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Cost–benefit of different methods for monitoring invasive corals on tropical rocky reefs in the southwest Atlantic

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ABSTRACT

Biological invasions need to be efficiently monitored in order to detect change in invader abundance and the modification of receptor communities so that management options can be effectively applied. We compared four methods, visual census (VC), photo-quadrats of 50 × 50 cm (PHOT50), mosaic of photo-quadrats of 25 × 25 cm (PHOTS25) and video-quadrats (VIDEO), to determine 1) the percent cover of the most abundant taxa in reef communities undergoing invasion by the corals *Tubastraea coccinea* and *Tubastraea tagusensis* and 2) direct counts of the invasive species for density estimates per unit area. The study was carried out on eight islands in the Tamoios Ecological Station Marine Protected Area, Ilha Grande Bay, Brazil. The digital methods did not differentiate some *T. coccinea* from *T. tagusensis* and both *Tubastraea* densities were higher in the VC method, followed by PHOTS25, PHOT50 and VIDEO. An ANOSIM indicated differences among sampled communities but not between the methodologies. The richness, diversity and evenness indices did not differ significantly between the methods for the different benthic communities investigated. In the field, the VC was slower and PHOT50 was faster; however, in the laboratory VC was faster and PHOTS25 was slower. Overall the VC method was quickest, followed by PHOT50, VIDEO and PHOTS25. The overall cost was highest in PHOTS25 method, followed by the VC, VIDEO and PHOT50. VC had the best cost-to-benefit ratio and digital methods were not reliable for estimating the densities of corals.

1. Introduction

Monitoring programs are extremely important for a better understanding of processes, patterns and changes that occur in marine benthic populations and communities, as well as for the comprehension and prevention of ecological and economic impacts resulting from natural and human disturbances. One specific demand of monitoring programs is to detect biological invasion and subsequent change in receptor communities during the invasion process. Such monitoring programs subsidize management and conservation programs.

Monitoring programs must be sufficiently sensitive to detect change but robust enough to be widely applicable at reduced cost. Thus, the evaluation of various methods is important as a precursor to the start of monitoring programs and comparisons of different methodologies are needed in order to improve and/or optimize the monitoring, reducing costs and maximizing the benefits over time (Fairweather, 1991). The choice of which methodology is used for monitoring benthic communities and populations depends on the purpose of the study, the local conditions, the biological knowledge of those who carry out the work, the scale of study and the degree of accuracy required.

With the advance in technology and perceived demands of managers, monitoring programs and research are becoming commonplace in reef environments, with frequent and efficient use of photographs, filming and remotely operated vehicles supplementing or replacing more traditional in situ visual methods. Several studies have assessed the efficiency of and compared methods to sample the percent of cover and population densities of subtidal benthic communities on reefs (Brown et al., 2004; Burgess et al., 2010; Chiappone and Sullivan, 1991; Dumas et al., 2009; Filho et al., 2008; Houk and Van Woesik, 2006; Lam et al., 2006; Leonard and Clark, 1993; Leujak and Ormond, 2007; Lirman et al., 2007; Miller et al., 2003; Parravicini et al., 2009; Preskitt et al., 2004; Ramos et al., 2010; Rogers and Miller, 2001; Segal and Castro, 2001). According to the above studies, in general, digital methods are faster and do not need a taxonomic expert in the field, allowing larger areas to be sampled or increase the number of replicas. Also, digital methods permit a permanent record of data, enabling revision of the images to obtain or verify information or confirm identification of any organism. The down side is that these methods consume more time in the laboratory, need specialized software for processing and analysis of data, have limited taxonomic resolution (especially

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smaller organisms), require good water clarity and the equipment used are expensive to buy and maintain.

Changes in the size of a population, especially with an invasive species, can impact other populations, causing community change, thus making density an important variable to focus on in monitoring programs; these data can increase our ability to detect and understand changes on subtidal benthic environments. Despite this, rather few previous studies have compared methods used to record the density of subtidal benthic organisms (Burgess et al., 2010; Leujak and Ormond, 2007).

Rocky reefs along the Brazilian coastline in the southwest Atlantic are currently suffering biological invasion by the cup corals *Tubastraea coccinea* Lesson, 1829 and *Tubastraea tagusensis* Wells, 1982 (de Paula and Creed, 2004; Ferreira, 2003; Mantelatto et al., 2011; Sampaio et al., 2012; Silva et al., 2011). The aim of the present study was to quantify invasive coral densities on subtidal rocky reefs in a marine protected area in the southwest Atlantic and characterize and quantify the receptor communities. Furthermore we wanted to identify which of the four methods is most efficient and had the best cost–benefit ratio for the monitoring of communities during biological invasion.

2. Methods

2.1. Study site

This study was conducted in the Tamoios Ecological Station, Rio de Janeiro, Brazil, a federal Marine Protected Area (MPA) created to mitigate the installation of a nuclear power plant in the region. The MPA is composed of 29 islands, islets and reefs, situated in the Ilha Grande Bay, a tropical region (Brasil, 1990). The region was recently invaded by the corals *T. coccinea* and *T. tagusensis* (Silva et al., 2011). These invasive corals are expanding their range along the Brazilian coast (Ferreira, 2003; Mantelatto et al., 2011; Silva et al., 2011) and have also invaded the Gulf of Mexico (Fenner, 2001; Sammarco et al., 2004). In order to monitor the densities of *Tubastraea* spp. and the receptor communities (see Lages et al. (2011) for a description of typical communities in the region) eight sites were selected based on a previous visual census of the relative abundance of coral *Tubastraea* spp. (Silva et al., 2011): (1) high abundance — Queimada Pequena Island (23°05′28″S, 44°18′34″W) and Queimada Grande Island (23°05′05″S, 44°18′36″W), (2) medium abundance — Cobras Island (23°03′18″S, 44°24′17″W) and Imboassica Island (23°04′58″S, 44°19′45″W), (3) low abundance — Sabacu Island (23°00′26″S, 44°22′56″W) and Búzios Island (23°03′25″S, 44°24′19″W) and (4) no *Tubastraea* spp. — Araçatiba de Fora Island (23°00′43″S, 44°22′07″W) and Araçatiba de Dentro Island (23°00′36″S, 44°21′48″W) (Fig. 1).

2.2. Methods

Four methodologies, visual census (VC), 50 × 50 cm photo-quadrats (PHOT50), mosaic of 25 × 25 cm photo-quadrats (PHOTS25) and video-quadrats (VIDEO) were used to determine the percent cover of the most abundant taxa in the community and the densities of individuals/colonies of *Tubastraea* spp. Fifty meter transects were placed parallel to the shore on rocky reefs 2–6 m depth and 28 points along each transect were randomly selected and the sampled with a quadrat.

The VC method is already used to monitor the invasive corals in Ilha Grande (RJ) (Lages et al., 2011) consisting of 50 × 50 cm quadrats, subdivided into 25 10 × 10 cm areas; the dominant organism in each subdivision is recorded and the number of colonies of *T. tagusensis* and *T. coccinea* are also counted.

We used a Canon PowerShot G12 digital camera with a waterproof case (Canon WP-DC34) coupled to a sample quadrat for underwater filming and photography. PHOT50 was a 50 × 50 cm quadrat coupled 90 cm below the digital camera; the PHOTS25 method consisted of a 25 × 25 cm quadrat coupled 45 cm below the digital camera; for this method four contiguous quadrats were photographed to provide a 50 × 50 cm coverage. On the computer a mosaic of the images was created, producing a single image of 50 × 50 cm. The VIDEO method used a square of 50 × 50 cm subdivided into 10 × 10 cm. The squares were filmed (Full HD) with a distance of 100 cm from the substrate. The squares were frozen and converted into high resolution images which served for analysis. All images were obtained perpendicular to the substratum. The percent cover and density of *Tubastraea* spp. captured in the field were analyzed in the laboratory using a blind and randomized procedure by the same researcher diver (MCC) who collected the data in situ by the VC method. Coral Point Count with Excel extension 4.0 (Kohler and Gill, 2006) was used to help determine the dominant organism in each subdivision of 10 × 10 cm. The number of colonies of *T. tagusensis* and *T. coccinea* was also recorded for each image.

2.3. Data analysis

Densities (colonies $\cdot$ m^{-2}) of each species of *Tubastraea* spp. were estimated for each method and corresponding stations. Subsequently, the areas with *Tubastraea* spp. were grouped for each corresponding methodology and these were compared using the Kruskal–Wallis test with the null hypothesis that the densities of *Tubastraea* spp. of the different methods were equal. The community data of each method and corresponding station were transformed into percent cover and compared using the Bray–Curtis similarity index. In order to remove shadow and unidentifiable taxa the relative percentage cover found for each

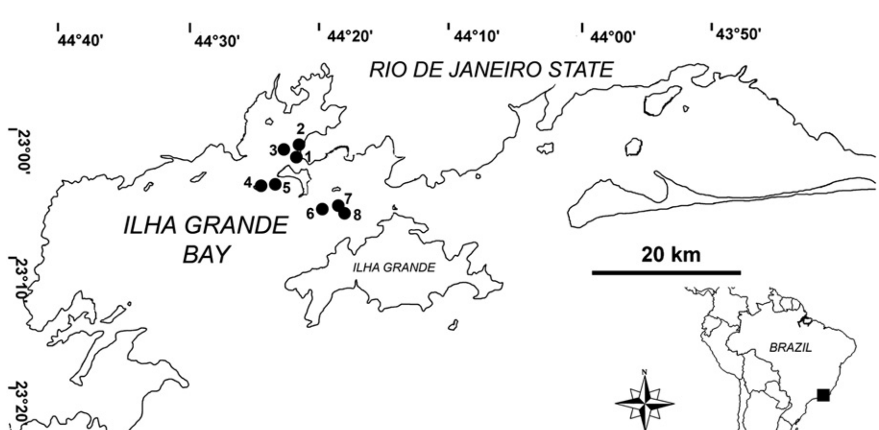

Fig. 1. Study sites at the Tamoios Ecological Station Marine Protected Area, Ilha Grande Bay, Brazil: (1) Araçatiba de Fora Island, (2) Araçatiba de Dentro Island, (3) Sabacu Island, (4) Búzios Island, (5) Cobras Island, (6) Imboassica Island, (7) Queimada Grande Island and (8) Queimada Pequena Island.

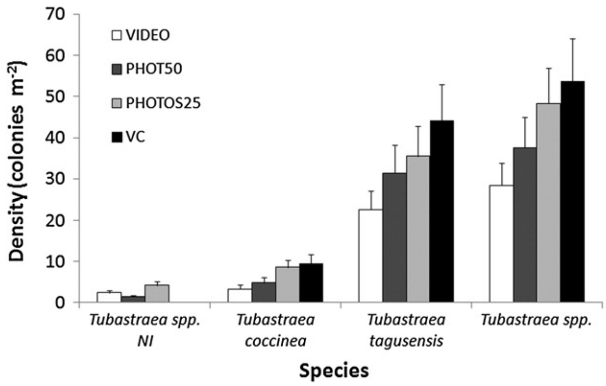

Fig. 2. Densities (means + SE) of colonies of *Tubastraea* spp. (not identifiable), *T. coccinea*, *T. tagusensis* and Total *Tubastraea* spp. quantified in the Tamoios Ecological Station Marine Protected Area, Ilha Grande Bay, Brazil by using four different methods: visual census (VC), single 50 × 50 cm photoquadrats (PHOT50), four 25 × 25 cm photoquadrats (PHOTS25), and video transect (VIDEO).

subcategory was proportionally distributed among the organisms sampled at each station before analysis. ANOSIM (similarity analysis) was used to test for differences in communities between different methods. SIMPER (similarity percents analysis) was used to identify the species that contributed most to the similarities between the groups. The richness (S), the Shannon–Wiener diversity index (H′), (log) and Pielou evenness (J′) were calculated for each station and corresponding method and the results were compared between the methodologies by ANOVA.

2.4. Time and cost

The total time for each dive conducted for each transect-and-method combination was recorded. In the laboratory, the time taken to treat, process and analyze the images generated was also recorded. The VC lab time recorded was the transfer of data from the clipboard to spreadsheet. The time in the field, laboratory and the sum for each method were compared by ANOVA and subsequently by a posteriori Tukey tests. The monetary cost of each method was calculated for the field and laboratory. To calculate the cost in the field the costs of renting a boat, SCUBA gear and the workforce were considered. The cost of the laboratory only considered the cost of the workforce. All costs were summed separately for each method in order to obtain a monetary value necessary to estimate the percent cover of the community and the density of corals *Tubastraea* spp. in all sites previously defined.

3. Results

3.1. Densities of Tubastraea spp.

In some images it was not possible to differentiate *T. coccinea* and *T. tagusensis*, thus the category *Tubastraea* spp. NI was created (*Tubastraea* spp. not identified to the species level). *Tubastraea* spp. only occurred in three stations. The densities of *T. coccinea*, *T. tagusensis* and the sum of the total density of *Tubastraea* spp. was highest in the VC, then PHOTS25, PHOT50 and VIDEO, whereas *Tubastraea* spp. NI was higher in PHOTS25 (Fig. 2). The result of the Kruskal–Wallis test indicated that the densities of *T. coccinea* ($H = 14.653$, $DF = 3$, $p < 0.005$) and *Tubastraea* spp. NI ($H = 32.330$, $DF = 3$ and $p < 0.001$) were similar between methods but not for *T. tagusensis* ($H = 3.031$, $DF = 3$, $p > 0.1$) and *Tubastraea* spp. ($H = 3.388$, $DF = 3$, $p > 0.1$).

3.2. Community

It was not possible to identify some organisms from photographs or captured video so 'shadow' and 'unknown' categories were created. The average total percent cover of unknown organisms was 0.79% and 0.66% on PHOT50 and PHOTS25, respectively, and the shadow subcategory was 1.37%, 0.52% and 0.23% to PHOT50, PHOTS25 and VIDEO, respectively. The total average percent cover for unknown organisms and shadow between the stations was higher in the methodology of PHOT50, followed by PHOTS25 and VIDEO. The overall composition (21 taxa) of the benthic communities at the Tamoios Ecological Station MPA is summarized in Table 1. Generally, turf forming algae had the

Table 1
Major space-occupying taxa/functional groups and their percentage cover (%) using each of the four different sampling methods to assess community structure on the rocky reef benthos at eight stations in the Tamoios Ecological Station Marine Protected Area, Brazil. Data are means (Standard Error) of the eight stations.

Taxon/functional group	Visual census	Single 50 × 50 cm photoquadrats	Four 25 × 25 cm photoquadrats	Video transect
Algae				
Multi-species turf forming	62.82 (7.13)	65.69 (8.07)	65.63 (7.48)	65.26 (7.39)
Crustose coralline algae	1.13 (0.67)	0.82 (0.51)	1.20 (0.74)	0.89 (0.53)
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	2.25 (1.06)	2.66 (1.38)	3.12 (1.88)	3.54 (1.97)
Caulerpa racemosa (Forsskål) J. Agardh	0.50 (0.30)	0.24 (0.16)	0.27 (0.20)	0.31 (0.20)
Sargassum spp.	1.79 (1.14)	0.75 (0.62)	0.76 (0.50)	0.93 (0.62)
Acanthophora spicifera (M. Vahl) Børgesen	0.34 (0.34)	0.16 (0.16)	0.17 (0.17)	0.09 (0.09)
Laurencia sp.	0.07 (0.05)	0 (0)	0 (0)	0 (0)
Cnidaria				
Palythoa caribaeorum (Duchassaing & Michelotti, 1860)	26.54 (7.98)	26.83 (8.21)	25.60 (7.63)	25.52 (7.54)
Mussismilia hispida (Verril, 1901)	0.18 (0.05)	0.15 (0.05)	0.09 (0.04)	0.16 (0.07)
Tubastraea tagusensis (Wells, 1982)	0.09 (0.05)	0.07 (0.06)	0.18 (0.12)	0.20 (0.18)
Zoanthus sociatus (Ellis & Solander, 1786)	1.23 (0.81)	0.45 (0.29)	0.41 (0.24)	0.50 (0.33)
Carijoa riisei (Duchassaing & Michelotti, 1846)	0.39 (0.37)	0.43 (0.41)	0.39 (0.39)	0.43(0.41)
Pennaria disticha (Goldfuss, 1820)	0.04 (0.02)	0.02 (0.02)	0 (0)	0.02 (0.02)
Ectoprocta				
Schizoporella spp.	0.02 (0.02)	0 (0)	0 (0)	0 (0)
Porifera				
Desmapsama anchorata (Carter, 1882)	1.45 (0.55)	1.00 (0.43)	1.43 (0.64)	1.31 (0.68)
Porifera sp. 1	0.38 (0.21)	0.19 (0.10)	0.27 (0.13)	0.32 (0.16)
Tedania ignis (Duchassaing & Michelotti, 1864)	0.14 (0.11)	0 (0)	0.06 (0.04)	0 (0)
Iotrochota birotulata (Higgin, 1877)	0.39 (0.15)	0.47 (0.23)	0.31 (0.13)	0.38 (0.18)
Haliclona caerulea (Hechtel, 1965)	0.13 (0.07)	0.02 (0.02)	0.04 (0.02)	0.05 (0.05)
Amphimedon viridis (Duchassaing & Michelotti, 1864)	0.13 (0.08)	0.08 (0.05)	0.07 (0.05)	0.09 (0.06)
Haliclona manglaris (Alcolado, 1984)	0.02 (0.02)	0 (0)	0 (0)	0 (0)

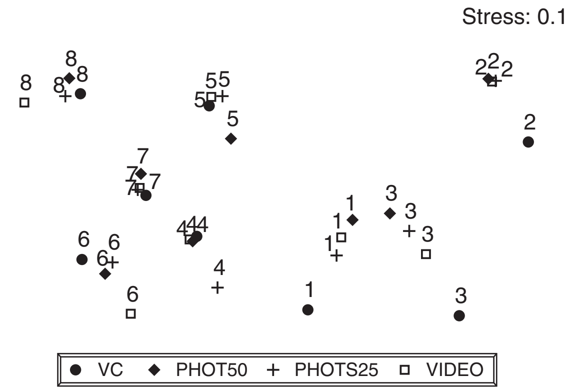

Fig. 3. Multi-dimensional scaling (MDS) analysis of community structure of rocky reefs of the Tamoios Ecological Station Marine Protected Area, Ilha Grande Bay, Brazil, comparing four different sampling methods and eight stations: visual census (VC), single 50 × 50 cm photoquadrats (PHOT50), four 25 × 25 cm photoquadrats (PHOTS25), and video transect (VIDEO); (1) Araçatiba de Fora, (2) Araçatiba de Dentro, (3) Sabacu, (4) Búzios, (5) Cobras, (6) Imboassica, (7) Queimada Grande and (8) Queimada Pequena.

higher percent cover followed by the zoanthid *Palythoa caribaeorum* (Duchassaing & Michelotti, 1860). Ectoprocta and Porifera represented together less than 3% of all samples. Only *T. tagusensis* was recorded, and the cover was highest in the VIDEO, then PHOTS25, VC and PHOT50. The VC method sampled a few more taxons (e.g. *Laurencia* sp., *Schizoporella* spp. and *Haliclona manglaris*, was recorded only in the VC) than the digital methods but the mean richness, diversity and evenness did not differ significantly between methods (ANOVA: $F = 1.914$, $p = 0.150$, $F = 0.055$, $p = 0.982$ and $F = 0.226$, $p = 0.877$, respectively). ANOSIM indicated significant differences in communities between sites (One-way ANOSIM: global $R = 0.997$, $p < 0.05$) but not between methods (One-way ANOSIM: global $R = -0.121$). When communities were compared together the test confirmed the difference between the stations and not between the methods (Two-way crossed ANOSIM: $R = 0.866$ and $R = -0.098$, respectively) (Fig. 3). SIMPER analysis confirmed the similarity between the methodologies over different sites, with similarities lower than 90% only in Araçatiba de Fora, Araçatiba de Dentro and Sabacu.

3.3. Time and cost

Fig. 4 shows the total time spent in each methodology to estimate the percent cover of the community and densities of *Tubastraea* spp. in all locations. During the fieldwork VC was the slowest and PHOT50 was the fastest method; however, in the laboratory VC was faster and PHOTS25 was slowest. Overall the VC method was fastest, followed by PHOT50, VIDEO and PHOTS25. The time in the field differed between methods (ANOVA: $F = 23.190$, $p < 0.001$) and a posteriori Tukey test shows that there was no difference between VC and PHOTS25 ($p = 0.873$) or between PHOT50 and VIDEO ($p = 0.443$). The lab time also differed between methods (ANOVA: $F = 139.865$, $p < 0.001$) and an a posteriori Tukey test shows that there was no significant difference between PHOTS25 and VIDEO ($p = 0.341$). When the total time for all methods was compared, the test indicated that they differed significantly (ANOVA: $F = 80.393$, $p < 0.001$) but there was no significant difference (or it was marginal) between VC and PHOT50 ($p = 0.06$). Table 2 shows values of time and cost to the methods in various work steps. The field and laboratory times reflected in the total cost, with VC being more expensive in field and PHOTS25 being more costly in the laboratory. The overall cost was higher in the PHOTS25 method, followed by VC, VIDEO and PHOT50.

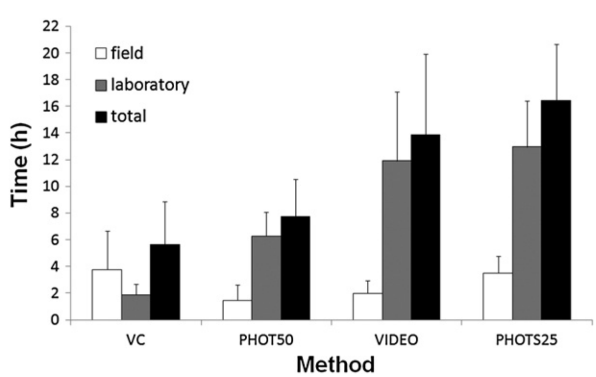

Fig. 4. Time (hours) spent in field, laboratory and total time necessary to estimate cover of the communities and densities of the invasive corals *Tubastraea* spp., comparing four different sampling methods: visual census (VC), single 50 × 50 cm photoquadrats (PHOT50), four 25 × 25 cm photoquadrats (PHOTS25), and video transect (VIDEO). Data are means (+SE) of all monitoring stations.

Table 2
Time taken (minutes) and costs US$ incurred using each of the four different sampling methods to assess community structure and populations of the invasive corals *Tubastraea* spp. in the rocky reef benthos of eight stations at the Tamoios Ecological Station Marine Protected Area, Brazil.

Activity	Visual census	Single 50 × 50 cm photoquadrats	Four 25 × 25 cm photoquadrats	Video transect
Time (min)				
Preparation of images	0	43	430	214
Image analysis	0	293	305	315
Data recording	113	41	42	36
Total time in the laboratory	113	377	777	565
Total time in the field	225	88	210	118
Total time	338	465	987	683
Costs ($)				
Field	234.34	102.45	225.33	120.47
Laboratory	17.84	21.98	83.60	48.84
Total cost	252.18	124.43	308.93	169.31

4. Discussion

We evaluated the efficiency and the cost–benefit ratio of four techniques for monitoring benthic communities undergoing invasion and the invasive coral populations themselves on the rocky reefs, comparing the visual census method (VC), with other methods that use photography and filming (PHOT50, PHOTS25 and VIDEO). Table 3 shows a summary of the main advantages and disadvantages of each method compared in this work.

Table 3
Advantages and disadvantages of selected criteria using each of the four different sampling methods to assess community structure and populations of the invasive corals *Tubastraea* spp. in the rocky reef benthos of eight stations at the Tamoios Ecological Station Marine Protected Area, Brazil.

Criteria	Visual census	Single 50 × 50 cm photoquadrats	Four 25 × 25 cm photoquadrats	Video transect
Time in the field	–	++	-	+
Time in the laboratory	++	+	–	-
Total time	++	+	–	-
Total costs	-	+	–	++
Densities values	++	-	+	–
Organism identification	++	–	-	+
Sensitivity	++	–	+	-
Permanent record	No	Yes	Yes	Yes

++ = very advantageous, + = advantageous, - = disadvantageous, – = very disadvantageous.

Density values of *T. coccinea*, *T. tagusensis* and *Tubastraea* spp. obtained by the VC method were higher than the other methods which successively underestimated invader densities; PHOTS25 > PHOT50 > VIDEO. Digital methods also failed, at some sites, to differentiate the two invasive corals, *T. coccinea* and *T. tagusensis*. Lower values of *Tubastraea* spp. density obtained by digital methods in this study can be explained by the presence of algae (especially *Asparagopsis taxiformis*), which may cover corals at the moment of image capture, thus hiding some individuals. Recruits represent success in the settlement process and early post-settlement survival, and the population on reefs depends in part on the settlement of new individuals, and so is an important parameter for temporal monitoring. However, as these are small (the average diameter of recruits of *T. coccinea* 24 h post-settlement is 1.26 mm and 12 d post settlement is 2.66 mm) (Glynn et al., 2008), it is understandably difficult to identify and quantify individuals by digital methods. Cover of coral recruits was also underestimated in digital methods when compared with visual methods in Egypt (Leujak and Ormond, 2007); likewise juvenile corals (<4 cm in diameter) were not detected by video methods in Florida reef banks (Lirman et al., 2007) and photographic images underestimated the density of corals in Australia's Great Barrier Reef (Burgess et al., 2010). *Tubastraea* spp. is often reported in areas with negative surfaces, crevices and holes (de Paula and Creed, 2005). The roughness of the environment coupled with the bi-dimensional nature of the images excludes or hampers scoring and/or identification of some organisms, as well as creating dark shadow areas in images (Foster et al., 1991; Preskitt et al., 2004).

Community values obtained by different methods were similar but digital methods were hampered by shadow and unknown categories, which was not the case for VC. Also, in situ VC method scored some organisms which were not scored ex situ by the digital methods despite the fact that the overall aim of the methods was geared towards scoring only the larger space occupying taxons. In the Pacific the use of video methods reduced the taxonomic resolution of monitoring (Carleton and Done, 1995). The use of digital methods tends to underestimate cover and the number of taxa and ignores rare, small and cryptic organisms (Foster et al., 1991; Leonard and Clark, 1993; Leujak and Ormond, 2007; Preskitt et al., 2004). The decrease in the distance of the digital camera from the substrate increased the resolution and image quality for analysis, producing results which approximate those produced by visual methods (Parravicini et al., 2009). The quality of the digital camera, the images captured and the characteristics of the environment are important factors that influence the identification of the organisms. The lower taxonomic resolution of digital methods can be solved with the use of maps or the identification of some organisms in situ, although this will increase the total time in the field.

Time is an important factor in monitoring activities, as it will influence the financial cost as well as the amount of information and data collected and analyzed. In the field the digital methods were faster than the visual method, enabling more data and locations to be sampled in a shorter period of time. However, digital methods consumed considerable time in the laboratory and needed specialized software to prepare and to analyze the images captured. These conclusions agree with most studies that have compared time costs (Brown et al., 2004; Lam et al., 2006; Leonard and Clark, 1993; Leujak and Ormond, 2007; Meese and Tomich, 1992; Pech et al., 2004). The time using VC in the field can be reduced by divers obtaining data simultaneously, and the time in the laboratory of digital methods can be reduced with other observers analyzing the images. Nevertheless, observers must be previously trained, increasing the precision and accuracy and reducing the error associated between them (Meese and Tomich, 1992).

Time values found in the different stages of the work reflected in the financial costs. The field costs were higher in VC and the laboratory costs in PHOTS25. By the end, the most costly method was PHOTS25 followed by the VC, VIDEO and PHOT50. In a comparative study of methodologies in Hawaii (USA), the video transect method proved cheaper, with the visual method being the more expensive (Brown et al., 2004).

The digital methods have the advantage of permanently recording the data, enabling return to the images for more information or to confirm identification of an organism. The visual method has the advantage of a better resolution for taxonomic identification, especially small, rare and inaccessible (e.g. crevices and holes) cases. In contrast the VC requires a trained observer in the field which can approach close enough to identify the organisms. Moreover, this method is independent of the need for highly transparent water. When a permanent record is of interest, where costs are high and time is a limiting factor in the field, an alternative would be to apply VC concurrently with the method of PHOT50 or VIDEO.

Monitoring programs should focus on the ability to detect changes regardless of the chosen method (Brown et al., 2004) and the VC method was efficient in responding to the issues and objectives and in assessing the impact of *Tubastraea* spp. on native communities of Ilha Grande (RJ) (Lages et al., 2011). The present study suggests that digital methods are not a reliable alternative for estimating the densities of these invasive corals, so the VC method is the most desirable in terms of cost-to-benefit ratio. It should be remembered, however, that the choice of methodology to be used in monitoring studies depends on the question(s) to be answered, the objective of the study, the time available for field and laboratory, cost and financial constraints, local conditions as well as the biological knowledge of those who carry out the work, the scales of the study being undertaken and the degree of precision required to answer the questions originally asked.

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