1998

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DOI: 10.18785/goms.1602.09

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Recommended Citation

Pattengill-Semmens, C. V. and B. X. Semmens. 1998. An Analysis of Fish Survey Data Generated by Nonexpert Volunteers in the Flower Garden Banks National Marine Sanctuary. *Gulf of Mexico Science* 16 (2). Retrieved from <https://aquila.usm.edu/goms/vol16/iss2/9>

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An Analysis of Fish Survey Data Generated by Nonexpert Volunteers in the Flower Garden Banks National Marine Sanctuary

CHRISTY V. PATTENGILL-SEMMENS AND BRICE X. SEMMENS

Using nonexpert volunteers in monitoring programs increases the data available for use in resource management. Both scientists and resource managers have expressed concerns about the value and accuracy of nonexpert data. We examined the quality of fish census data generated by Reef Environmental Education Foundation (REEF) volunteers of varying experience levels (nonexperts) and compared these data to data generated by experts. Analyses were done using data from three REEF field survey cruises conducted in the Flower Garden Banks National Marine Sanctuary. Species composition and structure were comparable between the skill levels. Nonexpert data sets were similar to expert data sets, although expert data were more statistically powerful when the amount of data collected was equivalent between skill levels. The amount of REEF survey experience was positively correlated with the power of the data collected. The statistical power of abundance estimates varied between species. These results provide support for the use of nonexpert data by resource managers and scientists to supplement and enhance monitoring programs.

Quantitative benthic monitoring has been conducted at the Flower Garden Banks National Marine Sanctuary (FGBNMS) for over 20 yr (Viada, 1996). In 1994, a fish assemblage monitoring program was initiated (Pattengill, 1998). Field survey time for this project was often shared with a volunteer-based monitoring program. Participating volunteers were trained in reef fish identification and they accompanied teams of experts in fish identification on several survey cruises. This paper examines the utility of the data collected by the volunteer surveyors for use by the FGBNMS.

Monitoring changes in a natural community is essential to effective conservation (Spellerberg, 1991). Coral reef ecosystems are complex, as are the interrelationships between habitat, biotic, and abiotic components. Long-term monitoring facilitates the understanding of ecosystem processes and establishes a baseline that can be used to assess natural and anthropogenic impacts (Spellerberg, 1991). As resource managers and scientists attempt to address the increasing pressures placed on coral reefs, monitoring data will be required to assess community health. Because reef ecosystems are complex, components of the system are often used as indicators of changes. Fish abundance and diversity can reflect reef conditions, because reef fish are mobile and many species depend on specific types of food and substrate (Sale, 1991; Reese, 1993). Visual survey methods are routinely used for gathering data on reef fish communities, and because they are nonextractive, such methods are ideal

for marine protected areas or for long-term, repetitive sampling.

The goal of monitoring is to detect and quantify change if it occurs. The sampling variance characteristic of many kinds of ecological data and the inherent natural variability in ecological systems cause concern for managers and scientists. When using data to detect change in abundance, proper resource management requires (1) statistical analysis to evaluate a null hypothesis (H_0) of static condition and (2) calculation of β , the probability of failing to reject a false H_0 (Peterman, 1990). Statistical power, or $1-\beta$, is the probability that the rejected H_0 was indeed false and can be used to determine the detectable effect size or minimum detectable change, a measure of the magnitude of change that could be detected by an experimental design or data set (Eckblad, 1991). Effect size, significance level (α), sample size, and sample variance all affect the power of data. Data that have high power have a high probability of correctly detecting an effect, if one exists. Therefore, the minimum detectable effect obtained by a given number of samples is a vital component when interpreting monitoring results (Peterman, 1990).

Power analysis is a useful tool because it provides the magnitude of effect that can be detected by the experimental design. Given a sample size n , power analysis estimates the accuracy of the mean in terms of percent deviation from the true mean (minimum detectable change, MDC). For example, an MDC of 10% indicates that the monitoring data are power-

ful enough to detect at least a 10% difference in mean values. If detecting a 7% change is desired, then sample variance will need to be reduced, either by increasing the sample size or the sampling precision.

Traditionally, scientists have been responsible for data collection in natural systems. They provide accurate but often limited information. The use of nonexpert volunteers to collect data in ecological monitoring programs has increased dramatically in recent years and has been particularly helpful when financial or logistical restrictions limit scientific study in a particular area. Volunteers also generally provide data on a broader spatial and temporal scale than do scientists. A clear understanding of the statistical power and limitations of nonexpert data is necessary if resource managers and researchers are to use them effectively.

The Reef Environmental Education Foundation (REEF; Key Largo, FL) is a nonprofit organization that educates and trains volunteer sport divers to collect fish distribution and abundance data. REEF, with support from The Nature Conservancy (TNC) and the sport diving industry, offers educational training, data-collection cruises, and survey supplies to encourage volunteer learning and participation. REEF volunteers use the roving diver technique (RDT), a visual survey method developed specifically for volunteer data collection (Schmitt et al., 1993, 1998). The REEF/TNC database, initiated in 1994, is publicly accessible via their website (<http://www.reef.org>) and currently contains over 16,000 reef fish surveys from the tropical western Atlantic. In 1997, the program was implemented along the U.S. Pacific coast.

REEF volunteers provide species lists, frequency of occurrence, and relative abundance data. Data generated by highly trained REEF volunteers (who are considered experts) were used to produce a status report on the reef fishes of the Florida Keys National Marine Sanctuary (FKNMS) (Schmitt, 1996) and are currently being used to describe baseline conditions and changes as FKNMS management plans are implemented. Over time, REEF data should show dynamic, species-specific distribution patterns and will be useful for alerting scientists and managers to unusual changes that might otherwise go unnoticed (Bohnsack, 1996). The REEF/TNC database provides a better understanding of the geographic distribution of reef fish species and their frequency of occurrence. In this regard, the REEF data set is analogous to Audubon's annual bird counts, that are conducted by hundreds of

thousands of nonprofessional bird-watchers throughout the world. In addition to providing data, REEF participants develop an increased awareness, understanding, and sense of ownership of the resource. Resource stewardship by the public is considered a vital component of resource management.

REEF volunteers trained and experienced in reef fish identification, behavior, and field survey techniques (who are considered experts by the REEF program) can generate data comparable to other published data on reef fish assemblages (Schmitt and Sullivan, 1996). In this chapter, data generated by nonexpert REEF volunteers were analyzed, because they are likely to generate the largest amount of data for the FGBNMS and elsewhere. Since June 1995, the REEF program has generated 1,222 surveys in the FGBNMS, which represents approximately 800 hr of survey time. The purpose of this study was to evaluate the utility and limitations of this large data set and to initiate discussions on the management and conservation applications of the REEF program. The similarity and statistical power of the RDT data generated by nonexperts and experts during three FGBNMS field surveys were examined.

METHODS

Study area.—The East (EFG) and West (WFG) Flower Garden Banks are two of numerous high-relief banks that occur in the northwestern Gulf of Mexico. The Flower Garden Banks (FGB) are located on the outer continental shelf, approximately 175 km SSE of Galveston, TX and are 21 km apart (EFG—27°54.5'N, 93°36.0'W; WFG—27°52.5'N, 93°49.0'W; Fig. 1). The banks are topographic expressions of seafloor uplift and occur as submerged banks of hard substratum surrounded by vast expanses of terrigenous continental-shelf sediments (Bright, 1977). Between 18 and 36 m, the banks contain coral zones with 20 species of western Atlantic hermatypic corals (Bright, 1977), covering approximately 50% of the area. The minimum depths of the reefs on the EFG and WFG are 18 and 21 m, respectively, and the total area of the high-diversity zones is 1.08 and 0.35 km², respectively. The FGB are near the northern limits of reef coral growth in the Gulf of Mexico and are approximately 600 km from the closest coral reefs in the southwestern Gulf. However, the thousands of gas and oil platforms in the northwest Gulf of Mexico may act as stepping stones for dispersal or as nurseries for hard-bottom-associated fish-

Fig. 1. Map of study area.

es (Pattengill et al., 1997). Both banks lack a nearby shallow, vegetated habitat, such as seagrasses or mangroves, which could act as "nursery areas," or larval settlement areas.

Data collection.—The fish assemblages of the EFG and WFG were visually counted, during three REEF field-survey cruises, using the RDT (Schmitt et al., 1993; Schmitt and Sullivan, 1996). Each cruise consisted of REEF participants (nonexperts of varying skill levels) and experts. The same expert surveyors were used for all three cruises. Surveyors classified as expert were experienced in the FGBNMS fish assemblages and had been surveying the fishes of the Banks for at least 2 yr prior to this study. All nonexperts participated in a 3-hr pre-cruise training course as well as in ongoing training and review sessions during each cruise.

During RDT surveys, the divers swam freely through a dive site and recorded every observed species. At the conclusion of each survey, one of four $\log_{10}$ abundance categories [single (1); few (2–10); many (11–100), and abundant (>100)] were assigned to each species observed. Dive times generally varied between 30 and 45 min, depending on the depth and dive-safety time limits. At the conclusion of each dive, the species data along with survey time, depth, temperature, and other environmental information, were recorded on pre-

printed data sheets, that were then returned to REEF and optically scanned into a database. In an effort to minimize misidentifications, a REEF survey leader reviewed all data sheets submitted and questioned suspect sightings. Questionable sightings were changed or deleted only when the surveyor confirmed the mistake. Field identifications were based on Humann and DeLoach (1994), Robins et al. (1986), and Stokes (1980).

Data analysis.—The nonexpert and expert data from each cruise and bank were analyzed separately. In order to evaluate the application of nonexpert data to resource monitoring and management, several comparative analyses were performed between the nonexperts and experts on the reported species richness, species composition, and community structure (species relative abundance).

Percent sighting frequency (%SF) for each species was the percentage of dives (during a survey) in which the species was recorded. The density score (D) for each species was a weighted average index based on the frequency of observations in different abundance categories, calculated as

$$D = ((n_S \times 1) + (n_F \times 2) + (n_M \times 3) + (n_A \times 4)) / (n_S + n_F + n_M + n_A),$$

where n_S , n_F , n_M , and n_A represent the number

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TABLE 1. Number of expert and nonexpert surveys conducted during each survey cruise.^a

	Aug. 1996		June 1997		Aug. 1997		Total
	WFG	EFG	WFG	EFG	WFG	EFG	
# Nonexpert surveys	88	72	53	28	85	76	402
# Expert surveys	27	28	24	20	30	22	151
Total survey hours	77.3	71.3	58.6	41.3	82.3	76.4	407.2
Total # nonexpert surveyors		22		17		17	
Total # expert surveyors		7		9		6	

^a WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

of times each abundance category was assigned for a given species. This measure does not account for nonsightings, and different distributions of sightings across abundance categories could result in similar density index values (Schmitt and Sullivan, 1996). Therefore, an abundance score to account for density, frequency of occurrence, and zero observations was calculated as

$$\text{abundance score} = D \times \%SF.$$

Species richness during each cruise was compared between the nonexpert and expert surveyors. In order to measure similarity in species composition by each skill group, Jaccard's Coefficient (J) (Ludwig and Reynolds, 1988) was calculated as

$$J = C/A + B,$$

where A and B were the number of species recorded by nonexperts and experts, respectively, and where C was the number of species recorded by both skill groups. This coefficient was calculated for each skill level for each cruise. The value J was also calculated using only those species seen in more than two RDT surveys on a single cruise. This subset of species eliminates most questionable identifications and chance encounters.

Using the computational technique of Eckblad (1991), the accuracy of the mean abundance score was estimated in terms of percent deviation from the true mean, as a function of sample size. The accuracy of the mean is the MDC ($\alpha = 0.05$). Using power analysis, the MDC in abundance for a given species was estimated for each skill level. In addition, a comparison of the frequency of sighting, D, and the MDC levels between the two skill groups was performed. In order to examine the effect of sample size on estimated power of nonexpert data, the MDCs for the top 30 species were calculated based on a standard sample size of 27. All power analyses were performed using Sample Size Worksheet (Oakleaf Systems, Decorah, IA).

RESULTS

REEF field survey cruises were conducted in Aug. 1996, June 1997, and Aug. 1997, and cruises lasted for 5, 4, and 5 d, respectively. During each cruise, the WFG was surveyed first. Sixty-one divers completed 553 surveys during the three cruises (Table 1). Fifty-two nonexperts participated. The nonexperts on the Aug. 1997 trip were considered "advanced nonexperts," because they had all participated in at least one other REEF field survey prior to coming to the FGBNMS. Average RDT survey time was 44 (± 9 SD) min. The Aug. 1996 and Aug. 1997 cruises had a similar number of survey hours (Table 1). The June 1997 cruise had considerably fewer survey hours because of the shorter cruise duration. Survey effort at each bank among each skill level was similar, except for the nonexpert June 1997 data.

Species richness recorded by nonexperts was higher than that reported by the experts early in each field survey (WFG data) but was more similar later in the cruise (EFG data) and during longer trips (Aug. 1996 and Aug. 1997), when survey hours were similar in the two groups (Table 2). A total of 150 species were recorded during the three field surveys: 140 by nonexperts and 130 by experts. Fifty-six species were seen on at least 20% of all surveys.

The similarity in species composition recorded by the two skill levels (based on Jaccard's coefficient) was 72–83% (Table 3). The amount of overlap in the species recorded was considerably higher (88–95%) when compared using only species seen by more than two divers (regardless of skill level) during the survey.

The power analysis for the top 56 species (Table 4) provided the MDC in abundance score detectable by each skill level. The percent change detectable ranged from 0.0 to 208.0%. The summary at the bottom of Table 4 showed that the "advanced nonexperts" on the Aug. 1997 trip had lower MDC values than did experts for most species, especially later in

TABLE 2. Species richness for the two skill levels for each survey.^a

	Aug. 1996				June 1997				Aug. 1997			
	WFG		EFG		WFG		EFG		WFG		EFG	
	Nonexpert	Expert	Nonexpert	Expert	Nonexpert	Expert	Nonexpert	Expert	Advanced nonexpert	Expert	Advanced nonexpert	Expert
Species richness	93	83	91	90	95	91	94	104	104	92	103	102

^a WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

the week. Additionally, Aug. 1996 nonexpert data had considerably more species with lower MDC values than did nonexpert data from the shorter June 1997 trip.

The 56 most frequently sighted species were categorized according to MDC for experts and nonexperts (Table 5). Minimum detectable change of nonexperts was lower than that from experts for 23 species; MDC from expert data was lower for nonexperts for 25 species, and MDC was similar (within 1%) for 8 species. The average differences in %SF and D between experts and nonexperts were 10.7% and -0.02, respectively, for species that nonexpert data could detect smaller changes in relative abundance. For species with smaller MDC levels in expert data, the average differences were 27.0% and 0.19, respectively.

In order to show the effect of sample size on the power of nonexpert data, average MDCs in abundance scores for the 30 most frequently sighted species were calculated for all data and for a standardized sample size of 27 (Table 6). Given an equal sample size, the nonexpert data tended to be less accurate, but a few species in each survey had smaller MDC levels in the nonexpert data. These species included Bermuda chub/yellow chub (*Kyphosus sectatrix/incisor*), great barracuda (*Sphyræna barracuda*), longsnout butterflyfish (*Chaetodon aculeatus*), rock beauty (*Holacanthus tricolor*), blue chromis (*Chromis cyanea*), and blue tang (*Acanthurus coeruleus*). With a standardized sample size, the "advanced nonexpert" data had lower MDC levels than did that of other nonexperts. Furthermore, in all three trips, nonexpert sur-

vey data had higher accuracy later in the week (EFG data). There were minimal power differences in the expert data between EFG and WFG.

DISCUSSION

To date, the REEF/TNC data set contains over 16,000 fish surveys from the tropical western Atlantic region and represents a potentially large source of information to the research and management communities of the FGBNMS and elsewhere. These data contain species presence information on a scale that would otherwise be unavailable.

Comparisons between the expert surveyors used in the FGBNMS fish monitoring program and nonexpert REEF participants revealed comparable data, given that a larger amount of nonexpert data was always collected. Species richness and the individual species recorded were similar between the two skill levels. Some of this similarity may be an artifact, because species-richness estimates from nonexpert data probably were artificially inflated by misidentifications. The fact that expert surveyors consistently recorded higher species richness on the EFG than on the WFG, whereas nonexperts did the opposite, provided evidence of misidentifications. When large data sets created from REEF field surveys are used, however, misidentified species fall to the bottom of a list sorted by %SF and can be effectively eliminated by selecting the upper portion of this list for analyses.

Nonexperts quickly gained experience dur-

TABLE 3. Similarity in species recorded by the two skill levels, as measured by Jaccard coefficient (J) values. Values were generated from the entire species list (J all spp. incl.) and using only species seen in more than two surveys (J spp. w/n_i > 2).^a

	Aug. 1996		June 1997		Aug. 1997	
	WFG	EFG	WFG	EFG	WFG	EFG
% J all spp. incl.	75.2	74.0	72.2	81.7	81.7	83.0
% J spp. w/n _i > 2	88.2	90.4	95.0	91.5	91.7	90.8

^a WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

ing the 4 and 5-d surveys. Although there was little difference in the J values calculated from nonexpert data collected early (WFG) or later (EFG) in each trip, the nonexpert MDC levels for a majority of species decreased (became more accurate) over the course of a trip, despite a smaller sample size at the EFG (Table 4). The advanced nonexpert data provided further evidence of the influence that even a minimal amount of experience had on power. The advanced nonexperts on the Aug. 1997 field survey generated data with smaller MDC values than did the other two groups of nonexperts. The J coefficients for this group were consistently higher, indicating a high similarity in the species recorded by advanced nonexperts and experts. For the advanced nonexperts, the average MDC value for all trips combined was 24.3%, considerably better than the average for the Aug. 1996 nonexperts (33.3%), the June 1997 nonexperts (47.7%), or the experts (31.8%) (Table 4). In addition, this advanced group had more species with lower MDC levels than did other nonexperts and the experts (bottom of Table 4).

Because of the larger sample size, nonexperts provided a more powerful estimate of abundance than experts did for some species (Table 5). In general, these were species that were conspicuous and easy to identify [e.g., blue tang, black durgon (*Melichthys niger*), rock beauty, and bicolor damselfish (*Stegastes partitus*)]. Several were relatively rare (infrequently sighted), and the larger sample size of nonexperts documented these species more consistently, providing more powerful information [e.g., trumpetfish (*Aulostomus maculatus*), spotfin hogfish (*Bodianus pulchellus*), crevalle jack (*Caranx hippos*), black jack (*Caranx lugubris*), and dog snapper (*Lutjanus jocu*)]. Experts were better at estimating abundance for species with several distinct life-history stages (wrasses and parrotfishes), for small cryptic species (blennies, gobies, and hawkfish), for planktivorous schooling species [brown chromis (*Chromis multilineata*), creolefish (*Paranthias furcifer*), and bonnetmouth (*Emmelichthys atlanticus*)], and for species that were difficult to distinguish from other members of their family (e.g., damselfishes).

The small difference in average density scores (Table 5) indicated that nonexperts and experts made similar assignments to abundance categories. This was especially true in species that had higher power in nonexpert data, as listed above. Though the relationship between a species' actual abundance on a reef and the D generated by the RDT for that spe-

cies is not a direct one, the density estimates can provide a sensitive record of change in species abundance.

The RDT method used in the REEF program has been shown to provide similar overall results when compared with other visual census techniques (Schmitt and Sullivan, 1996; Pattengill, 1998). The relative abundance information from RDT surveys is relatively coarse. However, Spearman correlation analysis indicated a high rank correlation (0.83) between RDT data and data from the more quantitative point-count method described by Bohnsack and Bannerot (1986) (Pattengill, 1998). It is proposed that the abundance score estimates for moderately abundant and frequent species appear to be good estimates of actual abundance. Using RDT data to detect change in species that are either very abundant or very rare is difficult. Detecting changes in %SF may be more useful for these species. Frequency data, if not confused as a measurement of abundance, can provide a valuable monitoring tool. With large sample sizes, such as those produced by volunteer monitoring programs like REEF, frequency data are especially useful. For example, the 95% confidence interval of one observation out of 100 surveys (average %SF of 1.0%) is 0.02–5.45% (Rohlf and Sokal, 1981). This narrow interval provides support for the idea that infrequently sighted species are indeed rare. By monitoring shifts in frequency, changes in overall abundance could be inferred.

A complete record of species sightings is valuable as a monitoring tool, even though the abundance data collected for many of the infrequently sighted species may not be very accurate. Volunteer data are particularly useful, because these data are often collected on a larger geographic scale (e.g., regionwide) than is found in most scientific studies, and they may provide a better understanding of the geographic distribution of reef fishes. A complete record of species sighted can also be useful to detect temporal change in species composition. Detecting such changes would only be possible if all species were monitored.

While all species should be considered in the FGBNMS monitoring program in order to more accurately assess the condition of the system, in certain instances (e.g., rapid assessment analyses), it may be desirable to use a subset of the RDT data. Power analysis results can provide guidelines for managers to decide how confident they are in a given component of the REEF data set. Twenty-three of the species included in Table 5 had an average MDC

TABLE 4. Minimum detectable change (MDC) for the 56 most frequent species; MDC values calculated using the actual sample size and abundance scores for each skill level during each survey. Asterisks (***) indicate that species were not recorded. A comparison of nonexpert (P_n) and expert (P_e) power for each cruise is presented at the bottom, where greater power indicates a lower MDC. Species are ranked by average nonexpert MDC levels. All values indicate percent (%).^a

Species	Common name	Aug. 1996				June 1997				Aug. 1997			
		WFG		EFG		WFG		EFG		WFG		EFG	
		Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Advanced nonexpert	Expert	Advanced nonexpert	Expert
<i>Chromis cyanea</i>	Blue chromis	6.3	7.4	6.9	10.5	10.7	6.1	8.7	12.7	6.2	9.1	6.2	15.9
<i>Sphyræna barracuda</i>	Great barracuda	5.4	7.1	6.8	11.0	6.0	11.3	4.2	5.4	6.8	11.3	7.1	18.4
<i>Chaetodon sedentarius</i>	Reef butterflyfish	14.2	10.5	6.3	10.4	15.5	7.4	8.7	9.6	7.9	7.2	7.1	13.7
<i>Thalassoma bifasciatum</i>	Bluehead	7.4	5.6	10.1	5.6	9.4	6.1	14.5	9.2	10.1	11.6	9.1	12.5
<i>Melichthys niger</i>	Black durgon	13.2	11.5	10.0	7.8	17.2	22.0	16.9	15.5	10.1	14.6	8.8	17.1
<i>Sparisoma viride</i>	Stoplight parrotfish	12.1	12.4	9.5	8.2	16.0	12.7	12.1	8.6	10.3	10.5	7.6	13.7
<i>Acanthurus coeruleus</i>	Blue tang	9.5	10.5	10.3	7.9	14.2	10.9	10.0	18.6	10.7	10.4	9.3	15.0
<i>Bodianus rufus</i>	Spanish hogfish	14.0	11.2	14.1	8.2	35.2	8.7	18.1	15.2	10.8	14.9	10.9	13.5
<i>Kyphosus sectatrix/incisor</i>	Bermuda/yellow chub	14.1	12.6	18.7	35.0	12.0	10.8	20.1	17.4	11.3	7.4	10.7	16.4
<i>Scarus vetula</i>	Queen parrotfish	10.9	6.4	8.7	8.3	8.4	8.4	8.0	8.0	11.4	4.5	8.2	11.5
<i>Stegastes partitus</i>	Bicolor damselfish	10.2	16.0	8.4	12.8	17.7	10.5	11.9	10.1	11.4	9.0	7.0	9.1
<i>Chromis multilineata</i>	Brown chromis	12.0	5.4	9.9	3.6	14.5	0.0	4.0	11.0	11.8	11.0	6.1	5.0
<i>Lactophrys triqueter</i>	Smooth trunkfish	19.9	16.7	12.3	16.7	23.9	16.1	20.1	18.1	12.8	16.9	15.0	13.2
<i>Holacanthus tricolor</i>	Rock beauty	14.9	22.9	12.6	19.0	21.2	14.7	14.7	11.0	13.1	19.0	10.0	20.5
<i>Canthigaster rostrata</i>	Sharpnose puffer	14.4	11.2	14.5	9.1	22.8	26.9	22.4	22.3	13.4	11.4	8.0	10.8
<i>Scarus taeniopterus</i>	Princess parrotfish	16.9	13.4	12.8	11.9	22.5	15.9	21.7	15.2	13.4	20.8	12.0	19.9
<i>Stegastes planifrons</i>	Threespot damselfish	15.2	6.4	10.1	5.5	23.3	19.3	25.3	16.9	13.4	11.2	9.7	23.4
<i>Epinephelus cruentatus</i>	Graysby	22.0	13.6	18.1	16.0	34.7	24.9	30.2	16.0	13.9	16.6	10.5	17.0
<i>Chaetodon aculeatus</i>	Longsnout butterflyfish	16.7	22.0	16.3	34.0	31.0	15.3	36.4	23.7	14.3	22.9	16.0	41.1
<i>Mulloidichthys martinicus</i>	Yellow goatfish	18.0	10.6	14.3	11.6	37.2	8.0	21.2	9.4	15.1	13.7	13.8	26.1
<i>Paranthias furcifer</i>	Creolefish	24.6	6.6	20.4	10.6	20.8	9.8	16.1	2.6	16.5	6.7	11.4	16.9
<i>Halichoeres garnoti</i>	Yellowhead wrasse	18.1	19.7	16.3	13.7	27.6	12.2	44.8	20.0	17.0	16.1	12.7	29.9
<i>Microspathodon chrysurus</i>	Yellowtail damselfish	20.1	29.3	13.3	12.9	25.1	25.2	16.0	13.6	20.3	36.1	17.3	14.1
<i>Segastes variabilis</i>	Cocoa damselfish	14.3	18.0	11.7	8.9	32.9	15.3	30.3	19.7	20.5	17.6	13.9	18.3
<i>Chromis insolata</i>	Sunshinefish	49.1	31.8	82.2	66.8	114.4	59.2	205.2	96.0	21.4	19.1	35.0	64.1
<i>Holacanthus ciliaris</i>	Queen angelfish	27.4	36.8	22.8	34.2	30.2	26.4	26.2	20.7	23.1	34.0	21.3	42.8
<i>Acanthurus bahianus</i>	Ocean surgeonfish	25.0	23.2	21.8	14.4	34.9	29.9	42.2	20.1	23.6	23.4	16.2	13.7
<i>Emmelichthyops atlanticus</i>	Bonnetmouth	47.9	26.3	20.9	27.2	***	***	***	***	23.8	25.2	19.3	28.2
<i>Sparisoma aurofrenatum</i>	Redband parrotfish	26.2	15.8	17.6	12.1	32.9	15.3	29.9	14.8	24.7	11.3	22.7	21.2
<i>Chromis scotti</i>	Purple reeffish	37.8	20.1	42.8	27.9	49.2	15.5	61.5	33.2	25.2	26.2	33.4	39.6
<i>Canthidermis sufflamen</i>	Ocean triggerfish	35.0	32.2	37.2	44.6	22.5	18.4	19.0	14.5	26.9	31.8	44.6	47.4

TABLE 4. Continued.

Species	Common name	Aug. 1996				June 1997				Aug. 1997			
		WFG		EFG		WFG		EFG		WFG		EFG	
		Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Advanced nonexpert	Expert	Advanced nonexpert	Expert
<i>Gobiosoma oceanops</i>	Neon goby	23.5	13.1	25.9	17.7	60.7	48.2	56.2	20.0	27.5	28.8	16.5	18.8
<i>Caranx ruber</i>	Bar jack	46.7	32.1	44.3	71.5	44.5	32.6	36.6	23.8	27.6	37.0	29.5	36.9
<i>Clepticus parrae</i>	Creole wrasse	50.4	34.6	40.8	40.4	33.0	22.2	25.8	5.9	27.8	22.7	31.4	52.6
<i>Halichoeres radiatus</i>	Puddingwife	148.4	43.6	40.0	22.3	91.2	49.8	90.8	44.7	28.1	30.0	22.0	36.0
<i>Acanthurus chirurgus</i>	Doctorfish	27.2	37.4	21.8	34.1	36.4	38.5	31.8	30.5	28.6	34.0	22.6	36.9
<i>Caranx latus</i>	Horse-eye jack	27.2	29.5	47.8	72.3	71.8	76.8	74.6	71.4	30.2	27.8	24.1	38.3
<i>Pomacanthus paru</i>	French angelfish	34.8	73.6	33.4	44.8	50.3	84.1	39.3	31.9	31.8	61.2	31.3	39.8
<i>Amblycirrhitus pinos</i>	Redspotted hawkfish	60.6	34.3	44.4	24.8	69.9	37.4	44.0	44.7	32.8	35.5	23.0	42.8
<i>Halichoeres maculipinna</i>	Clown wrasse	34.9	32.9	27.8	24.9	66.5	33.2	77.0	38.2	35.2	22.9	46.6	43.3
<i>Caranx lugubris</i>	Black jack	118.8	150.9	77.0	57.9	35.9	38.8	54.0	26.6	35.8	53.2	57.6	103.1
<i>Bodianus pulchellus</i>	Spotfin hogfish	92.6	37.4	***	102.8	69.9	26.3	65.1	54.4	36.0	42.1	60.0	208.0
<i>Cantherhines pullus</i>	Orangespotted filefish	36.8	26.9	28.6	27.3	36.4	29.1	43.7	19.0	36.6	53.9	34.0	33.6
<i>Chaetodon ocellatus</i>	Spotfin butterflyfish	27.8	36.1	30.1	41.7	44.8	51.0	31.2	39.2	37.1	42.6	24.3	26.2
<i>Aulostomus maculatus</i>	Trumpetfish	50.4	68.2	51.5	67.1	42.4	59.2	46.8	73.3	37.4	74.0	72.5	143.5
<i>Stegastes fuscus</i>	Dusky damselfish	66.6	34.1	39.6	13.7	119.2	90.4	142.4	47.4	39.6	89.6	38.0	59.8
<i>Mycteroperca interstitialis</i>	Yellowmouth grouper	60.1	43.6	51.8	26.6	104.3	52.0	48.0	24.0	42.4	35.5	24.0	20.5
<i>Pseudupeneus maculatus</i>	Spotted goatfish	48.2	38.0	19.8	32.1	66.5	47.9	84.7	58.8	44.2	74.0	32.7	66.4
<i>Mycteroperca tigris</i>	Tiger grouper	35.7	43.6	36.6	53.9	25.6	27.6	34.8	24.0	45.2	58.0	27.6	52.9
<i>Caranx hippos</i>	Crevalle jack	104.5	79.2	200.0	145.4	10.6	14.2	17.2	18.1	45.2	124.0	47.5	143.5
<i>Cantherhines macrocerus</i>	Whitespotted filefish	47.1	60.3	32.2	32.0	50.6	48.2	30.7	28.2	46.7	74.2	32.7	33.0
<i>Ophioblennius atlanticus</i>	Redlip blenny	39.2	19.1	29.1	18.3	121.8	***	62.1	47.4	47.7	89.6	30.9	46.6
<i>Holocentrus rufus</i>	Longspine squirrelfish	52.7	55.6	30.7	57.4	62.4	71.5	67.5	44.3	48.7	66.6	28.9	44.9
<i>Abudefduf saxatilis</i>	Sergeant major	43.7	67.2	13.9	20.1	47.8	80.7	23.4	17.1	50.5	74.2	23.1	30.1
<i>Gnatholepis thompsoni</i>	Goldspot goby	92.4	59.3	55.7	30.3	***	78.6	142.4	48.0	57.5	61.6	36.4	49.8
<i>Lutjanus jocu</i>	Dog snapper	50.3	60.3	83.9	96.7	82.8	84.1	41.1	43.9	58.8	72.9	40.5	42.8
# Species with													
	$P_e > P_n$	$P_n > P_e$		$P_e \gg P_n$									
WFG Aug. 96	34	31		1									
EFG Aug. 96	30	22		5									
WFG June 97	38	12		6									
EFG June 97	42	7		7									
WFG Aug. 97	14	33		10									
EFG Aug. 97	6	45		6									

* WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

TABLE 5. Summary values for the 56 most frequent species. Species are categorized into three groups according to power (P), based on minimum detectable change (MDC) in abundance score. Percent sighting frequency (%SF), the difference between expert (e) %SF and nonexpert (n) %SF ($\Delta\%SF_{e-n}$), the difference between density scores (ΔD_{e-n}), MDC for experts (MDC_e) and nonexperts (MDC_n), and the difference between MDC levels (ΔMDC_{e-n}) are given. An asterisk (*) indicates species with an average MDC level of 20% or better.

Species	Common name	%SF (%)	$\Delta\%SF_{e-n}$ (%)	ΔD_{e-n}	MDC_e (%)	MDC_n (%)	ΔMDC_{e-n} (%)
<i>Group I: $P_n > P_e$</i>							
<i>Aulostomus maculatus</i>	Trumpetfish	23.5	0.0	-0.05	80.9	50.2	30.7
<i>Pomacanthus paru</i>	French angelfish	37.3	6.5	-0.12	55.9	36.8	19.1
<i>Caranx hippos</i>	Crevalle jack	29.7	0.6	0.36	87.4	70.8	16.6
<i>Abudefduf saxatilis</i>	Sergeant major	44.7	9.1	-0.14	48.2	33.7	14.5
<i>Bodianus pulchellus</i>	Spotfin hogfish	21.7	25.0	-0.02	78.5	64.7	13.8
<i>Mycteroperca tigris</i>	Tiger grouper	42.5	14.5	0.03	43.3	34.2	9.1
<i>Caranx lugubris</i>	Black jack	24.1	17.7	-0.22	71.8	63.2	8.6
<i>Holocentrus rufus</i>	Longspine squirrelfish	30.6	12.9	0.02	56.7	48.5	8.3
<i>Holacanthus ciliaris</i>	Queen angelfish	58.2	12.5	-0.08	32.5	25.2	7.3
<i>Lutjanus jocu</i>	Dog snapper	22.2	13.6	-0.18	66.8	59.6	7.2
<i>Acanthurus chirurgus</i>	Doctorfish	52.3	12.3	0.01	35.2	28.1	7.2
<i>Chaetodon ocellatus</i>	Spotfin butterflyfish	43.0	13.9	-0.05	39.4	32.6	6.9
<i>Caranx latus</i>	Horse-eye jack	38.5	17.8	-0.13	52.7	46.0	6.7
<i>Cantherhines macrocerus</i>	Whitespotted filefish	36.3	19.9	-0.03	46.0	40.0	6.0
<i>Sphyræna barracuda</i>	Great barracuda*	96.6	-0.3	-0.01	10.8	6.1	4.7
<i>Chaetodon aculeatus</i>	Longsnout butterflyfish	70.2	9.4	0.19	26.5	21.8	4.7
<i>Pseudupeneus maculatus</i>	Spotted goatfish	34.2	17.0	0.08	52.9	49.3	3.5
<i>Holacanthus tricolor</i>	Rock beauty*	81.9	5.7	-0.05	17.8	14.4	3.4
<i>Microspathodon chrysurus</i>	Yellowtail damselfish*	71.8	13.0	-0.23	21.9	18.7	3.2
<i>Chromis cyanea</i>	Blue chromis*	95.8	0.8	0.01	10.3	7.5	2.8
<i>Kyphosus sectatrix/incisor</i>	Bermuda chub/yellow chub*	80.3	10.1	-0.01	16.6	14.5	2.1
<i>Melichthys niger</i>	Black durgon*	86.8	7.6	0.09	14.8	12.7	2.1
<i>Acanthurus coeruleus</i>	Blue tang*	90.8	6.7	0.03	12.2	10.7	1.5
<i>Group II: $P_n \approx P_e$</i>							
<i>Caranx ruber</i>	Bar jack	40.3	25.6	-0.23	39.0	38.2	0.8
<i>Canthidermis sufflamen</i>	Ocean triggerfish	48.8	23.8	0.07	31.5	30.9	0.6
<i>Stegastes partitus</i>	Bicolor damselfish*	89.7	7.6	0.29	11.2	11.1	0.2
<i>Chaetodon sedentarius</i>	Reef butterflyfish*	90.6	8.9	0.05	9.8	10.0	-0.2
<i>Sparisoma viride</i>	Stoplight parrotfish*	90.1	9.2	0.18	11.0	11.3	-0.2
<i>Scarus taeniopterus</i>	Princess parrotfish*	80.5	14.0	0.36	16.2	16.6	-0.4
<i>Canthigaster rostrata</i>	Sharpnose puffer*	81.9	14.3	0.18	15.3	15.9	-0.6
<i>Lactophrys triqueter</i>	Smooth trunkfish*	78.5	15.9	0.14	16.3	17.3	-1.0

TABLE 5. Continued.

Species	Common name	%SF (%)	$\Delta\%SF_{c-n}$ (%)	ΔD_{c-n}	MDC _c (%)	MDC _n (%)	ΔMDC_{c-n} (%)
<i>Group III: $P_e > P_n$</i>							
<i>Emmelichthys atlanticus</i>	Bonnetmouth	39.2	16.6	0.23	26.7	28.0	-1.2
<i>Scarus vetula</i>	Queen parrotfish*	92.9	7.1	0.35	7.9	9.2	-1.4
<i>Thalassoma bifasciatum</i>	Bluehead*	93.7	6.0	0.53	8.4	10.1	-1.7
<i>Stegastes planifrons</i>	Threespot damselfish*	82.3	16.0	0.63	13.8	16.2	-2.4
<i>Chromis multilineata</i>	Brown chromis*	89.3	11.2	0.23	6.0	9.7	-3.7
<i>Halichoeres garnoti</i>	Yellowhead wrasse	73.1	23.5	-0.18	18.6	22.8	-4.2
<i>Epinephelus cruentatus</i>	Graysby*	73.2	23.0	0.18	17.4	21.6	-4.2
<i>Stegastes variabilis</i>	Cocoa damselfish*	75.4	24.0	0.12	16.3	20.6	-4.3
<i>Cantherhines pullus</i>	Orangespotted filefish	45.6	32.4	0.07	31.6	36.0	-4.4
<i>Clepticus parrae</i>	Creole wrasse	44.7	30.9	0.04	29.7	34.9	-5.1
<i>Bodianus rufus</i>	Spanish hogfish*	81.9	20.5	0.20	11.9	17.2	-5.2
<i>Acanthurus bahianus</i>	Ocean surgeonfish	61.3	32.2	0.20	20.8	27.3	-6.5
<i>Mulloidichthys martinicus</i>	Yellow goatfish*	75.2	26.6	0.18	13.2	19.9	-6.7
<i>Amblycirrhitus pinos</i>	Redspotted hawkfish	39.6	31.9	0.04	36.6	45.8	-9.2
<i>Paranthias furcifer</i>	Creolefish*	74.5	28.4	0.48	8.9	18.3	-9.4
<i>Sparisoma aurofrenatum</i>	Redband parrotfish*	64.9	36.9	0.27	15.1	25.7	-10.6
<i>Gobiosoma oceanops</i>	Neon goby	55.3	36.0	0.04	24.4	35.0	-10.6
<i>Ophioblennius atlanticus</i>	Redlip blenny	34.2	23.2	0.12	44.2	55.1	-10.9
<i>Chromis scotti</i>	Purple reeffish	44.1	42.7	0.61	27.1	41.6	-14.6
<i>Halichoeres maculipinna</i>	Clown wrasse	39.2	40.5	0.00	32.6	48.0	-15.4
<i>Stegastes fuscus</i>	Dusky damselfish	27.3	30.6	0.12	55.8	74.2	-18.4
<i>Mycteroperca interstitialis</i>	Yellowmouth grouper	36.5	40.7	0.17	33.7	55.1	-21.4
<i>Gnatholepis thompsoni</i>	Goldspot goby	21.5	31.2	0.20	54.6	76.9	-22.3
<i>Chromis insolata</i>	Sunshinefish	30.2	25.2	0.10	56.2	84.6	-28.4
<i>Halichoeres radiatus</i>	Puddingwife	37.1	36.5	-0.06	37.7	70.1	-32.3

TABLE 6. Average minimum detectable change (MDC) in abundance scores. Values calculated using the top 30 most frequently sighted species for each survey, using the actual number of surveys conducted and a standardized sample size.

	Aug. 1996				June 1997				Aug. 1997			
	WFG		EFG		WFG		EFG		WFG		EFG	
	Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Non-expert	Expert	Advanced non-expert	Expert	Advanced non-expert	Expert
Actual n	88	27	72	28	53	24	28	20	85	30	76	22
Average MDC (%; n = actual)	17.7	15.7	16.5	17.5	24.6	16.7	23.3	16.9	15.9	17.0	13.9	20.9
Average MDC (%; n = 27)	32.0	15.7	27.0	17.8	34.4	15.8	23.7	14.6	28.3	17.9	23.3	18.8

^a WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

value of 20% or better, and 21 of these had an average nonexpert MDC value of 20% or better. Furthermore, all species with an average MDC value of 20% or better also had an average %SF of 65% or more. The 23 species with high power and %SF represent an ecologically diverse range of reef fishes, including all trophic levels and several different ecological roles. For example, the great barracuda (*S. barracuda*) is a highly mobile, pelagic piscivore, whereas the threespot damsel (*Stegastes planifrons*) is a territorial, reef-dwelling herbivore. The combination of high power and high sighting frequency in these species suggests that they provide a sensitive monitor of change within the community.

When establishing monitoring programs, it is critical to employ a method that can detect change if it occurs, and therefore, it is desirable to increase accuracy in data collection. There are two ways of achieving this goal: increasing precision of the sampling technique or increasing the intensity of sampling (sample size). Goodall (1970) suggested that increasing sample effort is more effective. The strength of volunteer programs comes from the manpower. The ability to increase statistical power using more surveys is often easier than increasing the precision of the survey method. The power of nonexpert data was strongly influenced by sample size, as is evident by the difference in accuracy levels of the data when a standardized number of surveys (n = 27) was used in the analyses (Tables 2 and 6). Because coral reefs have naturally patchy fish distributions, large amounts of data are required to reduce variance and to distinguish trends. In this study, nonexpert data had power similar to that of data collected by experts, in part because of the larger amount of nonexpert data collected.

As this program continues to grow, care

must be taken in evaluating the utility of these data. This study is the first step in gaining a better understanding of the advantages and drawbacks of the REEF program and its database. The economy of effort and the large volume of data collected are this program's greatest advantages. The standardized census method, applied over a wide geographic range, will provide a consistency in the data collection effort that is not often available. Such a large amount of electronic information, housed in a publicly accessible database, should not be ignored. The challenge lies in identifying its potential applications in science, conservation, and management. The utility of the data in other areas of the tropical western Atlantic and elsewhere (e.g., temperate reef assemblages) will need to be assessed. In addition, the standards and quality of volunteer training must be continually monitored and updated as needed.

Data presented in this paper demonstrate that, given similar sample sizes, experts had higher accuracy, but the increased sample effort of nonexperts provided data with comparable power. Most volunteer monitoring will provide considerably more nonexpert data than expert data. This, combined with the increase in nonexpert accuracy that results from experience, provides support for the use of nonexpert data by resource managers and scientists. Such data are a valuable element in environmental monitoring programs. In addition, the value of enrolling the public in science and monitoring activities and of the increased sense of ownership by the public cannot be underestimated and clearly enhances the management and protection of the area.

ACKNOWLEDGMENTS

The authors extend thanks to the dive team, L. Akins, G. Bunch, S. Gittings, T. Sebastian, L.

Walsh, and L. Whaylen, and to all of the REEF volunteers who participated in the field surveys. This project would not have occurred without the support of REEF and the FGBNMS. Funding and support for this project were provided by Texaco Exploration and Production, Inc.; SeaSpace, Inc.; the Gulf of Mexico Foundation; the Texas A&M University Woman's Faculty Network; the International Women's Fishing Association; Rinn Boats; and the staffs of the FGBNMS and REEF. B. Waltenberger produced the map. The support of D. Owens and S. Gittings is also appreciated.

LITERATURE CITED

- BOHNSACK, J. A. 1996. Two visually based methods for monitoring coral reef fishes, *In*: A coral reef symposium on practical, reliable, low cost monitoring methods for assessing the biota and habitat conditions of coral reefs, Jan 26–27, 1995. M. P. Crosby, G. R. Gibson, and K. W. Potts (eds.). Office of Ocean and Coastal Resource Management, NOAA, Silver Spring, MD.
- , AND S. BANNEROT. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report, NMFS 41, 15 p.
- BRIGHT, T. J. 1977. Coral reefs, nepheloid layers, gas seeps and brine flows on hard-banks in the northwestern Gulf of Mexico. Third Int. Coral Reef Symp. 1:39–46.
- ECKBLAD, J. W. 1991. How many samples should be taken? *BioScience* 41(5):346–348.
- GOODALL, D. W. 1970. Statistical plant ecology. *Ann. Rev. Ecol. Syst.* 1:99–124.
- HUMANN, P., AND N. DELOACH. 1994. Reef fish identification. 2d ed. New World Publications, Inc., Jacksonville, FL.
- LUDWIG, J. A., AND J. F. REYNOLDS. 1988. Statistical ecology. John Wiley and Sons, New York, NY.
- PATTENGILL, C. V. 1998. The structure and persistence of reef fish assemblages of the Flower Garden Banks National Marine Sanctuary. Ph.D. thesis, Texas A&M Univ. College Station, TX.
- , B. X. SEMMENS, AND S. R. GITTINGS. 1997. Reef fish trophic structure at the Flower Garden Banks and Stetson Bank, NW Gulf of Mexico. 8th Inter. Coral Reef Symp. 1:1023–1028.
- PETERMAN, R. M. 1990. Statistical power analysis can improve fisheries research and management. *Can. J. Fish. Aquat. Sci.* 47:2–15.
- REESE, E. S. 1993. Reef fish as indicators of conditions on coral reefs, p. 59–65. *In*: Colloquium on global aspects of coral reefs: health, hazards, and history. R. N. Ginsberg (ed.). Miami, FL.
- ROBINS, C. R., G. C. RAY, AND J. DOUGLASS. 1986. Peterson field guides—Atlantic Coast fishes. Houghton Mifflin, New York.
- ROHLF, F. J., AND R. R. SOKAL. 1981. Confidence limits for percentages (Table 23). *Statistical tables*. 2d ed. W. H. Freeman and Co., New York.
- SALE, P. F. 1991. The ecology of fishes on coral reefs. Academic Press, Inc., San Diego.
- SCHMITT, E. (COMPILER). 1996. Status of reef fishes in the Florida Keys National Marine Sanctuary. The Nature Conservancy, Miami, FL.
- SCHMITT, E. F., D. W. FEELEY, AND K. M. SULLIVAN (EDS.). 1998. Surveying coral reef fishes: a manual for data collection, processing, and interpretation of fish survey information for the tropical northwest Atlantic. The Nature Conservancy, Marine Conservation Science Center, Coral Gables, FL.
- , B. X. SEMMENS, AND K. M. SULLIVAN. 1993. Research applications of volunteer generated coral reef fish surveys. The Nature Conservancy, Miami, FL.
- , AND K. M. SULLIVAN. 1996. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. *Bull. Mar. Sci.* 59(2):404–416.
- SPELLERBERG, I. F. 1991. Monitoring ecological change. Cambridge University Press, New York.
- STOKES, F. J. 1980. Handguide to the coral reef fishes of the Caribbean and adjacent tropical waters including Florida, Bermuda, and the Bahamas. Lippincott and Crowell Publications New York.
- VIADA, S. T. 1996. Long-term monitoring at the East and West Flower Garden Banks. Proc. 15th Information Transfer Meeting, December 1995, OCS study 96-0056. p. 55–62.
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