Fish escape behavior as a monitoring tool in the largest Brazilian multiple-use Marine Protected Area

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ABSTRACT

Understanding the decision-making process of fish when they escape from approaching spearfishers has a crucial role in elucidating the management conflicts in reef systems. Here, we used the Flight Initiation Distances – FID metric to assess how the management strategies, including fishing and tourism reef sites, could distinctively influence the escape behavior of the target reef fish. This work presents the differences in wariness of three reef fish species with a distinctive history of catches by spearfishing, *Epinephelus adscensionis*, *Acanthurus bahianus*, and *Chaetodon striatus*, in a multiple-use Marine Protected Area (MPA) in the Brazilian Northeastern coast. Our findings demonstrate that the protection level has a consistent effect on wariness of the target species, but the use of tourism sites as a conservation strategy to fishing pressure could be controversial. Furthermore, the species-specific traits can clearly express how the risk perception varies among species and can simplify the understanding of flight measure results. Taken together with other data, *e.g.* quantitative data (biomass, abundance), changes in the fish behavior, such as escape decisions, may add important knowledge to the monitoring of marine protected areas, especially in the Brazilian coast where the effectiveness of these MPAs is often questioned. The use of FID measurements as a management tool could improve the monitoring policies in MPAs, and reveal reefs systems where human activities should be reduced or banned.

RESUMO

Compreender as decisões que os peixes tomam para escapar da abordagem de pescadores subaquáticos tem um papel crucial para elucidar conflitos de manejo em sistemas recifais. Neste trabalho, utilizamos a métrica Distância Inicial de Fuga – DIF para avaliar como estratégias de manejo, incluindo áreas recifais utilizadas para pesca e turismo, podem influenciar distintivamente o comportamento de fuga de peixes recifais alvo da pesca. Este trabalho apresenta diferenças na cautela de três espécies de peixes recifais com distintos históricos de captura pela pesca subaquática, *Epinephelus adscensionis*, *Acanthurus bahianus* e *Chaetodon striatus*, em uma Área Marinha Protegida (AMP) de múltiplos-usos na costa nordeste Brasileira. Nossos resultados demonstram que o nível de proteção tem um efeito significativo na cautela das espécies alvo, mas o uso das áreas de turismo como estratégia de conservação contra a pressão de pesca pode ser controverso. Adicionalmente, características específicas das espécies podem claramente expressar como a percepção do risco varia entre elas, além de simplificar a compreensão dos resultados obtidos por meio das medições da DIF. Quando consideradas juntamente a outros dados, *e.g.* quantitativos (abundância, biomassa), as alterações comportamentais dos peixes, como as decisões de fuga, podem adicionar importante conhecimento para o monitoramento de áreas marinhas protegidas, especialmente na costa Brasileira onde a efetividade dessas áreas tem sido frequentemente questionada. O uso das medições da DIF como uma ferramenta de manejo pode aperfeiçoar políticas de monitoramento em AMPs, e indicar sistemas recifais onde as atividades antrópicas devem ser reduzidas ou banidas.

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1. Introduction

Brazilian fisheries provide food and livelihood support to coastal communities that are economical, socially and/or culturally dependent on this activity, supplying 66% of consumed fish (Gasalla et al., 2017). Since 2013, national per capita fish consumption has been showing an increasing trend, reaching 12 kg/year in 2015 (Gasalla et al., 2017). The main fishery landings occur in the Southern and Southeast regions, however, landings from artisanal fisheries account for about 200.000 tones in Northern and Northeastern regions (Gasalla et al., 2017; Zeller et al., 2004). The artisanal fishery, problems in communication, organizational structure and lack of institutional interest are within the factors that make Brazilian data collection from fishing sector unclear (Zeller et al., 2004).

Marine Protected Areas (MPA) have generally been implemented in coastal communities in order to sustain ecosystem services as well as manage and protect marine resources against human threats, such as overexploitation. These areas must maintain and restore marine biodiversity and also improve socio-economic conditions by increasing tourism and local fishing outside of the MPA (Gallacher et al., 2016; Gell and Roberts, 2003). However, the multiple-use within MPAs may interfere with the enforcement of regulations, essential to improving the success level linked to management objectives (Gallacher et al., 2016).

A recent literature review has identified the most frequently used indicators of success on MPAs from three broad categories: biophysical, socioeconomic and governance (Gallacher et al., 2016). These indicators include species abundance, the level of stakeholder participation and the existence of a decision making and management body (Gallacher et al., 2016). Nevertheless, expanding these indicators is important. Previous research has drawn attention to the potential role of the knowledge of animal behavior in conservation actions (Berger-Tal et al., 2016; Greggor et al., 2016). Antipredatory behavior has a great potential to serve as an indicator of management efficacy. For instance, fish in unprotected marine areas frequently display more fearful behavior. In such places, fish are caught arbitrarily unlike in protected areas, where fish do not suffer from the threat of fishing (Gotanda et al., 2009).

Importantly, fishes are among the most diverse assemblages of vertebrates on the Earth and account for approximately 10% of the global fishery catch (Hixon, 2011). They are the main protein source for many populations and an ideal group of marine animals for field experiments and long-term observations (Hixon, 2011). By considering that fish can respond to humans as if they were predators (Frid and Dill, 2002), their wariness or risk-tolerance could be assessed from the Flight Initiation Distance (FID) between the fish and the fisherman (Cooper and Frederick, 2007). Because FID is relatively easy to measure, this metric has been used abundantly in literature for evaluating hypotheses on escape theory and quantifying an individual's fearfulness under human threat (Blumstein, 2010, 2006; Stankowich and Blumstein, 2005).

Among the main human pressures on marine ecosystems, fishing is responsible for substantial changes in many populations over the centuries (Jackson et al., 2001), shaping the trophic composition, abundance, diversity, and influencing the behavior of reef fish assemblages (Januchowski-Hartley et al., 2011; Mora et al., 2011). When fish are exposed to fishing, they can increase wariness due to the association of human presence with a threat (Januchowski-Hartley et al., 2015; Yue et al., 2004). Thus, fish may come to perceive humans as a predator (Frid and Dill, 2002), and individuals that flee from predators will also flee from an approaching fisherman, soon after detection. The "flush early and avoid the rush hypothesis" (Blumstein, 2010) enables wildlife managers to identify the conditions under which human pressures affect the wariness behavior of animals. Indeed, many factors are known which influence fearfulness and in turn the antipredator behavior of animals (Stankowich and Blumstein, 2005). For the fish, experience

with predation is predicted to increase their wariness and thereby the flight distances. Furthermore, there are species-specific effects (*e.g.* physical condition, morphological adaptations, body size, sociability), and environmental ones (*e.g.* distance to cover, refuge disponibility, turbidity) which may act in how these animals make economic decision (cost-benefit) when fleeing from predation (Gotanda et al., 2009; Stankowich and Blumstein, 2005; Ydenberg and Dill, 1986).

Despite the literature (Benevides et al., 2016; Nunes et al., 2016, 2015), wildlife managers in Brazilian MPAs do not generally recognize FID metric's applicability and efficiency as a management tool. Maintaining the effectiveness and integrity of Brazilian MPAs has been a challenge (Araújo and Bernard, 2016; Oliveira Júnior et al., 2016; Schiavetti et al., 2013). For example, in the largest Brazilian MPA, the Environmental Protected Area Costa dos Corais (hereafter referred to as EPACC), has a zoning system proposed in 2012 with seven classes: Sustainable Use Zone; Beach Zone; Conservation Zone; Fishing Exclusive Zone; Visitation Zone; Marine Life Preservation Zone; and Transition Zone (ICMBio, 2012). This variety of classes draw attention to the distinctive use of coastal resources by population and, consequently, highlight the need for adopting effective assessment tools for helping managers in better estimating human pressures and threats in these areas.

The primary objective of this study is to evaluate whether management zones with fishing and tourism activities could distinctly influence the FID of target reef fish. Since fish can increase their flight distances due to experience with predation, it was expected that they would become more wary of a spearfisher's approach in fishing areas than in tourism ones. To explore this question, the escape behavior of three fish species with a distinctive history of catches by spearfishing was assessed using the measures of FID, body size, distance from refuge, and group size.

2. Methods

2.1. Study area

Created in 1997, the Environmental Protected Area Costa dos Corais – EPACC is the first federal conservation area to protect the Brazilian reefs on the northeastern coast, beyond being the largest MPA in the country. The management of natural resources is proposed through the regulation of tourism (*e.g.* ecological, scientific or cultural) and fishing activity (*e.g.* artisanal, commercial, subsistence or amateur) (ICMBio, 2012). EPACC borders twelve cities between Maceió, in Alagoas State and Tamandaré, in Pernambuco State, where almost every city relies on fishing and/or tourism as a main source of income (ICMBio, 2012) (Fig. 1).

This study was conducted at four sites within the management zone EPACC (two with fishing activities *vs* two with tourism activities) and four sites outside the management zone (*i.e.* in Maceió city) (two with fishing activities *vs* two with tourism activities) (Fig. 1). Wherever fishing is the main activity, spearfishing is the most common catch method. Tourism activities focus on recreational diving, including snorkeling or guided dive, and tours on sail or motor boats. In these areas, reefs are made of calcareous structures growing on top of sandstone banks. Generally, parallel to the coast at depths from 1 m to 8 m, exposing during low-tide (Ferreira and Maida, 2006; ICMBio, 2012). Fishing and tourism sites were selected according to zoning of EPACC (ICMBio, 2012; Pereira et al., 2014), information provided by local fishermen, drivers of boat tours, and the authors' personal observations. Underwater surveys were performed in coral reefs with depth ranging from 1 m to 6 m and with mean visibility of 5 m.

2.2. Study species

Groupers (Epinephelidae) are a globally significant catch for commercial fishing and one of the most heavily targeted tropical marine