A NEW APPROACH TO TRACKING CHANGE ON CORAL REEFS

Protocols for Monitoring with Digital Video and a SONAR-based Locating System

INTRODUCTION

This document includes two, integrated protocols for monitoring coral reefs. The protocols were developed by biologists in the US Geological Survey (USGS), based at the Virgin Islands Field Station, under the auspices of the National Park Service/USGS Inventory and Monitoring Program. The objective is to collect information on the structure and condition of coral reefs, and specifically, to document change in coral reef ecosystems over time, including shifts in abundances of major reef organisms.

Protocol I ("Using Videotape to Sample Coral Reefs") describes the use of a digital video camera in an underwater housing and an innovative application of readily available computer software for processing the digital images. Protocol II ("Using AquaMap at a Study Site) describes the use of a SONAR-based underwater position-locating system that allows random selection of reef transects for videotaping. The selection of random, independent transects satisfies the criteria for rigorous statistical analysis. Together, the protocols address:

- selection of transects within selected reef zones
- videotaping of transects (quantitative)
- processing of video images
- calculation of percent cover by reef organisms and substrate types, and
- data analysis

These two protocols have been used together successfully at 4 locations in the US Virgin Islands, at 3 reefs off St. John and one reef off Buck Island, St. Croix.

Although these protocols were developed specifically for use by NPS, other scientists have already started to use them in their monitoring programs. The approach we are recommending, the one we think provides the highest quality of data, involves the use of quantitative video to record cover by the benthic components along randomly selected, permanent transects. [The videotapes provide quantitative data because they are taken a set distance above the reef substrate-- see details below.] Others may decide that they can accomplish their specific objectives by using modifications of this approach, for example, quantitative video along random transects that are not permanent, or along transects that were haphazardly chosen. Even qualitative videos can be extremely useful. Videotapes showing the general appearance of a coral reef provide a substantial amount of qualitative information on the relative abundance of hard corals, gorgonians, and other organisms, and on the presence or absence of conspicuous conditions such as bleaching, coral diseases, and storm damage. Comparisons of qualitative videotapes from the same locations taken at successive time periods can provide valuable information on the changes occurring on reefs, including new incidence of disease or bleaching, or recovery from these conditions. These tapes often provide general information that may be sufficient for some management purposes. We also recommend that these "qualitative" videotapes be taken each time the "quantitative" tapes are taken along linear transects as they provide a more representative view of the reef structure.

For long-term monitoring programs designed to detect changes on reefs over time, it is essential that quantitative videos be taken. These are analyzed to provide data on the amount of "cover" by key organisms and non-living substrate along transects (see below).

Rationale for monitoring coral cover

Several variables can be used to describe the structure of a particular reef, including coral cover, density of colonies, condition of colonies, coral colony size frequency distributions, and topographical relief (rugosity). Although all of these are useful, we have decided to emphasize monitoring of coral cover (as well as algal cover) for several reasons. Most of the stresses that affect corals cause loss of coral tissue. If the corals fail to recover, the affected areas are usually rapidly colonized by algae. Major stresses therefore will result in a decrease in the amount of “cover” of living coral on the reef and, usually, an increase in the amount of algae. These changes represent a significant shift from framework building organisms to organisms that do not contribute to the reef’s structure.

Because this method is being developed for the National Park Service, we are especially interested in being able to document the effects of anthropogenic (i.e., more “manageable”) stresses. However, reefs in national parks in the USVI and Florida have experienced several severe hurricanes in the last two decades, and these storms (along with several coral diseases) have reduced coral cover on the reefs, rendering them more susceptible to detrimental human activities (e.g., Rogers et al. 1997). Monitoring should provide information on the responses of the reefs to a combination of natural and human stresses and should help to differentiate natural rates of change from those induced by humans.

Rationale for using the video method

We decided to use an underwater video method as our primary technique for monitoring of reefs because it offers several advantages over alternative methods. Videotapes are especially effective in recording the effects of a variety of stresses that cause conspicuous changes in the appearance of coral colonies---for example, the physical breakage from hurricanes and boat anchors, and the bright white patches from coral diseases and bleaching. They can also show recovery of reefs following damage.

Other, non-photographic techniques for monitoring reefs require more time in the water, and therefore, are constrained by depth and time limits for scuba diving. They also depend on the diver’s ability to identify a high diversity of organisms in the field. However, an experienced diver who lacks training in identification of reef species can collect data with the video method.

Because scuba diving imposes depth and time constraints, most reef monitoring studies have been based on very small areas. Use of video cameras provides the opportunity to efficiently collect larger amounts of certain types of data, giving increased return for the time spent underwater (see Carleton and Done 1995). For example, it takes less than 15 minutes to record a video transect 20 m long but sometimes over 4 hours to collect information along the same transect using the linear chain transect method. Although the chain transect method provides data on the 3-dimensionality of the reef surface and on organisms which are not visible from a vantage point directly above the reef (the "planar" view recorded with video), it is not suitable for collecting data over a large spatial scale. The video method requires a skilled diver but no expertise in identification of reef organisms in the field, the basis of the chain transect method. In other words, non-scientists can use this method. The video method can provide a substantial amount of useful information while minimizing a diver's time in the water, and unlike most other methods, provides an archivable, visual record of the reef. Video transect images can be stored on write-to CD. Archived images can be sent to other researchers electronically, and the same image and pixels can be identified for quality control.

We have compared this video method to the more-widely used chain transect method and believe that it is more suitable for use in long-term monitoring programs in national parks (see also Rogers and Miller, in press, for a comparison of the results of using both methods to document cover, bleaching and storm damage on a reef in St. John, USVI).

Disadvantages of the video method

In spite of its numerous advantages, the video method has its limitations. In some cases, the chain transect method will be more appropriate. With the chain method, identifications are made on site, in the field. The identification of benthic components from videotapes may be difficult because at times only portions of these components are included within the frame that is being analyzed, and therefore the "context" is missing. In addition, changes in the amount of living coral recorded with still photography or video are changes in the amount of living coral tissue visible in planar (2-dimensional) view. This technique will under-represent colonies with a more vertical morphology (e.g., pillar coral) and is more suitable for monitoring reef zones with species exhibiting encrusting and hemispherical morphologies. The video method is not appropriate for monitoring recruitment of hard corals because resolution is not adequate to provide images of recruits less than about 4 cm in diameter. Also, sometimes it is difficult to differentiate macroscopic algae ("macroalgae") from algal "turf" species because of the planar perspective. In areas with high sedimentation rates, sediment particles may obscure the underlying algae resulting in underestimates of the algal cover. These are important considerations given that increases in macroalgae are considered one of the clearest indications of severe stress to reefs. Image analysis takes a considerable amount of experience, expertise, and time (an estimated two or more hours per 20 m transect) whereas chain transect data can be processed relatively quickly. The chain method may be more appropriate for quantifying storm damage because it provides a measure of the topographical relief of the site. The video method is more appropriate if the interest is in documenting visible changes such as bleaching or coral diseases.

Rationale for using randomly selected, permanent transects

Random vs. Non-random sampling units:

In most cases, the selection of the coral reefs to be monitored will not be a random process because certain reefs will be of greater interest for management purposes or scientific reasons. However, it is essential that the sampling units themselves [that is, the quadrats or transects] at these reefs be chosen in a random manner. As Green notes, "Putting samples in "representative" or "typical" places is not random sampling" (Green 1979). Underwater research does not lend itself easily to random sampling because it is very difficult for divers to locate the exact positions of (sometimes widely distributed) transects determined before they enter the water. Because of logistic, financial, and time constraints, most scientists have used **haphazard** sampling in which the diver surveys a portion of the reef, e.g., a transect, and then swims a random number of fin kicks or meters away to the subsequent sampling site, and so forth. In this case, the location of each transect is dependent on the one which precedes it, i.e., the sampling units are not independent of each other. In contrast, truly random sampling ensures that each transect (sampling unit) has an equal probability of being selected for examination. If the sample size (i.e., number of transects) is large enough, haphazard transects may give values (e.g., for coral cover) that are very similar to those from random transects, but it is not strictly appropriate to analyze the data from the haphazard transects using statistical analyses which require independent samples. The inherent variability (patchiness) in coral reef structure presents real challenges for sampling of these ecosystems.

We strongly recommend that reef monitoring programs have sampling designs based on **random** selection of sites within reefs chosen for study. Green points out, "It requires effort to ensure that sampling is random"(Green 1979). Although numerous manuals on coral reef monitoring recommend random selection of study sites (or quadrats, transects, etc.), none to date addresses exactly how these sites will be selected (English et al. 1994, Oxley 1994, Rogers et al. 1994). In this protocol we present a statistically rigorous approach to sampling cover of reef organisms and substrate along transects that depends on random selection of locations for transects using an underwater position-locating system (see Protocol II).

Permanent vs. Non-permanent Transects

Because of the inherent variability of most reefs, it is essential to monitor the same transects over time rather than to select different transects each sampling period. Establishing permanent transects will allow a greater ability to detect changes in coral cover and cover by other organisms. Transect locations can be determined with an underwater position locating system such as the Aqua Map described in this document without the installation of survey stakes or other markers.

References

Aronson RB, Edmunds PJ, Precht WF, Swanson DW, Levitan DR (1994) Large scale, long-term monitoring of Caribbean coral reefs: simple, quick, inexpensive techniques. Atoll Research Bulletin 421: 1-19

CARICOMP (1997) CARICOMP monitoring of coral reefs. Proc of the 8th Int Coral Reef Sym1: 651-656

Carleton JH, Done T (1995) Quantitative video sampling of coral reef benthos:large-scale application. Coral Reefs 14: 35-46

Connell JH (1997) Disturbance and recovery of coral assemblages. Coral Reefs 16, Suppl.:S101-S113

English S, Wilkinson C, Baker V (eds) (1994) Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science. Townsville, Australia. 368 pp

Green RH (1979) Sampling design and statistical methods for environmental biologists. Wiley, New York. 257 pp

Green RH, Smith SR (1997) Sample program design and environmental impact assessment on coral reefs. Proc of the 8th Int Coral Reef Sym 2: 1459-1464

Oxley, WG (1994) Sampling design and monitoring. In: English S, Wilkinson C, Baker V (eds) Survey Manual for Tropical Marine Resources. Australian Institute of Marine Science. Townsville, Australia. pp299-312

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, U.S. Virgin Islands. Proc. 8th Int Coral Reef Sym 1: 555-560

Rogers C, Garrison G, Grober R., Hillis Z-M., Franke MA (1994) Coral reef monitoring manual for the Caribbean and Western Atlantic. National Park Service. 100 pp. including photographs

Smith SV (1978) Coral-reef area and the contributions of reefs to processes and resources of the world's oceans. Nature 273: 225-226.

Spalding M, Grenfell AM (1997) New estimates of global and regional coral reef areas. Coral Reefs 16: 225-230.

Wheaton JL, Jaap WC, Dustan P, Porter J (1996) Coral reef hard bottom monitoring project. Annual and 4th Quarterly Report. Florida Keys National Marine Sanctuary Water Quality Protection Plan. 30 pp