Stock Analysis and Management Strategies for Red Hind, *Epinephelus guttatus*, in the U.S. Virgin Islands

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ABSTRACT

Analysis of landings data from 1984 to 1988 demonstrated a significant decline in average size and the apparent loss of large size classes of red hind, *Epinephelus guttatus*, in St. Thomas, U.S. Virgin Islands. The two large islands in the U.S. Virgin Islands, St. Thomas and St. Croix, are on separate geological platforms with different species abundances; therefore, data were analyzed separately. Fisheries parameters analyzed differed between the two platforms. Information obtained from fishermen suggested a classic case of overfishing spawning aggregations. The decline of red hind mirrors the demise of Nassau grouper, *E. striatus*, off St. Thomas during the mid-1970's. Landings information from a known spawning aggregation during 1988 and 1989 demonstrated a trend for smaller average size for red hind and a skewed sex ratio toward an abundance of gravid females. This suggests a shortage of males in the population and an increased potential for spawning failure.

Strict management strategies have been recommended to reverse the present trend. Protection of spawning sites has been proposed as the first critical action for maintaining adequate spawning success. Additional management strategies, such as gear restrictions and establishment of permanent refuges, are also needed to insure adequate stock recovery.

INTRODUCTION

Fisheries in the Caribbean are a traditional and culturally important food source, especially on small islands. Even in the developed islands with abundant imported foods, fresh seafood is a daily staple. However, increased demand due to larger island populations and modernization of harvest techniques has resulted in local and regional decline of reef fish stocks.

Stock decline is particularly apparent for large, carnivorous reef fishes, such as groupers and snappers. Many of these species are especially vulnerable to overfishing due to the reproductive behavior of forming large spawning aggregations, longevity, and slow growth. For these reasons, tropical groupers and snappers have received much attention and scientific investigation in recent years (Polovina and Ralston, 1987).

Red hind, *Epinephelus guttatus*, has historically been an important grouper species in most Caribbean fisheries. Following the documented decline and eventual loss of the Nassau grouper (*E. striatus*) fishery in the U.S. Virgin Islands (Olsen and LaPlace, 1978), *E. guttatus* has become the dominant grouper in the fishery. Due to its abundance, size and palatability, *E. guttatus* has become one of the most preferred species in the fishery with a value of $3.00 to

$3.50 (US) per pound (1989 market price). Presently, *E. guttatus* is one of the five dominant species by weight in commercial landings in the St. Thomas fishery (Division of Fish and Wildlife, DFW files).

Recent investigations have documented several of the important aspects of the biology of *E. guttatus*. As in some other Caribbean grouper species, *E. guttatus* is a protogynous hermaphrodite which forms spawning aggregations during full moon periods between December and March (Shapiro, 1987). Sex change from female to male appears over a large size range (Sadovy, pers. comm.). Size and age at first reproduction has been documented at approximately 220 mm TL and age 2 – 3, respectively (Sadovy *et al.*, 1989).

Spawning aggregations of snappers and groupers have been known and intensively fished in the U.S. Virgin Islands for two decades. During the 1970's, fishing pressure on spawning aggregations increased dramatically. From 1968 to 1976, four to thirteen small fishing boats were observed fishing *E. striatus* during peak aggregation periods (an average of two to four per day) using an average of approximately ten fish traps (Olsen and LaPlace, 1978). By the early 1980's, ten to fifteen boats were present per day with several "strings" of traps, six to fifteen traps per string, set at the spawning site.

The two island groups in the U.S. Virgin Islands are on separate geological platforms with St. Croix approximately 40 miles south of St. Thomas-St. John. Species composition of the fishery varies between island groups with red hind (*E. guttatus*) and queen triggerfish (*Balistes vetula*) being in greater abundance on St. Thomas-St. John than on St. Croix (unpublished data, DFW files). Coney (*E. fulvus*) is more abundant in the fishery on St. Croix. Both island groups have experienced species shifts in recent years with landings presently dominated by parrotfishes (Scaridae) and surgeonfishes (Acanthuridae; unpublished data, DFW files).

The fisheries differ between the two island groups in other important aspects. The dominant gear type is the fish trap with 1-1/2 inch mesh (1986 – 1987 data: St. Thomas, 72.1% by weight; St. Croix, 62.6%) with handlining more important on St. Croix (24.3%; St. Thomas, 15.0%). A large difference in marketing exists with most fish taken to central market for resale on St. Croix while on St. Thomas fish are sold by fishermen at shore, from trucks or taken to contracted restaurants.

The intensive fishing effort has resulted in a total loss of aggregations of Nassau grouper (*E. striatus*) at the known spawning site south of St. Thomas and on Lang Bank north-northeast of St. Croix. Large aggregations of *E. guttatus* have apparently replaced *E. striatus* at these spawning sites in recent years. Increased effort and reports by fishermen have suggested a decline in *E. guttatus* abundance. Similar reports were noted in Puerto Rico (Y. Sadovy, pers. comm.).

In view of the declining stocks of *E. guttatus*, the present investigation was

initiated to study their spawning aggregations and to assess stocks in the U.S. Virgin Islands.

METHODS

Biostatistical sampling of red hind (*Epinephelus guttatus*) was initiated in 1984 in the U.S. Virgin Islands as part of the Virgin Islands/National Marine Fisheries Service Cooperative Fisheries Statistics Program. One study objective has been to obtain length and weight data on as many commercial species as possible during every month. The approach was to obtain a stratified sample of commercial harvest by sampling catches by different gear types on a voluntary basis with cooperative fishermen. Ideally, complete catches from most fishermen on all islands would be sampled each year.

Data recorded on individual specimens were fork length (total length for *E. guttatus*) in millimeters, weight in grams, and reproductive condition, if available. Additional information was collected on vessel length, gear soak time, location fished, units of gear, and estimated total catch. Standard length was taken to develop conversions.

Intensive data collection was conducted during spawning periods. Observations from fishermen were recorded and data on individual specimens were collected, when available. Scuba dives were conducted during peak spawning to observe aggregation size and fish behavior and to record habitat information.

Landings data for red hind (*Epinephelus guttatus*) were summarized by month and year. Length data were compiled into 1 cm increments. Due to the longevity of red hind (Thompson and Munro, 1983; Sadovy *et al.* , 1989) and the small sample size per month, neither independent modes nor modal progressions were apparent among length-frequency output, therefore, computation of age and growth parameters was not conducted.

Data were entered on a microcomputer in Lotus 1-2-3 for summary and analysis. Fisheries parameters were calculated following Ricker (1975). Statistical analyses were performed using Systat. Graphical analyses were completed using Lotus 1-2-3 and Harvard Graphics.

Sampling biases were:

1. Few fishermen volunteer for sampling.
2. Complete catches are rarely sampled.
3. Large catches are rarely sampled on St. Thomas.
4. Preferred species are frequently undersampled since many fishermen bag these fishes before landing.
5. Large individuals of many species are sold before a sample can be taken.
6. Effort data are not reliable.

RESULTS

Observations of Spawning Aggregations

Documented spawning aggregation sites of commercially important species in the Virgin Islands are presented in Figure 1. Heavy fishing pressure has been observed at all sites. Other locations have been noted by fishermen primarily in the British Virgin Islands which sustain less fishing pressure.

In addition to these large aggregations, fishermen relate that *Epinephelus guttatus* and *E. striatus*, as well as other important species form small, loose aggregations in some areas, especially on banks or large prominences. Small aggregations of *E. guttatus*, *E. striatus* and *Lutjanus analis* have been reported around prominences near the shelf edge north of St. Thomas.

Although Olsen and LaPlace (1978) documented the Nassau grouper (*E. striatus*) spawning aggregation south of St. Thomas, *Epinephelus striatus* have not been observed at this spawning site for several years. Spawning aggregations of *E. guttatus* were not observed at this site during this previous investigation; however, during recent years this location has been the primary spawning site of *E. guttatus* south of St. Thomas and St. John.

In January, 1989, observational dives were conducted at the grouper aggregation site south of St. Thomas to record fish behavior and relative abundance and to record habitat characteristics. Local spawning aggregations display strong lunar periodicity; therefore, observational dives were made during peak spawning periods which occur during the week of the full moon in January. Water depth of the shelf edge reef was 38 – 48 m. The substrate was dominated with dense scleractinian cover, primarily plates of *Montastrea annularis*. Additional habitat information was described by Olsen and LaPlace (1978). Numerous fish traps were observed, each with 10 – 30 individuals of *E. guttatus* inside. Few *E. guttatus* individuals were observed over surrounding substrate. During previous years, large numbers of individuals had been noted on the bottom.

Intensive port sampling was conducted during the 1988 – 1989 spawning season. Fishermen observed smaller spawning aggregations with low catches of immature individuals and gravid females. No spent females nor any males were observed. Fishermen reported that large males were captured but not in abundance. Additional information from fishermen suggested that the previously reported yellowfin grouper (*Mycteroperca venenosa*) spawning aggregation south of St. Thomas did not occur in 1989.

Analysis of Port Sampling Data

Length-frequency data are presented for St. Thomas in Figure 2 and for St. Croix in Figure 3. *Epinephelus guttatus* usually appear in the U.S. Virgin Islands fishery at the 20.0 cm size class. During the years analyzed, the dominant size classes ranged from 25.0 to 30.0 cm. Length and weight statistics for St. Thomas

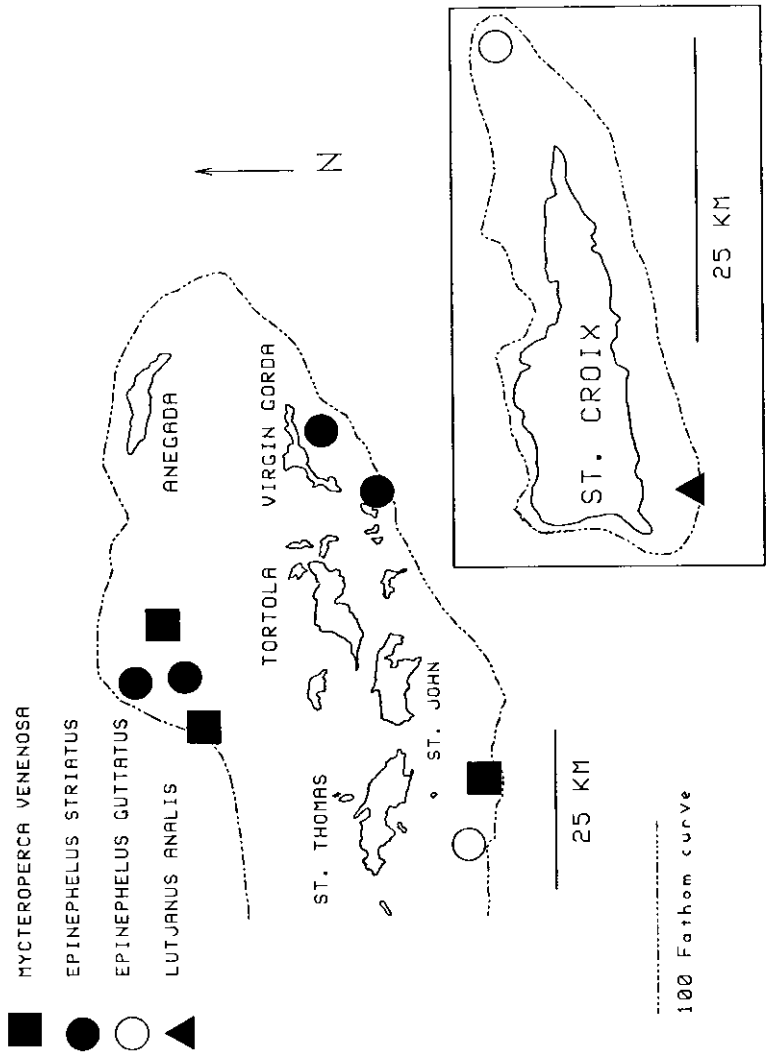

Figure 1. Location of known spawning aggregations in the Virgin Islands.

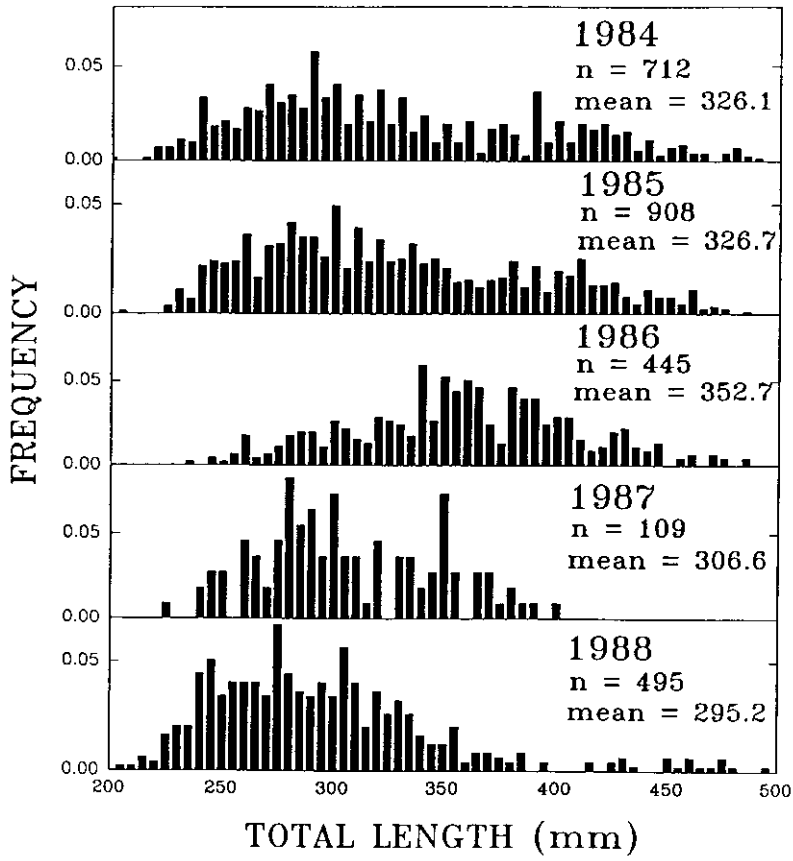

Figure 2. Length frequency distributions of red hind, *Epinephelus guttatus*, for St. Thomas, 1984 – 1988.

and St. Croix (1984 – 1988) are given in Table 1.

On St. Thomas, there has been a significant shift toward smaller fish with a sharp decline in the larger size classes. The small sample size in 1987 is due to lower sampling effort and not a decline in abundance of *E. guttatus*. The decline in large size classes is quite evident between 1984 and 1988 (Figure 4). A Kolmogorov-Smirnov test demonstrated a significant difference between these

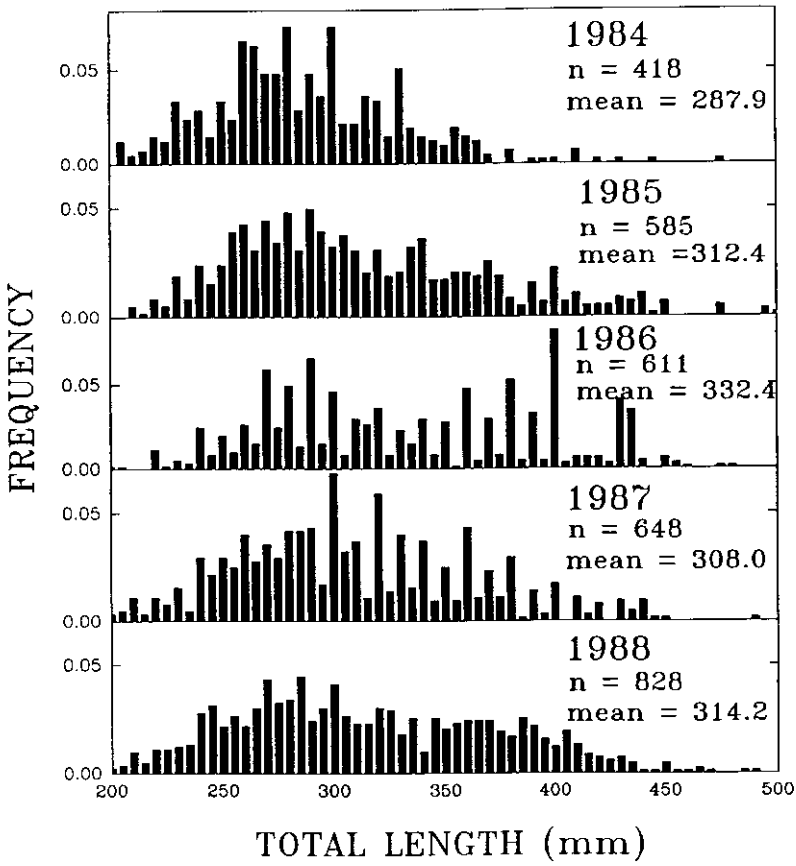

Figure 3. Length frequency distributions of red hind, *Epinephelus guttatus*, for St. Croix, 1984 – 1988.

frequency distributions ($D = 0.079$, $p < 0.05$). The difference in mean length between these years was statistically significant (Table 2).

Variation in the length frequency distribution among years for St. Croix was small (Figure 3). No large aggregation of *E. guttatus* has been documented for St. Croix. The size increase noted in 1986 for both islands (Figures 2 and 3) was

Table 1. Length and weight statistics for *Epinephelus guttatus*, St. Thomas and St. Croix (1984 - 1988). (length=mm FL; weight=grams)

	MINIMUM		MAXIMUM		MEAN	
	Length	Weight	Length	Weight	Length	Weight
ST. THOMAS						
1984	196	113	535	2155	335.50	584.50
1985	205	125	514	2040	326.62	575.36
1986	235	175	520	1815	356.38	726.61
1987	225	150	398	975	306.55	456.79
1988	205	100	504	1900	297.25	432.64
ST. CROIX						
1984	203	113	475	1588	287.90	374.93
1985	208	100	496	2438	312.43	538.55
1986	200	150	480	2200	332.44	631.78
1987	200	150	490	1850	308.01	528.18
1988	178	100	490	2400	313.69	591.13

possibly due to a strong age class which dominated the catch.

The mean total length for all individuals measured was significantly different between islands (St. Thomas: 324.2 mm, n = 2651; St. Croix: 312.6 mm, n = 3073; T-statistic = -7.402, p = 0.001).

Sex determination was conducted on samples from the spawning aggregation south of St. Thomas. Few males (n = 8; females, n = 117) were observed among reproductively active individuals sampled. No males were observed in the 1989 sample. Females averaged 339.6 mm TL (range: 245 – 455 mm TL) while males averaged 397.0 mm TL (range: 260 – 493 mm TL; Figure 5).

Regression analysis conducted to determine the length (mm) - weight (g) relationship for St. Thomas and for St. Croix were:

St. Thomas

$\log W = -4.833 + 3.001 * \log TL$

$W = 0.0000147 * TL^{3.001}$ $\quad N = 2651; r^2 = 0.92$

St. Croix

$\log W = -4.711 + 2.966 * \log TL$

$W = 0.0000195 * TL^{2.966}$ $\quad N = 3073; r^2 = 0.89$

These relationships are similar to those previously calculated for *E. guttatus* (Thompson and Munro, 1983; Bohnsack and Harper, 1988; Sadovy *et al.*, 1989).

Table 2. Results of ANOVA and Tukey HSD for total length among years for *Epinephelus guttatus*, 1984-1988, St. Thomas and St. Croix.

Source	s.s.	df	m.s.	F	p
ANOVA table - St. Thomas					
among	819674.3	4	204918.5	59.534	0.000
within	9169591.4	2664	3442.039		
ANOVA table - St. Croix					
among	510862.6	4	127715.6	40.658	0.000
within	9690579.1	3085	3141.193		
Tukey HSD, p=0.05					
St. Thomas	1984	1985	1986	1987	1988
St. Croix	1984	1985	1987	1988	1986

A graphic representation of the length-weight relationships for St. Thomas and St. Croix is presented in Figure 6. The log-transformed data were analyzed for homogeneity of slopes and proved to be significantly different ($F = 6.811$, $p = 0.011$).

A standard length-total length regression analysis was conducted from samples on St. Thomas to develop the following conversion formula:

Total Length = 24.716 + 1.108 * Standard Length (in mm).

$N = 494$; $r^2 = 0.974$; standard error of coefficient = 0.0081. This is comparable to those previously reported (Thompson and Munro, 1983; Sadovy *et al.*, 1989).

DISCUSSION

Spawning aggregations have been fished in the Caribbean for decades and probably longer. This was of little consequence until increased population and tourism, combined with modernization of artisanal fishing methods, allowed efficient removal of large numbers of fish from spawning aggregations. Olsen and LaPlace (1978) estimated a reduction in catch of Nassau grouper, *Epinephelus striatus*, at a known spawning aggregation from 14,460 kg to 4,930 kg between two consecutive seasons with an increase in effort. *Epinephelus striatus* is now rare in the U.S. Virgin Islands fishery. Although *E. guttatus* replaced *E. striatus* in the fishery, increased effort and lack of protection has yielded similar declining trends.

Fishermen have developed excellent knowledge of the behavior of spawning aggregations. *Epinephelus guttatus* aggregate south of St. Thomas during the week of a full moon primarily during one lunar cycle from December

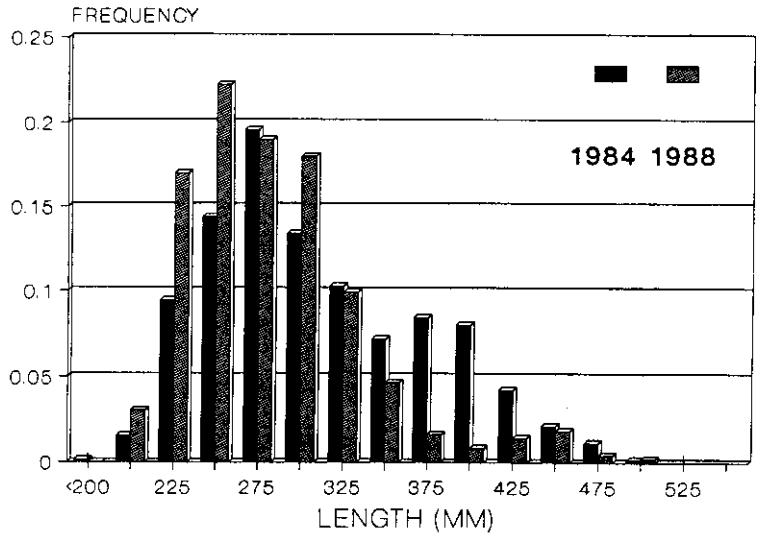

Figure 4. Comparison of length frequency distributions of red hind, *Epinephelus guttatus*, for 1984 and 1988 for St. Thomas.

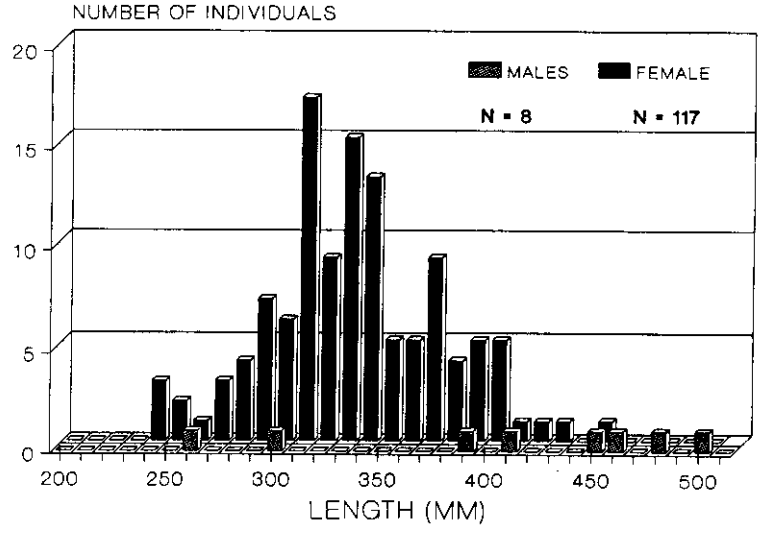

Figure 5. Length frequency distribution of red hind, *Epinephelus guttatus*, by sex for St. Thomas.

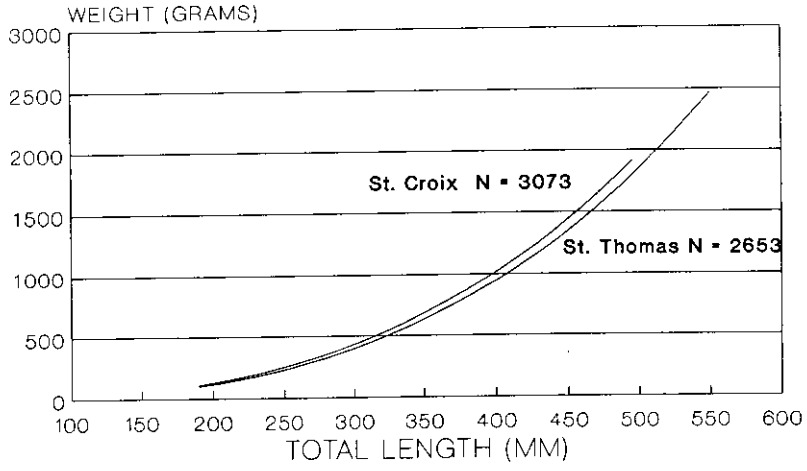

Figure 6. Length-weight data for red hind, *Epinephelus guttatus*, for St. Thomas and St. Croix. Data for all years pooled.

through February, usually in January. This was also true for *E. striatus* (Olsen and LaPlace, 1978) and similar to other reports (Smith, 1972; Thompson and Munro, 1983; Shapiro, 1987). Peak aggregation periods for *Mycteroperca venenosa* have been reported as February through April and March through May for *Lutjanus analis* (Clavijo and Tobias, 1985; Clavijo *et al.*, 1986).

The maximum total length of *E. guttatus* sampled in the U.S. Virgin Islands during the present study (535.0 mm TL) was greater than reported for Jamaica (480.0 mm TL, Thompson and Munro, 1983) and Puerto Rico (474.0 mm TL; Bohnsack *et al.*, 1986; Bohnsack and Harper, 1988; Sadovy and Figuerola, 1990) although mean total length was greater for Jamaica (378.0 – 387.0 mm TL; St. Thomas: 324.2 mm TL; St. Croix: 312.6 mm TL). The mean total length on St. Thomas during the present study is lower than that reported by Olsen and LaPlace (1978; 1974 – 1975 data: 342.0 mm TL).

We believe that the data presented in this study indicate a declining stock of *E. guttatus* on St. Thomas. Size declined among years (Figures 2 – 4; Tables 1 and 2). The absence of males sampled during 1988 – 1989 suggests potential spawning failure. We feel that the decline is due to overfishing spawning aggregations although an alternative hypothesis is that the pattern is due to differential recruitment.

These data in combination with information from other studies (*e.g.*,

Sadovy and Figuerola, 1992), should provide a basis for development of successful management strategies. This study indicates that:

1. Fishermen are capturing reproductively active individuals at spawning aggregation locations prior to spawning, as well as large numbers of immature individuals.
2. The mean size of red hind, *Epinephelus guttatus*, on St. Thomas is declining.

Additionally, St. Thomas and St. Croix are on separate geological platforms which display differences in species composition, abundances, and values for fishery parameters within the same species. The reef fish species form separate populations with different population parameters, therefore, management strategies may be different for certain species.

Several management strategies have been discussed by regional fisheries scientists and managers to reverse the decline of the important *E. guttatus* fishery in the U.S. Virgin Islands. The concensus was that the most important, immediate action was to close spawning seasons and/or aggregation sites during spawning periods (*e.g.*, Bohnsack, 1989). Division of Fish and Wildlife staff working with the Fishermen's Committee of Overseers on St. Thomas initiated a regulation prohibiting fishing on the *E. guttatus* spawning aggregation from December through February of each year. The territorial regulation and equivalent emergency interim federal regulation (Federal Fisheries New Bulletin, Dec. 5, 1989) were approved during 1989.

A future effort includes documentation of all existing spawning aggregations and initiating regulations protecting those spawning sites. The rationale for regulating areas versus season in the U.S. Virgin Islands is that an area is easily patrolled during the short spawning period each month and protection of an area does not put undue hardship on fishermen who are fishing other areas and not targeting *E. guttatus*.

The single strategy of closing spawning aggregation sites has been recognized as only a partial solution. Additional strategies are necessary to sustain adequate spawning stock biomass. Bohnsack (1989) provided excellent reasons for protecting spawning aggregations, but also suggested that recruitment becomes dangerously low when adult population size declines below a certain threshold. If a few years of unsuccessful spawning and/or recruitment occur, the population of a species with very small spawning stock biomass can collapse, especially if high fishing pressure continues as it does in a multi-species trap fishery.

Gear restrictions and limitations are being considered as additional management strategies. Present legislation allows 1-1/4 in mesh size on fish traps, however, 1-1/2 in mesh size is used almost exclusively. An increase to a 2

in mesh size would allow the escape of a greater abundance of immature *E. guttatus*. In a multi-species fishery, such as exists in the Virgin Islands, an increase in mesh size should help to protect other species. A trap limitation restricting the maximum number of traps per fishermen is being considered along with limited access. A trap inspection program has been proposed in order to insure conformance of mesh size and degradable panels to fishery regulations.

The establishment of marine protected areas is another management strategy being considered. Legislation exists in the U.S. Virgin Islands to establish marine parks. We are currently identifying important coral reefs, seagrass beds, and mangrove areas to be established as marine protected areas to include both juvenile and adult habitats.

Other stategies, such as size limits, are not presently being considered in the U.S. Virgin Islands due to enforcement difficulties. Hopefully, adequate management strategies and assessment methods can be implemented to provide for improved local and regional fisheries.

ACKNOWLEDGEMENTS

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