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# Efeito do turismo de natureza sobre o comportamento de peixes em riachos de cabeceira

São José do Rio Preto
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Tese apresentada como parte dos requisitos para obtenção do título de Doutor em Biologia Animal, junto ao Programa de Pós-Graduação em Biologia Animal, Área de Concentração – Ecologia e Comportamento, do Instituto de Biociências, Letras e Ciências Exatas da Universidade Estadual Paulista "Júlio de Mesquita Filho", Campus de São José do Rio Preto.

Orientadora: Profª. Drª. Eliane Gonçalves de Freitas

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São José do Rio Preto
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À Cristina, minha esposa e companheira de todas as horas nesse processo conturbado que é a aquisição de um título de doutor.

“A verdade sobre a natureza é muito mais bela do que nossos maiores poetas poderiam cantar.”

Konrad Lorenz

“Se naturalistas vão para o céu (coisa de que tenho consideráveis dúvidas eclesiásticas), espero que lá eu receba um bando de papagaios para me entreterem, em vez de uma televisão.”

Gerald Durrell

# SUMÁRIO

# RESUMO

O turismo de natureza tem sido apontado como solução para o dilema entre conservar o ambiente ou lucrar com ele. No entanto, o turismo de natureza também causa impactos, o que ainda é pouco estudado. Meu objetivo foi avaliar como o turismo afeta o comportamento dos peixes testando se os peixes evitarão os turistas ou mudarão seu comportamento social em resposta à visitação a longo prazo, mesmo na ausência do turista, uma abordagem inovadora. Dividi riachos de Nobres, Mato Grosso em três tratamentos: Áreas Referência (RA nos artigos em Inglês), Áreas de Visitação Monitorada (MVA) e Áreas de Visitação Não-Monitorada (NMVA). Comparei uso de microhabitats, período de atividade, agressividade e nidificação nesses três tratamentos. As dez espécies de peixes analisadas não mudaram o uso dos microhabitats nem o período de atividade. Como os ambientes estão degradados pelo turismo, isso me levou a considerar inadequados estes indicadores. Os comportamentos sociais (agressividade e nidificação) responderam apenas à falta de monitoramento. Assim, o monitoramento do turista é fundamental para a conservação. Em conclusão, o turismo de natureza pode aliar conservação e exploração econômica, desde que use indicadores de impactos funcionais e que o comportamento dos turistas seja monitorado.

Palavras-chave: Conservação. Cichlidae. Characiformes. Territorialidade. Nidificação. Uso de microhabitats. Período de atividade.

# *ABSTRACT*

*Nature-based tourism has been touted as a solution to the dilemma between conserving the environment or taking profit from it. However, nature tourism also causes impacts, which is still understudied. My objective was to evaluate how tourism affects fish behavior by testing whether the fish avoid tourists or change their social behavior in response to visitation in the long term, after visitors have left, an innovative approach. I divided the streams of Nobres, Mato Grosso, Brazil, in three treatments: Reference Areas (RA), Monitored Visitation Areas (MVA) and Non-Monitored Visitation Areas (NMVA). I compared microhabitat use, activity period, aggressiveness and nesting in these three treatments. The ten fish species analyzed did not change microhabitat use or activity periods. Since the environment is degraded by tourism, I considered these inadequate indicators. Differently, social behaviors (aggression and nesting) responded only to lack of monitoring. Thus, monitoring the tourists is fundamental for conservation. In conclusion, nature tourism can combine conservation and economic exploitation, provided you use functional impacts indicators and monitor tourists' behavior.*

*Keywords*: *Conservation. Cichlidae. Characiformes. Territoriality. Nidification. Microhabitat use. Activity period.*

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# INTRODUÇÃO GERAL

## Os valores da biodiversidade

O termo biodiversidade foi cunhado por Edward O. Wilson para incluir três níveis da diversidade biológica (Wilson, 1988): o nível molecular, ou genético; o nível orgânico, ou taxonômico; e o nível da paisagem. Todos os três níveis apresentam seu valor para a humanidade, mas estão ameaçados por nosso modelo econômico naquela que já é considerada uma nova era geológica, o Antropoceno (Zalasiewicz et al., 2011).

Um dilema entre o desenvolvimento econômico mundial e a conservação da biodiversidade foi preconizado, embora ele seja, de fato, um falso dilema (Sabino et al., 2012). Considero esse dilema falso por dois motivos que se localizam nas duas pontas do processo econômico: a matéria prima e o mercado consumidor. Primeiro porque toda atividade humana tem na sua base matéria prima natural. Deixar de se preocupar com a biodiversidade é abrir mão da matéria prima que move a economia. Segundo porque toda a economia depende de um mercado consumidor. Esse mercado, composto por nós humanos, compõe uma delicada rede de interações que depende em certo grau de estabilidade ecológica. Caso a economia degrade demais o ambiente, seus consumidores serão penalizados, afetando-a por consequência.

Vivendo numa sociedade capitalista, atribuir valor à biodiversidade é interessante (Kopnina, 2012) e, ao mesmo tempo, uma tarefa complexa. De forma a pautar a atribuição de valor à biodiversidade, esse valor foi dividido em três (Sabino et al., 2012). O valor de mercado considera como valioso aquilo que gera recursos concretos. Quando um rio produz grande quantidade de peixes próprios para o consumo humano, esse rio possui valor de mercado. Considera-se valor de amenidade aquele proporcionado pela experiência que um item da biodiversidade nos causa. É o valor de amenidade que leva um turista a deslocar-se de sua casa para um ambiente natural para fazer ecoturismo. Por fim, todos os integrantes da biodiversidade são o produto de um processo evolutivo de bilhões de anos e atuam em funções chave em seus ecossistemas. No valor moral, considera-se que por isso todas as espécies têm o direito de existir.

**A humanidade busca a natureza**

A hipótese da biofilia pode ser definida como nosso vínculo inato com a natureza (Wilson, 1984). A humanidade evoluiu num panorama natural, por isso, a presença de elementos naturais desencadeia a sensação de bem-estar em nosso organismo. Humanos buscam instintivamente o contato com a natureza, o que nos causa bem-estar físico e psicológico (Heinsch, 2012). Existem evidências disso na velocidade de recuperação de doentes (Annerstedt e Wahrborg, 2011) e na resiliência ao sofrimento (Tidball, 2012). Talvez devido a esse desejo de estar com a natureza o homem busque o ecoturismo.

O ecoturismo como vemos hoje surgiu na década de 1980 e é o segmento do turismo que mais cresce (Hawkins & Lamoureux, 2001). As definições de ecoturismo são dissonantes (Donohoe & Needham, 2006), algumas definem ecoturismo pelo foco: locais de natureza preservada. Outras pelo modo: turismo que não oferece, ou oferece minimamente, impactos ambientais. Talvez a definição ideal esteja numa junção das duas: visitação a locais preservados causando o menor impacto possível (Blamey, 2001, Tabela 1.1).

A Organização Mundial do Turismo estima um crescimento cerca de três vezes maior para o ecoturismo do que o da indústria turística como um todo, cerca de 7% de todos os gastos com viagens internacionais no mundo (Shum, 2007). Segundo projeções, o ecoturismo pode passar a movimentar nos próximos anos cerca de US$ 473 bilhões por ano (World Tourism Organization, 2010). Os dados disponíveis para o Brasil são menos completos, mas destinos ecoturísticos constam de diversos relatórios e perspectivas de aumento da importância econômica do turismo brasileiro (Barbosa, 2010). Dos 184 destinos turísticos vinculados pela EMBRATUR à Copa de 2014, por exemplo, 140 são destinos voltados para o ecoturismo (Ministério do Turismo, 2012).

Essa busca por contato com a natureza não é diferente nos ambientes aquáticos. Da mesma forma que grandes símios incluem fontes de água em seus territórios, a proximidade da água nos conforta (Wilson, 1984), tornando-a um elemento comum no paisagismo (Mador, 2008), mas também um ambiente a ser visitado. O ecoturismo tem crescido principalmente no mar, mas também em grandes rios, lagos e riachos de cabeceira. Esses últimos têm recebido turistas para a prática do mergulho livre, a chamada flutuação (Sabino & Andrade, 2003). Nobres, em Mato Grosso, área de estudo desta tese, é um ponto de ecoturismo em água doce cuja importância vem crescendo.

## Ecoturismo e impactos ambientais

O ecoturismo tem aparecido como uma grande esperança na valorização da natureza e na geração de renda sem a degradação ambiental (United Nations Environmental Program, 2005). No entanto, fica claro que essa mesma atividade tem potencial de degradar o ambiente onde ocorre (McKercher, 1993). Sendo o ecoturismo a busca pela interação com um ambiente natural preservado, temos um paradoxo para a sustentabilidade econômica dessa atividade: o turismo degrada, mas o turista busca paisagens preservadas. Assim, é primordial desenvolver estratégias de monitoramento e mitigação dos impactos causados pelo ecoturismo, especialmente estratégias baseadas em dados científicos.

Estudos anteriores apontaram impactos do ecoturismo sobre a fauna. Turistas frequentemente afastam a fauna de grandes animais (Rogala et al., 2011). Mesmo acostumar-se à presença humana pode ser prejudicial (Higham & Shelton, 2011), podendo resultar, por exemplo, no contágio da fauna por doenças humanas (Muehlenbein et al., 2010). O ruído produzido pelos turistas é outra forma de impacto (Davenport & Davenport, 2006; Constantine et al., 2004).

Em ambiente recifal ocorre a simplificação estrutural do habitat pelo turismo nos recifes de coral (Rouphael & Inglis, 2001; Daby, 2003) e a oferta de alimento (Ilarri et al., 2008). Em rios são conhecidos os impactos causados pela pesca amadora (Catella et al., 1997). Mais recentemente alguns estudos enfocaram o turismo de flutuação nos riachos de cabeceira. A perda de complexidade do habitat e o pisoteio do substrato (Teresa et al., 2011), e a oferta de alimento (Obs. Pess.) são alguns fatores que começaram a ser explorados, embora os estudos ainda sejam incipientes. Ainda não existe, por exemplo, uma ferramenta clara de monitoramento e mitigação dos impactos turísticos em riachos.

**Ferramentas para monitoramento e manejo do ecoturismo**

O ecoturismo pode ser uma alternativa viável para lucrar com ambientes preservados, desde que realizado de maneira sustentável (United Nations Environmental Program, 2005). Alguns manuais de boas práticas em ecoturismo foram propostos (Drumm & Moore, 2003; Higginbottom, 2004; Ministério do Meio Ambiente, 2006; Tapper, 2006). Protocolos de avaliação de impactos também são essenciais.

O primeiro protocolo de sustentabilidade turística baseou-se na capacidade de carga. Essa medida diz respeito ao número de visitantes que uma área pode suportar. A capacidade de carga, no entanto, não considera especificidades do ambiente nem o comportamento do visitante (McCool & Lime, 2001).

Alternativas incluem indicadores mensuráveis selecionados pelo gestor do turismo para cada atração. Foi o caso do monitoramento de impacto da visitação, VIM na sigla em inglês (Graefe et al., 1990), o protocolo de limites aceitáveis de alteração (Stankey et al., 1984) e o protocolo de experiência do visitante e proteção dos recursos (Manning et al., 1995).

**O comportamento no manejo do ecoturismo em ambientes aquáticos**

Muitos protocolos de gerenciamento do ecoturismo se pautam em indicadores escolhidos pelo próprio gestor da atividade ou órgão de regulação ambiental ou turística. Seria interessante usar indicadores embasados em argumentos empíricos (Tarlow & Blumstein, 2007). É comum usar espécies ou a estrutura da comunidade como indicadores (Casatti et al., 2010), mas o comportamento ainda é pouco explorado na conservação (Caro & Sherman, 2011).

Respostas comportamentais já são conhecidas para diversos tipos de impactos como poluição química (Craig & Laming, 2004), sonora (Schwemmer et al., 2011; Rolland et al., 2012), introdução de espécies invasoras (Mattos & Orrock, 2010), iluminação artificial (Witherington, 1992) e mudança na disponibilidade de sítios de nidificação (Semel & Shermann, 2001). Isso indica que o comportamento pode ser uma importante ferramenta para o diagnóstico de novos impactos ambientais (Wingfield, 2003), desde que informações básicas e empíricas subsidiem sua aplicação. De acordo com Semeniuk et al., (2011), três níveis comportamentais devem ser considerados para avaliação de impactos ambientais: 1) História de vida; 2) Socialidade e reprodução; e 3) Alimentação e interação predador-presa. Assim, esses níveis podem servir como base para estudos sobre impactos do ecoturismo.

Alguns esforços já foram feitos para encontrar indicadores comportamentais de impactos do turismo em ambientes aquáticos. A resposta de golfinhos nariz de garrafa (*Tursiops truncatus*) aos barcos turísticos serviu de base para a regulação da observação de golfinhos na Nova Zelândia (Constantine et al., 2004). Milazzo e colaboradores (2006) apresentam dados sobre alterações comportamentais de peixes recifais em decorrência da oferta de alimento. Esses autores são tolerantes com a prática, desde que restrita a uma área só, devido ao seu valor na interação entre peixes e turistas. Em riachos, o comportamento alimentar de peixes na relação nuclear-seguidor é afetado indiretamente pelo turismo, por meio da simplificação do habitat (Teresa et al., 2011).

## Desafios do uso do comportamento no manejo do ecoturismo

Ainda há alguns entraves para a aplicação do comportamento animal na conservação (Caro, 2007). Conhecer as espécies de peixes de cabeceiras tropicais nos dará bases para entender padrões comportamentais naturais e alterados por impactos humanos como o turismo. Serão esses padrões alteráveis que funcionarão como indicadores (Tarlow & Blumstein, 2007). Esse conhecimento precisa transcender a taxonomia, um início necessário, mas que demanda complementação. Com uma base teórica robusta, muitas vezes puramente descritiva, fica mais fácil usar o comportamento no manejo do ecoturismo e comparar comportamentos naturais com respostas aos impactos.

Outra necessidade reside na busca por padrões de resposta. Compreender todos os ambientes onde o ecoturismo possa se instalar será impossível. Dessa maneira, conhecer padrões de respostas comportamentais por meio da integração de dados de diferentes ambientes pode ser a chave para o manejo. Mesmo situações diferentes como a resposta comportamental à oferta de alimento numa ilha do Mediterrâneo (Milazzo et al., 2006) num recife do nordeste brasileiro (Ilarri et al., 2008) e num riacho de cabeceira (Obs. Pess.) têm características em comum e a solução encontrada para um pode ser aplicada aos outros. Uma massa crítica de pesquisas será necessária para permitir as extrapolações necessárias ao uso do comportamento no controle de impactos do turismo.

O comportamento animal padece de um grave problema, muitas pessoas acreditam fazer pesquisas e observações comportamentais sem dominarem as técnicas relacionadas. Talvez por isso existam tantos trabalhos sobre métodos em comportamento animal (Altmann, 1974; Lehner, 1998; Martin & Bateson, 2007). Para aplicar o comportamento ao manejo do turismo será necessário formar observadores, sejam eles os gestores da atividade turística, cientistas, ambientalistas ou até os turistas. Todos esses personagens podem ser coletores dos dados necessários ao manejo, desde que sejam treinados.

Por fim, é necessário convencer os tomadores de decisão do valor das pesquisas no embasamento das políticas públicas, incluindo o valor do comportamento enquanto indicador de impactos (Buchholdz, 2007) e seu papel no manejo de atrações turísticas. Indicadores fisiológicos (Sprague, 1971) e ecológicos (Casatti et al., 2010) de impactos ambientais já são bem conhecidos e utilizados na conservação. Indicadores comportamentais ainda são novidade, portanto sua eficácia ainda precisa de aceitação. É só com o acúmulo de pesquisas e de aplicações bem sucedidas que esse reconhecimento virá.

**O conteúdo desta tese**

Esta tese de doutorado busca apresentar indicadores comportamentais dos impactos decorrentes do turismo de forma a torná-lo uma ferramenta de conservação desse ambiente. Em outras palavras, a pergunta que norteou toda essa pesquisa foi: Como a ocorrência de turismo altera o comportamento dos peixes de cabeceira? Procurei avaliar a aplicabilidade de comportamentos dos peixes que habitam esses riachos como medidas do grau de alteração causada pelo ecoturismo. Uma das novidades desse estudo consiste na avaliação em longo prazo dos impactos do turismo, ou seja, além do momento em que o turista e o peixe estavam em contato direto (Bejder et al., 2006).

Há duas formas de abordar os efeitos do ecoturismo, uma abrange a comunidade, a outra enfoca a espécie. Utilizei essas duas abordagens. Esses são dois dos três comportamentos apontados como mais susceptíveis a impactos por Semeniuck et al. (2011). Tais dados podem servir de base para propostas de políticas públicas sobre a gestão de riachos de cabeceira utilizados para turismo.

No primeiro capítulo avaliei como dez espécies de peixes abundantes (veja apêndice para a lista completa de espécies) e importantes para o visitante escolhem seus microhabitats e seu período de atividade em áreas sem visitação, com visitação monitorada e com visitação não-monitorada. Previ uma ocupação de ambientes mais crípticos e atividade em horários alternativos em locais onde o turismo ocorria de modo mais impactante. Isso porque evitar o contato direto com o visitante é um mecanismo de defesa comum entre animais afetados pelo turismo (Bejder et al., 2006). O uso de dez espécies de importância para os visitantes buscou atender aos requisitos propostos por Caro (2007). Apesar do impacto do turismo ser visível (conforme diagnosticado pelo monitoramento do impacto de visitação), os microhabitats ocupados e os períodos de atividade não se alteraram, sinalizando que esses podem não ser bons indicadores de impacto do ecoturismo. Os peixes têm adaptações fortes para a ocupação de locais específicos do rio e para seu horário de atividade, não lhes sendo facultado alterá-los em resposta ao turismo. Esse capítulo, já em inglês, está formatado e será submetido ao *Journal of Fish Biology*.

No segundo capítulo avaliei como o ecoturismo afeta o comportamento de nidificação e agressivo em uma espécie social, *Crenicichla lepidota*. Espécies sociais têm um importante papel ecológico e são indicadores eficientes de estressores ambientais, causando um controle da comunidade de baixo para cima (Wong, 2012). De fato, minhas predições de redução do número de casais nidificando e redução da agressividade foram confirmadas em áreas com turismo não-monitorado (sem o uso adequado de medidas conservacionistas). Ficou ainda demonstrada a importância do monitoramento das atrações turísticas para a manutenção do comportamento desse peixe. Esse capítulo será submetido ao periódico *Tourism Management*.

## Referências


Altmann, J. (1974). Observational study of behavior: sampling methods. *Behaviour, 49*, 227–265. doi: 10.1163/156853974X00534

Annerstedt, M., & Wahrborg, P. (2011). Nature-assisted therapy: Systematic review of controlled and observational studies. *Scandinavian Journal of Public Health, 39,* 371–388. doi: 10.1177/1403494810396400

Barbosa, L. G. M. (2010). *Índice de Competitividade do Turismo Nacional: 65 Destinos Indutores do Desenvolvimento Turístico Regional*. Brasília, Ministério do Turismo.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., & Krützen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology, 20*, 1791–1798. doi: 10.1111/j.1523-1739.2006.00540.x

Blamey, R. K. (2001). Principles of ecotourism. In Weaver, D. B (Ed.), *The encyclopedia of ecotourism* (pp. 5–22). Wallingford: CABI Publishing.

Buchholdz, R. (2007). Behavioural biology: an effective and relevant conservation tool. *Trends in Ecology and Evolution, 22,* 401–407. doi: 10.1016/j.tree.2007.06.002

Caro, T. (2007). Behavior and conservation: a bridge too far? *Trends in Ecology and Evolution, 22,* 394–400. doi: 10.1016/j.tree.2007.06.003

Caro, T., & Sherman, P. W. (2011). Endangered species and a threatened discipline: behavioural ecology. *Trends in Ecology and Evolution, 26,* 111–118. doi: 10.1016/j.tree.2010.12.008

Casatti, L., Romero, R. M., Teresa, F. B., Sabino, J., & Langeani, F. (2010). Fish community structure along a conservation gradient in Bodoquena Plateau streams, central west of Brazil. *Acta Limnologica Brasiliensia, 22*, 50–59. doi: 10.4322/actalb.02201007

Catella, A. C., Nascimento, F. L., Moraes, A. S., Resende, E. K., Calheiros D. F. et al. (1997). Ictiofauna. In Ministério do Meio Ambiente (Ed.), *Plano de Conservação da Bacia do Alto Paraguai (Pantanal) - PCBAP. Diagnóstico dos Meios físico e biótico: meio biótico* (pp. 324–400). Brasília: Ministério do Meio Ambiente.

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation, 117,* 299–307. doi: 10.1016/j.biocon.2003.12.009

Craig, S., & Laming, P. (2004). Behaviour of the three-spined stickleback, *Gasterosteous aculeatus* (Gasterosteidae, Teleostei) in the multispecies freshwater biomonitor: a validation of automated recordings at three levels of ammonia pollution. *Water Research, 38,* 2144–2154. doi: 10.1016/j.watres.2004.01.021

Daby, D. (2003). Effects of seagrass bed removal for tourism purposes in a Mauritian bay. *Environmental Pollution, 125,* 313–324. doi: 10.1016/S0269-7491(03)00125-8

Davenport, J., & Davenport, J. L. (2006). The impact of tourism and personal leisure transport on coastal environments: A review. *Estuarine, Coastal and Shelf Science, 67,* 280–292. doi: 10.1016/j.ecss.2005.11.026

Donohoe, H. M., & Needham, R. D. (2006). Ecotourism: The Evolving Contemporary Definition. *Journal of Ecotourism, 5,* 192–210. doi: 10.2167/joe152.0

Drumm, A., & Moore, A. (2003). *Ecotourism development: A manual series for conservation planners and managers*. Arlington, VA: The Nature Conservancy.

Graefe, A. R., Kuss, F. R., & Vaske, J. J. (1990). *Visitor Impact Management: The Planning Framework*. Washington, DC: National Parks and Conservation Association.

Hawkins, D. E., & Lamoureux, K. (2001). Global growth and magnitude of ecotourism. In D. B. Weaver (Ed.), *The encyclopedia of ecotourism* (pp. 63–73). Wallingford: CABI Publishing.

Heinsch, M. (2012). Getting down to earth: Finding a place for nature in social work practice. *International Journal of Social Welfare, 21,* 309–318. doi: 10.1111/j.1468-2397.2011.00860.x

Higginbottom, K. (2004). *Wildlife Tourism, Impacts, Management and Planning.* Altona: Common Ground Publishing.

Higham, J. E. S., & Shelton, E. J. (2011). Tourism and wildlife habituation: Reduced population fitness or cessation of impact? *Tourism Management, 32,* 1290–1298. doi: 10.1016/j.tourman.2010.12.006

Ilarri, M. I., Souza, A. T., Medeiros, P. R., Grempel, R. G., & Rosa, I. M. L. (2008). Effects of tourist visitation and supplementary feeding on fish assemblage composition on a tropical reef in the Southwestern Atlantic. *Neotropical Ichthyology, 6,* 651–656. doi: 10.1590/S1679-62252008000400014

Kopnina, H. (2012). The Lorax complex: deep ecology, ecocentrism and exclusion. *Journal of Integrative Environmental Sciences, 9,* 235–254. doi: 10.1080/1943815X.2012.742914

Lehner, P. N. (1998). *Handbook of ethological methods*. Cambridge: Cambridge University Press.

Mador, M. L. (2008). Water, Biophilic design and the built environment. In S. R. Kellert, J. Heerwagen, & M. L. Mador (Eds.), *Biophilic design: The theory, science and practice of bringing buildings to life* (pp. 43–58). Hoboken: John Wiley & Sons.

Manning, R., Lime, D., Hof, M., & Freimund, W. (1995). The visitor experience and resource protection (VERP) process: The application of carrying capacity to arches national park. *The George Wright Forum, 12,* 41–45. http://www.uvm.edu/parkstudieslaboratory/publications/VERP.pdf

Martin, P., & Bateson, P. (2007). *Measuring behaviour, an introductory guide*. Cambridge: Cambridge University Press.

Mattos, K. J., & Orrock, J. L. (2010). Behavioural consequences of plant invasion: an invasive plant alters rodent antipredator behaviour. *Behavioural Ecology, 21,* 336–561. doi: 10.1093/beheco/arq020

McCool, S. F., & Lime, D. W. (2001). Tourism carrying capacity: Tempting fantasy or useful reality? *Journal of Sustainable Tourism, 9,* 372–388. doi: 10.1080/09669580108667409

McKercher, R. (1993). Some fundamental truths about tourism: understanding tourism's social and environmental impacts. *Journal of Sustainable Tourism, 1,* 6–16. doi: 10.1080/09669589309514793

Milazzo, M., Anastasi, I., & Willis, T. J. (2006). Recreational fish feeding affects coastal fish behavior and increases frequency of predation on damselfish *Chromis chromis* nests. *Marine Ecology Progress Series, 310,* 165–172. doi: 10.3354/meps310165

Ministério do Meio Ambiente (MMA). (2006). *Diretrizes para a visitação em Unidades de Conservação*. Brasília: Ministério do Meio Ambiente.

Ministério do Turismo (MTur). (2012). *Roteiros da Copa 2014*. Brasília: Ministério do Turismo.

Muehlenbein, M. P., Martinez, L. A., Lemke, A. A., Ambu, L., Nathan, S., Alsisto, S., & Sakong, R. (2010). Unhealthy travelers present challenges to sustainable primate ecotourism. *Travel Medicine and Infectious Disease, 8,* 169–175. doi: 10.1016/j.tmaid.2010.03.004

Rogala, J. K., Hebblewhite, M., Whittington, J., White, C. A., Coleshill, J., & Musiani, M. (2011). Human activity differentially redistributes large mammals in the Canadian Rockies national parks. *Ecology and Society, 16,* 16. doi: 10.5751/ES-04251-160316

Rolland, R. M., Parks, S. E., Hunt, K. E., Castellote, M., Corkeron, P. J., Nowacek, D. P., Wasser, S. K., & Kraus, S. D. (2012). Evidence that ship noise increases stress in right whales. *Proceedings of the Royal Society B, 279,* 2363–2368. doi:10.1098/rspb.2011.2429.

Rouphael, A. B., & Inglis, G. J. (2001). “Take only photographs and leave only footprints”?: An experimental study of the impacts of underwater photographers on coral reef dive sites. *Biological Conservation, 100,* 281–287. doi: 10.1016/S0006-3207(01)00032-5

Sabino, J., & Andrade, L. P. (2003). Uso e conservação da ictiofauna na região de Bonito, Mato Grosso do Sul: o mito da sustentabilidade ecológica no rio Baía Bonita (Aquário Natural de Bonito). *Biota Neotropica, 3,* 1–9. http://www.biotaneotropica.org.br/v3n2/pt/fullpaper?bn00403022003+pt

Sabino, J., Andrade, L. P., & Bessa, E. (2012). Ecoturismo, Valorizar a natureza para gerar negócios sustentáveis e renda. In J. Sabino (Ed.), *Ecoturismo: Nas Trilhas da Biodiversidade Brasileira* (pp. 16–23). Campo Grande, SEBRAE/Natureza em Foco.

Schwemmer, P., Mendel, B., Sonntag, N., Dierschke, V., & Garthe, S. (2011). Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. *Ecological Applications, 21,* 1851–1860. doi: 10.1890/10-0615.1

Semel, B., & Shermann, P. W. (2001). Intraspecific parasitism and nest-site competition in wood ducks. *Animal Behaviour, 61,* 787–803. doi: 10.1006/anbe.2000.1657

Semeniuk, C. A. D., Musiani, M., & Marceau, D. J. (2011). Integrating spatial behavioral ecology in agent-based models for species conservation. In A. Sofo (Ed.), *Biodiversity* (pp. 3–26). Rijeka: InTech.

Shum, K. (2007). Green Travel: Trends in Ecotourism. Obtido em: http://www.lohas.com/green-travel. Visualizado em 16 de fevereiro de 2013.

Sprague, J. B. (1971). Measurement of pollutant toxicity to fish III: Sublethal effects and “safe” concentrations. *Water Research, 5,* 245–266. doi: 10.1016/0043-1354(71)90171-0

Stankey, G. H., McCool, S. F. & Stokes, G. L. (1984). Limits of Acceptable Change: A New Framework for Managing the Bob Marshall Wilderness Complex. *Western Wildlands, 10,* 33–37. http://prdp2fs.ess.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5346576.pdf

Tapper, R. (2006). *Wildlife Watching and Tourism: a study on the benefits and risks of a fast growing tourism activity and its impacts on species*. Bonn: UNEP/CMS Secretariat.

Tarlow, E. M., & Blumstein, D. T. (2007). Evaluating methods to quantify anthropogenic stressors on wild animals. *Applied Animal Behaviour Science, 102,* 429–451. doi: 10.1016/j.applanim.2006.05.040

Teresa, F. B., Romero, R. M., Casatti, L., & Sabino, J. (2011). Microhabitat simplification affects nuclear-follower foraging relationship among stream fishes. *Neotropical Ichthyology, 9,* 121–126. doi: 10.1590/S1679-62252011005000009

Tidball, K. G. (2012). Urgent Biophilia: Human-Nature Interactions and Biological Attractions in Disaster Resilience. *Ecology and Society, 17,* 5. doi: 10.5751/ES-04596-170205

United Nations Environmental Programme (UNEP). (2005). *Forging links between protected areas and the tourism sector: how tourism can benefit conservation*. Paris: UNF.

Wilson, E. O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.

Wilson, E. O. (1988). The actual situation of biological diversity. In E. O. Wilson (Ed.), *Biodiversity* (pp. 5–20). Washington, DC: National Academy Press.

Wingfield, J. C. (2003). Control of behavioural strategies for capricious environments. *Environmental Management, 47,* 960–968.

Witherington, B. E. (1992). Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica, 48,* 31–39. doi: 10.2307/3892916

Wong, M. Y. L. (2012). Abiotic stressors and the conservation of social species. *Biological Conservation, 155,* 77–84. doi: 10.1016/j.biocon.2012.05.018

World Tourism Organization (WTO). (2010). Tourism 2020 vision. Obtido de: http://www.unwto.org/facts/eng/vision.htm. Visualizado em 16 de fevereiro de 2013.

Zalasiewicz, J., Williams, M., Haywood, A., & Ellis, M. (2011). The Anthropocene: a new epoch of geological time? *Philosophical Transactions of the Royal Society A, 1938,* 835–841. doi: 10.1098/rsta.2010.0339

# Microhabitat use and activity period do not indicate impacts from aquatic nature tourism on fish

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**Abstract**

The maintenance of environmental integrity in headwater streams requires an effective technique for evaluating impacts caused by nature tourism. Here we evaluated how useful microhabitat use and activity period are for that purpose by predicting that tourism, especially that done without monitoring, would alter where fish stay and when they are more active. We divided the sampling points in reference areas, monitored tourism areas and non-monitored tourism areas, then we evaluated each area's conservation state with a visitation impact monitoring protocol. We preformed underwater censuses evaluating microhabitat use and activity by ten fish species in different hours of the day. The fish neither changed microhabitat use, nor activity period in response to tourists. Since we ruled out that the river was not impacted by tourism with the visitation impact monitoring protocol, we conclude that microhabitat use and activity period are not appropriate indicators of the impacts caused by nature-based tourism in headwater streams. This may be because these characteristics are species-specific; fish are adapted to a certain microhabitat and activity period and cannot inhabit other sites or be active in other periods.

## Introduction

Nature tourism industry has been growing all over the world (Weaver and Lawton, 2007). Then research regarding the impact that such activity can cause in exploited places has being growing accordingly (*e.g*. Praveena et al., 2012). To the moment results are dissonant, sometimes pointing at a sustainable coexistence between conservation and touristic exploitation (White et al., 2008), sometimes registering impacts (Uyarra & Côté, 2007). This may reflect either that the indicators of impact used are not adequate to infer environment impacts or that the nature tourism is not an impacting activity, this last being the most unlikely. Therefore, attributing the responsibility for impacts to nature tourism is still a conundrum and more effective means of impact evaluation are needed.

Many authors have used a single species to monitor visitation impacts, either because the monitored species is a central touristic attraction (Quiros, 2007), because it pertains to a better studied taxon (Müllner et al., 2004), or because it is considered a charismatic or flagship species (Bejder et al., 2006). Contrastingly, Blumstein et al. (2005) suggest that a more precise measure of the human effect on the wildlife should consist on the evaluation of numerous species of that fauna. In this way, analysis of impacts from tourism on a larger array of species by quantitative metrics would generate more efficient evaluation protocols, which could conciliate tourism and conservation based on empiric evidence (Tarlow and Blumstein, 2007).

Touristic visitation is increasing in clear headwater streams where visitors can snorkel along underwater trails. Such kind of environment is rich in animal and plant species, but still understudied and subject to numerous impacts (Yates & Bailey, 2010). Moreover, due to the agricultural expansion and their smaller volume, low-order streams are frequently more affected by environmental impacts (Casatti et al., 2012). Altogether, touristic exploitation, lack of information and environmental fragility make urgent the study of headwater streams.

Among the taxa that compose stream communities, fish are good candidates for indicator species. Besides already being used as indicators for diverse ecologic impacts (Alyan, 2007), fish are efficient indicators of touristic impact on coral reefs (Milazzo et al., 2005) and freshwater streams (Teresa et al., 2011a). They are also the most attractive species for tourists during snorkeling, thus, their behavior should produce effective and practical evaluation protocols.

We measured microhabitat use and activity period changes by ten fish species as indicators of touristic disturbances. The behavior is expected to respond faster to environmental changes than other biological factors, such as population or community structure (Wingfield, 2003). It is known that animals respond to the presence of humans as they respond to predators (Frid & Dill, 2002), so they were expected to occupy the environment in a different fashion where tourists are present (Rogala et al., 2011; Lusseau, 2004). Tourists might also influence fish activity period, inhibiting activity during visitation periods, what was already observed in mammals (Duchesne et al., 2000; Lusseau, 2004).

With this study we aimed to evaluate if fish microhabitat use and their activity period are disturbed by tourism. First we guaranteed that tourism is damaging the environment with a visitation impact monitoring protocol. Next we predicted that: i) fish that prefer open substrate and the water column would move to more cryptic microhabitats in the presence of visitors, especially if managers do not monitor the touristic activity; and ii) the period when fish are more active would change to periods before or after the tourists were present, more markedly where tourism is not monitored. We also evaluated if analyzing more species gives a more complete scenario of the environment status by observing if species response varied. By studying environments without visitors and with controlled visiting we depicted good comparison to non-monitored visiting areas.

## Materials and Methods

### Study areas

Good representative areas to test tourism indicators occur in Nobres, in Mato Grosso, Brazil (14° 43’ 13”S; 56° 19’ 39”W; Fig. 1). Many touristic attractions are located there receiving around 5 thousand visitors every month, according to the touristic agencies operating there. Government and particular investments are improving the tourism in the area and attracting more visitors. Nobres is placed on the Brazilian Central Plateau on limestone soil, there are streams with visibility beyond 20 m due to the flocculation of sediments caused by the calcium carbonate provided by the soil (Strahler, 1952). Those streams sustain rich fauna and flora with strong aesthetic appeal. All these characteristics makes of Nobres an ideal site for aquatic nature tourism, especially in the rivers Estivado, Triste and Salobra, where tourists practice underwater trails.

In that environment, we could define three treatments, according to the intensity of the tourism: Reference areas (RA), natural areas where visitation does not occur; monitored visitation areas (MVA), where touristic attraction manager strictly monitor tourism (controlled number of tourists, floatation equipment and presence of a guide); and non-monitored visitation area (NMVA), in which the tourism occurs without any sort of regulation. We controlled river depth, diversity of water velocity and depth, combination of pool-riffle-run, substrate coverage, fish abundance and predator abundance (Table 1).

To evaluate fish microhabitat preference, we sampled the proportion occupied by each substrate microhabitat with eight 5 $m^2$ quadrants randomly placed in each treatment. We identified seven types of microhabitats (Fig. 2) common to the three treatments based on Romero and Casatti (2012): large wood pieces (LW), hard substrate (HS), unconsolidated substrate (US), channel surface (CS), channel center (CC), macrophytes and roots (MR) and litter (LI). Macrophytes and roots were considered two distinct microhabitats by Romero and Casatti (2012), but since macrophytes commonly occurred amidst the roots in our study area, we considered it a single microhabitat.

Evaluation of the nature tourism impact

To test if our treatments are under tourism pressure, we used a visitation impact monitoring protocol (Graefe et al., 1990), which is based on qualitative and quantitative physical, biological and social factors influencing the environment, summarized in Table I.

Data collection

We conducted the *in situ* study applying snorkeling techniques. Collects occurred from June 2010 to September 2011, always during the dry season. We focused ten species chosen according to their visibility, easiness of identification, abundance and attractiveness to the tourists and diurnal activity period during tourist visitation: *Astyanax asuncionensis, Brycon hilarii, Characidium zebra, Cichlasoma dimerus, Crenicichla lepidota, Hyphessobrycon eques, Leporinus friderici, Leporinus striatus, Prochilodus lineatus* and *Salminus brasiliensis* (Fig. 2, see appendix too for the complete species list). Testimony specimens of the smaller species are deposited in the Coleção de Peixes (DZSJRP numbers 14789-14810).

For the analysis of microhabitat use we did 30 visual censuses (Labrosse et al., 2002) in 10 m transects randomly placed in the treatment area. For 5 min the diver swam along the transect at a continuous speed of 2 $m.min^{-1}$ to avoid bias. We registered the number of individuals of each species, the microhabitat they were at and how exposed or hidden they were. We considered in hidden substrate fish amidst plants, inside wood pieces, buried under the litter or beneath large rocks; on the opposite, we considered in open substrates fish at the surface or mid water, on the litter, sand or rocks. The records along transects were done from 08:00 to 12:00 with intervals between sessions of no less than 4 h and no more than 20 days to avoid temporal autocorrelation and seasonal interference, respectively.

For the activity period we performed five visual censuses in each treatment, logging if individuals of the ten studied species were active (feeding, moving, outside the shelters) or inactive (immobile by the river bed, inside shelters). The censuses were performed before the arrivals of tourists (06:00), during the morning visitation period (09:00), during the afternoon visitation period (15:00), after visitation period (18:00) and at night (20:00). At night we used indirect light with a red filter to avoid disturbing the animals. Similarly, the censuses did not start before a 10 min adjustment period during which the diver stood still.

Data analysis

A chi-square test was applied to compare the frequency of occurrence of each species in each microhabitat and in open or closed substrate between the treatments. The same test compared the frequency of active versus inactive fish in the three treatments. We considered as expected the values found for the reference areas and as observed the values for monitored visitation areas and non-monitored visitation areas. Significant values were set at $\alpha > 0.05$.

The connectance is a measure generally used to evaluate predators' specialization, but we used it here to evaluate microhabitat use according to Romero and Casatti (2012). Connectance is the ratio between the number of possible connections and the number of observed connections. The connectance was compared between treatments to check for preference for a microhabitat due to tourism. We used variance to check how much variation occurred between the treatments. We also correlated connectance and microhabitat proportion using a Spearman ranks test (Zar, 1999).

## Results

The visitation impact monitoring results demonstrate that the tourism in its current form has already impacted the environment (Table I). As expected, non-monitored visitation areas are the most disturbed environment, with a minor touristic effect on monitored visitation areas. Marginal erosion and modification, riparian forest degradations, nests of *C. lepidota*, number of visitors and presence of rubbish were the factors that varied the most between non-monitored visitation areas and reference areas. We also registered the hybrid tambacu (*Piaractus mesopotamicus* x *Colossoma macropomum*) in both visited areas, an invasive species.

Each studied species preferred a microhabitat in the streams (Fig. 2 and 3). Nevertheless, the preference for an open or closed microhabitat was not altered by the touristic use of the area. Microhabitat use was similar between reference, monitored and non-monitored visitation areas (Table II).

The fish were generally connected to the same microhabitats, despite how impacted by the tourism the area was. Connectance was not correlated to substrate abundance in any of the treatments (Reference areas: Spearman's $\rho = 0.243$; $p = 0.600$; Monitored visitation areas: $\rho = 0.572$; $p = 0.180$; Non-monitored visitation areas: $\rho = 0.724$; $p = 0.066$;). The connectance between fish species and microhabitats were similar and had little variation (Reference areas = 0.70; Monitored visitation areas = 0.59; Non-monitored visitation areas = 0.61; Variance = 0.035) in the three treatments (Fig. 3).

All the studied species were more active during the morning and afternoon (Fig. 4). The fish were not more active right before or after the touristic visiting, activity period did not change in response to tourism.

## Discussion

Against our predictions, the fish did not move from the microhabitats they originally occupied when exposed to tourism, even though this activity is certainly causing impacts, as evidenced by the visitation impact management protocol. Similarly, no change in activity period was observed, taking to the rejection of our second prediction. The species showed high connectance to their microhabitats, allowing us to conclude that they are not plastic in relation to this resource.

Our behavioral results suggest two possibilities: i) that the tourism was not impacting the streams; or ii) that, although an impact is occurring, our indicators are not efficient at pointing it. We relied on visitation impact management to decide between these possibilities. Visitation impact monitoring is a protocol widely used by tourism managers that applies specific factors to evaluate visitation impacts (Graefe et al., 1990). How arbitrary this protocol is depends heavily on the choice of these factors, but it is considered a better choice than concurrent protocols such as cargo capacity (McCool & Lime, 2001) and recreation opportunity spectrum (Higginbottom, 2004). Thus, we carefully chose the factors used in our visitation impact management protocol.

The physical factors we applied refer to structural changes in the habitat due to visitation. The marginal erosion occurs due to an increase in water turbulence and transit of tourists both in the river and by the margins. Building stairs and timbering may serve the touristic activity, but results in changes in habitat structure. Tourists frequently hang on sunken objects and end up breaking those (Rouphael & Inglis, 2001), thus, this is a common indicator used on land protocols. Land protocols also frequently use unofficial tracks and shortcuts (Li et al., 2005), a similar impact occurs when the tourist decides to enter or exit the floatation in unofficial points.

Biological factors include impacts to the fauna and flora. Riparian forest can be put down to facilitate tourist access to the river, but at a devastating cost to the environment (Teresa & Casatti, 2010). Unnatural behaviors, such as fish swimming towards the visitors begging for food is a sign of human impact (Milazzo et al., 2006). Invasive species, such as the tambacu hybrid found in the study area, are indicative of impacted areas (Casatti et al., 2010). We also used the presence of reproductive couples of the pike cichlid *Crenicichla lepidota* as indicator of quality (Pers. Obs.).

The social factors involve visitors' perception and direct impact on the environment. Although the cargo capacity paradigm has failed to protect visited areas (McCool & Lime, 2001), the number of visitors per meter of floatation track is an important adjuvant measurement. We also asked five visitors how conserved they recognize the area in a scale of 1 to 5 (one being very degraded and 5 being very conserved) and if they could report any inadequate behavior by other people. Finally, we recorded two inadequate visitors' behaviors:

feeding the fish (Ilarri et al. 2008) and the presence of rubbish in the water. It is widely accepted that tourism can disturb the environment (McKercher, 1993), including in headwater streams (Teresa et al., 2011b) and in our own study area (Bessa & Gonçalves-de-Freitas, *in prep*.). Thus, the visitation impact monitoring protocol confirmed that the studied streams are under tourism impacts, especially those in non-monitored visitation areas; ruling out the environmental integrity and confirming that microhabitat use and activity period are not good indicators of tourism impacts.

The species we observed were recorded for microhabitats and activity periods that mostly agree with previous studies (Romero & Casatti, 2012 for *A. asuncionensis*; Sabino & Sazima, 1999 for *B. hilarii*; Zuanon et al., 2006 for *C. zebra*; Romero & Casatti, 2012 for *C. dimerus*; Sazima, 1986 for *C. lepidota*; Carvalho & Del-Claro, 2004 for *H. eques*; Bizzotto et al. 2009 for *L. friderici*; Romero & Casatti, 2012 for *L. striatus*; Teresa et al., 2011a for *P. lineatus*; and finally  Bessa, et al., 2011 for *S. brasiliensis*). At least two fish species occupied all the microhabitats in our treatments. Microhabitat use is consistent across different study sites and day hour.

Fish usually present site fidelity (Zuanon & Sabino, 1998; Cetra et al., 2011; but see Grossman & Ratajczak Jr., 1998 for contrasting data). One of the predictions from the ecomorphological hypothesis (Bock & von Wahlert, 1965; Casatti & Castro, 2006) is that the use of a given microhabitat is determined by each species' morphological aspects. Considering that a microhabitat puts selective pressures on its inhabitants, it follows that the fish's body responds to the pressures of that specific microhabitat, making them unsuitable to others. Microhabitat fidelity was previously linked to reducing competition among species with dietary overlap (Cetra et al., 2011). In fact, the predominant plastic diet with high niche overlap of most freshwater fish (Hartley, 1948) may be possible only due to microhabitat fidelity. Thus, occupying a microhabitat is not just a matter of refuge from a threat, but a much more enduring relation, even when threatened by predators. For instance, *L. friderici* does not shelter under rocks or amidst the vegetation when threatened by predators, but flee within the same microhabitat (Lima et al., 2012). The same can occur in response to human visitors, changing microhabitats seems not to be an option.

Because fish species are not leaving their microhabitats, it is likely that with the loss of microhabitat diversity, many species should go extinct. The most connected microhabitats in our study were the channel center, hard substrate and unconsolidated substrate, while

Romero and Casatti (2012) report marginal vegetation, fine roots, and hard substrate as the most important microhabitats in their cross-watershed study. The low correlation between microhabitat occurrence and fish occupying them in our study may reflect the small fish communities in rheophilic streams (Belliard et al., 1997). This means low competition for space so that the species could move to another microhabitat in response to tourism, which reinforces that a morphological limitation, not competition, prevented the fish from moving. Being restricted to certain microhabitats, the spatial conservation of streams should be a concern in aquatic management programs.

Fish did not respond to the presence of the tourists by shifting their activity period either. Cronobiology is the science that studies how organisms cope with time. According to it, every animal, including fish, has an endogenous activity rhythm which is mostly innate, but may be dragged by environmental cues (*zeitgebers*) such as light-dark cycles (Volpato & Trajano, 2006). We expected that the presence of tourists could function as a *zeitgeber*, as has been shown for competition (Cetra et al., 2011) and predation (Metcalf et al., 1998), but our results show this is not the case. Even when some plasticity is recognized in the activity period, this is not an immediate response, depending on the exposure to a consistent *zeitgeber* during critical parts of the fish's life history (Metcalf et al., 1998). At least the eye morphology has been considered a morphological constrain to activity period plasticity in fish (Schmitz & Wainwright, 2011). The time-budget of the studied species may not allow them to reduce activity during the visitation period or anticipate or delay their active period simply because the fish are not physiologically adapted to being active in a different period.

Staying in the same microhabitat and being active in the same period can be interpreted as habituation, but this does not mean lack of impact. The term 'habituation' is frequently misused (Bejden et al., 2009), resulting in tourists and managers considering that the animals are well and receptive. Even when habituation does occur, it can harm an animal by reducing its defense behaviors and altering the time spent in other behaviors (Shackley, 1996). Thus, habituation is not a sign of impact cessation, but a reduction of the overall fitness of the species (Higham & Shelton, 2011).

Even though our data did not present significant variation among the studied species, this is more likely due to the inefficiency of our metrics than to multiple species analyses being unimportant. Previous studies demonstrate that species respond differently to visitation impact depending on numerous aspects of their biology (reviewed by Blumstein et al., 2005).

In general, species whose feeding and social habits are impacted by the tourism should be closely watched (Medeiros et al., 2007; Ilarri et al., 2008; Teresa et al., 2011a; Bessa & Gonçalves-de-Freitas, *in prep.*).

Social behavior has a knock-on effect on community structure (Wong, 2012) with direct influence on microhabitat use. When humans affect abiotic variables, which may disturb social stability (Gonçalves-de-Freitas et al., 2008), they also alter group and population structure. In turn, social-species' populations will influence the community (Waldie et al., 2011). Finally, community structure and microhabitat use are connected; community was responsible for 60 to 80% of microhabitat distribution between coral reef fish (Robertson & Gaines, 1986). Visitation impacts on Nobres' streams are still in the base of this cascade with no measurable impacts on the microhabitat use and activity period. Measuring more base-level changes, like territoriality and other social behaviors, should be more effective.

We conclude that microhabitat use and activity period are not good indicators of impacts caused by nature tourism visitation. Further studies should evaluate trophic interactions, sensitive species' abundance and social behavior as potential indicators. In an applied aspect, environmental management protocols for touristic areas, such as Visitation Impact Monitoring (VIM) and Least Acceptable Change (LAC), should not apply microhabitat use and activity period as metrics for impact evaluation.

**References**


Alyan, S. (2007). Aggressive behaviour in *Betta splendens* as a bio-indicator of freshwater pollution. *Fresenius Environmental Bulletin* **16**: 176–181.

Bejder, L., Samuels, A., Gales, N., Mann, J., Connor. R., Heithaus, M., Watson-Capps, J., Flaherty, C. & Krützen, M. (2006). Decline in Relative Abundance of Bottlenose Dolphins Exposed to Long-Term Disturbance. *Conservation Biology* **20**: 1791–1798. doi: 10.1111/j.1523-1739.2006.00540.x

Bejder, L., Samuels, A., Whitehead, H., Finn, H. & Allen, S. (2009). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Marine Ecology Progress Series* **395**: 177–185. doi: 10.3354/meps07979

Belliard, J., Boët, P. & Tales, E. (1997). Regional and longitudinal patterns of fish community structure in the Seine River basin, France. *Environmental Biology of Fishes* **50**: 133–147. doi: 10.1023/A:1007353527126

Bessa, E., Carvalho, L. N., Sabino, J. & Tomazzelli, P. (2011). Juveniles of the piscivorous dourado *Salminus brasiliensis* mimic the piraputanga *Brycon hilarii* as an alternative predation tactic. *Neotropical Ichthyology* **9**: 351–354. doi: 10.1590/S1679-62252011005000016

Bizzotto, P. M., Godinho, A. L., Vono, V., Kynard, B., & Godinho, H. P. (2009). Influence of seasonal, diel, lunar, and other environmental factors on upstream fish passage in the Igarapava Fish Ladder, Brazil. *Ecology of Freshwater Fish* **18**: 461–472. doi: 10.1111/j.1600-0633.2009.00361.x

Blumstein, D. T., Fernández-Juricic, E., Zollner, P. A. & Garity, S. C. (2005). Inter-specific variation in avian responses to human disturbance. *Journal of Applied Ecology* **42**: 943–953. doi: 10.1111/j.1365-2664.2005.01071.x

Bock, W. J. & von Wahlert, G., (1965). Adaptation and the form-function complex. *Evolution* **19**: 269–299. doi: 10.2307/2406439

Carvalho, L. N. & Del-Claro, K. (2004). Effects of predation pressure on the feeding behaviour of the serpa tetra *Hyphessobrycon eques* (Ostariophysi, Characidae). *Acta Ethologica* **7**: 89–93. doi: 10.1007/s10211-004-0093-1

Casatti, L. & Castro, R. M. C. (2006). Testing the ecomorphological hypothesis in a headwater riffles fish assemblage of the rio São Francisco, southeastern Brazil. *Neotropical Ichthyology* **4**: 203–214. doi: 10.1590/S1679-62252006000200006

Casatti, L., Langeani, F., Silva, A. M. & Castro, R. M. C. (2006). Stream fish, water and habitat quality in a pasture dominated basin, southeastern Brazil. *Brazilian Journal of Biology* **66**: 681–696. doi: 10.1590/S1519-69842006000400012

Casatti, L., Romero, R. M., Teresa, F. B., Sabino, J., & Langeani, F. (2010). Fish community structure along a conservation gradient in Bodoquena Plateau streams, central west of Brazil. *Acta Limnologica Brasiliensia* **22**: 50–59. doi: 10.4322/actalb.02201007

Casatti, L., Teresa, F. B., Gonçalves-Souza, T., Bessa, E., Manzotti, A. R., Gonçalves, C. S. & Zeni, J. O. (2012). From forests to cattail: how does the riparian zone influence stream fish? *Neotropical Ichthyology* **10**: 205–214. doi: 10.1590/S1679-62252012000100020

Cetra, M., Rondineli, G. R. & Souza, U. P. (2011). Compartilhamento de recursos por duas espécies de peixes nectobentônicas de riachos na bacia do rio Cachoeira (BA). *Biota Neotropica* **11**: 87–95. doi: 10.1590/S1676-06032011000200010

Duchesne, M., Côté, S. D. & Barrette, C. (2000). Responses of woodland caribou to winter ecotourism in the Charlevoix Biosphere Reserve, Canada. *Biological Conservation* **96**: 311–317. doi: 10.1016/S0006-3207(00)00082-3

Frid, A. & Dill, A., (2002). Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* **6**: 11.

Gonçalves-de-Freitas, E., Teresa, F. B., Gomes, S. F., & Giaquinto, P. C. (2008). Effect of water renewal on dominance hierarchy of juvenile Nile tilapia. *Applied Animal Behaviour Science* **112**: 187–195. doi: 10.1016/j.applanim.2007.07.002

Graefe, A. R., Kuss, F. R. & Vaske, J. J. (1990). *Visitor Impact Management: The Planning Framework*, Vol. 2. Washington, DC: National Parks and Conservation Association.

Grossman, G. O. & Ratajczak Jr., R. E. (1998). Long-term patterns of microhabitat use by fish in a southern Appalachian stream from 1983 to 1992: effects of hydrologic period, season and fish length. *Ecology of Freshwater Fish* **7**: 108–131. doi: 10.1111/j.1600-0633.1998.tb00178.x

Hartley, P. H. T. (1948). Food and Feeding Relationships in a Community of Fresh-Water Fishes. *Journal of Animal Ecology* **17**: 1–14. doi: 10.2307/1604

Higginbottom, K. (2004). *Wildlife Tourism, Impacts, Management and Planning.* Altona, Australia: Common Ground Publishing.

Higham, J. E. S. & Shelton, E. J. (2011). Tourism and wildlife habituation: Reduced population fitness or cessation of impact? *Tourism Management* **32**: 1290–1298. doi: 10.1016/j.tourman.2010.12.006

Ilarri, M. I., Souza, A. T., Medeiros, P. R., Grempel, R. G. & Rosa, I. M. L. (2008). Effects of tourist visitation and supplementary feeding on fish assemblage composition on a tropical reef in the Southwestern Atlantic. *Neotropical Ichthyology* **6**: 651–656. doi: 10.1590/S1679-62252008000400014

Labrosse, P., kulbicki, M. & Ferraris, J. (2002). *Underwater visual census surveys, proper use and implementation.* Noumea: Reef Resource Assessment Tools.

Li, W., Ge, X. & Liu, C. (2005). Hiking trails and tourism impact assessment in protected area: Jiuzhaigou Biosphere Reserve, China. *Environmental Monitoring and Assessment* **108**: 279–293. doi: 10.1007/s10661-005-4327-0

Lima, M. R. L., Bessa, E., Krinski, D. & Carvalho, L. N. (2012). Mutilating predation in the Cheirodontinae *Odontostilbe pequira* (Characiformes: Characidae). *Neotropical Ichthyology* **10**: 361–368. doi: 10.1590/S1679-62252012000200011

Lusseau, D. (2004). The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. *Ecology and Society* **9**: 2.

McCool, S. F. & Lime, D. W. (2001). Tourism carrying capacity: tempting fantasy or useful reality? *Journal of Sustainable Tourism* **9**: 372–388. doi: 10.1080/09669580108667409

McKercher, B. (1993). Some fundamental truths about tourism: understanding tourism's social and environmental impact. *Journal of Sustainable Tourism* **1**: 6–16.

Medeiros, P. R., Grempel, R. G., Souza, A. T., Ilarri, M. I. & Sampaio, C. L. S. (2007). Effects of recreational activities on the fish assemblage structure in a northeastern Brazilian reef. *Pan-American Journal of Aquatic Sciences* **2**: 288–300.

Metcalfe, N. B., Fraser, N. H. C. & Burns, M. D. (1998). State-dependent shifts between nocturnal and diurnal activity in salmon. *Proceedings of the Royal Society of London B* **265**: 1503–1507. doi: 10.1098/rspb.1998.0464

Milazzo, M., Anastasi, I. & Willis, T. J. (2006). Recreational fish feeding affects coastal fish behavior and increases frequency of predation on damselfish *Chromis chromis* nests. *Marine Ecology Progress Series* **310**: 165–172. doi: 10.3354/meps310165

Milazzo, M., Badalamenti, F., Fernández, T. V. & Chemello, R. (2005). Effects of fish feeding by snorkellers on the density and size distribution of fishes in a Mediterranean marine protected area. *Marine Biology* **146**: 1213–1222. doi: 10.1007/s00227-004-1527-z

Müllner, A., Linsenmairb, K. E. & Wikelskic, M. (2004). Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). *Biological Conservation* **118**: 549–558. doi: 10.1016/j.biocon.2003.10.003

Praveena, S. M., Siraj, S. S. & Aris, A. Z. (2012). Coral reefs studies and threats in Malaysia: a mini review. *Reviews in Environmental Science and Bio/Technology* **11**: 27–39. doi: 10.1007/s11157-011-9261-8

Quiros, A. P. (2007). Tourist compliance to a Code of Conduct and the resulting effects on whale shark (*Rhincodon typus*) behavior in Donsol, Philippines. *Fisheries Research* **84**: 102–108. doi: 10.1016/j.fishres.2006.11.017

Robertson, D. R. & Gaines, S. D. (1986). Interference competition structures microhabitat use in a local assemblage of coral reef Surgeonfishes. *Ecology* **67**: 1372–1383.

Rogala, J. K., Hebblewhite, M., Whittington, J., White, C. A., Coleshill, J. & Musiani, M. (2011). Human activity differentially redistributes large mammals in the Canadian Rockies national parks. *Ecology and Society* **16**: 16. doi: 10.5751/ES-04251-160316

Romero, R. M. & Casatti, L. (2012). Identification of key microhabitats for fish assemblages in tropical Brazilian savanna streams. *International Review of Hydrobiology* **97**: 526–541. doi: 10.1002/iroh.201111513

Rouphael, A. B. & Inglis, G. J. (2001). “Take only photographs and leave only footprints”?: An experimental study of the impacts of underwater photographers on coral reef dive sites. *Biological Conservation* **100**: 281–287. doi: 10.1016/S0006-3207(01)00032-5

Sabino, J. & Sazima, I. (1999). Association between fruit eating fish and foraging monkeys in western Brazil. *Ichthyological Exploration of Freshwaters* **10**: 309–312.

Sazima, I. (1986). Similarities in feeding behaviour between some marine and freshwater fishes in two tropical communities. *Journal of Fish Biology* **29**: 53–65. doi: 10.1111/j.1095-8649.1986.tb04926.x

Schmitz, L. & Wainwright, P. C. (2011). Nocturnality constrains morphological and functional diversity in the eyes of reef fishes. *BMC Evolutionary Biology* **11**: 338. doi: 10.1186/1471-2148-11-338

Shackley, M. (1996). *Wildlife tourism*. London: Thomson Learning.

Strahler, A. (1952). Quantitative analysis of watershed geomorphology. *Transactions American Geophysical Union*. **38**: 913–920. doi: 10.1029/TR038i006p00913

Tarlow, E. M. & Blumstein, D. T. (2007). Evaluating methods to quantify anthropogenic stressors on wild animals. *Applied Animal Behaviour Science* **102**: 429–451. doi: 10.1016/j.applanim.2006.05.040

Teresa, F. B. & Casatti, L. (2010). Importância da vegetação ripária em região intensamente desmatada no sudeste do Brasil: um estudo com peixes de riacho. *Pan-American Journal of Aquatic Sciences* **5**: 444–453.

Teresa, F. B., Romero, R. M., Casatti, L. & Sabino, J. (2011a). Microhabitat simplification affects nuclear-follower foraging relationship among stream fishes. *Neotropical Ichthyology* **9**: 121–126.

Teresa, F. B., Romero, R. M., Casatti, L. & Sabino. J. (2011b). Fish as indicators of disturbance in streams used for snorkeling activities in a tourist region. *Environmental Management* **47**: 960–968. doi: 10.1007/s00267-011-9641-4

Uyarra, M. C. & Côté, I. M. (2007). The quest for cryptic creatures: Impacts of species-focused recreational diving on corals. *Biological Conservation* **136**: 77–84. doi: 10.1016/j.biocon.2006.11.006

Volpato, G. L. & Trajano, E. (2006). Biological rhythms. In *Fish Physiology: The physiology of tropical fishes*, Vol. 21 (Val, A. L., Almeida-Val, V. M. & Randall, D. J. eds.), pp. 101–153. Amsterdan: Elsevier Science.

Waldie, P. A., Blomberg, S. P., Cheney, K. L., Goldizen, A. W. & Grutter, A. S. (2011). Long-term effects of the cleaner fish *Labroides dimidiatus* on coral reef fish communities and how they share the microhabitat. *PLoS One* **6**: e21201. doi: 10.1371/journal.pone.0021201

Weaver, D. B. & Lawton, L. J. (2007). Twenty years on: The state of contemporary ecotourism research. *Tourism Management* **28**: 1168–1179. doi: 10.1016/j.tourman.2007.03.004

White, P. J., Borkowski, J. J., Davis, T., Garrott, R. A., Reinhart, D. P. & McClure, C. (2008). Wildlife Responses to Park Visitors in Winter. In *The ecology of large mammals in central Yellowstone: Sixteen years of integrated field studies*, Vol. 3 (Garrott, R. A., White, P. J. & Watson, F. G. R., eds), pp. 581–601. San Diego, CA: Academic Press. doi: 10.1016/S1936-7961(08)00226-1

Wingfield, J. C. (2003). Control of behavioural strategies for capricious environments. *Environmental Management* **47**: 960–968. doi: 10.1006/anbe.2003.2298

Wong, M. Y. L., 2012. Abiotic stressors and the conservation of social species. *Biological Conservation* **155**: 77–84. doi: 10.1016/j.biocon.2012.05.018

Yates, B. G. & Bailey, R. C. (2010). Selecting objectively defined reference sites for stream bioassessment programs. *Environmental Monitoring and Assessment* **170**: 129–140. doi: 10.1007/s10661-009-1221-1.

Zar, J. H. (1999). *Biostatistical Analysis*, 4th Edn. Upper Saddle River, NJ: Prentice Hall.

Zuanon, J. & Sabino, J. (1998). A stream fish assemblage in central Amazonia: distribution, activity pattern and feeding behavior. *Ichthyological Exploration of Freshwaters* **8**: 201–210.

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**: 107–118. doi: 10.1590/S1679-62252006000100012

Table I – Visitation Impact Management (VIM) results demonstrating the effect of tourism on the treatments, but the similarity between the environments in other aspects that could influence microhabitat use and activity period controlled by us. VIM includes both qualitative and quantitative factors, Diversity of water velocity and depth, and Combination of pool-riffle-run in accordance with Casatti et al. (2006) scale. RA = Reference Area; MVA = Monitored Visitation Area; NMVA = Non-monitored visitation Area.

| | **Factors** | **Measure** | **RA** | **MVA** | **NMVA** |
|---|---|---|---|---|---|
| **Physical factors** | Visible points of marginal erosion | m per 100 m | 0.86 | 1.17 | 5 |
| | Visible points of modified margins | m per 100 m | 0 | 3.2 | 12 |
| | Broken trunks or roots | unities per 100 m | 0 | 1.78 | 4.25 |
| | Non-official exits along the floatation | m per 100 m | - | 2 | 4 |
| **Biological factors** | Riparian forest coverage | % of forest coverage | 80 | 70 | 10 |
| | Fish swimming towards the visitors | Presence or absence | Absence | Presence | Presence |
| | Invasive species | Presence or absence | Absence | Presence | Presence |
| | Nesting *Crenicichla lepidota* | Presence or absence | Presence | Presence | Absence |
| **Social factors** | Cargo capacity | visitors per m | - | 0.04 | 0.5 |
| | Visitors perception of conservation | 1 very degraded - 5 very conserved | - | 5 | 3.67 |
| | Reports of inadequate behavior | reports per 5 visitors | - | 1 | 3 |
| | Artificial fish feeding | Presence or absence | Absence | Absence | Presence |
| | Rubbish | unities per 100 m | 0 | 3 | 12 |
| **Unaffected factors** | Depth | m (mean±standard deviation) | 1.5±0.3 | 1.8±0.5 | 1.4±0.5 |
| | Diversity of water velocity and depth | Good – Very poor | Good | Good | Good |
| | Combination of pool-riffle-run | Good – Very poor | Good | Good | Good |
| | Total abundance of fish | mean±standard deviation | 138.1±144.25 | 135.0±178.64 | 142.5±47.14 |
| | Predator abundance | mean±standard deviation | 0.5±0.58 | 1.0±0.81 | 0.3±0.50 |

Table II – The fish did not alter their spatial distribution in response to tourism. Microhabitat use by ten species in relation to exposure. N is the sample size. RA = reference area; MVA = monitored visitation area; NMVA = non-monitored visitation Area; E is the expected value and O1 and O2 are the observed values.

| Species | N | Individuals in open microhabitats/individuals recorded | | | Analysis | |
|---|---|---|---|---|---|---|
| | | RA (E) | MVA ($O_1$) | NMVA ($O_2$) | Highest $\chi^2$ value | Lowest p value |
| *Astyanax asuncionensis* | 114 | 1 | 1 | 1 | 0 | 1 |
| *Brycon hilarii* | 274 | 0.977 | 0.783 | 0.467 | 8.842 | 0.452 |
| *Characidium zebra* | 71 | 1 | 0.955 | 1 | 2 | 0.991 |
| *Cichlasoma dimerus* | 95 | 0 | 0 | 0 | 0 | 1 |
| *Crenicichla lepidota* | 69 | 1 | 1 | 0.95 | 0 | 1 |
| *Hyphesobrycon ecques* | 24 | 0 | 0 | 0 | 0 | 1 |
| *Leporinus friderici* | 257 | 0.833 | 0.729 | 0.809 | 1.263 | 0.998 |
| *Leporinus striatus* | 43 | 0.357 | 0.197 | 0.098 | 2 | 0.991 |
| *Prochilodus lineatus* | 120 | 1 | 0.923 | 1 | 2 | 0.991 |
| *Salminus brasiliensis* | 11 | 1 | 1 | 1 | 5 | 0.834 |

Figure 1 – Map of the study area. Location of Nobres (black rectangle) within Mato Grosso (grey area) and Brazil (white) (14º 43’ 13”S; 56º 19’ 39”W), studied rivers and sample sites for the three treatments:  Reference Areas (RA); Monitored Visitation Areas (MVA); and Non-Monitored Visitation Areas (NMVA).

Figure 2 – Representation of a stream microhabitats. The fish, which are out of scale, are represented in their preferred microhabitat. LW = Large Wood pieces; HS = Hard Substrate; US = Unconsolidated Substrate; CS = Channel Surface; CC = Channel Center; MR = Macrophytes and Roots; and LI = Litter. Aa = *Astyanax asuncionensis*; Bh = *Brycon hilarii*, Cz = *Characidium zebra*; Cd = *Cichlasoma dimerus*; Cl = *Crenicichla lepidota*; He = *Hyphesobrycon ecques*; Lf = *Leporinus friderici*; Ls = *Leporinus striatus*; Pl = *Prochilodus lineatus*; Sb = *Salminus brasiliensis*.

Figure 3 – Frequency of the fish occupying each microhabitats within touristic impact treatments. The fish did not occupy different microhabitats according to the visitation impact. RA = Reference Area; MVA = Monitored Visitation Area; NMVA = Non-monitored visitation Area. LW = Large Wood pieces; HS = Hard Substrate; US = Unconsolidated Substrate; CS = Channel Surface; CC = Channel Center; MR = Macrophytes and Roots; and LI = Litter.

Figure 4 – Activity period of the ten studied species in the three treatments (tourism impact) mostly overlap. RA = Reference Area; MVA = Monitored Visitation Area; NMVA = Non-monitored visitation Area; $\chi^2$ = chi-square test result; *p* = probability of type I error.

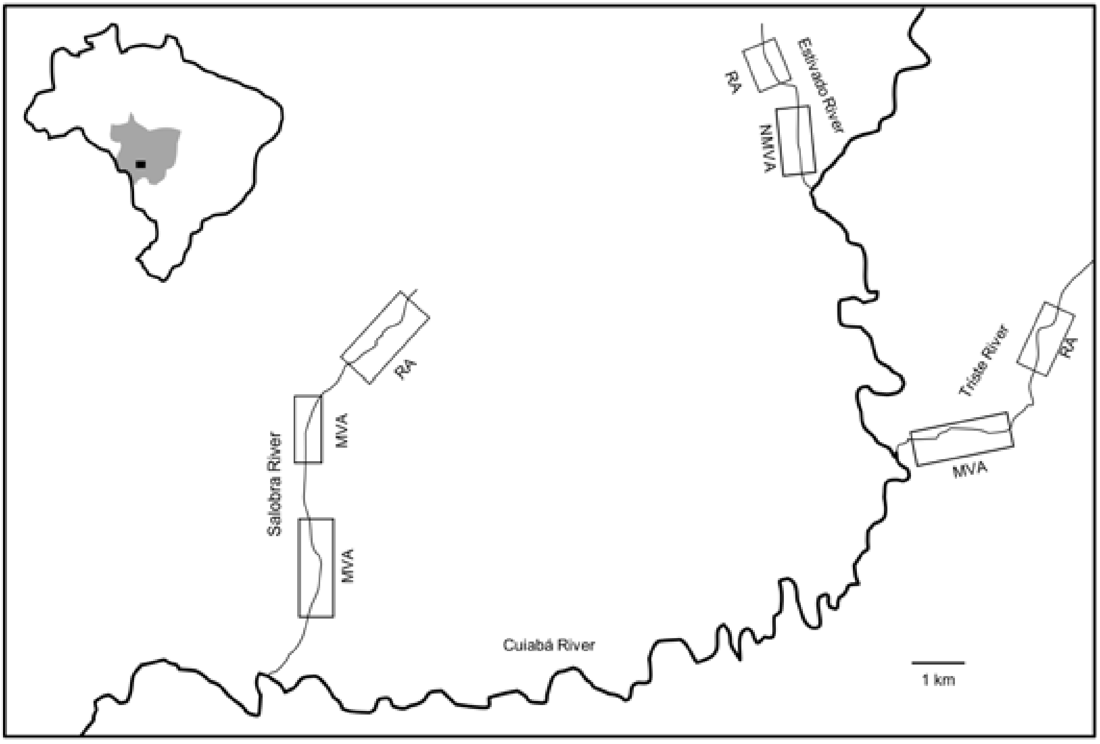

RA
Estivado River
NMVA
RA
MVA
Salobra River
MVA
Triste River
RA
MVA
Cuiabá River
1 km

Fig. 1

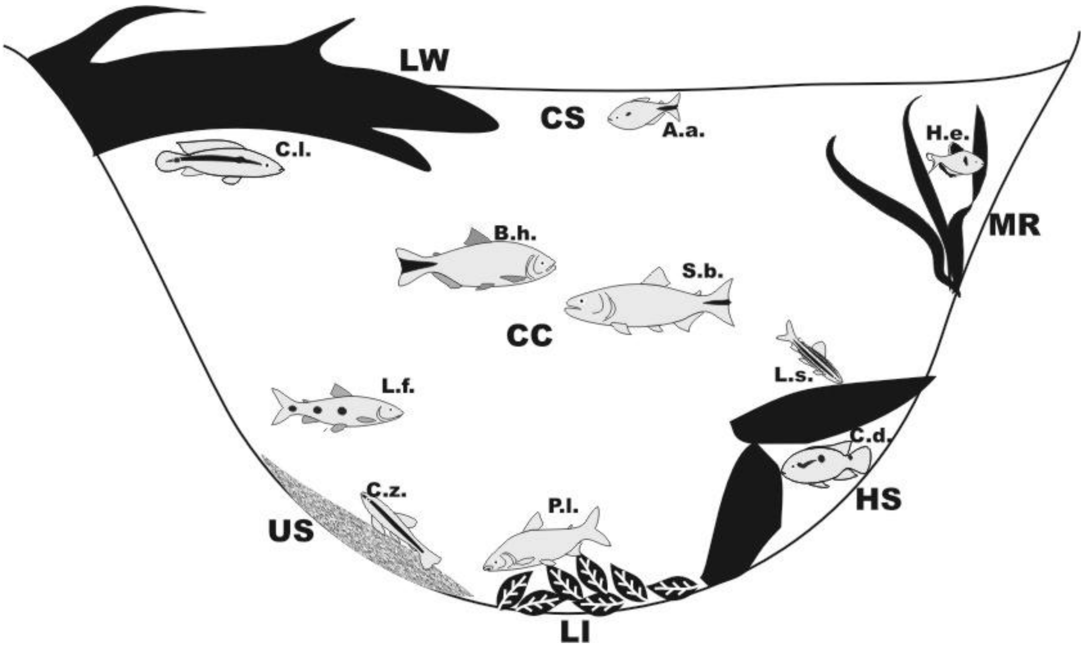



Fig. 2

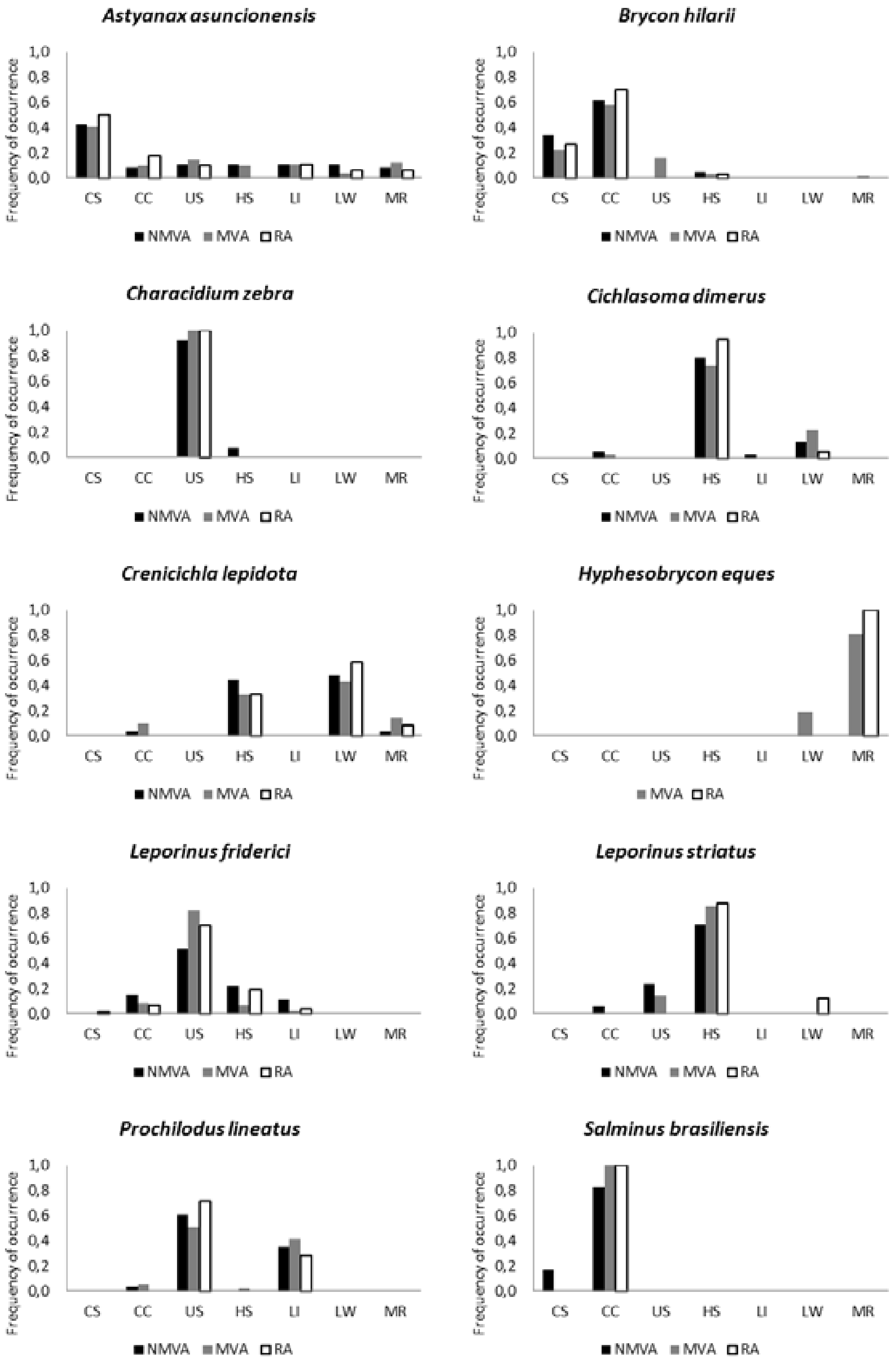
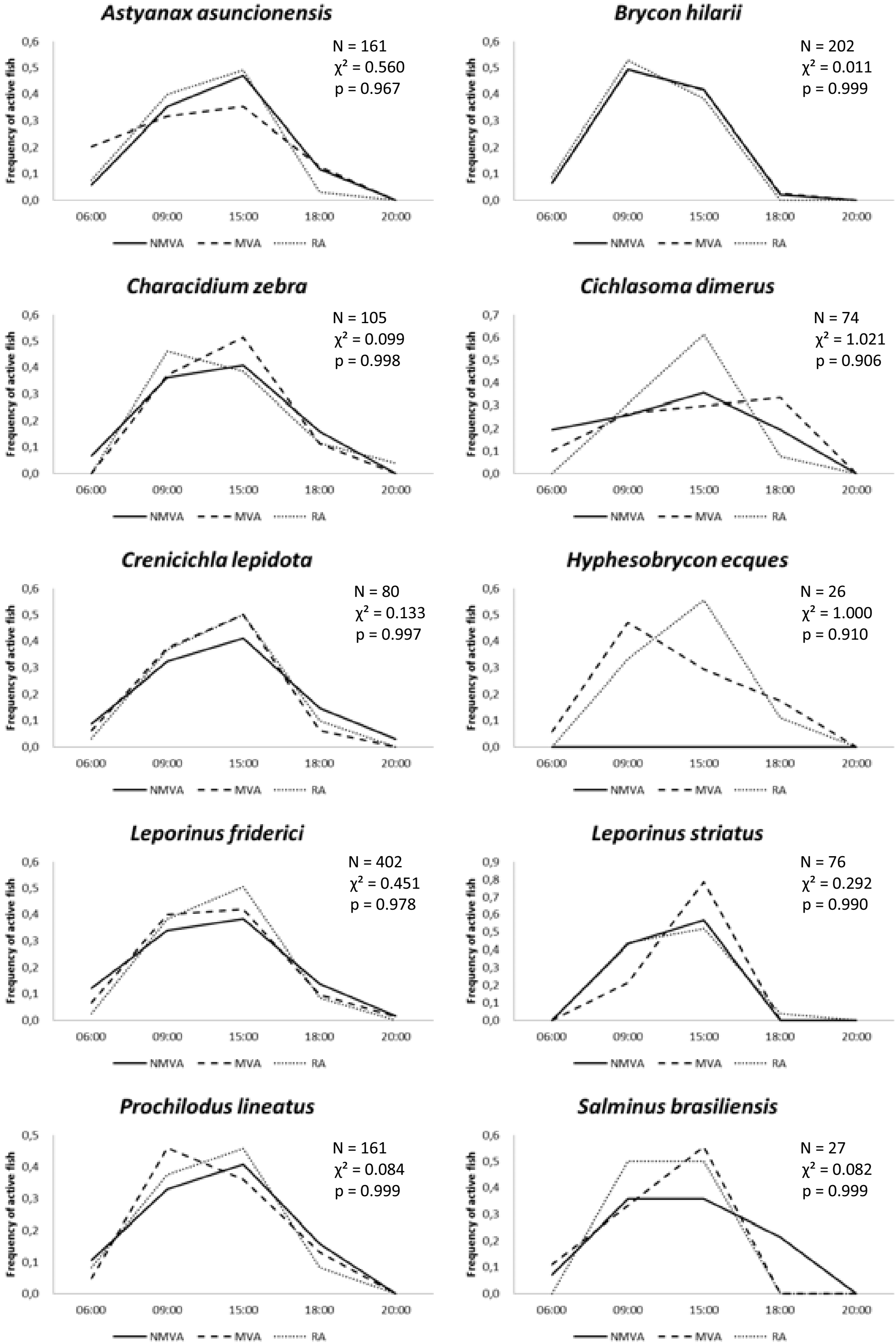

Astyanax asuncionensis
Brycon hilarii
Characidium zebra
Cichlasoma dimerus
Crenicichla lepidota
Hyphesobrycon eques
Leporinus friderici
Leporinus striatus
Prochilodus lineatus
Salminus brasiliensis
Frequency of occurrence
1,0
0,8
0,6
0,4
0,2
0,0
CS
CC
US
HS
LI
LW
MR
NMVA
MVA
RA

Fig. 3



Astyanax asuncionensis
N = 161
χ² = 0.560
p = 0.967
Brycon hilarii
N = 202
χ² = 0.011
p = 0.999
Characidium zebra
N = 105
χ² = 0.099
p = 0.998
Cichlasoma dimerus
N = 74
χ² = 1.021
p = 0.906
Crenicichla lepidota
N = 80
χ² = 0.133
p = 0.997
Hyphesobrycon ecques
N = 26
χ² = 1.000
p = 0.910
Leporinus friderici
N = 402
χ² = 0.451
p = 0.978
Leporinus striatus
N = 76
χ² = 0.292
p = 0.990
Prochilodus lineatus
N = 161
χ² = 0.084
p = 0.999
Salminus brasiliensis
N = 27
χ² = 0.082
p = 0.999
Frequency of active fish
06:00
09:00
15:00
18:00
20:00
NMVA
MVA
RA


Fig. 4

# Monitored tourism conserves territorial fish

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**Abstract**

Nature tourism is a growing industry frequently noted as the solution to the conflict between preservation and economic exploitation. Nevertheless, it is known to cause several effects. Here, we address for the first time the idea that monitored tourism avoids triggering the emergency life history strategy in the social cichlid fish, *Crenicichla lepidota*, in the long term. We studied the aggression toward territorial intruders and the number of nests built in pristine reference areas, in monitored visiting areas and in non-monitored visiting areas. We observed suppressed aggressive behavior and suppressed nesting, presumed fear responses, only in the non-monitored area. We conclude that by monitoring visitations, including the avoidance of stepping on the river bed, artificial fish feeding and a reduced number of visitors, it is possible to avoid the emergency life history strategy that indicates damage caused by nature tourism, even in the long term.



**Keywords**

River snorkeling. Ecotourism. Cichlidae. Emergency life history theory. Sustainable tourism. Social Behavior. Mato Grosso, Brazil. Tourism monitoring techniques.


**Highlights**

- This is a long-term study of nature tourism impact on fish behavior
- This study focuses underwater snorkeling trails in rivers
- Fish respond to nature tourism changing their social and nesting behavior

- Monitoring tourism avoids impacts
- Floating equipment, time of exposure to visitor and fish feeding should be monitored

# Monitored tourism conserves territorial fish

**Abstract**

Nature tourism is a growing industry frequently noted as the solution to the conflict between preservation and economic exploitation. Nevertheless, it is known to cause several effects. Here, we address for the first time the idea that monitored tourism avoids triggering the emergency life history strategy in the social cichlid fish, *Crenicichla lepidota*, in the long term. We studied the aggression toward territorial intruders and the number of nests built in pristine reference areas, in monitored visiting areas and in non-monitored visiting areas. We observed suppressed aggressive behavior and suppressed nesting, presumed fear responses, only in the non-monitored area. We conclude that by monitoring visitations, including the avoidance of stepping on the river bed, artificial fish feeding and a reduced number of visitors, it is possible to avoid the emergency life history strategy that indicates damage caused by nature tourism, even in the long term.

**Keywords**

Ecotourism

Cichlidae

Emergency life history theory

Sustainable tourism

Social Behavior

Tourism monitoring techniques

## 1. Introduction

All types of natural environments are liable to unpredictable disturbances, and animals must cope with this. These disturbances include natural catastrophes, variations in the predator population or food items and also the impact of human activities. The latter one has become a major concern, and the immediate form of coping with such disturbances is by behavioral responses called emergency life history strategies (Wingfield, 2003). Among human impacts, one recently considered as a potential disturbance is nature tourism. Although about half of the human population lives in cities (Lederbogen et al., 2011), mankind finds comfort in nature, seeking it frequently (Wilson, 1984). The definitions of nature tourism and ecotourism have long been argued (Wallace & Pierce, 1996). Ecotourism is defined as any type of tourism regarding the conservation of natural resources, whereas nature tourism is defined as the visitation to natural landscapes, not necessarily in a sustainable manner (Drumm & Moore, 2003). Accordingly, we will refer to “nature tourism” to describe the act of visiting natural places.

Whereas the nature tourism business benefits from human visitations to pristine environments, this activity can result in environmental impacts, causing a dilemma. On one hand, more visits will increase the profits; on the other hand, more visits will degrade what the visitors are attracted to (Machado, 2005). Undoubtedly, nature tourism can disturb the environment by consuming resources, building structures and leaving debris behind (McKercher, 1993). The solution to this dilemma lies in the planned exploitation of natural resources, but empirical data to support this idea are still weak.

In aquatic environments, non-monitored, nature-based tourism has caused impacts in many places. For instance, tourists capture more fish than all of the local fishing industry (Catella et al., 1997). Populations of turtles were reported to decline in response to human recreation (Garber & Burger, 1995). The number of omnivorous fish increased and the community evenness decreased in a coral reef during visitations (Ilarri et al., 2008). Because of such undesirable effects, it is necessary to evaluate how to monitor activities that were previously established so that nature tourism is sustainable. Fish are potential models for this purpose because they respond to diverse human impacts and they are easy to observe (Amundsen, 2003); it is worth deepening the knowledge of emergency life histories in this group (Wingfield, 2003); they are the main attraction of several aquatic touristic activities, such as diving, fishing and underwater tracks.

Aquatic nature tourism is frequently related to coral reefs. However, a less charismatic, but equally important, environment is that of clear water streams. The streams of Nobres, in Mato Grosso, Brazil, are appropriate environments for evaluating the effects caused by non-monitored tourism. The different streams are subject to an array of visitation and monitoring styles, which could be used as treatments to test whether adequate monitoring can prevent visitation impacts. In our case, monitoring is any technique that is used to prevent impacts on the river bed from stepping on it, to protect riparian vegetation and to reduce the fish’s exposure to visitors.

Among the various fish species that occur in headwater streams, some are very good models for addressing certain questions. This is the case for cichlids because they tend to stay in within a certain area and do not move along the river (Hert, 1992), thus providing more detailed information about a particular locality. Within the cichlids, a behavioral repertoire consisting of territoriality and parental care are characteristic of the group (Keenleyside, 1991; Teresa & Gonçalves-de-Freitas, 2011). Thus, we chose the cichlid *Crenicichla lepidota* as our model because it is locally abundant, easy to observe and there is available knowledge about its behavior.

Behavior is a good way to assess environmental effects because it is the most immediate way that an animal can cope (Wingfield, 2003), it has previously been used as an environmental quality indicator (Teresa et al., 2011a) and it is also considered a key to improving conservation (Caro & Sherman, 2011). Previous studies focused on the acute effects of visitors on fish behavior, i.e., the effects during the presence of visitors (e.g., Duchesne, Côtè, & Barrette, 2000; Constantine, Brunton, & Dennis 2004; White et al., 2008). However, long term effects (i.e., those occurring after the visitors leave) tend to be more informative (Bejder et al., 2006). The long term can be considered because remembering aversive stimuli is known to occur in cichlids (Moreira & Volpato, 2004) and salmonids (Moreira, Pulman, & Pottinger, 2004). Thus, ours is the first study focusing on chronic behavioral effects and relating them to two different levels of monitored visiting.

Behavioral changes allow fish to intensify or reduce behaviors, such as territoriality and nesting, in response to visitors. Animals can respond to the sight of visitors (Frid & Dill, 2002), to the food they offer (Milazzo, Anastasi, & Willis, 2006), or to the noise they make (Codarin et al., 2009), resulting in stress and, therefore, in emergency life history strategies. Animals frequently respond to humans like they respond to predators, hiding more during visitation (Frid & Dill, 2002). Thus, non-monitored visitation is expected to reduce territorial aggression and reproductive behavior because defending a territory and building a nest means expending energy and time and exposure to risks, such as predation (Candolin & Voigt, 2001).

One of the ways territoriality may be defined is the defense of an area containing a restrictive resource through aggression (Maher & Lott, 1995). *Crenicichla lepidota* guards territories containing suitable nest sites which are those with no feeding importance, as is common among cichlids. Territory is, then, part of the reproductive behavior of cichlids, and it is the place where nests are built. Reproduction is the most vulnerable part of the life cycle (Barlow, 1991) and promoting reproduction is an important part of the maintenance of a population. In cichlids, there is evidence that approximately 40% of the individuals die during the egg phase and another 40% die in the larval phase (Cacho, Chellappa, & Yamamoto, 2006). Part of this risk is mitigated by females choosing males with safer nests (Candolin & Voigt, 2001). Likewise, a non-monitored area should result in less couples nesting if visitors are considered to be threats.

We hypothesized that areas without visitation monitoring will trigger emergency life history strategies, causing the fish to be less proactive (i.e., exposing themselves less to territorial intruders) (Wingfield, 2003), altering the territorial and reproductive behaviors of *C. lepidota*, whereas reference areas and areas with visitation monitoring will not differ. This introduces three predictions: 1) territorial individuals will not attack invaders as much in non-monitored visitation areas as they will in reference areas or monitored areas; 2) the fish will take longer to attack; 3) fewer nests are expected in the non-monitored visitation areas than in the other areas. We did not predict a gradient of response to tourism from reference areas to non-monitored areas because we trusted and desired to test if monitoring is sufficient for preserving social behaviors.

# 2. Materials and Methods

## 2.1. Study area

We studied an area of nature tourism based on fish watching by snorkeling in clear headwater streams. The clear water necessary for this is the result of dolomitic limestone soil (CPRM, 2009), which flocculates suspended particles. The streams house a diverse fish fauna with strong aesthetic appeal, making our research area a popular touristic destination, with an increasing number of visitors. Tourists come to watch fish and birds, visit caves and sightsee in the savanna.

Nobres, in Mato Grosso, Brazil (14º 43’ 13”S; 56º 19’ 39”W; Figure 1) is located on the Serra do Tombador Karstic Plateau, in the Tocantins Province, Cuiabá Group (CPRM, 2009). The rivers we studied are tributaries of the Cuiabá River and belong to the La Plata System with an area of 3.2 million $km^2$. The most visited rivers in the region are the Estivado, Salobra and Triste Rivers. There are two seasons, a dry season from May to September and a rainy season from October to April.

Nobres is a suitable research area. There are comparable stretches of river with and without touristic visitation that are either monitored or not. We used three levels of exploitation (non-visited or reference, monitored visitation and non-monitored visitation) as treatments (Table 1; Figure 1). We controlled river depth, diversity of water velocity and depth, combination of pool-riffle-run, substrate coverage, fish abundance and predator abundance. (see appendix for a complete list of fish species). The reference areas refer to the pristine environments of the Estivado, Salobra and Triste Rivers located above the visited areas, at least 600 m away from the visited stretches. The second treatment refers to monitored visitation areas, including stretches of the Salobra and Triste Rivers that are visited by tourists, but there are certain monitoring rules (see Table 1). The third level of exploitation used as a treatment refers to a non-monitored visitation area, in which intense touristic visitation without any monitoring occurs in the Estivado River.

### 2.2. Data collection

We tested the long-term interference of the degree of touristic visitation (absence of visitation in reference areas; monitored visitation; and non-monitored visitation) on the territorial and nesting behavior of *C. lepidota*. Territorial behavior was evaluated by the change in the latency to attack and the number of aggressive interactions against a territory invader. The nesting behavior was measured by counting the number of nests with offspring in each area.

Between December 2009 and August 2011 we completed 42 h of snorkeling from 0900 to 1600, the peak activity period for *C. lepidota.* Visibility during data collection was always above 10 m. We recorded the data on an underwater writing slate.

For the analysis of the effect of visitation on the aggression in the three areas we conducted 30 replicates. In the reference area, we observed eight individuals in the Estivado River, six in the Triste River and 16 in the Salobra River. In the monitored visitation areas we observed 12 individuals in the Triste River and 18 in the Salobra River. In the non-monitored visitation area we observed all 30 individuals in the Estivado River, the only place where this type of visitation occurs. All of the samples were collected during the dry season (May to August 2010 and May to September 2011).

Males of *C. lepidota* measuring 7.2 ± 0.7 cm (N= 3) were collected using a hand seine during each field trip. We kept these individuals in an aerated 8 L aquarium filled with water from the capture site for a maximum of 5 days between observation days. We fed them industrialized fish food and returned the fish to where they were collected at the end of the observations. One individual is deposited as voucher material in the Coleção de Peixes (DZSJRP 14803) after being sacrificed with a lethal dose of anesthetic benzocaine.

During the observations, we put one male in a 500 ml glass jar. This jar was placed within a 20-cm distance from the territorial male using an acrylic stick attached to the jar's lid while the observer was at least 1.5 m away from the territory and after 5 min of habituation. Randomly selected guarding males were larger than the invader in the jars (estimated around 10 cm). As soon as we introduced the invaders, we began timing how long it took before the first attack (latency) and counting the number of attacks made by the guarding male toward the enclosed male. We considered an attack any overt aggressive behavior towards the invader, including mouth fighting, undulations and chases (see Teresa & Gonçalves-de-Freitas, 2011 for description of these behaviors).

To evaluate the effect of nature tourism on the number of nests with offspring, we used 15 transects 6 m wide and 10 m long for each treatment non-overlapping and randomly placed over suitable habitats for nests of *C. lepidota* (large rocks, logs or vegetation). In the reference areas there were three transects in the Estivado River, five in the Triste River and seven in the Salobra. In the monitored visitation areas we used six transects in the Triste River and seven in the Salobra River. In the non-monitored visitation area, the 15 transects were all performed in the Estivado River. All of the observations were conducted during the reproductive phase for *C. lepidota*, which occurs during the rainy season (December 2009 and December 2011 to January 2012).

We measured these transects with a tape measure and circled them with a cord marked at every meter. The diver had 15 min to swim along the transect while counting the number of nests occupied by a reproductive couple and their fry. To guarantee that the entire area received the same attention, the diver spent no more than 4 min in each third of the transect. To avoid observer bias, the same diver did all of the counts. The problem of double counts (Labrosse, Kulbicki, & Ferraris, 2002) was lessened because *C. lepidota* is a sedentary species.

### 2.3. Ethics statement

All of the observations were in accordance with animal welfare (ASAB, 2006). SISBIO (Permit number 16482-1) provided the permits for researching the study site, collecting and holding the experimental animals. This study was carried out on private land, with permission from their owners Mrs. Joana Lambert, Messrs. Kleber Oliveira, Antônio Campos. *Crenicichla lepidota* is not an endangered or protected species.

### 2.4. Data analysis

We compared the frequency of aggressive behavior and latency of attack among the reference areas, the monitored visitation areas and the non-monitored visitation areas using a one-way ANOVA. Between treatment comparisons were made with the Fisher- least significant difference (LSD) test. We also compared the frequency of nesting in each treatment using a Kruskal-Wallis test and a post-hoc analysis using the median test. The use of this non-parametric test was due to a non-normal distribution of the data (Shapiro-Wilks; $W= 0.78997$; $p< 0.0001$) (Zar, 1999). The significance level was set at $\alpha= 0.05$.

## 3. Results

Non-monitored visitation reduced the aggression of *C. lepidota*. The fish whose territories were in the non-monitored visitation areas took twice as long to attack than the fish in the monitored visitation areas or in the reference areas ($N= 30$; $F= 25.995$; $p= 0.0001$; Figure 2a). Moreover, the fish attacked the enclosed invader five times less in the non-monitored visitation area than in the other two environments ($N= 30$; $F = 21.556$; $p= 0.0001$; Figure 2b).

The same response pattern was observed for the selection of nesting sites (Figure 3). In 15 transects, the reference areas and the monitored visitation areas totaled 21 and 15 nests, respectively, whereas the non-monitored visitation areas had only two nests ($H= 13.774$; $p= 0.01$). Unpublished data on community ecology shows that no difference in *C. lepidota* abundance was observed between treatments ($H= 0.422$; $p= 0.810$), reinforcing that our results account for nesting preference, not density.

## 4. Discussion

We show here, for the first time, that monitoring nature tourism can preserve a territorial fish. This conclusion is supported by *C. lepidota*'s behavior being similar in the monitored visitation areas and the reference areas, both of which are significantly different from the non-monitored visitation areas. The results supported the predictions that aggression and reproduction would decrease in the non-monitored visitation areas and that monitoring tourism results in the preservation of territorial fish, such as cichlids. Moreover, our methods allow us to state that the change in cichlid behavior endures after the visitors have left, implying a long-term effect from non-monitored tourism.

The reduction of territorial aggression caused by the lack of monitoring effects the most characteristic behavior of cichlids: territoriality. Defending a territory depends on keeping away potential invaders and neighbors through aggressive displays or direct aggression (Hinsch & Kondeur, 2010). On one hand, territoriality guarantees limited resources that are precious to the territory holder (Wilson, 2000), in the case of cichlids who spawn on the substrate, a nest site and even a sexual selected trait (Keenleyside, 1991). On the other hand, territorial aggression is energetically expensive and exposes the territory holder to predation risk (Magnhagen, 1995). Therefore, there is a trade-off between territorial aggression and safety.

*Crenicichla lepidota* avoids defending a territory in areas where the tourist visitation is not monitored. This may be because some animals react to human visitors like they react to predators (Frid & Dill, 2002). The fish are exposed less in behaviors such as feeding (Carvalho & Del-Claro, 2004), habitat selection (Power, 1984), fighting (Kelly & Godin, 2001) and courting (Evans et al., 2002) when a predator is present. Predation risk avoidance explains this reduction in exposure, resulting in less territorial aggression in the non-monitored visitation areas.

The reproductive couples of cichlids will be confined to a part of the stream where eggs will be laid and larvae will hatch and be protected in a nest (Keenleyside, 1991).

Females are selective in relation to the nest site, prompting males to establish well-placed territories (Sargent, 1982). Females prefer partners with safer territories (Zahavi, 1985) because predation risk is a cost of reproduction (Magnhagen, 1991). That is why nesting in the non-monitored visitation areas was avoided. The nesting site also indicates that females consider the monitored visitation areas suitable for nest sites. Some studies demonstrate changes in the pattern of habitat selection by fish in touristic areas, in both coral reefs (Davenport & Davenport, 2006) and freshwater streams (Teresa et al., 2011b, but see Hasler & Ott, 2008, for an exception). The same negative response toward visitors in the breeding season was observed for birds (Müllner, Linsenmair, & Wikelski, 2004), another group in which nesting site depends on environmental pressures. This leads to the conclusion that monitoring visitors is necessary for keeping a touristic stream adequate for fish reproduction.

In addition to visitors being perceived as predators, they also produce noise, which is immediately detected by the octavolateralis senses of fish (Montgomery & Carton, 2008). Sound communication among cichlids is gaining importance for comprehending their sociality (Amorim, 2006). Noise is also known to cause stress (Rolland et al., 2012), which can reduce activity, including promptness to fight, but only in the long term (Øverli, Kotzian, & Winberg, 2002). Noisy visitors may cause the results we observed in the territorial and the nesting behaviors.

A reactive type of emergency life history can also be explained by the mechanism involved in avoiding aversive stimuli. For instance, the Nile tilapia cichlid can remember aversive stimuli by increasing the release of cortisol as a conditioned response to confinement stress (Moreira & Volpato, 2004). Rainbow trout can continue remembering a stressful stimulus for 21 days (Moreira, Pulman, & Pottinger, 2004).

Furthermore, the fear reaction has been recently demonstrated in fish (e.g., Yue, Moccia, & Duncan, 2004; Martins et al., 2011). Thus, we have to consider the reduction of territorial response and nesting as a possible effect of cognitive ability of fish.

Our study indicates how important it is to monitor nature tourism visitors. In our study, the most important monitoring techniques for promoting sustainable tourism include: 1) preservation of habitat complexity through the maintenance of riparian vegetation and the use of flotation equipment; 2) reduction of fish exposure to tourists by controlling the number visitors and how long they stay in the water; 3) the preservation of the natural diet of fish by forbidding the offering of artificial food and preserving the riparian vegetation; and 4) the preservation of the river bed, where fish nest and reproduce, by the use of flotation equipment. None of the mentioned techniques are applied in the non-monitored visitation areas. Thus, measures such as those described above are fundamental to avoid triggering emergency life histories in *C. lepidota* and should be widely applied to underwater trails' management.

Monitoring will reduce the effect of fish exposure to visitors, resulting in more territorial aggression and nesting, which in turn will indirectly influence reproduction and sustain the population. Techniques for achieving this result include the control of the food supply for the fish, the preservation of riparian vegetation, a limited number of visitors and the use of fluctuation equipment. Our findings support the compatibility between environmental preservation and economic exploitation of headwater streams for tourism. They also offer a basis on which to build public policies that regulate tourism in places where cichlids are important for tourism.

**References**

Amorim, M. C. P. (2006). Diversity of Sound Production in Fish. In F. Ladich, S. P. Collin, P. Moller, & B. G. Kapoor (Eds.), *Communication in Fishes* (pp. 71-105). Sidney, Science Publishers.

Amundsen, T. (2003). Fishes as models in studies of sexual selection and parental care. *Journal of Fish Biology*, *63*, 17-52.

ASAB, Association for the Study of Animal Behaviour. (2006). Guidelines for the treatment of animals in behavioural research and teaching. *Animal Behavour, 71*, 245-253.

Barlow, G. W. (1991). Mating systems among cichlid fishes. In M. H. A. Keenleyside editor, *Cichlid Fishes, Behavior, ecology and evolution* (pp 173-190). London: Chapman and Hall.

Bejder, L., Samuels, A., Gales, N., Mann, J., Connor, R., et al. (2006). Decline in Relative Abundance of Bottlenose Dolphins Exposed to Long-Term Disturbance. *Conservation Biology*, *20*, 1791-1798.

Cacho, M. S. R. F., Chellappa, S., & Yamamoto, M. E. (2006). Reproductive success and female preference in the Amazonian cichlid angel fish, *Pterophyllum scalare* (Lichtenstein, 1823). *Neotropical Ichthyology*, *4*, 87-91.

Candolin, U., & Voigt, H. R. (2001). Correlation between male size and territory quality: consequence of male competition or predation susceptibility? *Oikos*, *95*, 225-230.

Caro, T., & Sherman, P. W. (2011). Endangered species and a threatened discipline: behavioural ecology. *Trends in Ecology and Evolution*, *26*, 111-118.

Carvalho, L. N., & Del-Claro, K. (2004). Effects of predation pressure on the feeding behavior of the serpa tetra *Hyphessobrycon eques* (Ostariophysi, Characidae). *Acta Ethologica, 7,* 89-93.

Casatti, L., Langeani, F., Silva, A. M., & Castro, R. M. C. (2006). Stream fish, water and habitat quality in a pasture dominated basin, southeastern Brazil. *Brazilian Journal of Biology, 66,* 681-696.

Catella, A. C., Nascimento, F. L, Moraes, A. S., Resende, E. K., Calheiros, D. F. et al. (1997). Ictiofauna. In Ministério do Meio Ambiente (Ed.), *Plano de Conservação da Bacia do Alto Paraguai (Pantanal) - PCBAP*. *Diagnóstico dos Meios físico e biótico: meio biótico* (pp. 324-400). Brasília: Ministério do Meio Ambiente.

Codarin, A., Wysocki, L. E., Ladich, F., & Picciulin, M. (2009). Effects of ambient and boat noise on hearing and communication in three fish species living in a marine protected area (Miramare, Italy). *Marine Pollution Bulletin*, *58,* 1880-1887.

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation, 117,* 299-307.

CPRM, Brazilian Geologic Service (2009). *Geological Map of the State of Mato Grosso*. Brasília. Available at: http://www.cprm.gov.br/publique/media/mapa_mato_grosso.pdf.

Davenport, J., & Davenport, J. L. (2006). The impact of tourism and personal leisure transport on coastal environments: A review. *Estuarine Coastal and Shelf Science, 67,* 280-292.

Drumm, A., & Moore, A. (2003). *Ecotourism Development - A Manual for Conservation Planners and Managers. Volume 1: An Introduction to Ecotourism Planning*. Virginia: The Nature Conservancy.

Duchesne, M., Côté, S. D., & Barrette, C. (2000). Responses of woodland caribou to winter ecotourism in the Charlevoix Biosphere Reserve, Canada. *Biological Conservation, 96,* 311-317.

Evans, J. P., Kelley, J. L., Ramnarine, I. W., & Pilastro, A. (2002). Female behavior mediates male courtship under predation risk in the guppy (*Poecilia reticulata*). *Behavioral Ecology and Sociobiology, 52,* 496-502.

Frid, A., & Dill, L. M. (2002). Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology, 6,* 11.

Garber, S. D., & Burger, J. (1995). A 20-yr study documenting the relationship between turtle decline and human recreation. *Ecological Applications, 5,* 1151-1162.

Hasler, H., & Ott, J. A. (2008). Diving down the reefs? Intensive diving tourism threatens the reefs of the northern Red Sea. *Marine Pollution Bulletin, 56,* 1788-1794.

Hert, E. (1992). Homing and home-site fidelity in rock-dwelling cichlids (Pisces: Teleostei) of Lake Malawi, Africa. *Environmental Biology of Fishes, 33,* 229-237.

Hinsch, M., & Kondeur, J. (2010). Defence, intrusion and the evolutionary stability of territoriality. *Journal of Theoretical Biology, 266,* 606-613.

Ilarri, M. I., Souza, A. T., Medeiros, P. R., Grempel, R. G., & Rosa, I. M. L. (2008). Effects of tourist visitation and supplementary feeding on fish assemblage composition on a tropical reef in the Southwestern Atlantic. *Neotropical Ichthyology, 6,*651-656.

Keenleyside, M. H. A. (1991). Parental care. In M. H. A. Keenleyside (Ed.), *Cichlid Fishes, Behavior, ecology and evolution* (pp. 190-208). London: Chapman and Hall.

Kelly, C. D., & Godin, J. J. (2001). Predation risk reduces male-male sexual competition in the Trinidadian guppy (*Poecilia reticulata*). *Behavioral Ecology and Sociobiology, 51,* 95-100.

Labrosse, P., Kulbicki, M., & Ferraris, J. (2002). *Underwater visual census surveys, proper use and implementation*. Noumea: Reef Resource Assessment Tools.

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., et al. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature, 474,* 498-501.

Machado, A. (2005). *Ecoturismo: um produto viável*. Rio de Janeiro: SENAC.

Magnhagen, C. (1991). Predation risk as a cost of reproduction. *Trends in Ecology and Evolution, 6,* 183-186.

Magnhagen, C. (1995). Sneaking behavior and nest defence are affected by predation risk in the common goby. *Animal Behaviour, 50,* 1123-1128.

Maher, C., & Lott, D. F. (1995). Definitions of territoriality used in the study of variation in vertebrate spacing systems. *Animal Behaviour, 49,* 1581-1597.

Martins, C. I. M., Silva, P. I. M., Conceição, L. E. C., Costas, B., Höglund, E., Øverli, Ø., & Schrama, J. W. (2011). Linking Fearfulness and Coping Styles in Fish. *PLoS ONE 6*: e28084.

McKercher, B. (1993). Some fundamental truths about tourism: Understanding tourism's social and environmental impact. *Journal of Sustainable Tourism, 1,* 6-16.

Milazzo, M., Anastasi, I., & Willis, T. J. (2006). Recreational fish feeding affects coastal fish behavior and increases frequency of predation on damselfish *Chromis chromis* nests. *Marine Ecology Progress Series, 310,* 165-172.

Montgomery, J. C., & Carton, A. G. (2008). The senses of fish: chemosensory, visual and octavolateralis. In C. Magnhagen, V. A. Braithwaite, E. Forsgren, & B. G. Kapoor (Eds.), *Fish Behaviour* (pp. 3-31). Enfield USA: Science Publishers.

Moreira, P. S. A., Pulman, K. G. T., & Pottinger, T. G. (2004). Extinction of a conditioned response in rainbow trout selected for high or low responsiveness to stress. *Hormones and Behavior, 46,* 450-457.

Moreira, P. S. A., & Volpato, G. L. (2004). Conditioning of stress in Nile tilapia. *Journal of Fish Biology, 64*, 961-969.

Müllner, A., Linsenmair, K. E., & Wikelski, M. (2004). Exposure to ecotourism reduces survival and affects stress response in hoatzin chicks (*Opisthocomus hoazin*). *Biological Conservation, 118,* 549-558.

Øverli, Ø., Kotzian, S., & Winberg, S. (2002). Effects of cortisol on aggression and locomotor activity in rainbow trout. *Hormones and Behavior, 42*, 53-61.

Power, M. E. (1984). Depth distributions of armoured catfish: predator induced resource avoidance? *Ecology, 65*, 523-528.

Rolland, R. M., Parks, S. E., Hunt, K. E., Castellote, M., Corkeron, P.J., Nowacek, D. P., Wasser, S. K., & Kraus, S. D. (2012). Evidence that ship noise increases stress in right whales. *Proceedings of the Royal Society B., 279,* 2363-2368.

Sargent, R. C. (1982). Territory quality, male quality, courtship intrusions, and female nest-choice in the threespine stickleback, *Gasterosteus aculeatus*. *Animal Behaviour, 30*, 364-374.

Teresa, F. B., & Gonçalves-de-Freitas, E. (2011). Reproductive behavior and parental roles of the cichlid fish *Laetacara araguaiae*. *Neotropical Ichthyology, 9,* 355-362.

Teresa, F. B., Romero, R. M., Casatti, L., & Sabino, J. (2011a). Habitat simplification affects nuclear-follower foraging association among stream fishes. *Neotropical Ichthyology, 9,* 121-126.

Teresa, F. B., Romero, R. M., Casatti, L., & Sabino. J. (2011b). Fish as indicators of disturbance in streams used for snorkeling activities in a tourist region. *Environmental Management, 47,* 960-968.

Wallace, G. N., & Pierce, S. M. (1996). An evaluation of ecotourism in Amazonas, Brazil. *Annals of Tourism Research, 23,* 843-873.

White, P. J., Borkowski, J. J., Davis, T., Garrott. R. A., Reinhart, D. P., et al. (2008). Wildlife Responses to Park Visitors in Winter. *Terrestrial Ecology, 3,* 581-601.

Wilson, E. O. (1984). *Biophilia*. Cambridge: Harvard University Press.

Wilson, E. O. (2000). *Sociobiology, the new synthesis – 25th anniversary edition*. Cambridge, Belknap Press.

Wingfield, J. C. (2003). Control of behavioral strategies for capricious environments. *Animal Behaviour, 66,* 807-816.

Yue, S., Moccia, R. D., & Duncan, I. J. H. (2004). Investigating fear in domestic rainbow trout, *Oncorhynchus mykiss*, using an avoidance learning task. *Applied Animal Behavior Science, 87,* 343-354.

Zahavi, A. (1985). Mate selection – A selection for a handicap. *Journal of Theoretical Biology, 53,* 205-214.

Zar, J. H. (1999). *Biostatistical Analysis*. New Jersey: Prentice Hall.

**Table and table caption**

**Table 1.** Main features of the three treatments showing how tourism management features vary, but not environmental characteristics. ✓feature present; ✗ feature absent; - not applicable. Reference Areas (RA); Monitored Visitation Areas (MVA); and Non-Monitored Visitation Areas (NMVA). Diversity of water velocity and depth, and Combination of pool-riffle-run agrees with Casatti et al. (2006) scale.

| | RA | MVA | NMVA |
|---|---|---|---|
| 30 m of preserved riparian vegetation | ✓ | ✓ | ✗ |
| Marginal embankment with buildings | ✗ | ✗ | ✓ |
| Number of visitors per group | - | 12 | Unrestricted |
| Number of visitors per hour | - | 24 | ~40 |
| Stepping on the river bed | ✗ | ✗ | ✓ |
| Obligatory use of flotation equipment | - | ✓ | ✗ |
| Training of the visitors before snorkeling | - | ✓ | ✗ |
| Presence of a guide | - | ✓ | ✗ |
| Feeding the fish | - | ✗ | ✓ |
| Depth (mean±standard deviation) | 1.5±0.3 | 1.8±0.5 | 1.4±0.5 |
| Diversity of water velocity and depth | Good | Good | Good |
| Combination of pool-riffle-run | Good | Good | Good |
| Substrate diversity (Shannon index) | 0.66 | 0.66 | 0.63 |
| Fish abundance (mean±standard deviation) | 138.1±144.25 | 135.0±178.64 | 142.5±47.14 |
| Predator abundance (mean±standard deviation) | 0.5±0.58 | 1.0±0.81 | 0.3±0.50 |

**Figure captions**

**Figure 1. Map of the study area.** Location of Nobres (black rectangle) within Mato Grosso (grey area) and Brazil (white) (14º 43’ 13”S; 56º 19’ 39”W), studied rivers and sample sites for the three treatments:  Reference Areas (RA); Monitored Visitation Areas (MVA); and Non-Monitored Visitation Areas (NMVA).

**Figure 2. The presence of non-monitored visitation inhibits territory aggression.** Latency to fight (a) and number of attacks (b) show less aggression by individuals in visited areas where there is no monitoring. Bars represent the mean value and whiskers represent the standard error. The values are from Fisher-LSD post hoc test (ns = not significant).

**Figure 3. Nesting individuals prefer either reference areas or monitored visitation areas.** The number of nests with offspring were the same in both the reference and the monitored visitation areas, but were reduced in the non-monitored visitation areas. Horizontal lines represent the median value, boxes represent the quartiles and whiskers the maximum values. Significances are from median post hoc test (ns = not significant).

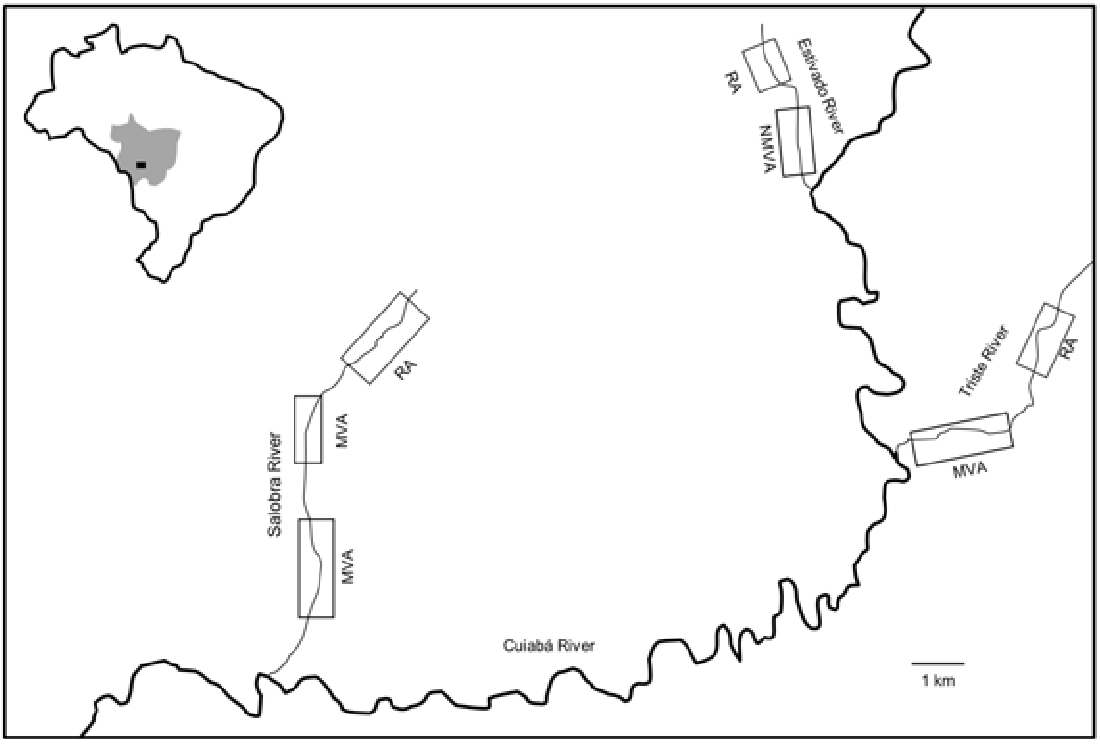
Estivado River
RA
NMVA
RA
MVA
Salobra River
MVA
Triste River
RA
MVA
Cuiabá River
1 km

Figure 1.

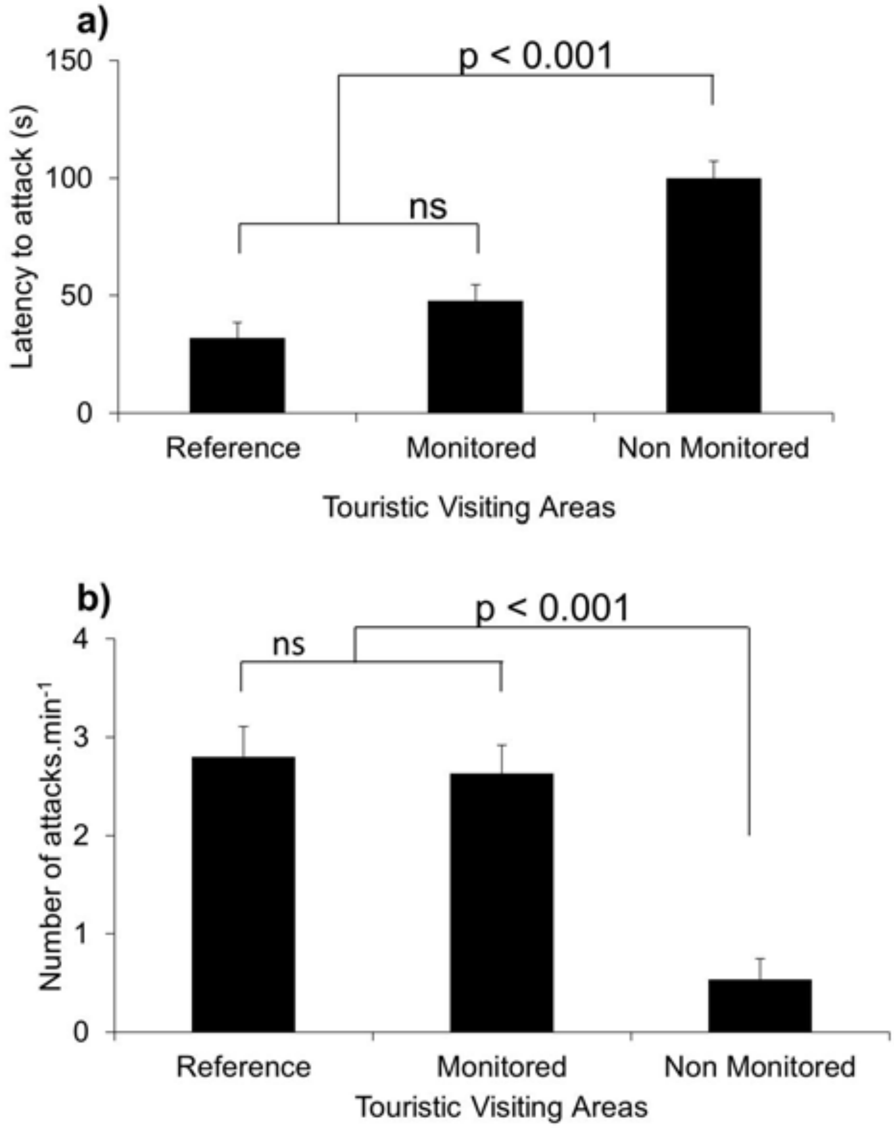
a)
p < 0.001
ns
Latency to attack (s)
150
100
50
0
Reference
Monitored
Non Monitored
Touristic Visiting Areas
b)
p < 0.001
ns
Number of attacks.min-1
4
3
2
1
0
Reference
Monitored
Non Monitored
Touristic Visiting Areas

Figure 2.

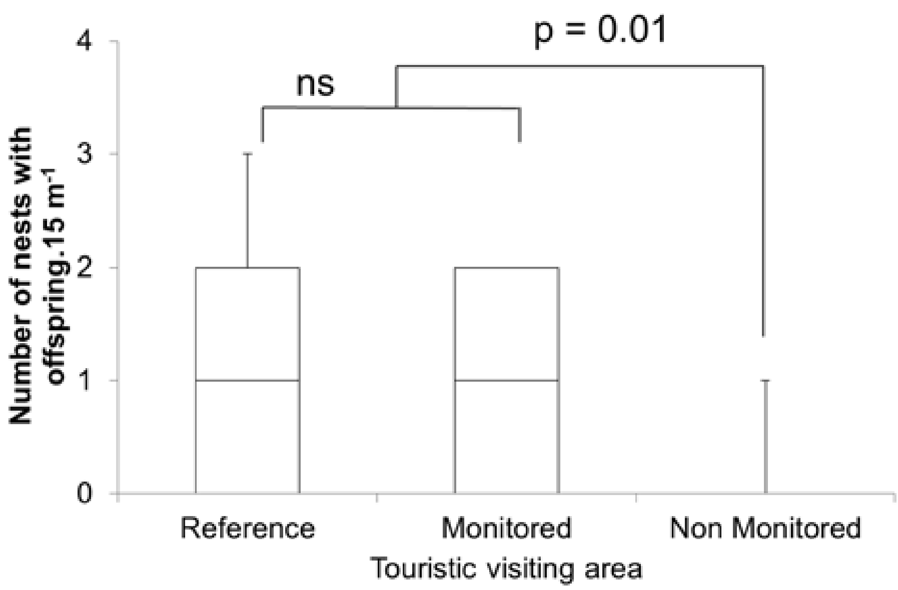
p = 0.01
ns
Number of nests with offspring.15 m-1
4
3
2
1
0
Reference
Monitored
Non Monitored
Touristic visiting area

Figure 3.

# CONCLUSÃO

O uso dos microhabitats e o período de atividade não indicam eficientemente os impactos da visitação turística em nenhuma das espécies estudadas, inclusive *Crenicichla lepidota*. Por outro lado, o local que *Crenicichla lepidota* escolhe para nidificar e a agressividade que usa para defender seu território refletem os impactos do turismo. Assim, comportamentos sociais, como a escolha do sítio de nidificação e a agressividade territorial, são indicadores mais eficientes que comportamentos ligados à história de vida, como a escolha do microhabitat e o período de atividade.

A escolha do sítio de nidificação e a agressividade territorial respondem à ocorrência do turismo de natureza, mas apenas quando a visitação não é monitorada. O bom gerenciamento do turismo passa pelo monitoramento do comportamento do visitante e suas consequências ambientais. As técnicas de monitoramento consideradas mais importantes incluem: 1) a preservação da complexidade do habitat, por meio da manutenção da mata ciliar e do uso de equipamentos de flutuação; 2) a redução da exposição de peixes aos turistas, controlando o número de visitantes e a duração da visita; 3) a preservação da dieta natural dos peixes, evitando a oferta de alimento pelo visitante e preservando a mata ciliar; e 4) a proteção do leito do rio, onde os peixes nidificam e se reproduzem, por meio da utilização de equipamento de flutuação adequado.

O monitoramento reduz o impacto que os visitantes causam sobre os peixes. Isso permite ao peixe defender um território mais valioso e estabelecer ninhos. Em longo prazo o monitoramento favorece a reprodução e a manutenção dessa população de peixes sociais no ambiente explorado pelo turismo. Fica evidente na resposta comportamental dos peixes na ausência do turista que existe uma antecipação e uma memória do impacto causado pelo turismo, uma resposta de medo. O risco de predação ajuda a modelar o comportamento evitando a exposição de *C. lepidota* ao turista durante a nidificação e a agressividade territorial. A partir do nível individual esse comportamento pode ser projetado, podendo influenciar a comunidade.

Os resultados apresentados sustentam a compatibilidade entre a preservação ambiental e a exploração econômica de riachos de cabeceira para o turismo, desde que essa exploração seja monitorada com indicadores de impacto adequados. Eles também oferecem uma base sobre a qual construir políticas públicas que regulam o turismo em riachos.

# APÊNDICE

Lista de espécies e sua abundancia relativa em áreas referência (AR), com visitação monitorada (AVM) e com visitação não monitorada (AVNM) de Nobres, MT.

| **Ordens, Famílias e Subfamílias** | **Espécies e descritores** | **Abundância Relativa (%)** | | |
|---|---|---|---|---|
| | | **AR** | **AVM** | **AVNM** |
| **Characiformes** | | | | |
| **Characidae** | | | | |
| Tetragonopterinae | *Jupiaba acanthogaster* (Eigenmann, 1911) | 1,08 | 3,52 | 7,33 |
| | *Moenkhausia sanctaefilomenae* (Steindachner,1907) | 0,18 | 1,85 | 13,09 |
| | *Astyanax asuncionensis* (Géry, 1972) | 0,90 | 0,37 | 0,52 |
| | *Astyanax marionae* (Eigenmann, 1911) | - | 2,22 | 5,76 |
| | *Astyanax* sp.1 | 45,39 | 51,30 | - |
| | *Phenacogaster jancupa* Malabarba & Lucena, 1995 | 2,17 | 6,48 | 4,04 |
| Cheirodontinae | *Odontostilbe pequira* (Steindachner, 1882) | 12,14 | 18,70 | 56,14 |
| Characinae | *Charax leticiae* (Lucena, 1987) | - | 0,19 | - |
| Serrassalminae | *Serrasalmus maculatus* (Kner, 1858) | - | 0,93 | - |
| **Crenuchidae** | | | | |
| Characidinae | *Characidium zebra* Eigenmann, 1909 | 4,89 | 1,85 | 2,28 |
| Erithrinidae | *Hoplias malabaricus* (Bloch, 1794) | - | 0,19 | - |
| **Siluriformes** | | | | |
| **Pimelodidae** | *Phenacorhamdia hoehnei* (Ribeiro, 1914) | 0,36 | 0,19 | - |
| **Callichthyidae** | *Corydoras aeneus* (Gill, 1858) | 1,63 | 0,37 | - |
| **Loricariidae** | | | | |
| Loricariinae | *Farlowella paraguayensis* (Retzer & Page, 1997) | 1,08 | - | 0,17 |
| | *Spatuloricaria evansii* (Boulenger, 1893) | 0,18 | - | 0,87 |
| | *Rineloricaria* sp. | 0,18 | - | 0,35 |
| Hypoptopomatinae | *Hisonotus* sp. n. | 0,72 | - | 0,17 |
| | *Otocinclus bororo* (Schaefer, 1997) | 0,36 | - | - |
| | *Otocinclus vittatus* (Regan, 1904) | 4,52 | - | - |
| Ancistrinae | *Ancistrus pirareta* (Muller, 1989) | 0,72 | - | 0,52 |
| | *Ancistrus* sp. | 1,45 | 1,85 | - |
| Hypostominae | *Hypostomus cochliodon* (Kner, 1854) | 0,72 | 0,93 | - |
| | *Hypostomus* sp. | 2,89 | 0,93 | 0,70 |
| Heptapteridae | *Imparfinis* sp. | 0,54 | - | - |
| **Ciprinodontiformes** | | | | |
| Poeciliidae | *Pamphorichthys hasemani* (Henn, 1916) | 4,16 | 3,89 | - |
| Rivulidae | *Rivulus punctatus* (Boulenger, 1895) | - | 0,19 | - |
| **Perciformes** | | | | |
| Cichlidae | *Crenicichla lepidota* (Heckel, 1840) | 3,07 | 1,67 | 0,52 |
| | *Crenicichla semifasciata* (Heckel, 1840) | 0,18 | - | 0,17 |
| | *Cichlasoma dimerus* (Heckel, 1840) | - | 0,19 | 3,14 |
| **Synbranchiformes** | | | | |
| Synbranchidae | *Synbranchus marmoratus* (Bloch, 1795) | 0,18 | 0,19 | - |