

Sexual Maturity and Reproductive Seasonality of King Mackerel (*Scomberomorus cavalla*) and Cero (*Scomberomorus regalis*) in Puerto Rico

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ABSTRACT

Between August 2001 and November 2002, 357 specimens of *Scomberomorus regalis* and 334 of *S. cavalla* were collected all around Puerto Rico, with the objective to describe the annual reproductive cycle and to estimate the size of sexual maturity. For *S. regalis*, the histological analysis revealed that 50% of males and females reach their maturity at 350 and 413 mm Fork Length (FL), respectively. The males of *S. cavalla* mature at 450 mm FL, whether females do so at 585 mm FL. All males of *S. regalis* bigger than 450 mm FL were mature, whether in females this size was 550 mm FL. In *S. cavalla*, all males and females bigger than 550 and 750 mm FL, respectively, were mature. In *S. regalis*, the monthly distribution of gonadal development stages and the fluctuations of the gonadosomatic index suggest that the species reproduces virtually during all year, although an increase in reproductive activity was observed from April to September. The spawning season for *S. cavalla* is also extended, although limited or no activity was detected between September and March. For both species females prevail in higher size classes. The information obtained during this research suggests that the fishery of *S. regalis* has remained stable during the last years. About 11% of males and 37% of females were captured before reaching the size of sexual maturity. On the other hand, for *S. cavalla* there is a different situation. Larger individuals (i.e. >30 pounds), common during the 1970s, were very scarce in the landings sampled during this study. That trend was confirmed by several commercial and sport fishers around the island. About 14% of males and 51% of females of *S. cavalla* were captured under our estimated size of sexual maturity. This species, due to its commercial and sport fishing importance, has been considered as overfished in several jurisdictions and therefore, management measures had been implemented in an attempt to achieve a recovery of the populations. In 2004 minimum sizes for the capture of *S. cavalla* and *S. regalis* were established in Puerto Rico.

KEY WORDS: Reproductive seasonality, *Scomberomorus* sp., sexual maturity

Madurez Sexual y Estacionalidad Reproductiva del Carite (*Scomberomorus cavalla*) y la Sierra (*Scomberomorus regalis*) en Puerto Rico

Entre agosto de 2001 y noviembre de 2002 se colectaron, a través de todo Puerto Rico, 357 especímenes de *Scomberomorus regalis* y 334 de *S. cavalla* con el propósito de describir el ciclo reproductivo anual y estimar el tamaño de madurez sexual. Para *S. regalis*, el análisis histológico de las gónadas reveló que el 50% de los machos y hembras son maduros a los 350 y 413 mm largo de horquilla (Lh), respectivamente. Los machos de *S. cavalla* maduran a los 450 mm Lh, mientras que las hembras lo hacen a los 585 mm Lh. Todos los machos de *S. regalis* mayores de 450 mm Lh son maduros, mientras que en las hembras ese tamaño es de 550 mm Lh. En *S. cavalla*, todos los machos y hembras mayores de 550 y 750 mm Lh, respectivamente, son maduros. En *S. regalis*, la distribución mensual de las etapas de desarrollo gonadal y las fluctuaciones del índice gonadosomático sugieren que esta especie se reproduce virtualmente durante todo el año, aunque se observa un período de mayor actividad reproductiva desde abril a septiembre. La temporada de desove en *S. cavalla* es también extendida, aunque entre los meses de septiembre a marzo existe poca o ninguna actividad. En ambas especies las hembras predominan en las clases de tamaños mayores. La información recopilada durante este estudio sugiere que la pesquería de *S. regalis* en Puerto Rico se ha mantenido estable durante los últimos años. El 11% de los machos y el 37% de las hembras fueron capturadas antes de alcanzar el tamaño de madurez sexual. Por otro lado, existen indicios de que para *S. cavalla* la situación es diferente. Los individuos de mayor tamaño (> 30 libras) eran relativamente comunes en la década de los 1970, siendo actualmente muy escasos en los muestreos. Esa tendencia fue confirmada por varios pescadores comerciales y deportivos alrededor de la isla. El 14% de los machos y el 51% de las hembras de *S. cavalla* fueron capturados por debajo del tamaño de madurez. Esa especie, por su importancia comercial y recreativa, ha sido considerada como sobrepescada en varias jurisdicciones y se han tomado medidas de manejo con la intención de lograr la recuperación de las poblaciones. En el año 2004 se establecieron en Puerto Rico tamaños mínimos de captura para ambas especies.

PALABRAS CLAVES: Estacionalidad reproductiva, madurez sexual, *Scomberomorus* sp.

INTRODUCTION

The genus *Scomberomorus* (Family Scombridae) contains 18 species, and they are represented in Puerto Rico waters by two of them: cero (*S. regalis*) and king mackerel (*S. cavalla*). Both species are in the Western Atlantic from Massachusetts to Brazil (Collette and Russo, 1979), and they are important in commercial and recreational fisheries along their distribution zone. The *S. regalis* distribution is more associated with the tropics. *S. regalis* is a coastal epipelagic species which is found in clear water along coral reefs, occasionally forming small schools. They fed primarily of small fishes from the Family Clupeidae (sardines and herrings), from the genus *Harengula*, *Jenkinsia* and *Opisthonema* (Randall 1967). They could reach 80 cm (32 inches) in length and 11.4 kg (25 pounds), approximately. *S. cavalla* is also an epipelagic species, mainly coastal, but it is not common on coral reef areas (Cervigón *et al.* 1993). Big individuals are usually alone and small fishes form schools in which individuals have similar sizes. This species do extensive migrations along the Gulf of Mexico and the Atlantic coast of the United States, although some individuals stay on determined zones. Similar traveling patterns had been observed in Puerto Rico and Virgin Islands waters (CFMC 1983). Their feeding habits are similar of *S. regalis* but also include species from the family Lutjanidae, Carangidae Hemiramphidae and others (Collette and Russo 1979). It reaches 170 cm (68 inches) in length and 45.5 kg (100 pounds) in weight.

Data collected by Fisheries Statistics Program of the Fisheries Research Laboratory of the PRDNER shows that, as a group, *Scomberomorus* occupied the second place by pounds reported during 2001, exceeded only by the snappers (Matos 2004). During that year the fisheries

statistics reported 38,505 kg (84,711 pounds) of *S. regalis* and 46,169 kg (101,572 pounds) of *S. cavalla*, for 84,653 kg (186,238 pounds) in total (6.5% of the total pounds of fish reported). During last years the landings reported for both species are stable, maintaining 6.5% to 5% of the total pounds of fish reported (Figure 1).

The information published for *S. regalis* is scarce and is mostly researches about distribution and general aspects of their biology (Cervigón 1995, Collete and Russo 1979, 1984, García-Cagide 1994). Finucane and Collins (1984) make a study about reproductive biology in South Florida. In Cuba and Jamaica there are some studies about the fishery of the species (Howell-Rivero 1953, Cooper 1982, León and Guardiola 1984). Erdman (1976, 1978) published the only studies realized in Puerto Rico that make a general reference of the spawning season and the fishery of the species. On the other hand, the literature about *S. cavalla* is extensive, mostly because their commercial and recreational importance in countries like United States and Brazil. There are studies about reproduction, age, and growth, fisheries and population, larval distributions and migrations, etc. (Manooch *et al.* 1978, Collete and Russo 1979, 1984, Fishbase 2003). In the Caribbean, Sturm and Salter (1990) have studied reproductive aspects, age and growth in Trinidad, whether Torres (1986) studied aspects of their biology in Venezuela. The only studies known for *S. cavalla* in Puerto Rico are from Erdman (1976, 1978).

In this study two aspects from the reproductive biology of the king mackerel and cero are examined, which are essential to develop management strategies: estimate the size in which they reach sexual maturity size (SMS) and to determine the spawning season with the histological study of the annual reproductive cycle.

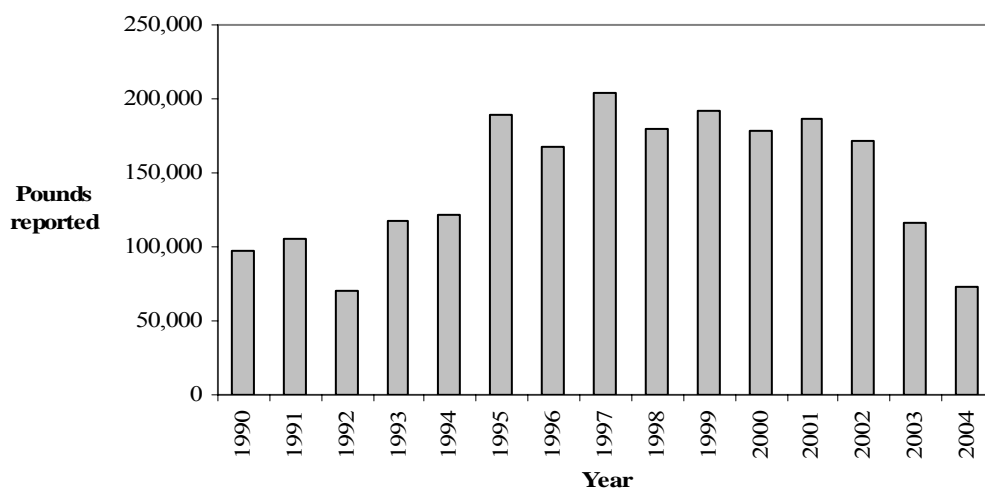


Figure 1. Landings reported for the genus *Scomberomorus* to the Fisheries Statistic Program, DNER

METHODS

The samples used in this study were obtained by the Fisheries Research Laboratory, DNER, personnel and with the cooperation of the fishers all around Puerto Rico. The sampling period was from August 2001 through November 2002. During this period a total of 691 specimens were collected.

The fishing gears used the most was hook and line and the beach seine. All fishes were measured and weighted in millimeters (mm) and grams (g), all measures referred to the fork length (FL). The gonads were removed, weighted at 0.01 grams of precision and fixed in Davidson (Yevich and Barszcz 1981), later they were histological processed using paraffin, cut about 8µm, mounted in a slide and then stained with hematoxylin and eosin. The classifications of the developing stages of the gonads in females were based on Figuerola *et al.* (1998). For the classification of the developing stages for male gonads was following the histological criteria used by Sadovy *et al.* (1994).

The size of sexual maturity is defined here by the size in which 50% of individuals are sexually mature (including sexual maturity stages 2 - 5 in females). The annual reproductive cycle it is defined by the percentage of females in each stage (stage 2 - 5) by month. The frequency of females on the most advanced developing stage (H4) and the gonadosomatic index were used as principal criteria to determine the spawning period. To determine in more precise way the spawn days the criteria used was the presence of hydrate oocytes in the gonads. To compare the length frequency distribution between males and females the test used was Kolmogorov-Smirnov (Sokal and Rohlf 1981).

The gonadosomatic index (GSI), to indicate the moment of spawn, it is calculated using this formula: $GSI: [\text{gonad weight} / \text{fish weight} - \text{gonad weight}] \times 100$.

RESULTS

A total of 691 specimens were collected during the sampling period that extended from August 2001 to November 2002 (Table 1). Ninety four percent (n = 650) of the samples were histological processed. Table 2 shows data about sizes and sex for both species examined.

Scomberomorus regalis

Figure 2 presents the length frequency distribution for *S. regalis*. The cero of bigger size was a female of 809mm and the smallest measured 199mm (Table 2).

From 357 individuals analyzed, 198 were females and 142 males, the sex ratio was 1♂:1.4♀. The other 17 individuals the sex couldn't be determined, due to the quality of the sample or because the specimens were too small and the sex was undetermined. Although the females tend to prevail on bigger sizes, there is no difference in the length frequency distribution between males and females (Kolmogorov-Smirnov: $D = 0.077$, $p > 0.01$) (Figure 3).

Males mature at smaller sizes than females. The smallest mature male measured 262 mm FL, while the smallest mature female measured 295 mm FL (Table 2). The estimate size for the 50% of sexual maturity was 350 mm FL. All males were mature at 450 mm FL (Figure 4). In females the maturity size was 413 mm FL, been all mature at 550mm FL (Figure 5). Using the length frequency distribution of the samples and the maturity estimates mentioned 11% of the males and the 37% females captured before reaching their sexual maturity.

Figure 6 shows the monthly variation of the gonadosomatic index for females of *S. regalis*. The GSI begins to increase on March, reaching their maximum development in May, and then it descends quickly between May and August.

The monthly distribution for the gonad development stages in females is presented in Figure 7. During all year doing the sampling, except for January, advance mature females were found. A similar pattern was found for females that had already spawned. This information indicates that *S. regalis* spawn in Puerto Rico all year. Although there is a peak of reproduction between April and September, being June and maybe July, the ones with more activity. Fifty two percent (52%) of ceros collected between April and September were classified as H4 (advance mature). During June the females H4 were greater, 87%. From October to March the percent of females H4 was 9%, with fluctuations between 0 and 20%. The relation between the moon phases and the moment of spawning was not established, because female ovaries with sign of imminent or recent spawning were found at different phases of the moon cycle.

Scomberomorus cavalla

The Figure 8 presents the length frequency distribution for *S. cavalla*. The biggest king mackerel collected for this study was a female that measured 1,191 mm and the smallest was 225 mm (Table 2).

For these species, 174 males and 136 females were analyzed, for 310 individuals in total, and a sex ratio of 1♂:0.8♀. For 24 specimens the sex couldn't be determined. There was a significant difference between the sizes of males and females (Kolmogorov-Smirnov: $D = 0.182$, $p < 0.05$), having a greater fork length and dominating higher sizes, above 1,000 mm FL (Figure 9).

As in *S. regalis*, males mature at smaller sizes than females. The smallest mature males measured 365 mm FL and the smallest mature female measured 468 mm FL (Table 2). The size estimated for 50% maturity in males was 405 mm FL; all males were mature at 550 mm FL (Figure 10). Females mature at 585 mm FL, being all mature at 750 mm FL (Figure 11). Using the same criteria mentioned previously for *S. regalis*, 14 % of the males and 51% of females were captured below their sexual maturity size.

The GSI calculated between August 2001 and September 2002 reached its maximum value in April, decreasing gradually between May and June; and July was the lowest value (Figure 12).

Figure 13 shows the monthly distribution of gonadal development stages. From April to August 39% of all females collected were advanced mature, while between September and March only 3% of the gonads showed that stage of development. The months of greater proportion of advance mature females were May and August, with 58%

and 60%, respectively. During the months of January, July, September, October and December no females in mature stages were found. This information suggests that *S. cavalla* reproduce on local waters mainly during April and August, with less or non reproductive activity during the rest of the year. The specimens of *S. cavalla* with gonads showing signs of imminent spawn were captured between the first and fourth day of the new moon.

Table 1. Monthly samples collected for both species from August 2001 and November 2002.

Month	<i>S. regalis</i> (n=357)	<i>S. cavalla</i> (n=334)
January	39	19
February	36	39
March	23	54
April	28	18
May	14	31
June	35	29
July	0	24
August	35	30
September	12	20
October	54	43
November	38	8
December	43	19

Table 2. Size of the fishes captured during the study (All measures referred to fork length in millimeters).

<i>Scomberomorus regalis</i>	Total (n=357)	Males (n=142)	Females(n=198)
Maximum Size	809	617	809
Minimum Size	191	254	200
Average Size (\pm d.e)	437 (100.4)	440.9 (85.7)	447.2 (107.4)
Size smallest mature male	262		
Size smallest mature female	295		
Sex ratio (σ : ϕ)	1:1.4		
<i>Scomberomorus cavalla</i>	Total (n=334)	Males (n=174)	Females(n=136)
Maximum Size	1191	1029	1191
Minimum Size	225	278	291
Average Size (\pm d.e)	606.9 (214.5)	596.0 (178.5)	657.4 (234.4)
Size smallest mature male	365		
Size smallest mature female	468		
Sex ratio (σ : ϕ)	1:1.3		

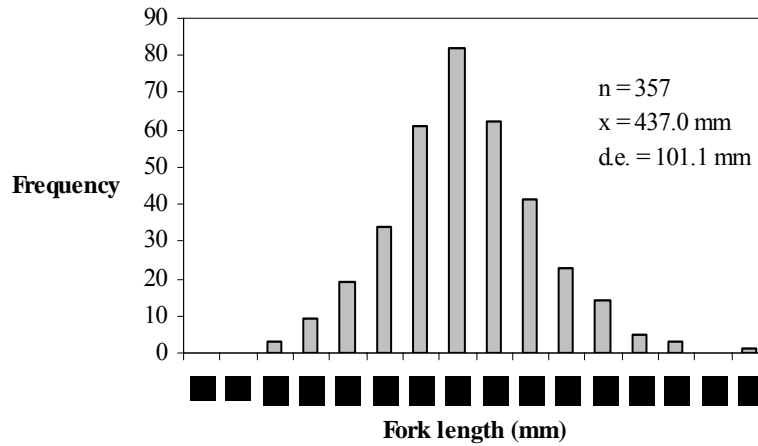


Figure 2. Length frequency distribution for *Scomberomorus regalis* collected between October 2001 and November 2002.

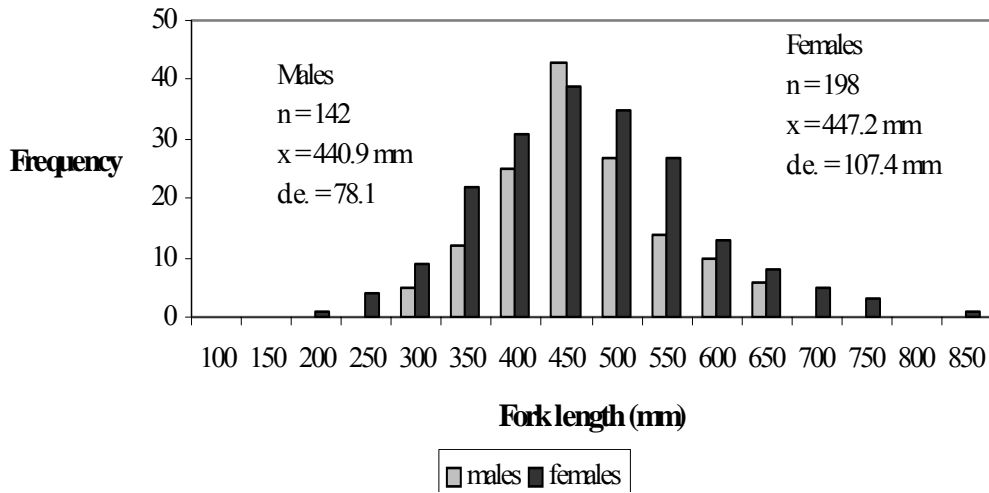


Figure 3. Length frequency distribution by sex for *Scomberomorus regalis* collected from October 2001 to November 2002.

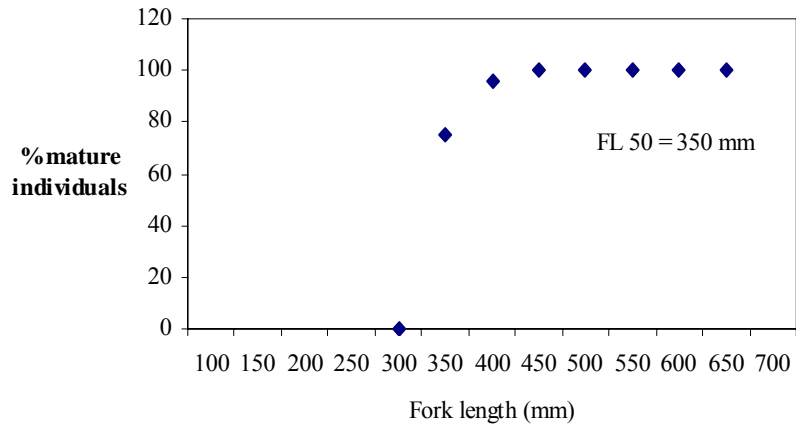


Figure 4. Percent of mature males by size class of *Scomberomorus regalis*. FL50 is the length in which 50% of individuals were mature ($n=142$)

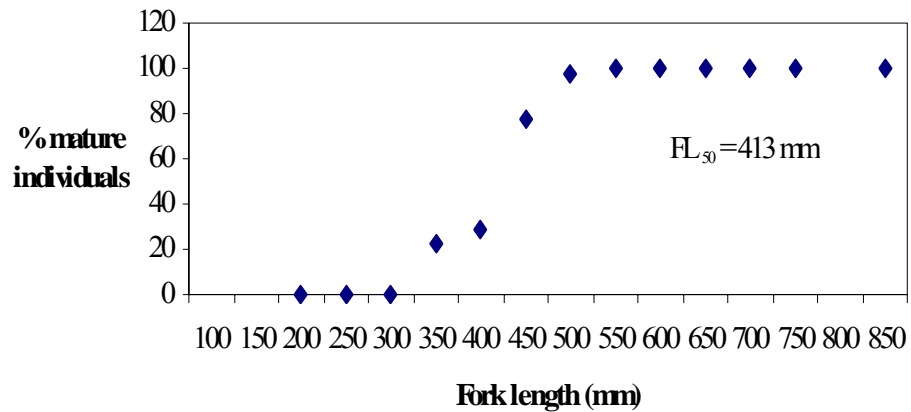


Figure 5. Percent of mature females by size class of *Scomberomorus regalis*. FL50 is the length in which 50% of the individuals were mature (n = 198)

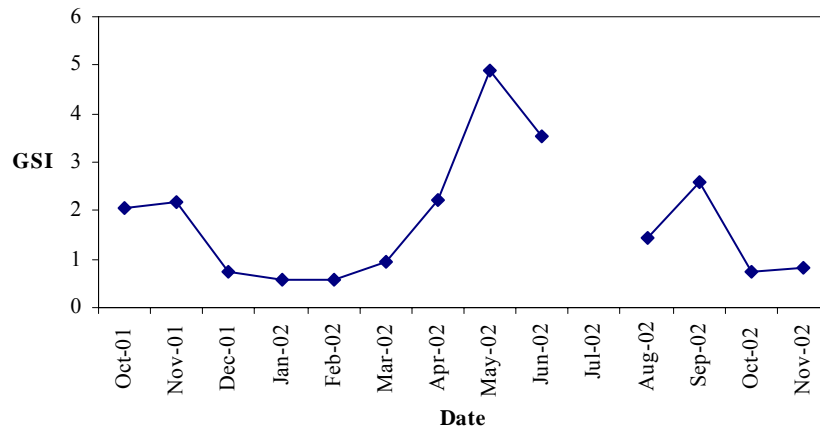


Figure 6. Monthly average of gonadosomatic index (GSI) for females of *Scomberomorus regalis* collected during October 2001 and November 2002 (n =

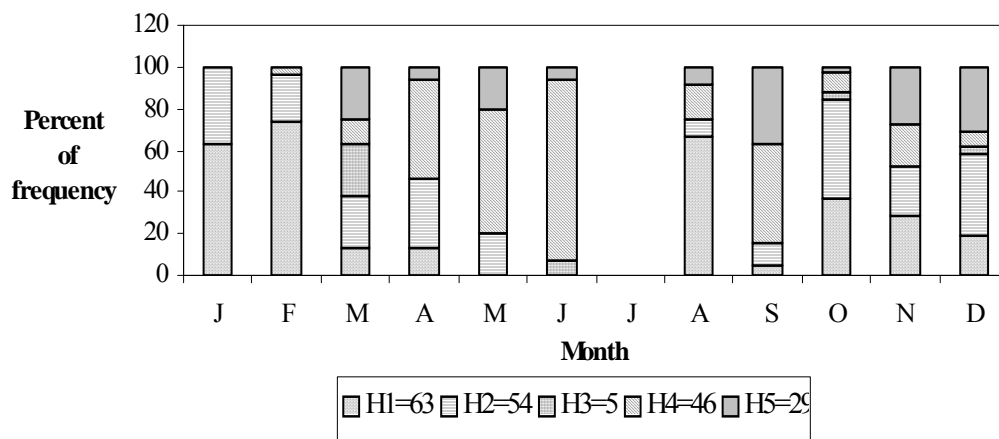


Figure 7. Distribution by percent of gonad development stages by month of females of *Scomberomorus regalis*

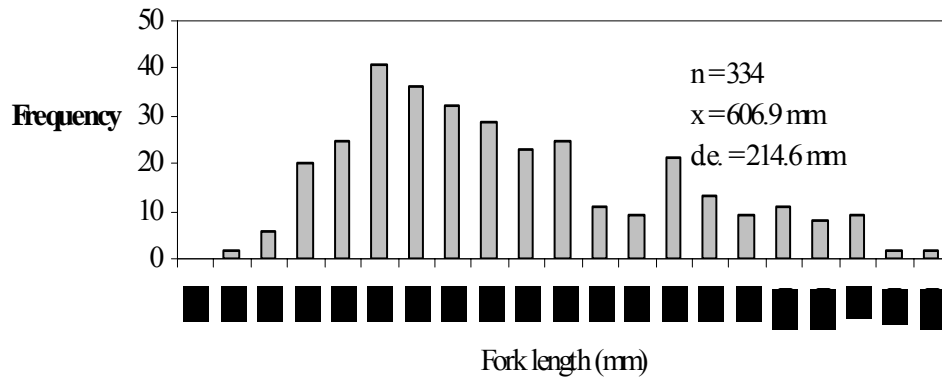


Figure 8. Length frequency distribution of *Scomberomorus cavalla* collected between August 2001 and November 2002.

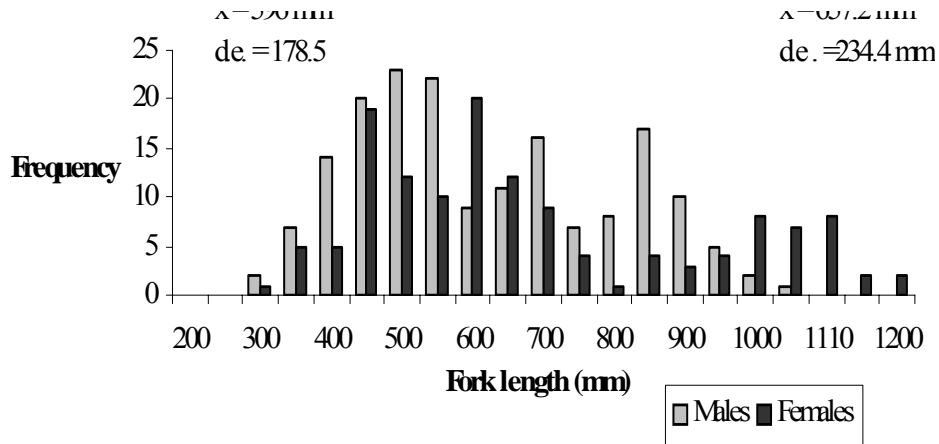


Figure 9. Length frequency distribution by sex for *Scomberomorus cavalla* collected between August 2001 and November 2002.

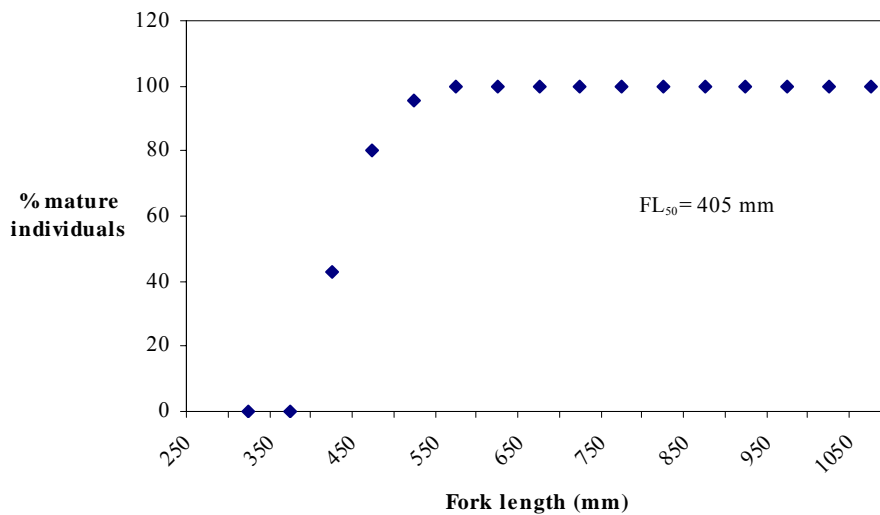


Figure 10. Percent of mature males by size class of *Scomberomorus cavalla*. FL₅₀ is the length in which 50% of individuals were mature (n = 173).

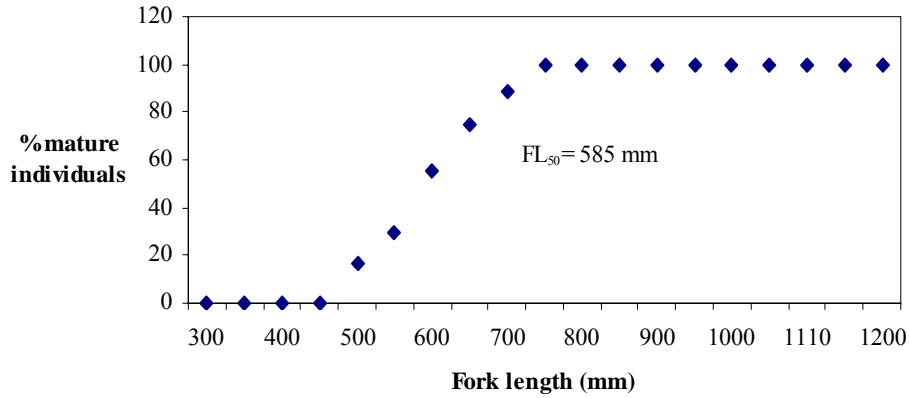


Figure 11. Percent of mature females by size class of *Scomberomorus cavalla*. FL 50 is the length in which 50% of the individuals were mature (n = 136)

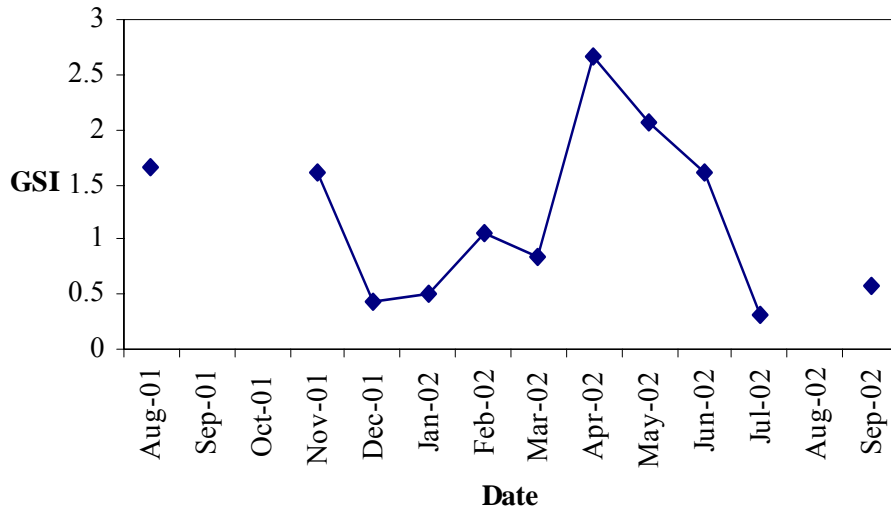


Figure 12. Monthly average of gonadosomatic index (GSI) for females of *Scomberomorus cavalla* collected during August 2001 and November 2002 (n = 60).

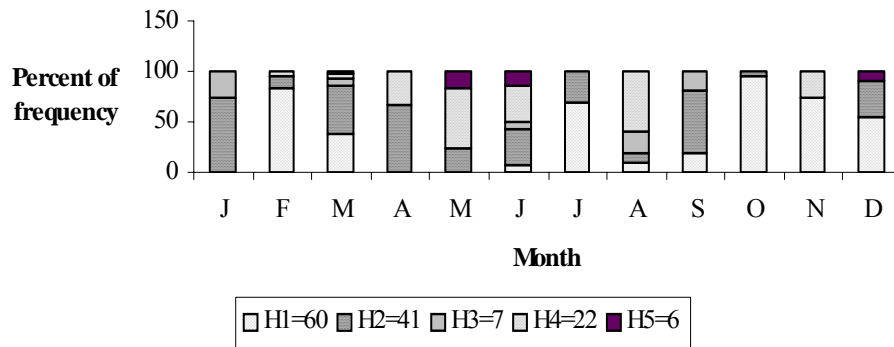


Figure 13. Distribution by percent of gonad development stages by month of females of *Scomberomorus cavalla*.

DISCUSSION

Scomberomorus regalis

Analyzing the length frequency distributions for these species, the females prevail on bigger sizes classes. Finucane and Collins (1984) obtained similar results in a research made in Florida. There are several factors that could explain these differences like fishing gear selectivity, growth rate and /or mortality between sexes, geographic distribution, a combination of factors, and others. For *S. cavalla*, age and growth studies have corroborated that females grow faster than males. It is possible that something similar occurs in *S. regalis*.

The data obtained in this study show that males of *S. regalis* reach their sexual maturity at smaller sizes than females. All males and females greater than 450mm FL and 550 mm FL, respectively, were mature. The same tendency was reported in Florida by Finucane and Collins (1984), although maturity sizes were smaller than the reported in this study. According to these authors, in Florida all males greater than 350mm FL were mature and the females were 350 mm FL. For this study, the estimates were 350 mm FL for males and 413 mm FL for females, while in Florida 50% of the males mature between 325 - 350 mm FL, and the females between 350 - 400 mm FL. In Cuba, García-Cagide et al. (1994) report only maturity size for females, 430 mm FL. Cervigón (1994) estimated the maturity size in Venezuela, 416 mm, and 415 mm of total length for males and females, respectively.

The sexual maturity size is a parameter that is closely related to the habitat conditions of the species in each region. Probably food availability is an important issue in this process. In Cuba the average maturity for a lot of species occur at 60% of the maximum size for both sexes (García-Cagide et al. 1994). In this study, males reach their sexual maturity at 56% of their maximum size, while in females is at 51%. Grimes (1987) points out that populations and species of the family Lutjanidae from insular areas mature at bigger sizes than the continental. Also other external factors might have some influence like the intensity of the fisheries exploitation and predator abundance (Wootton 1990). All of this stands out the importance of obtaining this information locally when the need to establish management measures based on sexual maturity size. Several studies demonstrate that the increase in fishing pressure can lead to a reduction of maturity size (Jorgensen 1990, Harris y McGovern 1997, Zhao y McGovern 1997). The estimates calculated in this research are the first made for this species in Puerto Rico, and therefore it is not possible to compare it's relation with the fishing pressure that occur.

The monthly distribution of the gonad development stages and the gonadosomatic index reveal that the reproductive activity occurs at some degree during all year, mostly from April to September. From the data it could be inferred that there is a spawn peak during May, June and

probably July, although there are no samples of that month. Erdman (1976, 1978) reported that, in Puerto Rico, *S. regalis* spawns virtually all year, with an increase during spring and summer. In Jamaica, most of the fishes captured between April and October in a place known as California Bank were spawning or their gonads were mature (Cooper 1982). According to Finucane and Collins (1984), in coastal waters in South Florida the spawning season of the mackerel extends all year. These authors found advanced mature females from March to July with a spawning peak in April and May. García-Cagide et al. (1994) mentioned the presence of females with advanced mature gonads between April to December in Cuba. In Venezuela the reproductive activity occur all year but the most common months to find mature individuals are between April and September (Cervigón 1993).

Scomberomorus cavalla

As in *S. regalis*, *S. cavalla* females are more abundant in the larger size classes. This tendency agrees with several studies that demonstrate that females of this species grow faster and/or reach bigger sizes than males (Beaumariage 1973, Johnson et al. 1983, de León y Guardiola 1984, Manooch et al. 1987, Collins et al. 1989, Sturm y Salter 1990, DeVries y Grimes 1997).

Our data indicate that, males reach their maturity at 39% of their maximum size, while in females is at 49%. The maturity estimate is 585 mm FL for females, in general is similar to several estimates published for this species. In Trinidad, Sturm and Salter (1990) report a SMS of 585 mm FL. In Brazil, the SMS estimated by Alves and Tomé (1967) was 586 mm FL, while Gesteira and Mesquita (1976) reported a FL of 635 mm. Ivo (1972), also in Brazil obtained an estimate of the first maturity between 435 - 565 mm FL and 50% maturity occurring at 770 mm FL. In the Southeast of the United States, Finucane et al. (1986) reported a SMS between 449 and 699 mm FL. In the southeast of Cuba, the estimate for maturity size is 500 mm FL (García-Cagide et al. 1994). The bigger SMS found in the literature was reported by Beaumariage (1973), who estimates a value of 840 mm FL for the females in Florida. For males in this study, the estimate was 405 mm FL. The estimates reported by other authors' show a maturity size significantly lower in males compared to females. In Florida and Trinidad, the SMS of the males was 730 and 545 mm FL, respectively (Beaumariage 1973, Sturm y Salter, 1990).

In terms of reproductive seasonality of the king mackerel in local waters, the GSI reaches its maximum value in April, decreasing gradually and reaching the lowest value in July. This information, joined with the monthly distribution of development stages of the gonads suggests that *S. cavalla* reproduce on local waters mainly between April and August, with less or non activity during the rest of the year. This agrees with Erdman (1976) who pointed out that *S. cavalla* spawns in Puerto Rico mainly during July and August, although he found at least one female ready to

spawn in April and a mature male in November. Nevertheless, is necessary to recall that Erdman (1976) data is based on visual observations which don't have the precision of an histological analysis. In the southeastern United States (from Texas to North Carolina), Finucane *et al.* (1986) found that most of the specimens examined during May and September were reproductively active, and some individual were in spawning conditions earlier in April and later in October. Similar results were reported by McEachran *et al.* (1980) for the western region of the Gulf of Mexico. In the Northeast of Brazil spawning is observed all year round (Ivo, 1972). Based on preliminary data, in Cuba the spawning period coincides with the publication by Beaumariage (1973) in Florida, which says that it extends from April to November with a peak in July and August (de León and Guardiola 1984).

All gonads of *S. cavalla* with evidence of spawning were captured around the days of new moon. It has been established that small fluctuations of the environmental conditions in the tropics can provoke noticeable variations in the physiological conditions and could lead to the establishment of a specific reproductive rhythm. Among these factors are the temperature, the photoperiod and the moon phases (see García-Cagide *et al.* 1994).

The less abundant development stages of the gonads were the active mature (stage 3) and spawned (stage 5). These results agree with García-Cagide *et al.* (1994). These authors said that the vitelogenesis (oocytes pass from stage 2 to stage 4) generally occurs quickly lasting only a few days. The final maturation (from stage 4 to stage 5) occurs in few hours, immediately before spawning. Spawning duration at individual level (number of days that the same individual could spawn) couldn't be estimated for neither of the species in this study. It has been estimated that this period varies from one day in the mullets (Family Mugilidae) to 30 days on sardines (Family Clupeidae). The extended spawning season is an important mechanism to maintain the production of recruits during most part of the year increasing the probability to colonize the spaces that became vacant. The differences observed in the peak spawning activity among the two species might be a mechanism to maximize the larval development in terms of space and time (see García-Cagide *et al.* 1994).

The landings of the genus *Scomberomorus* reported during the past 15 - 20 years commercial fishermen in Puerto Rico, in combination with the percent of individuals captured below their sexual maturity size and the length frequency distribution, suggests that the fishery of *S. regalis* is stable on local waters. On the other hand, there is a high percent of females of *S. cavalla* captured below their sexual maturity size and fishes of larger sizes (> 30 pounds) were scarce along the sampling period, indicating of a possible overfishing situation. Commercial and recreational fishermen that used to fish this species confirm that big individuals, common in 1970 and 1980, are disappearing and today are considered uncommon.

In the Gulf of Mexico and the southeast coast of the United States, the establishment of management plan in the 1980s was in response to the decrease in captures associated with an increase in fishing pressure from the commercial and recreational sector (Legault 1998). Actually, there are management plan for both sectors in all states of the south east of the United States and the Gulf of Mexico. Recreational fishermen have a size limit of 24" FL and a maximum of two fishes/fishermen/day. For the commercial fishermen, there are size limit of 24" FL an annual quota, by region and fishing gears (GMFMC 2004 a,b). According to Legault (1998), the management measures had resulted in a recovery of the populations. Due to the situation described for *S. cavalla*, on March 2004 the Puerto Rico Fisheries Regulation 6768 under Law 278 established a minimum size requirement of 19.9"(505mm) FL for *S. cavalla* and 16" (406mm) for *S. regalis*. There is also bag limit for recreational fishermen of five (5) fishes/fishermen/day or 20 per boat/day for both species.

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