CORAL BLEACHING, HURRICANE DAMAGE, AND BENTHIC COVER ON CORAL REEFS IN ST. JOHN, US VIRGIN ISLANDS: A COMPARISON OF SURVEYS WITH THE CHAIN TRANSECT METHOD AND VIDEOGRAPHY

Caroline S. Rogers, US Geological Survey, Caribbean Field Station, P.O. Box 710, St. John, USVI 00830 USA caroline_rogers@usgs.gov

Jeff Miller, US Geological Survey, Caribbean Field Station, P.O. Box 710, St. John, US Virgin Islands 00830 USA j_miller@usgs.gov

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ABSTRACT

The linear chain transect method and videography were used to quantify the percent cover by corals, macroalgae, gorgonians, other living organisms, and substrate along permanent transects on two fringing reefs off St. John. Both methods were used simultaneously on Lameshur reef in November 1998, and on Newfound reef in March and October 1998. Hurricane Georges passed over St. John in September 1998, and a severe coral bleaching episode began the same month. Both methods gave remarkably similar values for coral cover, while the video method gave consistently higher values for gorgonians and macroalgae. The most dramatic difference was in the quantification of bleaching. At Newfound, the chain method indicated 13.4% (SD = 14.1) of the coral tissues were bleached and the video method, 43.4% (SD = 13.0). Corresponding values at Lameshur were 18.1% (SD = 22.3) and 46.5% (SD = 13.3). Although hurricane damage was conspicuous at Newfound reef, neither method showed significant changes in coral cover or other categories as a result of the storm.

INTRODUCTION

In 1998, compelling evidence of reef degradation from the most severe bleaching episode on record, coral disease, hurricanes, and other stresses heightened the alarm over the condition of reefs worldwide and increased awareness of the need for both assessment of present conditions and monitoring for trends in coral cover, algal cover, and status of other reef organisms. Furthermore, the President's Executive Order 13089 of June 1998 on Coral Reef Protection calls for "a comprehensive program to map and monitor U.S. coral reefs" and for "research aimed at identifying the major causes and consequences of degradation of coral reef ecosystems". Monitoring requires significant funding, experience, commitment, and time, and the choice of the appropriate methods to use requires considerable thought. The question is not "What is the best monitoring method to use on coral reefs?", but, "What method or combination of methods will answer our questions?" Sometimes, the objectives of a monitoring program are very specific—e.g., to determine if a dredging project is increasing sedimentation on a nearby reef. In other cases, the objectives might be more general, e.g., to track changes on a remote and relatively undisturbed reef for comparison with reefs that are subject to more stresses.

Our U.S. Geological Survey research team (formerly with the National Park Service) has been conducting monitoring of reefs around St. John in the US Virgin Islands since 1989. Our objective has been to quantify "natural" variation in the abundance of corals and other organisms on reefs protected within Virgin Islands National Park for comparison with reefs more exposed to destructive human activities. Since the beginning of our program, our study reefs have been affected by hurricanes, coral diseases, and bleaching; algal cover on one of the reefs indicates possible nutrient input, or, more likely, effects of overfishing (Rogers et al., 1997). Much of our work has been done with the chain transect method. We were interested in comparing this method to the video method described by Aronson et al. 1994 and others. In this paper, we compare the results from these two methods used in 1998 on two reefs, and evaluate their effectiveness in measuring benthic cover, bleaching and hurricane damage.

MATERIAL AND METHODS

We selected study sites on two reefs off St. John, U.S. Virgin Islands. The first is in Newfound Bay off the northeast coast of the island, and the second is in Lameshur Bay off the island's southern coast (Fig. 1). The watershed in Newfound is undeveloped, while the Lameshur watershed has a small field station, unpaved road, and other minor construction. Both reefs are fringing reefs dominated by *Montastraea annularis* and slope to sand plains at depths of about 13.7 to 15 m. Only Newfound has a well-defined reef crest and backreef zone. Forty hard coral species (scleractinians and *Millepora* spp.) have been recorded at Newfound, and 33 at Lameshur. The Lameshur site suffered significant damage from Hurricane Hugo in 1989, while the site at Newfound escaped the storm's effects. In September 1998, Newfound reef suffered damage from Hurricane Georges. Hurricane Georges was classified as a Category 2 storm, with maximum sustained winds of about 176 km/hr and a minimum central pressure of 972 millibars on

September 21, 1998, when it passed about 48 km to the south of St. John. Corals at both sites showed substantial bleaching beginning in late summer and worsening after the storm. Water temperature was measured with a Ryan Industries thermistor at each reef. At Newfound, water temperature varied from 27.3 to 30.1° C over the period from April to November 1998, with the highest temperature recorded on Sept. 12 and the lowest on April 22 (depth = 7.5 m). At Lameshur water temperature was recorded at a depth of 11 m over the period from October 1997 through November 1998 and ranged from 26.0° (on March 11) to 30.1° (on Sept. 8).

The two monitoring methods were used simultaneously at Newfound reef in both March and October of 1998 and at Lameshur reef in November 1998 along permanent transects marked at each end with a survey stake. At Newfound, a 100 m long transect with survey stakes installed every 10 m was established at a depth of 7.6 m. At Lameshur, five 20-m transects were installed at depths of 10.7 to 12.7m. At each site, transects of 10 m were examined with each method after stretching a measuring tape between two survey stakes. The chain transect method involves conforming a light-weight chain to the reef along the measuring tape, and recording the number of chain links of each sessile organism or substrate type (see Rogers et al., 1994 for details). Corals that were very pale or white were categorized as bleached. Data were compiled in QuattroPro spreadsheets and analyzed.

The video method we used, based on those described by Aronson et. al., 1994, Carleton and Done, 1995, and Wheaton et al., 1996, involves videotaping with the camera perpendicular to the substratum (approximately 40 cm above it), beginning at the survey stake and progressing slowly (approximately five minutes per 10 m) along the transect line. We used a Sony DVX-1000 digital video camera, with a wide angle lens in a watertight housing. A "wand" attached to the camera housing was used to maintain a distance of 40 cm above the substrate. A "red filter" was used as necessary (depth >6m), and no artificial lights were used. The camera settings (focus, exposure, etc.) were generally on "automatic". The date, site, and transect number were written on a magnetic slate underwater and videotaped at the beginning of each transect. Analysis of the video tape involved the use of commercially available Image Pro and Microsoft Excel software, and "Point Count" (developed by O. Meier, J. Leard, and P. Dustan at the University of Charleston). Using Point Count, unique, non-overlapping frames are "captured" and ten random dots are applied onto each frame. The sessile organisms and substratum components are identified and recorded in an Excel spreadsheet for analysis. Each transect yields approximately 24-28 unique frames, for a total of 240-280 data points. The point count data were analyzed to determine the percent cover of the same categories as the chain transects: hard corals, soft corals, sponges, zoanthids, and three algal components: macroalgae ("maca"), dead coral with "turf" algae ("dca"), and crustose coralline algae. As with the chain method, corals that were very pale or white were considered bleached. Identifications of hard corals, and macroalgae were made to the lowest taxonomic level possible. Substrate such as sand, pavement, and rubble were often difficult to differentiate. When random dots were located over the transect tape or "wand" they were placed in the categories "tape" or "wand" as appropriate. In addition, dots sometimes fell on areas of the image that were in shadow or in a hole in the reef structure, or on areas which could not be identified because of insufficient resolution of the video image (poor lighting or out of focus). These points were categorized as "shadow" or "unknown". Points in the "wand", "shadow", and "tape" categories were omitted from the analysis. The number of points that fell into the "unknown" category always represented less than 4% of the total number of points analyzed. Data are expressed in terms of percent cover for each method.

To examine possible differences in the results from the two methods, we analyzed data from Newfound in March and October 1998, and from Lameshur in November 1998. To assess damage from Hurricane Georges (September 1998) to Newfound reef, data from March 1998 before the storm were compared with results in October 1998. We have also compared the results from both of these methods during the severe fall bleaching episode.

Finally, diversity (H') was calculated for each reef based on results from each method for all transects combined and each sampling period. Diversity was calculated as $H' = -\sum p_i \ln p_i$ where $p_i = n_i/N$ (Shannon and Weaver, 1949). For the chain transect method, N = the total number of centimeters (individuals) of all species under the line, and n_i = the number of centimeters of species "i". For the video method, N = the total number of points of all coral species counted and n_i = the number of points of species "i". Rugosity (spatial index) was also calculated for each sampling period as the ratio of the number of centimeters of chain to the number of centimeters of measuring tape (i.e., the length of the transect).

Because we were using two different methods to sample the same reef transects (rather than comparing two samples from the same population measured with a single method), it is not appropriate to use statistical analyses. Therefore, we are presenting our results with means and standard deviations.

RESULTS

Comparison of benthic cover with chain and video transect methods

Newfound reef---

Comparison of results from the two methods used in March and October at Newfound (Fig. 2) showed that mean values for coral cover and cover by *Montastraea annularis* were very similar, while cover by macroalgae and gorgonians were higher with the video technique for both sampling periods. Mean cover by sponges was higher with the chain method for both periods. Zoanthids and other living organisms ("other") were in such low abundance that comparisons between methods are not meaningful. Mean cover by algal turf growing on dead coral ("dca"), generally the largest category, did not differ consistently between the two methods. Details of the results by individual transect show that for some categories (macroalgae, gorgonians) results with the video were consistently higher, while for other components, chain transects gave higher values, or no trends were evident (Tables 1,2).

Lameshur reef--

At Lameshur reef in November, mean coral cover and cover by *Montastraea annularis* were also very similar in both methods, although cover by macroalgae and gorgonians were higher with the video method (Fig. 3). Mean cover by sponges was higher with the chain method, although standard deviations overlapped. Unlike at Newfound reef, macroalgae covered more of the reef than "dca". Mean cover by dca was higher with the chain method here, although standard deviations overlapped. Comparison of results for each individual transect showed macroalgae were consistently higher with video while gorgonians were higher in all but one transect (Table 3).

The chain method gave higher results for diversity (H') and the number of coral species observed within transects at each reef than the video method (Table 4). Lameshur reef had a lower spatial index than Newfound (Table 4).

Detection of coral bleaching at Lameshur and Newfound reefs with the chain and video transect methods

For both Newfound and Lameshur reefs, the video method gave values for bleached coral and for bleached *Montastraea annularis*, which were substantially higher than the chain method. At Newfound, mean percent cover by bleached coral was 43.4 (SD = 13.0) [video] and 13.4 (SD = 14.1) [chain], while the corresponding values for *M. annularis* were 51.7 (SD = 20.4) and 17.7 (SD = 17.5), respectively (Fig. 4). At Lameshur, cover by bleached coral was 46.5% (SD = 13.3) [video] and 18.1% (SD = 22.3) [chain], while cover by bleached *M. annularis* was 62.7 % (SD = 9) [video] and 31.7% (SD = 37.0) (Fig. 5).

Detection of hurricane damage with chain and video methods at Newfound reef

A comparison of results from both methods at Newfound in March with those from October, following Hurricane Georges, indicated no changes in coral cover, cover by *Montastraea annularis*, or any other category (except macroalgae) as a result of the storm (Fig. 2, Tables 1,2).

DISCUSSION

A comparison of the results from the chain method and videography in terms of quantification of benthic cover, physical damage from a storm, and coral bleaching revealed some surprising similarities and some marked differences. The two methods gave remarkably similar values for coral cover at Newfound and Lameshur reefs, given that the methods do not sample exactly the same portion of the reef; the video camera photographs a “band” about 45 cm wide giving a planar view while the chain transect method provides a 3-dimensional aspect and samples only those surfaces directly under a chain about 1 cm wide positioned along the contours of the substrate. The video method consistently gives higher values for gorgonians, which is expected because only gorgonian holdfasts are included in the chain method. The video method always gives higher values for macroalgae as well, which is harder to explain. It is often impossible to differentiate between macroalgae and algal turf in the videotapes. The distinction between these two categories is an important one ecologically as increases in macroalgae often signal nutrient input or reductions in the amount of herbivory (for example, as result of overfishing). Because the chain method includes crevices and holes in the reef, not visible in planar view, and because algal turf is often found growing on these surfaces, we had expected higher values for "dca" with the chain method. In fact, the results for this category were quite similar at both reefs.

The most dramatic difference in the two methods was the quantification of bleached coral, with much higher values with the video technique. The higher values for bleached coral with videography probably reflect the more severe bleaching that was observed on the upper surfaces (rather than the sides) of the corals, most of which were *Montastraea annularis*. While "completely" bleached (white) corals are obvious with either method, it can be difficult to decide if pale or mottled coral colonies are bleached, especially with the video method where image resolution can affect the apparent coloration of the colonies.

Neither of the two quantitative methods used indicated changes from Hurricane Georges at Newfound reef, although dives within one week of the storm showed smashed and overturned corals, and detached sponges and sea fans. Qualitative observations and photographs of damage taken as soon as possible following storms will provide valuable information that may not be reflected using quantitative methods. Physical damage will not necessarily result in decreases in coral cover within permanent transects or quadrats; for example, detached coral colonies or fragments can be hurled into permanent transects or quadrats increasing (at least temporarily) the amount of living coral. Storm seas can detach macroalgae which were obscuring living corals (a beneficial effect!). Sea fans, broken off at their holdfasts, can end up lying horizontally on the bottom, covering other organisms and increasing the cover by gorgonians. The "hit or miss" nature of storms also can result in either an overestimate or underestimate of physical damage based on surveys of a small number of transects in one geographic area of a reef. In contrast to the lack of evidence of storm damage in transects at Newfound reef after Hurricane Georges, significant decreases in coral cover and cover by *Montastraea annularis* were quantified using the chain transect method along the same transects surveyed in this study at Lameshur reef following Hurricane Hugo in 1989 (Rogers et al., 1997).

The video method gave lower values for diversity than the chain transect method, reflecting the lower number of species observed in planar view. With the chain transect method, species growing on undersurfaces and not visible in planar view will be detected.

A major advantage of the video method is that it provides a permanent visual record of a reef. There is also the opportunity to go back to the tape for more information. Unlike the chain transect method, a diver using the video technique does not need expertise in field identification of reef organisms. It is also extremely useful to show videotapes of reefs that have been damaged to managers of national parks and other marine protected areas or judges presiding over boat damage cases. Video footage taken perpendicularly over reef substrate should always be accompanied by tapes showing the general appearance of the reef to give a more representative view of the structure of the reef and its condition. The video method requires much less time in the field than the chain transect method (less than 10 minutes per 10 m transect vs. up to 2 hours of diving). However, it requires far more time in the laboratory to analyze the images than to enter chain transect data into a spreadsheet. Consistent identification of substrate from video images is a concern, but quality control is facilitated because the images can be archived and viewed again to ensure accurate and consistent identifications.

A major strength of the chain transect method is that identifications of organisms are made on site rather than from video images. Also, unless boats or anchors have crushed them, most reefs are not flat (planar), and the chain transect method records the 3-dimensional surfaces of the reef bottom.

Neither the chain transect or video method is strictly repeatable from one sampling period to the next, because neither surveys exactly the same portion of the reef each time. It is impossible to position the chain in precisely the same position on the reef, or to keep the video camera at exactly the same distance and angle from the bottom on successive surveys. However, the video camera will record the same general "band" or "swath" along the reef bottom.

Our study indicates that both methods provide the same results for coral cover but does not definitively conclude that one method or the other is more effective or accurate at documenting non-coral cover, hurricane damage or bleaching on a coral reef. The chain transect method may be more appropriate for documenting storm damage because it provides a measure of the topographical relief of the site. Quantitative video is more appropriate if the interest is in documenting visible changes such as portions of corals that are bleached or diseased. In addition, we recommend the use of video or still photographs to document the general appearance of any reef that is being monitored. The conclusions we present here are based on reefs dominated by *Montastraea annularis* and would not necessarily hold true for reefs dominated by coral species with very different morphologies, for example, *Acropora* spp., *Agaricia tenuifolia*, and *Dendrogyra cylindrus*.

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