). Vertebrate Zoology 62 (1): 83-96.

Ottoni FP, Costa WJEM (2008) Taxonomic revision of the genus *Australoheros* ŘÍČAN & KULLANDER, 2006 (Teleostei: Cichlidae) with descriptions of nine new species from southeastern Brazil. Vertebrate Zoology 58 (2): 207–232.

Oyakawa OT (2003) Erythrinidae (Trahiras). In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 238–240.

Paiva RFPS, Coelho RC (2015) O Programa Produtor de Água e Floresta de Rio Claro/RJ enquanto ferramenta de gestão ambiental: o perfil e a percepção ambiental dos produtores inscritos. Desenvolvimento e Meio Ambiente 33. https://dx.doi.org/10.5380/dma.v33i0.36702

Peters WCH (1859) Eine neue vom Herrn Jagor im atlantischen Meere gefangene Art der Gattung Leptocephalus, und über einige andere neue Fische des Zoologischen Museums. Monatsberichte der Königlichen Preussischen Akademie der Wissenschaften zu Berlin 1859: 411-413.

Pereira EHL, Oliveira JC, Oyakawa OT (2000) *Hemipsilichthys papillatus*, a new species of loricariid catfish (Teleostei: Siluriformes) from Minas Gerais, Brazil. Ichthyological Exploration of Freshwaters 11 (4): 377-383.

Quoy JRC, Gaimard JP (1824) Description des Poissons. Chapter IX. In: Freycinet LCD (Eds) Voyage autour du Monde... exécuté sur les corvettes de L. M. "L'Uranie" et "La Physicienne," pendant les années 1817, 1818, 1819 et 1820. Chez Pillet aìné, Paris, 192-401. https://dx.doi.org/10.5962/bhl.title.15862

Rapp Py-Daniel LH (1997) Phylogeny of the Neotropical armored catfishes of the subfamily Loricariinae (Siluriformes: Loricariinae). PhD dissertation, University of Arizona, Arizona, 280 pp.

Reis RE (2003) Family Callichthyidae. In: Reis RE, Kullander SO, Ferraris Jr CJ (Eds) Check List of the Freshwater Fishes of South and Central America. Edipucrs, Porto Alegre, 291-309

Reis RE, Pereira EHL, Armbruster JW (2006) Delturinae, a new loricariid catfish subfamily (Teleostei, Siluriformes), with revisions of *Delturus* and *Hemipsilichthys*. Zoological Journal of the Linnean Society 147(2): 277-299. http://dx.doi.org/10.1111/j.1096-3642.2006.00229.x

Reis RE, Albert JS, Di Dario F, Mincarone MM, Petry P, Rocha LA (2016) Fish biodiversity and conservation in South America. Journal of Fish Biology 89 (1): 12–47. https://dx.doi.org/10.1111/jfb.13016

Ribeiro AC, Menezes NA (2015) Phylogenetic relationships of the species and biogeography of the characid genus *Oligosarcus* Günther, 1864 (Ostariophysi, Characiformes, Characidae). Zootaxa 3949 (1): 41-81. http://dx.doi.org/10.11646/zootaxa.3949.1.2

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM (2009) The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142 (6): 1141–1153. http://dx.doi.org/10.1016/j.biocon.2009.02.021

Ribeiro MC, Martensen AC, Metzger JP, Tabarelli M, Scarano F, Fortin MJ (2011) The Brazilian Atlantic Forest: A Shrinking Biodiversity Hotspot. In: Zachos FE, Habel JC (Eds) Biodiversity Hotspots. Springer, Berlin, 405-434. https://dx.doi.org/10.1007/978-3-642-20992-5_21

Říčan O, Kullander SO (2006) Character- and tree-based delimitation of species in the "Cichlasoma" facetum group (Teleostei, Cichlidae) with the description of a new genus. Journal of Zoological Systematics and Evolutionary Research 44 (2): 136–152. http://dx.doi.org/10.1111/j.1439-0469.2005.00347.x

Santos EO (1958) Peixes de água doce: vida e costumes dos peixes do Brasil. Segunda edição. Editora Itatiaia, Belo Horizonte, 267 pp.

Sarmento-Soares LM, Mazzoni R, Martins-Pinheiro RF (2007) A fauna de peixes na bacia do Rio Peruípe, extremo Sul da Bahia. Biota Neotropica 7 (3): 291–308. https://dx.doi.org/10.1590/S1676-06032007000300031

Silfvergrip AMC (1996) A systematic revision of the Neotropical catfish genus *Rhamdia* (Teleostei, Pimelodidae). Stockholm University, Stockholm, 156 pp.

Slobodian V, Akama A, Dutra GM (2017) A new species of *Pimelodella* (Siluriformes: Heptapteridae) from the Guiana Shield, Brazil. Zootaxa 4338 (1): 85–100. http://dx.doi.org/10.11646/zootaxa.4338.1.4

Souza UP, Ferreira FC, Carmo MAF, Braga FMS (2015) Feeding and reproductive patterns of *Astyanax intermedius* in a headwater stream of Atlantic Rainforest. Anais da Academia Brasileira de Ciências 87 (4) : 2151–2162. https://dx.doi.org/10.1590/0001-3765201520140673

Steindachner F (1875) Die Süsswasserfische des südöstlichen Brasilien (II). Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Classe 71 (3): 211-245.

Steindachner F (1877a) Die Süsswasserfische des südöstlichen Brasilien (III). Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Classe 74 (1): 559-694.

Steindachner F (1877b) Die Süsswasserfische des südöstlichen Brasilien (IV). Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Classe 76 (1): 217-230.

Steindachner F (1908) Über eine während der brasilianischen Expedition entdeckte *Brachyplatystoma*-Art aus dem Rio Parnahyba und über eine dicht gefleckte und gestrichelte Varietät von *Giton fasciatus* aus den Gewässern von Santos (Staat Sao Paulo). Anzeiger der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Classe 45 (9): 126-130.

Travassos H (1949) Notas ictiológicas. I. *Characidium lauroi* n. sp. (Actinopterygii, Ostareophysi). Revista Brasileira de Biologia 9 (1): 87-92.

Travassos H (1967) Três novas espécies do gênero *Characidium* Reinhardt, 1866 (Actinopterygii, Characoidei). Papéis Avulsos de Zoologia, Museu de Zoologia da Universidade de São Paulo 20 (4): 45-53.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE (1980) The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences 37 (1): 130–137. https://dx.doi.org/10.1139/f80-017

Vieira F, Gomes JPC, Maia BP, Silva LG (2015) Peixes do Quadrilátero Ferrífero - Guia de Identificação. Fundação Biodiversitas, Belo Horizonte, 208 pp.

Vilar MB, Bustamante J, Ruiz M (2012) Produtores de Água e Floresta, Rio Claro, Rio de Janeiro. In: Tubbs Filho D, Antunes JCO, Vettorazzi JS (Eds) Bacia hidrográfica dos Rios Guandu, da Guarda e Guandu-Mirim: experiências para a gestão dos recursos hídricos. Instituto Estadual do Ambiente (INEA), Rio de Janeiro, 273-291.

Anexos

Appendix 1. Trophic guilds of native species.

Species	Trophic guild	Bibliographic references
CHARACIFORMES		
Crenuchidae		
Characidium sp.	Invertivore	(Azevedo, 2011; Mazzoni et al., 2012)
Characidium sp. aff. *interruptum*	Invertivore	(Mazzoni et al., 2012)
Characidium sp. aff. *vidali*	Invertivore	(Azevedo, 2011; Mazzoni et al., 2012)
Characidium interruptum	Invertivore	(Mazzoni et al., 2012)
Characidium lauroi	Invertivore	(Braga & Gomiero, 2009)
Characidium vidali	Invertivore	(Azevedo, 2011; Mazzoni et al., 2012)
Erythrinidae		
Hoplias malabaricus	Piscivore	(Rosana Mazzoni & Costa, 2007)
Anostomidae		
Hypomasticus mormyrops	Herbivore	(Rodrigues, 2013)
Curimatidae		
Cyphocharax gilbert	Detritivore	(Bizerril & Primo, 2001)
Characidae		
Astyanax sp.	Omnivore	(Araújo et al., 2003)
Astyanax sp. 2 gr. *fasciatus*	Omnivore	(Araújo et al., 2003)
Astyanax sp. aff. *scabripinnis*	Omnivore	(Braga & Gomiero, 2009)
Astyanax giton	Omnivore	(Araújo et al., 2003)
Astyanax hastatus	Omnivore	(Araújo et al., 2003)
Astyanax intermedius	Omnivore	(Souza et al., 2015)
Astyanax lacustris	Omnivore	(Araújo et al., 2003)
Astyanax taeniatus	Omnivore	(Araújo et al., 2003)
Brycon opalinus	Omnivore	(Gomiero et al., 2008)
Bryconamericus sp. aff. *tenuis*	Invertivore	(Mazzoni & Rezende, 2009)
Bryconamericus ornaticeps	Invertivore	(Mazzoni & Rezende, 2009)
Hyphessobrycon bifasciatus	Omnivore	(Coutinho et al., 2000)
Mimagoniates microlepis	Invertivore	(Mazzoni & Costa, 2007; Wolff et al., 2013)
Oligosarcus hepsetus	Piscivore	(Carolina & Castelo, 2005)
SILURIFORMES		
Trichomycteridae		
Microcambeva barbata	Invertivore	(Zuanon et al., 2006)
Trichomycterus immaculatus	Invertivore	(Braga & Gomiero, 2009)
Trichomycterus macrophthalmus	Invertivore	(Braga & Gomiero, 2009)
Trichomycterus mariamole	Invertivore	(Braga & Gomiero, 2009)
Trichomycterus nigroauratus	Invertivore	(Braga & Gomiero, 2009)
Trichomycterus zonatus	Invertivore	(Braga & Gomiero, 2009)
Callichthyidae		
Scleromystax barbatus	Omnivore	(Gonçalves & Cestari, 2013)
Loricariidae		
Ancistrus multispinis	Detritivore	(Wolff et al., 2013)
Harttia carvalhoi	Detritivore	(Araújo et al., 2009)

Species	Trophic guild	Bibliographic references
Harttia loricariformis	Detritivore	(Araújo et al., 2009)
Hemipsilichthys gobio	Detritivore	(Araújo et al., 2009)
Hemipsilichthys papillatus	Detritivore	(Araújo et al., 2009)
Hisonotus notatus	Detritivore	(Ferreira & Casatti, 2006)
Hypostomus affinis	Detritivore	(Gomes et al., 2010)
Hypostomus luetkeni	Detritivore	(Gomes et al., 2010)
Kronichthys heylandi	Detritivore	(Wolff et al., 2013)
Neoplecostomus granosus	Invertivore	(Braga et al., 2008)
Neoplecostomus microps	Invertivore	(Braga et al., 2008)
Pareiorhaphis garbei	Detritivore	(Dias & Fialho, 2011)
Pareiorhina rudolphi	Herbivore	(Braga & Gomiero, 2009)
Parotocinclus maculicauda	Detritivore	(Leitão et al., 2007)
Rineloricaria sp. 1	Detritivore	(Wolff et al., 2013)
Rineloricaria sp. 2	Detritivore	(Wolff et al., 2013)
Rineloricaria sp. cf. *lima*	Detritivore	(Wolff et al., 2013)
Schizolecis guntheri	Detritivore	(Wolff et al., 2013)
Auchenipteridae		
Trachelyopterus striatulus	Omnivore	(Carolina & Castelo, 2005; Rodrigues, 2013)
Heptapteridae		
Acentronichthys leptos	Invertivore	(Wolff et al., 2013)
Imparfinis minutus	Invertivore	(Moraes & Braga, 2011)
Pimelodella lateristriga	Invertivore	(Rosana Mazzoni & Costa, 2007)
Rhamdia quelen	Piscivore	(Brazil-Sousa et al., 2009)
Rhamdioglanis transfasciatus	Invertivore	(Brazil-Sousa et al., 2009)
Pseudopimelodidae		
Microglanis nigripinnis	Invertivore	(Esguicero & Arcifa, 2010)
GYMNOTIFORMES		
Gymnotidae		
Gymnotus carapo	Invertivore	(Castro & Casatti, 1997)
Gymnotus pantherinus	Invertivore	(Castro & Casatti, 1997)
Sternopygidae		
Eigenmannia sp. gr. *trilineata*	Invertivore	(Ferreira & Casatti, 2006)
GOBIIFORMES		
Eleotridae		
Eleotris pisonis	Omnivore	(Perrone & Vieira, 1991)
Oxudercidae		
Awaous tajasica	Detritivore	(Andreata, 2012)
CICHLIFORMES		
Cichlidae		
Australoheros sp.	Invertivore	(Ottoni & Katz, 2017)
Cichlasoma sp.	Invertivore	(Gurgel & Canan, 1999)
Crenicichla lacustris	Piscivore	(Gurgel et al., 1998)
Crenicichla lepidota	Piscivore	(Gurgel et al., 1998)
Geophagus brasiliensis	Omnivore	(Rosana Mazzoni & Costa, 2007)

Species	Trophic guild	Bibliographic references
CYPRINODONTIFORMES		
Poeciliidae		
Phalloceros harpagos	Detritivore	(Wolff et al., 2013)
Phalloceros tupinamba	Detritivore	(Wolff et al., 2013)
Poecilia vivipara	Omnivore	(Araújo et al., 2009)
SYNBRANCHIFORMES		
Synbranchidae		
Symbranchus marmoratus	Piscivore	(Wolff et al., 2013)
SYNGNATHIFORMES		
Syngnathidae		
Microphis lineatus	Invertivore	(Corrêa & Uieda, 2007)
Pseudophallus mindii	Omnivore	(Corrêa & Uieda, 2007)

Appendix 2. Metric values obtained in sampling sites in the Guapiaçu river in August 2016 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Guapiaçu			M. Alexandre
Metric	**1**	**3**	**4**	**1**
1	5	14	20	6
2	101	148	183	65
3	2	5	7	2
4	100%	71%	60%	100%
5	20%	14%	40%	17%
6	40%	30%	63%	54%
7	80%	57%	20%	83%
8	60%	68%	8%	46%
9	0%	7%	5%	0%
10	0%	1%	1%	0%
11	0%	0%	0%	0%
12	0%	0%	0%	0%
13	0%	0%	5%	0%
14	0%	0%	6%	0%
15	0%	14%	15%	0%
16	0%	1%	6%	0%
17	0%	0%	10%	0%
18	0%	0%	115%	0%
19	0%	7%	0%	0%
20	0%	1%	0%	0%
21	0%	0%	5%	0%
22	0%	0%	35%	0%
23	0%	0%	0%	0%
24	0%	0%	0%	0%
25	3	7	9	4
26	20%	0%	0%	17%
27	40%	0%	0%	54%
28	0%	0%	0%	0%
29	0%	0%	0%	0%
30	0%	0%	0%	0%
31	0%	0%	0%	0%
32	0%	0%	0%	0%
33	0%	0%	0%	0%
34	0%	0%	5%	0%
35	0%	0%	25%	0%
36	0%	14%	35%	0%
37	0%	30%	60%	0%
38	20%	14%	5%	17%
39	1%	1%	2%	6%
40	0%	0%	0%	0%
41	0%	0%	0%	0%
42	60%	29%	15%	50%
43	59%	62%	7%	38%
44	0%	0%	0%	0%
45	0%	0%	0%	0%
46	0%	14%	0%	17%
47	0%	4%	0%	2%
48	0%	0%	0%	0%

	Guapiaçu			M. Alexandre
Metric	**1**	**3**	**4**	**1**
49	0%	0%	0%	0%
50	0%	7%	5%	0%
51	0%	1%	1%	0%
52	0%	0%	0%	0%
53	0%	0%	0%	0%
54	0%	0%	0%	0%
55	0%	0%	0%	0%
56	0%	0%	0%	0%
57	0%	0%	0%	0%
58	0%	0%	5%	0%
59	0%	0%	6%	0%
60	0%	14%	15%	0%
61	0%	1%	6%	0%
62	0%	0%	10%	0%
63	0%	0%	13%	0%
64	0%	7%	0%	0%
65	0%	1%	0%	0%
66	0%	0%	5%	0%
67	0%	0%	35%	0%
68	0%	0%	0%	0%
69	0%	0%	0%	0%
70	0.36	0.34	0.18	0.42
71	1.17	1.50	2.24	1.07
72	0.64	0.66	0.82	0.58
73	20%	7%	0%	17%
74	1%	1%	0%	6%
75	2	4	4	2
76	60%	29%	30%	50%
77	59%	62%	25%	38%
78	40%	29%	20%	50%
79	41%	25%	7%	62%
80	0%	21%	40%	0%
81	0%	10%	66%	0%
82	0%	21%	10%	0%
83	0%	3%	2%	0%
84	0%	0%	0%	0%
85	0%	0%	0%	0%
86	100%	57%	25%	100%
87	100%	68%	14%	100%
88	0%	29%	70%	0%
89	0%	31%	85%	0%
90	0%	14%	5%	0%
91	0%	1%	1%	0%
92	0%	0%	0%	0%
93	0%	7%	35%	0%
94	0%	1%	31%	0%
95	60%	93%	60%	50%
96	53%	99%	68%	62%
97	40%	0%	5%	50%
98	47%	0%	2%	38%
99	100%	100%	85%	100%
100	100%	100%	92%	100%

	Guapiaçu			M. Alexandre
Metric	**1**	**3**	**4**	**1**
101	0%	0%	15%	0%
102	0%	0%	8%	0%

Appendix 3. Metric values obtained in sampling sites in the Guapiaçu river in December 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Guapiaçu				M. Alexandre	Gato
Metric	**1**	**2**	**3**	**4**	**1**	**1**
1	5	18	14	20	6	15
2	63	159	113	148	79	187
3	2	4	5	6	2	4
4	100%	72%	64%	65%	100%	87%
5	20%	22%	29%	30%	17%	40%
6	37%	31%	54%	34%	51%	71%
7	80%	50%	36%	35%	83%	47%
8	63%	55%	31%	24%	49%	18%
9	0%	0%	0%	5%	0%	0%
10	0%	0%	0%	1%	0%	0%
11	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%
13	0%	0%	7%	5%	0%	0%
14	0%	0%	1%	2%	0%	0%
15	0%	11%	21%	15%	0%	7%
16	0%	5%	12%	17%	0%	3%
17	0%	17%	7%	10%	0%	7%
18	0%	9%	3%	22%	0%	9%
19	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%
25	4	8	7	10	4	7
26	20%	6%	0%	0%	17%	13%
27	37%	2%	0%	0%	51%	7%
28	0%	0%	0%	5%	0%	0%
29	0%	0%	0%	1%	0%	0%
30	0%	0%	0%	0%	0%	0%
31	0%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	1%	0%	0%
35	0%	0%	0%	1%	0%	0%
36	0%	17%	29%	20%	0%	27%
37	0%	29%	54%	33%	0%	63%
38	20%	6%	7%	5%	17%	7%
39	8%	8%	1%	1%	6%	1%
40	0%	6%	7%	0%	0%	0%
41	0%	6%	5%	0%	0%	0%
42	40%	33%	21%	15%	50%	33%
43	51%	40%	25%	22%	38%	15%
44	0%	0%	0%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%
46	20%	6%	0%	15%	17%	7%
47	5%	1%	0%	2%	5%	2%
48	0%	0%	0%	0%	0%	0%
49	0%	0%	0%	0%	0%	0%

	Guapiaçu				M. Alexandre	Gato
Metric	**1**	**2**	**3**	**4**	**1**	**1**
50	0%	0%	0%	5%	0%	0%
51	0%	0%	0%	1%	0%	0%
52	0%	0%	0%	0%	0%	0%
53	0%	0%	0%	0%	0%	0%
54	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%
57	0%	0%	0%	0%	0%	0%
58	0%	0%	7%	5%	0%	0%
59	0%	0%	1%	2%	0%	0%
60	0%	11%	21%	15%	0%	7%
61	0%	5%	12%	17%	0%	3%
62	0%	17%	7%	10%	0%	7%
63	0%	9%	3%	22%	0%	9%
64	0%	0%	0%	0%	0%	0%
65	0%	0%	0%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%
69	0%	0%	0%	0%	0%	0%
70	0.37	0.13	0.27	0.14	0.39	0.20
71	1.18	2.40	1.76	2.27	1.15	1.96
72	0.63	0.87	0.73	0.86	0.61	0.80
73	40%	28%	29%	15%	33%	33%
74	44%	40%	28%	32%	57%	13%
75	2	4	4	4	2	3
76	40%	50%	36%	30%	50%	40%
77	51%	50%	28%	45%	38%	24%
78	60%	22%	21%	25%	50%	40%
79	49%	38%	51%	4%	62%	69%
80	0%	11%	29%	30%	0%	20%
81	0%	4%	8%	43%	0%	7%
82	0%	11%	7%	20%	0%	0%
83	0%	3%	7%	9%	0%	0%
84	0%	0%	0%	0%	0%	0%
85	0%	0%	0%	0%	0%	0%
86	100%	56%	43%	40%	100%	60%
87	100%	57%	32%	26%	100%	25%
88	0%	44%	57%	55%	0%	40%
89	0%	43%	68%	73%	0%	75%
90	0%	0%	0%	5%	0%	0%
91	0%	0%	0%	1%	0%	0%
92	0%	4%	3%	1%	0%	0%
93	0%	44%	57%	55%	17%	20%
94	0%	22%	21%	51%	0%	12%
95	80%	39%	36%	35%	67%	53%
96	52%	40%	28%	47%	63%	27%
97	40%	17%	14%	10%	50%	27%
98	48%	31%	45%	1%	37%	32%
99	100%	94%	93%	80%	100%	100%
100	100%	96%	97%	88%	100%	100%
101	0%	6%	7%	20%	0%	0%
102	0%	4%	3%	12%	0%	0%

Appendix 4. Metric values obtained in sampling sites in the Macaé river in June 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Macaé								S. Bento
Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**
1	3	7	7	6	14	10	15	18	6
2	16	451	51	34	222	73	66	778	91
3	1	4	3	2	5	6	7	7	3
4	100%	71%	86%	100%	71%	50%	47%	50%	83%
5	0%	29%	29%	17%	14%	20%	20%	39%	33%
6	0%	79%	37%	38%	15%	25%	21%	92%	26%
7	100%	43%	57%	83%	57%	30%	27%	11%	50%
8	100%	5%	57%	62%	68%	10%	26%	2%	19%
9	0%	14%	0%	0%	7%	0%	13%	6%	0%
10	0%	0%	0%	0%	3%	0%	3%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	10%	13%	11%	0%
14	0%	0%	0%	0%	0%	3%	29%	1%	0%
15	0%	0%	0%	0%	7%	20%	13%	17%	0%
16	0%	0%	0%	0%	3%	18%	17%	1%	0%
17	0%	14%	14%	0%	14%	10%	7%	11%	17%
18	0%	16%	6%	0%	10%	41%	2%	4%	55%
19	0%	0%	0%	0%	0%	10%	0%	0%	0%
20	0%	0%	0%	0%	0%	4%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	7%	6%	0%
24	0%	0%	0%	0%	0%	0%	7%	6%	0%
25	2	5	5	4	7	6	10	13	4
26	0%	0%	14%	17%	14%	0%	0%	6%	33%
27	0%	0%	20%	38%	15%	0%	0%	1%	26%
28	0%	0%	0%	0%	0%	0%	0%	6%	0%
29	0%	0%	0%	0%	0%	0%	0%	0%	0%
30	0%	0%	0%	0%	0%	0%	0%	0%	0%
31	0%	0%	0%	0%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%	0%	6%	0%
33	0%	0%	0%	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%	0%	0%	0%
36	0%	29%	14%	0%	0%	20%	20%	17%	0%
37	0%	79%	18%	0%	0%	25%	21%	90%	0%
38	0%	14%	0%	17%	0%	0%	0%	0%	0%
39	0%	0%	0%	3%	0%	0%	0%	0%	0%
40	0%	0%	0%	0%	7%	0%	0%	0%	0%
41	0%	0%	0%	0%	0%	0%	0%	0%	0%
42	67%	14%	43%	50%	36%	30%	13%	6%	33%
43	75%	2%	53%	56%	56%	10%	23%	2%	16%
44	0%	0%	0%	0%	0%	0%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%	0%	0%	0%
46	33%	14%	14%	17%	14%	0%	7%	6%	17%
47	25%	3%	4%	3%	6%	0%	2%	0%	2%
48	0%	0%	0%	0%	0%	0%	7%	0%	0%
49	0%	0%	0%	0%	0%	0%	2%	0%	0%

	Macaé								S. Bento
Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**
50	0%	14%	0%	0%	7%	0%	7%	0%	0%
51	0%	0%	0%	0%	3%	0%	2%	0%	0%
52	0%	0%	0%	0%	0%	0%	7%	6%	0%
53	0%	0%	0%	0%	0%	0%	2%	0%	0%
54	0%	0%	0%	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%	7%	6%	0%
57	0%	0%	0%	0%	0%	0%	17%	0%	0%
58	0%	0%	0%	0%	0%	10%	7%	6%	0%
59	0%	0%	0%	0%	0%	3%	12%	1%	0%
60	0%	0%	0%	0%	7%	20%	13%	17%	0%
61	0%	0%	0%	0%	3%	18%	17%	1%	0%
62	0%	14%	14%	0%	14%	10%	7%	11%	17%
63	0%	16%	6%	0%	10%	41%	2%	4%	55%
64	0%	0%	0%	0%	0%	10%	0%	0%	0%
65	0%	0%	0%	0%	0%	4%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%	7%	6%	0%
69	0%	0%	0%	0%	0%	0%	7%	6%	0%
70	0.54	0.52	0.25	0.27	0.21	0.25	0.12	0.73	0.35
71	0.78	0.90	1.59	1.46	2.01	1.69	2.29	0.77	1.36
72	0.46	0.48	0.75	0.73	0.79	0.75	0.88	0.27	0.65
73	67%	43%	43%	33%	21%	10%	0%	6%	50%
74	31%	20%	20%	21%	16%	41%	0%	1%	66%
75	2	3	3	2	5	3	4	4	2
76	67%	29%	57%	50%	57%	50%	27%	28%	50%
77	75%	17%	59%	56%	73%	53%	36%	6%	71%
78	33%	57%	29%	50%	29%	0%	20%	28%	50%
79	25%	16%	24%	44%	23%	0%	5%	2%	29%
80	0%	14%	14%	0%	7%	20%	33%	33%	0%
81	0%	67%	18%	0%	3%	38%	41%	91%	0%
82	33%	14%	14%	17%	7%	10%	7%	17%	17%
83	6%	2%	10%	18%	1%	3%	12%	2%	9%
84	0%	0%	0%	0%	0%	0%	0%	0%	0%
85	0%	0%	0%	0%	0%	0%	0%	0%	0%
86	100%	43%	71%	100%	71%	40%	40%	28%	83%
87	100%	5%	76%	100%	83%	12%	55%	4%	45%
88	0%	43%	29%	0%	21%	50%	47%	67%	17%
89	0%	94%	24%	0%	14%	84%	42%	96%	55%
90	0%	14%	0%	0%	7%	10%	13%	6%	0%
91	0%	0%	0%	0%	3%	4%	3%	0%	0%
92	0%	0%	0%	0%	1%	0%	0%	0%	0%
93	0%	14%	14%	0%	36%	50%	33%	44%	17%
94	0%	16%	6%	0%	20%	66%	47%	6%	55%
95	67%	86%	86%	100%	57%	40%	60%	50%	67%
96	31%	84%	94%	100%	73%	33%	52%	93%	37%
97	33%	0%	0%	0%	7%	10%	7%	6%	17%
98	69%	0%	0%	0%	7%	1%	2%	1%	8%
99	100%	100%	100%	100%	93%	100%	100%	94%	100%
100	100%	100%	100%	100%	99%	100%	100%	100%	100%
101	0%	0%	0%	0%	7%	0%	0%	6%	0%
102	0%	0%	0%	0%	1%	0%	0%	0%	0%

Appendix 5. Metric values obtained in sampling sites in the Macaé river in November 2017 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Macaé								S. Bento	Sana	
Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**1**	**2**
1	3	7	10	9	15	9	21	26	7	8	10
2	20	211	412	67	279	112	175	272	42	159	378
3	1	3	4	3	5	5	8	7	3	4	5
4	100%	71%	80%	89%	80%	44%	52%	58%	86%	75%	70%
5	0%	29%	30%	22%	20%	22%	24%	27%	29%	25%	20%
6	0%	76%	82%	67%	5%	13%	5%	65%	24%	23%	10%
7	100%	43%	50%	67%	60%	22%	29%	31%	57%	50%	50%
8	100%	21%	16%	28%	69%	4%	23%	9%	69%	52%	17%
9	0%	0%	0%	0%	7%	22%	5%	8%	0%	13%	10%
10	0%	0%	0%	0%	3%	7%	1%	4%	0%	1%	1%
11	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	10%	8%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	19%	6%	0%	0%	0%
15	0%	0%	10%	11%	7%	22%	10%	15%	0%	0%	10%
16	0%	0%	0%	4%	3%	53%	10%	4%	0%	0%	0%
17	0%	14%	10%	0%	7%	11%	10%	8%	14%	13%	10%
18	0%	3%	1%	0%	21%	23%	38%	10%	7%	23%	71%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
25	2	5	7	6	8	6	12	12	5	6	7
26	0%	0%	20%	11%	13%	0%	0%	0%	29%	25%	20%
27	0%	0%	8%	49%	4%	0%	0%	0%	24%	23%	10%
28	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%
29	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%
30	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
31	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
36	0%	29%	10%	11%	7%	11%	19%	23%	0%	0%	0%
37	0%	76%	75%	18%	0%	8%	5%	65%	0%	0%	0%
38	0%	14%	10%	11%	0%	0%	0%	0%	14%	13%	10%
39	0%	2%	6%	2%	0%	0%	0%	0%	24%	69%	43%
40	0%	0%	0%	0%	7%	0%	0%	0%	0%	0%	0%
41	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%
42	67%	14%	30%	33%	33%	11%	14%	15%	29%	25%	30%
43	50%	18%	14%	16%	59%	3%	21%	5%	24%	18%	8%
44	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
46	33%	14%	10%	22%	20%	11%	10%	8%	14%	13%	10%
47	50%	2%	1%	10%	6%	1%	2%	4%	17%	13%	3%
48	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%
49	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%

	Macaé								S. Bento	Sana	
Metric	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**1**	**2**
50	0%	0%	0%	0%	7%	11%	0%	4%	0%	13%	10%
51	0%	0%	0%	0%	3%	3%	0%	3%	0%	1%	1%
52	0%	0%	0%	0%	0%	11%	5%	4%	0%	0%	0%
53	0%	0%	0%	0%	0%	4%	1%	1%	0%	0%	0%
54	0%	14%	0%	0%	0%	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%	5%	4%	0%	0%	0%
57	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
58	0%	0%	0%	0%	0%	0%	5%	4%	0%	0%	0%
59	0%	0%	0%	0%	0%	0%	17%	6%	0%	0%	0%
60	0%	0%	10%	11%	7%	22%	10%	15%	0%	0%	10%
61	0%	0%	0%	4%	3%	53%	10%	4%	0%	0%	0%
62	0%	14%	10%	0%	7%	11%	10%	8%	14%	13%	10%
63	0%	3%	1%	0%	21%	23%	38%	10%	7%	23%	71%
64	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
65	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%
69	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
70	0.46	0.38	0.57	0.30	0.16	0.33	0.13	0.37	0.18	0.17	0.52
71	0.86	1.10	1.02	1.60	2.13	1.49	2.37	1.76	1.83	1.82	1.15
72	0.55	0.62	0.43	0.70	0.84	0.67	0.87	0.63	0.82	0.83	0.48
73	67%	43%	40%	33%	27%	22%	10%	8%	43%	38%	40%
74	55%	23%	6%	18%	29%	74%	15%	10%	33%	53%	77%
75	200%	300%	300%	400%	400%	400%	400%	400%	200%	200%	300%
76	67%	29%	40%	33%	47%	22%	29%	27%	43%	38%	40%
77	50%	21%	16%	16%	84%	26%	75%	21%	31%	41%	79%
78	33%	57%	40%	33%	33%	22%	14%	23%	57%	63%	50%
79	50%	40%	9%	54%	10%	7%	5%	9%	69%	59%	20%
80	0%	14%	20%	22%	13%	11%	29%	27%	0%	0%	10%
81	0%	38%	75%	22%	3%	51%	8%	67%	0%	0%	0%
82	0%	0%	0%	11%	7%	44%	29%	23%	0%	0%	0%
83	0%	0%	0%	7%	3%	16%	12%	3%	0%	0%	0%
84	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
85	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
86	100%	43%	70%	78%	73%	33%	38%	38%	86%	75%	70%
87	100%	21%	24%	78%	73%	9%	43%	15%	93%	75%	27%
88	0%	43%	30%	22%	20%	44%	48%	50%	14%	13%	20%
89	0%	79%	76%	22%	24%	84%	55%	80%	7%	23%	72%
90	0%	0%	0%	0%	7%	22%	10%	8%	0%	13%	10%
91	0%	0%	0%	0%	3%	7%	2%	4%	0%	1%	1%
92	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
93	0%	29%	20%	22%	27%	56%	48%	42%	14%	13%	20%
94	0%	3%	1%	12%	30%	82%	69%	22%	7%	23%	72%
95	67%	71%	80%	78%	60%	44%	52%	50%	71%	75%	60%
96	55%	97%	99%	88%	67%	18%	31%	77%	79%	76%	23%
97	33%	0%	0%	0%	13%	0%	0%	8%	14%	13%	20%
98	45%	0%	0%	0%	3%	0%	0%	1%	14%	1%	6%
99	100%	86%	100%	100%	100%	100%	100%	96%	100%	100%	100%
100	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
101	0%	14%	0%	0%	0%	0%	0%	4%	0%	0%	0%
102	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Appendix 6. Metric values obtained in sampling sites in the upper Piraí river drainage in July 2015 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Parado			P. Quatro		
Metric	**2**	**3**	**4**	**1**	**2**	**3**
1	2	13	14	7	8	16
2	204	156	476	590	783	269
3	2	5	5	4	4	4
4	50%	77%	79%	71%	63%	63%
5	0%	31%	21%	29%	38%	19%
6	0%	30%	4%	20%	13%	30%
7	50%	46%	57%	43%	25%	44%
8	2%	30%	33%	7%	9%	44%
9	0%	8%	7%	0%	0%	6%
10	0%	7%	1%	0%	0%	1%
11	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%
15	0%	8%	7%	14%	13%	19%
16	0%	11%	12%	2%	7%	10%
17	50%	8%	7%	14%	25%	13%
18	98%	22%	51%	71%	72%	15%
19	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%
25	2	8	9	6	6	8
26	0%	15%	7%	14%	25%	6%
27	0%	16%	1%	7%	5%	0%
28	0%	0%	7%	0%	0%	0%
29	0%	0%	1%	0%	0%	0%
30	0%	0%	0%	0%	0%	0%
31	0%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%
36	0%	15%	7%	14%	13%	13%
37	0%	14%	3%	13%	7%	30%
38	50%	15%	14%	29%	13%	6%
39	2%	3%	1%	4%	3%	5%
40	0%	0%	0%	0%	0%	0%
41	0%	0%	0%	0%	0%	0%

	Parado			P. Quatro		
Metric	**2**	**3**	**4**	**1**	**2**	**3**
42	0%	23%	29%	14%	13%	25%
43	0%	27%	31%	4%	5%	37%
44	0%	0%	0%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%
46	0%	8%	14%	0%	0%	13%
47	0%	1%	1%	0%	0%	3%
48	0%	0%	0%	0%	0%	0%
49	0%	0%	0%	0%	0%	0%
50	0%	8%	7%	0%	0%	6%
51	0%	7%	1%	0%	0%	1%
52	0%	0%	0%	0%	0%	0%
53	0%	0%	0%	0%	0%	0%
54	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%
57	0%	0%	0%	0%	0%	0%
58	0%	0%	0%	0%	0%	0%
59	0%	0%	0%	0%	0%	0%
60	0%	8%	7%	14%	13%	19%
61	0%	11%	12%	2%	7%	10%
62	50%	8%	7%	14%	25%	13%
63	98%	22%	51%	71%	72%	15%
64	0%	0%	0%	0%	0%	0%
65	0%	0%	0%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%
69	0%	0%	0%	0%	0%	0%
70	0.95	0.15	0.34	0.52	0.27	0.21
71	0.12	2.11	1.44	1.02	1.56	1.92
72	0.05	0.85	0.66	0.48	0.73	0.79
73	100%	54%	50%	86%	75%	38%
74	100%	74%	92%	93%	65%	59%
75	2	4	4	3	3	4
76	50%	31%	36%	29%	38%	38%
77	98%	49%	82%	74%	77%	52%
78	50%	46%	43%	43%	38%	31%
79	2%	26%	3%	11%	9%	8%
80	0%	15%	14%	29%	25%	13%
81	0%	21%	15%	15%	14%	35%
82	0%	8%	7%	0%	0%	19%
83	0%	4%	0%	0%	0%	5%
84	0%	0%	0%	0%	0%	0%
85	0%	0%	0%	0%	0%	0%

	Parado			P. Quatro		
Metric	**2**	**3**	**4**	**1**	**2**	**3**
86	50%	62%	71%	57%	50%	44%
87	2%	46%	33%	14%	14%	44%
88	50%	31%	21%	43%	50%	50%
89	98%	47%	66%	86%	86%	55%
90	0%	8%	7%	0%	0%	6%
91	0%	7%	1%	0%	0%	1%
92	0%	0%	0%	0%	34%	0%
93	50%	15%	29%	29%	38%	38%
94	98%	33%	63%	73%	78%	26%
95	50%	85%	71%	71%	63%	63%
96	2%	67%	37%	27%	22%	74%
97	0%	0%	0%	0%	0%	0%
98	0%	0%	0%	0%	0%	0%
99	100%	100%	100%	100%	88%	94%
100	100%	100%	100%	100%	66%	100%
101	0%	0%	0%	0%	13%	6%
102	0%	0%	0%	0%	34%	0%

Appendix 7. Metric values obtained in sampling sites in the upper Piraí river drainage in April 2016 used for calculation of the multimetric index. The numbers in the first column represent the metrics with same numeration listed in Table 5.

	Coutinhos			Papudos				Parado	
Metric	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**
1	12	8	15	7	4	10	10	3	2
2	69	121	134	466	51	79	126	204	9
3	5	4	5	3	3	5	4	2	2
4	83%	75%	80%	86%	75%	70%	80%	67%	0%
5	17%	38%	20%	14%	25%	30%	20%	0%	0%
6	32%	86%	72%	52%	29%	52%	33%	0%	0%
7	67%	38%	60%	71%	50%	40%	60%	67%	0%
8	54%	11%	19%	14%	45%	33%	30%	23%	0%
9	8%	13%	7%	0%	0%	10%	10%	0%	0%
10	9%	2%	1%	0%	0%	5%	7%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%	0%
15	0%	13%	7%	0%	0%	10%	10%	0%	50%
16	0%	2%	2%	0%	0%	3%	29%	0%	11%
17	8%	0%	7%	14%	25%	10%	0%	33%	50%
18	6%	0%	5%	34%	25%	8%	0%	77%	89%
19	0%	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%	0%
25	7	6	8	4	4	7	6	3	2
26	8%	13%	7%	0%	0%	10%	0%	0%	0%
27	3%	7%	2%	0%	0%	4%	0%	0%	0%
28	0%	0%	0%	0%	0%	0%	0%	0%	0%
29	0%	0%	0%	0%	0%	0%	0%	0%	0%
30	0%	0%	0%	0%	0%	0%	0%	0%	0%
31	0%	0%	0%	0%	0%	0%	0%	0%	0%
32	0%	0%	0%	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%	0%	0%	0%
36	8%	25%	13%	14%	25%	20%	20%	0%	0%
37	29%	79%	69%	52%	29%	48%	33%	0%	0%
38	8%	13%	13%	29%	25%	0%	20%	33%	0%
39	12%	2%	1%	3%	25%	0%	22%	3%	0%
40	0%	0%	0%	0%	0%	0%	0%	0%	0%
41	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Coutinhos			Papudos				Parado	
Metric	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**
42	33%	25%	33%	43%	25%	30%	20%	33%	0%
43	35%	8%	16%	12%	20%	28%	6%	20%	0%
44	0%	0%	0%	0%	0%	0%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%	0%	0%	0%
46	25%	0%	13%	0%	0%	10%	20%	0%	0%
47	7%	0%	1%	0%	0%	5%	2%	0%	0%
48	0%	0%	0%	0%	0%	0%	0%	0%	0%
49	0%	0%	0%	0%	0%	0%	0%	0%	0%
50	8%	13%	7%	0%	0%	10%	10%	0%	0%
51	9%	2%	1%	0%	0%	5%	7%	0%	0%
52	0%	0%	0%	0%	0%	0%	0%	0%	0%
53	0%	0%	0%	0%	0%	0%	0%	0%	0%
54	0%	0%	0%	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%	0%	0%	0%
57	0%	0%	0%	0%	0%	0%	0%	0%	0%
58	0%	0%	0%	0%	0%	0%	0%	0%	0%
59	0%	0%	0%	0%	0%	0%	0%	0%	0%
60	0%	13%	7%	0%	0%	10%	10%	0%	50%
61	0%	2%	2%	0%	0%	3%	29%	0%	11%
62	8%	0%	7%	14%	25%	10%	0%	33%	50%
63	6%	0%	5%	34%	25%	8%	0%	77%	89%
64	0%	0%	0%	0%	0%	0%	0%	0%	0%
65	0%	0%	0%	0%	0%	0%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%	0%	0%	0%
69	0%	0%	0%	0%	0%	0%	0%	0%	0%
70	0.16	0.63	0.49	0.39	0.25	0.26	0.19	0.64	0.80
71	2.09	0.88	1.31	1.15	1.38	1.72	1.83	0.62	0.35
72	0.84	0.37	0.51	0.61	0.75	0.74	0.81	0.36	0.20
73	42%	75%	53%	43%	75%	70%	60%	33%	100%
74	74%	91%	93%	90%	75%	89%	76%	77%	100%
75	4	4	4	3	3	4	4	2	2
76	42%	25%	40%	57%	50%	40%	20%	67%	50%
77	41%	8%	22%	45%	45%	35%	6%	97%	89%
78	42%	38%	33%	29%	25%	20%	40%	33%	0%
79	28%	11%	6%	3%	25%	9%	30%	3%	0%
80	8%	25%	13%	14%	25%	20%	20%	0%	50%
81	29%	80%	71%	52%	29%	47%	50%	0%	11%
82	8%	13%	13%	0%	0%	20%	20%	0%	0%
83	3%	1%	1%	0%	0%	9%	13%	0%	0%
84	0%	0%	0%	0%	0%	0%	0%	0%	0%
85	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Coutinhos			Papudos				Parado	
Metric	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**
86	67%	50%	60%	71%	50%	40%	50%	67%	0%
87	54%	17%	21%	14%	45%	32%	29%	23%	0%
88	25%	38%	33%	29%	50%	50%	40%	33%	100%
89	38%	81%	78%	86%	55%	63%	63%	77%	100%
90	8%	13%	7%	0%	0%	10%	10%	0%	0%
91	9%	2%	1%	0%	0%	5%	7%	0%	0%
92	0%	0%	0%	0%	0%	0%	0%	0%	0%
93	25%	13%	27%	14%	25%	30%	20%	33%	100%
94	10%	2%	10%	34%	25%	15%	30%	77%	100%
95	75%	88%	73%	57%	75%	70%	80%	33%	0%
96	90%	98%	90%	59%	75%	85%	70%	3%	0%
97	0%	0%	0%	29%	0%	0%	0%	33%	0%
98	0%	0%	0%	8%	0%	0%	0%	20%	0%
99	100%	100%	100%	100%	100%	100%	100%	100%	100%
100	100%	100%	100%	100%	100%	100%	100%	100%	100%
101	0%	0%	0%	0%	0%	0%	0%	0%	0%
102	0%	0%	0%	0%	0%	0%	0%	0%	0%

	Piraí				Pedras			
Metric	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	13	13	11	12	4	6	9	16
2	148	105	136	103	335	143	179	124
3	5	5	5	5	3	3	3	4
4	77%	77%	73%	67%	75%	83%	89%	88%
5	23%	31%	18%	33%	25%	33%	67%	38%
6	22%	16%	21%	32%	22%	34%	91%	33%
7	54%	46%	55%	33%	50%	50%	22%	50%
8	22%	26%	54%	43%	45%	43%	7%	32%
9	8%	8%	9%	8%	0%	0%	0%	0%
10	5%	2%	1%	1%	0%	0%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%	0%
12	0%	0%	0%	0%	0%	0%	0%	0%
13	0%	0%	0%	0%	0%	0%	0%	0%
14	0%	0%	0%	0%	0%	0%	0%	0%
15	8%	8%	9%	17%	0%	0%	11%	6%
16	45%	29%	23%	21%	0%	0%	2%	32%
17	8%	8%	9%	8%	25%	17%	0%	6%
18	5%	28%	1%	3%	33%	23%	0%	2%
19	0%	0%	0%	0%	0%	0%	0%	0%
20	0%	0%	0%	0%	0%	0%	0%	0%
21	0%	0%	0%	0%	0%	0%	0%	0%
22	0%	0%	0%	0%	0%	0%	0%	0%
23	0%	0%	0%	0%	0%	0%	0%	0%
24	0%	0%	0%	0%	0%	0%	0%	0%

	Piraí				Pedras			
Metric	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
25	8	9	7	7	4	5	6	8
26	0%	8%	0%	0%	25%	17%	22%	6%
27	0%	1%	0%	0%	22%	17%	24%	16%
28	8%	8%	0%	0%	0%	0%	0%	0%
29	1%	1%	0%	0%	0%	0%	0%	0%
30	0%	0%	0%	8%	0%	0%	11%	6%
31	0%	0%	0%	3%	0%	0%	1%	2%
32	0%	0%	0%	0%	0%	0%	0%	0%
33	0%	0%	0%	0%	0%	0%	0%	0%
34	0%	0%	0%	0%	0%	0%	0%	0%
35	0%	0%	0%	0%	0%	0%	0%	0%
36	15%	15%	18%	25%	0%	17%	33%	25%
37	22%	14%	21%	29%	0%	16%	66%	15%
38	15%	15%	0%	0%	25%	17%	0%	6%
39	2%	3%	0%	0%	3%	1%	0%	2%
40	0%	0%	9%	0%	0%	0%	0%	0%
41	0%	0%	3%	0%	0%	0%	0%	0%
42	23%	23%	18%	25%	25%	33%	22%	25%
43	13%	20%	46%	40%	42%	43%	7%	23%
44	0%	0%	0%	0%	0%	0%	0%	0%
45	0%	0%	0%	0%	0%	0%	0%	0%
46	15%	8%	27%	8%	0%	0%	0%	19%
47	7%	3%	5%	3%	0%	0%	0%	7%
48	0%	0%	0%	0%	0%	0%	0%	0%
49	0%	0%	0%	0%	0%	0%	0%	0%
50	8%	8%	9%	8%	0%	0%	0%	0%
51	5%	2%	1%	1%	0%	0%	0%	0%
52	0%	0%	0%	0%	0%	0%	0%	0%
53	0%	0%	0%	0%	0%	0%	0%	0%
54	0%	0%	0%	0%	0%	0%	0%	0%
55	0%	0%	0%	0%	0%	0%	0%	0%
56	0%	0%	0%	0%	0%	0%	0%	0%
57	0%	0%	0%	0%	0%	0%	0%	0%
58	0%	0%	0%	0%	0%	0%	0%	0%
59	0%	0%	0%	0%	0%	0%	0%	0%
60	8%	8%	9%	17%	0%	0%	11%	6%
61	45%	29%	23%	21%	0%	0%	2%	32%
62	8%	8%	9%	8%	25%	17%	0%	6%
63	5%	28%	1%	3%	33%	23%	0%	2%
64	0%	0%	0%	0%	0%	0%	0%	0%
65	0%	0%	0%	0%	0%	0%	0%	0%
66	0%	0%	0%	0%	0%	0%	0%	0%
67	0%	0%	0%	0%	0%	0%	0%	0%
68	0%	0%	0%	0%	0%	0%	0%	0%

	Piraí				Pedras			
Metric	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
69	0%	0%	0%	0%	0%	0%	0%	0%
70	0.25	0.19	0.26	0.19	0.33	0.27	0.32	0.17
71	1.83	1.96	1.70	1.94	1.17	1.42	1.49	2.18
72	0.75	0.81	0.74	0.81	0.67	0.73	0.68	0.83
73	54%	54%	55%	58%	25%	50%	56%	44%
74	89%	90%	89%	86%	33%	41%	61%	69%
75	4	4	4	5	2	3	5	5
76	31%	31%	36%	33%	50%	50%	22%	31%
77	18%	48%	50%	43%	75%	66%	7%	26%
78	31%	38%	27%	17%	50%	33%	22%	25%
79	11%	9%	5%	4%	25%	18%	24%	23%
80	15%	15%	18%	25%	0%	17%	33%	25%
81	53%	34%	34%	30%	0%	16%	67%	43%
82	23%	15%	18%	17%	0%	0%	11%	13%
83	18%	10%	11%	20%	0%	0%	1%	6%
84	0%	0%	0%	25%	0%	0%	11%	19%
85	0%	0%	0%	3%	0%	0%	1%	2%
86	54%	62%	45%	33%	75%	67%	44%	50%
87	20%	28%	52%	43%	67%	61%	31%	47%
88	38%	31%	45%	58%	25%	33%	56%	50%
89	75%	70%	46%	56%	33%	39%	69%	53%
90	8%	8%	9%	8%	0%	0%	0%	0%
91	5%	2%	1%	1%	0%	0%	0%	0%
92	0%	0%	0%	0%	0%	0%	0%	0%
93	38%	23%	45%	25%	25%	17%	11%	25%
94	55%	57%	32%	24%	33%	23%	2%	37%
95	62%	77%	55%	67%	50%	67%	67%	63%
96	45%	43%	68%	73%	25%	36%	83%	60%
97	0%	0%	0%	8%	25%	17%	22%	13%
98	0%	0%	0%	3%	42%	41%	15%	3%
99	100%	100%	100%	100%	100%	100%	100%	100%
100	100%	100%	100%	100%	100%	100%	100%	100%
101	0%	0%	0%	0%	0%	0%	0%	0%
102	0%	0%	0%	0%	0%	0%	0%	0%

Appendix 8. Species collected in the Guapiaçu river in August 2016.

	Guapiaçu			M. Alexandre
Species	**1**	**3**	**4**	**1**
CHARACIFORMES				
Crenuchidae				
Characidium vidali	40			35
Lebiasinidae				
Pyrrhulina australis			5	
Characidae				
Astyanax sp. 2 gr. *fasciatus*			69	
Astyanax hastatus		10	23	
Astyanax lacustris			6	
Astyanax taeniatus			1	
Bryconamericus sp. aff. *tenuis*		34		
Bryconamericus ornaticeps			7	
Hyphessobrycon eques			3	
Oligosarcus hepsetus			1	
SILURIFORMES				
Trichomycteridae				
Microcambeva barbata			3	
Trichomycterus immaculatus		1		
Trichomycterus zonatus	1	1		4
Loricariidae				
Ancistrus multispinis		1		1
Hypostomus affinis		1	3	
Neoplecostomus granosus	4			1
Pareiorhaphis garbei	43			23
Parotocinclus maculicauda		77	8	
Rineloricaria sp. 1		13	1	
Schizolecis guntheri	13			
Heptapteridae				
Acentronichthys leptos				1
Pimelodella lateristriga		4		
Rhamdia quelen		2		
GYMNOTIFORMES				
Gymnotidae				
Gymnotus carapo		1	1	
GOBIIFORMES				
Oxudercidae				
Awaous tajasica			11	
CICHLIFORMES				
Cichlidae				
Cichlasoma sp.			2	
Crenicichla lepidota		1	2	
Geophagus brasiliensis		1	7	

	Guapiaçu			M. Alexandre
Species	**1**	**3**	**4**	**1**
CYPRINODONTIFORMES				
Poeciliidae				
Phalloceros harpagos			3	
Poecilia vivipara			20	
Symbranchus marmoratus		1		
ANABANTIFORMES				
Osphronemidae				
Trichopodus trichopterus			7	

Appendix 9. Species collected in the Guapiaçu river in December 2017.

	Guapiaçu				M. Alexandre	Gato
Species	**1**	**2**	**3**	**4**	**1**	**1**
CHARACIFORMES						
Crenuchidae						
Characidium interruptum						2
Characidium vidali	23	3			40	12
Erythrinidae						
Hoplias malabaricus				1		
Lebiasinidae						
Pyrrhulina australis				1		
Characidae						
Astyanax sp.		1				
Astyanax sp. 2 gr. *fasciatus*				30		
Astyanax giton			3			
Astyanax intermedius						1
Astyanax taeniatus			1			7
Bryconamericus aff. *tenuis*		37	51			55
Hyphessobrycon bifasciatus				1		
Hyphessobrycon eques				13		
Mimagoniates microlepis		8	6			55
Oligosarcus hepsetus				5		
SILURIFORMES						
Trichomycteridae						
Microcambeva barbata				1		
Trichomycterus zonatus	5	12	1		5	1
Callichthyidae						
Scleromystax barbatus		9	6			
Loricariidae						
Ancistrus multispinis		2			1	19
Hypostomus affinis		3	1	1		
Kronichthys heylandi						1
Neoplecostomus granosus					1	
Pareiorhaphis garbei	30				28	
Parotocinclus maculicauda		9	26	27		1
Rineloricaria sp. 1		34	1	4		5
Rineloricaria sp. 2		13				2
Schizolecis guntheri	2	3				
Heptapteridae						
Pimelodella lateristriga				1		4
Rhamdia quelen		2		1		
Rhamdioglanis transfasciatus	3			1	4	
GYMNOTIFORMES						
Gymnotidae						
Gymnotus carapo				1		
GOBIIFORMES						

	Guapiaçu				M. Alexandre	Gato
Species	**1**	**2**	**3**	**4**	**1**	**1**
Oxudercidae						
Awaous tajasica			1	3		
CICHLIFORMES						
Cichlidae						
Apistogramma sp.				2		
Cichlasoma sp.			1			
Crenicichla lepidota		2	8	7		
Geophagus brasiliensis		6	4	16		6
CYPRINODONTIFORMES						
Poeciliidae						
Phalloceros harpagos		1				16
Phalloceros tupinamba		7				
Poecilia reticulata		7	3	2		
Poecilia vivipara				30		

Appendix 10. Species collected in the Macaé river in June 2017.

	Macaé								S. Bento
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**
CHARACIFORMES									
Crenuchidae									
Characidium sp.			10	13	32				11
Characidium sp. aff. *interruptum*								5	
Characidium sp. aff. *vidali*					1				13
Erythrinidae									
Hoplias malabaricus								2	
Curimatidae									
Cyphocharax gilbert								2	
Lebiasinidae									
Pyrrhulina australis								2	
Characidae									
Astyanax giton								22	
Astyanax hastatus								664	
Astyanax intermedius		301	9						
Astyanax lacustris							3	16	
Astyanax taeniatus						17	10		
Bryconamericus ornaticeps		54							
Oligosarcus hepsetus						1	1		
SILURIFORMES									
Trichomycteridae									
Trichomycterus zonatus		2		1					
Callichthyidae									
Scleromystax barbatus					13				
Loricariidae									
Neoplecostomus microps	1	7	5	6	2				8
Pareiorhaphis garbei	11								7
Parotocinclus maculicauda			1		10	4	11	13	
Rineloricaria sp. 1				3	9	2			
Rineloricaria sp. 2					15	1			
Schizolecis guntheri			21	10	89		4		
Heptapteridae									
Pimelodella lateristriga							1	2	
Rhamdia quelen					2				
Rhamdioglanis transfasciatus	4	15	2	1	12				2
Pseudopimelodidae									
Microglanis nigripinnis							1		
GYMNOTIFORMES									
Gymnotidae									
Gymnotus carapo							1		
Gymnotus pantherinus		2			7				
Sternopygidae									
Eigenmannia sp. gr. *trilineata*							1	1	

	Macaé								S. Bento
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**
GOBIIFORMES									
Eleotridae									
Eleotris pisonis							11	3	
Oxudercidae									
Awaous tajasica						2	8	5	
CICHLIFORMES									
Cichlidae									
Cichlasoma sp.								2	
Crenicichla lacustris						2	10	6	
Geophagus brasiliensis					7	11	1	1	
CYPRINODONTIFORMES									
Poeciliidae									
Phalloceros harpagos		70	3		21	30		11	50
Poecilia reticulata					2				
Poecilia vivipara							1	18	
SYNBRANCHIFORMES									
Synbranchidae									
Symbranchus marmoratus						3			
SYNGNATHIFORMES									
Syngnathidae									
Microphis lineatus								3	
Pseudophallus mindii							2		

Appendix 11. Species collected in the Macaé river in November 2017.

	Macaé								S. Bento	Sana	
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**1**	**2**
CHARACIFORMES											
Crenuchidae											
Characidium sp.			23	33	9				3	19	20
Characidium sp. aff. *vidali*			8		3				7	18	19
Erythrinidae											
Hoplias malabaricus						6	1	1			
Characidae											
Astyanax sp. 2 gr. *fasciatus*								2			
Astyanax giton							1				
Astyanax hastatus							2	163			
Astyanax intermedius		81	308	12	1						
Astyanax lacustris							4	2			
Astyanax taeniatus								7			
Bryconamericus ornaticeps		79									
Mimagoniates microlepis								2			
Oligosarcus hepsetus						9	1	1			
SILURIFORMES											
Trichomycteridae											
Trichomycterus zonatus		1	3	1					12	35	22
Callichthyidae											
Scleromystax barbatus					10						
Loricariidae											
Hisonotus notatus							19	1			
Hypostomus affinis							9	2			
Neoplecostomus microps	1	39	13	7	10				4	27	9
Pareiorhaphis garbei	9								6	1	1
Parotocinclus maculicauda					24	3	8	9			
Rineloricaria sp. 1			8	2	48			1			
Rineloricaria sp. 2					7						20
Schizolecis guntheri			38	2	77						
Auchenipteridae											
Trachelyopterus striatulus							1	1			
Heptapteridae											
Acentronichthys leptos					2						
Pimelodella lateristriga							3	9			
Rhamdia quelen				5	8	1	1	1			
Rhamdioglanis transfasciatus	10	4	5	2	6				7	20	11
Pseudopimelodidae											
Microglanis nigripinnis								1			
GYMNOTIFORMES											
Gymnotidae											
Gymnotus carapo						3		8			
Gymnotus pantherinus					9					2	5
Sternopygidae											
Eigenmannia sp. gr. *trilineata*						5	2	3			
SALMONIFORMES											
Salmonidae											

	Macaé								S. Bento	Sana	
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**1**	**2**
Oncorhynchus mykiss		1									
GOBIIFORMES											
Eleotridae											
Eleotris pisonis							4	1			
Oxudercidae											
Awaous tajasica							30	16			
CICHLIFORMES											
Cichlidae											
Cichlasoma sp.								1			
Crenicichla lacustris						2	13	4			
Geophagus brasiliensis			1	3	7	57	4	6			1
Oreochromis niloticus								1			
CYPRINODONTIFORMES											
Poeciliidae											
Phalloceros harpagos		6	5		58	26	23	20	3	37	270
Poecilia vivipara							43	8			
SYNBRANCHIFORMES											
Synbranchidae											
Symbranchus marmoratus							1				
SYNGNATHIFORMES											
Syngnathidae											
Microphis lineatus							3	1			
Pseudophallus mindii							2				

Appendix 12. Species collected in the upper Piraí river drainage in June 2009.

	Couti-nhos	Papudos			Piraí			Pedras			
Species	**4**	**2**	**3**	**4**	**1**	**2**	**3**	**1**	**2**	**3**	**4**
CHARACIFORMES											
Crenuchidae											
Characidium lauroi			18	1	32	1		3	6	50	3
Characidium vidali					1	1				10	1
Characidae											
Astyanax sp. aff. *scabripinnis*			1								
Astyanax giton					20		1				
Astyanax intermedius	22	7		15	21	21	29		51	81	15
Oligosarcus hepsetus			12	2	2	1	5			3	2
SILURIFORMES											
Trichomycteridae											
Trichomycterus macrophthalmus			1	2	4	16	12			4	1
Trichomycterus mariamole	2							2	1		
Trichomycterus nigroauratus			1	16	3			11		2	3
Loricariidae											
Harttia carvalhoi			4	4	9		3			2	3
Harttia loricariformis										1	
Hemipsilichthys gobio		1									
Hemipsilichthys papillatus					1						
Hypostomus affinis							1				
Neoplecostomus microps	1	8	23	13	27	14		6	8	27	17
Pareiorhina rudolphi								72	24		
Rineloricaria sp. cf. *lima*			5	1	1	7	10				7
Heptapteridae											
Imparfinis minutus					5	1				1	2
Pimelodella lateristriga			1			1					1
Rhamdia quelen			1		3	1	1				7
CICHLIFORMES											
Cichlidae											
Geophagus brasiliensis					7	3	3				38
Oreochromis niloticus					3						
CYPRINODONTIFORMES											
Poeciliidae											
Phalloceros harpagos	84	2	29	1	11	4	15	84	70	5	3

Appendix 13. Species collected in the upper Piraí river drainage in September 2010.

	Couti-nhos	Papudos				Piraí				Pedras			
Species	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
CHARACIFORMES													
Crenuchidae													
Characidium lauroi				32	4	1				25	10	13	26
Characidium vidali												13	69
Erythrinidae													
Hoplias malabaricus									1				
Bryconidae													
Brycon opalinus													3
Characidae													
Astyanax giton						2	5						5
Astyanax intermedius	31	91		15	58	34	28	5	10		19	42	51
Oligosarcus hepsetus				1	3	1	2		2			16	3
SILURIFORMES													
Trichomycteridae													
Trichomycterus macrophthalmus				1	5			5					
Trichomycterus mariamole	3									1			
Trichomycterus nigroauratus	1	16	1	1	30		5			2	7	2	3
Loricariidae													
Harttia carvalhoi				8	18		5		1			3	15
Harttia loricariformis				1	1							1	
Hypostomus affinis								1	1				
Neoplecostomus microps	6	21	13	34	20	8	9	4		9	17	15	47
Pareiorhina rudolphi		7	1							112	64		
Rineloricaria sp. cf. *lima*				8	2	4	2	12	10				3
Heptapteridae													
Imparfinis minutus				1		2	2	1	2				3
Pimelodella lateristriga									4				
Rhamdia quelen				1		4		1					
GYMNOTIFORMES													
Gymnotidae													
Gymnotus pantherinus								1	9				
CICHLIFORMES													
Cichlidae													
Australoheros sp.									2				
Geophagus brasiliensis				1	5	4	16	14	10				5
Oreochromis niloticus								3					
CYPRINODONTIFORMES													
Poeciliidae													
Phalloceros harpagos	67			36	1	4	5	55	16	43	136		1

Appendix 14. Species collected in the upper Piraí river drainage in July 2015.

	Parado			P. Quatro		
Species	**2**	**3**	**4**	**1**	**2**	**3**
CHARACIFORMES						
Crenuchidae						
Characidium lauroi		18		39	5	
Characidium vidali		7	3		37	1
Erythrinidae						
Hoplias malabaricus			1			
Characidae						
Astyanax intermedius		16	15	79	58	74
Oligosarcus hepsetus		6				6
SILURIFORMES						
Trichomycteridae						
Trichomycterus macrophthalmus		2	1	22	27	13
Trichomycterus nigroauratus	5	2	2	1		
Loricariidae						
Harttia carvalhoi		2	4			
Harttia loricariformis						4
Hypostomus affinis			3			1
Neoplecostomus microps		38	118	21	43	10
Rineloricaria sp. cf. *lima*		2	23			84
Heptapteridae						
Imparfinis minutus			3			5
Pimelodella lateristriga		1	1			
Rhamdia quelen						2
GYMNOTIFORMES						
Gymnotidae						
Gymnotus pantherinus		11	4			2
CICHLIFORMES						
Cichlidae						
Australoheros sp.						1
Crenicichla lepidota						5
Geophagus brasiliensis		17	57	11	53	20
CYPRINODONTIFORMES						
Poeciliidae						
Phalloceros harpagos	199	34	241	417	294	40
Poecilia reticulata					266	1

Appendix 15. Species collected in the upper Piraí river drainage in April 2016.

	Coutinhos			Papudos				Parado		Piraí				Pedras			
Species	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
CHARACIFORMES																	
Crenuchidae																	
Characidium lauroi		8				3								73	25	29	20
Characidium vidali	2		3								1					14	
Erythrinidae																	
Hoplias malabaricus										1	1						
Anostomidae																	
Hypomasticus mormyrops													3			1	3
Bryconidae																	
Brycon opalinus																25	1
Characidae																	
Astyanax giton													1				2
Astyanax intermedius	20	95	92	242	15	35	26			11	6	15	14		23	91	10
Oligosarcus hepsetus		1	1			3	16			21	9	13	15			2	5
SILURIFORMES																	
Trichomycteridae																	
Trichomycterus macrophthalmus	8		1				3			1							
Trichomycterus mariamole				2							1						
Trichomycterus nigroauratus		3	1	10	13		25	6		2	2			11	1		2
Callichthyidae																	
Scleromystax barbatus												4					
Loricariidae																	
Harttia carvalhoi	2		1			2					2						
Harttia loricariformis		2	1													1	4
Hemipsilichthys papillatus				1													
Hypostomus affinis	1		2							1		4					1
Hypostomus luetkeni													1				
Neoplecostomus microps	11	8	14	20	10	18	6			2	5		4		3	12	18
Pareiorhina rudolphi				34				40						141	58		
Rineloricaria sp. cf. *lima*	10		4			2	2			16	14	58	36				6
Heptapteridae																	
Imparfinis minutus	2						1			6		1	3				5
Pimelodella lateristriga	1		1								3	4					2
Rhamdia quelen	2		1			4	1			5		2					2
GYMNOTIFORMES																	
Gymnotidae																	
Gymnotus pantherinus	6	2	2			4	9			8	2	2	1				

	Coutinhos			Papudos				Parado		Piraí				Pedras			
Species	**1**	**2**	**3**	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
CICHLIFORMES																	
Cichlidae																	
Crenicichla lepidota													6				
Geophagus brasiliensis		2	3			2	37		1	67	30	31	16			4	40
CYPRINODON-TIFORMES																	
Poeciliidae																	
Phalloceros harpagos	4		7	157	13	6		158	8	7	29	2	3	110	33		3

Appendix 16. Catalog numbers of voucher specimens. The collected specimens that were not catalogued in the Ichthyology Collection of the Museu Nacional (MNRJ) until the present day were associated with the field number of their respective sampling site (PAB). Information about the specimens can be retrieved from the database of the Ichthyology Collection of the Museu Nacional with the field number when they are calagued.

Species	Catalog or field number (number of exemplars)
CHARACIFORMES	
Crenuchidae	
Characidium sp.	MNRJ 50742 (10), MNRJ 50748 (32), MNRJ 50762 (13), MNRJ 50812 (11), PAB2017111001 (23), PAB2017111002 (33), PAB2017111003 (9), PAB2017111201 (3), PAB2017111202 (29), PAB2017111203 (20)
Characidium sp. aff. *interruptum*	MNRJ 50772 (5)
Characidium sp. aff. *vidali*	MNRJ 50749 (1), MNRJ 50811 (13), PAB2017111001 (8), PAB2017111003 (3), PAB2017111201 (7), PAB2017111202 (18), PAB2017111203 (19)
Characidium interruptum	PAB2017121404 (2)
Characidium lauroi	MNRJ 36451 (3), MNRJ 36458 (3), MNRJ 36472 (32), MNRJ 36486 (1), MNRJ 36508 (50), MNRJ 36518 (6), MNRJ 37977 (1), MNRJ 38019 (26), MNRJ 38032 (13), MNRJ 38039 (10), MNRJ 38045 (25), MNRJ 43748 (39), MNRJ 43759 (5), MNRJ 43806 (18), MNRJ 46650 (8), MNRJ 46668 (73), MNRJ 46690 (25), MNRJ 46702 (20), MNRJ 47260 (29)
Characidium vidali	MNRJ 36457 (1), MNRJ 36471 (1), MNRJ 36497 (1), MNRJ 36507 (10), MNRJ 38018 (69), MNRJ 38031 (13), MNRJ 43758 (37), MNRJ 43767 (1), MNRJ 43807 (7), MNRJ 43821 (3), MNRJ 46636 (2), MNRJ 46822 (3), MNRJ 47023 (1), MNRJ 47261 (14), MNRJ 48592 (40), MNRJ 48630 (35), PAB2017121301 (23), PAB2017121302 (40), PAB2017121403 (3), PAB2017121404 (12)
Erythrinidae	
Hoplias malabaricus	MNRJ 38051 (1), MNRJ 43830 (1), MNRJ 46802 (1), MNRJ 47013 (1), MNRJ 50773 (2), PAB2017111004 (6), PAB2017111101 (1), PAB2017111102 (1), PAB2017121401 (1)
Anostomidae	
Hypomasticus mormyrops	MNRJ 46698 (3), MNRJ 47001 (2), MNRJ 47012 (1), MNRJ 47256 (1)
Curimatidae	
Cyphocharax gilbert	MNRJ 50771 (2)
Lebiasinidae	
Pyrrhulina australis	MNRJ 48624 (5), MNRJ 50781 (2), PAB2017121401 (1)
Bryconidae	
Brycon opalinus	MNRJ 38022 (3), MNRJ 46701 (1), MNRJ 47259 (25)
Characidae	
Astyanax sp.	PAB2017121403 (1)
Astyanax sp. 2 gr. *fasciatus*	MNRJ 48324 (69), PAB2017111101 (2), PAB2017121401 (30)

Species	Catalog or field number (number of exemplars)
Astyanax sp. aff. *scabripinnis*	MNRJ 36427 (1)
Astyanax giton	MNRJ 37834 (1), MNRJ 37835 (20), MNRJ 37974 (5), MNRJ 37986 (2), MNRJ 38021 (5), MNRJ 50768 (22), MNRJ 50819 (1), MNRJ 50820 (2), PAB2017111102 (1), PAB2017121402 (3)
Astyanax hastatus	MNRJ 48597 (10), MNRJ 48612 (23), MNRJ 50770 (664), PAB2017111101 (163), PAB2017111102 (2)
Astyanax intermedius	MNRJ 36428 (14), MNRJ 36439 (15), MNRJ 36447 (7), MNRJ 36459 (15), MNRJ 36473 (21), MNRJ 36487 (21), MNRJ 36498 (29), MNRJ 36510 (81), MNRJ 36519 (51), MNRJ 36524 (22), MNRJ 37954 (5), MNRJ 37965 (28), MNRJ 37978 (34), MNRJ 37987 (15), MNRJ 38001 (58), MNRJ 38014 (91), MNRJ 38020 (51), MNRJ 38033 (42), MNRJ 38040 (19), MNRJ 38053 (10), MNRJ 38087 (31), MNRJ 43749 (79), MNRJ 43755 (58), MNRJ 43766 (74), MNRJ 43805 (16), MNRJ 43820 (15), MNRJ 46631 (20), MNRJ 46643 (95), MNRJ 46651 (242), MNRJ 46658 (35), MNRJ 46689 (23), MNRJ 46699 (10), MNRJ 46713 (15), MNRJ 46781 (26), MNRJ 46791 (11), MNRJ 46813 (92), MNRJ 47002 (14), MNRJ 47014 (6), MNRJ 47252 (15), MNRJ 47257 (91), MNRJ 50736 (295), MNRJ 50736 (6), MNRJ 50741 (9), PAB2017110902a (76), PAB2017110902b (5), PAB2017111001 (308), PAB2017111002 (12), PAB2017111003 (1), PAB2017121404 (1)
Astyanax lacustris	MNRJ 48611 (6), MNRJ 50769 (16), MNRJ 50786 (3), PAB2017111101 (2), PAB2017111102 (4)
Astyanax taeniatus	MNRJ 48629 (1), MNRJ 50787 (10), MNRJ 50801 (17), PAB2017111101 (7), PAB2017121402 (1), PAB2017121404 (7)
Bryconamericus sp. aff. *tenuis*	MNRJ 48598 (34), MNRJ PAB2017121402 (51), PAB2017121403 (37), PAB2017121404 (55)
Bryconamericus ornaticeps	MNRJ 48615 (7), MNRJ 50737 (54), PAB2017110902a (71), PAB2017110902b (8)
Hyphessobrycon bifasciatus	PAB2017121401 (1)
Hyphessobrycon eques	MNRJ 48614 (3), PAB2017121401 (13)
Mimagoniates microlepis	PAB2017111101 (2), PAB2017121402 (6), PAB2017121403 (8), PAB2017121404 (55)
Oligosarcus hepsetus	MNRJ 36429 (12), MNRJ 36440 (2), MNRJ 36460 (2), MNRJ 36474 (2), MNRJ 36488 (1), MNRJ 36499 (5), MNRJ 36509 (3), MNRJ 37966 (2), MNRJ 37979 (1), MNRJ 37988 (1), MNRJ 38002 (3), MNRJ 38023 (3), MNRJ 38034 (16), MNRJ 38052 (2), MNRJ 43768 (6), MNRJ 43812 (6), MNRJ 46644 (1), MNRJ 46659 (3), MNRJ 46700 (5), MNRJ 46714 (13), MNRJ 46782 (16), MNRJ 46792 (21), MNRJ 46814 (1), MNRJ 47003 (15), MNRJ 47015 (9), MNRJ 47258 (2), MNRJ 48613 (1), MNRJ 50794 (1), MNRJ 50806 (1), PAB2017111101 (1), PAB2017111102 (1), PAB2017111004 (9), PAB2017121401 (5)
SILURIFORMES	
Trichomycteridae	

Species	Catalog or field number (number of exemplars)
Microcambeva barbata	MNRJ 48616 (3), PAB2017121401 (1)
Trichomycterus immaculatus	MNRJ 48610 (1)
Trichomycterus macrophthalmus	MNRJ 36467 (1), MNRJ 36478 (4), MNRJ 36494 (16), MNRJ 36504 (12), MNRJ 36513 (4), MNRJ 37957 (5), MNRJ 43750 (22), MNRJ 43760 (27), MNRJ 43772 (13), MNRJ 43813 (2), MNRJ 43832 (1), MNRJ 46640 (8), MNRJ 46795 (1), MNRJ 46825 (1)
Trichomycterus mariamole	MNRJ 36452 (2), MNRJ 36520 (1), MNRJ 36525 (2), MNRJ 38047 (1), MNRJ 38088 (3), MNRJ 47024 (1)
Trichomycterus nigroauratus	MNRJ 36453 (11), MNRJ 36468 (3), MNRJ 36477 (3), MNRJ 36512 (2), MNRJ 37968 (5), MNRJ 38025 (3), MNRJ 38035 (2), MNRJ 38041 (7), MNRJ 38046 (2), MNRJ 38091 (1), MNRJ 43719 (5), MNRJ 43754 (1), MNRJ 43814 (2), MNRJ 43833 (2), MNRJ 46645 (3), MNRJ 46669 (11), MNRJ 46694 (1), MNRJ 46712 (2), MNRJ 46796 (2), MNRJ 46824 (1), MNRJ 46834 (6), MNRJ 47025 (1), MNRJ 47026 (1), MNRJ 47253 (13)
Trichomycterus zonatus	MNRJ 48596 (1), MNRJ 48606 (1), MNRJ 48631 (4), MNRJ 50738 (2), MNRJ 50767 (1), PAB2017111001 (3), PAB2017111002 (1), PAB2017111201 (12), PAB2017111202 (35), PAB2017111203 (22), PAB2017121301 (5), PAB2017121302 (5), PAB2017121402 (1), PAB2017121403 (12), PAB2017121404 (1)
Callichthyidae	
Scleromystax barbatus	MNRJ 46722 (4), MNRJ 50754 (13), PAB2017111003 (10), PAB2017121402 (6), PAB2017121403 (9)
Loricariidae	
Ancistrus multispinis	MNRJ 48604 (1), MNRJ 48633 (1), PAB2017121302 (1), PAB2017121403 (2), PAB2017121404 (19)
Harttia carvalhoi	MNRJ 36461 (3), MNRJ 36480 (9), MNRJ 36501 (3), MNRJ 36515 (2), MNRJ 37969 (5), MNRJ 38026 (15), MNRJ 38036 (3), MNRJ 38057 (1), MNRJ 43816 (2), MNRJ 43823 (4), MNRJ 46641 (2), MNRJ 46826 (1), MNRJ 47022 (2)
Harttia loricariformis	MNRJ 36514 (1), MNRJ 38037 (1), MNRJ 43773 (4), MNRJ 46646 (2), MNRJ 46706 (4), MNRJ 46827 (1), MNRJ 47262 (1)
Hemipsilichthys gobio	MNRJ 36448 (1)
Hemipsilichthys papillatus	MNRJ 36482 (1), MNRJ 46657 (1)
Hisonotus notatus	PAB2017111101 (1), PAB2017111102 (19)
Hypostomus affinis	MNRJ 36502 (1), MNRJ 37958 (1), MNRJ 38062 (1), MNRJ 43781 (1), MNRJ 43824 (3), MNRJ 46632 (1), MNRJ 46710 (1), MNRJ 46723 (4), MNRJ 46803 (1), MNRJ 46820 (1), MNRJ 46821 (1), MNRJ 48601 (1), MNRJ 48617 (3), PAB2017111101 (2), PAB2017111102 (9), PAB2017121401 (1), PAB2017121402 (1), PAB2017121403 (3)
Hypostomus luetkeni	MNRJ 47007 (1)
Kronichthys heylandi	PAB2017121404 (1)
Neoplecostomus granosus	MNRJ 48594 (4), MNRJ 50714 (1), PAB2017121302 (1)

Species	Catalog or field number (number of exemplars)
Neoplecostomus microps	MNRJ 36431 (23), MNRJ 36442 (13), MNRJ 36449 (8), MNRJ 36454 (6), MNRJ 36462 (17), MNRJ 36481 (27), MNRJ 36489 (14), MNRJ 36516 (27), MNRJ 36521 (8), MNRJ 36526 (1), MNRJ 37960 (4), MNRJ 37971 (9), MNRJ 37983 (8), MNRJ 37993 (34), MNRJ 38008 (20), MNRJ 38013 (13), MNRJ 38017 (21), MNRJ 38028 (47), MNRJ 38038 (15), MNRJ 38043 (17), MNRJ 38049 (9), MNRJ 38089 (6), MNRJ 43751 (21), MNRJ 43761 (43), MNRJ 43774 (10), MNRJ 43808 (38), MNRJ 43825 (118), MNRJ 46633 (11), MNRJ 46647 (8), MNRJ 46653 (20), MNRJ 46662 (18), MNRJ 46691 (3), MNRJ 46708 (18), MNRJ 46785 (6), MNRJ 46797 (2), MNRJ 46816 (14), MNRJ 47006 (4), MNRJ 47017 (5), MNRJ 47254 (10), MNRJ 47263 (12), MNRJ 50732 (1), MNRJ 50735 (7), MNRJ 50743 (5), MNRJ 50753 (2), MNRJ 50763 (6), MNRJ 50814 (8), PAB2017110901 (1), PAB2017110902a (21), PAB2017110902b (18), PAB2017111001 (13), PAB2017111002 (7), PAB2017111003 (10), PAB2017111201 (4), PAB2017111202 (27), PAB2017111203 (9)
Pareiorhaphis garbei	MNRJ 48593 (43), MNRJ 48632 (23), MNRJ 50731 (11), MNRJ 50813 (7), PAB2017110901 (9), PAB2017111201 (6), PAB2017111202 (1), PAB2017111203 (1), PAB2017121301 (30), PAB2017121302 (28)
Pareiorhina rudolphi	MNRJ 36455 (72), MNRJ 36522 (24), MNRJ 38012 (1), MNRJ 38016 (7), MNRJ 38042 (64), MNRJ 38048 (112), MNRJ 46652 (34), MNRJ 46670 (141), MNRJ 46692 (58), MNRJ 46835 (40)
Parotocinclus maculicauda	MNRJ 48599 (77), MNRJ 48618 (8), MNRJ 50745 (1), MNRJ 50752 (10), MNRJ 50783 (13), MNRJ 50788 (11), MNRJ 50808 (4), MNRJ PAB2017111003 (24), PAB2017111004 (3), PAB2017111101 (9), PAB2017111102 (8), PAB2017121401 (27), PAB2017121402 (26), PAB2017121403 (9), PAB2017121404 (1)
Rineloricaria sp. 1	MNRJ 48600 (13), MNRJ 48628 (1), MNRJ 50760 (9), MNRJ 50766 (3), MNRJ 50810 (2), PAB2017111001 (8), PAB2017111002 (2), PAB2017111003 (48), PAB2017111101 (1), PAB2017111203 (20), PAB2017121401 (4), PAB2017121402 (24), PAB2017121403 (34), PAB2017121404 (5)
Rineloricaria sp. 2	MNRJ 50750 (15), MNRJ 50807 (1), PAB2017111003 (7), PAB2017121403 (13), PAB2017121404 (2)
Rineloricaria sp. cf. *lima*	MNRJ 36432 (5), MNRJ 36443 (1), MNRJ 36463 (7), MNRJ 36479 (1), MNRJ 36490 (7), MNRJ 36503 (10), MNRJ 37959 (12), MNRJ 37970 (2), MNRJ 37982 (4), MNRJ 37994 (8), MNRJ 38007 (2), MNRJ 38027 (3), MNRJ 38058 (10), MNRJ 43771 (84), MNRJ 43817 (2), MNRJ 43826 (23), MNRJ 46634 (10), MNRJ 46661 (2), MNRJ 46707 (6), MNRJ 46717 (58), MNRJ 46784 (2), MNRJ 46798 (16), MNRJ 46817 (4), MNRJ 47005 (36)
Schizolecis guntheri	MNRJ 48595 (13), MNRJ 50744 (21), MNRJ 50751 (89), MNRJ 50764 (10), MNRJ 50795 (4), PAB2017111001

Species	Catalog or field number (number of exemplars)
	(38), PAB2017111002 (2), PAB2017111003 (77), PAB2017121301 (2), PAB2017121403 (3)
Auchenipteridae	
Trachelyopterus striatulus	PAB2017111101 (1), PAB2017111102 (1),
Heptapteridae	
Acentronichthys leptos	MNRJ 48634 (1), PAB2017111003 (2)
Imparfinis minutus	MNRJ 36464 (2), MNRJ 36476 (5), MNRJ 36491 (1), MNRJ 36511 (1), MNRJ 37956 (1), MNRJ 37967 (2), MNRJ 37980 (2), MNRJ 37990 (1), MNRJ 38024 (3), MNRJ 38056 (2), MNRJ 43770 (5), MNRJ 43822 (3), MNRJ 46637 (2), MNRJ 46703 (5), MNRJ 46721 (1), MNRJ 46788 (1), MNRJ 46793 (6), MNRJ 47004 (3)
Pimelodella lateristriga	MNRJ 36434 (1), MNRJ 36465 (1), MNRJ 36492 (1), MNRJ 38055 (4), MNRJ 43815 (1), MNRJ 43831 (1), MNRJ 46639 (1), MNRJ 46704 (2), MNRJ 46715 (4), MNRJ 46823 (1), MNRJ 48602 (4), MNRJ 50785 (2), MNRJ 50796 (1), PAB2017111101 (9), PAB2017111102 (3), PAB2017121401 (1), PAB2017121404 (4)
Rhamdia quelen	MNRJ 36433 (1), MNRJ 36466 (7), MNRJ 36475 (3), MNRJ 36493 (1), MNRJ 36500 (1), MNRJ 37955 (1), MNRJ 37981 (4), MNRJ 37991 (1), MNRJ 43769 (2), MNRJ 46638 (2), MNRJ 46660 (4), MNRJ 46705 (2), MNRJ 46716 (2), MNRJ 46789 (1), MNRJ 46794 (5), MNRJ 46815 (1), MNRJ 47016 (3), MNRJ 48603 (2), MNRJ 50761 (2), PAB2017111002 (5), PAB2017111003 (8), PAB2017111101 (1), PAB2017111102 (1), PAB2017111004 (1), PAB2017121401 (1), PAB2017121403 (2)
Rhamdioglanis transfasciatus	MNRJ 50733 (4), MNRJ 50734 (3), MNRJ 50734 (12), MNRJ 50746 (2), MNRJ 50755 (12), MNRJ 50765 (1), MNRJ 50816 (2), PAB2017110901 (10), PAB2017110902a (2), PAB2017110902b (2), PAB2017111001 (5), PAB2017111002 (2), PAB2017111003 (6), PAB2017111201 (7), PAB2017111202 (20), PAB2017111203 (11), PAB2017121301 (3), PAB2017121302 (4)
Pseudopimelodidae	
Microglanis nigripinnis	MNRJ 50800 (1), PAB2017111101 (1)
GYMNOTIFORMES	
Gymnotidae	
Gymnotus carapo	MNRJ 48605 (1), MNRJ 48619 (1), MNRJ 50793 (1), PAB2017111101 (8), PAB2017111004 (3), PAB2017121401 (1)
Gymnotus pantherinus	MNRJ 37961 (1), MNRJ 38054 (9), MNRJ 43777 (2), MNRJ 43809 (11), MNRJ 43827 (4), MNRJ 46635 (6), MNRJ 46648 (2), MNRJ 46663 (4), MNRJ 46718 (2), MNRJ 46786 (9), MNRJ 46799 (8), MNRJ 46828 (2), MNRJ 47008 (1), MNRJ 47019 (2), MNRJ 50740 (2), MNRJ 50756 (7), PAB2017111003 (9), PAB2017111202 (2), PAB2017111203 (5)
Sternopygidae	

Species	Catalog or field number (number of exemplars)
Eigenmannia sp. gr. *trilineata*	MNRJ 50776 (1), MNRJ 50797 (1), PAB2017111101 (3), PAB2017111102 (2), PAB2017111004 (5)
SALMONIFORMES	
Salmonidae	
Oncorhynchus mykiss	PAB2017121401 (2)
GOBIIFORMES	
Eleotridae	
Eleotris pisonis	MNRJ 50782 (3), MNRJ 50792 (11), PAB2017111101 (1), PAB2017111102 (4)
Oxudercidae	
Awaous tajasica	MNRJ 48623 (11), MNRJ 50780 (5), MNRJ 50791 (8), MNRJ 50805 (2), PAB2017111101 (16), PAB2017111102 (30), PAB2017121401 (3), PAB2017121402 (1)
CICHLIFORMES	
Cichlidae	
Apistogramma sp.	PAB2017121401 (2)
Australoheros sp.	MNRJ 38060 (2), MNRJ 43780 (1)
Cichlasoma sp.	MNRJ 48622 (2), MNRJ 50778 (2), PAB2017111101 (1), PAB2017121402 (1)
Crenicichla lacustris	MNRJ 50777 (6), MNRJ 50789 (10), MNRJ 50803 (2), PAB2017111101 (4), PAB2017111102 (13), PAB2017111004 (2)
Crenicichla lepidota	MNRJ 43779 (5), MNRJ 47010 (6), MNRJ 48607 (1), MNRJ 48620 (2), PAB2017121401 (7), PAB2017121402 (8), PAB2017121403 (2)
Geophagus brasiliensis	MNRJ 36470 (38), MNRJ 36484 (7), MNRJ 36496 (3), MNRJ 36506 (3), MNRJ 37963 (14), MNRJ 37973 (16), MNRJ 37985 (4), MNRJ 37998 (1), MNRJ 38009 (5), MNRJ 38030 (5), MNRJ 38061 (10), MNRJ 43753 (11), MNRJ 43764 (53), MNRJ 43778 (20), MNRJ 43810 (17), MNRJ 43829 (57), MNRJ 46649 (2), MNRJ 46667 (2), MNRJ 46709 (40), MNRJ 46720 (31), MNRJ 46787 (37), MNRJ 46801 (67), MNRJ 46819 (3), MNRJ 47011 (16), MNRJ 47021 (30), MNRJ 47230 (1), MNRJ 47264 (4), MNRJ 48608 (1), MNRJ 48621 (7), MNRJ 50759 (7), MNRJ 50779 (1), MNRJ 50790 (1), MNRJ 50804 (11), PAB2017111001 (1), PAB2017111002 (3), PAB2017111003 (7), PAB2017111101 (6), PAB2017111102 (4), PAB2017111203 (1), PAB2017111004 (57), PAB2017121401 (16), PAB2017121402 (4), PAB2017121403 (6), PAB2017121404 (6)
Oreochromis niloticus	MNRJ 36485 (3), MNRJ 37964 (3), PAB2017111101 (1)
CYPRINODONTIFORMES	
Poeciliidae	
Phalloceros harpagos	MNRJ 36437 (29), MNRJ 36446 (1), MNRJ 36450 (2), MNRJ 36456 (84), MNRJ 36469 (3), MNRJ 36483 (11), MNRJ 36495 (4), MNRJ 36505 (15), MNRJ 36517 (5), MNRJ 36523 (70), MNRJ 36527 (84), MNRJ 37962 (55), MNRJ 37972 (5), MNRJ 37984 (4), MNRJ 37997 (36),

Species	Catalog or field number (number of exemplars)
	MNRJ 38010 (1), MNRJ 38029 (1), MNRJ 38044 (136), MNRJ 38050 (43), MNRJ 38059 (16), MNRJ 38090 (67), MNRJ 43722 (199), MNRJ 43752 (417), MNRJ 43762 (294), MNRJ 43775 (40), MNRJ 43811 (34), MNRJ 43828 (241), MNRJ 46642 (4), MNRJ 46655 (157), MNRJ 46664 (6), MNRJ 46671 (110), MNRJ 46693 (33), MNRJ 46711 (3), MNRJ 46719 (2), MNRJ 46800 (7), MNRJ 46818 (7), MNRJ 46836 (158), MNRJ 47009 (3), MNRJ 47020 (29), MNRJ 47231 (8), MNRJ 47255 (13), MNRJ 48627 (3), MNRJ 50739 (70), MNRJ 50747 (3), MNRJ 50757 (21), MNRJ 50774 (11), MNRJ 50802 (30), MNRJ 50815 (50), PAB2017110902b (6), PAB2017111001 (5), PAB2017111003 (58), PAB2017111101 (20), PAB2017111102 (23), PAB2017111201 (3), PAB2017111202 (37), PAB2017111203 (270), PAB2017111004 (26), PAB2017121403 (1), PAB2017121404 (16)
Phalloceros tupinamba	PAB2017121403 (7)
Poecilia reticulata	MNRJ 43763 (266), MNRJ 43776 (1), MNRJ 50758 (2), PAB2017121401 (2), PAB2017121402 (3), PAB2017121403 (7)
Poecilia vivipara	MNRJ 48626 (20), MNRJ 50775 (18), MNRJ 50798 (1), PAB2017111101 (8), PAB2017111102 (43), PAB2017121401 (30)
SYNBRANCHIFORMES	
Synbranchidae	
Symbranchus marmoratus	MNRJ 48609 (1), MNRJ 50809 (3), PAB2017111102 (1)
ANABANTIFORMES	
Osphronemidae	
Trichopodus trichopterus	MNRJ 48625 (7)
SYNGNATHIFORMES	
Syngnathidae	
Microphis lineatus	MNRJ 50784 (3), PAB2017111101 (1), PAB2017111102 (3)
Pseudophallus mindii	MNRJ 50799 (2), PAB2017111102 (2)