Fisheries, Growth, and Mortality of Yellowtail Snapper, *Ocyurus chrysurus,* in the Florida Keys, Florida, U.S.A.

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ABSTRACT

This paper reviews the status of the yellowtail snapper, *Ocyurus chrysurus,* commercial fishery in the Florida Keys based on data collected from 1985 to 1996 by the Florida Department of Environmental Protection's Florida Marine Research Institute (FMRI) port agents. Growth and mortality were estimated by using length-frequency data collected from the commercial fishery in three zones of the Florida Keys: upper Keys, lower Keys, and the Dry Tortugas. Growth parameters were estimated for 1985-1989 and for 1990-1996 for the three zones. For all years and all areas combined, the total instantaneous mortality rate (Z) was 1.44 /year. Total fishing mortality (F) was 0.80/year. Ralston's empirical formula was used to estimate a natural mortality (M) of 0.63/year. Exploitation rate (E) based on Pauly and Soriano's relative yield-per-recruit model was 0.56. These results indicate that the yellowtail snapper fishery operating in the Florida Keys is exploited at or close to the optimum. Results were compared with values from *Ocyurus chrysurus* populations obtained in Florida and the Caribbean.

KEY WORDS: *Ocyurus chrysurus;* stock assessment; Florida Keys, USA.

INTRODUCTION

The yellowtail snapper, *Ocyurus chrysurus,* is among the most important fish caught in the Florida Keys and throughout the Caribbean. Yellowtail snappers inhabit coastal waters at depths between 10 and 70 m (Thompson and Munro, 1983), principally around coral reefs. In the Florida Keys this species is fished commercially by hook and line. Age, growth, and mortality have been estimated for yellowtail snapper using several techniques - otoliths, scales, vertebrae, and length-frequency analysis throughout the Caribbean (Piedra, 1969; Thompson and Munro, 1983; Johnson, 1983; Dennis, 1991); however, estimating growth rates of the species by using length-frequency analysis has not been attempted in Florida. Length-frequency analysis is limited by the size and quality of the time-series data. Port agents from the Florida Marine

Research Institute (FMRI) of the Florida Department of Environmental Protection (FDEP) have been collecting biostatistical data for yellowtail snappers from commercial catches since 1985. This data set presents the first opportunity to conduct a reliable length-frequency analysis for the species in Florida. In this paper, we describe the status of the fishery based on landings, fishing effort, and size frequency. In particular, we evaluate the use of length-frequency analysis, based upon biostatistical data collected by FMRI, to estimate growth and mortality parameters and to evaluate the status of the resource.

METHODS

Commercial landings have been monitored since 1950 by the State of Florida in cooperation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. The biostatistical data collection program (Trip Interview Program or TIP) began in 1985 and is part of the Federal State Cooperative Statistics Program. The Marine Fisheries Information System (MFIS), administered by the Florida Department of Environmental Protection (Florida Administrative Code 62R-5, 1984), requires that records be kept and reported for every wholesale transaction of saltwater fish, saltwater products, bait, or marine life landed in the state, so that more accurate estimates of commercial landings can be made. The trip interview program is designed to collect bioprofile (fish length) and fishing effort (catch per unit effort, CPUE) data on individual fishing trips and to provide a long-term data base for fishery scientists and fishery managers. Prior to 1986, not all seafood dealers participated in the statistical reporting system (Bohnsack *et al.*, 1994).

The length-frequency data used in this study concerned commercial catches in the Florida Keysand were collected monthly from January 1985 to December 1996 by FMRI port agents. The total number of yellowtail snapper measured was 35,639 and ranged from 11 to 1,117 individuals per month. Total length (TL) was measured to the nearest 5 mm. Growth and mortality were estimated by using the FAO-ICLARM stock assessment tools, including the (FISAT) software package, which incorporates ELEFAN and LFSA software (Gayanilo *et al.*, 1995).

Study Area

The data were collected from three zones of the Florida Keys (Figure 1):

i) Upper Keys: (zone 1) from Key Largo to Marathon,
ii) Lower Keys: (zone 2) from Marathon to the Marquesas Keys, and
iii) Dry Tortugas: (zone 3) west of the Marquesas, including the Dry Tortugas.

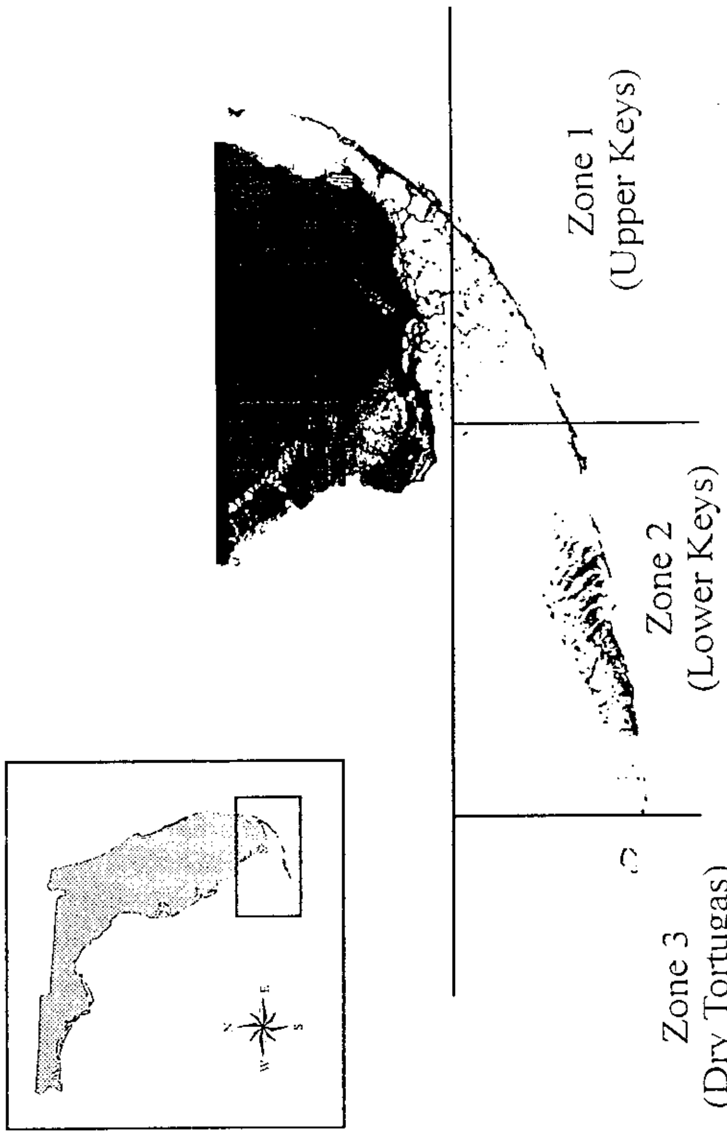

Figure 1. Map of the Florida Keys indicating the three fishing zones for yellowtail snapper.

Estimation of Growth Parameters and Mortality

The seasonally oscillating version of the von Bertalanffy growth function (VBGF) proposed by Pauly and Gaschutz (1979) as modified by Somers (1988) used in this study has the form:

$$L_t = L_\infty[1-\exp(-K(t-t_0) - CK/2(\sin 2\pi(t-t_s)))]$$

where L_t is length at time t, $L\infty$ is the asymptotic length an individual would reach if it lived indefinitely, K is the rate at which $L\infty$ is approached, and t_s = WP (winter point, the time of the year at which growth rate is slowest). The parameter t_0 is a location parameter, necessary to relate size to absolute age, and cannot be estimated by using length-frequency analysis. The growth parameters L_{oo} and K were estimated by using ELEFAN I of the FAO-ICLARM stock assessment software package FISAT (Gayanilo *et al.*, 1995), which incorporates Wetherall *et al.'s* (1987) method. The former was used to obtain preliminary estimates of $L\infty$ and the Z/K ratio, where Z is the instantaneous rate of total mortality. After preliminary estimates of $L\infty$ and K were obtained, the ELEFAN routine was used to estimate L_{oo} and K. Using different combinations of $L\infty$ and K, response surfaces of Rn, the goodness of fit index (Pauly and David, 1981), were generated. These response surfaces were inspected until the maximum Rn value was found and corresponding values of $L\infty$ and K determined.

To compare different estimates of growth parameters, the empirical equation of $\phi = \text{Log}_{10} K + 2 \text{Log}_{10} (L_\infty)$ of Pauly and Munro (1984) was used. Instantaneous natural mortality (M) was estimated by using the Ralston (1987) equation for snappers and groupers

$M = -0.066 + 2.53(K)$, in which K=growth coefficient, and Pauly's (1980) empirical equation

$$\text{Log}_{10} M = 0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where L_∞ and K are parameters of the VBGF and T is mean local sea temperature, which in the study area is 26.5°C.

Length-converted catch curve analysis was used to estimate Z (Ricker, 1975; Pauly, 1985). Data for each monthly sample were converted to percent frequency and then weighted by the square root of the sample size. Giving all monthly samples proportional weight prevents a single large monthly sample from being a major source of bias or from overly affecting the total annual sample. The exploitation rate, E = F/Z, based on the Beverton and Holt model of 1966 and modified by Pauly and Soriano (1986), was used to estimate exploitation rates.

RESULTS AND DISCUSSION

Description of the Fishery

The commercial yellowtail snapper fishery in the Florida Keys is multifaceted. Vessels range from skiffs (16 to 25 ft long) that usually fish for 6 to 10 hours to large boats (up to 40+ feet in long) that may fish for several days. These large boats generally fish west of Key West near the Dry Tortugas but may land their catches anywhere in the Keys. Fishing grounds include the main reef, patch reef, and hard bottom areas of the Florida reef tract, including the Dry Tortugas area. Fishing depth usually ranges from 10 m to 40 m (30 ft to 120 ft). Yellowtail snappers are caught year round by hook and line (rod and reel or hand lines), with a single hook. Natural bait of various types is used, and fish are attracted to the boat by chumming (hanging a small bag with groundfish and fish carcasses over the side of the boat).

There are some geographical differences in yellowtail fishing in the Florida Keys. In the upper Keys (zone 1) and lower Keys (zone 2) the boats are small, with one or two crew members conducting daily fishing trips (around eight hours), whereas the boats operating in zone 3 (Dry Tortugas) are mostly large boats that specifically target yellowtail snapper and fish west of Key West to the Dry Tortugas and beyond for 7 to 10 consecutive days. In the lower and upper Keys, many yellowtail fishers are winter residents only. Others are spiny lobster and stone crab fishers who fish for yellowtail during lobster and stone crab closed seasons.

Yellowtail snapper landings increased steadily from 1987 to 1994, from landings just less than 615 metric tons (1.4 million pounds) to more than 1,000 metric tons (2 million pounds), and then declined to 662 metric tons (1.5 million pounds) by 1996 (Figure 2). Fishing effort (as defined by number of fishing trips) has varied from a high of more than 20,000 trips in 1989 to a low of slightly more than 14,000 in 1996 (Figure 2). The decline which began in (1990) of fishing trips may be a result of regulations established by federal and state fishery management councils to limit entry into the fishery by requiring that only those with proof of income from commercial fishing could obtain permits. As a result, some fishermen were unable to obtain permits and others left the fishery. Florida has enacted a permit system for state waters (known as the restricted species endorsement) and the federal management councils enacted permit programs for the Atlantic Ocean and Gulf of Mexico. The Atlantic program is called the "snapper/grouper permit" and the Gulf program is called the "reef fish permit." The Florida regulations went into effect in February of 1990 and federal regulations two years later in January of 1992. The reasons for the downward trend from 1994 to 1996 are unclear.

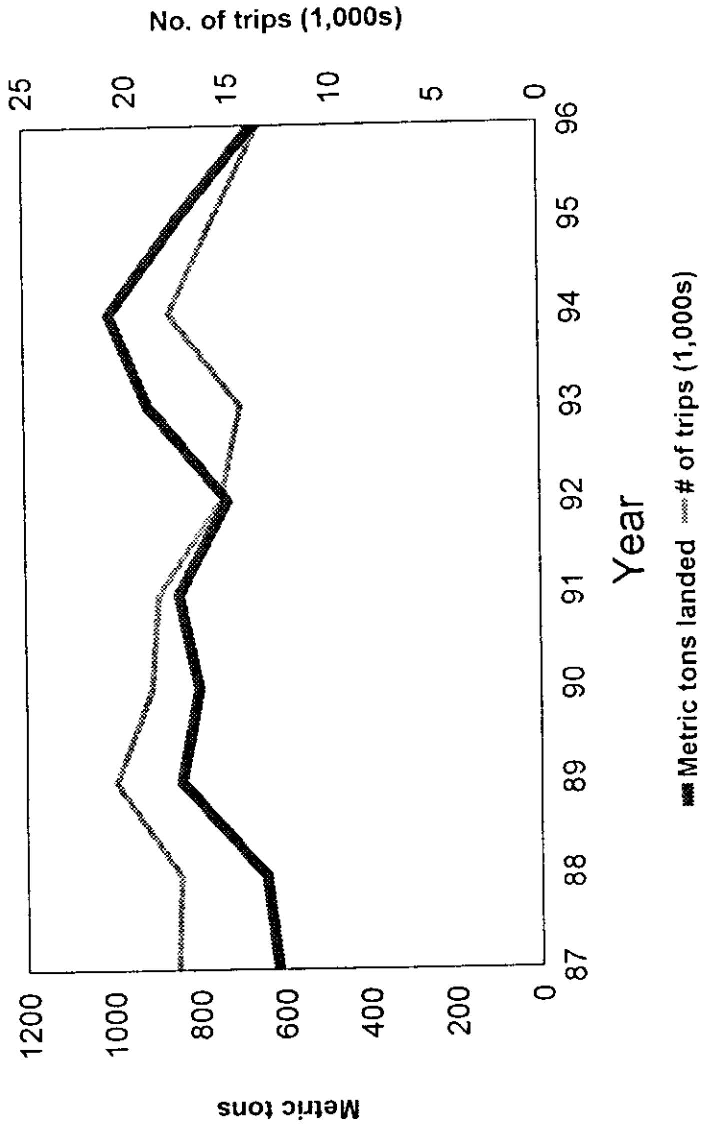

Figure 2. Yellowtail snapper landings and number of trips (1,000s) by year, 1987-1996, in the Florida Keys.

The number of pounds landed per fishing trip has increased from just over 36 kg (80 lb) in 1988 to around 59 kg (129 lb) per trip in 1994-96 (Figure 3). This may be a result of the availability of inexpensive navigational aids such as GPS. Average monthly landings (Figure 4) increased from February to June, then declined sharply and remained steady through the remainder of the year. The increase in landings from May to June are probably due to the entry of lobster or stone crab fishermen after those seasons close (lobster season closes March 31 and stone crab season closes May 15). The relatively steady number of fishing trips by month (Figure 5) from January to July is again related to the lobster and stone crab fishermen entering the fishery. The number of fishing trips during August and September dropped as lobster season opened, but trips increased upon the influx of winter residents to the Keys. The number of pounds per trip increased from May to June and dropped in July and August. The number of kilograms per trip increased again in September and October and remained constant during the rest of the year (Figure 6). The drop in July and August could be because the most efficient fishermen are shifting to lobster fishing.

There is evidence that if certain fishing methods are used in exploitating a resource, an entire fish population can undergo changes in age and size structures, in growth rate, or in reproductive capacity (Csirke, 1980). Mean lengths of yellowtail snappers were compared by year and broken down by zone (Figure 7). The overall mean size has declined from 430 mm TL in 1985 to 360 mm TL in 1996. The overall mean size has remained above the minimum legal size of capture of 305 mm TL. Two of the most notable points in this figure are the increase in mean size in the Dry Tortugas (Zone 3) and the reduction in mean size of the fish in the upper Keys (Zone 1), which is a result of a decreased proportion of older individuals.

Figure 8 shows the length-frequency distribution by zone between 1985-1989 and 1990-1996. Nearly all (96%) of the individuals were from 300 to 550 mm TL; only 2% were larger than 550 mm TL and 2% were smaller than 300 mm TL (Figure 8). Table 1 presents the results of the ELEFAN analyses by zone between 1985-1989 and 1990-1996 and for all areas combined from 1985-1996. The growth coefficients (K) estimated by the program were very large (K = 0.3 or higher). This suggested an increase in the growth rate not consistent with the life history of this species. Therefore, we decided to use the value of K = 0.279 year^{-1} estimated by Johnson (1983) for yellowtail snappers in the Florida Keys. The value of L_∞ during 1985-1989 ranged from 650 mm for the lower Keys and Dry Tortugas to 700 mm TL in the upper keys. In the 1990-1996 period, L_∞ increased L in the upper Keys from 700 to 730 mm and also increased in the lower Keys and Dry Tortugas, from 650 mm to 685 mm and 650 mm to 700 mm TL, respectively. The L_∞ of the von Bertalanffy equation is a theoretical maximum mean size at an indefinitely great age, and it need not be larger than the actual maximum observed size for an individual (Ricker, 1975).

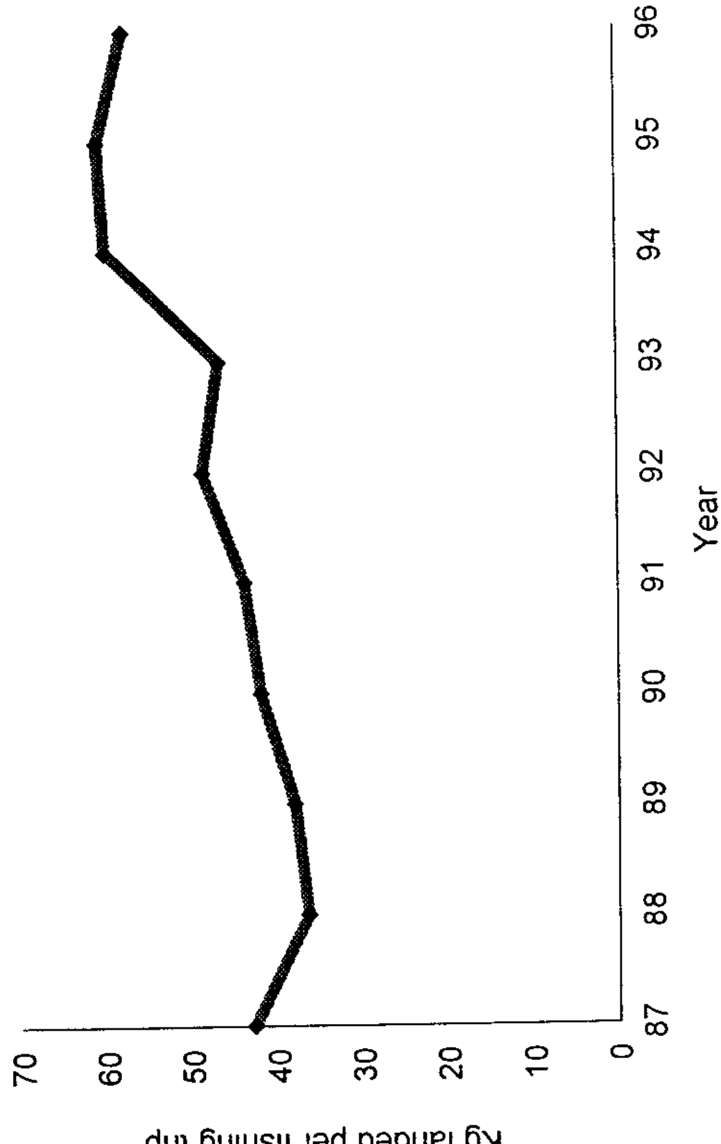

Figure 3. Yellowtail snapper landings (kgs) per fishing trip by year, 1987-1996, in the Florida Keys.

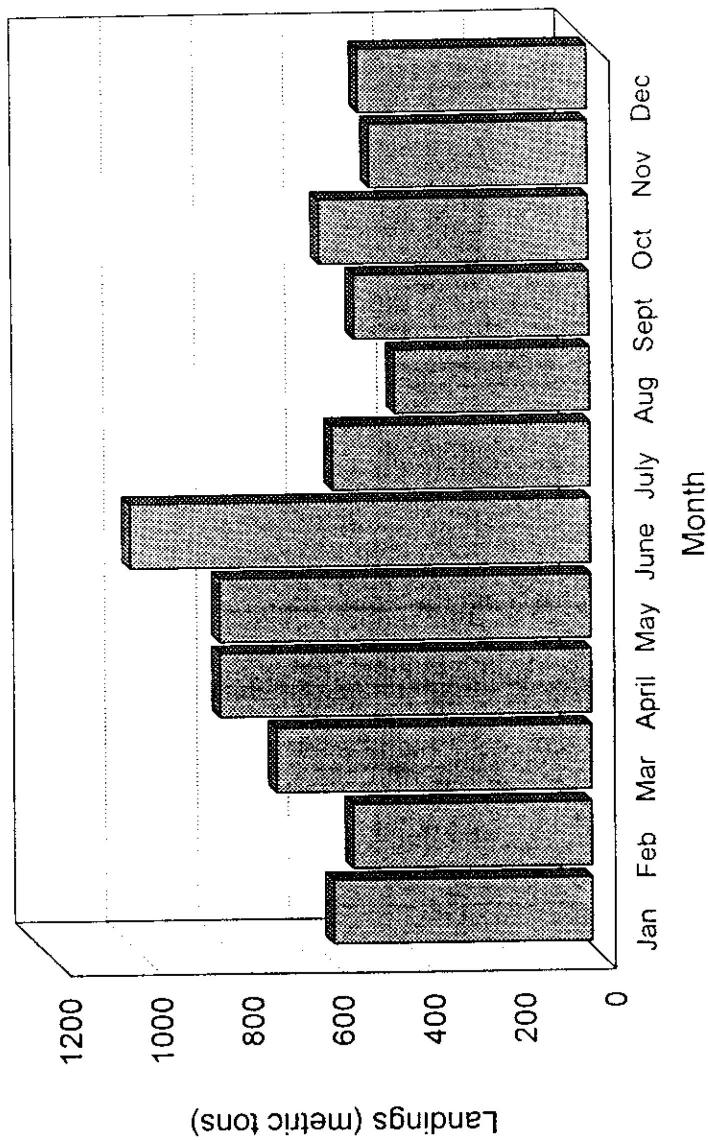

Figure 4. Number of metric tons (1,000's kg) of yellowtail snapper landed by month in the Florida Keys.

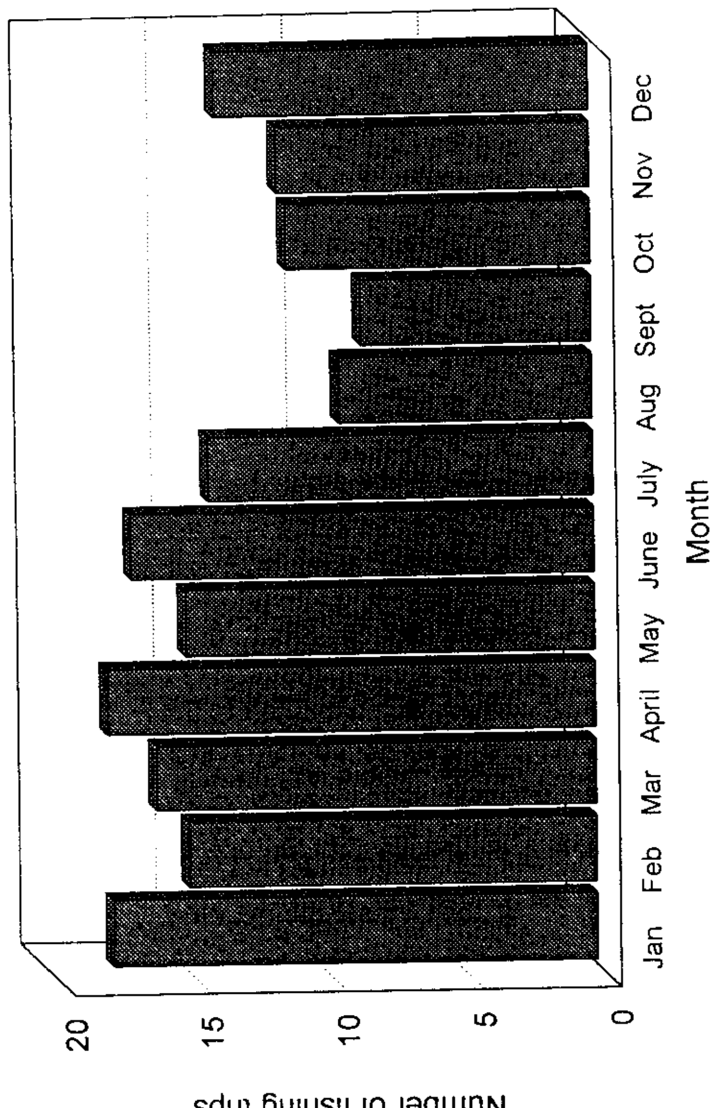

Figure 5. Number of fishing trips by month for yellowtail snapper in the Florida Keys.

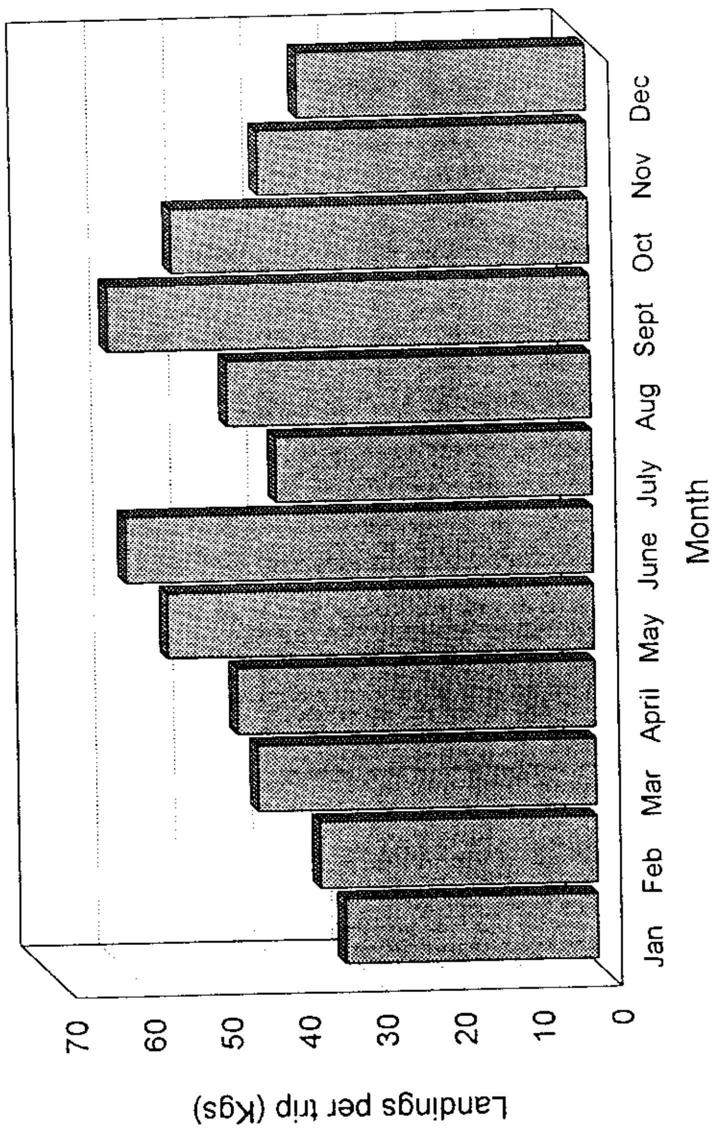

Figure 6. Florida Keys yellowtail snapper kilograms per fishing trip by month.

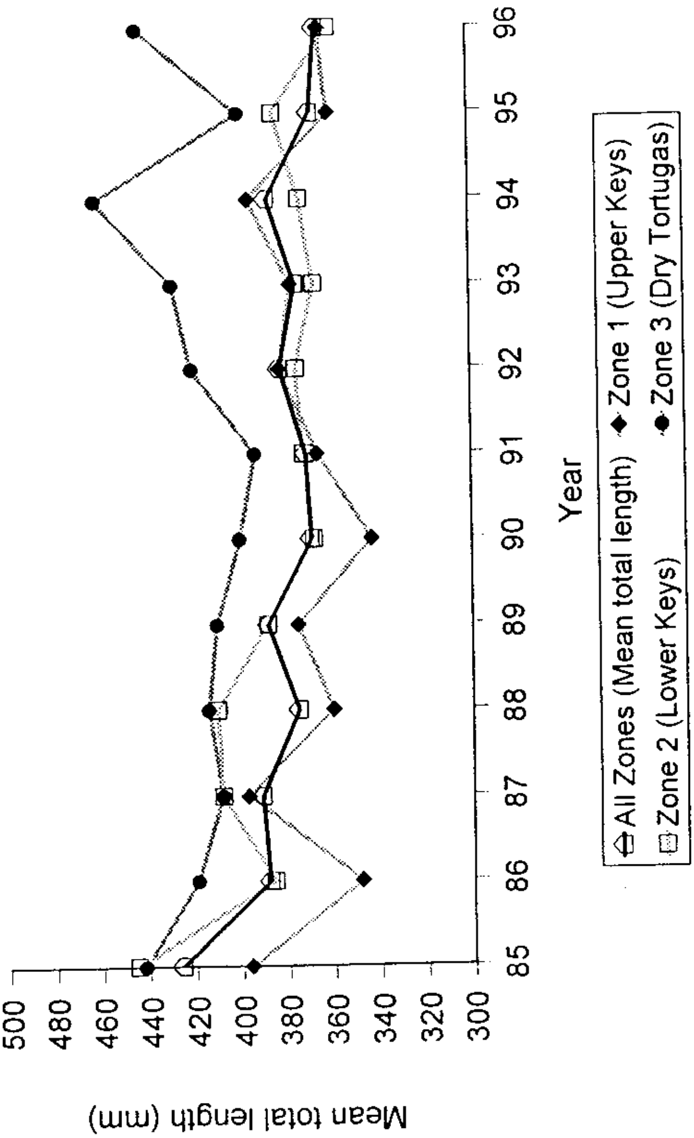

Figure 7. Mean length of capture (mm) for yellowtail snapper per fishing zone by year, 1985-1996.

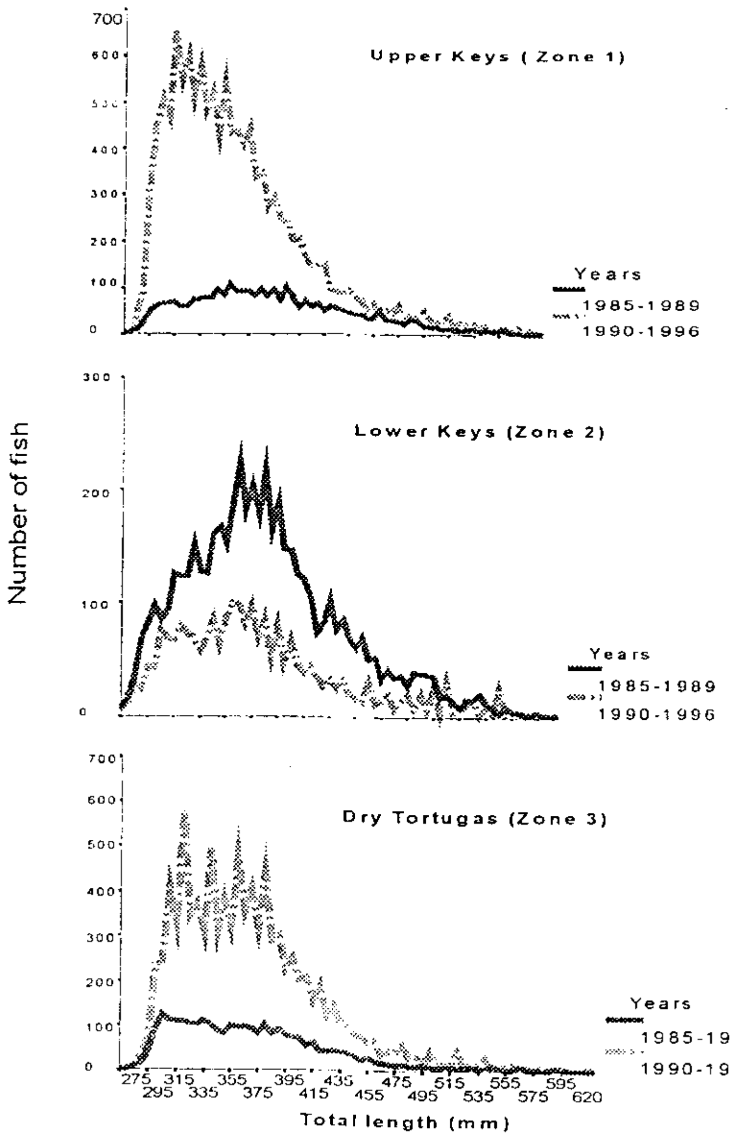

Figure 8. Total length-frequency distribution for yellowtail snapper by zone for 1985-1989 and 1990-1996.

The largest fish sampled in the upper Keys during the periods of 1985-1989 and 1990-1996 were 710 and 645 mm TL respectively, so an L_∞ of 730 to 700 mm TL, seems reasonable. The maximum total lengths observed for the lower Keys were 630 and 655 mm TL during the periods of 1985-1989 and 1990-1996, respectively. Consequently, the values of L_∞ of 650 and 685 mm TL for those periods also seem reasonable. Similarly, maximum sizes of fish sampled in the Dry Tortugas during the two periods were 640 and 655 mm TL, so estimates of L_∞ of 650 and 700 mm TL also seem reasonable. Estimates of L_∞ and K were higher than those obtained previously in Florida and other regions of the Caribbean (Table 2). The results are similar to those observed in Cuba (Piedra, 1964) and in Jamaica (Thompson and Munro, 1983). The largest yellowtail snappers reported in the FDEP's database ranged from 700 to 840 mm total length and were captured in the Gulf of Mexico. There is very little direct fishing for yellowtail snapper in this area.

Total mortality (Z) was estimated for two time periods (Table 1). Total mortality was highest in the upper Keys during both periods. The lower Keys showed a similar value of Z (1.07 and 1.04/year) during both periods. The increase in fishing effort in the Dry Tortugas between 1985-89 and 1990-96 resulted in an increase of Z from 0.85/year to 1.08/year. Natural mortality (M), estimated using both Pauly's (1984) and Ralston's (1987) equations, were 0.59/year and 0.63/year, respectively. Ralston's (1987) equation has been recommended to predict M for snapper and groupers (Manooch 1987; Brouard and Grandperrin 1984; Posada and Appeldoorn, 1996) and was used here. Fishing mortality (F) values for the three zones were as follows:

i) Upper Keys (zone 1): F was lower during 1985-89 (F = 0.66/year) than in 1990-1996 (F = 0.78/year);
ii) Lower Keys (zone 2): showed similar level of fishing mortality during both periods (F = 0.44 and 0.41/year$^-$);
iii) Dry Tortugas (zone 3): fishing mortality doubled from F = 0.22/year in 1985-89 to F = 0.45/year in 1990-96; this reflects the increased fishing effort in this zone during the latter period.

The exploitation rate values varied between zones but remained relatively constant between sampling years, with the exception of the Dry Tortugas (Table 1). In the Dry Tortugas the exploitation rate almost doubled from E = 0.26 during 1985-89 to E = 0.42 during 1990-96. Based on setting E = 0.5 as the optimization criterion (Pauly and Soriano, 1986; Silvestre, 1986) and categorically setting $0.40 \leq E < 0.55$ as sufficiently close to the optimum, $0.20 \leq E < 0.40$ as moderately underexploited, and $E < 0.20$ as considerably underexploited, our results indicated that the yellowtail snapper fishery operating in the Florida Keys is exploited at or close to the optimum.

Table 1. Growth, mortality and exploitation rate (E = F/Z) values for yellowtail snapper from the Florida Keys, 1985 - 1996. (1) Based on Johnoson (1983), (2) based on length-converted match curve; (3) based on Ralston's (1987) equation

Zone	L(inf) mm	K(1)	Z(2)	M(3)	F	E
Zone1						
1985 - 1989	700	0.279	1.29	0.63	0.66	0.51
95% C.I.	(664 - 736)					
1990 - 1996	730	).279	0.63			
	(713 - 747)					
Zone 2						
1985 - 1989	650	0.279	1.07	0.63	0.44	0.41
95% C.I.	(639 - 661)					
1990 - 1996	685	0.279	1.04	0.63	0.41	0.39
	(646 - 724)					
Zone 3						
1985 - 1989	650	0.279	0.85	0.63	0.22	0.26
95% C.I.	(634 - 666)					
1990 - 1996	700	0.279	1.08	0.63	0.45	0.42
	(680 - 720)					
Combined	727	0.279	1.44	0.63	0.8	0.56
	(707 - 747)					

Table 2. Comparison of growth parameters and mortality rates for yellowtail snapper from different areas. [1] Based on Johnson (1983); [2] based on Ralston (1987) equation; [3] based on Pauly (1980) equation.

Area	Aging Method	L(inf) mm	K	Z	M	phi	Source
Cuba	V	479	-0.161	-	0.55	4,567	Piedra, 1969
Cuba (SW)	?	681	0.159	0.61	0.43	4.867	Claro, 1983
Cuba (NW)	?	473	0.332	1.26	0.76	4.87	-
USVI and Puerto Rico	O	468	0.139	-	0.43	4.483	Manooch and Drennom, 1987
Jamaica	LF	600	0.25	-	0.6	-	R. Thompson and J.L. Munro, 1983
Florida	O	451	0.279	-	0.67	4.754	Johnson, 1983
Florida	Elefan	727	0.279[1]	1.53	0.63[2]	5.16	Present study
	Wetheral l	697			0.59[3]		
		Z/K = 3.907					

This preliminary analysis of the fishery suggests that it has been stable during the last 10 years except in the Dry Tortugas. Fishing pressure has remained constant in the upper Keys and lower Keys but has increased in the Dry Tortugas, perhaps as a result of larger boats and better navigational technology to find fishing grounds. As expected, the structure of the data has a large effect on the estimates derived using length-frequency analysis. Our approach of using length-frequency data to estimate growth parameters and mortality for *Ocyurus chrysurus* gives generally encouraging results but with some limitations. The data available did not allow structuring the data into smaller size-class intervals, and the absence of small fish in the data set lead to an overestimation of K. Length-converted catch curve estimates of total mortality are highly dependent on the estimated growth parameters. Consequently, estimates of Z generally parallel estimates of K and L_∞. In this case, the overestimation of K resulted in overestimation of Z. Keeping K fixed allows us to examine the effects of fishing in each of the zones studied. We concluded that these estimates of mortality correlate well with the patterns of fishing pressure exerted on this species. Beverton and Holt (1959) and others have suggested a relationship between natural mortality (M) and the growth coeficient (K). This implies that a pattern exists with respect to high or low K values and high or low mortality rates. The ratios of Z/K and M/K have great importance in size-based stock assessment. (Galluci *et al.*, 1996). The ratio of M/K uniquely defines exploitation rate (E) in a sized-based yield-per-recruit analysis. With this in mind, we have to be aware of the limitations of fixing K and using a value of M estimated from an empirical formula in the estimation of potential yields; and in the formulation of a suitable fishing strategy. We believe that length-frequency analysis should not be used in complete absence of life history information or with very small data sets. Information on catch by depth is also important, because some species show a depth distribution that is non-random with respect to size or age (Acosta and Appeldoorn, 1992).

The use of length-frequency methodologies to review the status of this fishery proved to be a valuable tool to follow the changes in fish abundance and size in the three zones studied. Port sampling of commercial catches for length composition is time consuming and difficult in a large area such as the Florida Keys, but it can provide valuable information if properly conducted. Greater efficiency in sampling length-structure can be achieved if sampling is planned and conducted with regard to the way in which the data will be used. If an increased sample size is needed, we suggest that collecting be done throughout the summer months rather than throughout the year. Finally, in fisheries in which there are legal restrictions prohibiting harvest of a fish below a minimum size, alternative sampling regimes need to be established to obtain data on the smaller size classes not sampled by the fishery.

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