

Southern Gulf of Mexico

JORGE TREJO MARTÍNEZ, THIERRY BRULÉ,
and TERESA COLÁS-MARRUFO

*Centro de Investigación y de Estudios Avanzados del IPN Unidad Mérida
Antigua Carretera a Progreso Km. 6
A.P. 73 “Cordemex”, C.P. 97310
Mérida, Yucatán, México*

ABSTRACT

The gag grouper, *Mycteroperca microlepis*, is the third most commercialized serranid species in the southern Gulf of Mexico. However, production volumes and the current fishery status of the Campeche Bank's stock are uncertain. This study focuses on the fecundity of the specie, a novel contribution towards understanding its reproductive biology and also providing valuable information on the stock for the southern Gulf of Mexico. Females from the 212 analyzed ranged from 45 cm to 111 cm furcal length (FL). Gonads were fixed in Bouin's liquid for histological examination and Gilson's liquid for the measurement and quantification of oocytes. Gag is a multiple spawner with an indeterminate fecundity: no hiatus was observed between previtellogenic (20 – 119 μm) and vitellogenic oocytes (75.3 μm – 1015.5 μm) during its maturation and spawning periods. The oocyte size-frequency method determined stage V oocytes (211.7 – 509.3 μm) as the most advanced batch of oocytes. The minimum diameter limit established for stage V oocytes was recorded at 290 μm . Absolute batch fecundity estimates were based on females ranging from 72 to 105 cm FL sampled during April 1996 through August 1999. The maximum absolute batch fecundity estimate obtained was 4,270,250 ova for a female of 97 cm FL, with a minimum of 170,610 ova for a female of 72 cm. The average absolute batch fecundity was 1,649,675 \pm 1,145,305 SD oocytes per female, a high variability which has also been observed for other grouper species, for example the red grouper, *Epinephelus morio*. The best predictor of absolute batch fecundity for *M. microlepis* from the Campeche Bank was gonad weight.

KEY WORDS: Fecundity, grouper, spawning, *Mycteroperca microlepis*

Fecundidad en la Cuna Aguajá *Mycteroperca microlepis*, (Serranidae, Epinephelinae), del Banco de Campeche, sur del Golfo de México

El mero cuna aguajá, *Mycteroperca microlepis*, es la tercera especie de serránido de importancia comercial en el sur del Golfo de México. Sin

embargo, los volúmenes de su producción y el estado actual del stock del Banco de Campeche son inciertos. Este estudio estuvo enfocado en la estimación de la fecundidad de la especie, a efectos de conocer su biología reproductiva y proveer información sobre el stock del sur del Golfo de México. La longitud furcal (LF) de las hembras varió de 45 cm a 111cm para los 212 organismos analizadas. La cuna aguají, presenta desoves múltiples con una fecundidad indeterminada: durante los periodos de maduración y desove, no se observó ningún hiato entre los ovocitos previtelogénicos (20 – 119 μm) y los vitelogénicos (75.3 – 1015.5 μm). Los ovocitos del estadio V (211.7 – 509.3 μm) constituyeron el lote más avanzado. El límite del diámetro mínimo estimado para los ovocitos del estadio V fue 290 μm . La estimación de la fecundidad absoluta estuvo basada en hembras cuyas tallas fluctuaron entre 72 y los 105 cm LF, colectadas durante el período de abril de 1996 a agosto de 1999. La estimación de la fecundidad absoluta máxima por lote fue de 4,270,250 ovocitos para una hembra de 97 cm de LF con un mínimo de 170,160 ovocitos para una hembra de 72 cm de LF. La fecundidad absoluta promedio por lote estimada fue de $1,649,675 \pm 1,145,305$ SD ovocitos por hembra, presentando una alta variabilidad similar a la de otras especies de meros como por ejemplo el mero rojo, *Epinephelus morio*. El peso de la gónada fue considerado el mejor predictor de la fecundidad absoluta por lote para *M. microlepis* del Banco de Campeche.

PALABRAS CLAVES: Fecundidad, mero, desove, *Mycteroperca microlepis*

INTRODUCTION

The Yucatan Peninsula is a region characterized by its wide continental shelf, of which 50,000 square miles correspond to the Campeche Bank (Chávez 1994). This platform is also the most heavily fished grouper area, exploited both by inshore and offshore, commercial Mexican and Cuban fleets (Solís-Ramírez 1970, Arreguín-Sánchez et al. 1997). Yucatan's grouper landings comprised 91.5% of the entire national fishing grouper production in Mexico in 1995. The following year in this State 9,691 tons of groupers were landed, which comprised 90.5% of the total Mexican production of groupers (SEMARNAP 1997). From 1999 to 2000 grouper landings fluctuated between 10,125 tons and 11,045 (SAGARPA 2001). However, current grouper landings for the Yucatan State decreased to 8,182 tons in 2001 and 9,100 tons for 2002, indicating a decrease in production in recent years (SAGARPA 2002). Based on studies by Colás-Marrufo et al. (1998) and Tuz-Sulub (1999), 17 different species of groupers were identified for the Campeche Bank. Of these, the most important are the red grouper (*Epinephelus morio*), the black grouper (*Mycteroperca bonaci*) and the gag grouper (*Mycteroperca microlepis*). However, the reproductive biology of reef fishery species has received remarkably little attention compared with other aspects of their natural history (Sadovy 1996).

Information on diverse aspects of the reproductive biology of a species is necessary in fishery regulations; for instance, in determining the minimum size of capture, seasons and/or zones for closed and open season (Tresierra and Culquichicon 1995). Fecundity relates to the number of eggs produced by a female and can be defined in many ways (Bagenal 1978, Kartas and Quignard 1984). Fecundity is a critical component of reproductive output and is included in stock assessments. It is evaluated in a number of ways but most commonly as total (standing stock of yolked oocytes), batch (number of hydrated oocytes released per spawning), and relative fecundities (fecundity divided by female weight) (Hunter et al. 1992, in Sadovy 1996). Fecundity influences population abundance, if the species abundance maintains itself more or less similar in time, it is expected to observe a similar proportion of the species from generation to generation (Tresierra and Culquichicon 1993).

Mycteroperca microlepis can be found in estuaries or seagrass beds for juveniles and in rocky bottoms for adults (Smith 1971, Vergara-Rodríguez 1976, Smith 1976, Bullock and Smith 1991, Heemstra and Randall 1993). Although studies have examined some aspects of gag reproduction, few have addressed fecundity. Currently for the Campeche Bank no analysis of fecundity has been done for *M. microlepis*. Therefore, due to this lack of information, the objective of the present study is to provide original data on the reproductive aspect for one of the most exploited groupers in Mexican waters for the Gulf of Mexico.

MATERIAL AND METHODS

Gag groupers collected for the present study were obtained from commercial catches carried out by fishing vessels from the port of Progreso, Yucatan. These catches were obtained monthly between April 1996 and August 1999, in 36 fishing sites located particularly in the eastern part of the Campeche Bank (Figure 1). Specimens were captured at depths of 30 to 120 m using long-line fishing gear. For each individual captured the following morphometric data were registered: furcal length (FL, in cm), taken from the extreme inferior mandible up to the middle posterior part of the caudal fin; total (ungutted) weight (TW, in g) and gutted (fish without digestive tract and gonads) weight (GW, in g).

Immediately following capture, gonads were extracted from all organisms and a sample was taken from the middle section of each one (approximately 1 cm³). These samples were fixed and conserved in Bouin's solution (Gabe 1968) and were thus used for histological observations. In the laboratory, weight of the gonads (gW) selected aboard vessels and conserved on ice, were recorded, including also, a fixed known sample weight (kW) between 20 and 30 g for each one placed in Gilson's liquid. These gonads were subsequently used in the counting of vitellogenic oocytes.

After fixing the gonads in Bouin, Gabe's (1968) classical histological technique was applied, which consists of the dehydration of the samples in 90% and 100% alcohol and embedding in paraffin at 58^oC. Sections of 6 micrometers (µm) in thickness were done using a semi-automatic microtome, finally, Gabe and Martoja's triple stain was applied before mounting these in a

synthetic resin (60% Xylol) (Gabe, 1968).

Microscopic observations of the gonads collected confirmed the sex and sexual maturity class of the individuals captured. All female gonads were analyzed and classified according to sexual maturity categories, taking into consideration the evolutionary microscopic scale of stages in oogenesis proposed by Brulé et al. (1999; 2003) (Table 1). For this study, sexual classes defined by Brulé et al. (1999; 2003) were modified according to the criteria given in Table 2; females at resting, initial maturation, advanced maturation, spawning and postspawning.

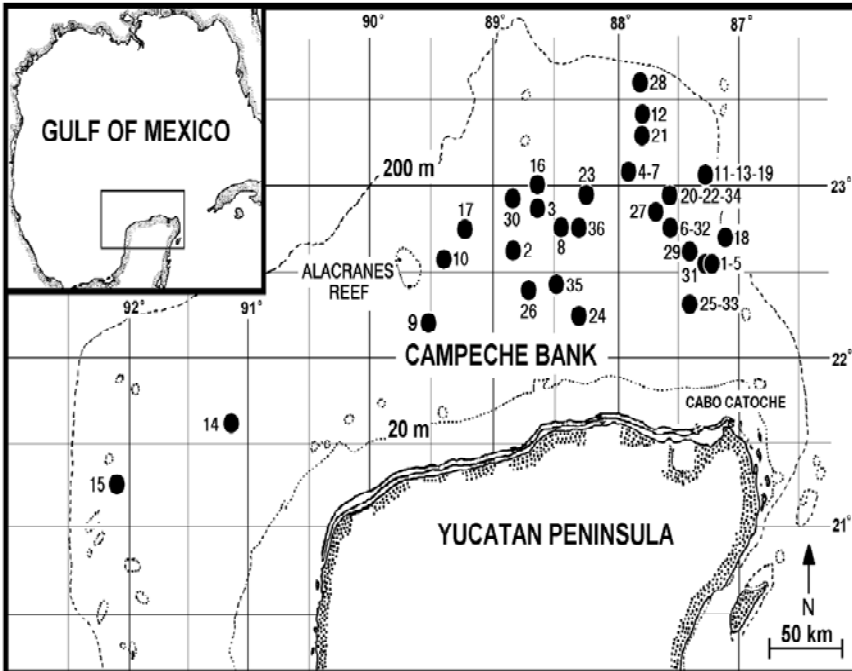


Figure 1. Geographic location of the Campeche Bank, in the Gulf of Mexico. Black round circles represent sampling sites for *M. microlepis*.

Relative frequencies for each stage of oogenesis present in the ovaries were determined using a methodology proposed by N'Da and Déniel (1993), so as to verify the fecundity pattern of the specie. This method requires, firstly, randomly counting and classifying 200 selected oocytes from histological sections pertaining to each female; done according to the oocyte microscopic scale of development (Table 1). Secondly, observations were made on a monthly basis for a year, following the relative percentages of each stage in oogenesis observed in the gonads.

Table 1. Microscopic characteristic stages in oogenesis for gag ovaries from the Campeche Bank (Brulé et al. 1999, 2003).

Stages in oogenesis	Microscopic characteristics
I. Primary oocyte	Nucleus with large central nucleus; nucleolus moves to the periphery of the nucleus during this stage
II. Immature oocyte	Nucleus with several nucleoli, one larger than the other, present around the nuclear periphery
III. Oocyte in primary vitellogenesis	Scattered vacuoles in cytoplasm around the nuclear margin and near the cellular periphery; thin zona radiata present
IV. Oocyte in early secondary vitellogenesis	Yolk droplets appear around vacuoles; cytoplasm divided in two concentric zones by a ring of yolk droplets filling <50% of the cellular volume; follicular layer well formed (granulosa, theca)
V. Oocyte in late secondary vitellogenesis	Yolk as numerous globules filling >50% of the cellular volume; vacuoles usually surround the nucleus and coalesce; migration of the nucleus to the animal pole in late stage; zona radiata remains as a broad striated band
VI. Hyaline oocyte	Oocyte hydrated; yolk as an homogeneous mass, lightly stained; thin and no striated zona radiata; nucleus not visible

Table 2. Characteristic histological patterns for sexual maturity classes as defined for gag females from the Campeche Bank (modified from Brulé et al. 1999).

Sexual maturity classes	Histological characteristics
1. Resting	Previtellogenic oocytes (stages I & II)
2. Initial maturation	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Atretic oocytes scarce
3. Advance maturation	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Oocytes in early and late secondary vitellogenesis (stages IV & V) Atretic oocytes present (At)
4. Spawning (partial)	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) Oocytes in early and late secondary vitellogenesis (stages IV & V) Hyaline oocytes (VI) and/or presence of postovulatory follicles (Pofs) Atretic oocytes present (At)
5. Postspawning (end of spawning)	Previtellogenic oocytes (stages I & II) Oocytes in primary vitellogenesis (stage III) and/or early and late secondary vitellogenesis (stages IV & V) residuals Numerous atretic oocytes present (At)

Due to an insufficient number of females with hyaline oocytes (stage VI), absolute batch fecundity was estimated using the egg-size frequency method of Hunter, et al. (1985) and Hunter and Macewicz (1985), respectively. As a result only stage V oocytes were used for absolute batch fecundity estimations. Using the following functions both absolute and relative batch fecundities were calculated, (Bagenal and Braum, 1978):

$$AF_{batch} = n \times \frac{A}{a} \times \frac{gW}{kW} \quad (1)$$

$$RF_{batch} = n \times \frac{A}{a} \times \frac{gW}{kW \times GW} \quad (2)$$

Where AF is the absolute batch fecundity, RF the relative fecundity, n the average number of hyaline or vitellogenic oocytes in both sub-samples of the ovary, A the volume of oocytes-water mixture (ml) in the ovary sample, a the volume of oocytes-water mixture (ml) of the ovary sub-sample, gW the weight of the gonad (g), kW the weight of the ovary sample (g), and GW the gutted weight of fish (g). Consequently absolute batch fecundity was regressed on FL , gW and GW .

RESULTS

Sex Identification and Length Frequency Distribution

From the total number ($n = 212$) of gag analyzed, histological examinations revealed that 75% ($n = 161$) individuals were females (Table 3) ranging in size from 45 to 111 cm TL (Figure 2). All females were considered in the analysis of the pattern of fecundity for the species, and 18 for estimating batch fecundity as a preliminary result on the fecundity of the gag stock from the southern Gulf of Mexico.

Oocyte Stage Diameters

Oocyte diameters of the six microscopic stages of oogenesis were determined. Stages I and II oocytes were classified as previtellogenic oocytes, and stages III to VI oocytes as vitellogenic oocytes (Table 1). Results are presented in Table 4.

Relative Percentage Frequency of Oocyte Stages

A qualitative analysis was performed for each female ($n = 161$) to determine the pattern of fecundity. The relative frequencies of the different stages of oocyte development observed during the annual sexual cycle of female gag are presented in Figure 3. Females presenting similar patterns of oocyte distribution, that is, with respect to oocyte stages were combined monthly in the same histogram (Figure 3). Following the aspect of the histograms and based on the criteria presented in Table 1, females were classified according to the five sexual classes defined in Table 2.

From June to September females were observed in a resting stage. In the following months (October to March), females were classified as being in an initial and/or advanced maturation stage. From January, to April, females were classified to be in spawning condition. Finally, from February to May females were in a state of postspawning.

Table 3. Total number of *M. microlepis* females used in histological examinations captured in offshore waters off the Campeche Bank, between April 1996 and August 1999.

Month	Females			
	1996	1997	1998	1999
Jan	-	3	19	-
Feb	-	3	11	-
Mar	-	-	3	2
Apr	5	-	-	7
May	8	1	1	11
Jun	-	6	8	-
Jul	-	11	6	-
Aug	-	15	4	1
Sept	-	7	-	-
Oct	-	12	-	-
Nov	1	6	-	-
Dec	3	7	-	-
Total = 161	17	71	52	21

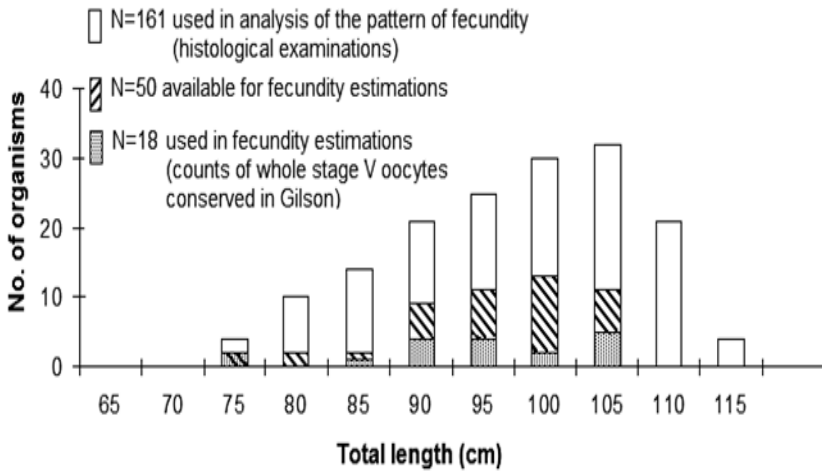


Figure 2. Frequency distributions of female lengths for gag *M. microlepis* from the Campeche Bank

Table 4. Average minimum and maximum diameter values (μm) of oocytes representative of the different stages in oogenesis. SD = Standard deviation. Diameter measurements were done from whole oocytes, freshly acquired from females that were collected.

Stage	Average \pm SD (μm)	Oocyte diameters (μm)	
		Range	
		Min	Max
Primary oocyte I & Immature oocyte II	68.5 \pm 22.1	20.0	119.5
Oocyte in primary vitellogenesis III	136.6 \pm 26.6	75.3	190.1
Oocyte in early secondary vitellogenesis IV	211.9 \pm 29.1	159.3	296.6
Oocyte in late secondary vitellogenesis V	387 \pm 59.5	211.7	509.3
Hyaline Oocytes VI*	920.5 \pm 58.3	737.1	1051.1

During maturation and spawning periods, gag females presented in their ovaries two main groups of oocytes:

- i) A reservoir of previtellogenic oocytes with:
 - Primary oocytes (stage I)
 - Immature oocytes (stage II)
- ii) A group of vitellogenic oocytes destined for the stock with:
 - Oocytes in primary vitellogenesis (stage III)
 - Oocytes in initial secondary vitellogenesis (stage IV)
 - Oocytes in late secondary vitellogenesis (stage V)
 - Hyaline oocytes (VI)

From the histograms obtained during these periods of the sexual cycle of gag (Figure 3), no gap or hiatus was observed in the frequency distribution of oocyte stages between small previtellogenic oocytes (I and II) and large vitellogenic oocytes (III, IV, V, and VI). A continuous production of vitellogenic oocytes from the reservoir of previtellogenic was observed during the entire maturation and spawning periods of the species.

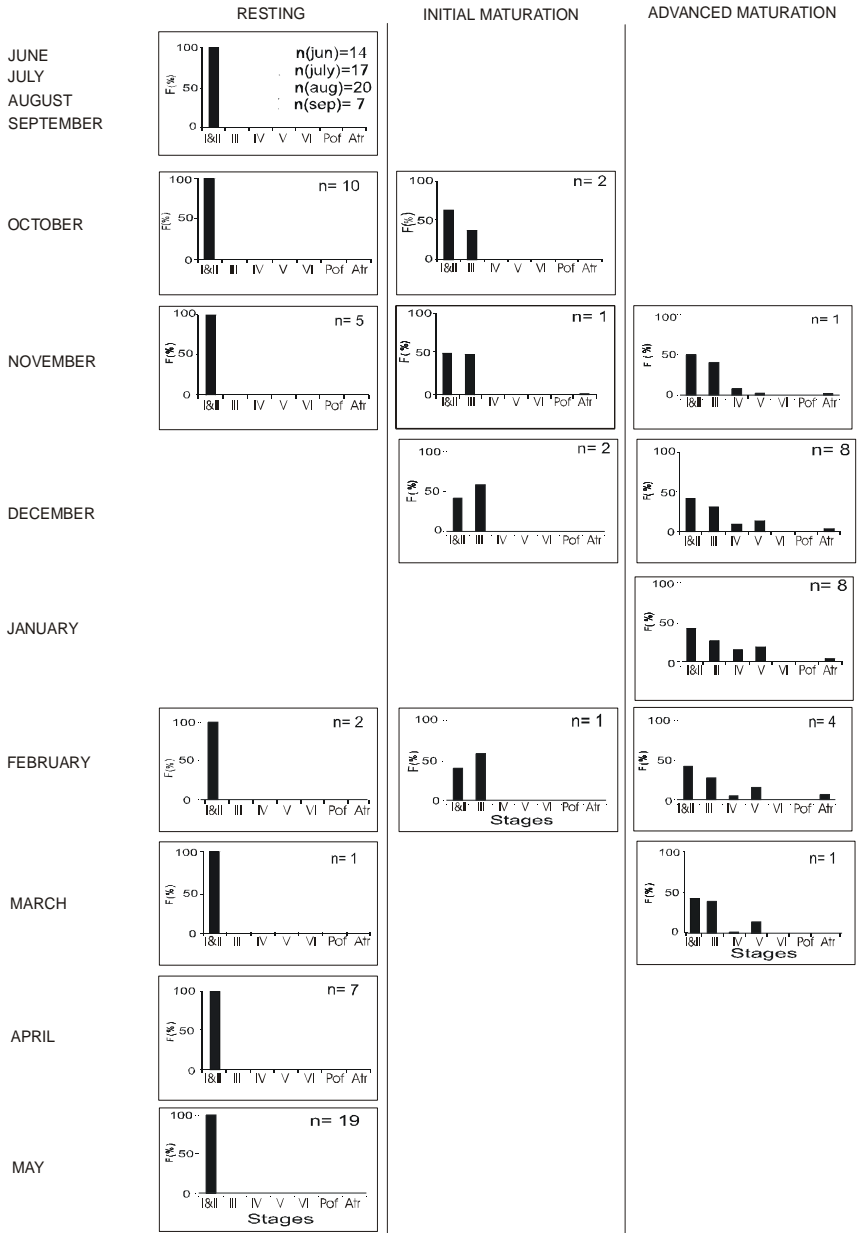


Figure 3. Evolution of the relative frequencies for the stages of oogenesis during the sexual cycle of *M. microlepis* from the Campeche Bank.

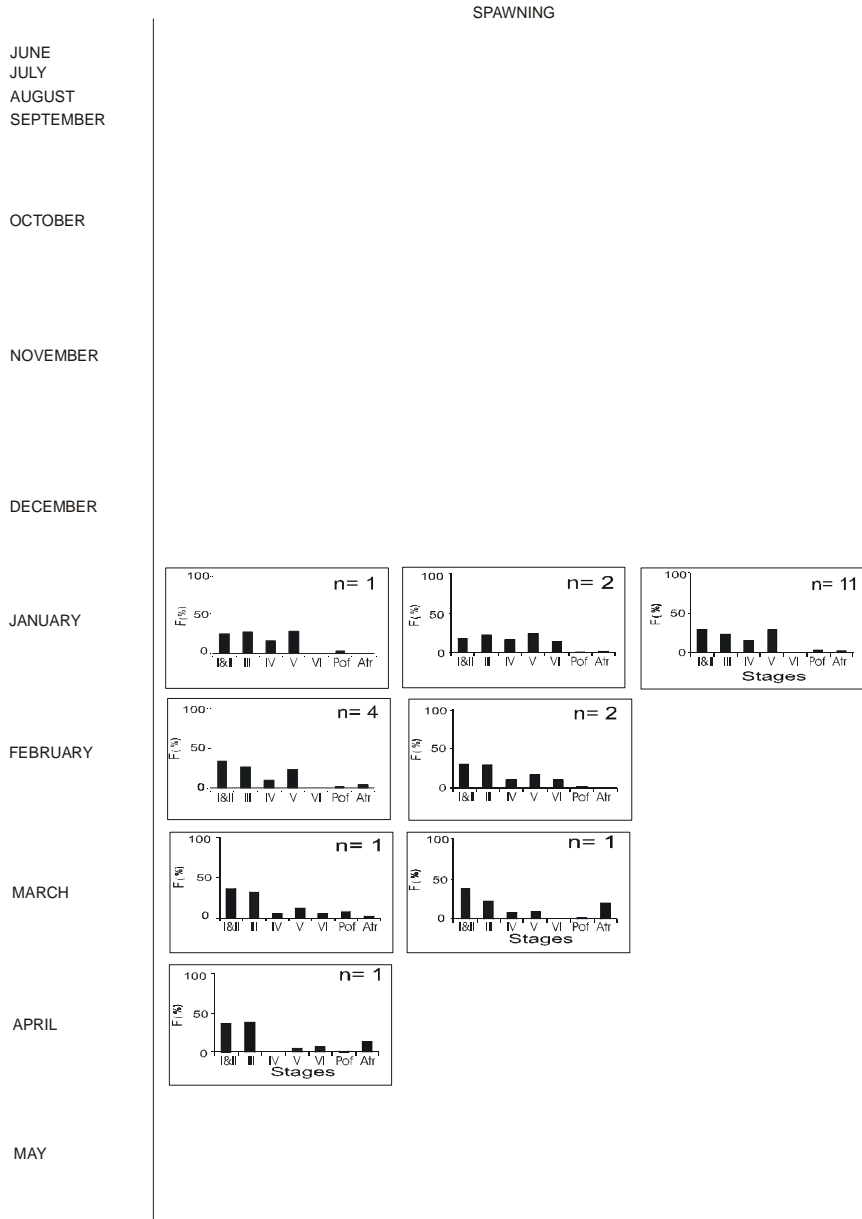


Figure 3. (continued)

POST-SPAWNING

JUNE
JULY
AUGUST
SEPTEMBER

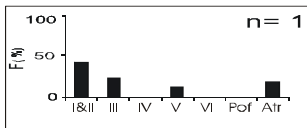
OCTOBER

NOVEMBER

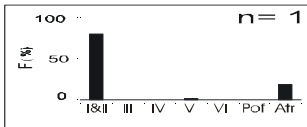
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JANUARY

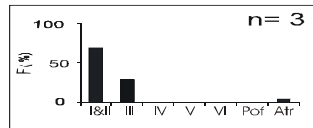
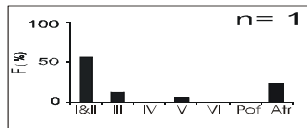
FEBRUARY



MARCH



APRIL



MAY

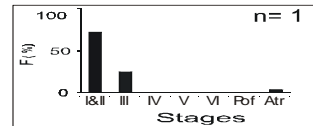
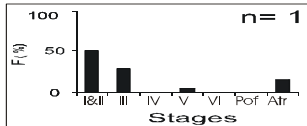


Figure 3. (continued)

Estimating Batch Fecundity

Diameter limits for stage V oocytes — Frequency distribution histograms of whole oocytes conserved in Gilson and obtained from ovaries of four selected females in spawning condition showed a multimodal distribution (Figure 4). Stage V was determined as the most advanced batch of oocytes required for batch fecundity estimates.

An evident overlap was observed between the largest diameter measurements recorded for stage IV oocytes and the smallest diameter measurements recorded for stage V oocytes (Figure 4). The occurrence of such an overlap made it necessary to establish a minimum diameter limit for stage V oocytes, recorded at 290 μm (Figure 5). All oocytes having diameters equal to, or above this value, not exceeding the maximum diameter established for stage V (509.3 μm), were considered in the quantitative estimation of batch fecundity.

The highlighted arrows clearly indicate that there is no gap or hiatus found between the size frequency distribution of stage I/II previtellogenic oocytes and stage III vitellogenic oocytes (Figure 4). This strongly confirms the pattern of fecundity analyzed through the distribution of the stages in oogenesis (Figure 3) during the sexual cycle of the species.

Absolute and Relative Batch Fecundities

Estimates of absolute and relative batch fecundities were analyzed for a total of 18 females of *M. microlepis* ranging from 72 to 105 cm FL and in weight from 4,950 to 14,350 g TW. Minimum and maximum fecundity estimates for this study are displayed in Table 4. Regression analysis showed significant positive linear correlations between absolute batch fecundity estimates (AF_{batch}) FL, TW, GW and gW. The gonad weight was the best predictor of absolute batch fecundity (Figure 6; AF_{batch} ; $r^2 = 0.7983$, $p < 0.0000$).

Table 4. Average minimum and maximum diameter values (μm) of oocytes representative of the different stages in oogenesis. SD= Standard deviation. Diameter requirements were done from whole oocytes, freshly acquired from females that were collected

Stage	Average \pm SD (μm)	Oocyte diameters (μm)	
		Range	
		Min	Max
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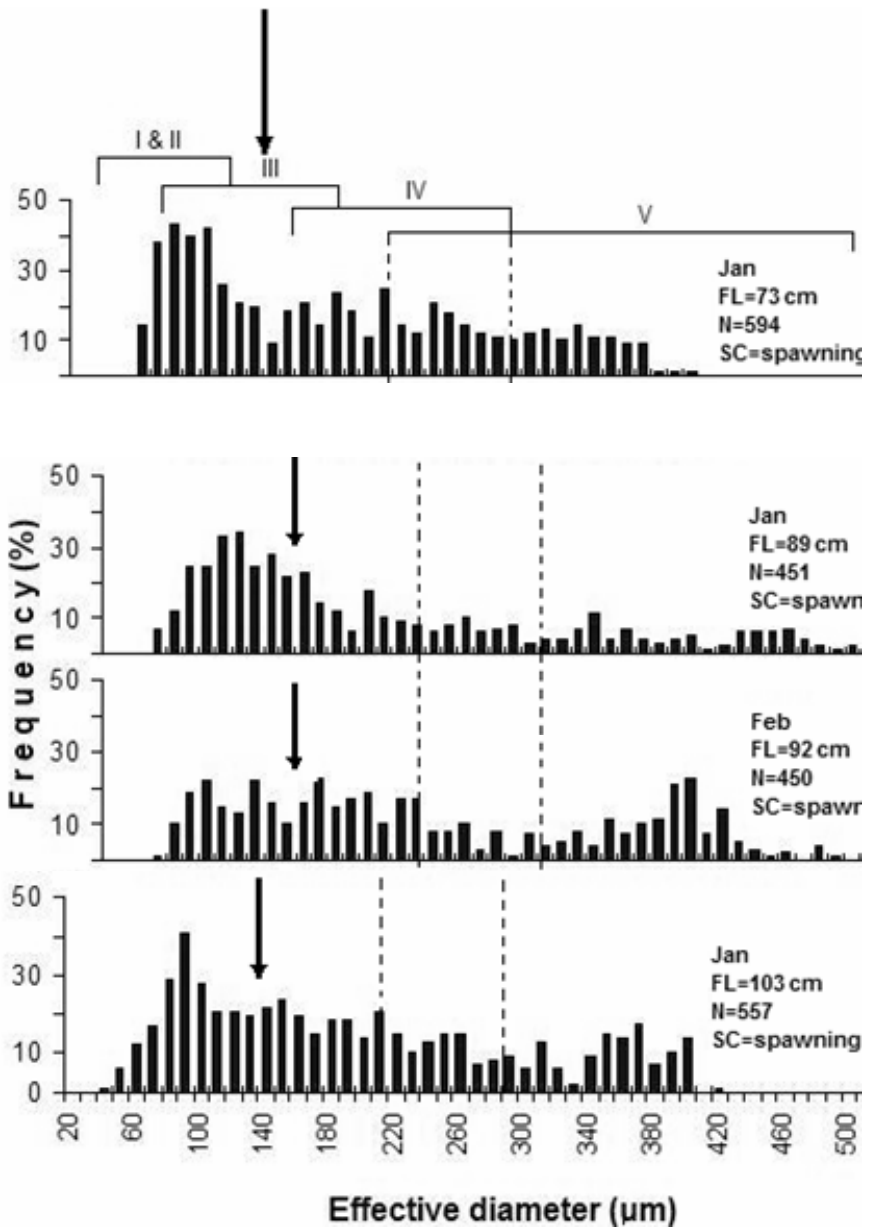


Figure 4. Histograms of diameter frequency distribution obtained through measurements of whole oocytes separated and conserved in Gilson's liquid, for four females from the Campeche Bank. FL= furcal length; N= number of oocytes measured; SC= sexual class.

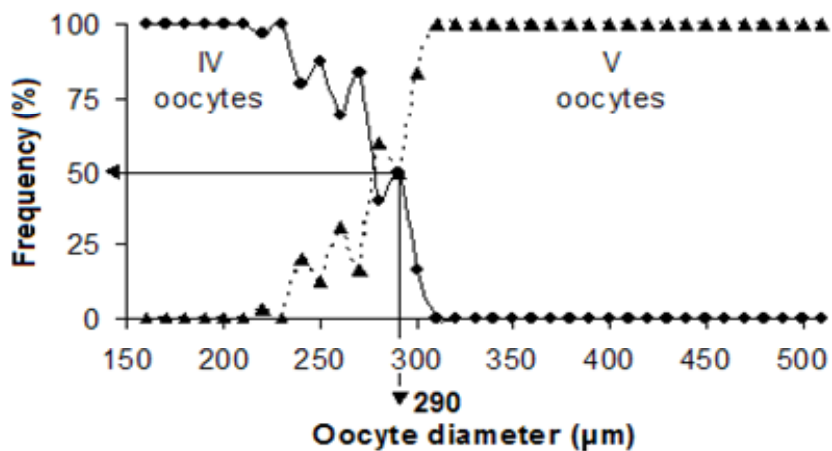


Figure 5. Minimum diameter of stage V oocytes considered for batch fecundity estimates obtained through histological examination of ovaries of female gag *M. microlepis* from the Campeche Bank.

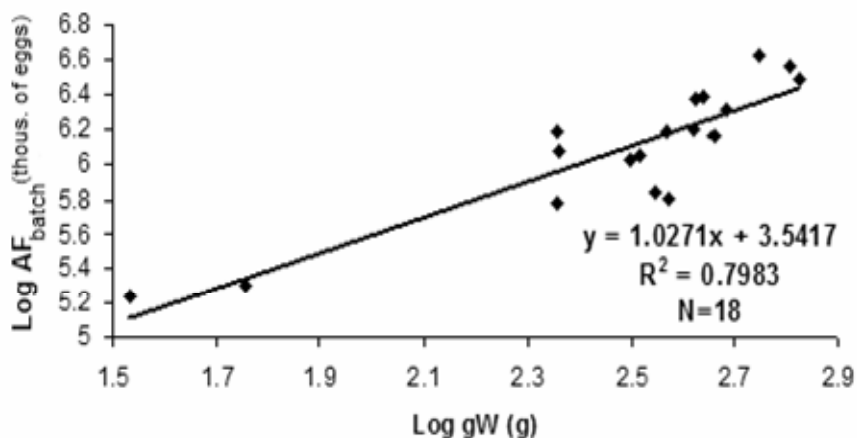


Figure 6. Relationship between log absolute batch fecundity - log female gonad weight for *M. microlepis* from the Campeche Bank.

DISCUSSION

Fecundity is usually defined as the number of ripening eggs found in the female just prior to spawning (Bagenal, 1978). As mentioned before, this biological aspect is a critical component of reproduction output and is included in stock assessments. Despite the importance of estimating fecundity, little reliable information is available for tropical fishes.

The traditional evidence for determinate fecundity is the presence of a major gap (hiatus) in oocyte maturity stages or size classes between the oocytes matured for the season and the reservoir of immature oocytes present year-round in the ovary (Yamamoto 1956, in Hunter and Macewicz 1985). The presence of such a gap in oocyte classes in females taken at the beginning of the season seems to be adequate proof that the standing stock of oocytes is a measure of maximum annual fecundity, as long as the gap is not between a batch of hydrated oocytes and other yolked oocytes.

The absence of such a discontinuity in oocyte classes is evidence for indeterminate fecundity. A continuous distribution of vitellogenic oocytes were observed during maturation and the spawning periods from histograms of diameter frequency distribution obtained from histological examination of oocytes; no apparent presence of a hiatus. The relative percentage frequencies calculated for females ($n = 161$) provided a qualitative analysis of the succession in maturation stages during the sexual cycle of the species, from females resting to females at post-spawning.

Histograms of diameter frequency distribution obtained through the volumetric method (whole vitellogenic oocytes), determined also a continuous distribution of diameters beginning with oocytes at the previtellogenic stages, I and II to the vitellogenic stage V of oogenesis. These results along with those obtained from histological examinations and relative percentage frequencies appear to be similar in nature.

The presence of distinct clusters of oocytes of various diameters and stages of development (including stage I and stage II oocytes) in gag ovaries throughout maturation and spawning periods, indicated that this species is a multiple-indeterminate spawner (batch spawner) with an indeterminate fecundity. These spawning and fecundity pattern characteristics displayed by gag from the Campeche Bank are similar to the results obtained by Collins et al. (1998) for a gag stock from the northeastern Gulf of Mexico and Koenig et al. (1996) for a gag stock from the eastern Gulf of Mexico.

In multiple-spawning fish species with indeterminate annual fecundity, the only useful fecundity measurement is the number of eggs produced in a single spawning batch (batch fecundity) (Hunter et al. 1985). The present study uses the volumetric method to estimate batch fecundity. According to Hunter et al. (1985), the volumetric method may be used in batch fecundity estimates if the eggs constituting the batch are identified using the oocyte size-frequency method.

However, gag samples for the Campeche Bank displayed an insufficient number of females with hyaline oocytes. Thus, for batch fecundity estimates in the present study the more time-consuming oocyte size-frequency distribution method was applied (Macgregor in Hunter et al. 1985). In this method, a

size frequency distribution of oocytes was constructed and the most advanced modal group of oocyte size classes (mode composed of the largest oocytes) was determined by inspection.

This method usually gives results similar to those based on counts of hyaline oocytes if females with highly advanced oocytes are used (Hunter and Goldberg 1980, Laroche and Richardson 1980, in Hunter et al. 1985).

This methodology was also applied by Ganiás et al. (2004) for the Mediterranean sardine. These authors stated that, at least for the Mediterranean sardine, simple identification of tertiary and migratory nucleus stages by microscopic examination of whole oocytes and their subsequent use in batch fecundity analysis may possibly offer a low-cost alternative to the hydrated oocyte method.

An indeterminate fecundity pattern along with the most advanced batch of vitellogenic stage V oocytes present in the ovaries of female gag allowed the estimation of absolute fecundity. Absolute batch fecundity estimates ($n = 18$) for the present study ranged from 170,610 to 4,270,250 stage V oocytes. These estimates came from gag 72 - 97 cm FL; 4,950 -12,300 g TW; and 34.09 - 555.7 g gW. Collins et al. (1998) report batch fecundity estimates ($n = 39$), for gag females from the northeastern Gulf of Mexico ranging between 10,864 and 865,295 hyaline oocytes; 69.0 - 106.5 cm FL; 4500 - 16,500 g TW; 23.4 - 871.9 g gW.

Due to the fact that fecundity is highly variable both within species and between years (Bagenal 1978), its estimation requires wide size ranges of individuals and clear explanations of methods. Consideration is also necessary of factors that may curtail potential fecundity such as parasitism and oocyte atresia (resorption of eggs prior to spawning) (Sadovy 1996).

The causes of variations in fish fecundity are also related to population density, temperature, food supply, stress, and other environmental effects (Bagenal 1978). This therefore, probably explains the possible fluctuations in fecundity estimates obtained by different authors for the same species from different regions.

There were significant positive linear relationships between absolute batch fecundity estimates (AF_{batch}) and FL, GW, TW, and gW. The best predictor of batch fecundity was gonad weight. This does not concur with results obtained by Bagenal and Braum (1978) and Snyder (1992), who proposed that length, is the best predictor of fecundity rather than fish weight or gonad weight. Bagenal (1978) stated that a close relationship is usually found between fecundity and length. This author pointed out that the length of a given fish does not change significantly as much as that of its weight. For example, the somatic weight changes significantly towards spawning.

However, Collins et al. (1998) also show that along with length, age, and gutted body weight, express positive linear correlations towards batch fecundity estimates. Other authors (Ludwig and Lange 1975) in Bagenal (1978) proposed a statistical model using age-length interaction which was more predictive of fecundity than length alone with Northern mottled sculpins, *Cottus bairdi*.

Collins et al. (2002) also obtained absolute batch fecundity estimates for a red grouper, *Epinephelus morio*, stock from the eastern Gulf of Mexico

ranging between 24,300 to 2,322,517 hydrated oocytes. Absolute batch fecundity estimates obtained for a tropical species population, the red snapper, *Lutjanus campechanus*, from the northeastern Gulf of Mexico, ranged from 458 to 1,704,736 hydrated oocytes (Collins et al. 1996). The present study provides similar results as compared to those obtained by the above authors, with absolute batch fecundity estimates ranging from 197,400 to 4,270,250 stage V oocytes.

Gag is suspected to migrate to spawning sites in the Gulf; however, no direct observations have been documented on these aggregations. Spawning migrations are implied from the consistent annual timing and location of the aggregations, as reported by Koenig et al. (1996).

Groupers exhibit complexities of reproductive biology that make them particularly susceptible to over-fishing such as hermaphroditism and spawning aggregations. Gag is known as a protogynous hermaphrodite and possibly exhibits spawning aggregations as mentioned previously. Hence, this species is vulnerable to heavy fishing activity. McGovern et al. (1998) reported that changes in life history aspects of gag from the Gulf of Mexico were attributed to steadily increasing fishing pressure.

However, little information is available on the reproductive output and production volumes for gag from the Campeche Bank. As reported, gag represents one of three commercially important serranid species heavily exploited in the southern Gulf of Mexico (Colás Marrufo et al. 1998) and is considered a highly fecund species according to Sadovy (2001). Thus, there is no doubt that efficient fishery regulations must be set in place by the proper authorities to monitor, manage, and conserve gag populations in the southern Gulf of Mexico. Mace and Hudson (1996), in Sadovy (2001) state that it is critical for conservation biologists and fishery managers to collaborate, for despite differences in perspectives, extinction in the case of conservation biologists and sustainability for fishery managers, there is much common ground.

Nevertheless, evidence for batch or multiple spawning is derived from direct observations of repeated spawning of individually identified females or through indirect methods, such as macroscopic examination of eggs (oocytes) size, and stages in development (Sadovy 1996). Direct observations are difficult, and assessment of spawning frequency is further complicated at least in some long-lived species; for example individual adults of *M. microlepis* may not spawn every year (Sadovy 1996).

Sadovy (1996) also mentioned that for indeterminate multiple spawning species the assessment of potential annual egg output is fraught with difficulties because it requires knowledge both of the number of eggs produced each time a female spawns, and the number of times it spawns per year.

LITERATURE CITED

- Arreguín-Sánchez, F., M. Contreras, V. Moreno, R. Valdés, and R. Burgos 1997. La pesquería de mero (*Epinephelus morio*) de la Sonda de Campeche, México. Pages 307-332 in: D. Flores-Hernandez, P. Sanchez-Gil, J.C. Seijo and F. Arreguín- Sánchez (eds.). *Análisis y Diagnóstico de los Recursos Pesqueros Críticos del Golfo de México*. Universidad Autónoma de Campeche. EPOMEX Serie Científica, 7. 496 pp.
- Bagenal, T.B. 1978. Aspects of fish fecundity. Pages 77-101 in: S.D. Gerking (ed.). *Methods for Assessment of Fish Production in Fresh Waters*. Blackwell Scientific Publications, Oxford, England.
- Bagenal, T.B. and E. Braum. 1978. Eggs and early life history. pp. 165 – 201 in: T.B. Bagenal (ed.). *Methods for Assessment of Fish Production in Fresh Waters*. Blackwell Scientific Publications, Oxford, England.
- Brulé, T., C. Déniel, T. Colás-Marrufo, and M. Sánchez-Crespo. 1999. Red grouper reproduction in the Southern Gulf of Mexico. *Transactions of the American Fisheries Society* **128**:385–402.
- Brulé, T., C. Déniel, T. Colas-Marrufo, and X. Renan. 2003. Reproductive biology of gag in the southern Gulf of Mexico. *Journal of Fish Biology* **63**:1505-1520.
- Bullock, L.H., and G.B. Smith. 1991. Seabasses (Pisces: Serranidae). *Proceedings of the Hourglass Cruises* **8**:2.
- Chávez, E. A. 1994. Los recursos marinos de la Península de Yucatán. Pages 1-2 in: A. Yañez- Arancibia (ed.). *Recursos Faunísticos del Litoral de la Península de Yucatán*. Universidad Autonoma de Campeche. EPOMEX Serie Científica 2. 136 pp.
- Colás-Marrufo, T., T. Brulé, and C. Déniel. 1998. Análisis preliminar de las capturas de meros realizadas a través de unidades de la flota mayor en el Sureste del Golfo de México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **50**:780-803.
- Collins, L.A., A.G. Johnson, and C.P. Keim. 1996. Spawning and annual fecundity of red snapper (*Lutjanus campechanus*) from the northeastern Gulf of Mexico. Pages 174-188 in: F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers*. ICLARM Conference Proceedings 48. Manila, Philippines. 449 pp.
- Collins L.A., A. G. Johnson, C.C. Koenig, and M.S. Baker Jr. 1998. Reproductive patterns, sex ratio, and fecundity in gag, *Mycteroperca microlepis* (Serranidae), a protogynous grouper from the northeastern Gulf of Mexico *Fisheries Bulletin* **96**:415-427.
- Collins, L.A., G.R. Fitzhugh, L.A. Lombardi-Carlson, H.M. Lyon, W.T. Walling, and D.W. Oliver. 2002. Characterization of red grouper (Serranidae: *Epinephelus morio*) reproduction from the eastern Gulf of Mexico. NMFS. SFSC: Contribution Series 2002-07.
- Gabe, M. 1968. *Techniques Histologiques*. Masson et Cie (ed.). Paris, France. 1113 pp.

- Ganias, K., S. Somarakis, A. Machias, and A. Theodorou. 2003. Pattern of oocyte development and batch fecundity in the Mediterranean sardine. *Elsevier Scientific Fisheries Research* **67**:13-23.
- Heemstra, P.C. and J.E. Randall. 1993. FAO species catalogue Vol. 16. *Groupers of the world (family Serranidae, subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date*. FAO Fisheries Synopsis No. 126 Vol. 16. FAO, Rome, Italy.
- Hunter, J.R., N.C.H. LO, and R.J.H. Leong, 1985. Batch fecundity in multiple spawning fishes. Pages 67-77 in: R. Lasker (ed.), *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.
- Hunter, J.R. and B.J. Macewicz. 1985. Measurement of spawning frequency in multiple spawning fishes. Pages 79-94 in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.
- Sadovy, Y. 1996. Reproduction of reef fishery species. Pages 15-59. in: N.V. C. Polunin and C.M. Roberts (eds.). *Reef Fisheries*. Chapman and Hall, London, England.
- Kartas, F. and J.P. Quignard. 1984. La fécondité des poissons téléostéens. Collection de Biologie des Milieux Marins 5 Masson, Paris, France. 121 pp.
- Koenig, C.C., F.C. Coleman, L.A. Collins, Y. Sadovy and P.L. Colin. 1996. Reproduction in gag (*Mycteroperca microlepis*) (Pisces: Serranidae) in the Eastern Gulf of Mexico and the consequences of fishing spawning aggregations. Pages 307-323 in: F. Arreguín-Sánchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.). *Biology, Fisheries and Culture of Tropical Groupers and Snappers*. ICLARM Conference Proceedings 48, Manila, Philippines. 449 pp.
- Laroche, J.L. and S.L. Richardson. 1980. Reproduction of northern anchovy, *Engraulis mordax*, off Oregon and Washington. Pages 67-77 in J.R. Hunter, N.C.H. LO, and R.J.H. Leong, 1985. Batch fecundity in multiple spawning fishes. in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.
- Ludwig, G.M. and E.L. Lange. 1975. The relationship of length, age, and age-length interaction to the fecundity of the northern sculpin *Cottus bairdi*. Pages 77-101 in: S. D. Gerking (ed.). *Aspects of Fish Fecundity*. Blackwell Scientific Publications, Oxford, England.
- Mace, G.M. and E.J. Hudson. 1999. Attitudes toward sustainability and extinction. *Conservation Biology* **13**:242-246.
- McGovern, J.C., D.M. Wyanski, O. Pashuk, C.S. Manooch II, and G.R. Sedberry. 1998. Changes in the sex ratio and size at maturity of gag, *Mycteroperca microlepis*, from the Atlantic coast of the southeastern United States during 1976-1995. *Fisheries Bulletin* **96**:797-807.

- MacGregor J.S. 1957. Fecundity of the Pacific sardine (*Sardinops caerulea*). Pages 67-77 in: R. Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.
- N'Da, K., and C. Déniel, 1993. Sexual cycle and seasonal changes in the ovary of the red mullet, *Mullus surmuletus*, from the southern coast of Brittany. *Journal of Fish Biology* **43**:229-244.
- Sadovy, Y. 1996. Reproduction of reef fishery species. Pages 15-59 in: N.V.C. Polunin and C.M. Roberts (eds.). *Reef Fisheries*. Chapman and Hall, London, England.
- Sadovy, Y. 2001. The threat of fishing to highly fecund fishes. *Journal of Fish Biology* **59**:90-108.
- SAGARPA 2001. *Anuario Estadístico de Pesca 2000*. México D.F. 268 pp.
- SAGARPA 2002. *Anuario estadístico de pesca 2002*. México D.F. <http://www.sagarpa.gob.mx>.
- SEMARNAP 1997. (Secretaría de Medio Ambiente, Recursos Naturales y Pesca). *Anuario estadístico de pesca 1996*. SEMARNAP, México City. 241 pp.
- Smith, C.L. 1971. A revision of the American grouper: *Epinephelus* and allied genera. *Bulletin of the American Museum of Natural History* **142**:67-241.
- Smith G.B. 1976. Ecology and distribution of Eastern Gulf of Mexico reef fishes. Florida Marine Research Publications No:19 pp.
- Snyder, D.E. 1992. Fish eggs and larvae. Pages 165-197 in: L.A. Nielsen and D.L. Johnson (eds.). *Fisheries Techniques*. American Fisheries Society, Bethesda, Maryland USA.
- Solis-Ramírez, M. 1970. The red grouper fishery of Yucatán Peninsula, Mexico. *Proceedings of the Gulf and Caribbean Fisheries Institute* **22**:122-129.
- Tresierra, A. A., and Z. Culquichicón. 1993. *Biología Pesquera*. Editorial Libertad. Trujillo – Perú. 232 – 250 pp.
- Tresierra, A. A., and Z. Culquichicón. 1995. *Manual de Biología Pesquera*. Trujillo – Perú. 56 – 68 Pp.
- Tuz-Sulub, A.N. 1999. Composición, distribución e importancia pesquera de los serranidos (subfamilia: Epinephelinae) en el Banco de Campeche Yucatán, México. Tesis de Licenciatura, Universidad Autónoma de Yucatán, Mérida, México. 77pp.
- Vergara-Rodríguez, R. 1976. Nuevos registros para la ictiofauna cubana. III. *Poeyana* **150**:1-7.
- Yamamoto, K. 1956. Studies on the formation of fish eggs. I. Annual cycle in the development of ovarian eggs in the flounder, *Liopsetta obscura*. Pages 79-94 in: Lasker (ed.). *An Egg Production Method for Estimating Spawning Biomass of Pelagic Fish: Application to the Northern Anchovy, Engraulis mordax*. U.S. Department of Commerce, NOAA Technical Report NMFS 36.

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