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How does tourist monitoring alter fish behavior in underwater trails?

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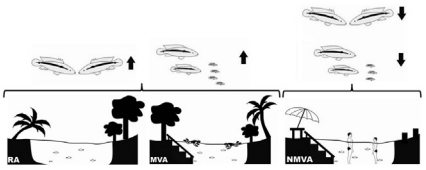
HIGHLIGHTS

- This is a study of enduring 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.
- Monitoring refers to floating equipment, time of exposure to visitors, fish feeding and riparian vegetation.

GRAPHICAL ABSTRACT



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ABSTRACT

Nature based tourism is becoming more popular because it is perceived as a solution to the conflict between conservation and economic exploitation. Nevertheless, it is known to cause several effects. This paper reports findings whereby monitored tourism avoids triggering adverse effects for social cichlid fish species, *Crenicichla lepidota*. Measures used included aggression toward territorial intruders and the number of nests built in pristine reference areas for monitored and in non-monitored tourist areas. We observed suppressed aggressive behavior and suppressed nesting only in the non-monitored area. We conclude that by monitoring visits, and using techniques including avoiding stepping on the river bed, reducing the number of visitors, prohibiting fish feeding and protecting riparian vegetation, it is possible to avoid the enduring damage caused by nature tourism.

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

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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, Souza, Medeiros, Grempel, & Rosa, 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 tourism 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 evaluated as conditions 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 visitation and eliminate the introduction of artificial fish feeding.

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, Romero, Casatti, & Sabino, 2011a) and it is also considered a key to improving conservation (Caro & Sherman, 2011). Previous studies focused on the acute effects of visitation on fish behavior, i.e., the effects during the presence of visitors (e.g., Constantine, Brunton, & Dennis, 2004; Duchesne, Côtè, & Barrette, 2000; White et al., 2008). However, enduring effects (i.e., those occurring after the visitors leave) tend to be more informative (Bejder et al., 2006). The medium to 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 visitation.

Fish behavioral changes allow these fish to intensify or reduce behaviors, such as territoriality and nesting, in response to visitation. 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, Wysocki, Ladich, & Picciulin, 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 esthetic appeal, making our research area a popular tourist 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 (14° 43′ 13″S; 56° 19′ 39″W; Fig. 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 visitation that are either monitored or not. We used three levels of exploitation (non-visited or reference, monitored visitation and non-monitored visitation) as conditions (Table 1; Fig. 1). We controlled river depth, diversity of water velocity and depth, combination of pool-riffle-run, substrate coverage, fish abundance and predator abundance. The reference areas refer to the pristine environments of the Estivado, Salobra and Triste Rivers located above the visitation areas, at least 600 m away from the visitation stretches. The second condition refers to monitored visitation areas, including stretches of the Salobra and Triste