Fish Census Data Generated by Non-experts In the Flower Garden Banks National Marine Sanctuary

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Using non-experts 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 non-expert data. We examined the quality of fish census data generated by Reef Environmental Education Foundation (REEF) volunteers of varying experience levels (non-experts), 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 (FGBNMS). Species composition and structure were comparable between the skill levels. Non-expert datasets were similar to expert datasets, 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 use of non-expert 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 years (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 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 inter-relationships 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

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on reef fish communities and, because they are non-extractive, such methods are ideal for marine protected areas or 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_o) of static condition and (2) calculation of β, the probability of failing to reject a false H_o (Peterman, 1990). Statistical power, or $1-\beta$, is the probability that the rejected H_o 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 dataset (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 powerful 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 by either increasing sample size or sampling precision.

Traditionally, scientists have been responsible for data collection in natural systems. They provide accurate but often limited information. The use of non-expert 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 scientists. A clear understanding of the statistical power and limitations of non-expert data is necessary for resource managers and researchers to use them effectively.

The Reef Environmental Education Foundation (REEF)[*] is a non-profit organization that educates and trains volunteer sport divers to collect fish distribution and abundance data. REEF, with support from The Nature

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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; Schmitt et al., 1998). The REEF/TNC database, initiated in 1994, is publicly accessible 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 (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 dataset is analogous to Audubon's annual bird counts conducted by hundreds of thousands of non-professional birdwatchers 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 (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 non-expert 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, representing approximately 800 hours of survey time. The purpose of this study was to evaluate the utility and limitations of this large dataset, and initiate discussions on the management and conservation applications of the REEF program. The similarity and statistical power of the RDT data generated by non-experts 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, Texas and are 21 km apart (EFG- 27°54.5'N, 93°36.0'W; WFG- 27°52.5'N, 93°49.0'W; Figure 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 m and 21 m, respectively, and the total area of the high diversity zones is 1.08 km^2 and 0.35 km^2, 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. Both banks lack nearby shallow, vegetated habitat such as seagrasses or mangroves that could act as "nursery areas" or larval settlement areas Mexico may act as "stepping stones" for dispersal or as nurseries for hard bottom associated fishes (Pattengill et al., 1997).

Data Collection—The fish assemblages of the EFG and WFG were visually censused during three REEF field survey cruises, using the Roving Diver Technique (RDT) (Schmitt et al., 1993; Schmitt and Sullivan, 1996). Each cruise consisted of REEF participants (non-experts 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 two years prior to this study. All non-experts participated in a three-hour pre-cruise training course as well as on-going 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], Abundant [>100]) were assigned to each species observed. Dive times varied, generally between 30 and 45 minutes, 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 preprinted 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 non-expert and expert data from each cruise and bank were analyzed separately. To evaluate the application of non-expert data to resource monitoring and management, several comparative analyses were performed between the non-experts 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:

$$D= ((n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)) / (n_S + n_F + n_M + n_A),$$

where n_S, n_F, n_M, and n_A represent the number of times each abundance category was assigned for a given species. This measure does not account for non-sightings 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:

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

Species richness during each cruise was compared between the non-expert and expert surveyors. 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 non-experts and experts, respectively, and C was the number of species recorded by both skill groups. This coefficient was calculated for each skill level for each cruise. J was also calculated using only 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 percentage deviation from the true mean, as a function of sample size. The accuracy of the mean is the minimum detectable change (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, density scores and the MDC levels between the two skill groups was done. To examine the effect of sample size on estimated power of non-expert data, the MDC 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 August 1996, June 1997 and August 1997 lasting five, four and five days, respectively. During each cruise, the WFG was surveyed first. Sixty-one divers completed 553 surveys during the three cruises (Table 1). Fifty-two non-experts participated. The non-experts on the August 1997 trip were considered "advanced non-experts" 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 S.D.) minutes. The August 1996 and August 1997 cruises had a similar number of survey hours (Table 1). The June 1997 cruise had considerably fewer because of the shorter cruise duration. Survey effort at each bank among each skill level was similar except for the non-expert June 1997 data.

Species richness recorded by non-experts was higher than that reported by the experts early in each field survey (WFG data), but was closer later in the cruise (EFG data) and during longer trips (August 1996 and August 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 non-experts 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 species recorded was considerably higher (88%-95%) when compared using only species seen by more than two divers (regardless of skill) 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 non-experts" on the August 1997 trip had lower MDC values than experts for most species, especially later in the week. Additionally, August 1996 non-expert data had considerably more species with lower MDC values than non-expert data from the shorter June 1997 trip.

The 56 most frequently sighted species were categorized according to MDC for experts and non-experts (Table 5). MDC of non-experts was lower than that from experts for 23 species. MDC from expert data was lower for non-experts for 25 species and MDC was similar (within 1%) for eight species. The average differences in %SF and D between experts and non-experts were 10.7% and -0.02, respectively, for species that non-expert 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.

To show the effect of sample size on the power of non-expert data, average MDC 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 non-expert data tended to be less accurate, but, a few species in each survey had smaller MDC levels in the non-expert data. These species included Bermuda chub/yellow chub (*Kyphosus sectatrix/incisor*), 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 non-expert" data had lower MDC levels than other non-experts. Furthermore, in all three trips non-expert 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 dataset 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 non-expert REEF participants revealed comparable data, given that a larger amount of non-expert 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 non-expert data probably were artificially inflated by misidentifications. The fact that expert surveyors consistently recorded higher species richness on the EFG than on the WFG, while non-experts did the opposite provided evidence of misidentifications. When large datasets 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.

Non-experts quickly gained experience during the four- and five-day surveys. Although there was little difference in the Jaccard values calculated from non-expert data collected early (WFG) or later (EFG) in each trip, the non-expert 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 non-expert" data provided further evidence of the influence even a minimal amount of experience had on power. The "advanced non-experts" on the August 1997 field survey generated data with smaller MDC values than the other two groups of non-experts. The Jaccard Coefficients for this group were consistently higher, indicating a high similarity in the species recorded by "advanced non-experts" and experts. For the "advanced non-experts", the average MDC value for all trips combined was 24.3%, considerably better than the average for the August 1996 non-experts (33.3%), June 1997 non-experts (47.7%), or experts (31.8%) (Table 19). In addition, this "advanced" group had more species with lower MDC levels than other non-experts and the experts (bottom of Table 4).

Due to higher sample size, non-experts 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, *Acanthurus coeruleus*; black durgon, *Melichthys niger*; rock beauty, *Holacanthus tricolor*; and bicolor damselfish, *Stegastes partitus*). Several were relatively rare (infrequently sighted) and the larger sample size of non-experts 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 in estimating abundance for species with several distinct life history stages (wrasses and parrotfishes), small cryptic species (blennies, gobies and hawkfish), planktivorous schooling species (brown chromis, *Chromis multilineata*; creolefish, *Paranthias furcifer*; and bonnetmouth, *Emmelichthyops atlanticus*) and 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 non-experts and experts made similar assignments to abundance categories. This was especially true in species that had higher power in non-expert data, as listed above. Though the relationship between a species' actual abundance on a reef and the density score 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 to 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 a 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 a good estimate 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% (Confidence Intervals for Percentages; Rohlf and Sokal, 1981). This narrow interval provides support 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. region-wide) than most scientific studies, and 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 to more accurately assess the condition of the system, in certain instances (e.g. rapid assessment analyses), it may be desirable to use a sub-set of the RDT data. Power analysis results can provide guidelines for managers to decide how "confident" they are in given component of the REEF dataset. Twenty-three of the species included in Table 5 had an average MDC value of 20% or better and 21 of these had an average non-expert 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 (*Sphyraena 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: 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 non-expert data was strongly influenced by sample size, as 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 distinguish trends. In this study, non-expert data had similar power to data collected by experts in part because of the larger amount of non-expert 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 better understanding 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 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 when needed.

Data presented in this paper demonstrate that, given similar sample size, experts had higher accuracy, but the increased sample effort of non-experts provided data with comparable power. Most volunteer monitoring will provide considerably greater non-expert data than expert data. This, combined with the increase in non-expert accuracy that results from experience, provides support for the use of non-expert data by resource managers and scientists as a valuable element of environmental monitoring programs. In addition, the value of enrolling the public in science and monitoring activities and 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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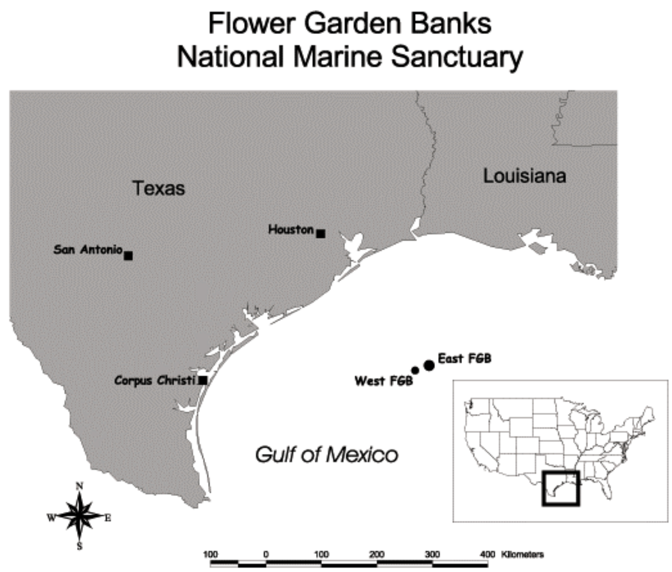

Figure 1. Map of Study Area.

Table 1. Number of expert and non-expert surveys conducted during each survey cruise.

	August 1996		June 1997		August 1997		
	WFG	EFG	WFG	EFG	WFG	EFG	Total
# non-expert 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
# non-expert surveyors	22		17		17		
# expert surveyors	7		9		6		

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

	August 1996				June 1997				August 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
Species Richness	93	83	91	90	95	91	94	104	104	92	103	102

Table 3. Similarity in species recorded by the two skill levels, as measured by Jaccard coefficient (J) values. Values were generated: 1) from the entire species list and 2) using only species seen in more than two surveys.

	August 1996		June 1997		August 1997	
	WFG	EFG	WFG	EFG	WFG	EFG
$J_{\text{all spp. incl.}}$ (%)	75.2	74.0	72.2	81.7	81.7	83.0
$J_{\text{spp. w/ } n_i > 2}$ (%)	88.2	90.4	95.0	91.5	91.7	90.8

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 species not recorded. A comparison of non-expert (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 non-expert MDC levels.

		August 1996				June 1997				August 1997			
		WFG		EFG		WFG		EFG		WFG		EFG	
species	common name	non-expert (%)	expert (%)	non-expert (%)	expert (%)	non-expert (%)	expert (%)	non-expert (%)	expert (%)	adv. non-expert (%)	expert (%)	adv. non-expert (%)	expert (%)
Chromis cyanea	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
Sphyraena barracuda	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
Chaetodon sedentarius	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
Thalassoma bifasciatum	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
Melichthys niger	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
Sparisoma viride	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
Acanthurus coeruleus	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
Bodianus rufus	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
Kyphosus sectatrix/incisor	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
Scarus vetula	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
Stegastes partitus	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
Chromis multilineata	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
Lactophrys triqueter	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
Holacanthus tricolor	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
Canthigaster rostrata	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
Scarus taeniopterus	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
Stegastes planifrons	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
Epinephelus cruentatus	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
Chaetodon aculeatus	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
Mulloidichthys martinicus	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
Paranthias furcifer	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
Halichoeres garnoti	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
Microspathodon chrysurus	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
Stegastes variabilis	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
Chromis insolata	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
Holacanthus ciliaris	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
Acanthurus bahianus	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
Emmelichthyops atlanticus	Bonnetmouth	47.9	26.3	20.9	27.2	***	***	***	***	23.8	25.2	19.3	28.2
Sparisoma aurofrenatum	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

Table 4. Continued.

species	common name	August 1996 WFG non-expert (%)	August 1996 WFG expert (%)	August 1996 EFG non-expert (%)	August 1996 EFG expert (%)	June 1997 WFG non-expert (%)	June 1997 WFG expert (%)	June 1997 EFG non-expert (%)	June 1997 EFG expert (%)	August 1997 WFG adv. non-expert (%)	August 1997 WFG expert (%)	August 1997 EFG adv. non-expert (%)	August 1997 EFG expert (%)
Chromis scotti	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
Canthidermis sufflamen	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
Gobiosoma oceanops	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
Caranx ruber	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
Clepticus parrae	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
Halichoeres radiatus	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
Acanthurus chirurgus	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
Caranx latus	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
Pomacanthus paru	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
Amblycirrhitus pinos	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
Halichoeres maculipinna	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
Caranx lugubris	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
Bodianus pulchellus	Spotfin Hogfish	92.6	37.4	***	102.8	69.9	26.3	65.1	54.4	36.0	42.1	60.0	208.0
Cantherhines pullus	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
Chaetodon ocellatus	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
Aulostomus maculatus	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
Stegastes fuscus	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
Mycteroperca interstitialis	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
Pseudupeneus maculatus	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
Mycteroperca tigris	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
Caranx hippos	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
Cantherhines macrocerus	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
Ophioblennius atlanticus	Redlip Blenny	39.2	19.1	29.1	18.3	121.8	***	62.1	47.4	47.7	89.6	30.9	46.6
Holocentrus rufus	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
Abudefduf saxatilis	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
Gnatholepis thompsoni	Goldspot Goby	92.4	59.3	55.7	30.3	***	78.6	142.4	48.0	57.5	61.6	36.4	49.8
Lutjanus jocu	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: $P_e > P_n$	$P_n > P_e$	Pe » Pn		# species with: $P_e > P_n$	$P_n > P_e$	Pe » Pn		# species with: $P_e > P_n$	$P_n > P_e$	Pe » Pn
WFG 8/96	34	31	1	WFG 6	38	12	6	WFG 8	14	33	10
EFG 8/96	30	22	5	EFG 6/	42	7	7	EFG 8/	6	45	6

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 non-expert (n) %SF (Δ%SF_{e-n}), the difference between density scores (ΔD_{e-n}), MDC for experts (MDC_e) and non-experts (MDC_n), and the difference between MDC levels ($\Delta\ MDC_{e-n}$) are given. An asterisk (*) indicates species with an average MDC level of 20% or better.

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

Table 5. Continued.

			%SF (%)	Δ %SF_{e-n} (%)	Δ D_{e-n}	MDC_e (%)	MDC_n (%)	Δ MDC_{e-n} (%)
			Group III: $P_e > P_n$					
	Bonnetmouth	*Emmelichthyops atlanticus*	39.2	16.6	0.23	26.7	28.0	-1.2
*	Queen Parrotfish	*Scarus vetula*	92.9	7.1	0.35	7.9	9.2	-1.4
*	Bluehead	*Thalassoma bifasciatum*	93.7	6.0	0.53	8.4	10.1	-1.7
*	Threespot Damselfish	*Stegastes planifrons*	82.3	16.0	0.63	13.8	16.2	-2.4
*	Brown Chromis	*Chromis multilineata*	89.3	11.2	0.23	6.0	9.7	-3.7
	Yellowhead Wrasse	*Halichoeres garnoti*	73.1	23.5	-0.18	18.6	22.8	-4.2
*	Graysby	*Epinephelus cruentatus*	73.2	23.0	0.18	17.4	21.6	-4.2
*	Cocoa Damselfish	*Stegastes variabilis*	75.4	24.0	0.12	16.3	20.6	-4.3
	Orangespotted Filefish	*Cantherhines pullus*	45.6	32.4	0.07	31.6	36.0	-4.4
	Creole Wrasse	*Clepticus parrae*	44.7	30.9	0.04	29.7	34.9	-5.1
*	Spanish Hogfish	*Bodianus rufus*	81.9	20.5	0.20	11.9	17.2	-5.2
	Ocean Surgeonfish	*Acanthurus bahianus*	61.3	32.2	0.20	20.8	27.3	-6.5
*	Yellow Goatfish	*Mulloidichthys martinicus*	75.2	26.6	0.18	13.2	19.9	-6.7
	Redspotted Hawkfish	*Amblycirrhitus pinos*	39.6	31.9	0.04	36.6	45.8	-9.2
*	Creole-fish	*Paranthias furcifer*	74.5	28.4	0.48	8.9	18.3	-9.4
*	Redband Parrotfish	*Sparisoma aurofrenatum*	64.9	36.9	0.27	15.1	25.7	-10.6
	Neon Goby	*Gobiosoma oceanops*	55.3	36.0	0.04	24.4	35.0	-10.6
	Redlip Blenny	*Ophioblennius atlanticus*	34.2	23.2	0.12	44.2	55.1	-10.9
	Purple Reeffish	*Chromis scotti*	44.1	42.7	0.61	27.1	41.6	-14.6
	Clown Wrasse	*Halichoeres maculipinna*	39.2	40.5	0.00	32.6	48.0	-15.4
	Dusky Damselfish	*Stegastes fuscus*	27.3	30.6	0.12	55.8	74.2	-18.4
	Yellowmouth Grouper	*Mycteroperca interstitialis*	36.5	40.7	0.17	33.7	55.1	-21.4
	Goldspot Goby	*Gnatholepis thompsoni*	21.5	31.2	0.20	54.6	76.9	-22.3
	Sunshinefish	*Chromis insolata*	30.2	25.2	0.10	56.2	84.6	-28.4
	Puddingwife	*Halichoeres radiatus*	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 (N=27).

	August 1996				June 1997				August 1997			
	WFG		EFG		WFG		EFG		WFG		EFG	
	non-expert	expert	non-expert	expert	non-expert	expert	non-expert	expert	adv. non-expert	expert	adv. 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