

A tale of two reefs: Comparison of coral cover and sample design on reefs around Virgin Islands National Park.

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Introduction

Some of the longest data sets on Caribbean coral reefs come from Virgin Islands National Park (VIIS), St. John. Under the National Park Service – US Geological Survey (USGS) Inventory and Monitoring program coral reefs are being monitored at several sites around Buck Island Reef National Monument (BUIS) and VIIS. Here we describe the results from two methods used to quantify benthic cover annually from 1999-2002 at two fringing reefs in St. John, US Virgin Islands and discuss an innovative approach to random sampling on coral reefs.

The main points are:

- 1) Despite being located in areas of good water quality and adjacent to undeveloped watersheds, a significant decrease in coral cover occurred at Newfound Reef between 1999-2001 ($p < 0.01$), and there has been no change in coral cover at Yawzi Reef (within VIIS) over the study period.
- 2) Random (independent) sampling is necessary to accurately reflect changes in benthic cover throughout an entire defined reef zone, although haphazard (dependent) sampling is most commonly used.
- 3) Repeated sampling of permanently located random samples provides more statistical power and can reduce sample size by half when compared to non-permanent random sampling.

Methods:

The linear chain transect method was used at five, permanent, 20-meter transects at Yawzi Reef, within the boundaries of Virgin Islands National Park, and at ten, continuous, 10-meter transects permanently established at Newfound Reef. Because the goal of this monitoring was to track changes in benthic cover at two of the “best” reef sites, transects were placed in areas of high coral cover, diversity and complexity (biased, dependent sampling). Values derived at these transects accurately describe the benthic cover **at these transects**, but may not be representative of the wider reef area.

The second method involved videotaping twenty, randomly selected, permanent 10-meter transects (and the previously described ‘linear chain transects’) with a digital video camera. Cover was calculated by identifying and quantifying benthic components under random dots overlaid on captured digital images. Random sampling was accomplished by mapping the reef study area perimeter, defining the sample population, and randomly choosing transects from within that population (Miller and Rogers 2000). In this manner each sample (transect) has equal opportunity to be selected (unbiased,

independent sampling), therefore the resulting benthic cover values are representative of **the entire defined reef area**. To compare permanent transects with re-randomized transects, twenty additional 10-meter transects were randomly selected and analyzed each year.

Data Analyses:

Data from random video transects were tested for normality and homogeneity of variances using Kolmogorov-Smirnov and Bartlett's Tests, respectively. While the data at Newfound were found to be normal, the arcsin transform was required at Yawzi to meet the assumptions of normality. Unequal variances were documented for some benthic cover types that could not be corrected with transforms, which required use of Welch's ANOVA to allow for unequal variances. Those instances precluded use of repeated measures ANOVA's, which would be preferable in cases where permanent transects are revisited across time.

Comparisons between means were made using Tukey-Kramer corrections. Where no significant differences were detected, actual p-values are provided.

Main Point #1:

The analysis at the permanent, random video transects at Yawzi Reef revealed that the coral cover was relatively low (mean range = 7.1- 8.4 %) throughout the study period with no statistical difference between years ($p = 0.9$; Fig. 1). Coral cover at Newfound Reef was higher (mean range = 12.3 - 18.2%), and decreased significantly from 1999-2001 ($p < 0.01$; Fig. 1). Although Yawzi Reef is within the boundaries of Virgin Islands National Park, and Newfound Reef is outside, both study sites are adjacent to undeveloped watersheds. Water quality is considered to be relatively pristine (EPA STORET database) however, both sites are

adjacent to commercial shipping lanes frequented by cargo and cruise ships; and both sites are frequently fished by hand-line and fishpots. Coral diseases, including black band disease and plague type II, have been observed in both locations, with plague being especially prevalent (Miller pers. obs.)

What about changes in other reef substrate? Analysis showed no significant changes in the relatively low cover values for gorgonians and sponges throughout the study period. In contrast, seaweed (macroalgae=MACA) and turf algae (dead coral with turf algae = DCA), and non-biotic substrate (sand, rubble, and pavement = SUBST) varied substantially. When present, macroalgae tend to cover DCA and non-living substrate. Conversely, when MACA is removed by wave action or grazing by fish, DCA and substrate are exposed thereby increasing their cover values (e.g.: Yawzi, 1999-2000; and Newfound, 2000-2001-2002; Fig. 1).

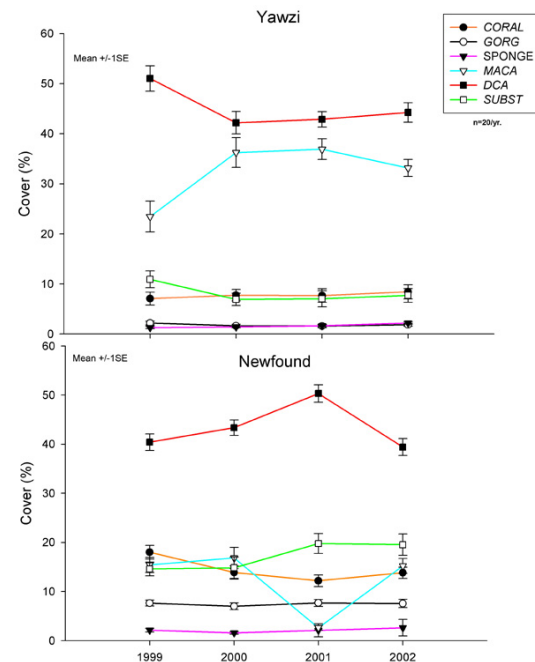


Fig. 1 Temporal trends in six cover types characterized by digital video analysis of permanent random transects between 1999 and 2002 Yawzi and Newfound Reefs, St. John, U.S.V.I.

In 1989, Hurricane Hugo reduced the coral cover at Yawzi Reef from 19.5% to 12.5% (at permanent linear chain transects; see Rogers *et al.* 1997) and it

may be that combination of diseases, subsequent storm events, anthropogenic stresses, and low coral cover suppress recovery of stony coral at this site. The cause for the decrease in coral cover at Newfound Reef is difficult to pinpoint, but most likely a combination of coral disease, recent storms (e.g.: Hurricanes Georges, 1998; Jose & Lenny, 1999) and anthropogenic effects.

Main Point #2:

The selection of random sampling points within a study area is an important yet under emphasized aspect of monitoring. “Putting samples in ‘representative’ or ‘typical’ places is **not** random sampling” (Green 1979). Random sampling is neither simple nor inexpensive, and working underwater with the inherent variability found in coral reefs presents many challenges. Most monitoring programs advocate random sampling but few say **how** to do it. This study uses a protocol designed specifically for random sampling in marine environments, and demonstrates the importance of a proper random sample design to interpret changes in benthic cover over a defined reef area.

Visual interpretation of the linear chain data from the biased, dependent transect locations at both Yawzi and Newfound reflect the placement of those samples in areas of relatively high coral cover (Fig. 2). However, when independent, random sampling was conducted throughout the entire defined reef, a greater spatial coverage was obtained (Fig.3 - 4 Site Maps) and lower values for coral cover were measured using the digital video analysis at both Yawzi and Newfound Reefs. Coral cover data from

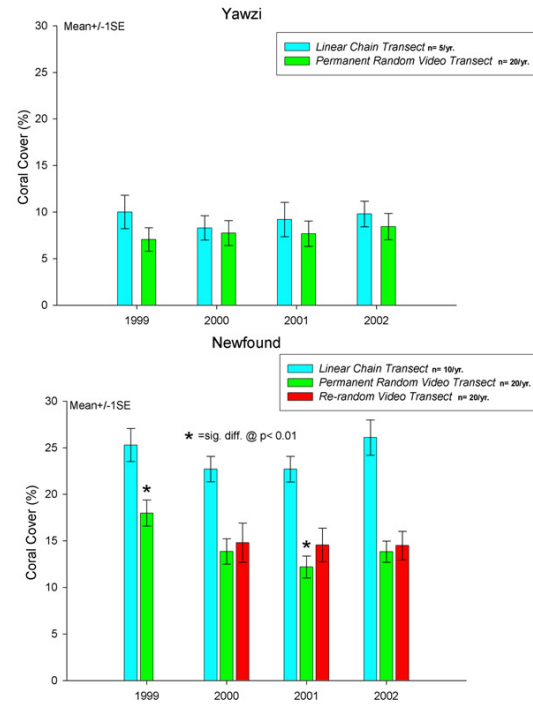


Fig. 2. Comparisons of live coral cover derived from linear chain transects and digital video analysis of permanent random and randomly reselected video transects at two study sites around St. John, U.S.V.I. from 1999 to 2002. Asterisk denotes statistically significant difference between means.

the linear chain transects for both sites were relatively unchanged, yet digital analysis at the randomly selected transects revealed a significant decrease in coral cover at Newfound Reef between 1999-2000 ($p < 0.01$).

To further compare the composition of the biased, dependent transects to the independent, random transects, we looked at the cover by stony coral using the digital video method at both sets of transects for both Yawzi and Newfound (Fig. 5). Visual comparisons of the permanent, random transects reveal mean coral cover at Newfound Reef was lower than the biased, dependent transects for each sample period. Yawzi Reef shows a similar trend with the mean coral cover being lower at the independent, random transects for three of the four years. Statistical comparisons were not possible due to autocorrelation between biased dependent linear chain transects.

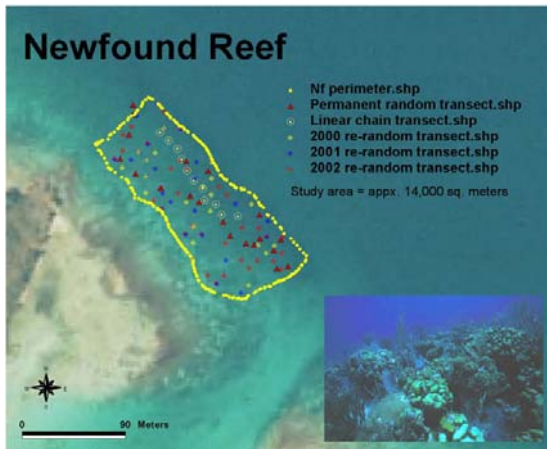


Figure 3. Newfound Reef

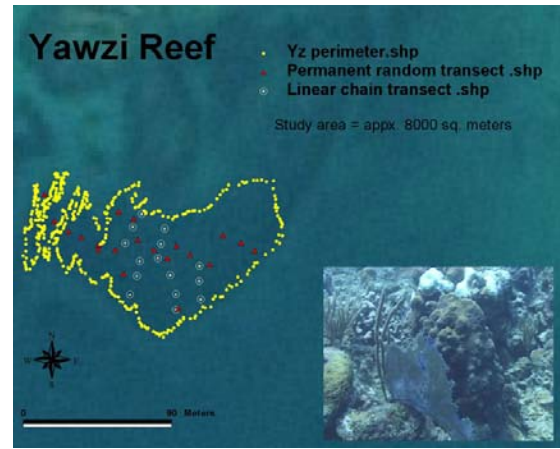
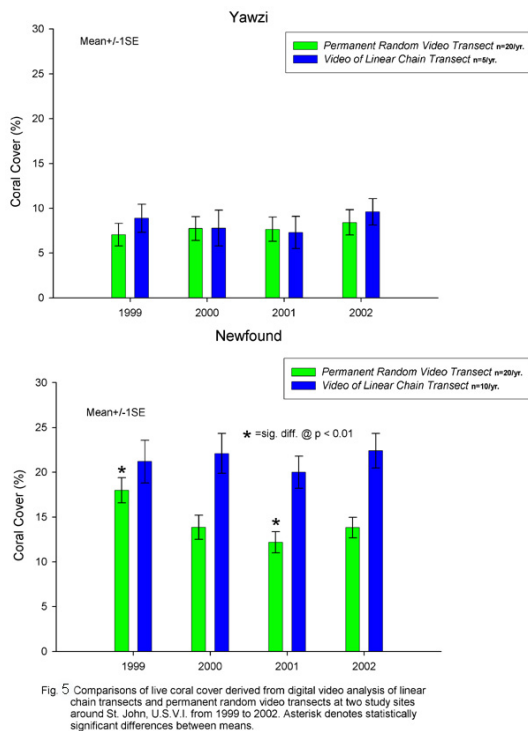


Figure 4. Yawzi Reef



Furthermore, the additional twenty re-randomized transects at Newfound were not statistically different from the permanent random twenty (2000, $p = 0.58$; 2001, $p = 0.27$; 2002, $p = 0.85$) indicating the values for and changes in coral cover on the permanent transects were a valid reflection of coverage throughout the entire defined reef.

Main Point #3:

Repeated monitoring of random transects allows for an increase in statistical power and therefore a potential reduction in monitoring costs. Our data showed the permanent transects could detect the same difference in change of coral cover with equivalent power (80%, using $\alpha = 0.05$) using half the number of transects as required if re-randomized annually.

Another benefit of monitoring permanent samples with video is the ability to make direct transect comparisons of both quantitative data and raw video imagery. Our results showed a significant decrease in coral cover at Newfound reef between 1999 and 2001. Comparing each of the 20 random transects at Newfound between 1999-2000 showed coral cover decreased at all 20 transects; between 2000-2001, 14 of 20 transects decreased in coral cover, and between 2001-2002, 13 of 20 increased. We can review the captured images or the raw videotape to monitor individual coral colonies through time; or evaluate whether changes in DCA were caused by coral mortality or uncovering by MACA. This visual “hindsight” is invaluable in helping to determine the specific cause of changes on reefs, an aspect of monitoring not possible with other methods, e.g.: linear chain.

Conclusion:

This study illustrates the potential hazard of relying on biased, dependent, or commonly referred to as “haphazardly” selected sample design to define reef health or composition over broad areas.

The selectively placed transects accurately defined the benthic cover, but only at those specific transects. Using data collected at biased, dependent transects provides a limited, albeit accurate, view of the reef, but may lead to erroneous conclusions or assumptions if used to interpret reef cover or condition beyond the actual transects.

Resource managers need to be aware of not only the data describing their resource, but the methodology used to collect that data. Haphazard sample design, the long-time standard in coral reef monitoring, may not accurately reflect the true condition or composition of a given study area, thus management actions based on that data may not have the desired outcome. Reefs in the US Virgin Islands, including those within marine protected areas such as VIIS and BUIS are showing evidence of degradation. Managers need solid data from statistically rigorous sampling to help them reverse these declines from natural and human stresses.

References:

Green R. (1979) Sample design and statistical methods for experimental design. John Wiley and Sons, New York. 257 pp.

Rogers C, Garrison G, Grober-Dunsmore R (1997) A fishy story about hurricanes and herbivory: seven years of research on a reef in St. John, US Virgin islands. Proc 8th Int Coral Reef Sym 1:550-560

EPA STORET database

Reference for protocols:

Miller J., Rogers C.S. (2000) A new approach to tracking change on coral reefs: Using videotape to monitor coral reefs, and Using AquaMap® at a study site. US Geological Survey, Inventory and Monitoring protocol document. 71pp.

Information on protocols are posted on the web:

<http://www.nature.nps.gov/im/monitor/protocoldb.cfm>