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ANALYSIS OF A VOLUNTEER METHOD FOR COLLECTING FISH PRESENCE AND ABUNDANCE DATA IN THE FLORIDA KEYS

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ABSTRACT

A roving diver fish survey method that requires relatively little time and equipment was developed for use by trained volunteer divers to regularly, rapidly, and inexpensively document patterns of reef fish distribution and abundance. In this method, a diver searches a dive site and records all observed fish species and their abundance in $\log_{10}$ categories. Results from 130 h of observation were analyzed from three regional surveys conducted in the Florida Keys at a total of 27 reefs by four observers during the summer of 1994. The Upper Keys had the most species (166) followed by the Lower Keys (151) and the Dry Tortugas (142). More uncommon species were found in the Dry Tortugas. Experienced volunteer divers were able to provide useful species listings, frequency of occurrence and abundance data. We recommend multiple surveys from one site and day and night surveys for providing most complete species listings. Cluster analysis of reefs using Jaccard similarity indicies showed that reefs within a region clustered together and that reefs in close geographical proximity generally had the highest similarity. Data showed spatial distributions and species abundance patterns consistent with previous studies.

Visual surveys are used around the world to document patterns of natural variability in coral reef fish communities. Visual surveys are ideal for coral reef fishes because of their distinctive markings, the availability of excellent identification guides, and usually clear water conditions (Brock, 1954; Bohlke and Chaplin, 1993; Starck, 1968; Springer, 1982). Reef fish abundance and diversity may reflect overall reef conditions (Sale, 1991). Hughes et al. (1987, 1994), for example, showed changes in benthic coverage of macroalgae and stony corals can produce concurrent changes in reef fish composition and abundance. Also, fishing and other human-related stresses may change species distribution and abundance (Richards and Bohnsack, 1990).

Many different methods have been used to survey fishes (Bortone et al., 1986; Bortone, 1991). These methods have relied on either destructive inventory techniques or non-destructive visual methods to obtain fish diversity, density and length-frequency information. Although destructive methods, such as poisoning, dynamiting, trawling and seining are necessary for some census work (Talbot and Goldman, 1973; Bortone et al., 1989), they are undesirable in protected areas, sensitive habitats, and when it is necessary to re-survey the same location. Typical non-destructive visual methods include the linear transect technique (Brock, 1954; Sale and Sharp, 1983; Sanderson and Solonsky, 1986); transects using video equipment, remotely operated vehicles, or underwater tape recorders; the stationary diver technique (Bohnsack and Bannerot, 1986); discrete group sampling (Greene and Alevizon, 1989); and the timed visual count (Jones and Thompson, 1978). Each visual survey method has different objectives, advantages, and disadvantages which can be used to meet different sampling needs (Thresher and Gunn, 1986; DeMartini and Roberts, 1982; Fowler, 1987). Most methods are tedious and routinely applied to only a few areas because they require highly trained professional scientists or expensive equipment which are in limited supply.

Our results present and evaluate a standardized visual survey method, the roving diver technique (RDT), designed for use by volunteer divers knowledgeable in fish identification. The RDT survey method was developed to regularly, rapidly, and inexpensively provide reliable data on fish species presence and abundance from many different sites. The method is based on volunteer divers "roving" freely throughout a dive site while listing observed species and their abundance in $\log_{10}$ categories. The RDT requires relatively little time and equipment and was designed to provide useful data while being entertaining and challenging for volunteer divers. The RDT is intended to supplement, but not replace, more rigorous visual survey methods. Because of the availability of large numbers of volunteers, the method can potentially create large sample sizes and provide wide spatial and temporal coverage that would be impractical using professional scientists and other methods.

Our work compares fish species composition, sighting frequency, and abundance on reefs in three regions of the Florida Keys using RDT data collected by highly experienced volunteers in June and July 1994. Concerns about a decline in coral reef resources in the Florida Keys (Hallock et al., 1993) helped prompt the formation of the Florida Keys National Marine Sanctuary (FKNMS) in 1990. The management plan calls for establishing zones with different levels of resource protection. For these reasons, there is a need to help document spatial differences between reefs and monitor changes in different management zones over time. RDT data are used to describe baseline conditions and to document patterns in fish species composition and abundance on reefs in the FKNMS before management plans are put into place (Goldsmith, 1991).

Methods

Study Area.—Visual surveys of reef fish occurred during three 5-day trips during the summer of 1994 in the Upper Keys (June 6–10), Lower Keys (July 18–22), and Dry Tortugas (June 20–24) at high relief spur and groove reefs and immediately surrounding areas. Study sites within these regions included reefs proposed for different levels of protection as replenishment reserves, sanctuary preservation areas, and general use zones by the Florida Keys National Marine Sanctuary (FKNMS) draft management plan (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 1994). Each region had an average of 37.3 ± 5.9 surveys with a total average survey time of 43.4 ± 6.9 h. Nine reefs were sampled in the Upper Keys (UK), eight reefs were sampled in the Lower Keys (LK), and 10 in the Dry Tortugas (DT) (Fig. 1). Survey sites, number of surveys, geographic coordinates, survey time and average depth are listed in Table 1. Each region had ten scheduled daytime dives and two or three nighttime dives. The number of actual surveys completed at a site ranged from 1–11 ($\bar{x}$ = 4.1 ± 2.1). Weather conditions were good during surveys with approximately 23m estimated horizontal visibility.

Field Methods.—The roving diver technique (RDT) involves divers well-trained in fish identification "roving" around a dive site observing and listing as many species as possible during a dive. The estimated abundances of each species are recorded in $\log_{10}$ categories as single (1), few (2–10), many (11–100), and abundant (>100). Observers are free to search as they wish with few special restrictions: divers may not physically disturb habitat and must have a buddy for safety. The length of the dive is allowed to vary, limited only by safe diving considerations usually determined by depth. At the end of the survey dive, each observer transfers data to a standard computerized scan form with pre-listed species. Other data recorded include the observer's name, dive site name, navigational coordinates, date, water temperature, duration of the survey, survey start time, estimated visibility, average depth, strength of the current, and habitat type where the survey took place.

All data in this study were collected by four highly trained volunteer divers with considerable experience in diving, fish identification, fish behavior, and field survey techniques. Each observer had previously identified more than 150 fish species correctly during field surveys. Field identifications were based on Humann and DeLoach (1989); Robins et al. (1986), and Stokes (1980).

Data Processing.—Standardized datasheets were electronically scanned through a National Computing Systems (NCS) scanner at the University of Miami testing center. All datasheets were checked by the author (EFS) before being scanned to make sure they were filled out correctly and only appropriate species had been marked as present. This procedure eliminated clerical mistakes of accidently recording species on the pre-printed scansheets that really had not been seen. Data were also checked for

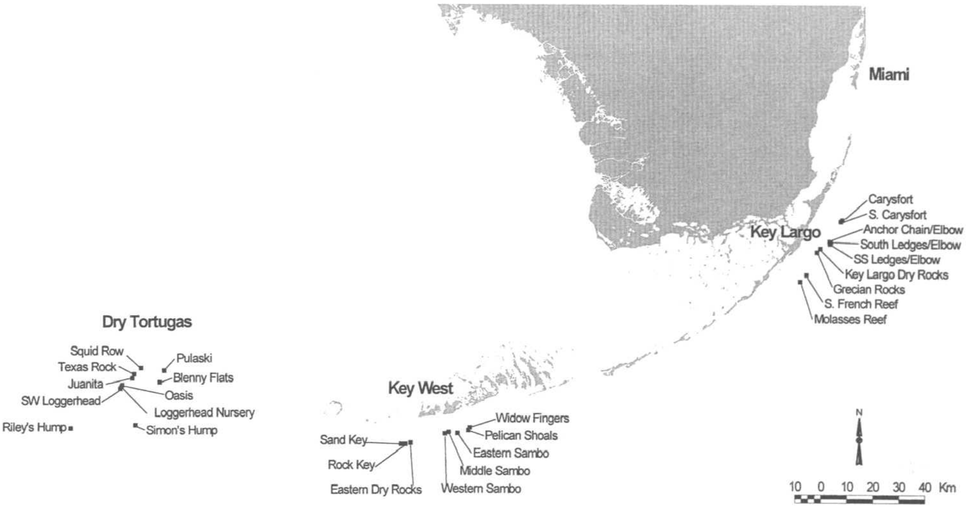

Figure 1. Map of fish survey sites on reefs in the Upper Keys, Lower Keys, and Dry Tortugas, Florida.

errors after being entered into the computer. Through this proof-reading procedure, Type I errors (recording a species when that species was not there) were reduced. Type II errors (failure to record a species when it was there) were addressed by allowing sufficient dive time to search the area as thoroughly as possible.

Data were stored as ASCII files and analyzed by specially developed software which calculates the following parameters for each species and family by site and region. *Percent sighting frequency (%SF)* was the percentage of all dives in which the species or family was recorded. Observed values ranged from 0 to 100%. *Density score (Den)* was a weighted average index calculated for each species or family based on the frequency of observations in different abundance categories. It was calculated as:

$$\text{Den} = (S \times 1) + (F \times 2) + (M \times 3) + (A \times 4)/n$$

where S, F, M, and A are the frequency categories of single, few, many, and abundant observations, respectively, for each species and n is the total number of dives. This index ranged from 1 to 4 and was representative of the abundance category most often recorded for a given species or family when observed. For example, a density score of 2.2 reflects a species that was most often seen in the second density category (Few) but since the density index is greater than two, there were some densities recorded for this species in larger density categories (either category 3 or 4). Note that different distributions of sightings in each abundance category could potentially give similar density index values. *Abundance score (Abund)* was calculated as Den × %SF which takes into account density, frequency of occurrence, and zero observations. Although potential values range from 0–4, observed values ranged from 0 to 3.2.

Data Analysis.—Data reports were compiled for the three regions showing sample size, the number of species and families observed, and a listing of species with their frequency and abundance scores. We examined sample time and number of species observed to determine if there were significant differences among regions and at sites within regions using the ANOVA, F statistic and non-parametric Kruskal-Wallis ANOVA, H statistic (Zar, 1984), ($\alpha = 0.05$) as appropriate. Power curves were fitted to plots of cumulative species versus sample time for the three regions to determine the rate at which new species were observed and the effectiveness of sampling.

Species were classified into three frequency categories for each region based on the percentage of dives on which a species was observed: frequent (≥70%), common (70% < x > 20%) and uncommon (≤20%). Uncommon species included species which were rare, cryptic, or pelagic (occasional reef visitors). The number of species and families in each frequency category were compared between regions. Additionally, frequent species from the three regions were compared.

Species were placed into four relative abundance categories based on percentiles: 0.0–25.0, 25.1–50.0, 50.1–75.0, and 75.1–100.0%. Relative abundance was compared to frequency of observation measures using UK data.

We compared similarity in species observed among observers within a single site at Western Sambo, LK to determine if observers that were sampling close together as members of a buddy pair would

Table 1. List of sites that were surveyed in each region. An asterisk (*) by the site name indicates that the site was surveyed at night. A cross (+) by the site name indicates that it was surveyed both during the day and night. All unmarked sites were surveyed during the day.

	Surveys (no.)	Lat./Long.	Avg. depth (m)	Total time (min.)	Total species
Upper Florida Keys					
Anchor Chain	6	25°08.70N 80°15.38W	8.3	506	113
South Ledges	3	25°08.42N 80°15.54W	8.3	250	95
+Grecian Rocks	5	25°06.70N 80°18.55W	6.7	355	98
Key Largo Dry Rocks	3	25°07.45N 80°17.80W	8.3	244	94
+South South Ledges	6	25°08.84N 80°15.66W	8.3	515	115
Carysfort	3	25°13.30N 80°12.74W	19.4	140	80
South Carysfort	3	25°13.00N 80°13.06W	10.6	248	96
South French Reef	2	25°02.06N 80°21.00W	11.7	160	90
Molasses Reef	2	25°00.74N 80°22.40W	8.3	175	92
Lower Florida Keys					
+Western Sambo	11	24°29.38N 81°42.68W	7.2	727	114
Eastern Sambo	7	24°29.50N 81°39.80W	7.0	478	106
Rock Key	4	24°27.21N 81°51.60W	7.5	285	94
Sand Key	4	24°27.19N 81°52.58W	6.7	290	89
Middle Sambo	4	24°29.71N 81°41.79W	7.5	273	92
Pelican Shoals	4	24°30.12N 81°37.38W	5.0	298	92
Widow Fingers	4	24°30.70N 81°37.03W	5.8	293	100
+Eastern Dry rocks	6	24°27.50N 81°50.44W	6.1	374	87
Dry Tortugas					
Juanita	6	24°40.03N 82°53.52W	8.3	469	89
Texas Rock	7	24°40.90N 82°53.08W	14.0	432	77
Pulaski	3	24°41.73N 82°53.08W	9.4	194	71
Blenny Flats	3	24°39.32N 82°47.26W	8.3	237	56
Riley's Hump	3	24°29.62N 83°07.31W	28.3	96	48
Loggerhead Nursery	3	24°38.31N 82°55.92W	8.3	253	61
+Oasis	4	24°38.65N 82°55.77W	11.7	242	79
Simon's Hump	3	24°30.46N 82°52.65W	21.7	113	63
*Squid Row	2	24°42.18N 82°51.56W	8.3	94	18
*SW Loggerhead	1	24°37.91N 82°56.17W	8.3	65	10

have observations that were more similar than those of observers sampling as part of other buddy teams. We also compared similarity between species observations taken by the same observer, and the same team of observers, at the same site (Western Sambo, LK), only on different days of the sampling week. Additionally, we compared similarity in species observed at different sites in UK and LK reefs. The percent similarity in species recorded was computed as percent overlap in species using the Jaccard coefficient (Ludwig and Reynolds, 1988). The Jaccard coefficient was determined as:

J = number of species in common between set A and B/total number of species in sets A and B

The resulting coefficients were plotted in a dendrogram so that patterns could be more easily detected. This method of clustering is patterned after the combinatorial linear model (Lance and Williams, 1967; Ludwig and Reynolds, 1988).

Results from this study were compared with two independent quantitative studies: Jones and Thompson (1978) and unpublished data collected during 1994 by the National Marine Fisheries Service (NMFS). Jones and Thompson (1978) provided species scores based on the time interval in which a species was recorded and the frequency that it was observed. The NMFS data provided species, abundance and frequency of occurrence based on a quadrat method (Bohnsack and Bannerot, 1986).

Results

Four observers surveyed 27 sites for a total of 130.1 h (Tables 1, 2). There was no significant difference in time spent sampling among regions for all sites ($F = 2.61$, $df = (2,24)$, $P = 0.094$), and for sites surveyed during the daytime

Table 2. This table shows the number of species and families observed as well as sample effort in the different regions. (Note that there is some overlap in species and families recorded for day and night surveys)

	Upper Florida Keys			Lower Florida Keys			Dry Tortugas		
	Day	Night	Total	Day	Night	Total	Day	Night	Total
Total # species	160	50	166	144	43	151	137	35	142
Total # families	47	18	47	43	23	43	33	15	33
# of sites	9	2	9	8	2	8	8	8	10
# of survey hours	37.4	5.8	43.2	43.6	6.7	50.3	31.9	4.7	36.6
# of surveys (N)	10	2	12	10	2	12	10	3	13
Mean species/survey	72.6	21.2	64.8	65.3	14.8	56.7	43.4	12.0	38.1
± (SD)	(9.7)	(8.7)	(21.0)	(7.5)	(3.6)	(19.7)	(8.2)	(2.1)	(14.6)

(H = 2.52, df = 2, P = 0.284). There was a significant difference in time spent sampling among regions for sites surveyed during the nighttime (F = 5.920, df = (2.5), P = 0.048).

A comparison was made of the total number of species and families recorded in each region (Table 2). UK had the most species (166) followed by LK (151) and DT (142). Significant differences were found in the number of species recorded among regions for all sites (H = 17.25, df = 2, P = 0.002), for all sites surveyed during the daytime (H = 13.94, df = 2, P = 0.001) and for all sites surveyed during the nighttime (F = 6.87, df = (2, 5), P = 0.037). Pairwise comparisons of number of species indicated that there was no difference in number of species between UK and LK, but there was a significant difference ($P <$ 0.05) between the number of species recorded in DT and the other two regions, even though sampling time was not different among these regions.

More species were always recorded during daytime than nighttime dives (Table 2) although several different species were only recorded at night. Using data collected only during daytime dives, there was no significant difference in the amount of time spent surveying different sites in the UK (H = 12.41, df = 8, P = 0.134). However, the survey time at Carysfort Reef (140 min) was lower than at the other sites (mean = 245 min). There was a significant difference in the number of species recorded (H = 22.12, df = 8, P = 0.005) among sites during daytime dives in the UK. The number of species at Carysfort (80), was less than most of the other sites (mean = 98). Anchor Chain, UK had a higher number of species (113) compared to the other sites (mean = 93). In LK, daytime sampling time was not significantly different among sites (H = 3.38, df = 7, P = 0.848), however, the number of species recorded was significantly different among sites (H = 19.19, df = 7, P = 0.008). The number of species recorded at Eastern Dry Rocks, LK (74) was lower than most of the other sites (mean = 98). DT daytime survey time was significantly different among sites (H = 22.72, df = 7, P = 0.002) and there was a significant difference in the number of species recorded among sites (H = 14.701, df = 7, P = 0.040).

Cumulative Species Curves.—Plots of cumulative species recorded versus survey hours showed that the number of species added began to level off quickly with increased survey time for the three regions (Fig. 2). Few additional species were being added toward the end of the regional surveys. After surveying for 32 h in the same region, an increase of 10% in sampling effort resulted in a less than 3% increase in number of species recorded for all three regions. Species were detected most rapidly in UK and most slowly in DT. This pattern was not an artifact of learning differences in observer performance because UK was surveyed first but

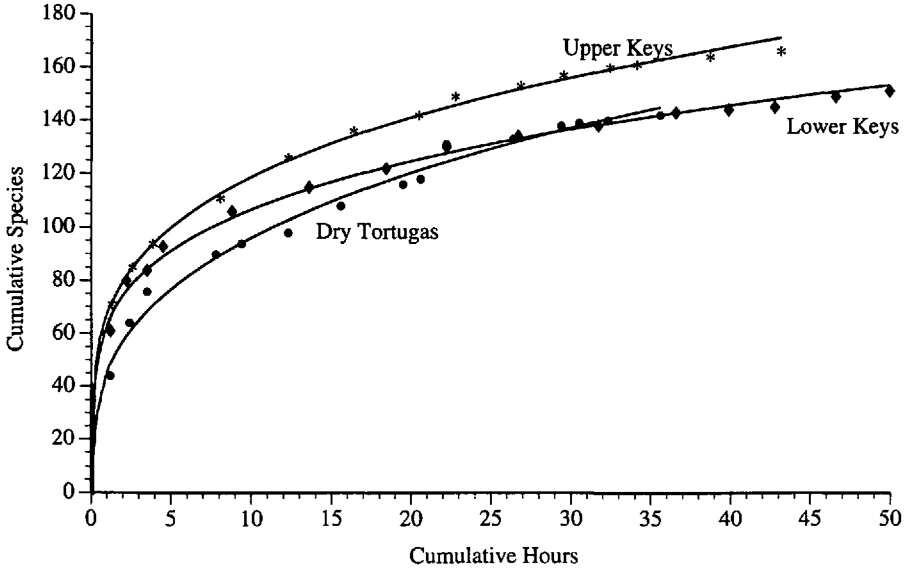

Figure 2. Cumulative hours vs. cumulative species for sites in the Upper Keys, Lower Keys, and Dry Tortugas. Includes 10 day dives and 2 night dives in the Upper and Lower Keys, and 3 night dives in the Dry Tortugas. Power curves are fitted to these points.

had the most observed species. Observers were all highly experienced and their performance did not change perceptibly throughout the study.

Frequency.—Performance curves (Fig. 2) suggested that DT had more uncommon species while the UK had more frequently observed species. This pattern was confirmed when species were analyzed in terms of observed frequency categories (Table 3). The number of species in each of the three frequency categories varied among regions but always increased from the frequent, common, to rare categories.

Abundance.—All species observed in UK were divided into frequency and abundance categories (Table 4). Although the total number of species in each abundance percentile category should be equal, they were not in this case because of tied values. Overall, the most frequently observed species tended to be abundant while uncommon species tended to have low abundance. However, frequency of occurrence was not necessarily a good predictor of abundance among frequently observed species even though the two measures were strongly related (Table 4). Among UK fishes, for example, *Stegastes partitus* and *Abudefduf saxatilis* were widespread and abundant while *Aulostomus maculatus* and *Pomacanthus arcuatus* were widespread with low abundance. In contrast, *Lutjanus synagris* and *Caranx*

Table 3. The number of species (families) are recorded by frequency category for fish surveys conducted in the Upper Keys, Lower Keys, and Dry Tortugas

	Upper Keys	Lower Keys	Dry Tortugas
Frequent (≥70% sighting frequency)	40 (17)	34 (13)	13 (10)
Common (70% 〈X〉 20% sighting frequency)	60 (23)	57 (28)	51 (18)
Uncommon (≤20% sighting frequency)	66 (32)	60 (30)	78 (25)
Total	166 (47)	151 (43)	142 (33)

Table 4. The number of species (families) are listed in various frequency and abundance categories from the Upper Keys. Actual ranges of abundance measures given below the percentile range. Note that it is possible for the same family to appear in different frequency and abundance categories.

	Sighting frequency (%SF)			
Abundance percentile	Frequent (≥70%)	Common (70% (X) 20%)	Uncommon (≤20%)	Total
75–100 (1.39–3.23)	35 (15)	7 (6)	0	42 (17)
50–75 (0.50–1.36)	5 (4)	36 (17)	0	41 (18)
25–50 (0.15–0.45)	0	17 (13)	24 (16)	41 (21)
0–25 (0.03–0.15)	0	0	41 (24)	41 (24)
Total	40 (17)	60 (23)	65 (32)	165 (47)

latus were uncommon, but locally abundant in schools, while *Scorpaena plumieri* and *Halichoeres poeyi* were uncommon and not abundant. Thus, species can be independently characterized by both frequency and abundance measures.

Frequently recorded species were considered most characteristic of a given region (Table 5). Only seven species were frequent in all three regions. UK had 12 unique frequently observed species followed by LK with four and DT with two. Another 25 species were frequently observed in two of the three regions.

Species Similarity.—Samples from Western Sambo, LK showed higher species similarity within buddy pairs (69% or 74%) than between pairs (60%) despite similar observer survey times ($\bar{x}$ = 67.8 ± 5.9 min) (Fig. 3). Clearly observers saw some different species despite swimming close to each other in buddy pairs. These values are comparable to similarities of 50–61% for one individual sampling the same reef, Western Sambo, LK on different days in the early afternoon within a 5-day sample period. When the group species list was compared from the first day sampling at Western Sambo, LK (3 observers, 196 min, 90 spp.) to the second day of sampling at the same site (3 observers, 221 min, 94 spp.), there was a total of 105 different species recorded with a 75% overlap in species observed.

When comparing sites based on all samples, UK and LK sites clustered by region in terms of species similarity. Also, within each region, sites that were geographically closer to one another, generally showed greater similarity (Fig. 4).

Discussion

Roving Diver Method.—Volunteers were able to provide species lists that compare favorably with earlier studies. The species-time curves suggested that 32 h of searching were necessary to provide an adequate regional species list. Volunteers were able to collect relative abundance data in $\log_{10}$ categories. Multiple divers or multiple dives provided useful frequency of occurrence data. The fact that species similarity patterns were not clustered at random and showed general geographical affinities reported in earlier studies, suggest that volunteer data reflected actual reef fish assemblages. Our results support the recommendation that both day and night surveys should be used to provide a more complete census of fishes in a given area (Collette and Earle, 1972). Although a greater number of species were always recorded during daytime surveys, several different species were recorded at night.

Table 5. Species which were seen frequently (≥70%) in the Upper Keys, Lower Keys, and Dry Tortugas. Species are listed in order of decreasing frequency ("*" indicates the species is frequent in all regions, "+" indicates the species is only frequent in the listed region). The frequency score is listed before each species name. After each species name the abundance score (% sighting frequency * density index) is given in parentheses.

Upper Keys		Lower Keys		Dry Tortugas	
94%	* Chaetodon ocellatus (1.9)	93%	Acanthurus bahianus (2.6)	86%	* Acanthurus coeruleus (1.9)
94%	* Acanthurus coeruleus (2.7)	89%	Haemulon sciiurus (2.6)	86%	* Haemulon plumieri (1.8)
94%	Haemulon sciurus (2.8)	89%	Haemulon flavolineatum (2.6)	80%	* Thalassoma bifasciatum (2.1)
91%	* Haemulon plumieri (2.2)	89%	Microspathodon chrysurus (2.1)	77%	* Pomacanthus arcuatus (1.3)
91%	Haemulon flavolineatum (2.8)	86%	* Acanthurus coeruleus (2.2)	77%	Pomacentrus variabilis (2.0)
91%	Sparisoma viride (2.8)	86%	Sparisoma viride (2.1)	77%	* Sparisoma aurofrenatum (1.5)
88%	Microspathodon chrysurus (2.3)	86%	Canthigaster rostrata (1.6)	77%	Gobiosoma oceanops (2.0)
88%	Scarus vetula (2.3)	84%	Chaetodon capistratus (1.7)	74%	+ Holacanthus bermudensis (1.4)
88%	* Sparisoma aurofrenatum (2.2)	84%	* Pomacanthus arcuatus (1.3)	74%	* Chaetodon ocellatus (1.3)
85%	+ Kyphosus sectatrix (2.1)	84%	Stegastes partitus (2.6)	74%	+ Calamus calamus (1.3)
85%	Stegastes partitus (3.2)	84%	Epinephelus cruentatus (1.6)	74%	* Ocyurus chrysurus (1.9)
85%	Abudefduf saxatilis (2.9)	84%	Halichoeres radiatus (1.8)	74%	Scarus croicensis (1.9)
85%	+ Aulostomus maculatus (1.4)	84%	Gobiosoma oceanops (2.1)	71%	Coryphopterus glaucofraenum (1.6)
82%	+ Acanthurus chirurgus (2.4)	82%	Sparisoma rubripinne (2.1)		
82%	+ Stegastes planifrons (2.1)	82%	Bodianus rufus (1.6)		
82%	Canthigaster rostrata (1.9)	82%	* Thalassoma bifasciatum (2.6)		
79%	Chaetodon capistratus (1.6)	80%	* Haemulon plumieri (1.8)		
79%	* Pomacanthus arcuatus (1.2)	80%	Halichoeres bivittatus (2.2)		
79%	Acanthurus bahianus (2.4)	80%	+ Holacentrus vexillarius (1.5)		
79%	+ Lutjanus apodus (1.8)	80%	+ Malacoctenus triangulatus (1.8)		
79%	+ Lutjanus mahogoni (2.0)	77%	* Chaetodon ocellatus (1.4)		
79%	* Ocyurus chrysurus (2.6)	77%	* Ocyurus chrysurus (2.2)		
79%	Anisotremus viriginicus (1.6)	77%	Scarus vetula (1.7)		
79%	Epinephelus cruentatus (1.3)	77%	Scarus croicensis (2.0)		
79%	Halichoeres radiatus (1.7)	77%	* Sparisoma aurofrenatum (1.8)		
79%	Halichoeres bivittatus (2.1)	73%	Holacanthus tricolor (1.2)		
79%	* Thalassoma bifasciatum (2.9)	73%	Anisotremus virginicus (1.3)		
79%	Halichoeres maculipinna (2.0)	73%	Abudefduf saxatilis (2.2)		
76%	+ Caranx ruber (2.0)	73%	Halichoeres maculipinna (1.8)		
76%	+ Serranus tigrinus (1.5)	73%	Coryphopterus personatus (1.8)		
76%	Coryphopterus personatus (2.1)	70%	+ Pomacentrus fuscus (1.6)		
76%	+ Lactophrys triqueter (1.2)	70%	+ Chromis multilineatus (1.9)		
76%	+ Mulloidichthys martinicus (2.0)	70%	Halichoeres garnoti (1.8)		
73%	Holacanthus tricolor (1.4)	70%	Coryphopterus glaucofraenum (1.5)		
73%	+ Sphyraena barracuda (1.5)				
73%	Pomacentrus variabilis (1.6)				
70%	Sparisoma rubripinne (1.5)				
70%	+ Lachnolaimus maximus (1.0)				
70%	Bodianus rufus (1.1)				
70%	Halichoeres garnoti (2.1)				

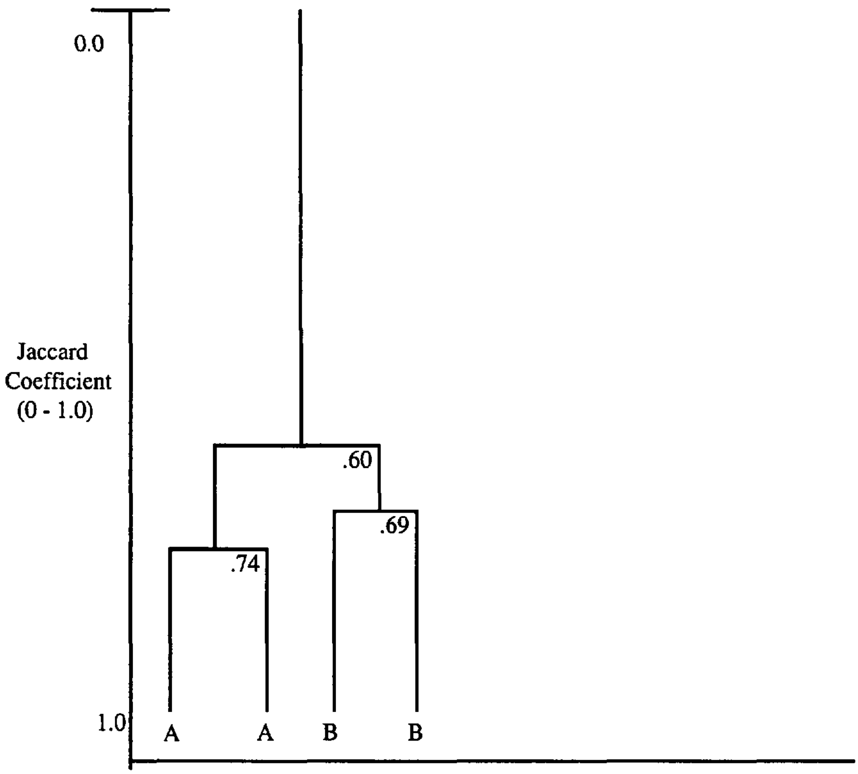

Figure 3. Dendrogram showing similarities in species lists among individual observers at Western Sambo, Lower Keys. Letters designate dive buddy teams of observers.

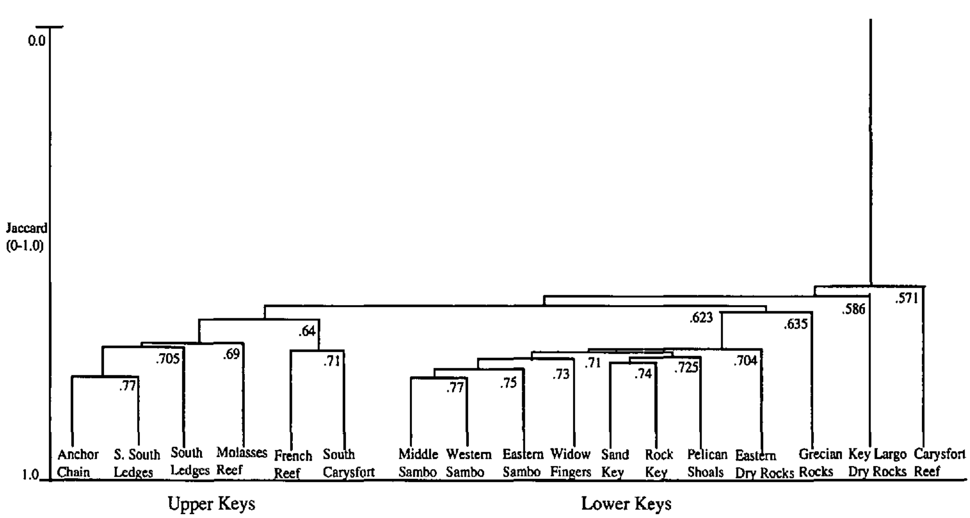

Figure 4. Dendrogram showing segregation of fish species assemblages on coral reef communities from the Upper and Lower Keys (Florida Reef Tract) based on similarity in species composition. Species composition was recorded as species seen or not seen at each reef site.

Buddy pairs are necessary when conducting fish surveys for safety reasons. We showed, however, that observers in buddy pairs will not record all the same species and, in fact, their observations were only slightly more similar (69–74%) per survey than between pairs (60%). Species lists from the entire survey team sampling at the same site on different days had 75% similarity. Differences between observers and chance factors in encountering low abundance species account for these differences in surveys. These results indicate that multiple surveys from one site are desirable for providing a more complete species listing.

When using RDT volunteer data scientists should consider survey time, depth, and the amount of volunteer experience, although this study only used highly trained and experienced volunteers. Differences in depth and survey time can affect the number and type of species recorded. However, attempting to rigorously control these parameters is impractical using volunteers. In this study, DT dives were at deep (>25 m) and shallow sites (<10 m) which led to shorter average survey times than in the other two regions where no dives were deeper than 20 m. Shorter average survey times may partially explain why DT had the fewest total species. The greater depth range may partially explain why DT had a high proportion of uncommon species as compared to the other two regions since different habitats and depth ranges were being sampled.

Regional Comparisons.—The most species were recorded in the UK. This may reflect extensive reef development and habitat complexity in this region compared to the other two regions (Shinn et al., 1977). However, more uncommon species were found in the DT possibly due to habitat differences or its isolation from other reef areas.

Results were similar to those found in previous studies. Jones and Thompson (1978) also found more species in UK (146) than in DT (134). Unpublished data collected by the NMFS during 1994 indicate a similar trend, with the most species in UK (123), a fewer number in LK (97) and DT (102). We identified more species at all three locations than had been identified previously (166 in UK, 151 in LK, and 142 in DT), possibly because we sampled more sites and had more total survey time. Jones and Thompson (1978) also found that diversity (Shannon-Weiner) and evenness (Pielou) were both slightly greater in UK ($H' = 4.64$, $P' = 0.93$) than in DT ($H' = 4.49$, $P' = 0.917$). Although our numbers were different due to the method of calculating density (our den parameter was used, while their species time score was used), we found the same trend of density and evenness in UK ($H' = 5.04$, $P' = 0.98$) and in DT ($H' = 4.91$, $P' = 0.99$).

RDT data showed similar regional patterns as reported by Jones and Thompson (1978) who found a total of 165 species in UK and DT with 71% overlap in species composition using the Curtis-Bray index and 70% overlap using the Jaccard coefficient. We found 193 total species and a 60% overlap using the Jaccard coefficient for UK and DT data. NMFS data had 141 total species and 62% similarity using the Jaccard coefficient for UK and DT data. This compares to 182 total species (73% overlap) that we found in UK and LK and 174 total species (68% overlap) between LK and DT. NMFS had 133 total species (65% overlap) between UK and LK and 125 total species (59% overlap) between LK and DT.

In an ordination analysis comparing species lists, Jones and Thompson (1978) found that four DT sites clustered closely together and separately from four sites in the UK which clustered closely together. We found a similar sorting of sites by locality. Ten sites from the LK generally sorted out from nine UK sites in a dendrogram plot. Jones and Thompson (1978) also found fish observations from reefs in close (approximately 3.7 km) proximity (Molasses and French Reefs) were the most similar (87%). We found 64% similarity between these two sites while the most similar sites were Middle Sambo and Western Sambo (LK) and Anchor Chain and South south ledges (Elbow Reef, UK) which were both 77% similar (Fig. 4).

Jones and Thompson (1978) listed their 32 most frequently seen species which we compared to the 32 most frequently seen species in this study and in NMFS surveys (NMFS, unpubl. data). The RDT lists from UK were 52% similar to Jones and Thompson (1978) and 58% similar to the NMFS data, while the Jones and Thompson (1978) and NMFS data were 62% similar. In DT, the RDT data were 47% similar to Jones and Thompson (1978) and 63% similar to the NMFS data, while the Jones and Thompson (1978) and NMFS data were 40% similar. The RDT lists from LK were 52% similar to NMFS data.

Some species showed similar patterns to those reported by Jones and Thompson (1978) and evident in NMFS data. *Aulostomus maculatus* (trumpetfish), although considered to be a ubiquitous species throughout its range, was rarely recorded in DT for all three data sets, despite intensive sampling. *A. maculatus* was not recorded by Jones and Thompson (1978), or in the NMFS, 1994 data. We found only one *A. maculatus* in DT, although it was frequent in UK and common in LK. Jones and Thompson (1978) reported that *Calamus calamus* (saucereye porgy) was common in DT but not in UK. This species was on the 32 most frequently seen species list according to all three data sets in DT but absent from the frequent lists in the other regions. *Holacanthus bermudensis* (blue angelfish) was also frequent only in DT in agreement with Jones and Thompson (1978) and NMFS data.

Overall Species Composition in the Regions.—We observed several predatory fishes were frequent only in UK. *Lujanus apodus* (schoolmaster) with 64% frequency, was observed on only 3% of surveys in the DT and 0% of NMFS surveys in DT. However, Jones and Thompson (1978) listed it among the 32 most common species in both DT and UK. We found *L. mahogani* (mahogany snapper) was frequent (79%) only in UK although it was not frequently observed in UK by Jones and Thompson (1978) (ranked number 46 of 146) or in unpublished NMFS data (22%). *Aulostomus maculatus* was frequent only in UK in both our study (85%) and Jones and Thompson (1978), where it ranked 18 of 146, and was common (27%) in NMFS data. We found no large predatory fishes recorded as frequent in DT or LK although several larger grunt (Haemulidae), wrasse (Labridae) and one snapper species, *Ocyurus chrysurus,* were abundant in these regions.

Conclusions

This study shows that experienced volunteer divers using the roving diver technique (RDT) were able to generate representative species lists and provide frequency of occurrence as well as relative abundance data. Patterns observed were generally consistent with other studies, although more species were identified on reefs using the RDT than in previous studies. As with any visual method, several variables can affect species observations, including underwater visibility, current, topography, size of area searched, search mode, general experience of the observer, familiarity with the dive site, dive time, depth, and temperature.

This technique was intended to provide useful data while keeping the interest and enthusiasm of volunteers. It is not meant to replace more rigorous scientific methods which better control for area and time searched, and which quantify actual densities and size distributions. However, because of its wide potential geographic and seasonal coverage in addition to the large number of samples that only volunteers can provide, this method can be used to collect very useful ancillary data to supplement more rigorous studies. With multiple divers, this technique can rapidly and thoroughly record data concerning species presence and abundance at a given reef site. It promises to be especially useful for documenting rare or low density species, such as Nassau Grouper and Jewfish which are under fisheries protection and for which fishery landings data are unavailable, over relatively large geographical regions. Sites sampled in this study are being re-surveyed annually as a project of the Reef Environmental Education Foundation[1] whose purpose is to educate and train volunteers to collect fish distribution and abundance data. Through the REEF fish survey project, approximately 400 volunteers have completed 5,000 fish surveys in Florida, the Bahamas, and Caribbean.

Volunteer RDT data can alert scientists to problems or generate questions that require more detailed scientific studies. Data collected using the RDT documented differences in the fish fauna among three regions in the Florida Keys in terms of species distribution, abundance, and frequency of occurrence. Fish species most characteristic of each region as well as species which were uncommon in each region were identified. Other studies will be necessary to determine the causes for these specific differences, which may be due to differences in habitat, species richness, diversity of the benthos, exploitation, water circulation, or other factors. This method can provide a basis to identify changes in fish species composition in the Florida Keys and elsewhere in the Caribbean.

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