Stock Analysis of Coney, *Epinephelus fulvus*, in St. Croix, U.S. Virgin Islands

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ABSTRACT

Landings data for the U.S. Virgin Islands were analyzed for the period from 1984 to 1989 to provide information on coney, *Epinephelus fulvus*. This species represents an important resource of growing concern in the Caribbean region with the rapid decline of stocks of larger groupers. Coney are landed in greater abundance on St. Croix (greater than 6% of landings by number) than St. Thomas-St. John (less than 2% of total landings by number), therefore, more comprehensive analysis was possible for St. Croix data. Differences in abundance of coney in catches and species composition between the two areas are presumably due to habitat differences between the separate shelves. Data analyses demonstrate significant declines in mean size and composition in total catches of coney on St. Croix during the six years included in analysis.

Spawning aggregations have not been observed for coney in the U.S. Virgin Islands as documented for larger groupers. However, landings data suggested that seasonal aggregations occur. Different management strategies may be needed for coney than for other groupers in the U.S. Virgin Islands.

KEYWORDS: *Epinephelus fulvus*, grouper, Caribbean fisheries, tropical fisheries, stock analysis.

INTRODUCTION

Reef fish stocks in the Caribbean have declined greatly in recent decades as island populations have grown and the artisanal fishing industry has technologically improved (Goodwin 1988). The abundance of large slower-growing reef species, such as groupers, have been greatly reduced in much of the Caribbean (Sadovy, 1994). Resource managers and scientists have increased their efforts in recent years to improve the resource and biological knowledge of these valuable species (Polovina and Ralston 1987; Sadovy *et al.* 1989; Sadovy in press; Beets and Friedlander in press).

The decline of grouper and snapper stocks in the U.S. Virgin Islands has been well documented. Olsen and LaPlace (1978) provided evidence of the decline of Nassau grouper (*Epinephelus striatus*) in St. Thomas. Beets and Friedlander (1989) showed that red hind (*E. guttatus*) has declined similarly.

Declines in other species have been documented based on landings data (Clavijo *et al.* 1986; DFW files).

Studies on large groupers have demonstrated that these species are protogynous hermaphrodites which form large spawning aggregations (Shapiro 1987). The Caribbean species tend to spawn during full moon phases from December through March (Shapiro 1987). This behaviour has resulted in overfishing of many aggregations and the complete loss of the large Nassau grouper aggregation south of St. Thomas.

Smaller groupers have received less attention but are of growing concern as species shifts occur in fisheries with the loss of larger groupers in catches. Two smaller groupers are important in regional fisheries, coney, *E. fulvus*, and graysby, *E. cruentatus*. Both have been documented as protogynous (Smith 1959, Nagelkerken 1979), however, spawning aggregations have not been observed.

In the U.S. Virgin Islands, the proportion of *E. fulvus* in commercial harvests has increased. This has been particularly evident on St. Croix where *E. fulvus* has risen to the fifth dominant fish by weight in landings, comprising greater than 6% of all fish in total catches (Clavijo and Tobias 1985; Clavijo *et al.* 1986; DFW files). *Epinephelus cruentatus* has been harvested in much lower abundance than *E. fulvus* (Clavijo and Tobias 1985; Clavijo *et al.* 1986).

The purpose of this study was to analyze existing data on *E. fulvus* in the U.S. Virgin Islands to provide an assessment of the condition of the stock and to provide management recommendations for the maintenance of stocks.

METHODS

Data were collected as part of the biostatistical sampling study which was initiated in the U.S. Virgin Islands in 1984 as part of the Virgin Islands/National Marine Fisheries Service Cooperative Fisheries Statistical Program. One component of this study was to obtain length and weight data on all commercially important fishes.

Data analyses weres restricted to St. Croix because of the importance of *Epinephelus fulvus* to the local commercial fishery which resulted in large sample sizes. This species is landed in much lower abundance on St. Thomas and St. John (DFW files). Differences in commercial landings are probably due to habitat and recruitment differences between the two separate insular shelves (Beets and Friedlander 1989; Figure 1). A central fish market on St. Croix facilitated the collection of data on *E. fulvus* and other important species on a monthly basis. Individual total lengths (mm TL) and weights (g) were obtained on large numbers of fishes. Monthly and annual proportions of *E. fulvus* in total catches and size-frequency distributions were calculated.

Data were obtained from market samples on 8,815 individuals of *E. fulvus* in St. Croix between 1984 and 1989. The dominant gear used on St. Croix is the

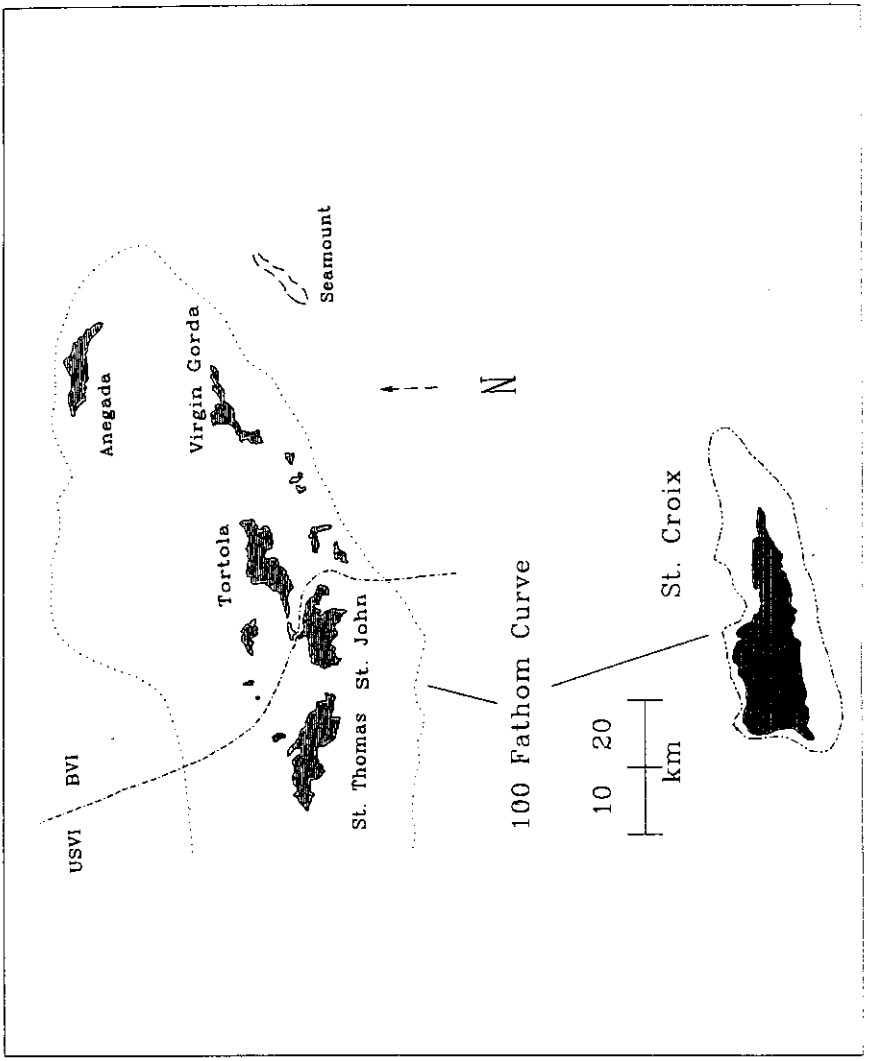

Figure 1. Location of St. Croix in the Virgin Islands showing its isolated insular shelf from the northern Virgin Islands.

antillean fish trap constructed of 1-1/2 inch wire mesh (1986-1987 data: 62.6% of total landings by weight, DFW files).

Data were analyzed using the SYSTAT microcomputer package (Wilkinson 1988). Mean weights and proportions of total catch were analyzed by pooling data by year. Nonparametric analysis of variance (Kruskal-Wallis test) was used to determine trends in these two parameters. Linear regression analysis was performed on log-transformed data pooled from 1985 to 1989 to determine the length-weight relationship.

Growth parameters were calculated using several computer- based length frequency analysis programs (ELEFAN: Gayanilo *et al.* 1989; LFSA: Sparre 1987). Due to the unequal distribution of records among months and years, data were pooled both monthly and quarterly for analysis. An artificial year was created with data from all years, pooled by month to maximize the number of samples per month (D. Pauly, per. com.). Analysis using this technique assumed no variability in growth among years and consistent, stable recruitment.

A Bhattacharya plot (Bhattacharya 1967) was used to identify modes within each frequency distribution. Means from this method were linked in a modal progression analysis (MPA). The MODALPR program in LFSA and the MPA module in ELEFAN then calculated a regression analysis corresponding to the Gulland and Holt plot (Gulland and Holt 1959) to estimate the von Bertalanffy growth function parameters, L and K (Sparre 1987). These parameters were also analyzed using Munro's Method (Munro 1982 cited in Gayanilo *et al.* 1989).

Powell's Method (Wetherall *et al.* 1987) was used to estimate the values for L (theoretical maximum length) and Z/K (total mortality/growth coefficient). A linearized catch curve based on length composition data (Pauly 1983) was calculated to obtain Z (total mortality). Natural mortality (M) based on a regression analysis of K, L , and sea surface temperature (T°C) was computed using Pauly's empirical formula: ln M=-0.0152 - 0.279 ln L + 0.6543 ln K + 0.463 ln T (Pauly 1980).

RESULTS

Evidence of declining stocks

Analysis of mean length per year demonstrated a significant decline since 1984 (Kruskal-Wallis nonparametric ANOVA: KW=40.891, P<0.001; Table 1). This trend is observed in a comparison of length frequency distributions among years (Figure 2). A shift to smaller size classes is readily apparent with the loss of larger size classes.

The proportion of *E. fulvus* in total catches by year also demonstrated a significant decline (Kruskal-Wallis test: 22.353, P<0.001; Table 1; Figure 3). A nonparametric analysis of these data demonstrated a significant difference

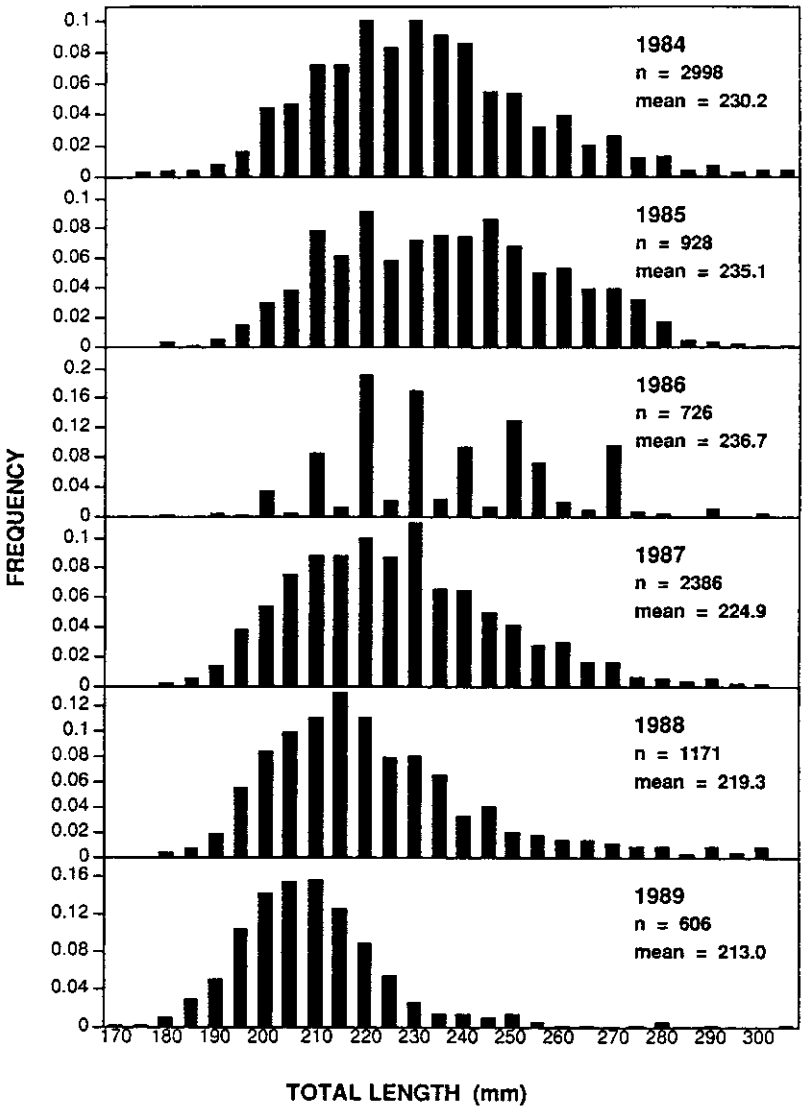

Figure 2. Length frequency distributions for *Epinephelus fulvus* by year on St. Croix, 1984 – 1989.

Table 1. Statistics for *Epinephelus fulvus*, St. Croix, U.S.Virgin Islands, 1984 – 1989.

Year	No. of Records	Mean Length (mm TL)	S.D.	Mean Weight (g)	S.D.	Proportion In Total Catches
1984	2998	230.2	22.1	209.7	63.3	1.1814
1985	928	235.1	23.2	226.5	75.1	0.5499
1986	726	236.7	22.5	242.9	76.8	0.9865
1987	2386	224.9	20.7	203.9	58.8	0.8952
1988	1171	219.3	19.4	198.1	50.5	0.3668
1989	606	213.0	15.9	193.5	39.2	0.4090

among years. Although not significant, peaks in the proportion of coney in catches were apparent in July - August and in December - January (Figure 4).

The length - weight relationship (Figure 5) calculated from linear regression of log-transformed data was:

$\log W = -3.3889 + 2.4214 * \log TL$

$W = 0.0004084 * TL^{2.4214}$ $N = 5815; r^2 = 0.682$

Estimation of Growth Parameters

The various analyses of restructured data in the ELEFAN microcomputer package, which is calculated from running averages, did not provide realistic parameters. The most realistic results were derived from modal progression analysis using the Bhattacharya method (Bhattacharya 1967) to identify means and the Gulland and Holt plot (Gulland and Holt 1959) to estimate growth parameters. Data were analyzed using the ELEFAN and LFSA microcomputer packages which yielded similar but not identical results. Data were pooled by quarters for these analyses to provide adequate sample size. Analyses were conducted by years and groups of years. The most realistic results were derived from the data for 1984 (Table 2), which had the largest sample size (N = 2998). Powell's method produced estimates of L ranging from 298.8 to 397.5 mm and of K/Z ranging from 2.29 to 9.21 (Table 3).

A linearized length converted catch curve using the most realistic growth parameters (L = 330-350 and K = 0.25-0.35) was used to calculate mortality estimates (Table 4). Pauly's empirical formula (Pauly 1983) was used to calculate natural mortality (M) which ranged from 0.661 to 0.838. Fishing mortality (F = Z - M) yielded exploitation rate (F/Z) values ranging from 0.334 to 0.624.

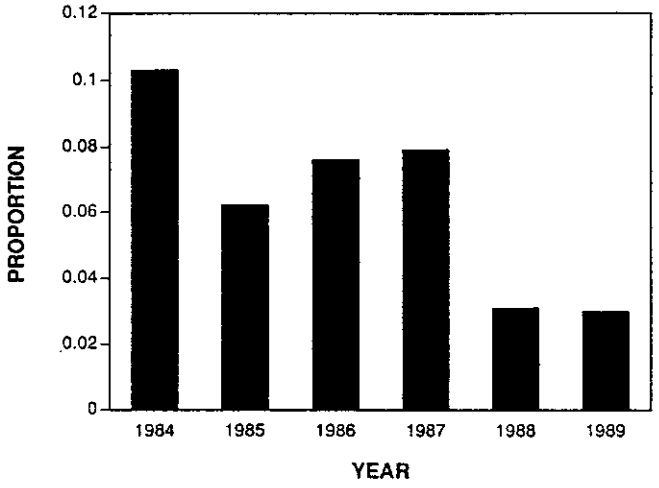

Figure 3. Proportions of individuals of *Epinephelus fulvus* in total catches by year on St. Croix, 1984 – 1989.

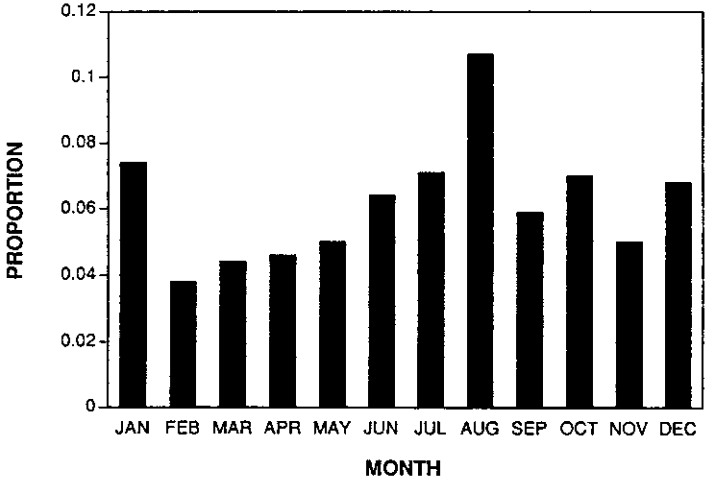

Figure 4. Proportions of individuals of *Epinephelus fulvus* in total catches by month on St. Croix. Data for all years pooled (1984 – 1989).

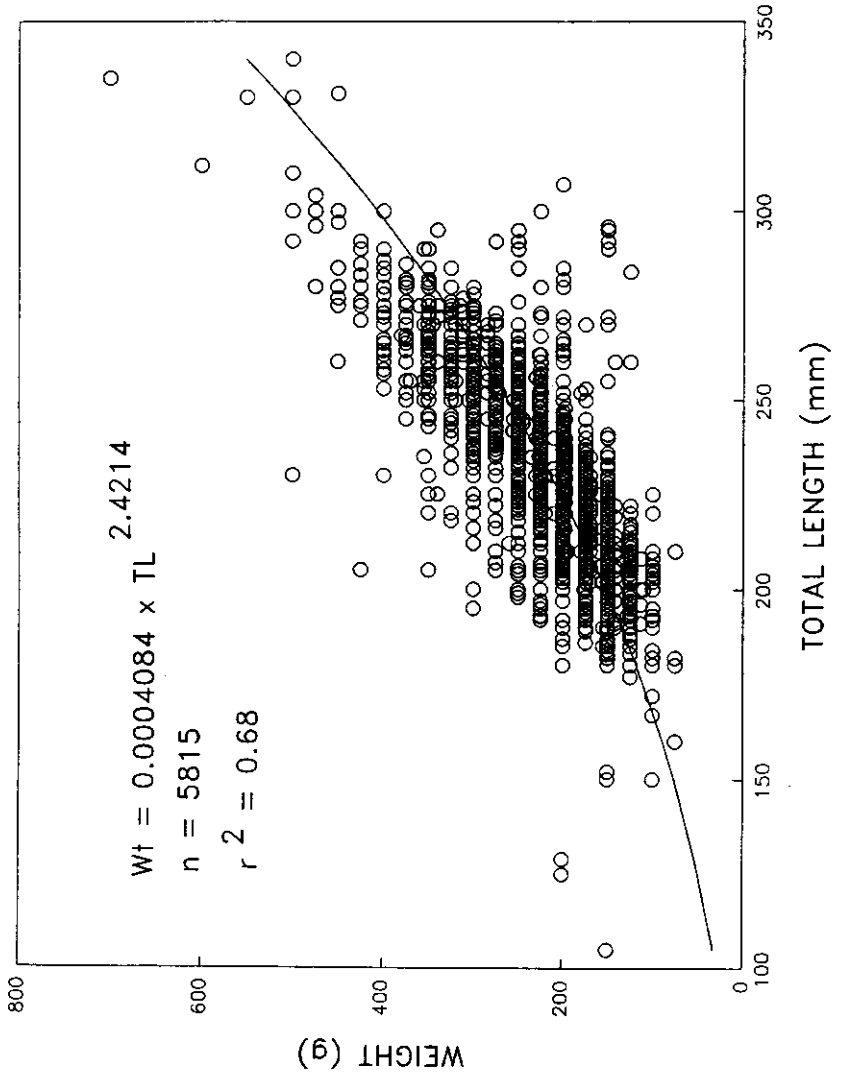

Figure 5. Length-weight relationship for *Epinephelus fulvus* on St. Croix. Equation: $W = 0.0004084 * TL^{2.4214}$. N = 5815; $r^2 = 0.682$. Total length in mm; weight in grams.

Table 2. Estimated fisheries growth parameters for *Epinephelus fulvus* from St. Croix using modal progression analysis. Estimates were derived using ELEFAN and LFSA microcomputer packages.

	Loo	K
1984	292.7-425.0	0.14-0.32
ALL YEARS	374.0-421.4	0.26-0.62

Table 3. Estimates of L and Z/K by year based on Powell's Method (Weatherall *et al.*, 1987).

Year	L	Z/K
1984	341.08	4.992
1985	298.80	2.292
1985*	322.22	3.386
1986	375.07	5.845
1986**	322.20	3.710
1987	335.50	5.443
1988	397.54	9.206

*1985 = Sq root transformation; 4th quarter excluded
**1986 = 2nd quarter excluded

Table 4. Estimates of total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) for *Epinephelus fulvus* from St. Croix. Estimates were derived using the linearized length converted catch curve analysis in the ELEFAN microcomputer package (Pauly 1983).

Year	L	K	Z	M	F	E
1984	330-350	.25-.35	1.212-2.038	0.661-0.838	0.540-1.214	0.446-0.596
1985	330-350	.25-.35	1.281-1.852	0.661-0.838	0.609-1.021	0.475-0.533
1986	330-350	.25-.35	0.885-1.414	0.661-0.838	0.218-0.537	0.334-0.407
1987	330-350	.25-.35	1.255-2.192	0.661-0.838	0.583-1.368	0.465-0.624
1988	330-350	.25-.35	1.237-2.191	0.661-0.838	0.565-1.367	0.457-0.624

DISCUSSION

Stock status of *Epinephelus fulvus* on St. Croix

Significant declines in mean length and proportion of total catch were demonstrated for data on *Epinephelus fulvus* from St. Croix. This decline was similar to the decline in mean length observed for red hind, *E. guttatus*, on St. Thomas for the same period (Beets and Friedlander in press). Nassau grouper, *E. striatus*, declined in St. Thomas (Olsen and LaPlace 1978) and is now rare in landings. Anecdotal information has suggested that the decline of Nassau grouper has also occurred on St. Croix.

Bohnsack *et al.* (1986) presented length frequency data for *E. fulvus* and other species which demonstrated shifts to smaller size classes among areas of greater fishing pressure. Shifts to smaller size classes are apparent for *E. fulvus* on St. Croix among length frequency data for different years. The number of licensed fishermen has remained relatively constant during the past ten years on St. Croix (DFW, unpublished data), although, with technological improvements in the fishery and capitalization, there has been an estimated 10-fold increase in number of traps during the past 15 years.

Due to this increased fishing effort and the protogynous reproductive strategy of *E. fulvus*, the loss of larger size classes suggests a differential loss of males in the population. This could result in spawning failure for the species depending on the mechanism of sex change. Thomson and Munro (1983) presented the size of sexual maturation as <160 mm TL and transitional size (from female to male) as 135-255 mm TL.

Very little information exists on the reproductive biology of this species although presumably reproductive strategies are similar to other groupers. Spawning aggregations of *E. fulvus* have not been noted. Although pair-spawning of individuals of *E. fulvus* has been observed in Puerto Rico (Colin *et al.* 1987), more recent observations suggest haremic spawning. Peaks in gonadal development were observed during January-March and June-July in Jamaica (Munro *et al.* 1973; Thompson and Munro 1983).

Peaks in proportion of total catches by month was observed on St. Croix (Figure 4). Although no significant difference was noted in the data, fishermen suggest that *E. fulvus* tend to concentrate during peak periods. The relationship of increased catches to spawning activity has not been investigated.

Comparison of fisheries parameters with previous studies

Interesting differences were obtained in fisheries parameters for *E. fulvus* between the study by Thompson and Munro (1983) in Jamaica and the present study (Table 5). The measured length ranges and fishing methods were similar for both studies. However, length frequency distributions from Jamaica study showed that average fish size was larger from Pedro Bank, an unexploited oceanic bank. The length-weight relationship of Thompson and Munro (1983)

Table 5. Comparison of statistics for *Epinephelus fulvus* for Jamaica, Puerto Rico, and St. Croix. Data for Jamaica are from Thompson and Munro (1983). Data for Puerto Rico are from Bohnsack and Harper (1988). Data for St. Croix are from the present study. All length data are in mm.

	Jamaica	St. Croix
Gear used	fish trap	primarily fish trap
Length range	165-330	100-340
L	340	340-425
K	0.63	0.14-0.32
Length-weight relationship		
Jamaica*	log WT = -3.7114 + 2.574 * log TL	
length range	180-300	
sample size	100	
Puerto Rico	log WT = -4.6508 + 2.9545 * log TL	
length range	157-639	
sample size	583	
St. Croix	log WT = -3.3889 + 2.4214 * log TL	
length range	100-340	
sample size	5815	

*converted from centimeter:grams to millimeter:grams

yields estimated weights over 10% greater than the relationship calculated in this study. Thompson and Munro (1983) used a smaller size range and smaller sample size for their calculations (Table 5).

Thompson and Munro (1983) calculated growth parameters for *E. fulvus* using length frequency analysis. In a modal progression analysis of the identified peaks, they calculated L = 340 mm TL and K = 0.63. This growth coefficient is high compared to other groupers (Manooch 1987) and appears unrealistic. These parameters would yield rapid growth for a grouper species and are quite dissimilar to growth parameters obtained for the closely related and similarluy sized species, *E. cruentatus*, during the same study in Jamaica (L = 340 mm TL, K = 0.34; Thompson and Munro 1983) and a study in Curacao (L = 415, K = 0.13; Nagelkerken 1979). Growth parameters obtained during the present study appear to be more realistic for *E. fulvus* (Table 5).

Conclusion and Recommendations

1) The stock of *E. fulvus* is in a state of decline and overfished. We support the increased mesh restriction recently approved in the Caribbean Fisheries Management Council Amendment 1 of the Shallow-water Reef Fish Fisheries Management Plan. This should allow for escape of a large proportion of small spawners. Thompson and Munro (1983) gave mean length at maturity (l_m) = <160 mm TL and mean length at sex change (l_s) = 270 mm TL. Minimum length captured during the present study was 100 mm TL.

2) Investigations on gonadal development and spawning behavior should be conducted to determine if seasonal aggregations occur. If aggregations are documented, we recommend the protection of identified spawning grounds and the establishment of marine fishery reserves (Bohnsack 1989, Plan Development Team 1990).

3) Based on the analyses from this study, we recommend the use of LFA for tropical fisheries data when used competently and carefully.

4) We recommend otolith analysis for *E. fulvus* in order to more adequately define growth parameters for future stock assessments.

LITERATURE CITED

Bannerot, S.P. , W. W. Fox, Jr.,and J. E. Powers. 1987. REproductive strategies and the management of snappers and groupers in the Gulf of Meico and Caribbeanj. In *Tropical Snappers and Groupers: Biology and Fisheries Management.* J. J. Polovina and S. Ralston (eds.), Westview Press, Boulder, CO.

Beets, J. and A. Friedlander. 1989. Stock analysis and management strategies for red hind, *Epinephelus guttatus*, in the U.S. Virgin Islands. *Proc. Gulf and Carib. Fish. Inst.* 42:66-79.

Bhattacharya, C.G. 1967. A simple method of resolution of a distribution into Gaussian components. *Biometrics* 23:115-135.

Bohnsack, J.A. 1989. Protection of grouper spawning aggregations. NOAA/NMFS/SEFC. Coastal Resources Division Contribution No. CRD-88/89-06.

Bohnsack, J.A., D.L. Sutherland, A. Brown, D.E. Harper, and D.B. McClellan. 1986. An analysis of the Caribbean biostatistical database for 1985. Coastal Resource Division Report for the Caribbean Fishery Management Council. Contribution No. CRD-86/87-10.

Bohnsack, J.A. and D.E. Harper. 1988. Length-weight relationships of selected marine reef fishes from the southeastern United States and the Caribbean. NOAA Technical Memorandum NMFS-SEFC-215, 31p.

Clavijo, I.E. and W.J. Tobias. 1985. Virgin Islands Commercial Fisheries Research and Development Project. PL 88-309. Project No. 2-411-R-1. Annual Report. April 1, 1984 to March 31, 1985. Report submitted to NMFS. 22 p.

Clavijo, I.E., W.J. Tobias, and C.A. Jennings. 1986. Virgin Islands Commercial Fisheries Research and Development Project. PL 88-309. Project No. 2-411-R-2. Annual Report. April 1, 1985 to March 31, 1986. Report submitted to NMFS. 15 p.

Colin, P.L., D.Y. Shapiro, and D. Weiler. 1987. Aspects of the reproduction of two groupers, *Epinephelus guttatus* and *E. striatus* in the West Indies. *Bull. Mar. Sci.* **40**(2):220-230.

Gayanilo, F.C., Jr., M. Soriano, and D. Pauly. 1989. A draft guide to the Compleat ELEFAN. ICLARM Software 2, 70. ICLARM, Manila, Philippines.

Goodwin, M. 1988. Changing times for Caribbean fisheries. *Oceanus* **30**: (4):57-64.

Gulland, J.A. 1971. *The fish resources of the oceans.* FAO Fishing News Books, Ltd., Surrey, England.

Gulland, J.A. and S.J. Holt. 1959. Estimation of growth parameters for data at unequal time intervals. *J. Cons. CIEM* **25**(1):47-49.

Manooch, C.S. III. 1987. Age and growth of snappers and groupers. In Polovina, J.J. and S. Ralston (eds.). 1987. *Tropical snappers and groupers: biology and fisheries management.* Westview Press, Boulder, Colorado. 659 p.

Munro, J.L., V.C. Gaut, R. Thompson, and P.H. Reeson. 1973. The spawning seasons of Caribbean reef fishes. *J. Fish Biol.* **5**:69-84.

Munro, J.L. and D. Pauly. 1983. A simple method for comparing growth of fishes and invertebrates. *Fishbyte* **1**(1):5-6.

Nagelkerken, W.D. 1979. Biology of the grasby, *Epinephelus cruentatus*, of the coral reefs of Curacao. *Stud. Fauna Curacao Other Carib. Isl.* **60**:1-118.

Olsen, D.A. and J.A. LaPlace. 1978. A study of a Virgin Islands grouper fishery based on a breeding aggregation. *Proc. Gulf Carib. Fish. Inst.* **31**: 130-144.

Pauly, D. 1983. Length-converted catch curves. A powerful tool for fisheries research in the tropics (Part 1). *Fishbyte* **1**(2):9-13.

Pauly, D. 1987. A review of the ELEFAN system for analysis of length-frequency data in fish and aquatic invertebrates. Pages 7-34 in D. Pauly and G.R. Morgan (eds.) *Length based methods in fisheries research.* ICLARM Conf. Proc. 13. ICLARM, Manila, Philippines. 468 p.

Pauly, D. and J.L. Munro. 1984. Once more on the comparison of growth in fish and invertebrates. *Fishbyte*, 2(1):21.

Plan Development Team. 1990. The potential of marine fishery reserves for reef fish management in the U.S. Southern Atlantic. NOAA Technical Memorandum NMFS-SEFC-261, 40p.

Polovina, J.J. and S. Ralston (eds.). 1987. *Tropical snappers and groupers: biology and fisheries management.* Westview Press, Boulder, Colorado. 659 p.

Sadovy, Y. 1994. Grouper stocks and their management in the Caribbean. *Proc. Gulf and Carib. Fish. Inst.* 43.43-64.

Sadovy, Y. 1989. The status of the red hind fishery in Puerto Rico and St. Thomas, as determined by yield-per-recruit analysis. *Proc. Gulf and Carib. Fish. Inst.* 42:23-38.

Sadovy, Y., M. Figuerola, and Ana Roman. 1989. The age and growth of the red hind, *Epinephelus guttatus* and the white grunt, *Haemulon plumieri* in, Puerto Rico an the U.S. Virgin Islands. Final Report to Caribbean Fisheries Management Council. 65pp.

Shapiro, D.Y. 1987. Reproduction in groupers. Pages 295-328. In Polovina, J.J. and S. Ralston (eds.). 1987. *Tropical snappers and groupers: biology and fisheries management.* Westview Press, Boulder, Colorado. 659 p.

Smith, C.L. 1959. Hermaphrodism in some serranid fishes from Bermuda. *Pap. Mich. Acad. Sci. Arts Lett.* 44:111-118.

Sparre, P. 1987. Computer programs for fish stock assessment, length-based fish stock assessment for Apple II computers. FAO Fish. Tech. Pap., (101) Suppl. 2:218 p.

Thompson, R. and J.L. Munro. 1983. The biology, ecology and bionomics of the hinds and groupers, Serranidae. Pages 59-81 in Munro, J.L. (ed). *Caribbean Coral Reef Fishery Resources.* ICLARM Studies and Review 7. ICLARM, Manila, Philippines. 276 p.

Wetherall, J.A., J.J. Polivina and S. Ralston. 1987. Estimating growth and mortality in steady-state fish stocks from length-frequency data. ICLARM Conf. Proc. (13):53-74.