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A PROPOSED METHOD FOR CORAL COVER ASSESSMENT: A CASE STUDY IN ABROLHOS, BRAZIL

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ABSTRACT

One of the methods most often used to evaluate reef community coverage are line intercept transects (LIT). However, collection of cover data using LIT has drawbacks. The optimization of data collecting permits an increase in number of replicates, allowing a more adequate quantification of the community and comparison among different sites/times. It was assumed that a LIT is composed of several adjacent data points and the number of data points necessary to 'describe' a whole line was investigated. Several LIT were deployed in the Abrolhos Archipelago, Brazil. The variation of the stand error for percent cover in relation to a varying number of points drawn from each LIT was evaluated. A relatively stable condition was reached with 500 (out of 2000) points. This procedure (point intercept transects - PIT) needed much less effort for two reasons: (1) time per transect (up to 62.5% reduction); and (2) for each point the diver can just mark species/categories in a ticklist, so less underwater skills are needed. We also demonstrate and discuss the necessity for line replicates. Species with less than 2% cover were detected in LIT and PIT.

The Abrolhos reefs, situated off the eastern coast of Brazil, are the most developed reef assemblages of the South Atlantic Ocean (Leão and Ginsburg, 1997). These reefs present some features, such as geomorphology, low coral diversity, high degree of coral endemism, and depositional setting (Laborel, 1970; Leão, 1996). The reefs are composed of isolated or fused reef columns, named *chapeirões* (Leão et al., 1997). In spite of their ecological importance, few quantitative benthic surveys have been conducted in the reefs of the area (but see Pitombo et al., 1988; Coutinho et al., 1993; Villaça and Pitombo, 1997; Figueiredo, 1997).

There are several constraints to sampling benthic reef communities. These include observer effort and skills needed to collect and record data underwater, distance from mainland, and problems related to weather conditions (boating and diving). Also, travel, boating, and equipment costs make it difficult to carry out large-scale sampling. This is compounded by logistic constraints or in areas of difficult access, as is the case for many Brazilian reefs. Because funding is limited, and cost is related to time and effort in the field, sampling replication is often restricted by these features. This condition may lead to samples that are not representative of the area under study. In Brazilian reefs the need for adequate sampling methodology is greater still because of the low coral coverage and species diversity, the small size of most coral species, and high water turbidity. This excludes the use of some of the methods developed in other locations such as video and photographic transects. These features can also demand a larger number of replicates to adequately describe an area, as low coverage or small species are often misrepresented with a small number of replicates. Sampling design, however, must balance costs, effort, and adequacy. An adequate sampling design includes an appropriate choice of sample size (including replication). If sample size is too small, the power of statistical tests may be insufficient to test hypotheses involving small differences between means (Bros and

Cowell, 1987). On the other hand, with too large a sample size, the power of the test will be adequate, but effort may be wasted in collecting and processing samples.

The most commonly used quantitative methods for assessing coral communities are transects, quadrats, and variations of both (Ohlhorst et al., 1988; Malatesta et al., 1992; Sullivan and Chiappone, 1992; Mumby et al., 1995; Chiappone et al., 1996). Line transect techniques have previously been recommended because of their facility in working underwater (Loya, 1978), the greater area sampled per unit of time, and because they may be less subject to bias caused by the heterogeneous distribution of reef benthos (Liddell and Ohlhorst, 1987). Although widely used, line intercept transects, as described by Loya (1972), present problems related to the great effort required in field work and skills required to take notes underwater. Also, Dodge et al. (1982) suggested that for rarer and/or smaller Bermudan specimens, more samples are required for point transects and other plotless methods in comparison to a belt quadrat technique. A further methodological concern is the problem of parallax (Porter, 1972). However, this problem may be even more pronounced with quadrat methods, due to the flat, inflexible nature of most sampling devices. Positioning (i.e., equilibrating) such a device on irregular topographies may also be problematic. These constraints make this sampling device not ideal to evaluate coverage of *Mussismilia braziliensis*—one of the main building species of the Abrolhos region—as it presents large, high colonies, projected well above the surrounding substrate. Moreover, Ohlhorst et al. (1988) found a tendency for quadrat methods to underestimate species coverage. This is also a problem regarding Brazilian reefs, where many coral species are small and present low coverage.

Elsewhere, video and photograph techniques have been used (Benedetti-Cecchi et al., 1996). However, these methods are usually inadequate for use in Brazil, because Brazilian reefs typically have low coral cover, small coral colony sizes, and limited water clarity. For example, an attempt to use video (Hi 8) at close range (image width 25 cm, distance camera to objects 40 cm) in Abrolhos reefs failed to detect or to identify most small coral colonies when results were compared to visual data (C. B. Castro, unpubl. data). Carleton and Done (1995) have recognized that video techniques might have limitations depending of circumstances such as those found in Brazilian reefs, including water clarity and accessibility of the reef (familiarity of researchers with its topography).

Clearly, there is still a demand for the optimization of sampling designs that accurately describe coral (and other organisms) cover, yet minimizing effort, time, and costs of field activities. The aim of our study was to develop faster and easier, yet accurate, methods of estimating benthic cover in conditions such as those at the Abrolhos reefs, Brazil, by optimizing field sampling procedures for line intercept transects. This could greatly benefit assessment and monitoring routines in reef studies.

Materials and Methods

The Abrolhos Archipelago lies on an enlargement of the southern part of the Eastern Brazilian continental shelf (Leão, 1982; Leão and Ginsburg, 1997). The reef complex is located from 10 to more than 65 km off the coast, down to the isobath lines of 25–30 m. The Abrolhos Archipelago (17°58′S and 038°42′W) has five islands (Fig. 1) and lies among reefs, some 55 km offshore. The channels between islands are usually less than 10 m deep. The islands are surrounded by shallow 'embryonic' fringing reefs (Pitombo et

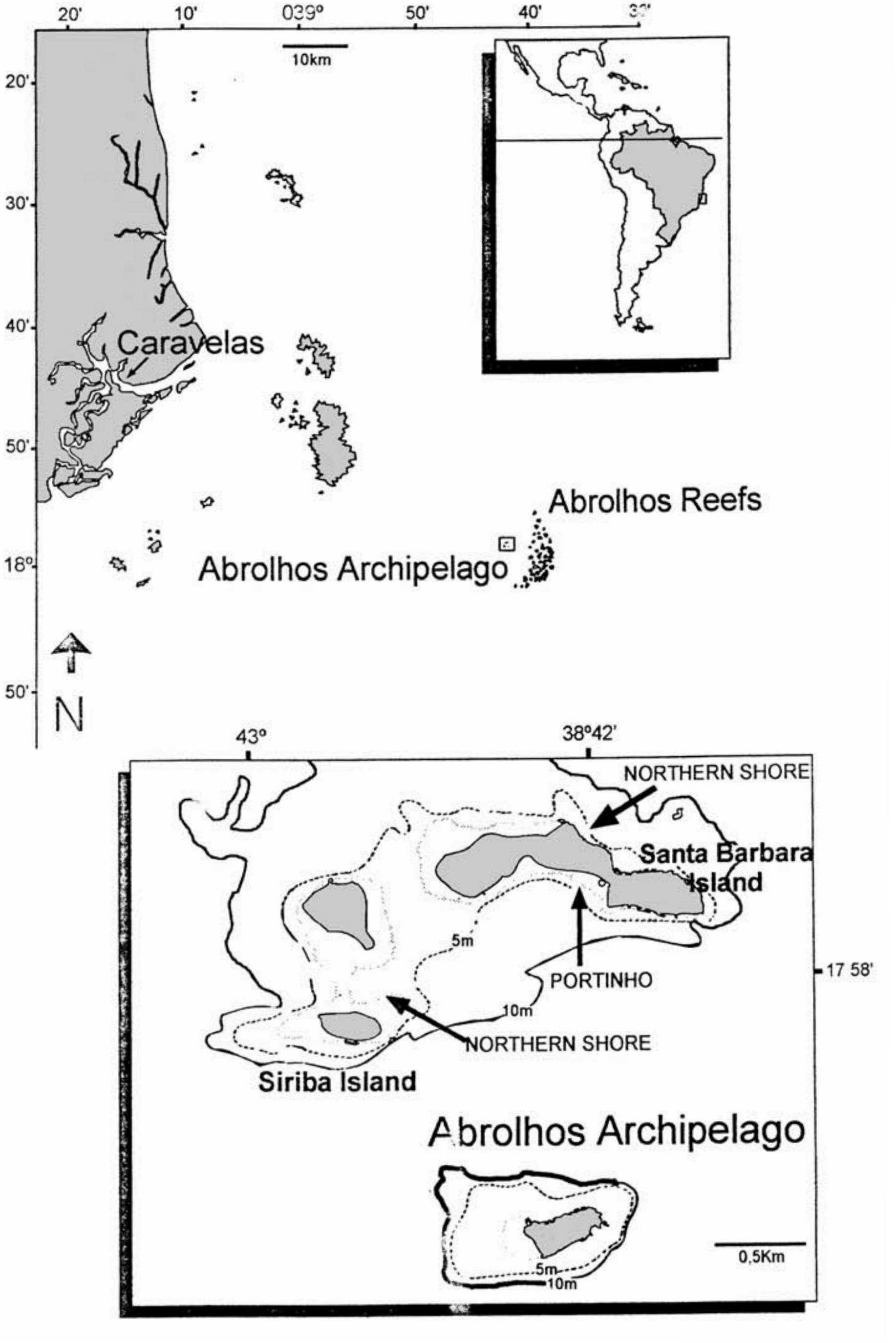

Figure 1. Map of the southern coast of Bahia State, showing the study sites at the Abrolhos Archipelago (modified from the Brazilian Navy Nautical Chart DHN n. 1311).

Table 1. Example of conversion table used to generate replicate line intercept transects with a possibility of 35% variation from the original. The interval between the lower and higher limit is (frequency × accepted variation)/100. Any original value (in a given centimeter) would be replaced by the value here indicated if the corresponding randomly generated number fell within the range between the lower and higher limit.

New Class	Frequency	Lower Limit	Higher Limit
Agaricia agaricites	0.012	>0.650	0.654
coralline algae	0.177	>0.654	0.716
Favia gravida	0.007	>0.716	0.718
Mussismilia braziliensis	0.245	>0.718	0.804
Porites branneri	0.004	>0.804	0.806
Siderastrea stellata	0.022	>0.806	0.814
Others	0.530	>0.814	1.000

al., 1988), with depths that rarely exceed 7.0 m. Three stations were sampled at the north and south faces of Santa Bárbara Island and two stations were sampled at the north face of Siriba Island. Stations depths were between 1.9 and 4.0 m.

Initially, a single 20 m long line intercept transect (LIT) was sampled at each station, as described by Loya (1972). Each 20 m long LIT was treated as being composed of 2000 1-cm units ('points'). Each LIT was subsampled according to the protocol indicated:

(1) Three coral species were chosen for the analysis of minimum number of points per transect: *Favia gravida*, *M. braziliensis,* and *Siderastrea stellata*. These species represented rather different coverage frequencies in the LIT.

(2) For each station, 20 simulations of replicate LIT were mathematically generated. It was assumed that different LIT from the same community would vary up to 35% (this is the highest standard deviation of coral cover—*S. stellata*—found in quadrats sampled in the same area by Coutinho et al., 1993). The frequency of each coverage class (algae, coral by species, other organisms) was determined for each locality, based on the 20 m LIT. A random number between zero and one was assigned to each centimeter of the line. When this number was higher than 0.65, the corresponding point was assigned to the class indicated in a previously established table (see Table 1). For each line generated, the original line was randomly reordered with the use of the random numbers of each centimeter. The whole process was repeated until 20 lines were generated from the original line.

(3) Sets of randomly selected points were sampled in all replicates of each station. These sets had a varying number of points, from 100 to 2000 points (the whole transect), in 100-point steps.

(4) The standard error of the percent coverage of *F. gravida*, *M. braziliensis*, and *S. stellata* of each set was plotted against the number of points of the set. This was repeated for each station.

(5) The set size with the lowest number of points where the standard error had already reached the flattened area of the graph lines was chosen as adequate to represent the whole original line (Bros and Cowell, 1987).

(6) Estimates of mean precision for the selected number of points (step 5) were calculated applying the formula standard error/mean (Andrew and Mapstone, 1987).

An estimate of the number of transect lines (i.e., replicates) necessary to represent the variation of coral cover at one station was carried out following a similar procedure. We drew points (according to the results of the previous analysis) from an increasing number of transect lines from 50 simulations of replicate LIT (see step 2 above). The standard error of the estimated coverage for the three species selected for the procedure above was plotted against the number of replicates tested.

Five new transects were sampled in the field, with the number of randomly chosen points indicated by the previous analyses. These parallel transects were surveyed with a 20 m weighted rope, the random points of which had been previously marked with colored lines stitched and tied to the rope. This procedure will be named herein point intercept transect (PIT).

A field test of the PIT method was performed with a comparison of coral communities from different areas of the Archipelago. Stations were compared by doing a multivariate analysis of similarities (ANOSIM), using the Bray-Curtis similarity coefficient (Clarke and Warwick, 1994), with the aid of a computer software (PRIMER, Plymouth Marine Laboratory, UK).

Results and Discussion

It was graphically ascertained that the minimum number of points necessary to describe a 20 m long transect was around 500, even for the less frequent species tested—*Favia gravida* (Fig. 2). Larger sample sizes would give relatively small decreases in standard error, which became increasingly smaller as sample sizes approached the whole line—2000 points. Thus, increasing sample size from 500 points to 600, 700, and so on would lead to a relatively little advantage, compared with a bigger effort and time needed to collect these extra data. The estimates calculated to verify the adequacy of such sample size (estimate of mean precision) fell within a range of 0.4–3.3%, which was considered very good.

The use of PIT equivalent methods have been suggested by previous authors (Lucas and Seber, 1977; Liddell and Ohlhorst, 1987), some even recommending their use in most reef censuses (Ohlhorst et al., 1988). Ohlhorst et al. (1988) used simulated reef communities of known ‘coral coverages’ to evaluate PIT, with fixed 20 cm intervals between points. These authors found a tendency for their PIT to overestimate coverage of those ‘species’ not correctly estimated within a ±10% error from the ‘real’ coverage. Their sampling would be equivalent to a 100-point sample in our lines. The results on our graphs (Fig. 2) suggest such a number of points is insufficient to represent an equivalent LIT. Although both strategies would be valid, our proposal was to collect PIT data that would correctly estimate the result of an equivalent LIT and not significantly increase the number of needed replicates to estimate the coverage of the whole area. In Ohlhorst et al.’s (1988) strategy, the effort to collect a single PIT would be minimized, but the number of replicates would have to be increased. The same should apply to Reef Check’s suggested method (http://www.ust.hk/~webrc/ReefCheck/methods.html) to describe substrate types on the reef (corals generically included as ‘hard coral’). This Program uses ‘point sampling’ on 20 m lines, with 0.5 m intervals (equivalent to 40 points sample).

The previous efforts with PIT used fixed intervals between points (Lucas and Seber, 1977; Ohlhorst et al., 1988; Reef Check). Although more feasible in terms of field efforts, it could cause problems with particular statistics (see below) when studied organisms are regularly spaced (Zar, 1974; Gauch, 1982), as has been shown for some corals (Stimson, 1974; Endean et al., 1997). Ideally, distances should be randomized between points, and the order should be randomized between each sample. By doing so, each point along the lines would have an equal and independent chance of being selected. This

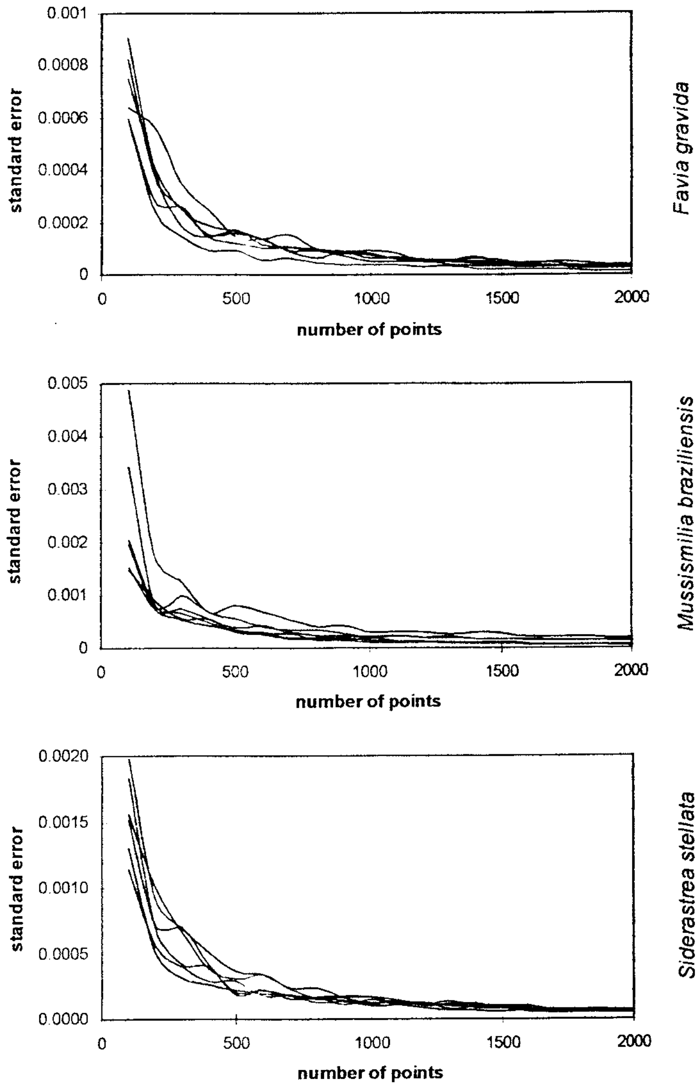

Figure 2. Standard error of estimates of coral cover for simulated PIT with different number of sampled points (centimeters) in stations in the Abrolhos Archipelago, Brazil.

would gather data on the most rigorous way for sound statistical analysis (Zar, 1974; Gauch, 1982).

The relevance of a careful evaluation of the trade-offs between precision and time, effort and costs of field work have been discussed before (see Gauch, 1982; Bros and Cowell, 1987). In our case, field experience showed that one diver would need some 80 min to sample a 20 m long LIT. A similar line was sampled in around 30 min with a PIT. This represents more than 60% reduction in time (effort) needed to sample a line. The less time spent at each sample allows an increase in the number of treatments or hypotheses tested (as indicated in Bros and Cowell, 1987). Moreover, the saved effort could be applied to increasing the number of replicates.

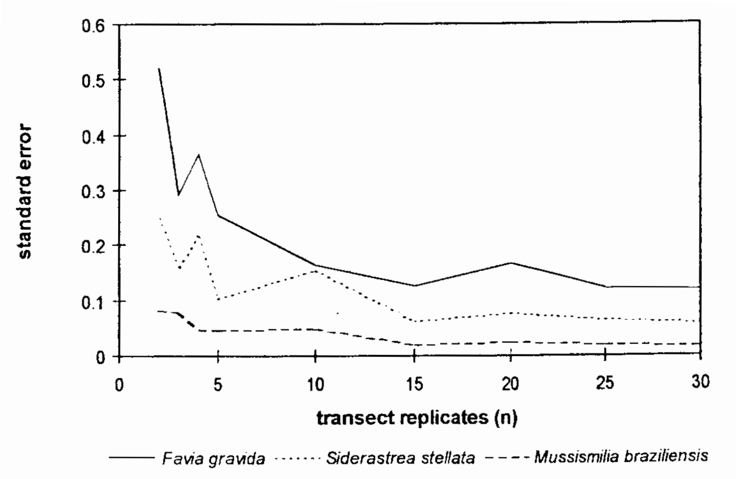

Figure 3. Standard error of estimates of coral cover for simulated PIT with different number of replicates in the Abrolhos Archipelago, Brazil.

The analysis of number of replicates needed to represent a station leaded to different interpretations depending on the abundance of the species evaluated (Fig. 3). *M. braziliensis* (15.2–24.6% coverage in our simulations) and *S. stellata* (0.4–4.4%) could be well represented with few replicates. On the other hand, a larger number of replicates would be needed to estimate *F. gravida*'s coverage (0–1.2%). We suggest that the number of replicates should be evaluated for each area, following a preliminary survey and taking in to account the balance between cost (effort) and benefit. For the present case we used five replicates (see Fig. 3).

It should be noted, however, that there are some disadvantages of the PIT method when compared to LIT. For example, the mean length of colonies under the transects and the number of colonies in LIT has been used to compare different samples (Loya, 1972; Pitombo et al., 1988). For colony related investigations, such as bleaching and disease studies, LIT may be the preferred choice. Even though it is obviously not possible to collect colony data with PIT, the PIT method allows replication with reduced sampling effort. Therefore, depending on the needs of the specific research, one may choose the more suitable method.

The PIT method detected some differences among the locations sampled (Table 2). The details of the differences among sites were explained elsewhere using univariate data (Segal-Ramos, 1998), and will not be discussed here. The important point is that data collected with PIT may be used successfully to detect differences among stations. Therefore, we conclude that PIT is an adequate methodology for comparing benthic communities in coral reef communities of low coral cover.

Sampling size, scale, and procedures, most of all in benthic communities, have been a persistent constraint to quantitative studies (Dodge et al., 1982; Chávez, 1993; Benedetti-Cecchi et al., 1996). Moreover, the need for quick and adequate techniques for reef censuses have being extensively discussed for monitoring and assessment (Ohlhorst et al., 1988; Lang et al., 1994; Mumby et al., 1995; Risk and Risk, 1997). Monitoring and management of coral reefs are dependent upon fast and accurate methods, because of limited time and funding for field work. We hope this optimization of the line transect

Table 2. Values of significance levels from the similarity test (ANOSIM, using Bray-Curtis index) in comparisons between stations. Global statistics (R) = 0.642; global significance level = 0.0%; * = significant differences.

Stations	Significance level
T3 Northern shore, T1 Portinho	0.8%*
T3 Northern shore, T2 Portinho	0.8%*
T3 Northern shore, T3 Portinho	0.8%*
T3 Northern shore, T1 Siriba	0.8%*
T3 Northern shore, T2 Siriba	0.8%*
T1 Portinho, T2 Portinho	9.5%
T1 Portinho, T3 Portinho	35.7%
T2 Portinho, T3 Portinho	30.2%
T1 Portinho, T1 Siriba	0.8%
T1 Portinho, T2 Siriba	0.8%*
T2 Portinho, T1 Siriba	1.6%
T2 Portinho, T2 Siriba	0.8%*
T3 Portinho, T1 Siriba	0.8%
T3 Portinho, T2 Siriba	0.8%
T1 Siriba, T2 Siriba	1.6%

method can contribute, through a reduction in time spent in the field and thus funds necessary for future monitoring and assessment programs of reef areas.

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