

CONSERVATION AND MANAGEMENT APPLICATIONS OF THE REEF VOLUNTEER FISH MONITORING PROGRAM

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Abstract. The REEF Fish Survey Project is a volunteer fish monitoring program developed by the Reef Environmental Education Foundation (REEF). REEF volunteers collect fish distribution and abundance data using a standardized visual method during regular diving and snorkeling activities. Survey data are recorded on preprinted data sheets that are returned to REEF and optically digitized. Data are housed in a publicly accessible database on REEF's Website (<http://www.reef.org>). Since the project's inception in 1993, over 40,000 surveys have been conducted in the coastal waters of North America, tropical western Atlantic, Gulf of California and Hawaii. The Fish Survey Project has been incorporated into existing monitoring programs through partnerships with government agencies, scientists, conservation organizations, and private institutions. REEF's partners benefit from the educational value and increased stewardship resulting from volunteer data collection. Applications of the data include an evaluation of fish/habitat interactions in the Florida Keys National Marine Sanctuary, the development of a multi-species trend analysis method to identify sites of management concern, assessment of the current distribution of species, status reports on fish assemblages of marine parks, and the evaluation of no-take zones in the Florida Keys. REEF's collaboration with a variety of partners, combined with the Fish Survey Project's standardized census method and database management system, has resulted in a successful citizen science monitoring program.

Keywords: marine fish, volunteer monitoring, conservation, citizen science, coral reef, reef fish

1. Introduction

Effective conservation and management of marine resources requires a comprehensive understanding of ecosystem structure and function. Through concerted and persistent data collection, researchers and resource managers can gain an understanding of these ecosystem components. The monumental task of surveying, recording and cataloging an immense liquid wilderness can be daunting for managers. Establishing monitoring programs at a scale large enough to appropriately monitor marine communities is frequently cited as a stumbling block to effective management (e.g. Baird et al., 2000). One solution is to use volunteers to help collect information. Volunteer data collection, or "citizen science", has become a widespread alternative for scientists and resource agencies needing information but lacking sufficient resources to gather it. With citizen science, a portion of monitoring costs is born by volunteers and sampling effort and geographic coverage are much larger than would otherwise be feasible. Additionally, volunteer involvement leads to increased resource stewardship.

The Reef Environmental Education Foundation (REEF) enlists thousands of recreational divers and snorkelers visiting coastal areas each year to provide meaningful information while learning about the environment. REEF was founded as a non-profit organization in 1990 out of growing concern for the health of the marine environment and the desire to provide the SCUBA diving community a way to

contribute to the understanding and protection of marine environments. REEF achieves this goal through its volunteer fish-monitoring program, the REEF Fish Survey Project. The Project was developed with support from The Nature Conservancy and guidance by the Southeast Fisheries Science Center of the National Marine Fisheries Service and the University of Miami.

The Fish Survey Project started in Florida in 1993, and since then has expanded to include the entire tropical western Atlantic (Florida, Caribbean, Bahamas, and Gulf of Mexico), southern Atlantic states (Georgia through North Carolina), the Northeast (Virginia through Newfoundland), the West Coast of the United States and Canada (California through British Columbia), the tropical eastern Pacific (Gulf of California to the Galapagos Islands), and most recently the Hawaiian Islands. By the end of 2001, over 40,000 surveys had been conducted by REEF members.

Volunteers conduct surveys on their own or during organized field surveys using the Roving Diver Technique (RDT; Schmitt and Sullivan, 1996). During RDT surveys, divers swim freely throughout a dive site and record every observed fish species. At the conclusion of each survey, divers assign each recorded species one of four log₁₀ abundance categories [single (1); few (2–10); many (11–100); and abundant (>100)]. The species data along with survey time, depth, temperature, and other environmental information are then transferred to a REEF scansheet. Complete scansheets are returned to REEF headquarters and are optically scanned. After being processed through a set of error checking/quality control steps, the data are loaded into REEF's publicly accessible database. Summary reports of the data can be generated through the Internet (www.reef.org) and raw datafiles are provided when requested by researchers and resource managers.

Volunteers are categorized as expert or novice according to survey experience and performance on a series of fish identification exams. The RDT survey data provide species lists, frequency of occurrence, and relative abundance data. Percent sighting frequency (%SF) for each species is the percentage of all dives in which the species was recorded. An estimate of abundance is calculated as:

$$\text{abundance score} = D \times \%SF \quad (1)$$

where the density score (D) for each species is a weighted average index based on the frequency of observations in different abundance categories. Density score is calculated as:

$$D = [(n_s \times 1) + (n_f \times 2) + (n_m \times 3) + (n_a \times 4)] / (n_s + n_f + n_m + n_a) \quad (2)$$

where n_s , n_f , n_m , and n_a represent the number of times each abundance category was assigned for a given species.

In this paper we describe the application of Fish Survey Project data to a variety of conservation and management projects. We first illustrate how REEF's program has been incorporated into monitoring and baseline data gathering efforts by man-

agement agencies through contracts and training programs. Next we summarize two regional analyses of the data, and discuss the contribution REEF data have made to the general knowledge of reef fish natural history. Finally, REEF's role in educating the public about the issues and threats facing marine resources is discussed. The intent is to outline the benefits that managers, scientists and the public derive from the REEF Fish Survey Project, to highlight the role partnerships have had in the Project's success, and to promote citizen science programs as a viable source of monitoring data and stewardship development.

2. REEF In Monitoring Programs

Useful monitoring programs should provide the means to compare the characteristics of different sites under the care of a managing agency through space and time. Ideally, monitoring includes sites outside the management area so that local trends can be distinguished from regional trends. For most local managing agencies, developing a monitoring program with such traits is difficult given limitations to budget, person-hours, and expertise. In such instances, REEF provides a solution.

REEF provides a large and willing pool of surveyors, a standard methodology, data management and reporting mechanisms. Several management agencies have taken advantage of REEF's services by incorporating the Fish Survey Project into monitoring programs.

2.1 TRAINING AND LOCAL APPLICATIONS

REEF provides government agencies and local conservation organizations fish identification and survey training. By incorporating the Fish Survey Project methodology into a monitoring program, an agency gains access to a data management system at no expense. Additionally, the data they collect are consistent with data collected by others over a broad geographic area. The following are examples of partnerships that REEF has formed with both international and local management agencies.

2.1.1 Marine Parks

The Negril Coral Reef Preservation Society and the Negril Environmental Protection Trust in Jamaica worked with REEF to provide training for marine park rangers, biologists and local dive leaders. The week-long program, funded by the United Nations Environmental Program, involved seminars in identification, survey methodology and applications of survey data. Park staff and volunteers now conduct regular survey dives as part of an ongoing monitoring program. In addition, local dive leaders are able to train visiting tourists to take part in the monitoring effort.

The National Marine Park in Cozumel became interested in incorporating the Fish Survey Project program into its regular monitoring efforts after learning of the large quantity of data available in the area. REEF members regularly visit this

area and conduct fish surveys during their dives. REEF worked with the Marine Park to train staff and biologists in field identification and survey methodology. Following a one-week staff training program, a separate program was conducted to train and involve key marine park volunteers. Local volunteers now conduct training on a regular basis for visiting divers as well as take part in regular monitoring dives scheduled by the Marine Park.

2.1.2 State Agency

Since 1980, the Florida Fish and Wildlife Conservation Commission (FWCC) has funded an artificial reef program using manmade materials to attract and replenish fish stocks throughout Florida's coastal waters. In 1999, the FWCC approached REEF to help meet the program's need for standardized methods and data reporting. The agency had contracted with county dive teams to conduct periodic fish surveys on the artificial reefs. However, the survey methods and data formats of the county dive teams were inconsistent, and comparing information among counties was difficult. Once involved, REEF conducted five regional training workshops with both classroom and field sessions. The FWCC now requires all county teams to conduct RDT fish surveys as a minimum level of data collection. REEF provides standardized format datafiles back to the FWCC on a quarterly basis.

2.2 MONITORING AND ASSESSMENT CONTRACTS

Resource agencies that do not have the expertise or person-power to monitor all the taxa and areas important to conservation and management can contract REEF to help meet their monitoring needs. REEF has established an Advanced Assessment Team (AAT) to fulfill monitoring and assessment contracts it is awarded. The AAT is made up of REEF's most experienced and knowledgeable surveyors. To be a part of the Team, members have conducted a minimum of 35 surveys, have passed the Advanced Exam, and have kept their survey experience up to date. In 1997, the Florida Keys National Marine Sanctuary (FKNMS) contracted REEF to begin monitoring fishes at select sites as part of the Sanctuary's zone monitoring program. The objective is to collect data from no-take areas and from reference sites in order to evaluate the effect of harvest restrictions. REEF formed the AAT in direct response to this contract, inviting highly trained and active members to become a part of the project. The annual FKNMS contract employs eight AAT to survey 37 sites during a two-week time frame each year. The contract also ensures that a minimum number of REEF surveys are conducted each year within the FKNMS. In addition to the data collection, the contract includes funding for data summaries and an annual report. Other National Marine Sanctuary sites have also initiated AAT monitoring contracts in order to fill data gaps, while engaging their constituents.

Through a recent partnership between REEF, The Ocean Conservancy (formally known as the Center for Marine Conservation) and NOAA's Coastal Zone Management Program, a series of training workshops have been organized on US Island Territories (Puerto Rico and the US Virgin Islands) to enable local stakeholders to collect data on their island's coral reefs. In addition to the workshops, the contracts include the gathering of baseline data for each area using REEF's AAT. AAT participation in the workshops provides additional training personnel, while increasing the amount of data collected from the area.

3. Data Analysis

As the REEF program grows, the data collected by volunteers increases accordingly. In program areas with particularly high survey effort, it is possible to "mine" the data to explore trends or anomalies among species, or sites. Since the inception of the REEF program, large amounts of data have been collected in both the Bonaire Marine Park and the Florida Keys National Marine Sanctuary. Here we describe analyses conducted on the data from these two areas.

3.1 BONAIRE MARINE PARK

The BMP is the oldest marine park in the Caribbean. However, the fishes of Bonaire have not been systematically studied. Since 1993, the BMP has been the focus of eight REEF Field Surveys (week-long survey trips by a team of volunteer surveyors). Additionally, individual survey effort there has been intense. The resulting data provide a thorough reef fish species inventory, as well as a baseline of information that the BMP can use to detect future changes in the resource. Site-specific data provide a tool to evaluate relationships between sites with different physical characteristics and levels of diver use.

The REEF dataset was used to provide a description of the fish assemblage of the BMP (Pattengill-Semmens, 1998). The paper evaluated REEF surveys conducted between December 1993 and September 1999. A total of 1,557 novice and 457 expert RDT surveys had been conducted by REEF volunteers on the reefs of Bonaire and Klein Bonaire, representing 1,937 survey hours at 77 sites. A total of 362 species was reported. At one of the sites, Bari Reef, volunteers reported 270 species, the highest species richness of all sites in the REEF database. In addition to the taxonomic inventory, relationships among sites on Bonaire and the neighboring island of Klein Bonaire were examined. Despite the close proximity of these two areas, results suggested that the fish assemblages of Bonaire sites were relatively distinct from those on Klein.

The use of REEF Fish Survey Project data to describe the fish assemblages of the BMP is a step toward better understanding the Park's resources and the results highlight the statistical power of a large survey effort. The paper represents the

most comprehensive taxonomic inventory of fishes within the Park, and it will serve as a baseline for comparison after another 20 years of management.

3.2 FLORIDA KEYS NATIONAL MARINE SACTUARY

REEF has a strong foundation in the Florida Keys. As of January 2001, REEF members had completed 6,630 fish surveys in the Florida Keys. These surveys are the result of several organized projects, individual survey activities, and the implementation of the annual AAT zone monitoring in 1997. Two projects that used the REEF data from the Florida Keys are described below.

3.2.1 *Biogeography*

Correlating benthic habitat variables with the distribution, abundance, and size of reef fishes can provide the basis of a model for estimating habitat affinities for individual species. The spatial distribution of benthic habitats often mediates the effects of ecological processes (e.g., predation, competition, dispersal) that determine the distribution and abundance of tropical fishes. The relationship between fishes and habitat has recently received a good deal of attention, especially with regard to identifying Essential Fish Habitat (EFH), as mandated by the Magnusen-Stevens Act (H.R. 2061).

In 1999 NOAA's Biogeography Program completed a benthic habitat GIS and wanted to include spatially referenced living marine resources data. To accomplish this, the Program initiated a joint project with REEF and NOAA's Marine Sanctuaries Division. The project's goal was to describe the distribution and abundance of reef fishes in the FKNMS, and to use that information to evaluate fish-habitat interactions and the performance of management zones. The first step has been completed (Jeffrey et al., 2001). Current efforts focus on correlating reef fish distribution and abundance with benthic habitat parameters and the development of predictive habitat affinity models for selected fish species (Jeffrey et al., in press). These efforts will provide a diagnostic tool that can be used in a variety of management and conservation applications, including marine reserve siting and locating essential fish habitat.

3.2.2 *Trend Analysis Tool*

Using the REEF FKNMS dataset, researchers from the University of Washington took an approach that addressed both the need for data-synthesis tools and the need for analysis techniques that are robust to large, volunteer generated datasets (Sauer et al., 1994). Semmens et al. (in press) developed a method for calculating multi-species trends in reef fish populations. The analysis method was adapted from techniques used to analyze data from breeding bird surveys in North America (James et al., 1996). This across-site comparison generated an objective categorization of sites, and provided coral reef managers with a powerful management tool to identify sites of management

concern. This work also highlighted the increasing role that the REEF dataset will play in providing a clear picture of which FKNMS sites are changing rapidly, versus sites that sustain relatively consistent reef fish assemblages.

4. Conservation Contributions

The data collected by volunteers and the REEF field survey expeditions have resulted in several significant contributions to the general knowledge of reef fish natural history. In collaboration with taxonomic experts, the bluestriped goby (*Ptereleotris randalli*; L. Rocha, pers. comm.), red banner blenny (*Emblemariopsis tayrona*; P. Hastings, pers. comm.), giraffe snake eel (*Heteroconger camelopardalis*), and yellow garden eel (*Heteroconger luteolus*) have all been described as new species in the Caribbean basin as a result of REEF surveyors. The REEF database is also a powerful tool for documenting species distribution patterns. As part of the partnership with the NOAA Biogeography Program, a distribution atlas is currently being produced.

The threat of exotic fish species has gained increased attention among scientists and resource agencies, and REEF surveyors have been enlisted to help track exotic sightings. This has been particularly useful in tropical waters where amateur aquarists release fish too big or undesirable for a fish tank. In 2000, REEF partnered with the New England Aquarium and the FKNMS to remove three Indo-Pacific orbicular batfish (*Platax orbicularis*) from a reef in the Florida Keys. Two were successfully captured and are now in an exhibit at the Aquarium that educates the public about exotic species.

5. Conclusions

REEF's standardized census method and database management system, combined with partnerships, have resulted in a successful citizen science monitoring program. Collaborations with international, federal, and state agencies, scientists, conservation organizations, and private institutions have led to a variety of conservation and monitoring applications. The Fish Survey Project has been incorporated into existing monitoring programs, its data have been used in analyses, and the database has provided an increased understanding of the distribution and natural history of fishes in the tropical western Atlantic.

In addition to the direct applications of the Fish Survey Project and its data, REEF has made significant contributions to public education and marine resource stewardship. Participation in the Fish Survey Project enhances a diver's ability to discern details about the marine environment. The excitement of finding a rare fish can only be appreciated if one knows it's rare. By learning identification techniques and recording observations, REEF surveyors become keen observers and naturalists. The benefits, however, extend beyond enhancing an individual diver's underwater experience. The sense of stewardship that arises from involvement in

citizen science programs such as REEF's Fish Survey program raises the public's awareness of and involvement in marine resource issues. Ultimately, REEF's efforts empower volunteers to take an active role in support of effective marine resource management. Volunteer or "citizen" science allows all those who are interested in the resource to contribute to its understanding. Beyond providing valuable data, the increased stewardship that comes from participation in the Fish Survey Project is vital to the protection of coastal marine resources.

References

- Baird, B. E., Miller-Henson, M., and Semmens, B. X.: 2000, Improving California's System of Marine Managed Areas: Final Report of the State Interagency Marine Managed Areas Workgroup, Resource Agency of California, Ocean Resources Management Program, Sacramento, CA. <http://ceres.ca.gov/cra/ocean/>.
- James, F. C., McCulloch, C. E., and Wiedenfeld, D. A.: 1996, 'New Approaches to the Analysis of Population Trends in Land Birds', *Ecology* 77(1), 13–27.
- Jeffrey, C. F. G., Pattengill-Semmens, C. V., Buja, K., Christensen, J. D., Coyne, M., Monaco, M. E., and Gittings, S.: in press, 'Benthic Habitat Associations of Reef Fishes in the Florida Keys: Coupling of Benthic Habitats and Fish Distributions via GIS Technology', Proceedings International Coral Reef Symposium, October 2000.
- Jeffrey, C. F. G., Pattengill-Semmens, C. V., Gittings, S., and Monaco, M. E.: 2001, Distribution and Sighting Frequency of Reef Fishes in the Florida Keys National Marine Sanctuary, Marine Sanctuaries Conservation Series MSD-01-1, US Dept. of Commerce, NOAA, Silver Spring, MD.
- Pattengill-Semmens, C. V.: 1998, 'The Reef Fish Assemblage of Bonaire Marine Park: an Analysis of REEF Fish Survey Project Data', Proceedings 52nd Gulf Caribbean Fisheries Institute Meeting.
- Sauer, J. R., Peterjohn, B. G., Link, W. A.: 1994, 'Observer Differences in the North American Breeding Bird Survey', *The Auk* 111(1), 50–62.
- Schmitt, E. F. and Sullivan, K. M.: 1996, 'Analysis of a Volunteer Method for Collecting Fish Presence and Abundance Data in the Florida Keys', *Bulletin of Marine Science*, 59(2), 404–416.
- Semmens, B. X., Ruesink, J. L., and Pattengill-Semmens, C. V.: in press, 'Multi-site Multi-species Trends: a New Tool for Coral Reef Managers', Proceedings International Coral Reef Symposium, October 2000.