Reproduction in Yellowtail Snapper *Ocyurus chrysurus* B. 1790, from the Campeche Bank, Southeastern Gulf of Mexico

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ABSTRACT

In the southern Gulf of Mexico, due to deteriorated red grouper (*Epinephelus morio*) catch volumes some species of snappers such as yellowtail snapper, *Ocyurus chrysurus*, is now being targeted by commercial fishers, causing recent increments in catches. Thus, constant catch increments in recent years, lack of information on the biology of the species and the non-existence of a management plan that regulates commercial exploitation now generate uncertainty on the state of this resource. In this study a total of 1,657 yellowtail snappers that ranged from 11.9 cm to 45.5 cm, fork length (FL) were captured monthly, by small-craft fleet in Campeche Bank waters, between February 2008 and January 2009. Gonads were fixed in Bouin's liquid for histological examination. Microscopic observations determined 50% females (n = 832) and 49.8% males (n = 825). Females measured from 13.4 cm to 45.5 cm and males 11.9 cm to 41.8 cm FL. The overall chi-square analysis for sex ratios (M:F) and sex ratios for respective size classes, indicated no significant differences from the expected 1:1 ratio. The smallest mature female (L min) was obtained at 14.1 cm FL, and length at first maturity (L_{50}), was 21.3 cm FL, whilst males (L min) was 14.2 cm FL and (L_{50}), 19.4 cm FL. Yellowtail snapper from Campeche Bank had a protracted spawning season extending from January to September, with spawning concentrated during spring (March to May) and fall (September). Therefore, yellowtail snapper from the southeastern Gulf of Mexico exhibits the 'insular' reproductive pattern. The results for this specie generally agree with those obtained by other authors within the Gulf and Caribbean region.

KEY WORDS: Snapper, reproduction, *Ocyurus chrysurus*, Campeche Bank, Gulf of Mexico

La Reproducción de la Rabirrubia *Ocyurus chrysurus* B. 1790 del Banco de Campeche, Sureste del Golfo de México

PALABRAS CLAVE: Rabirrubia, reproducción, *Ocyurus chrysurus*, Banco de Campeche, Golfo de México

La Reproduction du Vivaneau Queue Jaune, *Ocyurus chrysurus* B. 1790 du Banc de Campeche, Sud-Est du Golfe du Mexique

MOTS CLÉS: Vivaneau queue jaune, reproduction, *Ocyurus chrysurus,* Banc de Campeche, sud-est du Golfe du Mexique

INTRODUCTION

The yellowtail snapper, *Ocyurus chrysurus*, is a common reef fish species found extensively throughout the tropical and subtropical western Atlantic shelf and coastal waters. Because of its excellent taste and common occurrence, this species is highly sought after by recreational and commercial fishermen off the southeastern United States (Piedra 1969, Johnson 1983, Manooch and Drennon 1987). Throughout their geographical range, adult yellowtail snapper are commonly found near shore reefs, associated with hard or live bottom and also near the edge of shoals and banks, wrecks and artificial reefs. In the southern Gulf of Mexico, due to a strong fisheries impact on the red grouper (*Epinephelus morio*) and red snapper (*Lutjanus campechanus*), other species of snappers including yellowtail snapper *Ocyurus chrysurus*, with similar qualities compared to the red snapper *L. campechanus*, are now more frequently targeted by commercial fishermen, causing recent increments in catch volume (DOF 2004).

Thus, in Yucatan, yellowtail snapper landings increased two fold between 1994 (881 tonnes) and 2004 (1,898 tonnes) (Salas et al. 2006). In 2003 and 2004, this snapper fishery was ranked third and fourth in the national State percentage catches respectively (Salas et al. 2006).

Also, in 1994 and 1997, this fishery represented an economic value of US$ 1,630,000 and recently, in 2004 it generated revenues of US$ 2,600,000. The unit price in 1997 reached a maximum value of 1.93 US$/kg, and 57% of production was exported to the United States (Castro-Suaste et al. 2000, Salas et al. 2006).

Most importantly, in this State, fishermen have open access to this fishery resource, which, according to Castro-Suaste et al. (2000) may constitute for a fishery in expansion, a risk of overexploitation on a short to long-term basis, where a decrease in social economic income is also associated.

For the Gulf of Mexico and in particular for the Campeche Bank, basic available information on the

reproductive biology for yellowtail snapper is lacking and the state of their stocks is unknown.

As a result of an increase in commercial interest towards this specie in Yucatan and the need to establish a management plan for the fisheries industry of the State, this study intends to generate information on the aspects of reproduction for yellowtail snapper from Campeche Bank. Therefore, the objectives of this research were to:

    i)   Analyze size-frequency distribution and calculate sex ratio;

    ii)   Define spawning season; and

    iii) Estimate size at first maturity.

MATERIAL AND METHODS

Yellowtail snapper samples were obtained from catches done by small-craft fleet (fishery dependent) on the Campeche Bank, from three major snapper landing ports located along the north coast of the Yucatan Peninsula: Rio Lagartos, Dzilam de Bravo and Celestun respectively (Figure. 1). Samples were obtained monthly in adjacent water areas of each port, during an annual reproductive cycle between February 2008 and January 2009. According to fishermen experience on the major abundance of yellowtail snapper in each area, organisms were caught from various fishing sites and recorded with a Global Positioning System (GPS). Specimens were captured between 2.5 and 25 m in depth, using conventional hook and line fishing gear, by day (0800 - 0400 hours). The total length (TL in cm), fork length (FL), standard length (SL) Total (ungutted) weight (TW in g) and gutted weight (GW, g) gonad weight (gW, g) and liver weight (LW, g) for each fish was recorded. Additionally, a sample was taken from the central mid-section of the left gonad (approximately. 1cm^3) of each collected fish and was fixed, and conserved in Bouin's solution (Gabe 1968) for further use in histological observations.

In the laboratory classical histological techniques were applied, which consisted of the dehydration of gonads in several grades of ethanol, treated with UltraClear and embedded in paraffin at 58° C. Sections of 6 µm were done using a semi-automatic microtome. Finally, Gabe and Martoja's triple stain was applied before mounting these in a synthetic resin (Gabe 1968).

Microscopic observations of gonads confirmed the sex and sexual condition of individuals captured. The male: female ratio (M:F), was calculated considering both juvenile and adult yellowtail snappers. All male and female gonads were analyzed and classified according to reproductive phases, taking into consideration the evolutionary microscopic scale of stages in oogenesis (Table 1) proposed by Wallace and Selman (1981) and Brown-Peterson et. al. (1988), whilst for spermatogenesis according to Moe (1969). The reproductive phases for males and females were established in relation to the universal terminology proposed by Brown-Peterson et. al. (2007) as seen in Table 2: immature, developing, spawning capable, actively spawning, regressing and regenerating. According to Grier and Taylor (1998), Taylor et al. (1998) and Grier (2002), changes that occurred in the testicular epithelium during an annual reproductive cycle were used to distinguish five reproductive phases in males. Females and males classified in developing; spawning capable; actively spawning; and regressing phases were treated as sexually active individuals.

The Kruskall-Wallis and F-test was applied to compare median and mean FL between males and females, respectively. Size frequency distribution of males and females were compared by use of the Kolmogorov-Smirnov nonparametric test. The male:female ratio (M:F), was calculated considering both juvenile and adult yellowtail snappers using Pearson's x^2 to see if the ratio was different
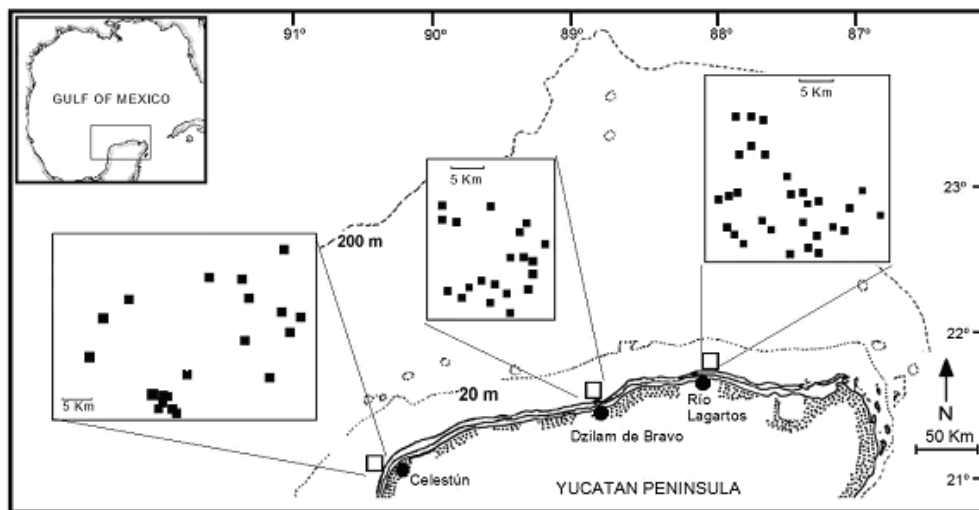

Figure. 1. Geographic distribution of sampling sites (■) for yellowtail snapper captured on the Campeche Bank, Mexico, between February 2008 and January 2009.

Table 1. Characteristic stages of oogenesis in teleost fish (Wallace and Selman, 1981; Brown-Peterson et al. 1988).

Class		Histological characteristics
Oocyte; primary growth	1 (CO)	Stage: nucleolar chromatin. Oocyte with scant cytoplasm, nucleus with a large central nucleolus; thin follicular membrane.
	2 (PO)	Stage: Perinuclear. Oocyte nucleus with various nucleolus some larger than others, present at periphery of nucleus.
Oocyte; initial vitellogenesis	3 (YVO)	Oocyte with yolked vesicles distributed at periphery of cytoplasm. Thin zona radiata appears.
	4 (YGO)	Oocyte with yolked granules of various sizes surrounds vesicles. Cytoplasm presents two concentric zones divided by a ring of yolked granules filling < 50% of cellular volume. Granulosa and theca are formed.
Oocyte; end of vitellogeneis		Oocyte with yolked granules filling > 50% of cellular volume. Vacoules usually surround nucleus. Zona radiata remains as a broad striated band. Final oocyte maturation (FOM) present
	5 (FOM)	
Oocyte; at maturation	6 (HO)	Hydrated oocyte. Migration of nucleus to animal pole of cell. Rupture of nuclear membrane (nucleus no longer visible). Increase in size of oocyte. Fusion of vesicles and granules. Yolk as a homogeneous and translucent mass (hydration).

Table 2. Histological criteria used to determine reproductive phases in yellowtail snapper from the Campeche Bank, Mexico (from Brown-Peterson et al. 2007)

Reproductive phase	Histological features	
	Female	Male
I- Immature	Presence of nucleolar chromatin oocytes (CO) and perinucleolar oocytes (PO)	Inactive spermatogenesis. Spermatogonia present
II- Regenerating	(CO) + (PO) with muscle bundles, connective tissue and blood vessels present at center of ovarian lamellae	Inactive Spermatogenesis. Interior lobule totally covered by a continuous germinal epithelium. Spermatogonia present; few residual spermatozoa sometimes present in lumen lobules or ducts
III- Developing	(CO) + (PO) and yolk vesicle oocytes (YVO)	Initial spermatogenesis. Interior lobule totally covered by a continuous germinal epithelium. Spermatogonia and spermatocytes present
IV- Spawning capable	(CO) + (PO) + (YVO) and yolk globule oocytes (YGO)	Active spermatogenesis. Discontinuous germinal epithelium occurs at the proximal part of lobule and continuous germinal epithelium occurs at the distal part of lobule. Spermatocytes, spermatids and spermatozoa present
V- Actively spawning	(CO) + (PO) + (YVO) + (YGO) and final oocyte maturation (FOM) and/or hydrated oocytes (HO) and/or postovulatory follicles (POFs)	Active spermatogenesis. Discontinuous germinal epithelium occurs even in distal parts of lobule. Spermatozoa present in lobule lumen and/or sperm ducts. Few scattered spermatogonia present
VI- Regressing	(CO)+(PO) and residuals (YVO) and (YGO) and/or atretic oocytes (vitellogenic oocytes undergoing alpha-or beta-stage atresia)	Inactive spermatogenesis. Spermatogonia scattered along basement membrane and at the distal termini of the lobules.

compared to a ratio in equilibrium (1:1) (Sherrer 1984). Significant level $\alpha = 0.05$ was used at all times.

Reproductive periodicity for both sexes was characterized through results obtained from seasonal variations in the gonadosomatic index (GSI = gW*100/GW) and hepatosomatic index (HSI = LW*100/GW), and in the relative proportion of individuals in each reproductive phase. Current spawning was indicated when ovaries and testes were recorded as actively spawning. Immature individuals were eliminated from the analysis.

First sexual maturity was calculated using a binary logistic regression, to determine the size at which 50% (L_{50}) of individuals were sexually mature for both sexes. For this analysis, developing, spawning capable, actively spawning, regressing and regenerating individuals were considered as sexually mature. Furthermore, the minimum size at which male and female become sexually mature for

the first time (FL min) was recorded, as was the percentage of maximum length at first maturity (FL min/FL max) for both sexes (where: FL max = maximum length of male and female recorded in samples), was determined (Grimes 1987).

RESULTS

Size Frequency Distribution and Sex Ratio

A total of 1,657 yellowtail snappers ranging from 11.9 to 45.5 cm (FL) were examined during this study. Histological examinations determined 50% females (n = 832), and 49.8% males (n = 825). Females captured, range from 13.4 to 45.5 cm (FL) and males from 11.9 to 41.8 cm (FL). Male FL (median = 25.4 cm; mean ± S.D. = 25.6 ± 4.5 cm) did not differ significantly from that of females (median = 25.6 cm; mean ± S.D. = 25.9 ± 4.7 cm) (Kruskal -Wallis; $p = 0.14$ and F-test; $p = 0.15$; n = 1,657, respectively), whilst male size range differed significantly from that of females (Kolmogorov-Smirnov; n = 1,657; $p = 0.01$).

The overall yellowtail sex ratio 1:1.01 (Pearson's $\chi^2 = 0.03$, d.f. = 1, $p = 0.86$) and sex ratios by size-class (range 1:1 to 1:1.5; Pearson's $\chi^2 = 0.00 - 1.61$; d.f. = 1; $p = 1.00 - 0.65$) did not differ significantly from 1:1.

Spawning Season

The mean GSI for female began to increase in January (1.7%), reach maximum values in March (2.1%), April (2%) and May (2.3%), and declined from June (1.8%) to August (1.0%), but with a slightly notable peak appearing in September (1.5%) (Figure. 2). Lowest mean GSI for female were observed between October (0.5%) and December (0.7%). The mean GSI for male followed a similar evolution: an increase since January with a peak value occurring in April (3.3%) and a decrease between May (2.4%) and August (1.2%), followed by another notable peak appearing in September (2.1%) (Figure 2). Lowest mean GSI for male were also observed between October (0.5%) and December (0.8%). The highest individual GSI values (Figure 3) during the annual cycle occurred in January (9.5%), May (5.8%) and September (6.1%) for females and in March (9.8%), July (8.7%) and September (10.0%) for males.

The mean HSI for female and male followed a similar evolution during the annual sexual cycle (Figure. 2). For both sexes, mean values were lower between January (0.7 - 0.8%) and April (0.6 - 0.8%) and began to increase (1.0%) in May for females and in June for the males. The mean HSI reached maximum values in October for females (1.5%) and males (1.6%), and declined from November to December (1.1 - 0.9%) for both sexes. The highest individual HSI values (Figure 3) during the annual cycle occurred in January (9.5%), May (5.8%) and September (6.1%) for females and in March (9.8%), July (8.7%) and September (10%) for males.

Sexually active females in developing or spawning capable phases were found year-round (Figure. 4). Actively spawning females were observed between January and September, but were most abundant in April (44%) and May (50%). Females in regressing phase were present in January, between May and August and in November, with highest percentage occurring in June and July (16%). Regenerating females were observed year-
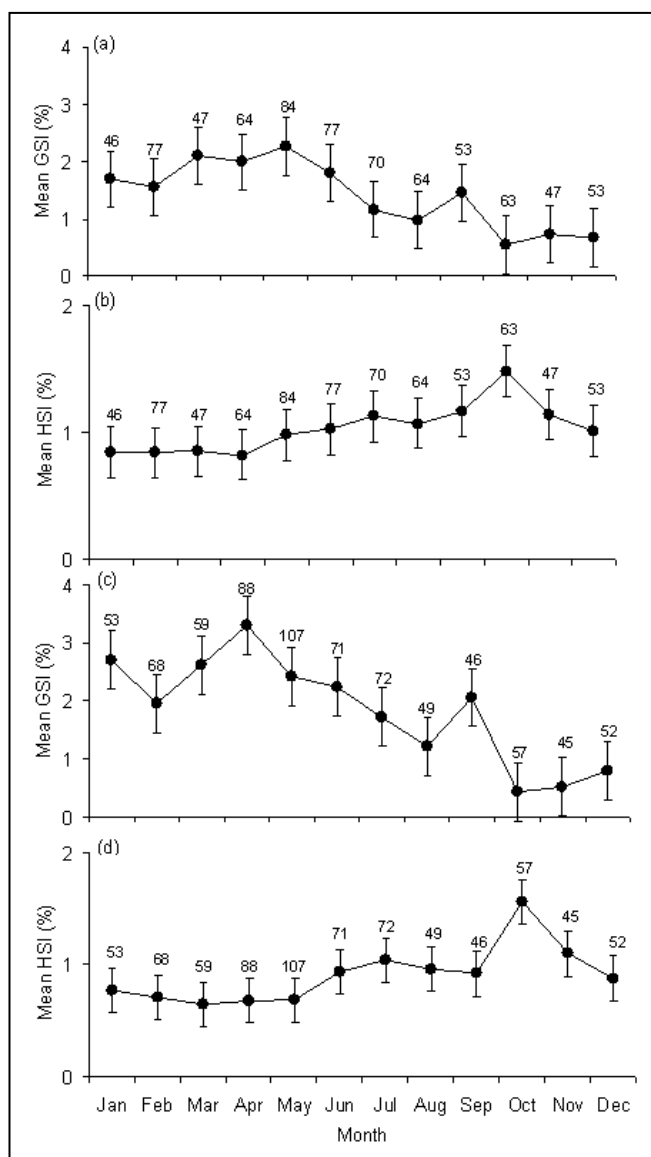

Figure 2. Mean ± S.D. gonadosomatic and hepatosomatic index values for (a), (b), female and (c), (d) male yellowtail snapper collected on the Campeche Bank, Mexico between February 2008 and January 2009. Number above each GSI and HSI value represents the number of individuals examined.
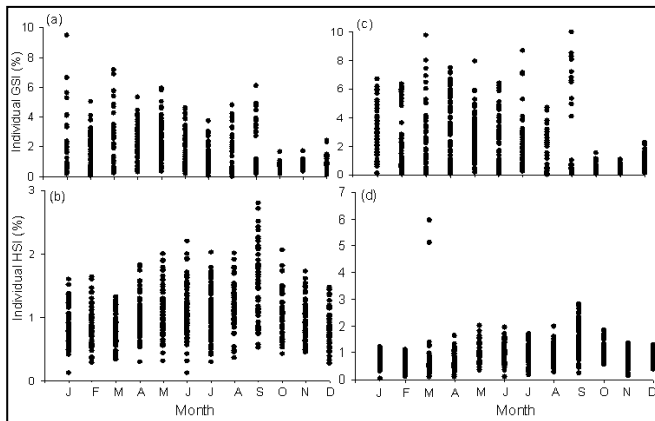
Figure 3. Individual gonadosomatic and hepatosomatic index values for (a), (b), female and (c), (d) male yellowtail snapper collected on the Campeche Bank, Mexico, between February 2008 and January 2009.

Figure 4. Monthly percent frequencies in (a) female and (b) male yellowtail snapper collected on the Campeche Bank, Mexico, between February 2008 and January 2009, categorized according to reproductive phases (**R**- regenerating, **D**- developing, **SC**- spawning capable, **AS**- actively spawning, **RG**- regressing). Number above each bar represents the number of fish sampled per month.

round with highest percentages occurring in October (95%) and lowest between March and May (17 - 2.4%). Sexually active males in developing or spawning capable phases were found year-round, except in August and October (Figure 4). Actively spawning males were observed between December and August, but were most abundant in April (50%) and May (51%). Regressing males were present all year-round, with highest percentage occurring in June (45%) and July (50%). Males in regenerating phase were observed year-round, except in April, with highest percentages occurring in October (65%) and lowest between January and June (6 - 1%).

Size at First Maturity

The length at first sexual maturity (L_{50}) for females was obtained at 21.3 cm and females >26.6 cm FL were all mature. (Figure. 5). The smallest mature female was 14.1 cm (FL min) and the largest mature female was 45.5 cm (FL max). Percentage of maximum length at first maturity for females was FL min/FL max = 31%. For males length at first sexual maturity (L_{50}) was obtained at 19.4 cm and males > 29.9 cm FL were all mature (Figure 5). The smallest mature male was 14.2 cm (FL min) and the largest mature male was 41.8 cm (FL max). Percentage of maximum length at first maturity for males was FL min/FL max = 34.

DISCUSSION

Yellowtail snapper overall sex ratio values reported in the available literature ranged from 1:0.8 to 1:1.6 and presented fluctuations between and within regions or habitats (Table 3). For example, the male to female ratios fluctuated from 1:1 to 1:1.6 for island populations from Cuba (Piedra 1969, Claro 1983, Carrillo de Albornoz and
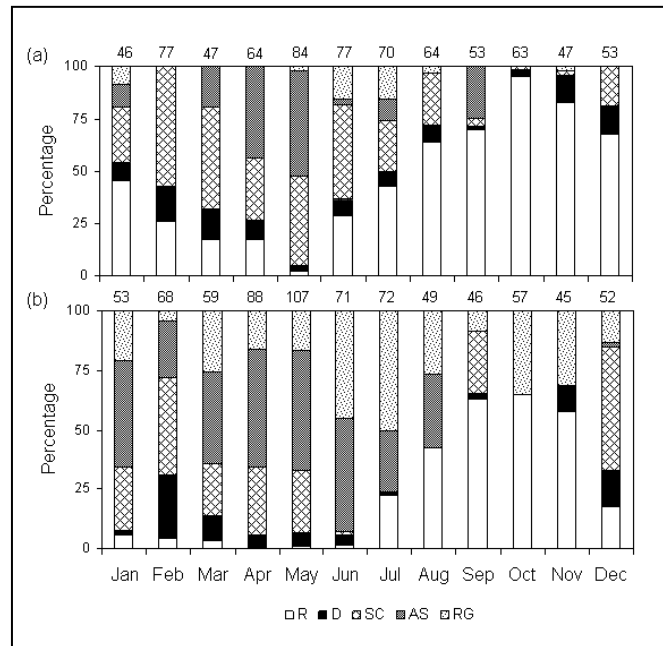
Ramiro, 1988) and from 1:1 to 1:1.2 for continental population from the Campeche Bank (López-Cuevas 1985). These deviations in snapper sex ratios are frequent and may be caused by a greater proportion of females among larger fish or by a variation in the numbers of males and females throughout time, particularly during the course of the spawning season (Sadovy 1996). Actually, according to Grimes (1987) various snapper studies suggested a tendency for females to be preponderant at a larger size. Piedra (1969) and Figuerola et al. (1998) noted that females were larger than males for yellowtail snapper from Cuba and Puerto Rico, respectively. In the present study, though median and mean sizes of males and females were identical, a slight tendency of females being more abundant in larger size-classes was observed.

A protracted spawning season with peak of spawning activity in spring was observed in yellowtail snapper from the Campeche Bank. Based on ovaries analyses which best reflect the duration of spawning activity (Sadovy 1996), spawning extended from January to September (9 months) with peaks occurring during April and May. According to Grimes (1987) two patterns of reproductive seasonality occurs in lutjanids: continental populations and species exhibit a restricted spawning period around summer, and insular populations and species reproduce year round with pulses of activity in spring and fall. This
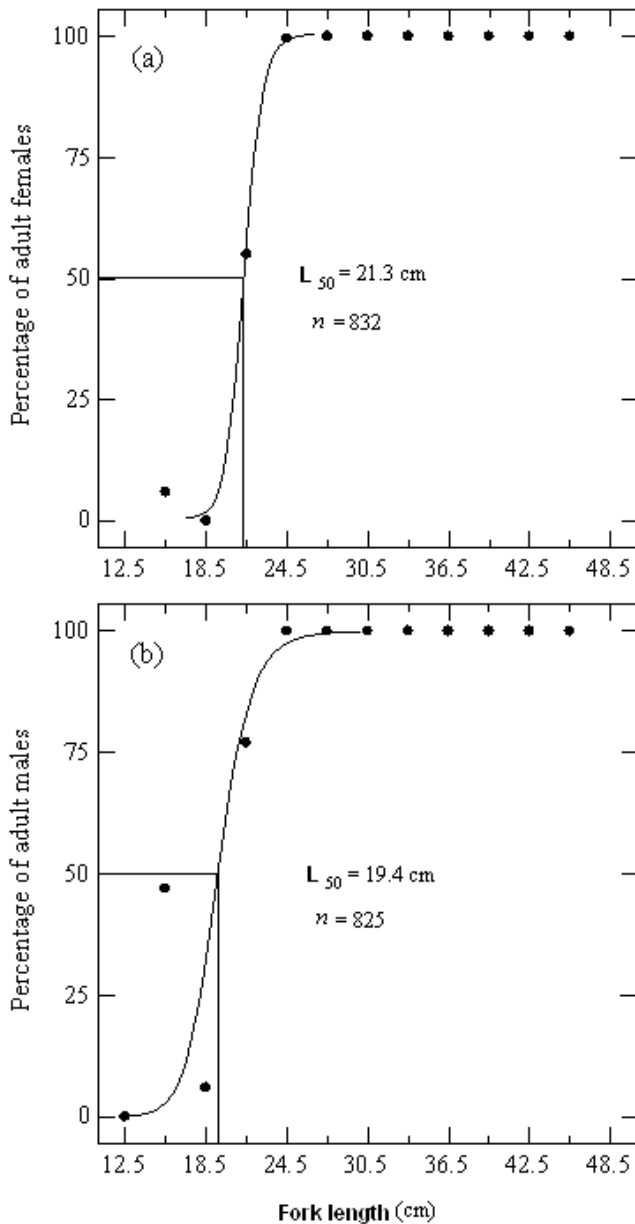
Figure 5. Percent of mature (a) female and (b) male in relation to fork length (FL) for yellowtail snapper from the Campeche Bank, Mexico (February 2008 - January 2009). Proportion of sexually mature females and males within each size class was plotted using a binary logistic regression. Line indicates length at 50% (L_{50}).

author stated that yellowtail snapper populations generally conformed to these patterns with the exception of populations from Cuba which exhibited the continental pattern of restricted spawning. Notwithstanding, the present results, together with reports from Southeast Florida and the Caribbean, showed that the spawning period and duration of spawning peaks for yellowtail snapper fluctuated between 4 to 12 months and between 1 to 5 months,

respectively (Table 3). Furthermore, most of the studies reported spawning activity occurring between March and September (Piedra 1969, Erdman 1976, Claro 1983, Thompson and Munro 1983, López-Cuevas 1985, Figuerola et al. 1998, Muller et al. 2003), and peaks of spawning activity occurring between April and June (Piedra 1969, Claro 1983, Thompson and Munro 1983, López-Cuevas 1985, Carrillo de Albornoz and Ramiro 1988, Figuerola et al. 1998, Muller et al. 2003) and eventually in September and October (Munro et al. 1973, Thompson and Munro 1983, López-Cuevas 1985). Therefore, contrary to Grimes' statement (1987), insular and continental yellowtail snapper populations analyzed to date, presented a similar pattern of reproduction character-ized by an extended spawning period (from late-winter to early-autumn), with pulses of spawning activity centered mainly during spring. A protracted spawning season from March to October, with peaks of spawning activity in March and July, was also observed for yellowtail snapper specimens held in captivity (Soletchnik et al. 1989). In the same way, the red snapper population from the Campeche Bank did not exhibit the continental pattern of restricted spawning but reproduced from February to November with a spawning peak occurring in early fall (Brulé et al. 2010). In tropical regions where conditions are less seasonal and temperature does not limit fish spawning, seasonality is imposed mainly by environmental factors that lead to the injection of nutrients and biotic pressures, such as competition for spawning grounds or living space (Lowe-McConnell 1987). On the Campeche Bank, spawning seasonality of yellowtail snapper population coincides with maximum activity of seasonal upwelling event (spring and summer) and high rainfall period (May to October) (Espejel 1987, Piñeiro et al. 2001). From April to October, denser water inflow from the northern edge Yucatan shelf and subterranean freshwater effluents reaching the coastal zone bring nutrients to the euphotic zone which stimulates rates of primary production in this region (Wiseman and Sturges 1999, Monreal-Gómez et al. 2004).

Bustamante et al. (1991) reported that adult yellowtail snapper from Cuba showed marked seasonal changes in HSI values and liver composition. These authors observed an increase in liver weight during vitellogenesis and a decrease during spawning days or immediately thereafter. Contrarily, seasonal changes in HSI values of yellowtail snapper from the Campeche Bank suggested a progressive accumulation of fat reserves in the liver after peak spawning occurred (June - September), which should be used during the gonad maturation process, prior to the beginning of the next spawning season (November - December). Therefore, both for female and male, mean HSI peak values were observed in October when lowest mean GSI values and highest percentages of regenerating individuals were noted.

In this study, lengths of smaller mature female and male

were similar, but were smaller than those determined previously by López-Cuevas (1985) for the same continental population between 25.3 cm FL min for female and 23.7 cm FLmin for male. For island yellowtail snapper populations, minimum sizes at which female and male become sexually mature were generally higher than those observed for the Campeche Bank population (Table 4.). Nonetheless, in Puerto Rico Figuerola et al. (1998) found males maturing as small as 11.1 cm FL min and in Cuba Piedra (1969) reported mature unsexed individuals as small as 13 and 14 cm FL min. The size at which 50% of yellowtail snapper from the Campeche Bank were sexually mature was higher in female than in male. These sizes were higher than that observed for Southeast Florida yellowtail snapper (17.3 cm L_{50} for unsexed fish; Muller et al. 2003) and smaller than those obtained for Puerto Rico population (24.8 cm L_{50} for female and 22.4 cm L_{50} for male; Figuerola et al. 1998). Data available on percentage

of maximum length at which maturity is attained (FLmin/ FLmax) indicated that Campeche Bank yellowtail snapper population matured at a slightly higher size than those from the Cuban population and at a smaller size than that of the Jamaica population (Table 3). The lengths at maturity observed for Campeche Bank (FL min/FL max = 31% for female and 34% for male) and Jamaica (FL min/ FL max = 52% for female and 46% for male) populations agreed with those reported by Grimes (1987) for other continental (41% on average) and island (51% on average) lutjanids, respectively. But length at maturity available for Cuban yellowtail population (FL min/FL max; range between 26% and 28% for unsexed fish) did not conform to Grimes' statement. However, due to a lack of comparative studies on yellowtail snapper reproduction across island and continental habitats throughout its geographic range of distribution, and methods of varying accuracy employed between available yellowtail snapper studies (Table 3), a more in-depth interpretation of the results was

Table 3. Sex ratio, size at maturity, and spawning period reported for continental and insular yellowtail snapper populations from Southeast Florida, Gulf of Mexico and Caribbean Sea

Area	Sex ratio (M:F)	Sex	FL_{min} (cm)	L_{50} (cm)	FL_{max} (cm)	FL_{min}/FL_{max} (%)	Spawning period[b]	Analysis[c]	Reference
Southeast Florida	-	M, F	-	17.3[a]	-	-	Spring/Summer	HS	Muller et al. (2003)
Campeche Bank	1:1.2	F	25.3[a]	-	-	-	[May-Jul] Year round	VS; I_G; K	López-Cuevas (1985)
		M	23.7[a]	-	-	-	[Apr; Jun; Oct]		
	1:1.0	F	14.1	21.3	45.5	31	Jan-Sep	HS; I_G; I_H	This study
		M	14.2	19.4	41.8	34	[Apr-May]		
Cuba	1:1.1	M, F	13-14	-	51	26-28	Mar-Sep	VS	Piedra (1969)
	1:1.6	M, F	17-19	-	-	-	[Apr-Jun] Mar-Nov	VS; I_G	Claro (1983)
	1.1.2 1:1.0	F	20-21	-	-	-	[Apr-Jun] Apr-Jun	VS; K	Carrillo de Abornoz &
		M	19-20	-	-	-	[Apr]		Ramiro (1988)
	-	-	-	-	-	-	-	-	Carrillo de Albornoz et al. (1989)
Puerto Rico	-	-	-	-	-	-	Apr-Jun; Sep	VS	Erdman (1976)
	1:1.4	F	19.2	24.8	-	-	Feb-Oct	HS	Figuerola et al. (1998)
		M	11.1	22.4			[Apr-Jul]		
Jamaica	1:0.8	F	29	-	56	52	Year round	VS	Munro et al. (1973) and
		M	25	-	55	46	[Feb-Apr; Sep-Oct]		Thompson and Munro (1983)

M, male; F, female; FL fork length; Lmin , minimum size at first sexual maturity; L50, size at which 50% of individuals were mature; FLmax, maximum size reported; FLmin/FLmax, percent of maximum size at first maturity.
[a] total length (TL, mm) data converted to FL (mm) using the formula: FL = 7.56 + 0.79 TL (Garcia et al., 2003), and then converted to FL (cm).
[b] Peak spawning months are given in brackets.
[c] HS, histological sections; GSI, gonadosomatic index; HSI, hepatosomatic index; K, condition factor; VS, visual maturity staging.

difficult.

Yellowtail snapper populations analyzed to date did not show a pattern of geographical or habitat variation (insular or continental) in sex ratio, sexual maturation or size at maturity. These results agree with Robertson's observations (1991) who noted that consistent patterns of geographic variation in spawning cycles of yellowtail snapper, and other lutjanid species, were lacking throughout the tropical Western Atlantic. Domeier et al. (1996) suggested that spawning pattern in snappers was not habitat dependent and concluded that two spawning strategies seem evident among Western Atlantic lutjanids: 1- schooling species that have protracted spawning seasons and do not migrate or aggregate for the purpose of spawning and 2- solitary species that migrate and aggregate for the purpose of spawning over a very short time period. These authors considered yellowtail snapper to be a strategy 1 spawner. Nonetheless, considering that yellowtail snapper has an effective schooling behavior and a protracted spawning season, and also forms spawning aggregations (Heyman and Kjerfve 2008), then they do not fit well into either of the spawning strategies defined by Domeier et al. (1996). According to Ralston (1987) snappers have relatively limited productive capacity and are vulnerable to overfishing. Notwithstanding, Muller et al. (2003) stated that the life history characteristics of yellowtail snapper supports a species that is moderately to highly resilient to fishing. Particularly, these authors considered that the persistence of the yellowtail snapper fishery in the Southeast United States stock was partly due to the early maturation at a small size and the larger minimum size implemented (30.5 cm TL; 24.9 cm LF). The present study's updated scientific information on the basic biology of yellowtail snapper and data obtained on the reproductive biology of the Campeche Bank population will provide insights to future sustainable management of this resource in the southeast Gulf of Mexico.

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