STANDARDIZED VISUAL COUNTS OF MUTTON SNAPPER OFF THE U.S. VIRGIN ISLANDS AND THEIR POSSIBLE USE AS INDICES OF ABUNDANCE

by

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Introduction

The only extended time series of fishery-independent observations of the abundance of mutton snapper in the U.S. Virgin Islands (USVI) come from a volunteer fish-monitoring program administered by the Reef Education and Environmental Foundation (REEF 2006). An inspection of the data revealed that the counts of mutton snapper differed among locations (Figure 1a and 1b) as well as during different months of the year (Figure 2). Hence, there is a need to standardize the observations such that the annual values reflect temporal trends in abundance rather than variations due to dive location, timing, and/or conditions.

The standardization of REEF data is complicated by the fact that observations of multiple fish are lumped together into a series of logarithmically-scaled categories (2-10, 11-100 and > 100). This precludes the use of most canonical approaches for standardizing count data. One alternative is to treat the series as presence-absence data, but this would ignore a considerable amount of the information content of the data. Porch and Eklund (2003) tackled this problem by use of a generalized linear model that assumed the actual number of fish observed under any given set of conditions was approximately Poisson distributed. In their case the study subjects were goliath grouper off Florida, which were never observed in numbers exceeding the 2-10 category. Hence, the recorded frequency of goliath grouper sightings in the REEF data are appropriately modeled by a Poisson distribution censored at 2.

Mutton snapper are encountered in larger groups than goliath grouper, hence observations of 2 or more fish are fairly common and on some occasions more than 10 are seen. In this paper we extend the approach of Porch and Eklund (2003) to explicitly accommodate all of the lumped categories included in the REEF data base and apply the extended model to Mutton snapper in the U.S. Virgin Islands.

Methods

Field data collection:

The REEF database is a compilation of the observations of volunteer divers trained in the roving diver technique (Pattengill-Semmens and Semmens 1998, Jeffrey et al. 2001). Essentially, divers roam freely about a dive site within a 100 m radius of the starting point, recording every species that they can positively identify. After the dive they assign each species to one of four, logarithmically-scaled abundance categories: (1) a single fish, (2) 2-10 fish, (3) 11-100 fish or (4) > 100 fish. Other metrics recorded include dive location and duration, depth, bottom temperature, visibility, habitat type and the experience level of the diver.

The data provided to us included 2096 surveys conducted at 201 dive sites from March 1994 through June 2006. Sites where mutton snapper were never observed and sites visited in fewer than 6 different years were culled from the analysis, leaving a total of 473 surveys at 13 sites (see Table 1). Five of the sites were located in St. Croix and the remaining sites were primarily located in the region between St. John and St. Thomas (Figure 3). The primary habitat types recorded for these sites were: (1) mixed, meaning a variety of individual habitats; (2) high profile reef, where coral structures rise > 1.3 m off the bottom and (3) low profile reef, where coral structures rise < 1.3 m off the bottom. On a few occasions some of these sites were also reported as rubble, sloping dropoffs, ledges, or shear dropoffs. In such cases rubble and sloping dropoffs were counted as mixed habitats while ledges and shear dropoffs were counted as high profile reefs. There were some surveys conducted on artificial structures but these surveys began primarily after the year 2000 and were too limited to include in the analysis.

Statistical modeling:

The expected number of mutton snapper observed on any given dive, μ_i, was modeled by the log-linear model

(4) $$\ln\mu_i = \gamma_\iota + \alpha + \beta_Y + \beta_S + \beta_L + \beta_E + \beta_V + \beta_H$$

where the γ_i is the offset covariate (dive duration) and the β are categorical variables representing the main effects of year, time of year (temporal), location, experience level, visibility and habitat type, respectively. There were thirteen levels of location (Table 1), three levels of visibility (poor, fair and good), two levels of experience (novice or experienced) and four levels of habitat (described above). To explore temporal effects the model was constructed with either two levels to represent spawning season (February–May, June-January), 4 levels for the season of the year (spring, summer, fall, winter), or 12 levels for each month of the year.

The frequency of sightings is assumed to follow a Poisson distribution such that the probability of observing a number of fish falling within the bounds of REEF category N is:

(3) $$p(N) = \begin{cases} \dfrac{e^{-\mu}\mu^N}{N!} & N = 0, 1 \\ \displaystyle\sum_{x=L_N}^{U_N} \frac{e^{-\mu}\mu^x}{x!} & N = 2, 3, 4 \end{cases}$$

where L_N is the lower limit of category N (2, 11, and 101, respectively), and U_N is the upper limit of category N (10, 100, and infinity, respectively). Accordingly, maximum likelihood estimates for the parameters α and β may be obtained by minimizing the negative loglikelihood expression

(4) $$L = \sum_{N_i=0}\mu_i + \sum_{N_i=1}(\mu_i - \ln\mu_i) - \sum_{N_i=2}\ln\left(\sum_{x=2}^{10}\frac{e^{-\mu}\mu_i^x}{x!}\right) - \sum_{N_i=3}\ln\left(\sum_{x=11}^{100}\frac{e^{-\mu}\mu_i^x}{x!}\right) - \sum_{N_i=4}\ln\left(1 - \sum_{x=0}^{100}\frac{e^{-\mu}\mu_i^x}{x!}\right)$$

All model fits (negative loglikelihood minimizations) were accomplished using the utilities provided in the software package AD Model Builder[1]. The most parsimonious combination of main effects was identified by use of the AICc criteria. Interaction effects were not estimated owing to the sparseness of the observations at many of the sites. Standardized measures of visual counts for each year were constructed as

(6) $$N_Y = \exp\{ \alpha + \beta_Y \}.$$

Results and Discussion

The data were first explored to discern any relationship between the number of mutton snapper counted and either spawning events or dive duration. Spawning is believed to occur in the spring in the USVI and a comparison of abundance codes recorded between February-May and those recorded between June-January showed no obvious relationship (Figure 4). However there appeared to be a cyclical pattern in the monthly counts so initially season (spring, fall, winter, summer), spawning (spawning season or not), and months were explored as potential covariates. The fit to the data was degraded by including season (4 levels) or spawning (2 levels) but was considerably improved by including month (12 levels) as a covariate.

Although there was no obvious relationship between the number of mutton snapper counted and dive duration (Figure 5), it would make sense that increased dive times should improve the ability of the diver to spot any mutton snapper that would be on the site. Unlike

[1] AD Model Builder Version 6.0.2. Otter Research Ltd., Box 2040, Sidney, B.C. V8L 3S3, Canada.

goliath grouper, whose large size probably made this affect insignificant, incorporating dive duration as the offset did improve the fit of the mutton snapper model according to the AICc. This underlying relationship may not be apparent in Figure 5 simply due to the unbalanced sampling design. Visibility which also proved insignificant in the goliath grouper application would also be expected to improve a diver's ability to spot mutton snapper and did improve the mutton snapper model fit according to the AICc. Including experience (2 levels) in the model, on the other hand, degraded the fit and was not included in the model.

The main effects associated with year, location (geozone), and month proved statistically significant. Location was the most significant covariate and had the greatest effect of the fit of the model. An examination of Figures 1a and 1b show obvious differences in the counts between the survey locations used in this analysis and provide a visual explanation of the importance of this factor. Although not as compelling, we also included dive duration as an offset and both visibility and habitat type as covariates which improved the fit of the model. The final results from the analysis indicate that in the areas surveyed abundance remained relatively low through 2001 when an increase in the number of mutton snapper began to occur (Figure 6). Note that the final data point for 2006 was derived from a relatively small sample size from only half of the year. Accordingly the calculated standard deviation is almost equal to the standardized index with a coefficient of variation just over 100%. Interpretation of these results should consider the uncertainty surrounding this point. Only additional data from 2006 and 2007 will provide a better indication if an increasing trend is still indicated.

Although the REEF survey does provide the only time series of fishery-independent data available for the region, the data are still relatively limited and the results should be used cautiously. However, the trend indicated in this analysis is consistent with trends observed for mutton snapper in Puerto Rico in the standardized indices presented in the Addendum to the SEDAR-DW-01 report. In both the hook-and-line and pot fisheries of Puerto Rico an increasing trend in abundance was indicated to have started around 1998. Although these studies clearly span relatively large geographic areas and may be discrete stocks, all of the limited data that is available from this region indicate that stocks of mutton snapper may have begun to increase in abundance sometime around 1998- 2000.

Literature Cited

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Table 1. Sites in the Reef Education and Environmental Foundation database used for this analysis, with the number of surveys conducted at each site between 1994 and 2006 and the total number of mutton snapper that were observed (abundance codes of 2 and 3 were counted as 2 and 11 individuals respectively).

Location	REEF Geozone	Number of Mutton Snapper	Number of Surveys	Number of Years
West Wall/Salt River Canyon	64010009	3	29	6
Cane Bay 'Oh The Wall'	64010013	16	38	6
Scotch Bank	64010014	9	33	6
Eagle Ray Pass	64010015	4	52	6
Cane Bay	64010019	15	29	6
Calf Rock	64020006	6	27	9
Ledges of Little Saint James	64020008	32	65	11
Cow Rock	64020009	93	71	10
Dog Rock	64020014	12	39	8
Grass Cay	64030008	12	19	6
Mingo Cay	64030011	6	32	10
Congo Cay	64030012	3	23	7
Greater Lameshur/Haulover Bays	64030018	4	16	6

Table 2. Relative standardized count index for mutton snapper in the US Virgin Islands.

Year	Number of Surveys	Relative Index	SD	CV (%)
1994	8	1.61	1.35	83.36
1995	6	0.01	0.01	97.55
1996	29	1.55	0.90	58.23
1997	7	0.01	0.01	83.36
1998	43	1.17	0.49	41.81
1999	66	0.31	0.19	62.26
2000	48	0.07	0.06	79.89
2001	63	0.09	0.05	54.03
2002	49	1.12	0.39	34.59
2003	36	0.81	0.28	34.90
2004	38	1.94	0.51	26.41
2005	69	4.09	0.83	20.21
2006	11	0.21	0.22	101.29

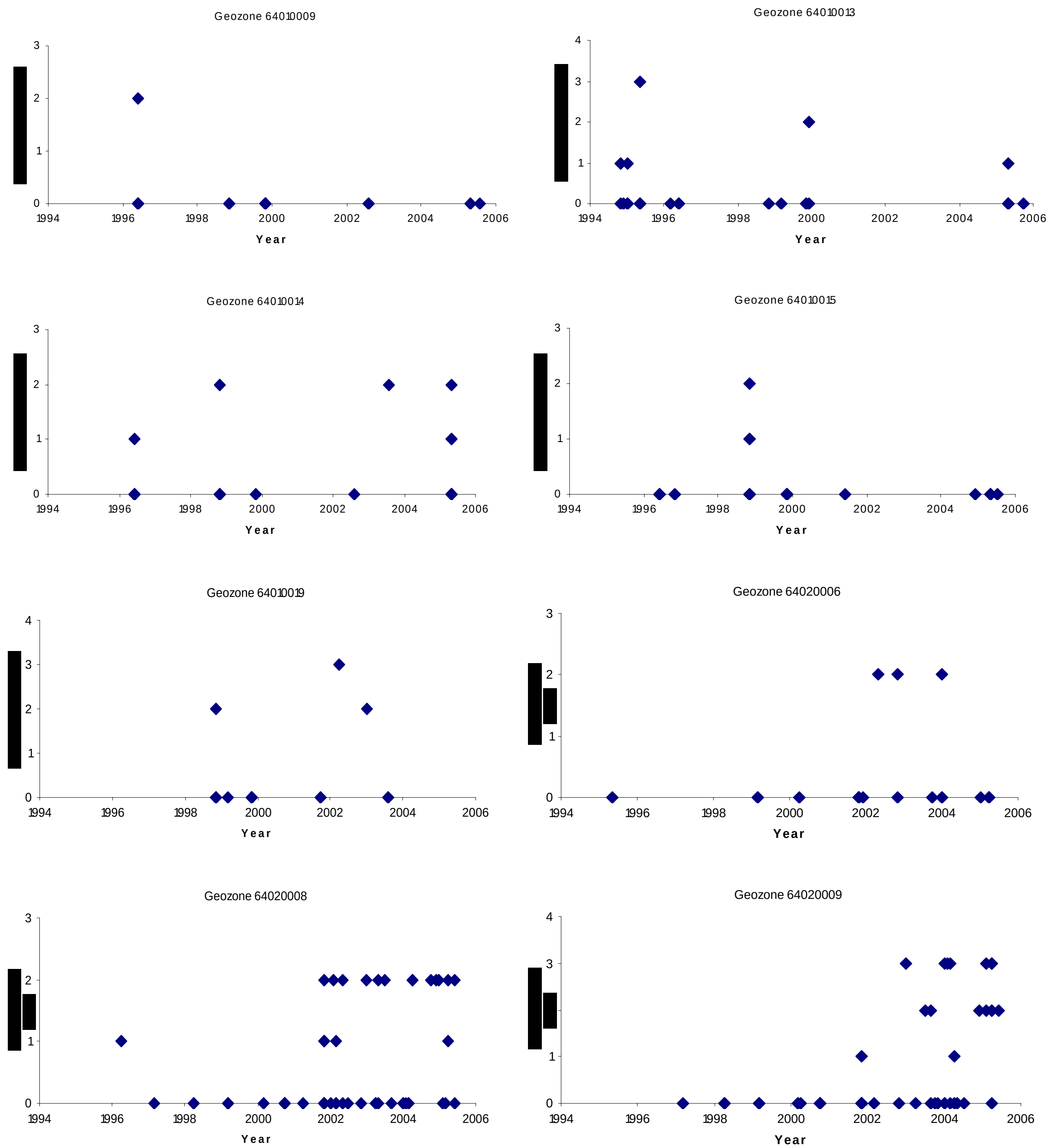


Figure 1a. Abundance codes recorded during the REEF surveys at the locations used in this analysis. Abundance codes 1, 2, and 3 represent 2-10, 11-100 and > 100 individuals respectively. Note that each plotted point may represent a number of surveys if the same abundance code was recorded during the same month (i.e. number of points will be less than sample size in Table 1).

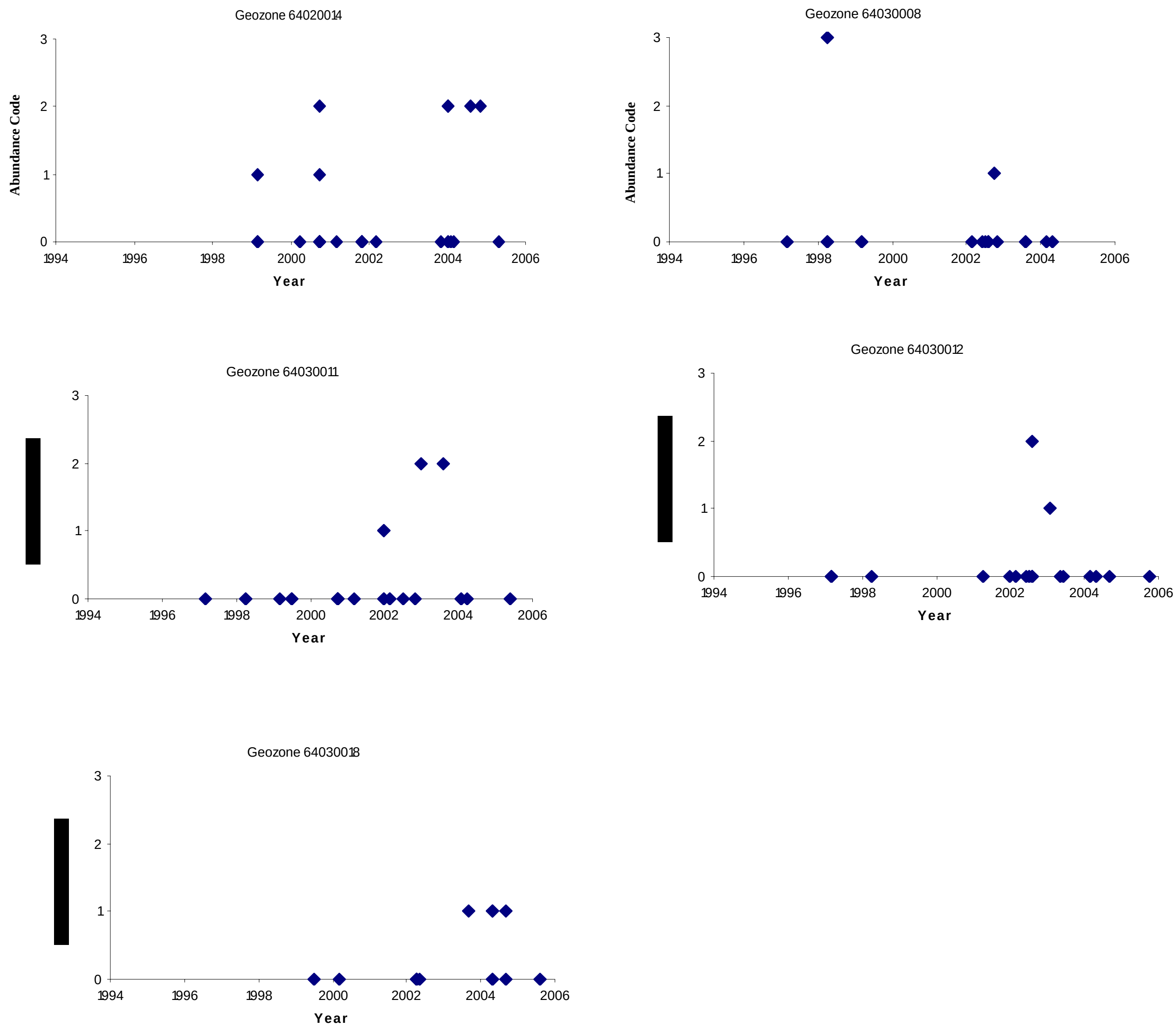


Figure 1b. Abundance codes recorded during the REEF surveys at the locations used in this analysis. Abundance codes 1, 2, and 3 represent 2-10, 11-100 and > 100 individuals respectively. Note that each plotted point may represent a number of surveys if the same abundance code was recorded during the same month (i.e. number of points will be less than sample size in Table 1).

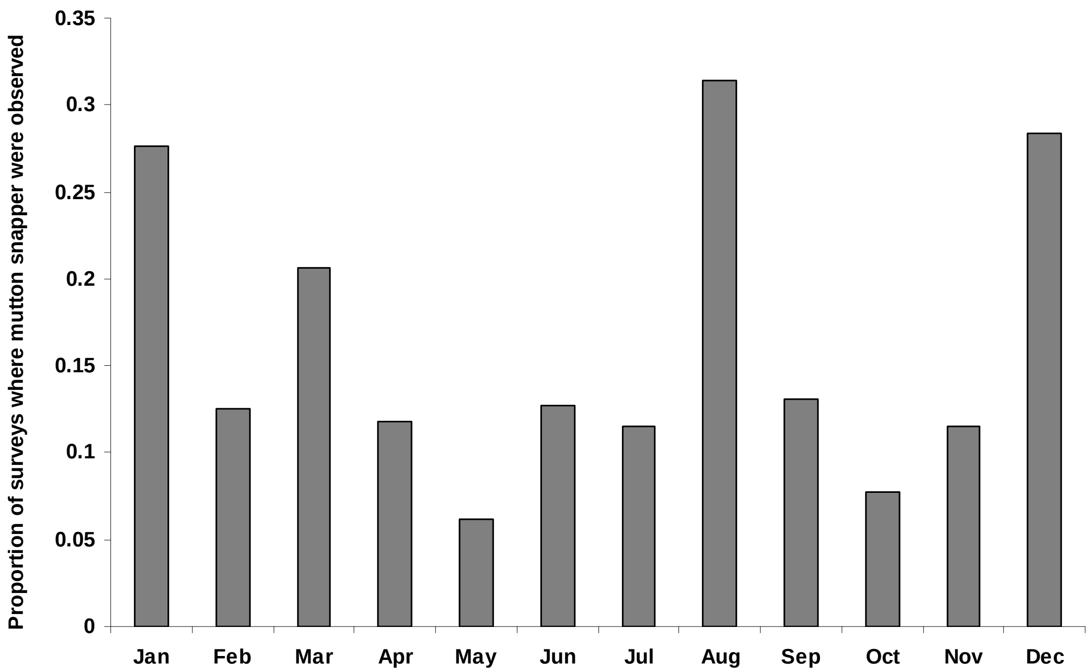


Figure 2. Proportion of REEF surveys where at least one mutton snapper was observed (number of positive surveys/total number of surveys) in the 13 sites locations used in this analysis.

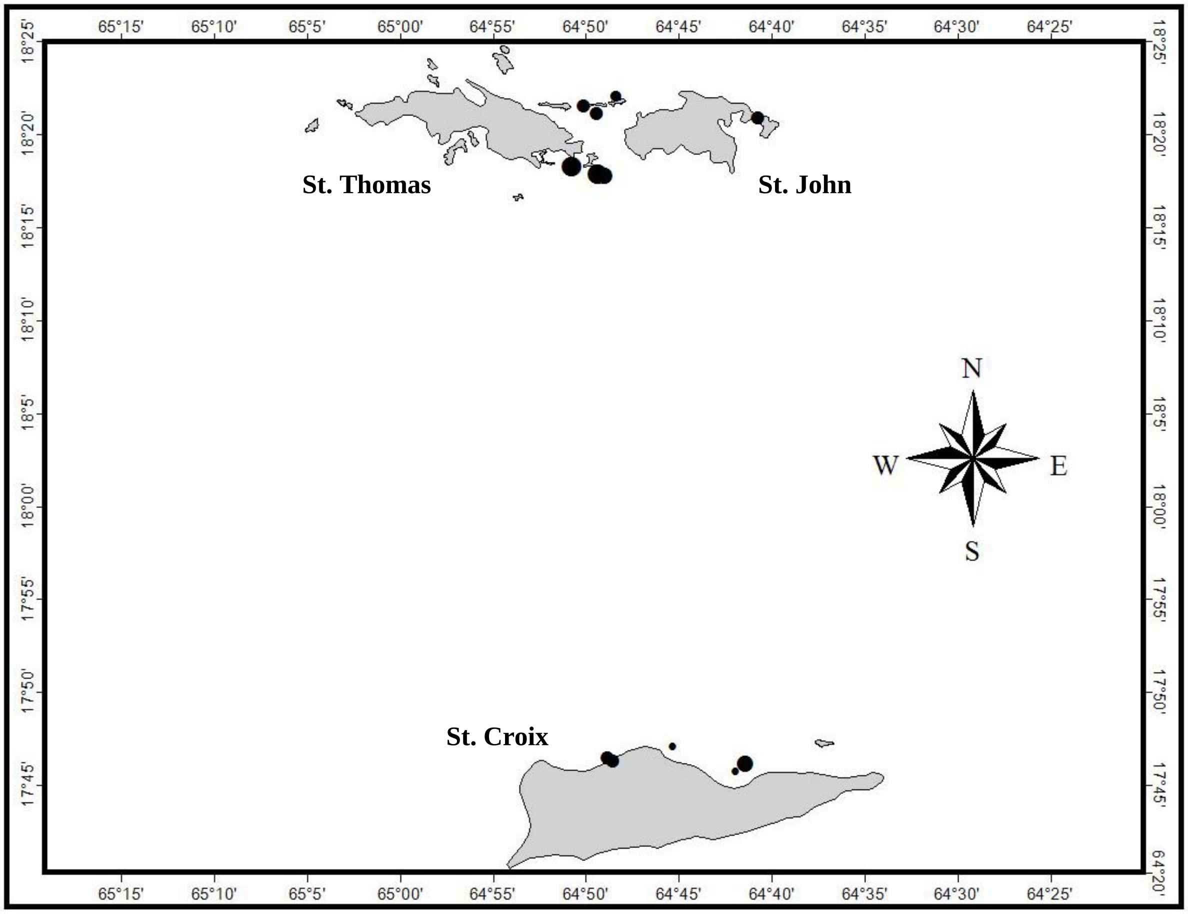


Figure 3. Survey locations where the Reef Education and Environmental Foundation's volunteer divers observed mutton snapper and conducted surveys in at least 6 years between 1994-2006. Size of bubble reflects the number of mutton snapper observed standardized by the number of surveys.

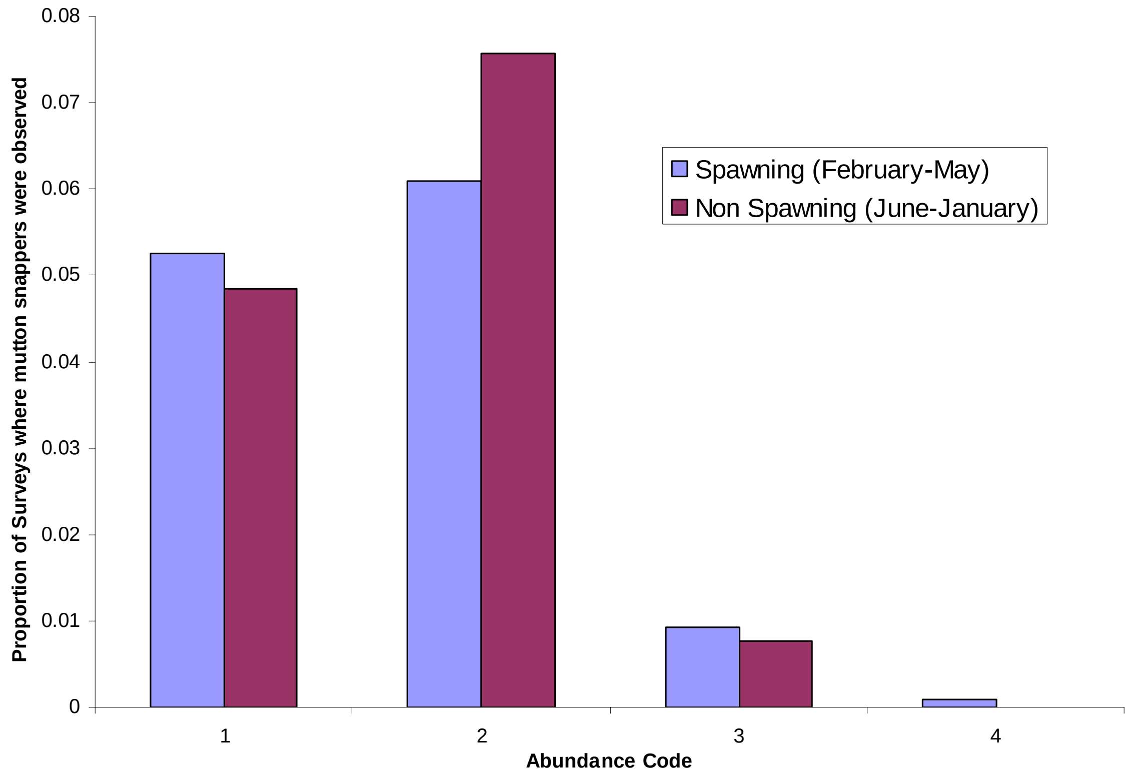


Figure 4. Proportion of surveys from the entire US Virgin Islands REEF database where the corresponding abundance code was recorded. Data were split assuming a spawning period in the spring from February – May. Abundance code 1 is 1 fish, 2 is 2-10 fish, 3 is 11-100, and 4 is greater than 100.

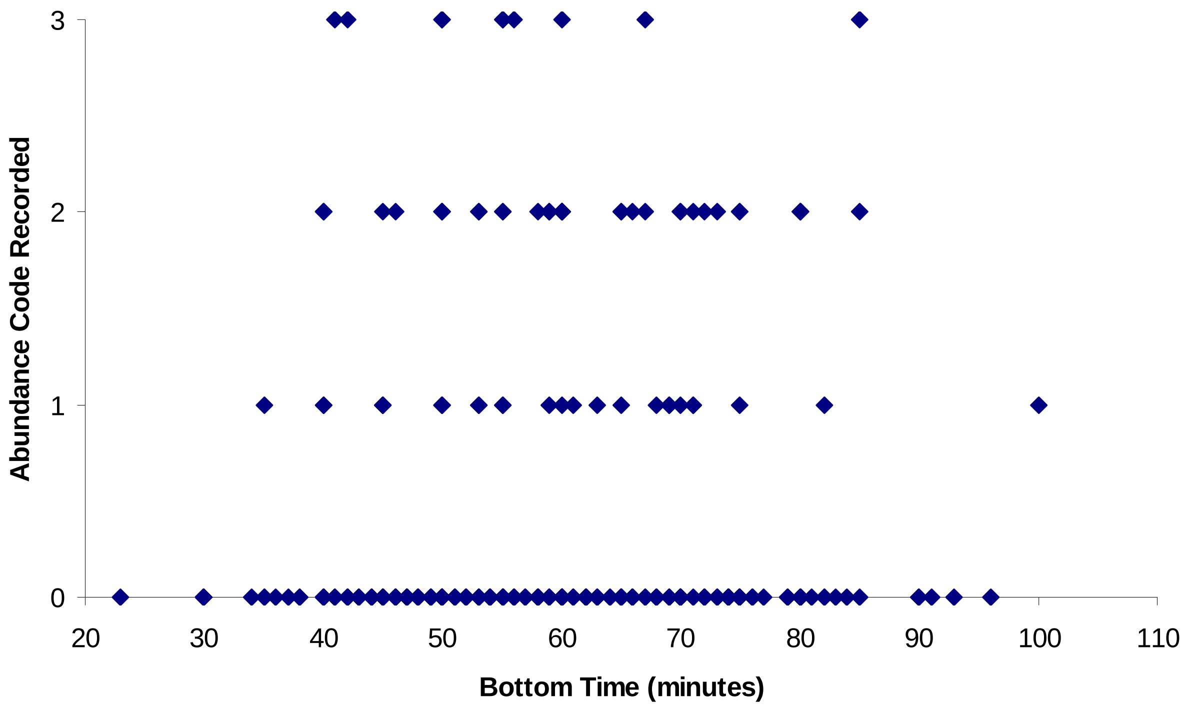
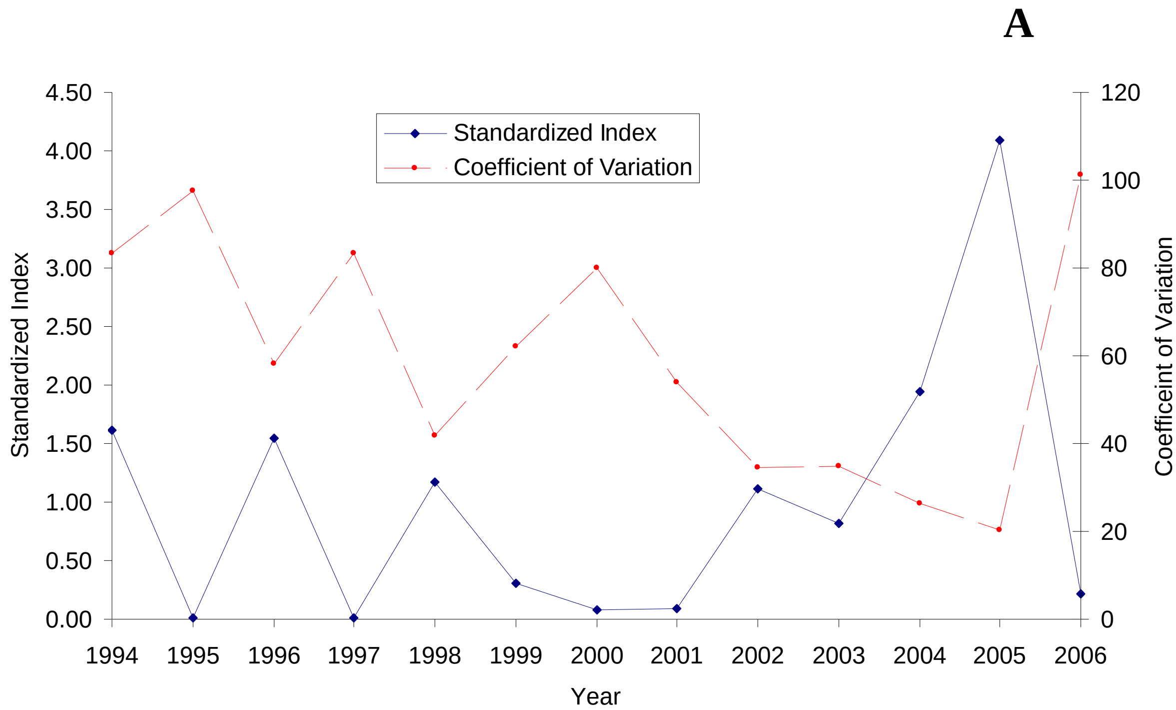


Figure 5. Relationship of dive duration to abundance codes recorded in the 13 sites used in this analysis



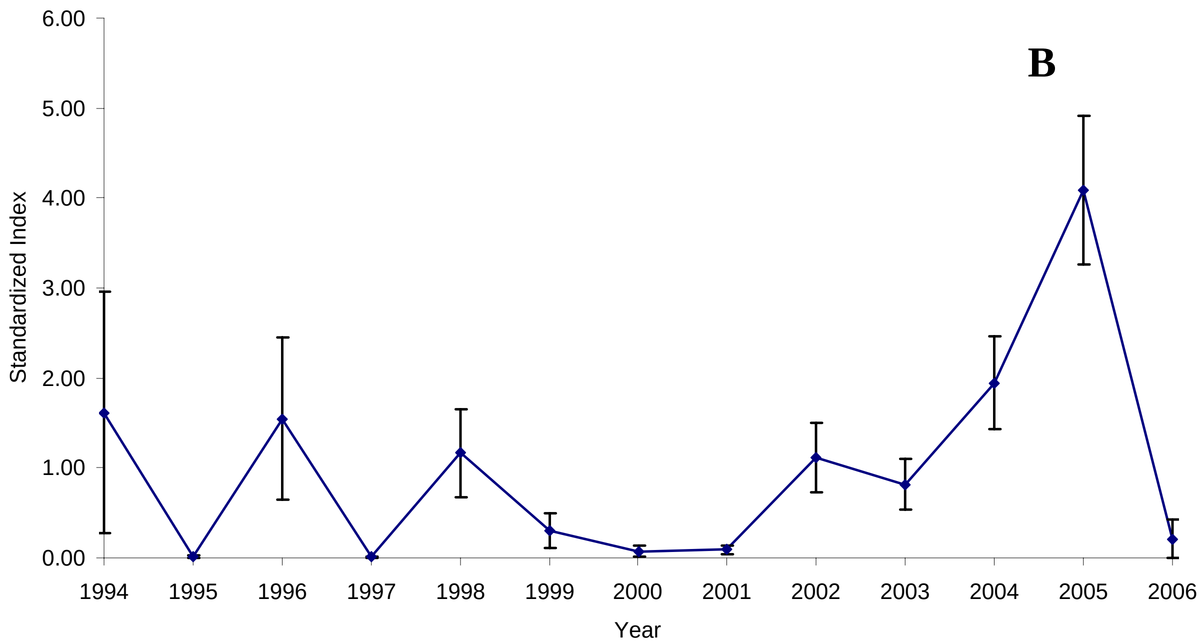


Figure 6. Relative standardized counts of mutton snapper (solid line) with the coefficient of variation (dashed line in A) and +/- standard deviation (error bars in B) from the REEF database of diver observations of mutton snapper in the US Virgin Islands, from 1994-2006. Note that 2006 data point only contains information from 11 surveys in the first part of the year.