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

Christy V. Pattengill-Semmens
Reef Environmental Education Foundation

Brice X. Semmens
National Center for Ecological Analysis and Synthesis

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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 $\beta$, 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 (Ekblad, 1991). Effect size, significance level ($\alpha$), 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 0.85 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-
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 precruise 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 log10 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

\[ D = \frac{(n_S \times 1) + (n_F \times 2) + (n_M \times 3) + (n_A \times 4)}{n_S + n_F + n_M + n_A}, \]

where \( n_S \), \( n_F \), \( n_M \), and \( n_A \) represent the number...
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 (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 (α = 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).
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/incisior), great barracuda (Sphyraena 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 that of other nonexperts. Furthermore, in all three trips, nonexpert survey 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. 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-

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**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 > 2).a

<table>
<thead>
<tr>
<th></th>
<th>Aug. 1996</th>
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<tbody>
<tr>
<td></td>
<td>WFG</td>
<td>75.2</td>
<td>74.0</td>
</tr>
<tr>
<td></td>
<td>EFG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% J all</td>
<td>WFG</td>
<td>88.2</td>
<td>90.4</td>
</tr>
<tr>
<td>spp. incl.</td>
<td>EFG</td>
<td></td>
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</tr>
</tbody>
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a WFG = West Flower Garden Banks; EFG = East Flower Garden Banks.

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

<table>
<thead>
<tr>
<th></th>
<th>Aug. 1996</th>
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<tbody>
<tr>
<td></td>
<td>WFG</td>
<td>93</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>EFG</td>
<td>83</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>WFG</td>
<td>95</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>EFG</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>WFG</td>
<td>100</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>EFG</td>
<td>102</td>
<td>102</td>
</tr>
</tbody>
</table>

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 values 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 (bennies, 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 species 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 (Pn) and expert (Pc) 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 (%).*

<table>
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<tr>
<td>Chromis cyanea</td>
<td>Blue chromis</td>
<td>6.3</td>
<td>7.4</td>
<td>6.9</td>
<td>10.5</td>
<td>10.7</td>
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<td>Great barracuda</td>
<td>5.4</td>
<td>7.1</td>
<td>6.8</td>
<td>11.0</td>
<td>6.0</td>
<td>11.3</td>
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<td>Chaetodon sedentarius</td>
<td>Reef butterflyfish</td>
<td>14.2</td>
<td>10.5</td>
<td>6.3</td>
<td>10.4</td>
<td>13.5</td>
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<td>Bluehead</td>
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<td>5.6</td>
<td>10.1</td>
<td>5.6</td>
<td>9.4</td>
<td>6.1</td>
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<tr>
<td>Melichthys niger</td>
<td>Black durgon</td>
<td>13.2</td>
<td>11.5</td>
<td>10.0</td>
<td>7.8</td>
<td>17.2</td>
<td>22.0</td>
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<tr>
<td>Sparisoma viride</td>
<td>Stoplight parrotfish</td>
<td>12.1</td>
<td>12.4</td>
<td>9.5</td>
<td>8.2</td>
<td>16.0</td>
<td>12.7</td>
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<td>Acanthurus coeruleus</td>
<td>Blue tang</td>
<td>9.5</td>
<td>10.5</td>
<td>10.3</td>
<td>7.9</td>
<td>14.2</td>
<td>10.9</td>
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<td>Bodianus rufus</td>
<td>Spanish hogfish</td>
<td>14.0</td>
<td>11.2</td>
<td>14.1</td>
<td>8.2</td>
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<td>8.7</td>
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<td>Kyphosus sectatrix/incipor</td>
<td>Bermuda/yellow club</td>
<td>14.1</td>
<td>12.6</td>
<td>18.7</td>
<td>35.0</td>
<td>12.0</td>
<td>17.4</td>
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<td>Queen parrotfish</td>
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<td>8.7</td>
<td>8.3</td>
<td>8.4</td>
<td>8.4</td>
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<td>Stegastes partitus</td>
<td>Bicolor damselfish</td>
<td>10.2</td>
<td>16.0</td>
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<td>Brown chromis</td>
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<td>Princess parrotfish</td>
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<td>12.8</td>
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<td>19.3</td>
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<td>13.6</td>
<td>18.1</td>
<td>16.0</td>
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<td>31.0</td>
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<td>Creolefish</td>
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*Pert R.e:pert MDC.

Note: Values indicate percent (%).
### Table 4. Continued.

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

https://aquila.usm.edu/goms/vol16/iss2/9

DOI: 10.18785/goms.1602.09
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 (Δ%SF<sub>e-n</sub>), the difference between density scores (ΔD<sub>e-n</sub>), MDC for experts (MDC<sub>e</sub>) and nonexperts (MDC<sub>n</sub>), and the difference between MDC levels (ΔMDC<sub>e-n</sub>) are given. An asterisk (*) indicates species with an average MDC level of 20% or better.

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<tr>
<th>Species</th>
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<th>MDC&lt;sub&gt;e&lt;/sub&gt; (%)</th>
<th>MDC&lt;sub&gt;n&lt;/sub&gt; (%)</th>
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<td>-4.3</td>
</tr>
<tr>
<td><em>Cantherhines pulchus</em></td>
<td>Orangespotted filefish</td>
<td>45.6</td>
<td>32.4</td>
<td>0.07</td>
<td>31.6</td>
<td>36.0</td>
<td>-4.4</td>
</tr>
<tr>
<td><em>Clepticus parrae</em></td>
<td>Creole wrase</td>
<td>44.7</td>
<td>30.9</td>
<td>0.04</td>
<td>29.7</td>
<td>34.9</td>
<td>-5.1</td>
</tr>
<tr>
<td><em>Bodianus rufus</em></td>
<td>Spanish hogfish*</td>
<td>81.9</td>
<td>20.5</td>
<td>0.20</td>
<td>11.9</td>
<td>17.2</td>
<td>-5.2</td>
</tr>
<tr>
<td><em>Acanthurus bahianus</em></td>
<td>Ocean surgeonfish</td>
<td>61.3</td>
<td>32.2</td>
<td>0.20</td>
<td>20.8</td>
<td>27.3</td>
<td>-6.5</td>
</tr>
<tr>
<td><em>Mullidichthys martinicus</em></td>
<td>Yellow goatfish*</td>
<td>75.2</td>
<td>26.6</td>
<td>0.18</td>
<td>13.2</td>
<td>19.9</td>
<td>-6.7</td>
</tr>
<tr>
<td><em>Amblycirrhitus pinos</em></td>
<td>Redspotted hawfish</td>
<td>39.6</td>
<td>31.9</td>
<td>0.04</td>
<td>36.6</td>
<td>45.8</td>
<td>-9.2</td>
</tr>
<tr>
<td><em>Paranthias furcifer</em></td>
<td>Creolefish*</td>
<td>74.5</td>
<td>28.4</td>
<td>0.48</td>
<td>8.9</td>
<td>18.3</td>
<td>-9.4</td>
</tr>
<tr>
<td><em>Sparisoma auriferum</em></td>
<td>Redband parrotfish*</td>
<td>64.9</td>
<td>36.9</td>
<td>0.27</td>
<td>15.1</td>
<td>25.7</td>
<td>-10.6</td>
</tr>
<tr>
<td><em>Gobiosoma oceanops</em></td>
<td>Neon goby</td>
<td>55.3</td>
<td>35.0</td>
<td>0.04</td>
<td>24.4</td>
<td>35.0</td>
<td>-10.6</td>
</tr>
<tr>
<td><em>Ophioblennius atlanticus</em></td>
<td>Redlip blenny</td>
<td>54.2</td>
<td>23.2</td>
<td>0.12</td>
<td>44.2</td>
<td>55.1</td>
<td>-10.9</td>
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<tr>
<td><em>Chromis scotti</em></td>
<td>Purple reeffish</td>
<td>44.1</td>
<td>42.7</td>
<td>0.61</td>
<td>27.1</td>
<td>41.6</td>
<td>-14.6</td>
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<tr>
<td><em>Halichoeres maculipinna</em></td>
<td>Clown wrase</td>
<td>39.2</td>
<td>40.5</td>
<td>0.00</td>
<td>32.6</td>
<td>48.0</td>
<td>-15.4</td>
</tr>
<tr>
<td><em>Stegastes fuscus</em></td>
<td>Dusky damselfish</td>
<td>27.3</td>
<td>30.6</td>
<td>0.12</td>
<td>55.8</td>
<td>74.2</td>
<td>-18.4</td>
</tr>
<tr>
<td><em>Mycteroperca interstitialis</em></td>
<td>Yellowmouth grouper</td>
<td>36.5</td>
<td>40.7</td>
<td>0.17</td>
<td>33.7</td>
<td>55.1</td>
<td>-21.4</td>
</tr>
<tr>
<td><em>Gnatholepis thompsoni</em></td>
<td>Goldspot goby</td>
<td>21.5</td>
<td>31.2</td>
<td>0.20</td>
<td>54.6</td>
<td>76.9</td>
<td>-22.3</td>
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<tr>
<td><em>Chromis insolata</em></td>
<td>Sunshinefish</td>
<td>30.2</td>
<td>25.2</td>
<td>0.10</td>
<td>56.2</td>
<td>84.6</td>
<td>-28.4</td>
</tr>
<tr>
<td><em>Halichoeres radiatus</em></td>
<td>Puddingwife</td>
<td>37.1</td>
<td>36.5</td>
<td>-0.06</td>
<td>37.7</td>
<td>70.1</td>
<td>-32.3</td>
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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 high %SF represent an ecologically diverse range of reef fishes, including all trophic levels and several different ecological roles. For example, the great barracuda (S. m. m仓) 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.

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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. Wattenberger produced the map. The support of D. Owens and S. Gittings is also appreciated.

**Literature Cited**


(CVPS) Reef Environmental Education Foundation, P.O. Box 246, Key Largo, Florida 33037; and (BXS) National Center for Ecological Analysis and Synthesis, 735 State Street, Suite 300, Santa Barbara, California 93101-5504. Date accepted: June 21, 1998.