Research Applications of Volunteer Generated Coral Reef Fish Surveys

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ABSTRACT

The paucity of information on coral reef communities and funds to support full-scale censusing of Caribbean reefs have precipitated the need to explore the utility of volunteer observations for scientific assessment and monitoring. The objectives of this study were to investigate the quality of data collected by volunteers, to use these data to determine some characteristics of upper Florida Keys reef fish communities, and to explore the utility of this information in directing research management and conservation. The fish communities of five sites within the upper Florida Keys tract were surveyed by volunteer and technical observers. Volunteer observers were trained in the identification of fishes through classroom instruction and field work in a course taught by the Reef Environmental Education Foundation (REEF) and by studying *Reef Fish Identification* (Humann and DeLoach, 1989). When collected by 8-10 people surveying the same site at the same time, volunteer data can provide a valuable species list that uniquely characterizes the reef sites. Based on frequency of observation, fish species recorded at the five study sites were separated into three categories.

1). Fish species that were observed by greater than 70 percent of all divers at each site; ubiquitous fishes,

2) Fish species that were observed by greater than 50 percent but fewer than 70 percent of all divers at some dive sites; site-specific fishes.

3) Fish species that were seen by fewer than 50 percent of all divers at each site; cryptic, rare fishes, occasional reef visitors.

This frequency of occurrence data was analyzed to address ecological questions such as the distribution of fish at different reef sites and to characterize the reef fish communities of the upper Florida Keys reef tract.

INTRODUCTION

Role of Fishes on Reefs

Fishes have a prominant and important role in coral reef communities. As a whole, reef fishes have a very high level of diversity (Sale, 1991). The coral reef habitat contains many types of fish that are rare or absent from most other marine habitats. There are an estimated 4, 000 species of fish inhabiting coral reefs and associated habitats of the Indo-Pacific. This is roughly 18 percent of all living fishes (Springer, 1982). Bohlke and Chaplin (1993) have documented 567 tropical fishes on the reefs of the Bahamas and adjacent waters. Detailed species accounts of fish on these coral reefs have also been described by Starck (1968) and Humann and DeLoach (1989). In their discussion of the ecological role of fishes on reefs, Choat and Bellwood (1991) have mentioned that in

effect, coral reefs are habitat units that are replicated many times in tropical seas. They have indicated a need for more robust estimates of reef fish abundances. Choat and Bellwood (1991), continued to mention that it is becoming apparent from the increasing amount of data, that reef fishes tend to be long-lived and many tend to remain within a localized habitat for their entire lives. Many reef fishes are associated with distinctive structural and biotic features of the coral reef. For these reasons, coral reef fishes are important indicators of the state of the environment. By understanding more about fishes, we can gain increased insight into the workings of coral reef ecosystems as a whole.

Need For Information

Currently the Caribbean reef system is approaching a state of crisis. Reefs of the Florida Keys, where there are more than 4 million visitors a year, are showing signs of resource depletion (Richards and Bohnsack, 1990). The reef ecosystem is suffering from over-fishing, loss of habitat, and general resource decline. These concerns prompted the formation of the Florida Keys National Marine Sanctuary (FKNMS) in 1990. There is a great need for census data on coral reef fish communities and the development of an ongoing monitoring program in this area since reef fishes serve as indicators of reef health and community diversity (Sale, 1991). Volunteers are able to provide this information by gathering baseline data on species presence-absence and relative abundance. Our study shows that through the coordinated efforts of at least 8-10 trained observers, volunteers are able to provide information such as the number of fishes present, the number of species present, and the species composition of the reef fish community at various sites throughout the year.

Overview of Census Methods

Many data collection techniques have been employed to census reef fish, each with varying objectives, advantages, and disadvantages (Table 1). The Reef Environmental Education Foundation (REEF) has initiated a program of reef fish identification and survey training. It has general objectives and with the use of volunteers collects a wealth of data. Volunteer recreational divers are trained during a week-long course to identify fishes of the Caribbean region using the book *Reef Fish Identification* (Humann and DeLoach, 1989). The volunteer observers are allowed free swimming range over the entire reef site to gather fish community data. Throughout the census, volunteers record all of the species present, as well as the general abundance category of each species recorded. This method represents the simplest inventory survey, requiring the least amount of equipment or training (Table 1).

Table 1. Overview of reef census methods. The author for each method is given with a brief description of the protocol.

Technique (author)	Survey Objective	Description	Advantages	Disadvantages
Stationary Diver (Bohnsack & Bannerot, 1986)	To record the fish species present in a cylindrical cycle.	Diver records all fish which enter a 7.5m cylinder of view.	Diver is stationary; there is a precise area being sampled; fish are counted and lengths estimated.	Diver is unable to approach species for better identification; species outside the sample area may not be recorded.
Transect (Brock,1954)	To record the fish species present along a line in a rectangular plot.	Diver records fish seen while swimming along a transect of specific length,width dimensions	Divers count fish in a precise sampling area emphasis for surveying territorial or residential species.	Labor intensive; some fish may be disturbed by the line placement.
Timed Roving Diver (Jones & Thompson, 1978)	To record the fish species present on a general reef site.	Diver records species and notes the 10 minute interval in which fishes are seen while swimming around the site.	Diver surveys the entire reef site;	There is no precise area measurement; the abundance of fishes must be inferred from time intervals.
Roving Diver (REEF, 1993)	To employ trained volunteers to record the fishe species present on a general reef site.	Diver records the species and the abundance category of fishes seen during a recreational dive.	Diver surveys the entire reef site. Volunteers gather data effectively, inexpensively.	There is no precise area measurement; the exact abundance is not recorded.

Investigative Objectives

The objectives of this investigation are to analyze the REEF roving diver census method and how baseline data generated from this method can be used to address questions in coral reef ecology. There are several basic questions which we address throughout the study.

1). How valid are volunteer observations of reef fishes? What guidelines concerning data collection and analysis would strengthen the value of the data?

2). What are ecological characteristics of upper Florida Keys reef fish communities?

MATERIALS AND METHODS

Sites Selected

The fish communities of various reef sites along the upper Florida Keys reef tract were visually surveyed by 7-10 volunteer fish observers and 4-5 technical fish observers during the summer of 1993. During the week, 11 different reef sites were visited. Five of these sites were selected for further analysis. The sites surveyed were of different reef types with differing dominant benthic flora and and fauna. Some of these sites like The Statue, Little Grecian, Benwood and Carysfort are within the Key Largo National Marine Sanctuary. The Statue is very frequently visited while a site adjacent to it, Little Grecian, is much less frequently visited. The Benwood Wreck was the only artificial reef in the study and was situated in relatively deep water with a low relief spur and groove surrounding habitat. Pickles reef is in federal waters where spearfishing is allowed. These sites are all within the newly established Florida Keys National Marine Sanctuary. Pickles reef, The Statue and Little Grecian were shallow spur and groove reefs. Carysfort reef was a fore reef terrace which varied in depth from shallow to deep and the Benwood was also in deeper water. These dive sites are in popular recreational diving locations. All of these sites except for Little Grecian have mooring buoys. Table 2 presents a summary of the site characteristics.

Volunteer Training; Data Collection

Volunteer fish observers attended a course on the identification of reef fishes. The participants in this study involved themselves out of interest and paid a fee to participate in the course. The typical volunteer observer was defined as a sport diver who showed interest in reef fish identification. Technical observers have more experience in reef fish identification and sampling methods. They are involved in fish identification on a professional basis. At the beginning of the course, students were given a pre-test consisting of 30 fish slides. At the end of the course the students were given the same test. The students were asked to identify these fishes by family and species name. Common names were accepted as per Humann and DeLoach (1989). The scores from these tests were used as a

Table 2. A description of reef sites surveyed by REEF observers during the week of July 19-23, 1993. The location represents the mooring buoy or anchorage. (Sites arranged by location from North to South)

Site Name (dive#of the week)	Location	Max. Depth (m)	Reef Type	Dom. Flora	Dom. Fauna
Carysfort(11)	25°13.20N 80°12.63W	22.0	fore reef terrace	*Dictyota cervicornis* *Titanoderma* *Halimeda opuntia*	*Montastraea annularis* *Colpophyllia natans* *Mycetophyll ferox*
The Statue(3)	25°07.40N 80°17.80W	7.7	spur and groove	*Lobophora variegata* *Dictyota cervicornis* *D. bartayresii*	*Montastraea annularis* *Millepora complanata* *Erthropodim caribaeorum*
Little Grecian(4)	25°07.21N 80°17.95W	10.0	spur and groove	*Dictyota cervicornis* *Titanderma sp.* *Halimeda opuntia*	*Porites asteroides* *Millepora complanata* *Gorgonia ventalina*
Benwood(8)	25°03.50N 80°20.00W	16.0	artificial reef	*Dictyota cervicornis* *D. bartayresii*	*Siderastrea siderea* *Milleproa alcicornis*
Pickles(7)	24°59.17N 80°24.94W	9.0	spur and groove	*Titanoderma sp.* *Halimeda opuntia* *Dictyota cervicornis*	*Palythoa caribaeorum* *Millepora complanata* *Gorgonia ventalina*

measure of how much the students learned and thus to evaluate the proficiency of volunteer observers in reef fish identification. The technical divers were able to correctly identify all the fish during both the pre- and post-tests, indicating a high level of competency.

During the identification course, students were shown slides of fishes (Humann and DeLoach, 1989) and taught to identify species by recognizing distinctive body shapes, fin placements, behavior, and body coloration. The course consisted of approximately 12 hours of lecture and 12 dives (10 day dives and 2 night dives). There were a total of 17 observers throughout the week.

Each day the students were given classroom instruction in the morning and conducted two dives in the afternoon or evening. These dives were field surveys of the reef fish community. Each pair of volunteer fish observers worked in a research team with a technical fish observer. In this way, the volunteer observers could learn to identify fishes more quickly and accurately. The volunteers' observations could also be compared to the observations of the technical observers. During each survey dive, observers were allowed to swim freely around the dive site for 60 minutes and record on their underwater slates the different fish species that they individually observed. At the end of the survey, each observer filled out a computerized data scan form indicating which species they had seen and the relative abundance category (1, 2-10, 11-100, >100) of the species.

DATA ANALYSIS

At each site data concerning the fish community was collected. Several comparisons were made. The percent similarity of species observations between volunteer and technical observers in their research teams was determined and compared over time. For this analysis, the coefficient of Dice (Hubalek, 1982) was calculated between the presence/absence inventories from technical and volunteer observers. A measure of the degree of similarity between reef sites can be computed from this fish survey information in a similar way.

The number of fish species seen at each site be all observers, and by technical observers was determined. In addition, the cumulative number of fish species seen by all observers, by volunteer observers and by technical observers was calculated. The effort (number of observation hours) spent at each site and the cumulative number of species per diver-hour was recorded.

Once a volunteer observer completes a field census, he/she completed a computerized data form which are scanned through a computer. This data is then analyzed by different parameters such as reef site, date, and time of day. From this analysis, the species observations are sorted by frequency of occurrence. This sorts the reef fishes into 3 categories:

1) Fish species that were observed by greater than 70 percent of all divers at each site; ubiquitous fishes (Table 3)

2) Fish species that were observed by greater than 50 percent but fewer than 70 percent of all divers at some sites; site specific fishes (Table 4)

3) Fish species that were observed by fewer than 50 percent of all divers at each site; cryptic, rare fishes, occasional reef visitors, and possible identification errors (Table 5).

The ubiquitous and site-specific species are combined to form a verified fishes inventory. This is a working database of the fishes which characterize a particular study site. The rare, cryptic or pelagic data set is studied for recurring observations over time until any mis-identified species are removed and only the rare, pelagic fishes remain (Figure 1). This frequency of occurrence data was analyzed to address ecological questions such as the distribution of fish at different reef sites and to characterize the reef fish community of the upper Florida Keys reef tract.

Table 3. Species seen by greater than 70% of all observers at the dive site-Ubiquitous Species.

	The Statue	LittleGrecin	Pickles	Benwood	Carysfort
Acanthuridae(Surgeonfish)					
Acanthus bahianus	100	73	91	92	92
Acanthurus coeruleus	93	87	82	92	92
Lutjanidae(Snapper)					
Ocyurus chrysurus	86	87	91	100	92
Haemulidae(Grunt)					
Anisotremus virginicus	79	87	82	100	92
Pomacentridae(Damselfish)					
*Microspathodon chrysurus*93		80	100	77	100
Stegastes partitus	93	87	100	85	100
Scaridae(parrotfish)					
Sparisoma viride	100	87	82	85	92
Labridae(Wrasse)					
Thalassoma bifasciatum	100	80	82	92	83
Mullidae(Goatfish)					
Pseudupeneus maculatus	86	80	73	92	83

Table 4. Species seen by fewer than 70%but greater than 50% of all observers for at least one dive site-Site-Specific Species.

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Chaetodontidae (Butterflyfish)					
Chaetodon ocellatus	43	87	82	77	67
Chaetodon capristratus	79	53	55	92	100
Chaetodon striatus	29	20	55	0	67
Chaetodon sedentarius	21	27	27	77	50
Pomacanthidae (Angelfish)					
Holacanthus tricolor	71	53	73	92	92
Holacanthus ciliaris	86	100	9	69	58
Pomacanthus paru	57	100	55	62	17
Pomacanthus arcuatus	93	93	36	69	67
Acanthuridae (Surgeonfish)					
Acanthurus chirurgus	79	73	82	69	58
Carangidae(Jack)					
Caranx ruber	71	93	45	77	67
Kyphosidae(Chub)					
Kyphosus sectatrix	86	80	55	92	75
Gerreidae(Mojarra)					
Gerres cinereus	86	27	0	8	0
Ephippidae (Spadefish)					
Chaetodipterus faber	0	60	9	38	0
Sphyraenidae (Barracuda)					
Sphyraena barracuda	71	80	9	92	42
Centropomidae(Snook)					
Centropomus undecimalis	0	0	0	54	0
Lutjanidae(Snapper)					
Lutjanus apodus	71	73	64	100	67
Lutjanus mahogoni	86	87	64	69	92
Lutjanus griseus	71	80	45	69	50
Lutjanus analis	29	67	0	31	8
Lutjanus synagris	21	27	0	100	33
Haemulidae(Grunt)					
Haemulon sciurus	71	60	91	85	100

Table 4. Continued

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Haemulon macrostomum	79	73	45	69	58
Haemulon chrysargyreum	64	40	64	46	25
Haemulon plumieri	86	60	55	69	67
Haemulon carbonarium	50	40	73	62	42
Haemulon flavolineatum	79	67	91	69	92
Haemulon aurolineatum	57	47	9	69	50
Haemulon parrai	50	60	82	38	25
Anisotremus surinamensis	79	67	9	85	25
Pomacentridae(Damselfish)					
Stegastes fuscus	93	73	91	31	100
Stegastes diencaeus	57	60	55	15	67
Stegastes variabilis	86	67	55	23	58
Stegastes planifrons	86	87	73	69	92
Abudefduf saxatilis	100	93	100	69	100
Chromis cyanea	36	53	82	85	92
Chromis multilineata	57	73	82	77	33
Serranidae(Seabass)					
Hypoplectrus puella	21	53	0	38	0
Hypoplectrus unicolor	50	33	0	46	83
Hypoplectrus nigricans	29	40	0	0	58
Hypoplectrus gemma	14	13	0	69	92
Epinephelus striatus	21	67	0	8	0
Mycteroperca bonaci	64	47	18	85	25
Cephalopholis cruentata	36	40	45	85	58
Serranus tigrinus	93	73	45	77	42
Scaridae(Parrotfish)					
Scarus vetula	86	67	91	85	67
Scarus guacamaia	29	27	18	15	83
Scarus taeniopterus	64	53	91	85	83
Scarus coeruleus	57	47	9	85	17
Scarus iserti	43	60	0	15	42
Scarus coelestinus	21	60	0	15	42
Sparisoma aurofrenatum	71	60	82	46	75
Sparisoma rubripinne	86	53	45	23	67
Sparisoma atomarium	14	20	9	8	67
Labridae(Wrasse)					
Lachnolaimus maximus	57	73	55	77	67

Table 4. Continued

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Bodianus rufus	79	93	91	92	42
Halichoeres radiatus	79	67	64	15	58
Clepticus parrai	14	27	9	77	75
Halichoeres bivittatus	86	80	82	69	25
Halichoeres maculipinna	86	73	82	46	58
Holocentridae(Squirrelfish)					
Holocentrus adscensionis	21	13	55	62	58
Holocentrus rufus	0	0	55	62	25
Priacanthidae(Bigeye)					
Heteropriacanthus cruentatus	21	0	9	62	25
Gobiidae(Goby)					
Gobiosoma oceanops	57	60	64	54	58
Coryphopterus personatus	72	0	27	77	67
Blenniidae(Blenny)					
Ophioblennius atlanticus	7	7	64	0	0
Scorpaenidae(Scorpionfish)					
Scorpaena plumieri	21	7	91	38	17
Aulostomidae(Trumpetfish)					
Aulostomus maculatus	86	73	73	54	58
Tetradontidae(Puffer)					
Canthigaster rostrata	86	93	91	69	75
Ostraciidae(Boxfish)					
Lactophyrs quadricornis	36	53	18	23	25
Lactophrys triqueter	71	60	82	85	50
Monacanthidae(Filefish)					
Aluterus scriptus	21	67	9	62	58
Cantherhines macrocerus	0	0	0	54	0
Monacanthus tuckeri	57	0	0	0	17
Mullidae (Goatfish)					
Mulloidicthys martinicus	64	73	36	69	58
Pempheridae (Sweeper)					
Pempheris schomburgki	14	13	45	54	42
Dasyatidae (Stingray)					
Urolophus jamaicensis	50	60	9	15	0

Table 5. Species seen by fewer than 50% of all observers at each dive site-Cryptic, Rare, Pelagic Species.

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Pomacanthidae (Angelfish)					
Holacanthus bermudensis	14	20	9	8	0
Centropyge argi	7	0	0	0	0
Acanthuridae (Surgeonfish)					
Acanthurus randalli	0	13	0	15	0
Carangidae (Jack)					
Caranx crysos	7	13	0	8	0
Caranx bartholomaei	14	33	9	8	0
Caranx lugubris	0	7	0	0	0
Seriola rivoliana	36	7	0	8	0
Elagatis bipinnulata	7	7	0	0	0
Trachinotus falcatus	7	20	18	8	8
Sparidae (Porgy)					
Calamus calamus	7	13	9	8	0
Calamus bajonado	7	7	0	0	0
Sphyraenidae (Barracuda)					
Sphyraena picudilla	7	0	0	0	0
Scombridae (Mackeral)					
Scomberomorus regalis					
Belonidae(Needlefish)					
Tylosurus crocodilus	14	0	0	0	0
Silversides					
Silversides	29	27	27	0	8
Lutjanidae(Snapper)					
Lutjanus joco	7	13	0	3	18
Lutjanus cyanopterus	7	27	0	0	0
Haemulidae (Grunt)					
Haemulon striatum	7	13	27	15	17
Haemulon melanurum	0	0	9	0	0
Haemulon album	21	33	0	15	17
Pomacentridae (Damselfish)					
Stegastes leucostictus	50	33	36	31	42
Chromis insolata	0	0	0	0	42

Table 5. Continued

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Chromis scotti	0	27	0	31	8
Serranidae (Seabass)					
Hypoplectrus gummigatta	0	0	0	0	8
Hypoplectrus aberrans	0	0	0	0	8
Hypoplectrus guttavarius	0	0	0	0	8
Hypoplectrus chlorurus	0	7	0	0	8
Epinephelus morio	7	47	0	0	0
Mycteroperca venenosa	0	0	0	8	0
Mycteroperca interstitialis	0	0	0	23	0
Mycteroperca phenax	0	0	0	8	0
Mycteroperca tigris	7	0	0	0	0
Epinephelus adscensionis	0	0	0	0	8
Cephalopholis fulvus	0	0	0	23	8
Serranus tortugarum	0	0	0	0	8
Serranus tabacarius	0	0	18	15	8
Liopropoma rubre	0	0	0	46	8
Serranus baldwini	7	20	0	8	50
Alphestes afer	0	0	0	8	0
Paranthias furcifer	7	7	0	0	0
Diplectrum formosum	0	0	0	0	8
Scaridae (Parrotfish)					
Sparisoma chrysopterum	36	0	45	8	8
Sparisoma radians	0	7	0	8	0
Labridae (Wrasse)					
Bodianus pulchellus	7	7	0	0	8
Halichoeres pictus	0	7	0	0	0
H. cyanocephalus	0	7	0	0	8
Halichoeres poeyi	21	7	0	0	0
Doratonotus megalepis	7	33	9	0	0
Xyrichtys martinicensis	7	7	9	0	0
Xyrichtys splendens	21	20	45	8	8
Apogonidae (Cardinalfish)					
Apogon townsendi	0	7	0	0	0
Holocentridae (Squirrelfish)					
Neoniphon marianus	14	7	9	0	8
Sargocentron vexillarius	0	0	18	0	0

Table 5. Continued

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Myripristis jacobus	0	7	36	8	0
Priacanthidae (Bigeye)					
Priacanthus arenatus	0	0	18	0	42
Table 5. Continued					
Gobiidae (Goby)					
Gobiosoma genie	0	0	0	8	0
Gobiosoma macrodon	0	0	0	0	8
Gnatholepis thompsoni	14	33	9	38	17
Coryphopterus dicrus	50	47	45	38	25
Coryphopterus eidolon	0	20	27	38	8
C. glaucofraenum	43	47	45	38	25
Ioglossus helenae	7	7	18	23	0
Microgobius carri	0	0	27	0	0
Ioglossuscalliuris	0	20	0	38	0
Clinidae (Blenny)					
Malacoctenus triangulatus	14	7	9	0	0
Acanthemblemaria aspera	0	0	0	8	0
A. chaplini	0	0	9	0	0
A. spinosa	14	13	0	15	0
Blennidae (Blenny)					
Parablennius marmoreus	0	13	18	0	0
Callionymidae (Dragonet)					
Paradiplogrammus bairdi	14	13	0	0	0
Opistognathidae (Jawfish)					
Opistognathus aurifrons	7	0	27	23	0
Cirrhitidae (Hawkfish)					
Amblycirrhitus pinos	14	0	45	0	0
Synodontidae (Lizardfish)					
Synodus intermedius	0	0	9	0	25
Malacanthidae (Tilefish)					
Malacanthus plumieri	14	27	36	15	0
Diodontidae (Spiny Puffer)					
Diodon holocanthus	7	13	18	8	25
Diodon hystrix	7	33	9	23	8

Table 5. Continued

	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Chilomycterus atinga	0	0	9	0	0
Ostraciidae (Boxfish)					
Lactophrys polygonia	7	7	18	0	0
Lactophrys trigonus	14	7	18	8	0
Lactophrys bicaudalis	21	27	9	38	0
Balistidae(Triggerfish)					
Balistes vetula	14	0	0	0	0
Table 5. Continued					
Canthidermis sufflamen	0	0	0	0	8
Monacanthidae (Filefish)					
Aluterus schoepfi	36	7	0	0	0
Cantherhines pullus	43	33	27	23	42
Mullidae (Goatfish)					
Mullus auratus	0	0	9	0	0
Sciaenidae (Drum)					
Equetus punctatus	21	13	9	15	50
Equetus lanceolatus	0	7	0	0	0
Equetus acuminatus	0	33	0	0	0
Equetus umbrosus	0	0	0	8	0
Odontoscion dentex	0	27	36	8	17
Grammistidae(Soapfish)					
Rypticus saponaceus	0	0	18	0	0
Muraenidae (Moray)					
Gymnothorax funebris	7	20	0	0	0
Gymnothorax moringa	7	13	27	23	0
Gymnothorax miliaris	0	0	9	0	0
Dasyatidae(Stingray)					
Dasyatis americana	7	0	0	0	0

RESULTS

Based on the identification test composed of 30 species, the volunteers' average pre-test score was 36.57 percent compared to their average post-test score of 87.14 percent. Volunteer observers improved their fish identification skills by 138 percentage points during the week.

At each site data was collected such as the number of volunteers, number of technical observers, species observed by all observers, species observed by technical observers, and species observed by volunteer observers. The number

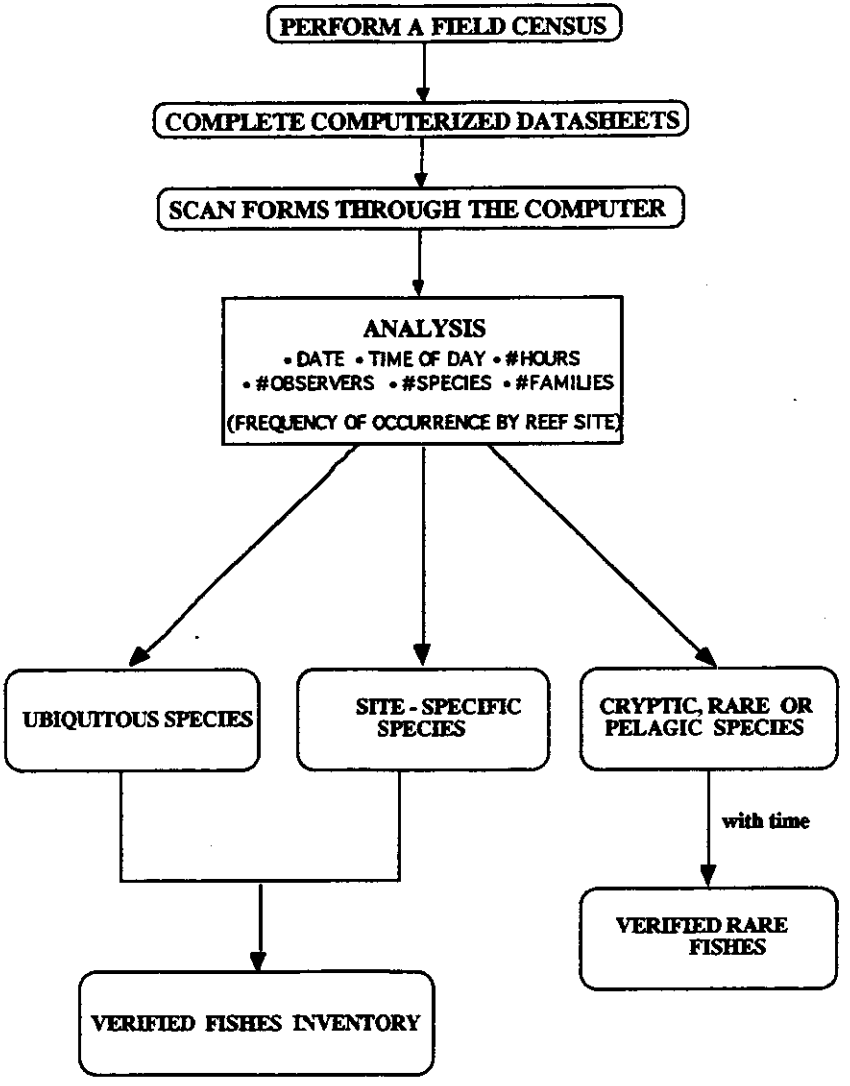

Figure 1. Reef Fish Community Survey Data Flow

Table 6. Summary of Survey Information (sites arranged by order of survey).

Site (Jurisdiction of site)	#volunteers	#technical	total obs hours	#species seen by tech.	#species seen by vols.	total#specie seen
The Statue (KLNMS)	9	5	14	105	124	133
Little Grecian (KLNMS)	10	5	15	104	135	138
Pickles (Federal)	7	4	11	97	106	119
Benwood Wreck (KLNMS)	9	4	13	102	124	128
Carysfort (KLNMS)	8	4	12	93	105	114

Table 7. Mean Number of Species Seen (1 Std. dev.) per Individual by Observer Type.

ObserverType	The Statue	Little Grecian	Pickles	Benwood	Carysfort
Volunteers Observers (mean, SD)	50.0 ±13.7	52.2 ±21.1	46.8 ±14.0	54.6 ±6.7	55.6 ±6.3
Technical Observers (mean, SD)	59.6 ±4.5	66.2 ±7.8	65.8 ±6.1	69.0 ±3.5	64.0 ±8.0

of fishes seen by the 7-10 volunteers was consistently higher than the number of fishes seen by the 4-5 technical fish observers. From these 5 survey sites, a total of 181 species were seen; 169 species were seen by volunteers and 154 species were seen by technical observers. In this analysis a total of 65 observation hours were spent underwater. Of the total amount of time spent underwater, 22 hours correspond to technical observations and 43 hours correspond to volunteer observations (Table 6).

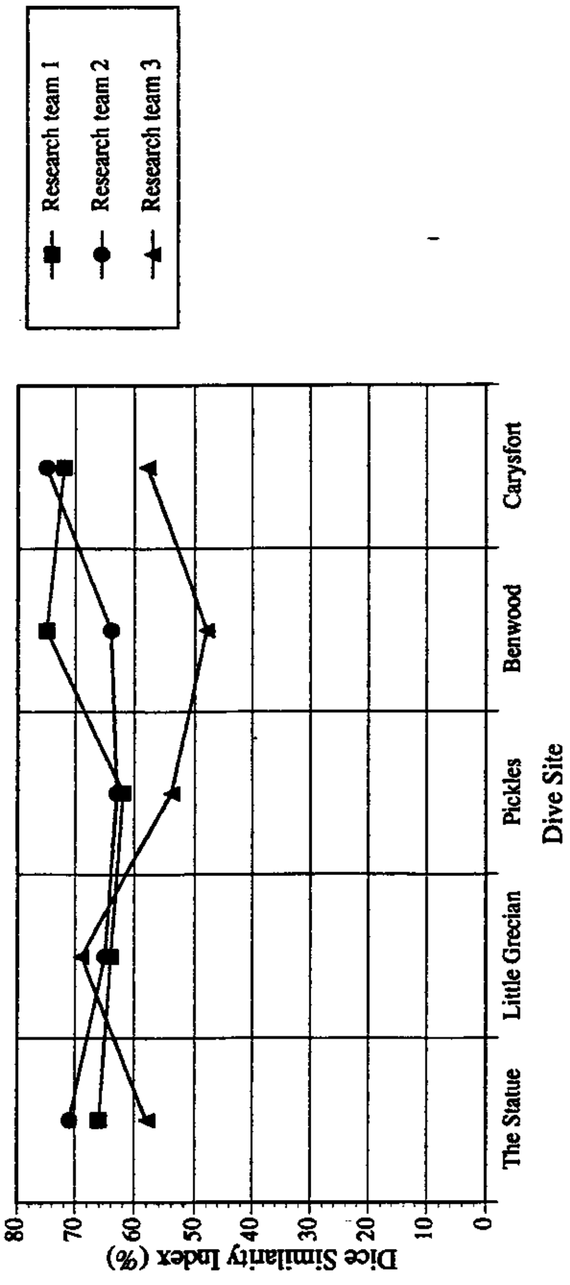

Figure 2. Similarities Between Technical and Volunteer Observers (Sites arranged by order of survey).

Although a larger number of volunteers saw more fishes than a smaller number of technical observers, an individual technical observer saw more fish than an individual volunteer observer. In general, there was more variation among the observations of volunteers than among the technical observers. However, the number of fishes seen on average by an individual volunteer increased and the standard deviation among their observations decreased over time (Table 7). This indicates that the observations of the volunteers were becoming more similar over time as the observers became more experienced. Figure 2 presents the degree of overlap between the observations of volunteer and technical fish observers in their research teams.

Table 8 presents the degree of the overlap between species observations at the sites. The two sites that were the closest, The Statue and Little Grecian, had the highest percent similarity. The other sites had less similarity.

When conducting fish surveys, it is important to know how many hours are required to see virtually all of the species at the reef site. By the time 8 hours of observation had been completed at Carysfort Reef, 97 percent of the total species counted had been observed. Once 10 hours of observation had been completed no additional species were recorded (Figure 3). This suggests that a larger number of volunteers are able to collect more data than a smaller number of technical observers.

The fishes recorded were of three categories based on their frequency of occurrence (Tables 3-5). There were 9 species representing 7 families of fish which were ubiquitous throughout the study area. There were 77 species representing 28 families of fish which were site-specific. There were 97 species representing 34 families of fish which were rare, occasional visitors to the reef, or mis-identified.

Table 8. Percent Similarity Between Survey Sites (Sites arranged from North to South) Dice coefficient values converted to percentages.

Site	Carysfort	The Statue	Little Grecian	Benwood	Pickles
Carysfort	----	62.1	62.2	66.0	63.0
The Statue	----	----	81.2	69.0	67.7
Little Grecian	----	----	----	72.1	66.2
Benwood	----	----	----	----	65.3
Pickles	----	----	----	----	----

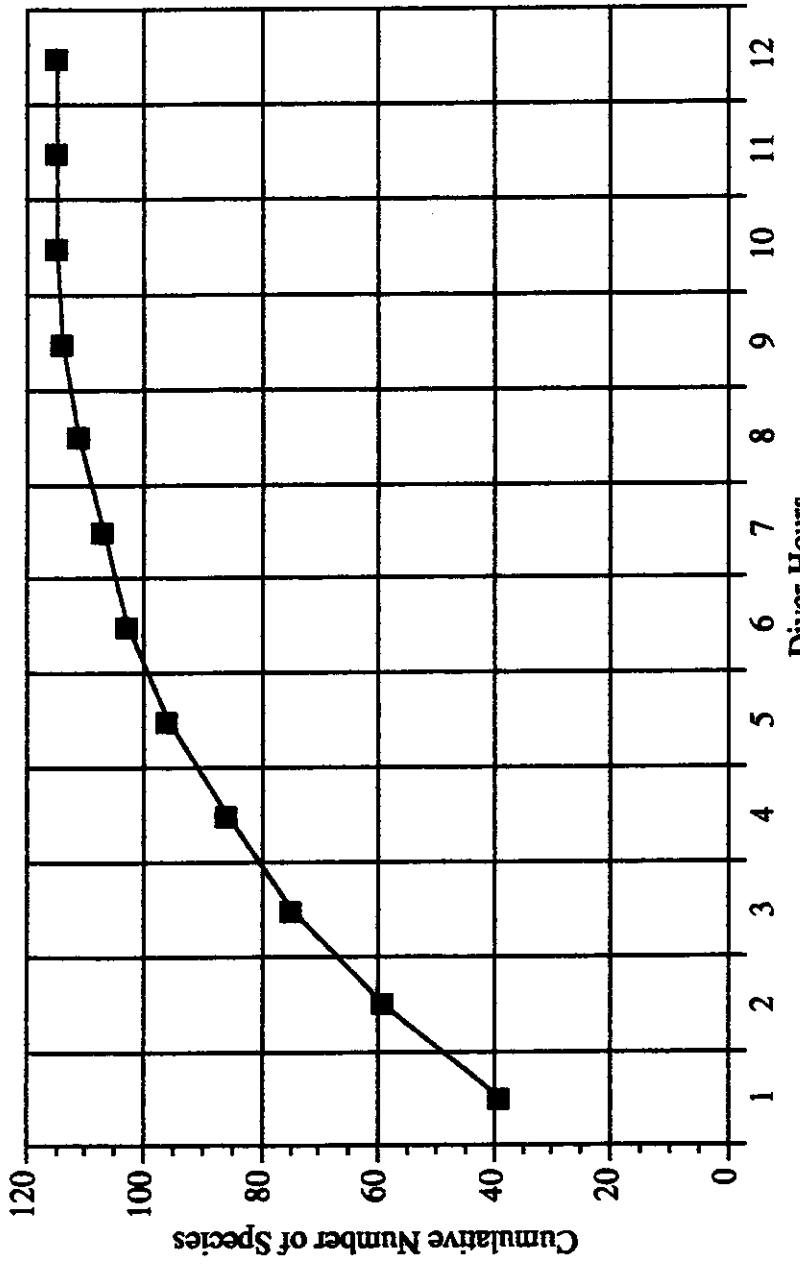

Figure 3. Cumulative number of species seen per diver-hour at Carysfort reef.

DISCUSSION

Fish community data collected by volunteers is valid and reliable when the volunteers have participated in a fish identification course or have had sufficient experience in the identification of reef fishes. Censusing of fishes at various sites was performed by several research teams. Larger groups of volunteers (7-10) were able to consistently identify more species than smaller groups of technical observers (4-5). Based on the result that no additional species were recorded after 10 hours and few additional species were recorded after 8 hours of observation at the same site, each censusing group composed of at least 8 observers sampling the reef fish community at the samesite and the same time was defined as a unique monitoring event and the data collected by each group was checked for accuracy and internal consistency. Therefore, in order to most effectively use volunteers for data collection, there must be 8 or more people observing fishes at the same time. Volunteers should sample the same reef site at the beginning and end of the training session as another measure of volunteer learning. The percent similarity between the observations of volunteers and technical observers in their research teams provided an indication of the extent to which the observations were similar and the ability of volunteers to identify fishes correctly. These observations became more similar over time, however, we did not expect all members of a research team to see all the same fish during a dive since the coral reef is a very complex three-dimensional habitat. Individual observations were compared to those made by all divers at the site. This frequency of occurrence also serves as a form of data quality control.

It is our aim to be somewhat conservative in the data analysis process so that any changes we observe will have ecological significance and our working database will be as accurate as possible. Therefore, we emphasize that observers only record those fishes that were definitely observed and correctly identified. There are some potential errors that may occur within the sampling technique:

1. An observer may be recording a fish species as being present when it is actually not occurring at the reef site, or

2. An observer may not be recording a fish species as being present when it actually does occur on the reef site.

However, with large enough data sets at a particulat site the effect of these errors is lessened. Some differences in the fish community that is recorded and the actual fish community as it exists in nature may be attributed not only to the experience of the fish observer, but also to the time of day when the survey is conducted, the behavior patterns of particular fish species, and potential seasonal differences in the community.

The frequency of fish species occurrence sorts the fish community data into several working datasets (Figure 1). One of these databases is a list of ubiquitous fishes. These are fishes which are present system wide and seen by over 70% of all observers at each site. The upper Florida Keys reef tract is considered to be

one ecological system (Jaap, 1984). Ubiquitous fishes would be expected to be habitat generalists, feeding generalists and widely distributed through propagule dispersal. Ubiquitous fishes of the upper Florida Keys reef tract are listed on Table3. *Acanthurus coeruleus* , *Ocyurus chrysurus*, and *Stegastes partitus* are typical representatives. *A. coerulus* is well adapted to feed on many forms of filamentous algae and is known to be the most common member of its genus in the Florida Keys (Randall, 1968). *O. chrysurus* feeds on planktonic organisms in the water column as well as benthic crustaceans and small fishes (Randall, 1968). It is also known to be long-lived and most abundant around the Antilles and South Florida (Fischer, 1979). *S. partitus* is planktivorous and also known to be common on coral reefs throughout Florida (Randall, 1968). In addition, a high level of gene flow has been documented within *S. partitus* populations in the Florida Keys (Lacson and Morizot, 1991), indicating a panmictic population in this area.

A second database includes fishes that are reef site-specific and may be indicator species of a particular reef community. These species are present at some, but not all, reef sites within the upper Florida Keys reef tract (Table 4). These fishes are expected to have specific habitat and feeding requirements and/or be less widely dispersed throughout the upper Florida Keys reef tract. Since these fishes are consistently reported, they are being accurately identified, but are only found at specific reef communities. Site-specific species are of three types:

1. Species which are impacted by management policies. For example, the literature suggests that *Epinephelus striatus* is a generalist (Randall, 1968) but it has been restricted by spearfishing activities.

2. Species or families of fish which are known to be feeding or habitat specialists (*i.e.* Hamlets (*Hypoplectrus* spp.), *Ophioblennius atlanticus*, *Chromis cyanea*).

3. Species which are indicative of oceanographic or seasonal phenomena *i.e. Centropomus undecimalis.*

E. striatus was absent from Pickles Reef, the site where spearfishing is allowed. *Hypoplectus* spp., and *Chromis cyanea* are known to prefer deeper water habitats (Randall, 1968) and were more frequently sighted at the deeper study sites. *Ophioblennius atlanticus* is a small benthic fish apparently more common in high relief areas (Bohlke and Chaplin, 1968). *C. undecimalis* is a typical mangrove associated species. Juvenile *C. undecimalis* spend most of their lives in the mangrove habitat, and they are known to leave mangroves in late winter or early spring when they have reached larger sizes (Peterson and Gilmore, 1991). Randall (1968) has explained that *C. undecimalis* is occasionally observed in reef areas near mangroves. The fishes contained in these two databases (ubiquitous and indicator) are combined to form a "verified

fishes event inventory". This is a working database of the fishes which characterize a particular study site as generated by volunteer and technical observers.

The third dataset is a list of cryptic, rare, pelagic, or possibly mis-identified species (Table 5). Some examples of fishes in this category are: the blennies (Clinidae and Blennidae) and *Amblycirrhitus pinos* which are extremely cryptic and often seen only by observers who are specifically looking for them; *Trachinotus falcatus* and *Scomberomorus regalis*, which are both pelagic and occasionally seen over the reef area (Randall, 1968); and *Chromis insolata* which is known only on deeper reefs (Randall, 1968). In order to separate mis-identified fishes from the others, this dataset is studied for recurring observations over time until mis-identified species are removed and only the rare, cryptic or pelagic fishes remain. Those species that are recorded in replicate censuses of the same site will be considered rare while those fishes that are only recorded in an extremely sporadic manner at the site will be considered mis-identified (Figure 1).

By gathering and analyzing fish census information, ecological questions may be addressed and research in the areas of management and conservation may be better directed. Differences in various reef fish communities may be detected while in the absence of this census information these differences would remain un-noticed. The reef fish communities on sites where spearfishing is allowed and where spearfishing is not allowed may be compared as well as sites that are frequently visited by divers versus those that are infrequently visited. Communities can be surveyed at different times of day and communities that are located in different habitats can also be compared to determine differences and similarities in fish community structure.

Data collected by volunteers can be used by scientists in order to better understand reef fish communities. A large number of trained volunteers can collect more data accurately than a small number of technical fish observers. In addition, it is a good conservational practice for scientists and the general public to work together because ultimately it is the people of our world who will choose to conserve our resources.

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