Project Title: **Volunteer Reef Fish Monitoring in the Florida Keys National Marine Sanctuary: 1994 - 2001**

Researchers: Reef Environmental Education Foundation (REEF) staff and Advanced Assessment Team

Survey Method: The Roving Diver Technique (RDT) is a non-point visual survey method specifically designed to generate a comprehensive species list along with frequency and abundance estimates. During RDT surveys, divers swim freely throughout a dive site and record every observed fish species. At the conclusion of each survey, divers assign each recorded species one of four $\log_{10}$ abundance categories [single (1); few (2-10), many (11-100), and abundant (>100)]. Following the dive, each surveyor records the species data along with survey time, depth, temperature, and other environmental information on a REEF scansheet. The scansheets are returned to REEF, and the data are loaded into the REEF database that is publicly-accessible on the Internet at http://www.reef.org.

As part of the Florida Keys National Marine Sanctuary (FKNMS) Zone Performance Monitoring (ZPM), REEF was contracted to collect reef fish data. This project supports a team of REEF's most experienced surveyors, the Advanced Assessment Team (AAT), to annually survey 37 sites in the, including 12 SPAs, 3 Research Only sites, 1 Ecological Reserve, 10 sites in the Dry Tortugas ER area, and 10 comparison/reference sites. A minimum of six RDT surveys were conducted at each site. These data were collected during a series of cruises in October, and complemented REEF's Fish Survey Project, a continual volunteer monitoring project that involves REEF volunteers conducting RDT surveys during their regular diving activities in the Florida Keys. The field season of 2001 was the fifth year that the AAT has monitored most of these sites and the eighth full year of REEF volunteer data collection in the Sanctuary.

During the 2001 REEF FKNMS ZPM, 473 RDT surveys were conducted by the REEF AAT, documenting 246 fish species. Between 1997 and 2001, 62 AAT members participated in REEF's FKNMS zone monitoring program, contributing 1,626 surveys. Through REEF's ongoing program, a total of 1,329 REEF volunteers have conducted 9,807 surveys from 311 sites in the FKNMS and have documented 415 fish species.

Findings to Date: This report summarizes all REEF data (Expert and Novice) collected at the 27 Zone Performance Monitoring sites in the FKNMS between 1994 and 2001 (the Dry Tortugas sites are not included). Table 1 lists the sites included, along with the level of protection (if any) granted in 1997 and annual REEF survey effort.

To estimate richness and evenness at each site, species accumulation curves were generated based on a standardized sample size of 23 Expert REEF RDT surveys using randomized sampling (Table 2). The data were fit to an asymptotic hyperbola using maximum likelihood to estimate the parameters for the Michaelis-Menten equation. The asymptote and the slope of the curve estimated site-level richness and evenness, respectively. This method allows for the estimation of diversity despite differences in survey effort among sites. This analysis was adapted from Semmens et al. (in prep). The inclusion of only REEF Expert data in this particular analysis was done to minimize the effect of species misidentifications. Sites that exhibited the lowest richness (the Newfound Harbor sites, Cannon Patch, Cheeca Rocks, and Delta Shoals) are all inshore patch reef sites. In all but four of the sixteen no-take/reference site pairs, the no-take sites had higher richness than the open reference site (see previous REEF Annual Reports for a listing of no-take/reference site pairs). A more complete GIS analysis of the FKNMS reef fish diversity, including how diversity may be associated with a variety of natural, anthropogenic, and environmental variables is currently being conducted (Semmens et al. in prep).

The basic statistic generated by REEF data is the abundance score, which is a weighted average of the abundance categories reported for each species combined with non-sightings[1]. The trends in abundance score between 1994 and 2001 for the top 75 species documented at ZMP sites were estimated. To generate the trend values, ordinal logistic regressions were conducted on each species at each site to evaluate the trend in the likelihood of an observer recording an abundance of either S, F, M, A or absent (Semmens et al. 2000). The likelihood is based on a regression of the ordinal values, and the trend is the slope of the ordinal regression line. This trend analysis is robust to the non-normal distribution of the categorical dataset.

The trend analysis highlighted several sites that are experiencing declines in a majority of the common fishes, and several sites that are experiencing increases in a majority of the common fishes. Sites where at least two-thirds (50) of the species declined more or increased less than at other sites included Grecian Rocks, Looe Key East, Eastern Sambo, and No Name Reef (Figure 1a). Sites where at least two-thirds of the species increased more or decreased less than at other sites were Molasses Reef, Conch Reef, Hen and Chickens, Sombrero Reef, Sand Key, and Newfound Harbor Open (Figure 1b).

There was no significant difference in the mean trends of all 75 species between open and protected sites. This is not surprising, as one would not expect reserves to produce changes in abundance across all fishes in a consistent manner. Interspecific interactions yield complex community responses and many species may actually exhibit short term declines due to trophic cascades and top-down effects. In addition, certain previously harvested species may fail to recover despite reserve designation due to changes in community structure, food web dynamics, and/or habitat and physical parameters.

More species changed in abundance at the protected sites than at the open sites. Using a Wald test of significance, the trend values of each species at each site were evaluated for significance. An alpha value of 0.10 was used as the significance threshold because, for this site level comparison, we were not interested in rejecting specific null hypotheses regarding species trends. Rather, we wished to identify those non-zero slope values that were "reasonably believable". Twelve of the 27 sites exhibited significant trends (positive or negative) in at least half of the 75 species (Table 3). A majority (9) of those sites were protected as no-take in 1997.

In an effort to pinpoint specific species that appear to be doing exceptionally well or poor, patterns in the slopes of the species' trends (positive or negative) were evaluated. The following species increased between 1994 and 2001, defined as positive trends in at least half (14) of the 27 sites – saddled blenny, beaugregory, bridled goby, colon goby, goldspot goby, black grouper, redtail parrotfish, and bluehead wrasse. The following species appear to be in general decline, defined as negative trends in at least half of the sites – rock beauty, smooth trunkfish, dusky damselfish, sharpnose pufferfish, ocean surgeonfish, and trumpetfish. Possible contributing factors to the general increase in the three sand/rubble-dwelling gobies (bridled, colon, and goldspot; Figure 2a) are the increase in sand/rubble areas from the hurricanes of 1998 and 1999, the increase in turf algae at many locations, and/or a decrease in predators. The decrease in mean abundance score of trumpetfish beginning in 1998 is shown in Figure 2b. One possible explanation for this decrease could be the slight decrease in octocoral cover reported by the EPA/FKNMS CRMP study, as trumpetfish often use octocorals for camouflage habitat. The decline in rock beauty was evident at all but a few sites, but rock beauty at protected sites decreased slightly less than at open sites (Figure 2c). The other common angelfishes (gray, French, and queen) exhibited little change in mean abundance. A likely cause of this change in rock beauty is harvesting for the aquarium industry, as juvenile rock beauty are one of the most collected fish species in the FKNMS.

[1] abundance score = $[(n_S x1)+(n_F x2)+(n_M x3)+(n_A x4)] / (n_S + n_F + n_M + n_A)$ * percent sighting frequency, where n is the number of times each abundance category was assigned

Of five targeted species (black grouper, hogfish, mahogany snapper, yellowtail snapper, and gray snapper), only gray snapper had significantly different trend values between protected and unprotected sites (one way ANOVA, p=0.003). The difference in trend values between protected and unprotected sites was marginally significant for hogfish (one way ANOVA, p=0.065). The mean annual abundance score values for the three snapper species and hogfish, based on all 27 sites, generally increased or remained unchanged from 1994 through 2002 (Figure 2d). As stated earlier, black grouper had positive trend values at a majority (20) of the sites and exhibited dramatic increases in mean abundance score and sighting frequency across all sites (Figure 3). Exceptions were Grecian Rocks and Cannon Patch, where black grouper exhibited statistically significant (p=0.041 and 0.012, respectively) annual decreases in abundance score between 1994 and 2001. While not a top 75 species, the sighting frequency of red grouper was also evaluated. This species was rarely encountered between 1994 and 1996, but has steadily increased since 1997 (Figure 4).

Future Plans: The REEF ZPM project in the FKNMS has generated annual data by REEF experts in the protected and reference areas. While the initial 5-year project recently has been completed, REEF plans to continue this annual monitoring effort and conducted another round of monitoring in September 2002. REEF will also continue to enable all divers to participate in its volunteer Fish Survey Project in the FKNMS. In the coming year, REEF will continue our partnership with NOAA's Biogeography Office to use the REEF database and the FKNMS Benthic Habitat database to investigate fish-habitat relationships, to map species distributions in the FKNMS, and to evaluate the effect of the zones by analyzing shifts in assemblage composition over time (Jeffrey et al. 2000). In late 2001, a baseline assessment of the proposed Dry Tortugas National Park zones was completed (REEF 2002). In 2002, several new projects were initiated, including 5-year monitoring projects of the Wellwood restoration and the *Spiegel Grove*. REEF staff are also currently working with Dr. Tom Gillespe (UCLA Geography Department) on several analyses using REEF FKNMS data.

Literature Cited:

Jeffrey, C.F.G., C. Pattengill-Semmens, S. Gittings, and M.E. Monaco. 2001. Distribution and sighting frequency of reef fishes in the Florida Keys National Marine Sanctuary. Marine Sanctuaries Conservation Series MSD-01-1. US Dept. of Commerce, NOAA, Silver Spring, MD. 51 pp. (http://www.sanctuaries.nos.noaa.gov/special/reef_fish/MSD_01_1.PDF)

REEF. 2002. Volunteer reef fish monitoring in the Dry Tortugas National Park – 2001 Final Report. (www.reef.org/data/DTNP.pdf)

Semmens, B.X., T.W. Gillespe, and C.V. Pattengill-Semmens. in prep. Predictors of fish species richness on coral reefs.

Semmens, B.X., J.L. Ruesink, and C.V. Pattengill-Semmens. 2000. Multi-site multi-species trends: a new tool for coral reef managers. International Coral Reef Symposium, October 2000.

Table 1. REEF survey effort by location and by year. Effort includes all Species and Abundance RDT surveys conducted during daylight hours (after 7am and before 8pm) greater than 20 minutes in length.

		REEF Survey Effort							
Location	Protectio	1994	1995	1996	1997	1998	1999	2000	2001
Ball Buoy Reef	Open	0	0	0	7	5	14	13	14
Grecian Rocks	SPA	27	17	26	30	10	43	74	60
Carysfort Reef	SPA	17	18	0	8	10	21	23	17
Molasses Reef	SPA	31	28	20	47	84	125	85	214
Little Grecian	Open	1	10	3	13	7	10	15	10
South Carysfort Ree	SPA	0	12	14	6	7	15	14	12
Cannon Patch	Open	0	0	0	6	16	1	14	21
Pickles Reef	Open	1	1	1	25	15	12	36	23
Conch Reef	SPA	37	21	7	32	11	19	16	47
Hen and Chickens	SPA	23	8	8	19	15	12	12	22
Tennessee Reef Rese	RR	34	0	0	16	9	9	8	12
Cheeca Rocks	SPA	0	0	0	17	11	9	6	13
Sombrero Reef	SPA	87	5	15	20	14	16	13	13
Samantha's Ledge	Open	38	0	6	13	11	12	15	13
Coffins Patch	SPA	35	0	5	6	28	11	10	14
Looe Key East	SPA	19	1	0	10	21	19	39	42
Looe Key Research	RR	18	0	0	6	8	13	9	12
Delta Shoals	Open	0	0	0	12	6	11	9	11
Newfound Harbor S	SPA	0	0	0	6	6	10	17	13
Newfound Harbor O	Open	0	0	0	6	6	10	9	12
No Name Reef	Open	0	0	0	6	6	10	9	12
Western Sambo	ER	40	34	19	7	15	10	14	105
Eastern Sambo	SPA	25	18	0	12	9	8	11	20
Sand Key	SPA	15	45	11	14	17	11	13	29
Middle Sambo	Open	13	18	0	11	9	9	12	20
Pelican Shoals	Open	13	16	10	0	0	0	11	24
Western Dry Rocks	Open	1	0	0	19	19	16	11	37

Table 2. Fish species richness and evenness estimates based on a sample size of 23 REEF Expert RDT surveys. Lower B values indicate higher evenness.

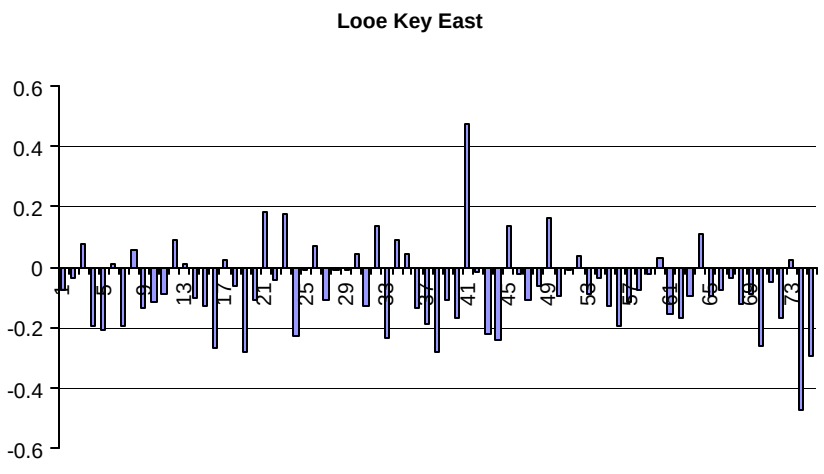
Location	Protection	M Parameter Estimate (Richness)	B Parameter Estimate (Evenness)
Conch Reef	No-Take	167	1.55
Coffins Patch	No-Take	167	1.56
Molasses Reef	No-Take	166	1.39
Western Dry Rocks	Open	165	1.65
Western Sambo	No-Take	165	1.58
Eastern Sambo	No-Take	165	1.95
Grecian Rocks	No-Take	164	1.93
Looe Key East	No-Take	162	1.44
Middle Sambo	Open	162	1.44
Little Grecian	Open	160	1.62
Sand Key	No-Take	160	1.52
Carysfort Reef	No-Take	159	1.56
No Name Reef	Open	156	1.60
Sombrero Reef	No-Take	155	1.57
Pelican Shoals	Open	153	1.82
Ball Buoy Reef	Open	152	1.40
Samantha's Ledge	Open	152	1.40
Tennessee Reef Research	No-Take	151	2.18
South Carysfort Reef	No-Take	149	1.44
Looe Key Research	No-Take	145	1.85
Hen and Chickens	No-Take	145	1.85
Pickles Reef	Open	145	1.37
Newfound Harbor SPA	No-Take	140	2.38
Delta Shoals	Open	136	1.31
Cheeca Rocks	No-Take	134	2.12
Cannon Patch	Open	131	2.46
Newfound Harbor Open	Open	124	2.12

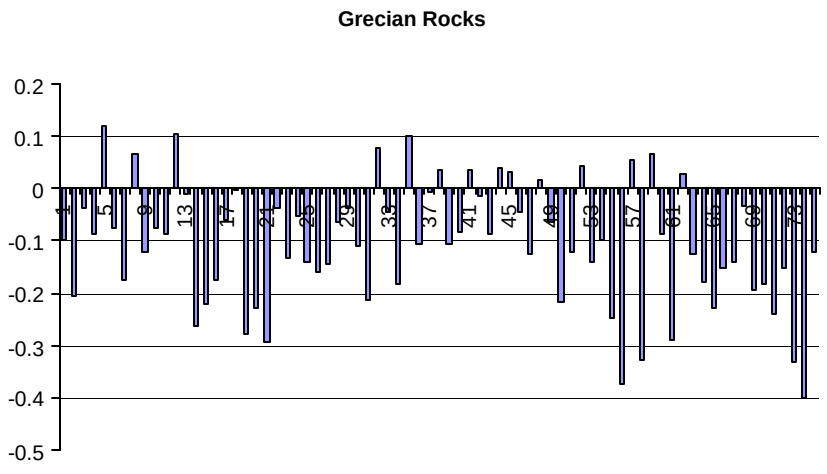
Table 3. The trend values of each species at each site were evaluated for significance. 12 of the 27 sites exhibited significant trends (postive or negative; alpha value 0.10) in at least half of the 75 species evaluated. A majority (9) of those sites were protected as no-take in 1997.

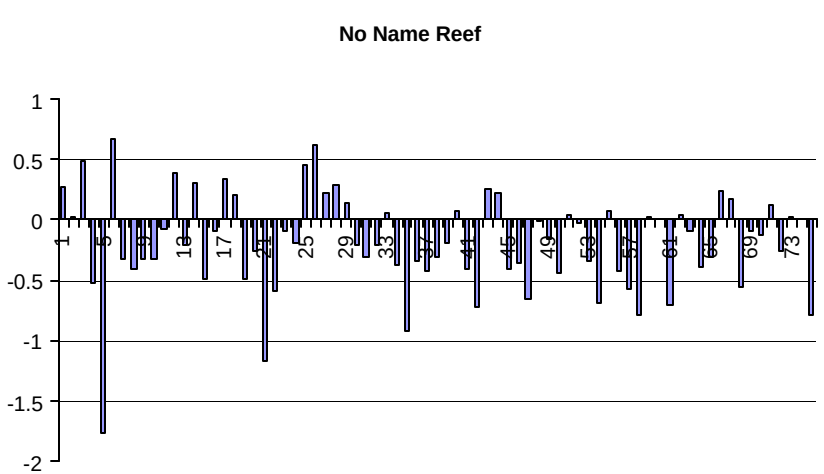
Site	Protection (as of July 1997)	Proportion of Species
Sombrero Reef	No-Take	77%
Molasses Reef	No-Take	68%
Conch Reef	No-Take	65%
Looe Key Research	No-Take	61%
Samantha's Ledge	Open	56%
Pelican Shoals	Open	55%
Hen and Chickens	No-Take	53%
Coffins Patch	No-Take	53%
Sand Key	No-Take	53%
Grecian Rocks	No-Take	52%
Middle Sambo	Open	52%
Eastern Sambo	No-Take	51%
Tennessee Reef Research	No-Take	47%
Carysfort Reef	No-Take	45%
Looe Key East	No-Take	45%
Western Sambo	No-Take	43%
Little Grecian	Open	37%
South Carysfort Reef	No-Take	36%
Pickles Reef	Open	36%
No Name Reef	Open	35%
Western Dry Rocks	Open	29%
Cannon Patch	Open	27%
Newfound Harbor Open	Open	24%
Cheeca Rocks	Open	21%
Delta Shoals	Open	21%
Newfound Harbor SPA	No-Take	19%
Ball Buoy Reef	Open	12%

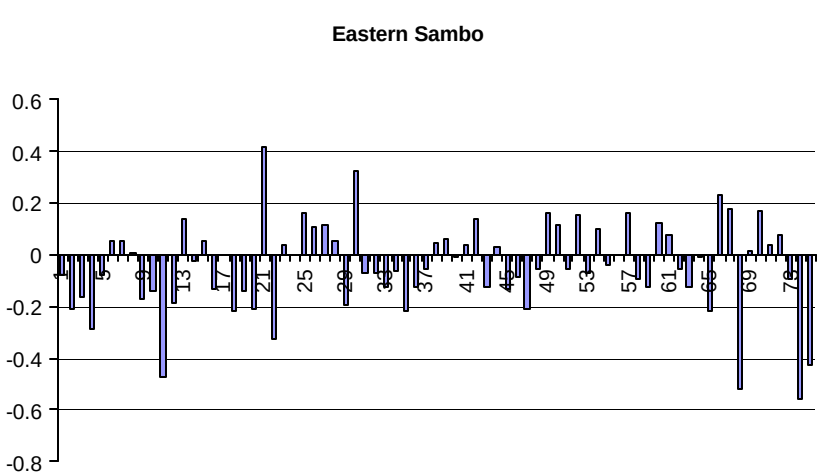
Figure 1. Abundance score trend values for the top 75 fish species, based on REEF data from 1994-2001. Species are listed in order of average sighting frequency*. a) Sites where at least two-thirds (50) of the species declined more or increased less than at other sites. b) Sites where at least two-thirds of the species increased more or decreased less than at other sites.

1a)

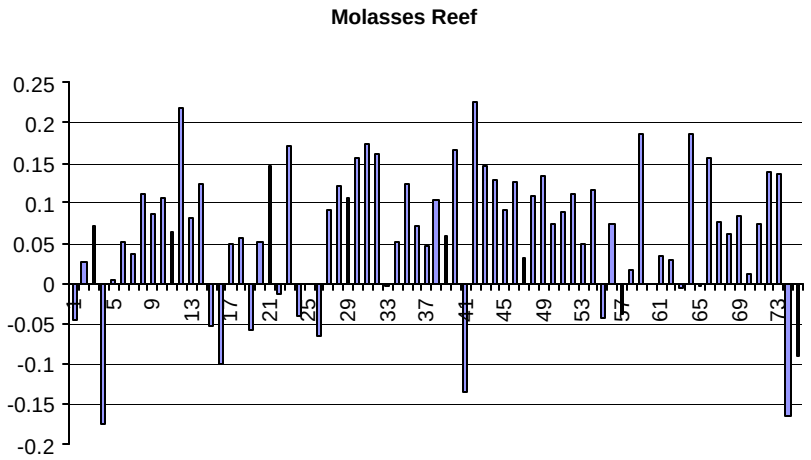


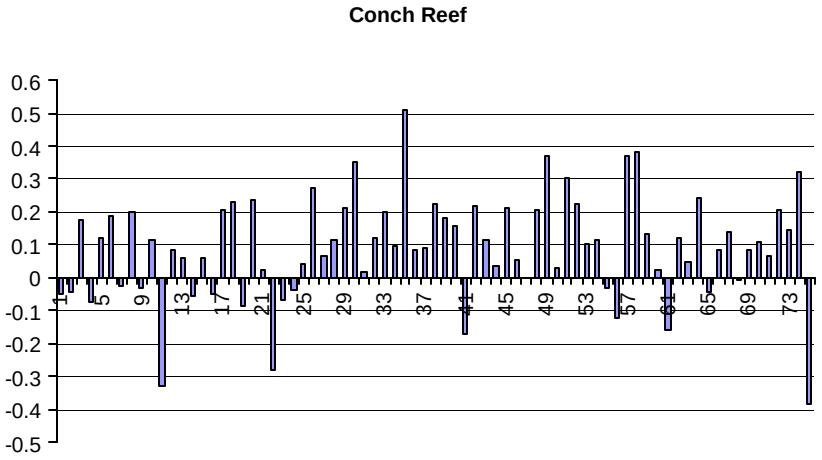






1b)


Molasses Reef
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73


Conch Reef
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1
5
9
13
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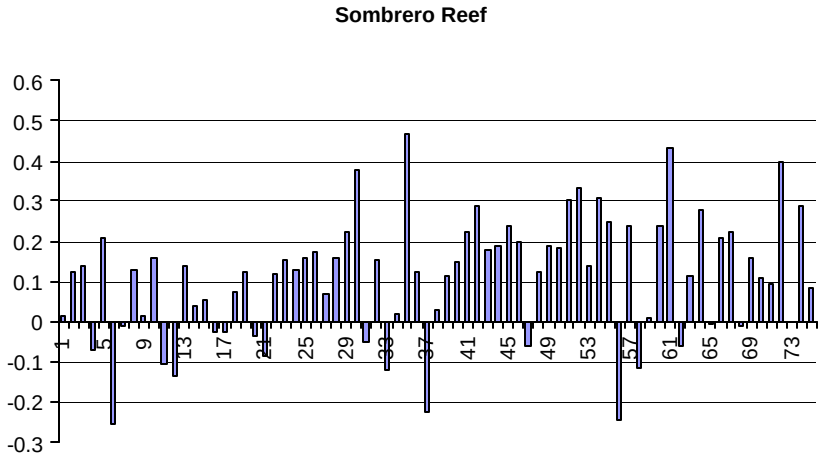
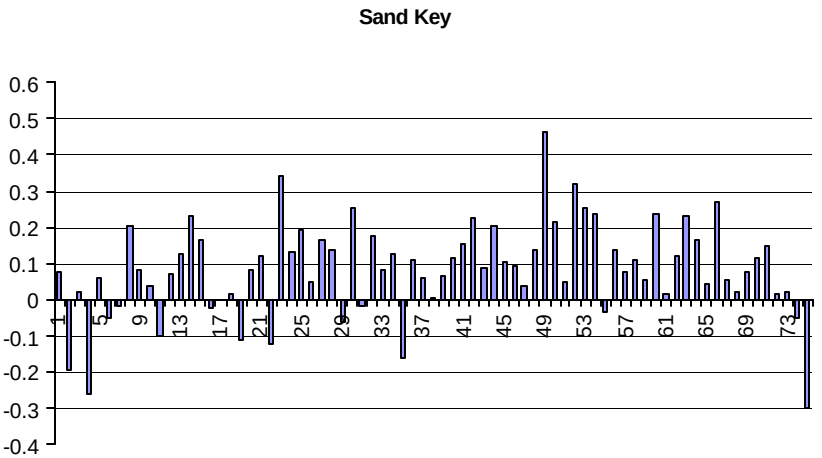
69
73


Sombrero Reef
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73


Sand Key
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73

1b, cont.)

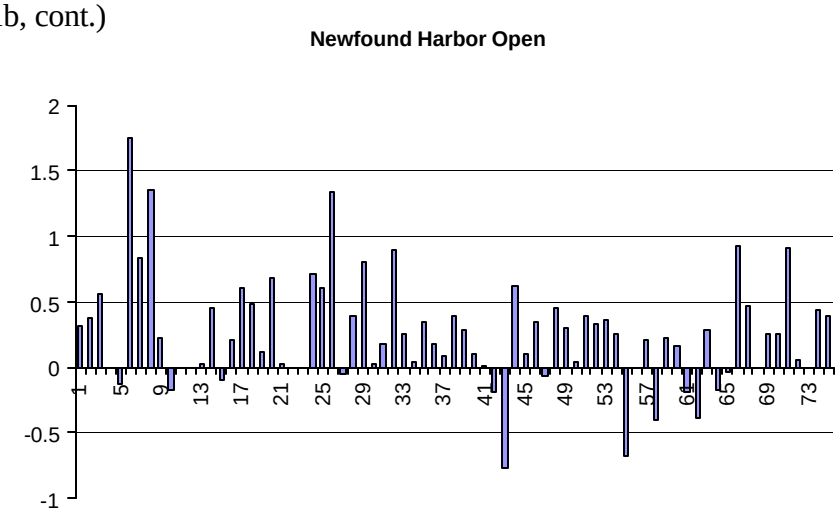
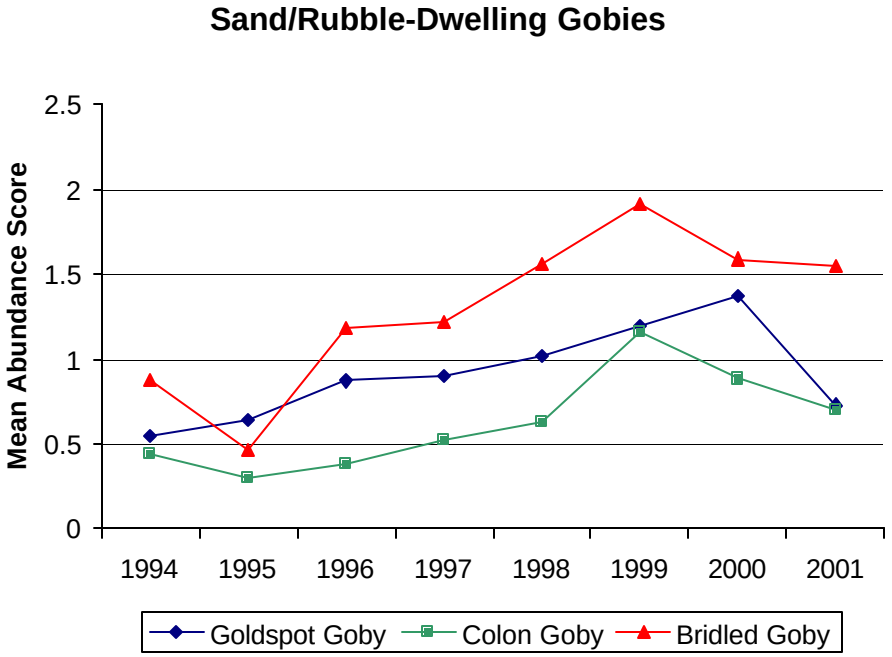


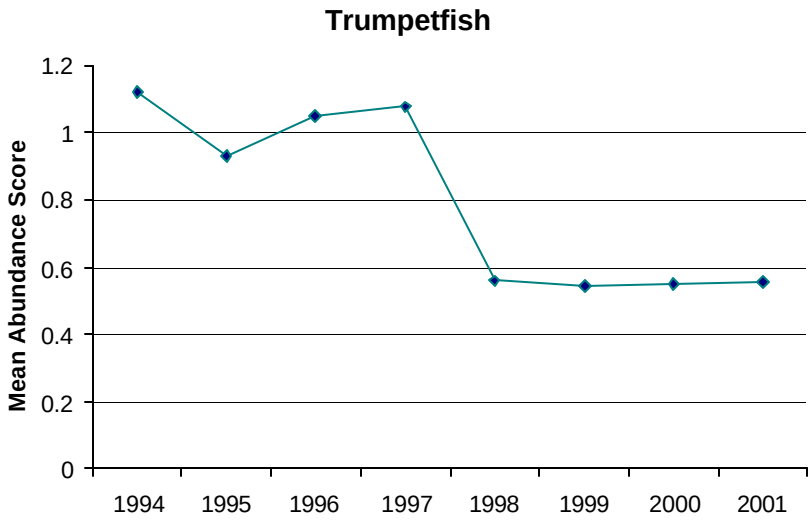
*Figure 1 x-axis: 1-French Angelfish; 2-Gray Angelfish; 3-Queen Angelfish; 4-Rock Beauty; 5-Great Barracuda; 6-Saddled Blenny; 7-Smooth Trunkfish; 8-Banded Butterflyfish; 9-Foureye Butterflyfish; 10-Spotfin Butterflyfish; 11-Blue Chromis; 12-Brown Chromis; 13-Beaugregory; 14-Bicolor Damselfish; 15-Cocoa Damselfish; 16-Dusky Damselfish; 17-Longfin Damselfish; 18-Sergeant Major; 19-Threespot Damselfish; 20-Yellowtail Damselfish; 21-Highhat; 22-Scrawled Filefish; 23-Spotted Goatfish; 24-Yellow Goatfish; 25-Bridled Goby; 26-Colon Goby; 27-Goldspot Goby; 28-Masked Goby/Glass Goby; 29-Neon Goby; 30-Black Grouper; 31-Graysby; 32-Bluestriped Grunt; 33-Caesar Grunt; 34-French Grunt; 35-Black Margate; 36-Porkfish; 37-Sailors Choice; 38-Smallmouth Grunt; 39-Spanish Grunt; 40-White Grunt; 41-Butter Hamlet; 42-Hogfish; 43-Spanish Hogfish; 44-Bar Jack; 45-Blue Parrotfish; 46-Midnight Parrotfish; 47-Princess Parrotfish; 48-Queen Parrotfish; 49-Rainbow Parrotfish; 50-Redbanc Parrotfish; 51-Yellowtail (Redfin) Parrotfish; 52-Redtail Parrotfish; 53-Stoplight Parrotfish; 54-Striped Parrotfish; 55-Sharpnose Puffer; 56-Harlequir Bass; 57-Gray Snapper; 58-Mahogany Snapper; 59-Schoolmaster; 60-Yellowtail Snapper; 61-Longspine Squirrelfish; 62-Squirrelfish; 63-Blue Tang; 64-Doctorfish; 65-Ocean Surgeonfish; 66-Bluehead; 67-Clown Wrasse; 68-Creole Wrasse; 69-Puddingwife; 70-Slippery Dick; 71-Yellowhead Wrasse; 72-Bermuda Chub/Yellow Chub; 73-Yellowhead Jawfish; 74-Glassy Sweeper; 75-Trumpetfish

Figure 2. Mean abundance score by year. All sites are combined, unless noted in the ledgend.

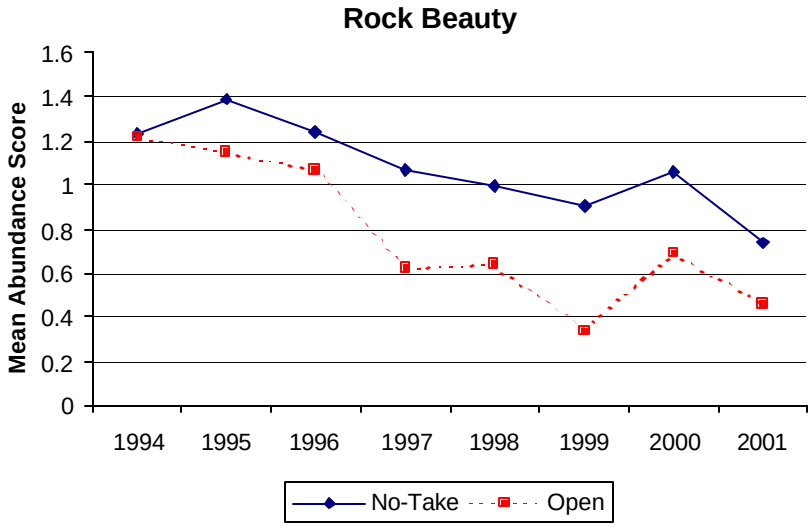
2a)



2b)


Trumpetfish
Mean Abundance Score
1.2
1
0.8
0.6
0.4
0.2
0
1994
1995
1996
1997
1998
1999
2000
2001

2c)


Rock Beauty
Mean Abundance Score
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1994
1995
1996
1997
1998
1999
2000
2001
No-Take
Open

2d)

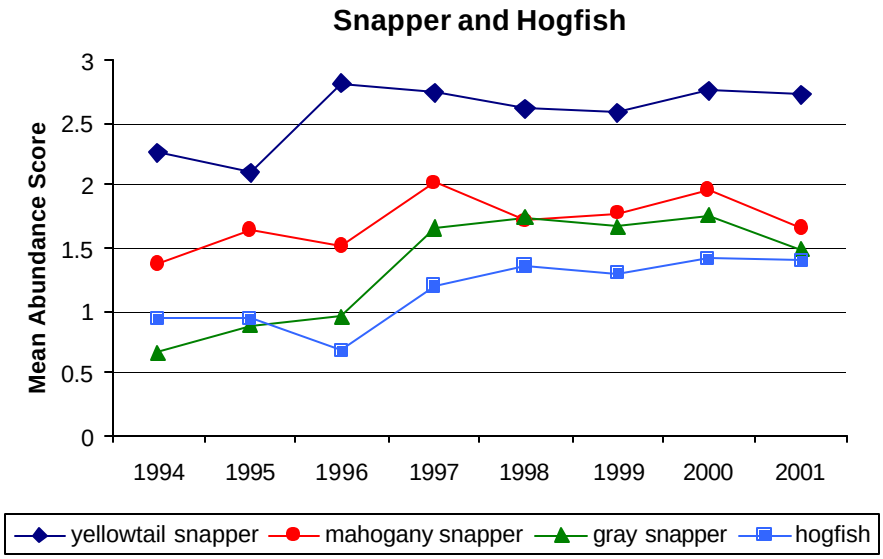
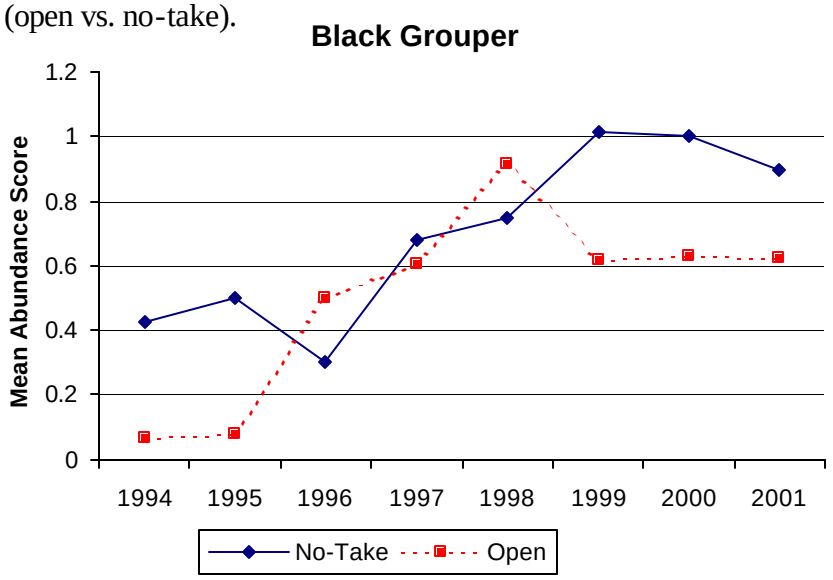

Snapper and Hogfish
Mean Abundance Score
3
2.5
2
1.5
1
0.5
0
1994
1995
1996
1997
1998
1999
2000
2001
yellowtail snapper
mahogany snapper
gray snapper
hogfish

Figure 3. Mean abundance score and sighting frequency by year for black grouper. Sites were grouped by protection (open vs. no-take).

3a)



3b)

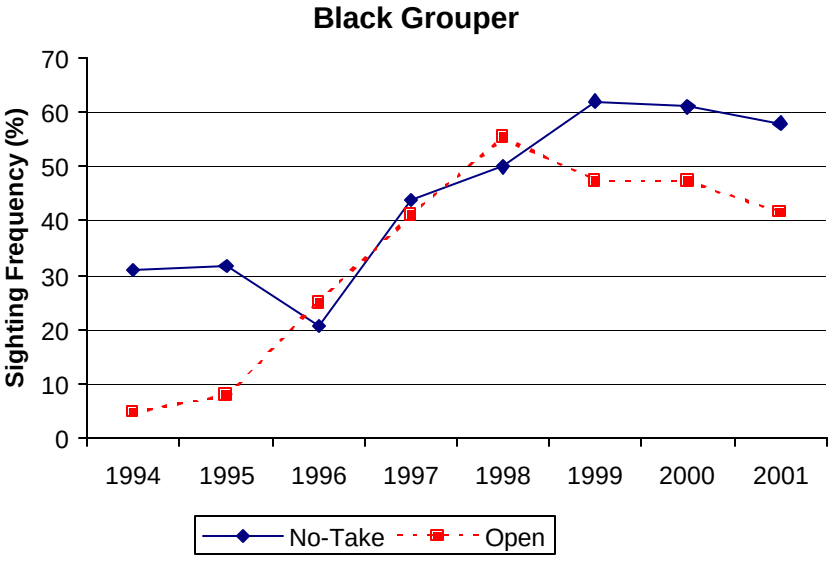


Figure 4. Sighting frequency for red grouper from 1994-2001. Data points represent all 27 sites.