marine ecology

Marine Ecology. ISSN 0173-9565

ORIGINAL ARTICLE

Observer presence may alter the behaviour of reef fishes associated with coral colonies

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Keywords
Behavioural ecology; coral–fish association; methodologies; remote cameras; South Atlantic reefs; visual census.

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Accepted: 17 October 2015

doi: 10.1111/maec.12345

Abstract

Although underwater visual census (UVC) is the most frequently used technique for quantifying reef fish assemblages, remote video analysis has been gaining attention as a potential alternative. In the South Atlantic Ocean, *Millepora* spp. (class Hydrozoa) are the only branching coral species; however, little is known about the ecological role that they play for reef fish communities. We compared these two observation methods (remote video and UVC) to estimate reef fish abundance and species richness associated with colonies of the fire-coral *Millepora alcicornis* at Tamandaré Reefs, Northeast Brazil. Additionally, the two different techniques were used to compare species behaviour in association with fire-corals in order to examine the biases associated with each technique and provide useful information for behavioural ecologists studying fish–coral associations. There were no differences in reef fish abundance or species richness sampled by remote video or UVC. However, a significant difference in the behaviour of associated fish was recorded between the two methods. In the presence of a diver carrying out a UVC, fish were observed spending more time sheltered amongst the coral branches compared with passively swimming on coral colonies with the remote video technique. Specifically, on the remote video recordings agonistic interactions between fish and passive swimming accounted for 33.3% and 22.2% of the census time, respectively. By comparison, when observed by a diver fish spent 34.8% of their time sheltering amongst the coral branches. We demonstrate that both techniques are similarly effective for recording fish abundance and species richness associated with fire-corals. However, differences were observed in the ability of each method to detect the behaviour of coral-associated fishes. Our findings show that behavioural ecologists studying complex fish–coral associations need to ensure that their aims are clearly defined and that they choose the most appropriate technique for their study in order to minimize methodological biases.

Introduction

Visual survey techniques are used widely to estimate the abundance of target organisms in terrestrial (Caughley 1977; Francis 1994) and aquatic ecosystems (Keast & Harker 1977; Solazzi 1984; Spalding & Jarvis 2002; Bijoux *et al.* 2013). To date, much of our understanding of shallow marine ecosystems and their ecological processes are supported by data collected via diver-based underwater visual censuses (UVCs). The UVC technique was first used by Brock (1954) and is currently a popular for carrying out population and community censuses of tropical fishes (Sale 1997; Samoilys & Carlos 2000; Edgar *et al.* 2004; Kulbicki *et al.* 2007). This technique has the advantages of being non-destructive, relatively inexpensive to perform and that data are immediately available (Stobart *et al.* 2007). However, many studies have highlighted sources of bias that have the potential to affect the accuracy and precision of results obtained via diver censuses (Brock 1982; Sale & Sharp 1983; Thompson & Mapstone 1997; Edgar *et al.* 2004). Owing to the limitations of UVCs, an examination of the relative merits of alternative methods for quantifying fishes, other mobile organisms and related environmental factors within marine ecosystems (Greene & Alevizon 1989; Harvey *et al.* 2001; Holmes *et al.* 2013; Goetze *et al.* 2015) has grown, including the use of remote video recorders (Willis & Babcock 2000; Willis *et al.* 2000; Cappo *et al.* 2003; Harvey *et al.* 2004; Pelletier *et al.* 2011; Wartenberg & Booth 2014).

Remote video systems provide an alternative or complementary method to that of traditional direct diver observation for surveying reef fish communities (Dunlap & Pawlik 1996; Bellwood & Fulton 2008; Burkepile & Hay 2008). The advantage of remote video methods is that they provide a permanent record of the fish that can be cross-checked by several observers as many times as necessary (Willis & Babcock 2000; Willis *et al.* 2000). Consultation with expert taxonomists and books is also possible for any doubtful remote video footage; by contrast, detailed taxonomic assessment of doubtful species can not normally be carried out when conducting a UVC (Pelletier *et al.* 2011; Wartenberg & Booth 2014). Additionally, video techniques offer a solution to some of the biases associated with UVCs, such as the attraction or repulsion of some fish to/from the diver (Lindfield *et al.* 2014). Lastly, remote camera systems can also be deployed at much greater depths (Francour *et al.* 1999; Zintzen *et al.* 2011). However, there are also important limitations associated with remote video recorders, such as difficulties in identifying species with cryptobenthic habits (*e.g.* Blenniidae and Gobiidae; Longo & Floeter 2012; Holmes *et al.* 2013) and the extra equipment needed to capture and process videos (Goetze *et al.* 2015).

Previous studies have shown that observer presence can alter the usual behaviour of different taxa, such as birds (Henson & Grant 1991), reptiles (Kerr *et al.* 2004) and mammals (Aguiar & Moro-Rios 2009; Iredale *et al.* 2010). Several behavioural changes, such as to home range size, foraging rates and stress levels, have been recorded as a result of observer presence during animal behaviour studies (Crockett *et al.* 2000; Iredale *et al.* 2010). Specifically for marine ecosystems, observer presence can also alter the usual behaviour of fishes on coral reefs (Watson *et al.* 2005; Colton & Swearer 2010; Dickens *et al.* 2011). Previous studies have suggested that diver presence may alter fish behaviour, causing some fish to seek refuge whereas others are attracted to the diver (Chapman *et al.* 1974; Lowry *et al.* 2011; Lindfield *et al.* 2014). In order to better understand the behaviour of fish associated with coral colonies, it is important for coral reef behavioural ecologists to use the best observation technique available. Researchers analysing the complex behavioural patterns of coral-associated fishes could be underestimating the influence of diver presence on fish behaviour. Therefore, the understanding of how fish interact with their coral host, without the effects of diver presence, could be more complex than previously thought.

The close association between reef fishes and their coral habitats has been extensively studied (Friedlander & Parrish 1998; Feary *et al.* 2007; Wilson *et al.* 2008; Wong & Buston 2013; see Coker *et al.* 2014 for a review). Branching corals are known to host a great diversity of organisms and play a vital role for associated species, providing shelter, food and reproduction sites (Bellwood *et al.* 2004). Within the Indo-Pacific, most research examining reef fish habitat associations has been conducted on scleractinian corals of the genus *Acropora*, with a focus on coral features such as size, health and prior residency (Holbrook *et al.* 2000; Almany 2004; Bonin *et al.* 2009; Noonan *et al.* 2012). However, in the South Atlantic Ocean, *Millepora* spp. are the only branching coral species and play a similar ecological role as *Acropora* spp. in the Indo-Pacific Ocean. Previous studies have reported that more than 30 reef fish species can live in close association with *Millepora* coral colonies in the South Atlantic Ocean (Coni *et al.* 2012; Pereira *et al.* 2012; Leal *et al.* 2013, 2015). Despite the ecological importance of *Millepora* spp., very few studies have examined the ecological role that they play in supporting fish communities and no studies have tested the relative effectiveness of UVC and remote video as observational methods for analysing fish communities associated with fire-corals.

Despite widespread use of *in situ* visual monitoring techniques in the assessment of fish communities, the relative biases associated with each method may have been underestimated and remain poorly understood for coral-associated species. For instance, the ways in which fish interact with fire-coral colonies are still unknown and selection of the best possible sampling technique is vital to progress in our understanding of these interactions. Therefore, in this study we compared the effectiveness of different techniques for quantifying reef fish associations with *Millepora alcicornis* colonies. Remote video and diver observation techniques were used to estimate reef fish abundance and species richness. The different techniques were also used to compare the behaviour of coral-associated fishes. For the first time, this study empirically tested the hypothesis that observer presence alter the usual behaviour of reef fishes associated with coral colonies.

Material and Methods

Study location

This study was conducted on coastal reefs located in the municipality of Tamandaré, Northeast Brazil (88°44′54″ S, 36°6′14″ W). Tamandaré is located 110 km from Recife, the capital of Pernambuco State. The reef complex studied, the 'Ilha do Norte' reef, is located within the 'Area de Preservação Ambiental Costa dos Corais' (Coral Coast Marine Protected Area; Fig. 1).

'Ilha do Norte' reef (Fig. 1) is located between 300 and 600 m from the shoreline, at an average depth of 5 m. Water visibility ranged from 5 to 10 m during the present study. This reef area is covered by macroalgae species, hermatypic corals (*Favia gravida*, *Montastrea cavernosa*, *Mussismilia* spp. and *Porites astreoides*) and colonies of the hydrocorals *Millepora alcicornis* and *Millepora braziliensis* (Ferreira & Maida, 2006). *Millepora alcicornis* was chosen because it is the most abundant and complex fire-coral species in the study area.

Sampling techniques

Underwater observations were conducted from September 2012 to April 2013, during the dry season. In order to maintain consistency between the two methods, observations were performed by a single observer at the same tide, time of day (08:00–14:00 h) and time of year. Observation time and distance of the observer/video system from the coral colonies were standardized to 5 min and 1.5 m, respectively, for both census methods. The distance of the observer/video system from the coral colonies was previously tested and standardized at 1.5 m in order to reduce any interference and increase the accuracy of fish identification. Additionally, the width around the sampled coral colonies was estimated to 1.5 m in order to standardize a similar sampling area for both techniques.

Fish community and species behaviour were analysed in a total of 26 *Millepora alcicornis* colonies that were sampled monthly. Colonies were selected, tagged and measured (diameter and height); their volumes (m^3) were then estimated assuming a cylindrical shape ($\pi r^2 \times$ height) following Holbrook *et al.* (2000). The base area was calculated from the average diameter of the colony. The colony height was measured as the distance from the substratum (*i.e.* coral base) to the highest branch. The average coral colony volume was 2.13 m^3.

Previous studies have shown that alternative sampling techniques may record fish behaviour differently (Willis *et al.* 2000; Lowry *et al.* 2011). Therefore, in order to determine the ability of the two different techniques to record the behaviour of fishes associated with *M. alcicornis* colonies, classification of the behaviour of fishes was standardized between census methodologies and the same behavioural categories were used. Behavioural categories were as follows: sheltered on coral branches: when individuals were recorded sheltering in the crevices and hollows of the coral; feeding on algae: when individuals were recorded eating algae on the structure of *M. alcicornis* colonies; feeding on coral polyps: when fishes were recorded biting *M. alcicornis* polyps; agonistic: when fishes were engaged in aggressive behaviour with other

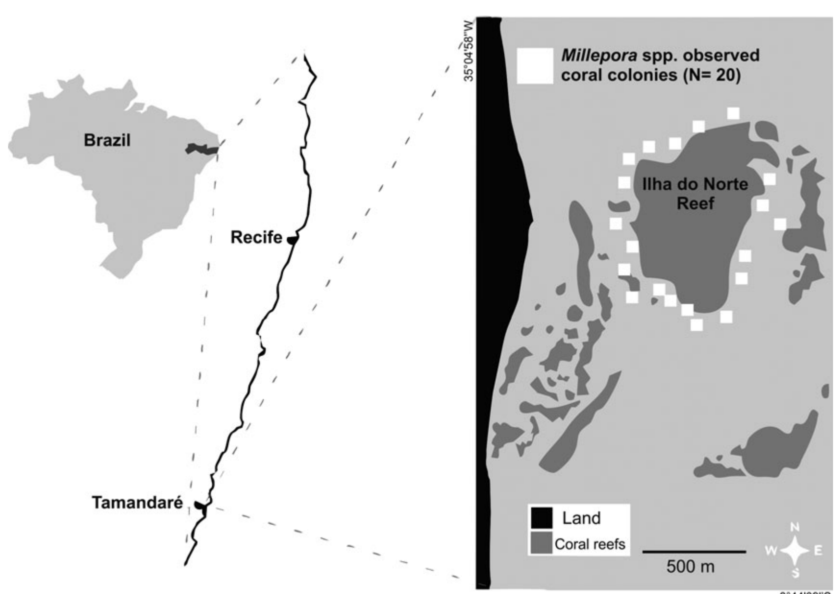

Fig. 1. Map of the study site, 'Ilha do Norte' reef in Tamandaré municipality, Northeast Brazil, indicating the position of the analysed *Millepora alcicornis* coral colonies. n = 26. Surveyed fire-coral colonies were located at the outer edges of the coral reefs.

fish that tried to approach or were roving close to *M. alcicornis* colonies; passive swimming: when associated fishes were recorded swimming close to fire-coral colonies.

Behaviour was recorded for 5 min for every individual associated with the fire-corals using the focal animal method (Altmann 1974). The time that each fish spent exhibiting the different behavioural categories was recorded and then converted into a percentage of the total 5-min observation time.

Remote video

The remote video technique was performed with a Go Pro Hero 2 video camera fixed on a weighted tripod (Fig. 2). The system was carried down by a diver and placed in front of the *Millepora alcicornis* coral colonies. Data recording did not occur for at least 5 min after the camera was deployed to avoid any influence of the diver and placement of the camera. Remote video footage was analysed using WINDOWS MEDIA PLAYER version 8.1 (http://windows.microsoft.com/en-us/windows/windows-media-player). Every fish observed during the video recording was identified to species level and the total number of individuals of each species was summed to estimate relative abundance. The concept of maximum number of individuals of each species (maxN) was applied during video sample analysis. The use of maxN has been proven to be a reliable and robust method for monitoring fish relative abundance in a variety of inshore marine environments (Willis *et al.* 2003; Stobart *et al.* 2007; Folpp *et al.* 2013). Detailed review of the use of maxN as an estimator of relative abundance and its effectiveness has previously been undertaken (Cappo *et al.* 2003).

Diver observation technique

A single observer performed all the diver observations during the entire sampling period in order to avoid any potential observer bias. The diver remained stationary at an average of 1.5 m away from the colonies of *Millepora alcicornis*. The same acclimatization period (at least 5 min) was used to match the remote video technique.

Data analyses

A Mann–Whitney *U*-test was used to compare the total number of individuals and species recorded by the two different observation methods (remote video and diver observation).

Tests for differences in behavioural categories between the two different observation methods were performed using permutational multivariate analysis of variance (PERMANOVA). Behavioural categorical data were grouped according to technique and reassembled in a Bray–Curtis similarity matrix. An unrestricted permutation of raw data was applied as this is the best technique for single-factor analysis.

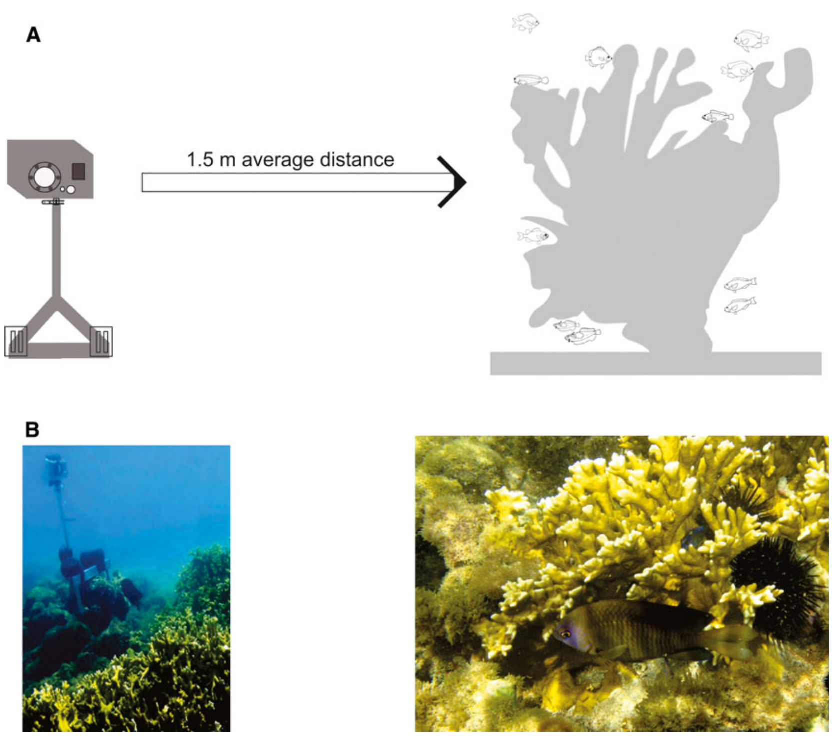

Fig. 2. (A) Schematic design of the remote video technique with a video camera fixed on a weighted tripod 1.5 m in front of each *Millepora alcicornis* coral colony. (B) *Millepora alcicornis* coral colonies used for reef fish community analyses.

A multidimensional scaling (MDS) bi-plot was produced to investigate correlations between the two different observation methods and behavioural categories. Percentage behavioural data were reassembled in a Bray–Curtis similarity matrix. The strength and nature of the correlation between observational methods and behavioural categories within the MDS space were represented by vectors in an ordination bi-plot.

PRIMER-E 6 PERMANOVA+1.0 software (v. 6.1.14) was used to conduct the PERMANOVA and MDS analyses.

Results

During the remote video analyses a total of 141 reef fish individuals belonging to 10 families and 14 species was recorded in association with *Millepora alcicornis* coral colonies. By comparison, during direct diver observation, a total of 138 individuals of reef fish belonging to 11 families and 16 species was observed (Table 1). In both techniques *Stegastes fuscus* (Pomacentridae) was the most abundant species, representing 70.2% of the total community during remote video analysis and 56.2% during diver observations. From the total of 17 species recorded in the present study, only one was observed exclusively through the remote video (*e.g. Aluterus scriptus*) and three exclusively through diver observation (*Pareques acuminatus*, *Epinephelus adscensionis* and *Muraena pavonina*) (Table 1).

Fish abundance was 5.4 ± 4.1 (average ± SD) individuals per recording period (ind.•5 min^{-1}) for remote video and 5.3 ± 4.5 for direct diver observation. Species richness was 2.0 ± 1.2 for remote video and 2.3 ± 1.8 for direct diver observation. No significant differences were observed between diver observation and remote video for abundance (P = 0.56) or species richness (P = 0.91) (Fig. 3).

Significant differences were observed when comparing behavioural categories between the two different census techniques (PERMANOVA: pseudo-$F_{1.55}$ = 2.38, P = 0.001). The most frequently recorded behaviour during remote video technique was agonistic behaviour (33.3%), followed by passive swimming around coral colonies (22.2%). By contrast, sheltered on coral branches (34.8%) and feeding on coral polyps (20.9%) were the most representative behaviours recorded by direct diver observation (Table 2).

The MDS bi-plot (2D stress 0.16) correlating the behavioural categories and observation techniques also showed differences between the methods (Fig. 4). Data were split on the horizontal axis between diver observation and remote video samples in the MDS, with the split clearly driven by sheltering on coral branches. This behaviour was highly correlated with the diver observation method, whereas 'passive swimming' was highly correlated with remote video (Fig. 4).

Table 1. Reef fish species and number of individuals recorded in association with *Millepora alcicornis* colonies using remote video and diver observation.

family	species	remote video rel. abund. (%)	diver observation rel. abund. (%)
Pomacentridae	*Stegastes fuscus*	70.21	56.52
Holocentridae	*Holocentrus adscensionis*	9.92	14.49
Pomacentridae	*Abudefduf saxatilis*	6.38	5.07
Labridae	*Sparisoma axillare*	2.83	0.72
Epinephilidae	*Cephalopholis fulva*	2.12	2.89
Scaridae	*Scarus zelindae*	2.12	0.72
Monacanthidae	*Aluterus scriptus*	1.41	0
Acanthuridae	*Acanthurus coeruleus*	0.70	3.62
Haemulidae	*Anisotremus virginicus*	0.70	0.72
Chaetodontidae	*Chaetodon striatus*	0.70	2.17
Labridae	*Haliocheres braziliensis*	0.70	0.72
Bleniidae	*Ophioblenius trinitatis*	0.70	3.62
Labrisomidae	*Labrisomus nuchipinnis*	0.70	0.72
Holocentridae	*Myripristis Jacobus*	0.70	2.89
Epinephilidae	*Ephinephelus adscensionis*	0	2.89
Scianidae	*Pareques acuminatus*	0	1.44
Muraneidae	*Muraena pavonina*	0	0.72

rel. abund. (%) = relative abundance.

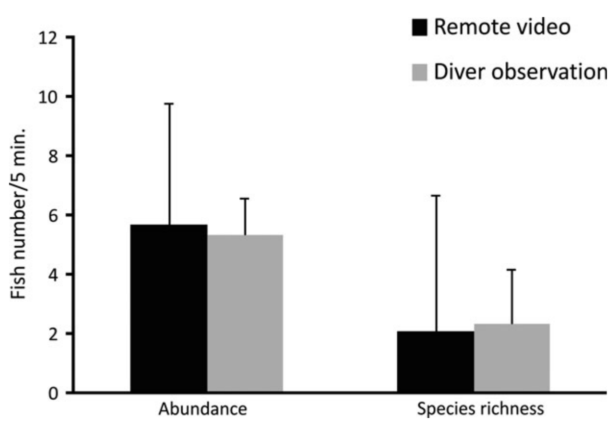

Fig. 3. Fish community data (abundance and species richness) recorded by remote video and diver observation. n = 26 *Millepora alcicornis* coral colonies for each sampling technique.

Table 2. Recorded behaviours of reef fish species associated with *Millepora alcicornis* using remote video and diver observation. See Methods for detailed descriptions of behavioural categories.

behavioural category	remote video (%)	diver observation (%)
passive swimming	22.2	9.3
agonistic	33.3	18.6
feeding on coral polyps	16.6	20.9
feeding on algae	11.1	16.2
sheltered on coral branches	16.6	34.8

% = percentage of survey periods.

Discussion

The use of different methodologies to investigate fish communities and their behaviour in different ecosystems has been the subject of much discussion over recent decades (Caughley 1977; Bortone *et al.* 1989; Watson & Harvey 2007; Fox & Bellwood 2008; Lowry *et al.* 2011; Goetze *et al.* 2015). During the present study we observed that diver observation and remote video techniques were similarly able to record abundance and species richness of reef fishes associated with *Millepora alcicornis* coral colonies. However, significant differences were detected between these survey techniques in the types of behaviour recorded for reef fishes associated with fire-coral colonies. Our findings demonstrated that diver presence significantly affected fish behaviour, causing fish to shelter on coral colonies, whereas the remote video technique recorded natural behaviours such as passive swimming and agonistic more effectively.

Similar levels of abundance and species richness were recorded by direct diver observation and remote video methods in the present study. This finding is consistent with observations made in other studies on tropical fish communities (Holmes *et al.* 2013; Goetze *et al.* 2015). This suggests that the presence of divers or the remote video system had little effect on reef fish assemblages associated with fire-coral *Millepora* spp. The absence of a difference between abundance and species richness for the two methods employed in the current study may be because coral colonies are usually inhabited by juvenile and territorial reef fishes (Coni *et al.* 2012; Leal *et al.* 2013) that are unlikely to travel long distances from their home habitat.

Although no significant difference was observed for fish abundance and species richness between the methods, three species that were recorded during diver observation were not seen by the remote video technique (*i.e. Epinephelus adscensionis*, *Muraena pavonina*, *Pareques acuminatus*). These species were probably not recorded by the remote video as they have previously been observed sheltering in crevices and cavities of *M. alcicornis* (Leal *et al.* 2013, 2015). The inability of remote video to see under ledges and into crevices is a limitation of this technique and has been acknowledged elsewhere (see Watson *et al.* 2005). Additionally, according to Holmes *et al.* (2013) lower abundance estimates of serranids (*e.g. Epinephelus* spp.) were recorded using video techniques, which is probably because of the limited ability of the camera to effectively search the highly complex coral reef habitat, where many of these species reside. The ability of a diver to physically inspect the architecturally complex branches of corals where fish may be residing could be another possible

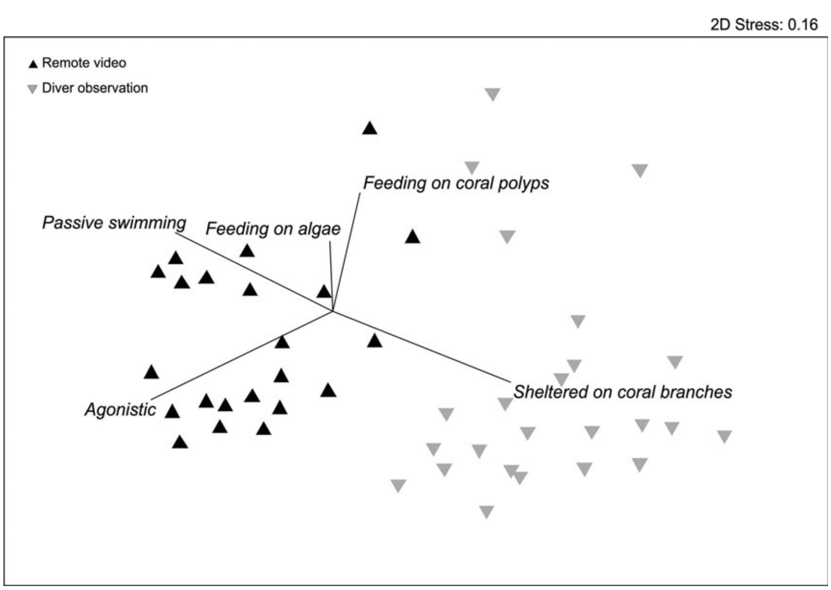

Fig. 4. Multidimensional scaling bi-plot constructed with Bray-Curtis similarity matrix correlating behavioural categories for the remote video and diver observation techniques.

explanation for the increase in species seen by the diver observation method in comparison to the remote video analysis here. By contrast, the species *Aluterus scriptus* was only recorded by the remote video method and so may have actively avoided the diver. *Aluterus scriptus* are not commonly seen in coastal reefs as adults, but are more often observed along deep coastal slopes or outer reef drop-offs (Kuiter & Tonozuka, 2001). Food resources may be the main reason for the association of *A. scriptus* with fire-corals as they apparently prey upon hydrozoans (Weitkamp & Sullivan 2003). It is also important to mention that owing to the small number of individuals detected only by the remote video technique it could be possible that those species were recorded by chance encounter.

A recent study comparing the UVC technique to video camera systems found higher estimates of abundance and species richness with UVC (Pelletier *et al.* 2011). The traditional UVC technique is thought to survey greater species richness and abundance owing to the advantages of the human eye (Le Grand 1968) compared with video cameras (*i.e.* reduced clarity of video images and the restricted field of view). However, Goetze *et al.* (2015) suggested that UVC can cause overestimation of fish abundance on transects, mainly for highly mobile species (Ward-Paige *et al.* 2010). Consequently, the preferred technique for a given study will be the one that documents fish abundance more accurately compared with the real numbers and not the technique that records more individuals. It is also important to note that differences in the species richness recorded between methods relate to the relative detectability of fish species by different techniques (Edgar *et al.* 2004; Bozec *et al.* 2011). Numerous factors influence the detectability of fish, including fish size and behaviour, visibility, diver expertise, habitat complexity and survey duration (Edgar *et al.* 2004; Ward-Paige *et al.* 2010; Bozec *et al.* 2011; Pelletier *et al.* 2011). The degree to which these factors influence fish detectability depends on how they interact with the particular method used. For example, Dickens *et al.* (2011) recorded a 70% decline in the abundance of parrotfishes as a result of ongoing diver presence. A comparable diver effect was found, to varying extents, in all reef fish groups examined (Dickens *et al.* 2011). A similar trend was also reported by Stanley & Wilson (1995), with a mean reduction of 60% of the fish community density with diver presence. As such, there may be little advantage using either diver observations or video technologies when quantifying fish abundance within single coral colonies; however, comparisons of these techniques are warranted for mobile species over larger spatial scales.

Significant differences were detected when comparing the behavioural categories recorded between the two different survey methodologies. The remote video technique is potentially more efficient at recording agonistic behaviours and those where fishes were outside the confines of the colony branches (passive swimming around coral colonies). By contrast, direct diver observation may influence species behaviour by causing fish to seek shelter. It has been shown that increased fishing activities or even just human presence can directly affect fish behaviour (Januchowski-Hartley *et al.* 2011; Pereira *et al.* 2011). Behavioural changes in fish may be dependent on the frequency of encounters between fish and stimuli (Brown *et al.* 2006); higher intensities of fishing pressure or even human presence may result in greater fish wariness. Although the present study site was within a Marine Protected Area, high fishing intensity and tourist activities have been recorded for the area (see Pereira *et al.* 2014 for description of activities), which are likely to increase the influence of diver presence on fish behaviour. Accordingly, it is clear that the use of video cameras to record behaviours of coral-associated fishes removes the effects of direct diver presence and so this technique may be more appropriate for such studies.

The relative amount of time that fish spent sheltered in coral colonies was doubled during direct diver observation compared with the remote video system; therefore, it is likely that diver presence affects fish behaviour. Although the influence of observer presence on species behaviour has not yet been fully analysed for coral-associated species; our results are the first to indicate that observer presence may alter the natural behaviour of reef fishes. Consequently, it seems that diver presence has a similar effect to that of predator presence on the behaviour of fish associated with coral colonies. According to Alvarez & Nicieza (2003), the presence of piscivorous fish significantly increased the use of refuges within prey fish communities. An increase in the total number of predator has also been shown to alter fish behaviour by increasing the time spent in shelter or by the fish moving to an alternative habitat (Milinski & Heller 1978; Werner *et al.* 1983). Therefore, the findings of the present study suggest that studies investigating the natural behaviour of fishes associated with coral colonies should give preference to remote video techniques. However, for studies aimed at recording fish community data (*i.e.* abundance and species richness), the UVC technique yields similar results to video analyses, but may be more appropriate owing to the decrease in costs and increased ease of logistics.

The high cost of recording systems and staff hours for video analysis often discourage researchers from using these techniques, particularly in countries where funding and technological resources are limited (Pelletier *et al.* 2011; Goetze *et al.* 2015), such as Brazil, where the present study was conducted. However, the number of qualified and trained researchers able to perform UVC with scientific accuracy in these countries is also very limited (P. H. C. Pereira, personal observation). Pelletier *et al.*

(2011) also suggested that remote video techniques could be also extremely useful in areas with no expert available to conduct fieldwork, where a non-specialist diver can operate the cameras. Consequently, the potential increased efficiency in using cameras for fish community surveys and species behavioural observations, in combination with the lack of qualified personnel in developing countries for UVC surveys may balance the overall costs associated with video techniques (Francour *et al.* 1999; Pelletier *et al.* 2011; Goetze *et al.* 2015).

Summary

In conclusion, the present study has demonstrated that both the UVC and remote video methods are similarly able to record fish abundance and species richness in association with *Millepora alcicornis* coral colonies. However, significant differences were observed in the behavioural categories between the two methods. Fish behaviour was influenced by diver presence, with fish spending more time sheltered on the coral branches during the UVC technique compared with passively swimming around corals with the remote video technique. Our findings indicate that recording systems are superior to traditional UVC for behavioural observations of coral-associated fishes. Therefore, if a choice needs to be made between methods, it is essential that the research aims are defined prior to the start of the study and the most appropriate technique chosen to avoid all the methodological issues mentioned herein.

Acknowledgements

The authors would like to thank Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Pesquisas Ecológicas de Longa (PELD), Idea Wild and the Percy Sladen Memorial Fund Grant for financial support.

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