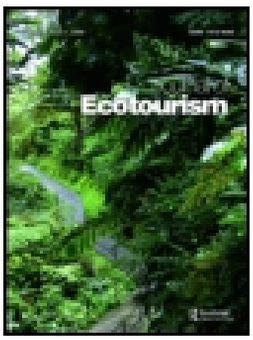

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Scuba diving and sedentary fish watching: effects of photographer approach on seahorse behavior

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ABSTRACT

Scuba diving tourism represents a growing non-extractive use of the marine environment, being an important income source for coastal communities. However, the activity can cause impacts on benthic sessile organisms by abrading tissues or breaking physical structures. The effects of scuba diving on fishes are less studied and there is no consensus about the impacts caused. We investigated if scuba divers are causing behavioral disruptions on seahorses. Divers using and not using cameras were observed while watching seahorses. We recorded the minimum distance that divers approached, the duration of interaction and physical contacts with seahorses, and the behavioral response of seahorses. Divers using action cameras attached to an extension pole approached the seahorses more closely, causing significantly more behavioral disruptions (escape) and physical contact with them. These repeated behavioral disruptions may negatively impact seahorse habits, such as feeding, reproduction, and resting. To mitigate the potential impacts on seahorses, we recommend the establishment of a minimum approach distance of 36 centimeters, the use of a pre-dive briefing to reinforce low-impact diving techniques, and close supervision by dive leaders to ensure appropriated in-water diver behavior.

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Scuba diving; marine protected area; tourism management; Brazil; coastal management; reef fish

Introduction

Scuba diving is one of the most popular recreational uses of the marine environment. The activity provides an important source of income for certain coastal communities and has a high potential for raising awareness of oceans conservation concerns (Dearden, Bennett, & Rollins, 2007; Spalding et al., 2017). Despite scuba diving being acknowledged as a low-impact recreational activity, after its increasing popularization since the 1990s, the damage caused to benthic organisms has been a matter of concern (Hawkins & Roberts, 1992; Zakai & Chadwick-Furman, 2002). Divers can contact the reef mainly by

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fin kicks, causing damage to corals, sponges, gorgonians and other benthic organisms (Roche et al., 2016). But the potential impact divers have on the behavior of fishes is a subject that has not been studied extensively. Surveys have revealed effects of diving tourism on reef fish physiology and behavior (Albuquerque et al., 2014; Dearden, Theberge, & Yasué, 2010; Titus, Daly, & Exton, 2015); however there is no consensus regarding the long-term impacts (Bradley, Papastamatiou, & Caselle, 2017; Hasler & Ott, 2008; Hawkins et al., 1999). Therefore, some issues remain poorly assessed, for instance, if underwater photographers are more likely to cause behavioral disturbances on fish behavior than non-photographers.

Seahorses are considered an iconic and charismatic group of fishes and are highly sought after by scuba divers and underwater photographers (Cater, 2007; Goffredo, Piccinetti, & Zaccanti, 2004; Uyarra & Côté, 2007). However, management concerns have been arising regarding the effects of divers on seahorse behavior (MMO, 2014) and potential damage to their habitat (Uyarra & Côté, 2007). As seahorses are cryptic, a flash is often required to take clear photographs. However, flash use is not recommended in the U.K. territories to photograph seahorses since 2011 because of the potential impact of disrupting behavior and harming their vision, causing temporary visual impairment and retinal damage (MMO, 2014).

The extension pole is a common accessory among underwater photographers using action cameras. It has made easier for divers to take better shots compared to holding the camera at arm's length. However, anecdotal evidence has suggested that scuba divers using extension poles are more willing to chase marine biota, causing short-term changes in the behavior of turtles, seahorses and other fish species (ICMBio, 2017; authors pers. obs.). Therefore, the use of extension poles attached to cameras has been prohibited for scuba diving in Fernando de Noronha National Marine Park, Brazil (ICMBio, 2017). However, the relationship between their use amongst divers with varying characteristics and the resulting behavioral responses by sedentary fish species is unknown. This study aimed to verify if photographers using extension poles cause short-term behavioral changes in a sedentary fish species, the longsnout seahorse, *Hippocampus reidi*. We used seahorses as a model to verify behavioral changes because of their small home ranges and high levels of site fidelity (less than 100 m^2; Foster & Vincent, 2004). Since this species relies on crypsis to camouflage (Garrick-Maidment, 1997), the simple fact of making it detach and swim would make it more visible to predators and its prey, as well as disrupting its behavior. In addition, we examined if divers using different photography equipment and non-photographers exhibited different behaviors while watching seahorses.

Methods

Study site

The study was conducted in the Arraial do Cabo Marine Extractive Reserve, a sustainable use marine protected area - MPA located in a subtropical marginal reef off southeastern Brazil (22°57′57″S, 42°1′40″W). In the MPA, commercial and recreational fishing and tourism are allowed under specific management guidelines, including fishing gear restrictions, spatial zoning and carrying capacity for tourism. Arraial do Cabo is one of the most popular scuba diving destinations in Brazil, with 13 diving companies serving scuba divers

inside the MPA. The use of cameras and extension poles are common among scuba divers (authors pers. obs.). Dives are conducted along shallow rocky reefs with depths ranging from 3 to 11 m and underwater visibility of 5 to 15 m. These reefs harbor a relatively high diversity of fish and benthic sessile organisms such as corals, gorgonians, zoanthids and sponges (Ferreira, Gonçalves, & Coutinho, 2001; Rogers et al., 2014). Annual diver visitation rate has been estimated at ~25,000 dives per year (Giglio, Ternes, Mendes, Cordeiro, & Ferreira, 2017).

The species surveyed

The longsnout seahorse, *Hippocampus reidi*, is the most abundant seahorse species in Brazil, and currently classified as Vulnerable on the Brazilian Red List of Endangered Species (MMA, 2014). The species exhibits strong site fidelity and can typically be found in shallow water associated with organisms such as gorgonians, corals, sponges, and tunicates (Rosa, Dias, & Baum, 2002). Seahorses are particularly susceptible to impacts from fishing and aquarium trade because of traits in their life history, such as high site fidelity, highly structured social behavior, and relatively sparse distributions (Foster & Vincent, 2004).

In Arraial do Cabo, longsnout seahorse is found at low densities, at 0.04 individuals per square meter (Oliveira & Freret-Meurer, 2012). The species is one of the main attractions among divers; individuals commonly are found associated with the shallow-water sponge *Aplysina* spp (authors pers. obs.).

Data collection and analysis

Scuba divers were observed during 51 diving operations between July and October 2015. The observer participated in the dive party as a regular visitor. Data was collected by one researcher to avoid potential bias among observers. For each observed diver the two first interactions with seahorses were recorded. An interaction began when divers sighted a seahorse and approached to observe or take photos, and ended when the diver moved away from the seahorse and continued along the diving trail. When an interaction was verified, the observer recorded; (1) If the diver was carrying a camera or not; (2) the type of camera, categorized as; (a) compact – point-and-shoot and simple operation cameras; (b) action – small sized, tough and very simple operation cameras; and (c) action camera attached to extension pole of more than 15 cm (extension poles less than 15 cm are used as a support to handle the camera); (3) the duration of the interaction (described in seconds); (4) the minimum approach distance of diver or camera from the seahorse (estimated visualy by a trained researcher); (5) if the diver or their gear made physical contact with the seahorse; and (6) if the interaction disrupted the behavior of the seahorse (*e.g.* swam away when diver approached or made physical contact).

Nonparametric analyses of variance (Kruskal–Wallis test) were conducted to verify if the timing of the interaction between seahorse and diver differed according to the type of photographic equipment used and non-photographer divers. The Mann–Whitney test was fitted to verify if the minimum distance approach differs for interactions that resulted in behavioral disturbance or not, and according to the photographic equipment used and non-users. The Fisher's exact test was used to test for differences among the

types of photographers or non-camera users and the frequency of physical contacts with seahorses as well as disrupting behavior caused by the interactions. Analyses were conducted at the significance level of 5% in the software R (R Core Team version 3.3.1, 2016).

Results

A total of 203 interactions between 144 scuba divers and seahorses were observed. Twenty-five percent of interactions ($n = 52$) were among divers carrying a compact camera, 21% ($n = 42$) carrying an action camera, 32% ($n = 65$) used an action camera and extension pole, and 22% ($n = 44$) were non-camera users. The overall mean duration of the interactions was 27.33 (± 11.7 SD) seconds. No significant differences were found in the time of interaction regardless of the type of photographic equipment used ($df = 3$, $x^2 = 4.7$, $p = 0.1$).

The average minimum distance of interactions that did not result in behavioral disruption was 36 ± 23 cm, $n = 179$. This value was significantly higher than interactions that caused behavioral disruptions (4 ± 7.4 cm, $n = 24$; $df = 1$, $x^2 = 51.2$, $p < 0.001$; see Figure 1). The minimum distance that divers approached seahorses was also significantly different among the types of photographic equipment used and non-camera users ($df = 3$, $x^2 = 97.9$, $p < 0.001$; Figure 2). Divers using action cameras attached to extension poles approached closer to seahorses (average = 10.7 ± 9.15 cm), causing significantly more physical contacts ($p < 0.001$; Figure 3(a)) and disruption in seahorse behavior when compared to divers using compact camera and non-camera users (21%; $p < 0.001$; Figure 3(b)), but did not differ to action camera users ($p > 0.05$).

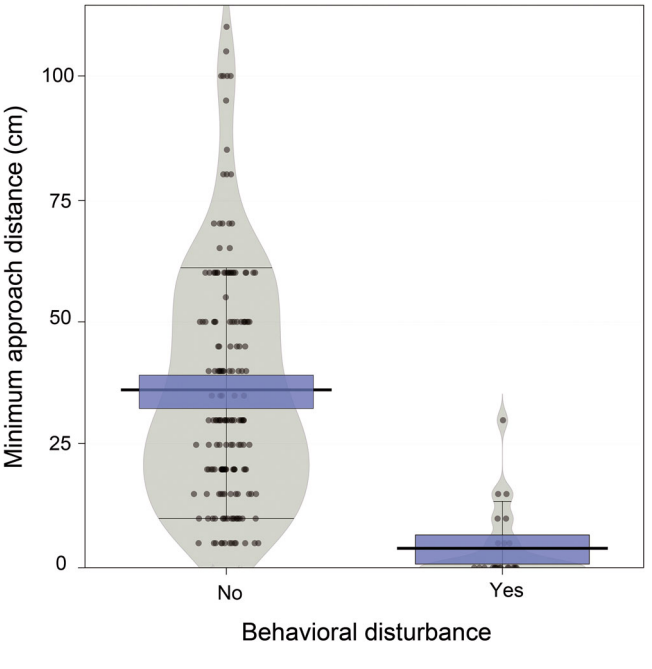

Figure 1. Minimum distance of divers approach to seahorses during observation and the occurrence or not of behavioral disturbance. Points are the raw data, black line represents the average, the bean is the density, band is the inference interval and deviations the 10th and 90th percentiles.

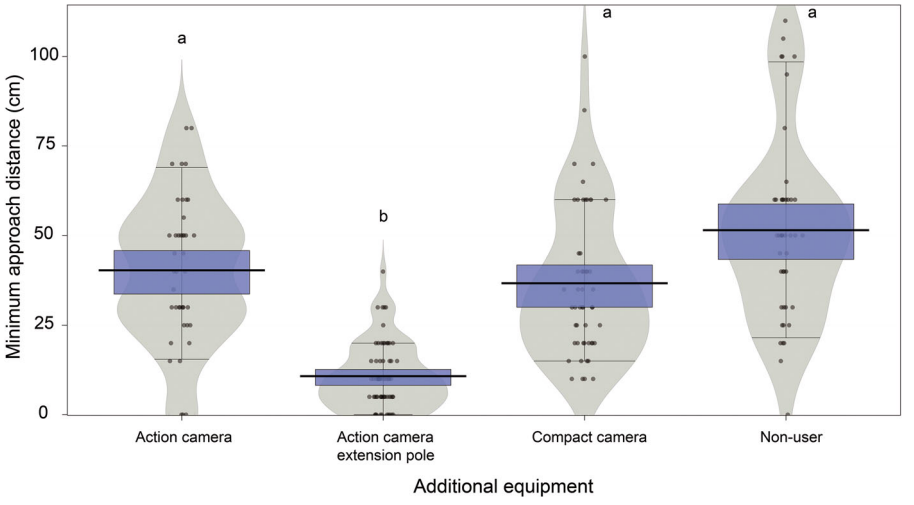

Figure 2. Minimum distance of divers approach to seahorses according to types of photographers and nonphotographers. Points are the raw data, black line represents the average, the bean is the density, band is the inference interval and deviations the 10th and 90th percentiles. Different letters above bars indicate significant differences (Dunn test, $p < 0.05$).

Discussion

This study revealed that scuba divers using action cameras attached to extension poles caused a higher frequency of short-term behavioral disruptions to seahorses. Most of

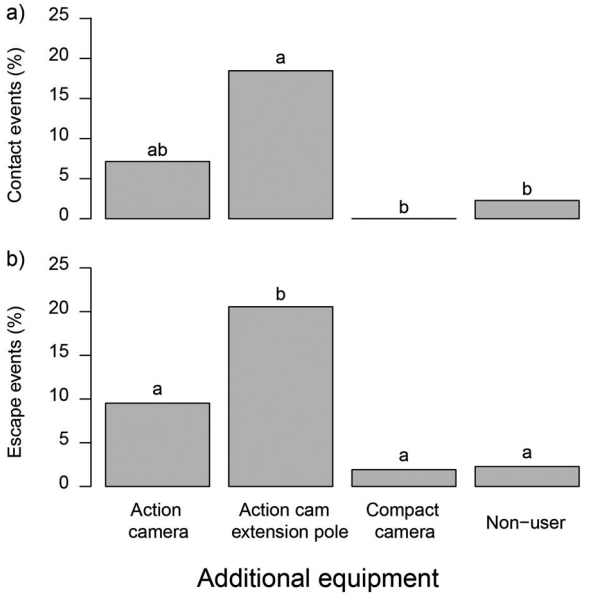

Figure 3. Behavior of divers during seahorse watching according to the type of photography equipment or nonphotographer. a) Frequency in which divers caused physical contacts with seahorses; and b) disrupting the behavior of seahorses (detach from holdfasts and start swimming along the reef). Different letters above bars indicate significant differences ($p < 0.05$).

disruptions were caused by unethical behaviors such as touching or moving individuals to get a better image. Seahorses are sedentary and occupy a small home range (Foster & Vincent, 2004). After a physical contact by a diver, the seahorse often swims away. This is described as behavioral stress response, where the individual moves away to escape and may even change skin coloration to improve camouflage (Garrick-Maidment, 1997). Stressed individuals also change their vocalization by increasing the number of clicks they produce. Click vocalization is generated by a skull stridulatory mechanism (Colson, Patek, Brainerd, & Lewis, 1998). Seahorses generate sounds in a variety of circumstances, e.g. during feeding, courtship, competition and stress (Oliveira, Ladich, Abed-Navandi, Souto, & Rosa, 2014). The change in sound patterns may result in the separation of pair-bonded individuals (Anderson, Berzins, Fogarty, Hamlin, & Guillette, 2011). Behavioral stresses influencing seahorses such as a flash lights, noise, and interactions with divers are suggested to negatively impact feeding, breeding, and resting habits (Claassens & Hodgson, 2017; MMO, 2014). Surveys have also revealed similar effects to other species of reef fish such as territorial damselfishes (Bracciali, Campobello, Giacoma, & Sarà, 2012). Invasive wildlife interaction decreases an individual's ability to camouflage themselves against predators because they move out from their habitat when disturbed (Geffroy, Samia, Bessa, & Blumstein, 2015). As verified in this study, photographers are more likely to cause a behavioral stress response in fish because they approach and pursue marine fauna to obtain close images (De Brauwer et al., 2018; Uyarra & Côté, 2007).

The behavioral changes in seahorses caused by divers using action cameras and extension poles observed in this study are in accordance with the perceptions of managers at destinations that have prohibited the use of extension poles, such as Fernando de Noronha National Marine Park, Northeastern Brazil (ICMBio, 2017). In the present survey, these subjects were more willing to get very close to seahorses since they did not need to run the risk of colliding when approaching the reef as divers using compact cameras do (see Figure 4). In most of the seahorse sightings, dive leaders were not present (VJ Giglio pers. obs.), but they often intervened when witnessing undesirable behavior. However, in Arraial do Cabo, there was no limit to the number of divers in a group and dive leaders guided groups with more than six divers, making it difficult to supervise the entire diver party. Dive leaders can easily intervene during nondesirable behaviors in smaller groups (Roche et al., 2016). Therefore, the establishment of a maximum number of divers per dive leader at six as a maximum is suggested. The reduction in group size can also contribute to closer surveillance of divers and facilitate intervention when unethical or damaging behavior is observed, such as fin kicks on corals (Hammerton & Bucher, 2015).

During data collection, divers using an action camera and extension poles were observed chasing other animals to get closer images, or selfies, with them, mainly turtles and rays. These animals were often frightened by this close approach and swam away quickly. Following this flight response, these individuals could not be subsequently observed by other divers in the same group. Charismatic species have high value as attractions in dive destinations (Giglio, Luiz, & Schiavetti, 2015; Uyarra, Watkinson, & Côté, 2009). The reduction of sightings may also result in economic losses. Scuba diving has emerged as a sustainable economic alternative to fishing in Arraial do Cabo, where most of the fish resources are overexploited (Bender et al., 2014;

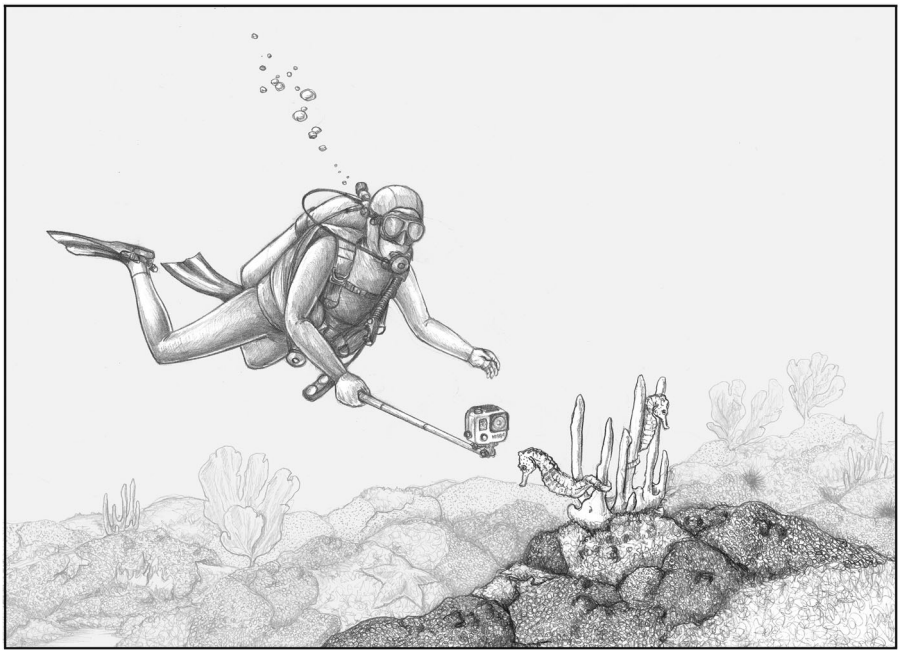

Figure 4. Scuba diver using an action camera attached to an extension pole, closely approaching seahorses to get images.

Giglio, Bender, Zapelini, & Ferreira, 2017). However, potential impacts caused by the diving sector to benthic organisms are matter of concern, like damage by boat anchoring (Giglio, Ternes, et al., 2017) and divers, considering high usage levels in Arraial do Cabo (Rogers et al., 2014). There is an urgent need to review the norms for recreational diving in Arraial do Cabo.

The use of educational initiatives is suggested to inform photographers about the potential negative effects caused by repeated disruptions on the behavior of reef fishes. In Arraial do Cabo, an educational video has been created in a collaborative manner involving researchers and diving stakeholders to serve as a pre-dive briefing to ensure low-impact diver behavior – www.youtube.com/watch?v=GrGT7fvnqaw (see details at Giglio, Luiz, Chadwick, & Ferreira, 2017). The video shows the correct approach to marine biota, emphasizing that divers must avoid touching the reef and encouraging behaviors that do not disrupt the natural behavior of animals. The experimental use of the video had a significant positive impact on the behavior of photographers resulting in fewer contacts with sessile benthic organisms (Giglio, Luiz, et al., 2017).

Conclusions and recommendations

Divers carrying action cameras and extension poles are a potential stressor to seahorses. This study has general implications for diving because the use of extension poles is popular among recreational divers. Based on our findings, we recommend the establishment of a minimum distance approach of 36 centimeters to reduce the likelihood of behavioral disruptions to seahorses. To foster appropriate behavior among scuba

divers, we recommend; (1) the use of pre-dive briefings to reinforce low-impact techniques, mainly among photographers; and (2) close supervision by dive leaders to ensure appropriate behavior in-water. Diving tourism needs to be effectively managed to achieve sustainability and continue to provide socioeconomic benefits for coastal communities.

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