Reproductive Biology of Three Important Baitfishes (Clupeidae) in Puerto Rico

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ABSTRACT

Since October 2003 to October 2007, 1,444 gonad samples of the clupeid fishes, *Harengula clupeola* (false pilchard), *Harengula humeralis* (redear sardine) and *Opisthonema oglinum* (thread herring) were collected and analized histologically. These three species are very important as baitfishes for commercial and recreative fisheries in Puerto Rico. The main objectives of the study were to estimate the size at sexual maturity (50% SSM) and to determine the reproductive season of each species in order to establish management measures in the future, if necessary. The 50% SSM estimate for the false pilchard was 75 mm fork length (FL) for males. All individuals larger than 105 mm FL were mature. The estimate for the females was 85 mm FL and all females larger than 105 mm FL were mature. It was determined that this species reproduces year round, showing more activity between March and September. For the redear sardine the maturity size estimates were 93 mm FL and 96 mm FL for males and females, respectively. For this species all males larger than 115 mm FL were mature and all females of more than 110 mm FL were mature. Similar to the false pilchard, the redear sardine reproduces during the whole year but, increased reproductive activity occurs from January to August. The 50% SSM estimate for the thread herring was 132 mm FL for males and 119 mm FL for females. All males and females larger than 190 mm FL were mature. Different from *Harengula spp*., the thread herring shows a reproductive season more definite that extends from April to September. The vulnerability of these species to fishing pressure during the reproductive season is considerable because during this period migrations to the shore take place. The elimination of the beach seine as a fishing gear in Puerto Rico could be crucial for the conservation of these species.

KEY WORDS: Size at sexual maturity, reproductive season, *Harengula spp*., *Opisthonema oglinum*

Biología Reproductiva de Tres Especies Importantes de Peces de Carnada (Clupeidae) en Puerto Rico

Desde octubre 2003 hasta octubre 2007 se colectaron y analizaron histológicamente, 1,444 gónadas de las especies de clupeidos, *Harengula clupeola* (sardina escamúa), *Harengula humeralis* (machuelo) y *Opisthonema oglinum* (arencón). Estas tres especies son de gran importancia en la pesca comercial y recreativa como carnada en Puerto Rico. El objetivo principal del estudio fue calcular el estimado del tamaño de madurez sexual (50% TMS) y determinar la época reproductiva de cada especie, con el propósito de establecer medidas de manejo en un futuro, de ser necesario. El estimado de 50% TMS para la sardina escamúa fue de 75 mm largo de horquilla (Lh) para los machos y todos los individuos mayores de 100 mm Lh eran maduros. El estimado para las hembras fue de 85 mm Lh y todas las hembras mayores de 105 mm Lh eran maduras. Se determinó que esta especie se reproduce durante todo el año, demostrando mayor actividad entre marzo y septiembre. Para el machuelo los estimados de 50% TMS fueron de 93 mm Lh y 96 mm Lh para machos y hembras, respectivamente. Para esta especie todos los machos mayores de 115 mm Lh eran maduros y todas las hembras sobre 110 mm Lh eran maduras. Al igual que la sardina escamúa, el machuelo se reproduce durante todo el año aunque la mayor actividad reproductiva ocurre entre los meses de enero a agosto. El estimado de 50% TMS para el arencón fue de 132 mm Lh para los machos y 119 mm Lh para las hembras. Todos los machos y hembras mayores de 190 mm Lh eran maduros. Contrario a *Harengula spp*., el arencón tiene una época reproductiva más definida que va desde abril a septiembre. La vulnerabilidad de estas especies a la presión pesquera durante la época reproductiva es considerable ya que ocurren migraciones de éstas a la orilla durante ese período. La eliminación del chichorro de arrastre como arte de pesca en Puerto Rico se espera sea determinante para la conservación de estas especies.

PALABRAS CLAVES: Tamaño madurez sexual, época reproductiva, *Harengula spp*., *Opisthonema oglinum*

Biologie de la Réproduction de Trois Éspecies de Poissons Appâts Importants (Clupeidae) au Porto Rico

D'octobre 2003 à octobre 2007, 1444 échantillons de gonades de poissons clupeidés, *Harengula clupeola* (anchois), *Harengula humeralis* (sardine) et *Opisthonema oglinum* (sardinelle brésilienne) ont été collectés et analysés histologiquement. Ces espèces sont très importantes en tant qu'appât pour la pêche commerciale et récreative au Porto Rico. Les objectifs principaux de l'étude étaient d'estimer la taille à la maturité sexuelle (TMS de 50%) et de déterminer la saison de reproduction de chacune des espèces afin d'établir à l'avenir des mesures de gestion. L'évaluation de TMS de 50% en longueur à la fourche (LF) pour l'anchois était de 75 mm (Floride) pour les mâles et 85mm pour les femelles. On a déterminé que ces espèces se reproduisent toute l'année, avec plus d'activité entre mars et septembre. Pour la sardine, l'évaluation de TMS état de 93 mm pour les mâles et 96 mm pour les femelles. Comme l'anchois, la sardine se reproduit toute l'année. L'activité reproductrice la plus forte va de janvier à août. L'évaluation de TMS (50%) pour les sardines brésiliennes était de 132 mm pour les mâles et de 119 mm pour les femelles. A la différence des espèces précédentes, le hareng présente une saison de reproduction bien délimitée d'avril à septembre. La vulnérabilité de ces espèces à la pression de pêche pendant la saison de reproduction est considérable parce qu'au cours de cette période les migrations vers la côte se produisent. L'élimination de la seine de plage comme engin de pêche au Porto Rico a pu être cruciale pour la conservation des espèces.

MOTS CLÈS: Taille de première maturité sexuelle, saison de reproduction, sardinelle brésilienne

INTRODUCTION

In Puerto Rico several species of clupeids are among the principal prey items for many important reef and pelagic fish, and also, are essential as bait in our commercial and recreational fisheries. An understanding of the life history and ecology of the forage base is important for an adequate management of the island fisheries (Beets and La Place 1991). The most commonly used are the thread herring (*Opisthonema oglinum*) and the sardines Harengula spp. (Kimmel 1991, Le Gore 2007).

The false pilchard, (*Harengula clupeola*) appear to have similar behavior and frequently form mixed schools with *H. humeralis* (Randall 1996). Is pelagic and it is distributed in coastal marine areas, including coral-reefs, sand beaches, estuaries and seagrass beds (Cervigón *et al.* 1993). False pilchards are nocturnal predators and planktivorous, feeding mainly on copepods, larvae of decapods and fishes, and stomatopods (Sierra 1987, Sierra *et al.* 1994; Ortaz *et al.* 1996). The false pilchard ranges from the Gulf of Mexico to Brazil, including the Bahamas, entire Caribbean, West Indies, and southeastern Florida (not north Florida) (Munroe and Nizinski 2002). The false pilchard has a faint black spot on side posterior to opercular margin. This species possess a series of abdominal scutes forming a distinct keel and have no lateral line. Teeth are small but gill rakers are long and numerous for sieving plankton. The false pilchard can attain about 17 cm, being common to 9 cm (Whitehead 1985).

The redear sardine (*Harengula humeralis*, Cuvier 1829) is pelagic and can be found near coral-reefs, sand beaches, estuaries and seagrass beds. When compared with H. clupeola in terms of habitat preferences, *H. humeralis* apparently prefers clear waters and coral-reef areas (Cervigón *et al.* 1993). Redear sardines fed mainly at night and are planktivorous, feeding mainly on copepods, larvae of decapods and fishes and stomatopods (Sierra 1987, Sierra *et al.* 1994, Ortaz *et al.* 1996). The redear sardine can be found in Bermuda, Florida, Bahamas, Caribbean and West Indies (not Gulf of Mexico or Brazil) (Munroe and Nizinski 2002). The redear sardine is easily distinguishable from the false pilchard by the presence of a prominent orange spot at upper end of gill opening and horizontal stripes on upper part of body. *H. humeralis* possesses a series of abdominal scutes forming a distinct keel and has no lateral line. As found in *H. clupeola*, teeth are small but gill rakers are long and numerous for sieving plankton. This species reaches a maximum size of about 22 cm, being common to 12 cm (Whitehead, 1985). The flesh of *H. humeralis* has been reported to occasionally be deadly poisonous (Brody 1972).

The thread herring (or Atlantic thread herring) *(Opisthonema oglinum,* LeSueur, 1818) is a tropical and subtropical pelagic clupeoid widely distributed in the western Atlantic from the Gulf of Maine to Bermuda and throughout the Gulf of Mexico and West Indies southward to northern Argentina (Cervigón and Bastida 1974). Schools of *O. oglinum* are especially common in shallow coastal waters and in the mouths of rivers, which are used as nursery and growth areas (Funicane and Vaught 1986). This species occurs most frequently in the upper 3 meters of the water column, although in some seasons it may be found very near to the bottom, especially the larger individuals (LeGore 2007, Cervigón *et al.* 1993). The body of *O. oglinum* is fusiform and compressed, with lower profile deeply curved and a keeled belly. The back and upper sides are blue-green, with 6 - 7 dark horizontal lines. It has a dark spot above opercle and a larger dark spot behind opercle. The last ray of the dorsal fin is filamentous. The lower sides and abdomen are silvery. Maximum size reported is 38 cm (exceptional); common to 20 cm. Thread herring feeds on a variety of phytoplankton and zooplankton, including copepods, gastropods, plant detritus, and sediments. Adults also take small fishes, crabs and shrimps (Carr and Adams 1973, Whitehead, 1985, Sierra *et al.* 1994). This species is targeted commercially by artisanal and moderately sized seine fisheries off the coasts of several countries of south and Central America, Caribbean, Gulf of Mexico and the Greater Antilles and along the southeastern coast of the United States (Reintjes 1978, Smith 1994). In Puerto Rico, the thread herring is important mainly as bait in both commercial and recreational fisheries but minor quantities are used for human consumption (LeGore 2007). Due to its relatively high economic importance, the life history and fisheries of the thread herring has been the subject of numerous studies through its range (Fuss *et al.* 1969; Valdés and Sotolongo 1983, Smith 1994, González-Cabellos and Mangual-Izquierdo 1995, Mexicano-Cíntora *et al.* 1996, Vega-Cendejas *et al.* 1997, García-Abad *et al.* 1998, Harvey *et al.* 2003, see LeGore 2007). In this species, as in other clupeoids, an extended reproductive season was observed. As in the case of *Harengula* spp. no previous work on the reproductive biology of this species has been done in Puerto Rico.

MATERIALS AND METHODS

Data for this study were collected between October 2003 and October 2007. False pilchard, redear sardine and thread herring were sampled monthly by project personnel. Additional samples were obtained from commercial fishermen, and other personnel of the Fisheries Research Laboratory of the Puerto Rico Department of Natural and Environmental Resources. Gear used to collect the samples consisted mainly of cast nets and beach seine. Samples were obtained from all around the Island, but most of them were collected in western Puerto Rico.

Each fish collected was measured to the nearest millimeter (mm) fork length (FL) and whole weight (W) was taken to the nearest gram (g). To establish the TL/FL relationship a subsample of all species was measured to the nearest mm total length (TL). Except when noted otherwise, all measurements reported in the text are fork length in mm. The gonads were removed and weighed to the nearest 0.01 g. One lobe, or a portion of it, was placed in Davidson's fixative (Yevich and Barszcz 1981) for histological processing. Gonads were preserved for 48 hours, washed for 24 hours and then stored in 70% ethanol until further processing. A sample from the central portion of one lobe of each gonad was dehydrated, embedded in paraffin (Paraplast) and sectioned to 8 µm, stained with hematoxylin and eosin, and mounted for microscopic examination. Table 1 shows gonads classification according to the stage of maturation for males and females. The gonad conditions described for males are immature and mature. For females, they are immature, mature inactive, mature active, ripe, and spent. Several slides were examined to compare cellular development through-out both gonad lobules of the species under study. Transverse sections from three gonad areas (anterior, central, and posterior), for each lobule, were prepared. No differences were detected between the lobules or sections.

Spawning seasonality are usually based solely on the assessment of ovaries because males are generally more difficult to stage than females, often do not show marked changes in gonad weight within time, and therefore could give less well defined estimate of the spawning season (see West, 1990). We determined reproductive seasonality by calculating the percentage of each maturity class in each month and by the average gonadosomatic index (GSI) plotted against month of collection. GSI was calculated to show differences in development of the gonads with respect to body weight using the relationship described by Maddock and Burton (1998), GSI = 100*(GW / FW), where GW = gonad weight (g) FW = fish weight (g).

The estimate mean length at first maturity (L_{50}) for males and females was determined by fitting the logistic curve to the percentage of mature individuals (maturity classes ≥ 2). The logistic curve was fitted by using a routine standard curve analysis provided in the graphing software SigmaPlot ver. 10.0 (Systat Software Inc.). L_{50} was defined as the smallest size class in which 50% of the individuals were sexually mature. Data were entered and analyzed using Microsoft Excel. The Kolmogorov-Smirnov two-sample test and the t-test were used to compare size frequency distributions and mean size. Sex ratios were tested statistically for significant deviations from the expected 1:1 with a chi-square test ($\alpha = 0.05$) (Sokal and Rolhf 1981).

Table 1. Microscopic description of sexual maturation of female and male gonads.

Stage of maturation	Microscopic descriptions
Ovaries:	
F1 (inmature)	Early stages of oogenesis predominate (oocytes in stages 1 and 2). Stage 3 oocytes absent or very few. Compact gonad. Thin muscular tunica. No evidence of previous spawning (thick tunica, ovary with empty areas, post-ovulatory follicles and atretic bodies present.
F2 (inactive mature)	Oocytes in stages 1, 2, and 3 present, but stages 3 do not predominate. Oocytes in stage 4 absent or very few. Thin tunica, except in spent individuals.
F3 (active mature)	Oocytes in stages 2, 3, and 4 present, but stage 4 do not predominate. Advanced stage 4 oocytes absent. Thin tunica, except in spent individuals.
F4 (ripe)	Oocytes in stages 2, 3, 4, and rarely 5 present. Advanced stages predominate. Thin tunica, except in spent individuals.
F5 (spent)	Post-ovulatory follicles and atretic bodies present. Thick tunica. Ovary with empty areas.
Testes:	
M1 (inactive)	Early stages of spermatogenesis, gonad small and compact with gonia and seminiferous tubules.
M2 (active)	All stages of spermatogenesis are equal, or later stages dominate. Post-spawning testes are disorganized with empty lumina.

RESULTS

Sampling, Size-frequency Distribution, and Sex Ratio

Five hundred and fifteen *H. clupeola* were collected from November 2003 to October 2007. Size range was 26-134 mm FL (mean = 93; sd = ± 21). Four hundred and sixty six were sexed (178 males and 288 females). Sex ratio was 1♂:1.6♀ ($\chi^2 = 20.82$, $p < 0.05$, S). Size-frequency distribution of males and females are signifi-cantly different (Kolmogorov-Smirnov, D = 0.1828, $p < 0.05$) (Figure 1). Males ranged in size from 54 - 126 mm FL (mean = 95; sd = ± 14) and females ranged from 50 - 134 mm FL (mean = 99; sd = ± 14). Females were clearly predominant in virtually all the size classes larger than 85 mm while males were slightly predominant in the smaller size classes (Figure 1). Individuals smaller than 75 mm were difficult to locate and collect and only 57 were sampled during the study, from which 19 were sexed (11 males and 8 females).

Four hundred and twenty one *H. humeralis* were collected from November 2003 to October 2007. Size range was 85 - 157 (mean = 119; sd = ± 13.6). Four hundred and eighteen were sexed (184 males and 234 females). Sex ratio was 1♂:1.37♀ ($\chi^2 = 5.98$, $p < 0.05$, S). Size-frequency distribution of males and females are significantly different (Kolmogorov-Smirnov, D = 0.243, $p < 0.05$) (Figure 2). Males ranged in size from 85 - 148 mm FL (mean = 115; sd = ± 13) and females ranged from 86 - 157 mm FL (mean = 123; sd = ± 13). Following a trend similar to the one observed in *H. clupeola* females were predominant in all the size classes larger than 120 mm while males predominate in the size classes < 110 mm (Figure 2-2). Individuals smaller than 100 mm were difficult to locate and collect and only 28 were sampled during the study, 25 were sexed (16 males and 9 females).

Five hundred and eight *O. oglinum* were collected from February 2004 to August 2007. Size range was 72 - 227 (mean = 148; sd = ± 35). Three hundred and sixty six were sexed (119 males and 247 females). Sex ratio was

1♂:2.1♀ (χ^2 = 44.76, $p < 0.05$, S). Size-frequency distribution of males and females are significantly different (Kolmogorov-Smirnov, D = 0.1607, $p < 0.05$ (Figure 3). Males ranged in size from 92 - 210 mm FL (mean = 147; sd = ± 27) and females ranged from 93 -227 mm FL (mean = 160; sd = ± 31). Females were predominant in all the size classes except the smallest individuals collected (< 110 mm; n = 8). A total of 54 individuals of thread herring were larger of 190 mm FL, of which 89 % (n = 48) were females.

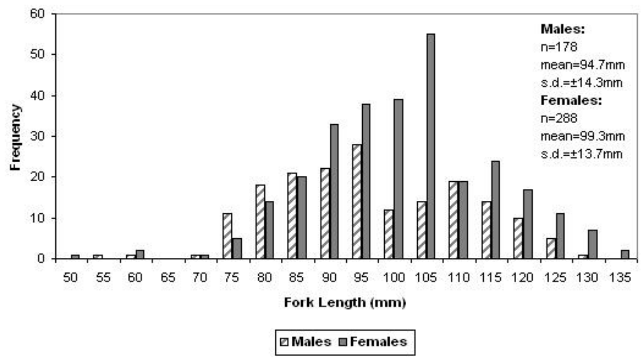

Figure 1. Size-frequency distribution of male and female false pilchard (*Harengula clupeola*) collected between November 2003 and October 2007.

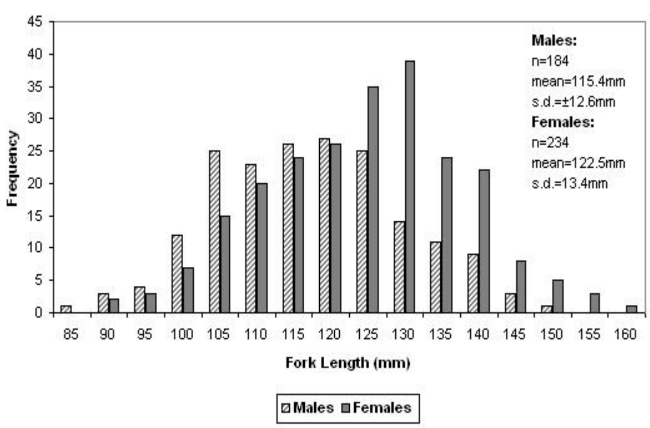

Figure 2. Size-frequency distribution of male and female redear sardine (*Harengula humeralis*) collected between November 2003 and October 2007.

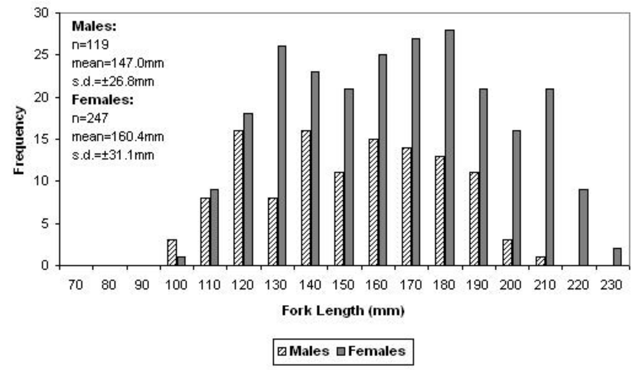

Figure 3. Size-frequency distribution of male and female thread herring (*Opisthonema oglinum*) collected between February 2004 and August 2007.

Size at Maturity

For the false pilchard the estimated median length at maturity was 74 mm FL for males (Figure 4) and 85 mm FL for females (Figure 5). Smallest mature male measured 77 mm FL while the smallest mature female was 73 mm FL. The discrepancy between the 50% maturity estimate and the smaller observed mature can be explained to the sharp decline of the maturity curve. All males larger than 100 and all females larger than 105 mm were mature (Figures 4 and 5).

Male and female *H. humeralis* mature at about the same size. Males started to mature at 90 mm FL while the smallest mature female was 92 mm FL. Estimated mean length at first maturity was 93 and 96 mm for males and females (Figures 6 and 7), respectively. All males larger than 115 and all females larger than 110 mm FL were mature (Figures 6 and 7).

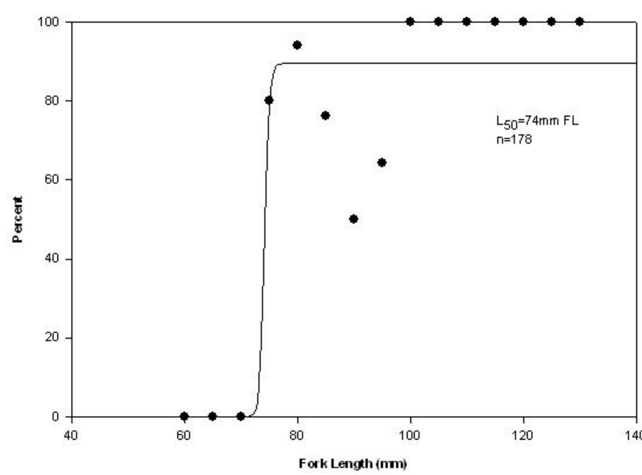

Figure 4. Percent of sexually mature male false pilchard (*Harengula clupeola*) as a function of fork length.

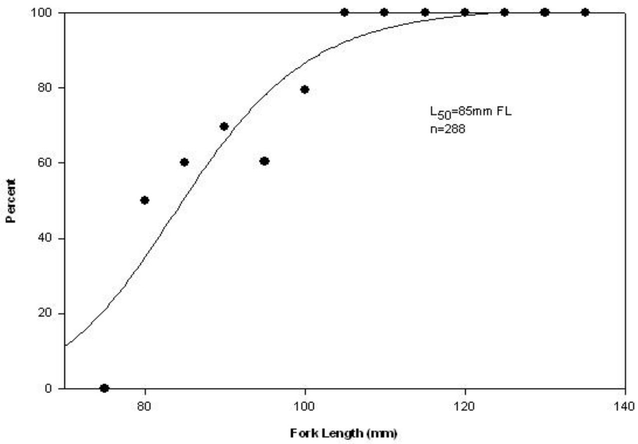

Figure 5. Percent of sexually mature female false pilchard (*Harengula clupeola*) as a function of fork length.

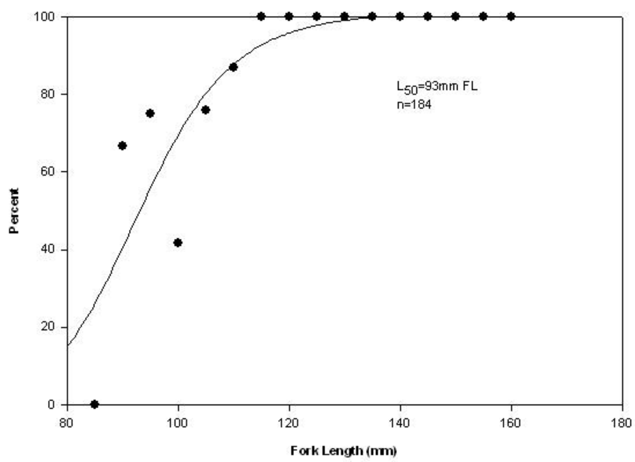

Figure 6. Percent of sexually mature male redear sardine (*Harengula humeralis*) as a function of fork length.

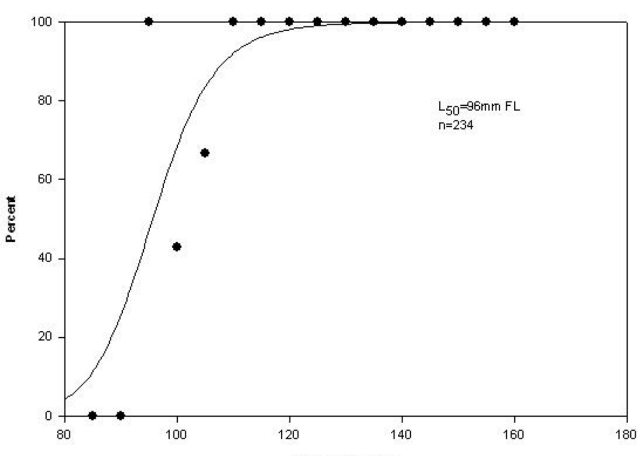

Figure 7. Percent of sexually mature female redear sardine (*Harengula humeralis*) as a function of fork length.

Male and female thread herring mature at about the same size. Estimated mean length at first maturity was 132 and 119 mm FL for males and females (Figs. 8 and 9), respectively. Smallest mature male measured 113 mm FL and the smallest mature female was 106 mm FL. All males and females larger than 190 mm FL were mature (Figures 8 and 9).

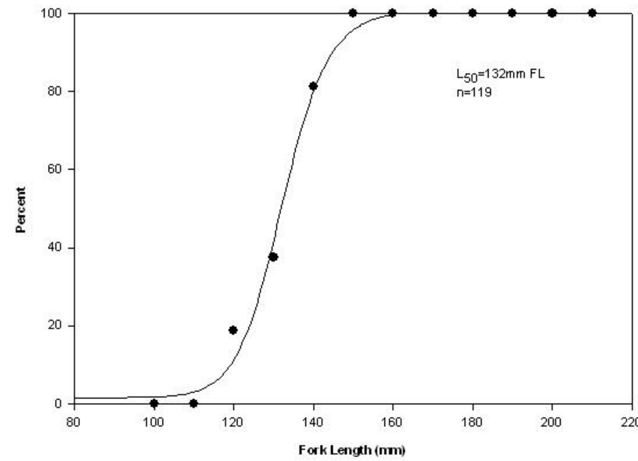

Figure 8. Percent of sexually mature male thread herring (*Opisthonema oglinum*) as a function of fork length.

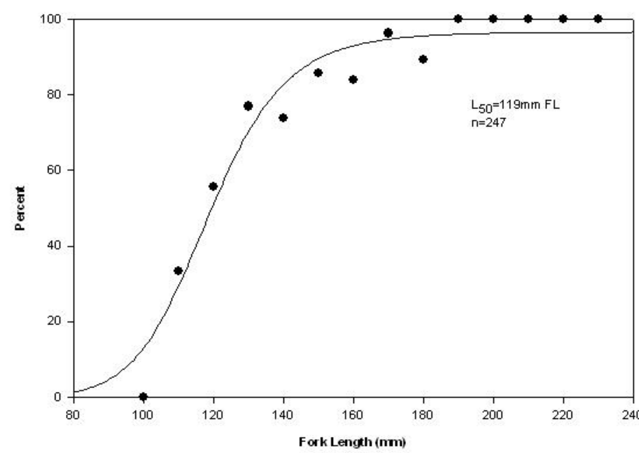

Figure 9. Percent of sexually mature female thread herring (*Opisthonema oglinum*) as a function of fork length.

Spawning Seasonality

Ripe females of *H. clupeola* were found in all months except October and December, suggesting that at least some spawning occurs probably year-round (Figure 10). The GSI values were highest in March, June, and September, reaching its minimum value in December (Figure 11). The percentage of ripe females was higher in March - April and June - September (Figure 10). Eight of the 24 females examined in that month had ovaries with hydrated oocytes, indicating imminent spawning. In summary, our data indicates an extended spawning season more active from March to September, with reduced reproductive activity between October and February.

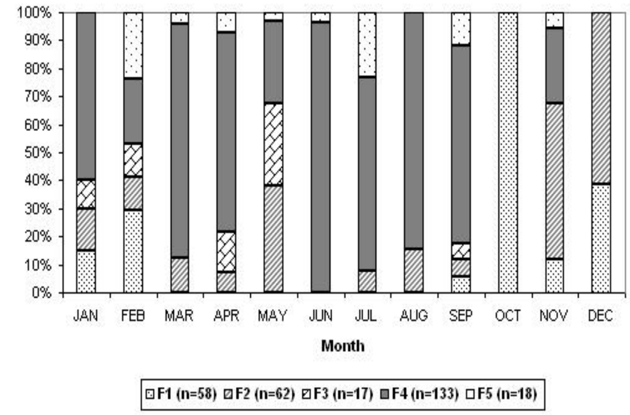

Figure 10. Monthly percentages of reproductive classes for female false pilchard (*Harengula clupeola*).

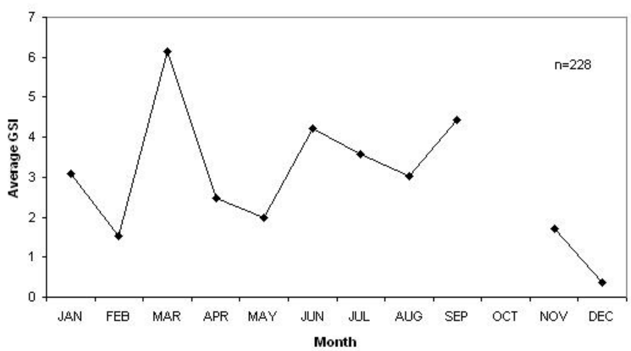

Figure 11. Monthly mean gonadosomatic index (GSI) for female false pilchard (*Harengula clupeola*).

Ripe females were present in all months, indicating that H. humeralis reproduces year-round in Puerto Rico (Figure 12). Reproductive activity is more intense from January through August. The percentage of ripe females during these months ranged from 59% in February to 100 % in May. During the period September - December the number of inactive mature females increased while the number of ripe females decreased. The percentage of ripe females during that period ranged from 7% in October to 42% in December. Both the monthly distribution of gonadal development stages and the GSI shown maximum values in May (n = 2, both fish with hydrated oocytes) (Figure 13).

In contrast to *Harengula* spp., histological data and the GSI show that *O. oglinum* have a six month spawning season. Ripe females were found from April through September. Mature active females were also only found in the same period. From October to March only immature and mature inactive females were collected (Figure 14). The GSI shows the same pattern, being < 0.5 between October – March, increasing significantly in April and remaining relatively high until September (Figure 15). Individuals collected during the no-spawning period had regressed gonads so small that many of them could not be sexed. The higher frequency of ovaries with hydrated oocytes was found in June and July.

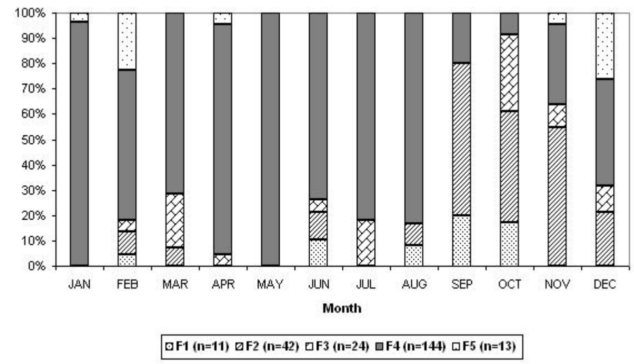

Figure 12. Monthly percentages of reproductive classes for female redear sardine (*Harengula humeralis*).

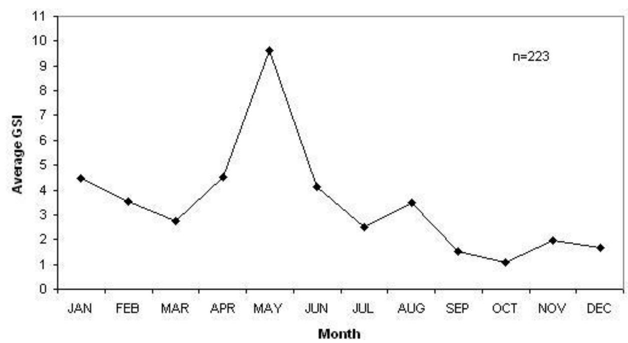

Figure 13. Monthly mean gonadosomatic index (GSI) for female redear sardine (*Harengula humeralis*).

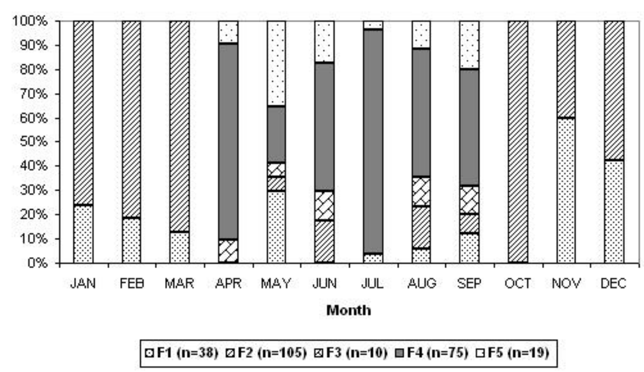

Figure 14. Monthly percentages of reproductive classes for female thread herring (*Opisthonema oglinum*).

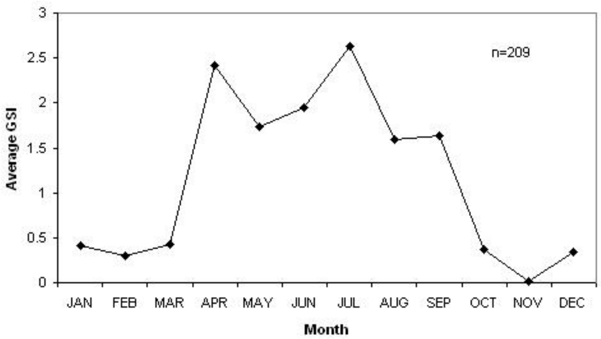

Figure 15. Monthly mean gonadosomatic index (GSI) for female thread herring (*Opisthonema oglinum*).

DISCUSSION

Sampling, Size-frequency Distribution, and Sex Ratio

All the *H. clupeola* samples were captured inshore with castnets by cooperating fishermen and project personnel. The largest false pilchard we collected measured 134 mm FL. In Venezuela, Posada *et al*. (1988) reported a maximum size of 109 mm SL, while Rivas (1963) working with many specimens from Florida, Bermuda, West Indies and Central America reported a maximum size of 142 mm SL. Cervigón (1991), after examining several localities in Venezuela, reported a maximum size of 166 mm TL for this species. Posada *et al*. (1988) observed sex ratio was not different from 1♂:1♀.

As in the case of the false pilchard, the redear sardine samples were captured inshore with castnets. *H. humeralis* reaches a larger size than *H. clupeola*. In this study, the largest *H. humeralis* measured 157 mm FL. In Venezuela, Posada et al. (1988) reported a maximum size of 173 mm SL, while Rivas (1963) working with many specimens from Florida, Bermuda, West Indies and Central America reported a maximum size of 172 mm SL. Cervigón (1991) after examining several localities in Venezuela, reported a maximum size of 192 mm TL for this species. García-Cagide (1988), in a study concerning the reproductive biology of *H. humeralis* in eastern Cuba, reports results similar to this study. This author found that females predominate in the larger size classes (130-170 mm FL) and report a sex ratio of 1♂:2.3♀. Posada *et al*. (1988) observed sex ratio was not different from 1♂:1♀ in *H. humeralis*.

The main fishing gears used to capture thread herrings were beach seines, hook and line, and cast nets. The largest individual in our samples measured 227 mm. This value is similar to others reports in the literature. García-Abad *et al.* (1998) reported a maximum size of 205 mm TL in the southern Gulf of Mexico. Also in Mexico (Yucatán), Mexicano-Cíntora *et al.* (1996) estimated a maximum size of 227 mm FL. The maximum estimated length calculated by Vega-Cendejas *et al*. (1997) was 223 mm TL. The largest fish measured by Valdés and Sotolongo (1983) was 200 mm FL, while Guitart (1974) states that *O. oglinum* reaches a size of 300 mm FL in Cuban waters. Harvey *et al*. (2003) noted a maximum size of 190 mm TL captured by the beach seine fishery of Jamaica. Very similar sizes have been reported in the United States. Smith (1994) and FMRI (2003) mention that this species reaches a maximum size of 200 mm FL along the North Carolina and west central Florida coasts, respectively. According to Cervigón (1991), this species can reach a size of 380 mm TL. Gónzalez-Cabellos and Mangual-Izquierdo (1995) calculated a maximum size of 298 mm FL in Venezuela. Our size frequency distribution by sex and sex ratio results agree with Valdés and Sotolongo (1983); these authors also found that females tended to be larger and more abundant than males, reporting a sex ratio 1♂:1.43♀. A similar trend was observed by García-Abad *et al.* (1998) who noted that females were more numerous in all months, except August. Smith (1994) also noted a sex ratio skewed toward females (1♂:1.67♀).

Size at Maturity

Estimated mean length for the false pilchard at first maturity was 74 mm for males and 85 mm for females. The smallest mature male was 77 mm, while the smallest mature female was 73 mm. Posada *et al*. (1988) estimated 50 % maturity at 104 mm TL for males and 111 mm TL for females. They reported a minimum maturation size of 93 mm and 83 mm TL for males and females, respectively. García-Cagide *et al*. (1994) reported a minimum maturation size of 70 mm FL for females and a 50% maturity value of 90 - 100 mm FL for males in southwestern Cuba. Our maturity estimates are smaller than those reported by previous studies. Although we do not have evidence suggesting a reduction in the maturity size of *H. clupeola* in Puerto Rico during the last decades, that is a possibility that can not be ruled out. Size at maturity can decrease as a consequence of increased fishing pressure (see Hood and Johnson 2000). Clupeids in general and *Harengula* spp. in particular are one the most important baitfish species in local waters (LeGore 2007). Kimmel (1991) carried out a baitfish survey in Puerto Rico in 1986 and his data suggested that baitfish landings (including *Harengula* spp.) were lower than any of the previous three years examined. Beets and LaPlace (1991) noted that complete aggregations of baitfish in bays may be eliminated through fishing. These authors mention that this has been observed on several occasions around St. Thomas and St. John (U.S. Virgin Islands). They also point out that if inshore migrations coincide with reproductive activity, heavy fishing pressure may severely impact reproductive success. García-Cagide (1988) states that spawning in *H. humeralis,* which frequently form mixed schools with *H. clupeola,* probably takes place at night and close to shore. During a sampling trip we did in March 26, 2006, 8 out of 24 (33%) of the females captured with cast net close to shore, had ovaries with hydrated oocytes. During this study we sporadically captured females in spawning condition in very shallow water, showing that at least some spawning takes place during the inshore movements, rendering this species and other clupeids that show similar habits, very vulnerable to intense fishing pressure. We agree with the recommendation made by Beets and LaPlace (1991) in that baitfish population should be monitored in selected areas to assess the need for management. Based on our estimated mean length at first maturity and the size-frequency distribution, about 76% of the 515 fish measured were mature (data sources: this study).

For redear sardine our 50% maturity estimates were 93 and 96 mm for males and females, respectively. Males started to mature at 90 mm while the smallest mature female measured 92 mm. In eastern Cuba, García-Cagide (1988) states that the smallest individual with mature gonad measured 110 mm FL (sex not specified) and that more than 45% of males were 110 - 130 mm FL while more than 45% of females were 120 - 140 mm FL. On the other hand, in southwestern Cuba, García-Cagide *et al.* (1994) reported a minimum maturation size of 80 - 90 mm FL for males and 90-100 mm FL for females. The same report mentions a 50% maturity value of 100 mm FL for males and 110 mm FL for females. Posada *et al.* (1988) estimated mean length at first maturity was 124 mm TL for males and 128 mm TL for females. The minimum maturation size reported by these authors was 103 mm and 93 mm TL for males and females, respectively. In the very similar species, *H. jaguana,* both sexes mature for the first time between 78 - 85 mm SL (Martínez and Houde 1975). It is interesting to note that, as in the case of the false pilchard, our 50% maturity estimates are smaller than the ones reported elsewhere. Females with hydrated oocytes were collected, in shallow water, in several sampling trips, although they were less common than in the case of false pilchard (see Discussion for *H. clupeola*). The two *Harengula* studied here frequently form mixed schools and their habits are very similar (see Posada *et al*. 1988). Our comments regarding possible management recommendations definitely apply to both species. Based on our estimated mean length at first maturity and the size-frequency distribution, about 98% of the 467 fish measured were mature (data sources: Daniel Matos, Unpubl. data, Fisheries Research Laboratory and this study).

Finally for the thread herring our estimated mean length at first maturity was 132 and 119 mm FL for males and females, respectively. Males started to mature at 113 mm while the smallest mature female measured 106 mm. In Campeche Bank, Vega-Cendejas *et al.* (1997) found that the smallest mature male was 115 mm FL; for females this corresponded with 106 mm FL. The size at 50% maturity was 151 mm FL and 155 mm FL for males and females, respectively. García-Abad *et al*. (1998) reported a size at first maturity of 135 mm TL in females of *O. oglinum.* Histological examination of thread herring gonads along the coast of the State of Ceara, Brazil, showed that size at first sexual maturity is 100 and 110 mm FL for males and females, respectively, while first maturity occurs in 50% of the population (unsexed fish) at 110 - 115 mm FL (Alves and Sawaya, 1975). Berkeley and Houde (1984) reported that females first reached maturity at 145 mm FL and males at 125 mm FL in the northeastern Gulf of Mexico. Some south Florida females were sexually mature at 135 mm FL (Prest 1971). Based on our estimated mean length at first maturity and the size-frequency distribution, about 71 % of 873 fish measured were mature (data sources: Daniel Matos Unpubl. data, Fisheries Research Laboratory and this study).

Spawning Seasonality

Our data for the false pilchard suggest that some spawning takes place year-round with a more active period occurring between March - September. These results, in general terms, agree with the findings reported by other investigators in the Caribbean region. Mester *et al.* (1974), in northern Cuba, noted that *H. clupeola* presented a maximum frequency of mature oocytes in April - May, but they did not examine the annual reproductive cycle. García-Cagide *et al*. (1994) found ripe females from April-June and in October and December. In Venezuela (Posada *et al.* 1988) reported two spawning periods for the false pilchard (February - June and October - December). In the close related species *H. jaguana* in the south Florida area, GSI indicated that spawning begins in February, peaks in April and May, and finishes by August; plankton collections supported these results (Martínez and Houde 1975).

According to the data we compiled, the redear sardine reproduces to some degree year-round, being January-August the period with more intense reproductive activity. Very similar results were reported by García-Cagide (1988) who found fish in spawning condition virtually year-round with an increment of reproductive activity from February until May, being April and May the peak months. Mester *et al*. (1974), in northern Cuba, noted that *H. humeralis* presented a maximum frequency of mature oocytes from April to May, but they only examined samples collected between February - July. In Venezuela (Posada *et al*. 1988) reported two spawning periods for the redear sardine (October - December and April - June).

The results of this study indicate that the thread herring spawning season extends from April to September, with a possible peak in June - July. This is in agreement with several studies that have been published regarding spawning seasonality in this species. García-Abad *et al*. (1998) also detected a protracted spawning season extending from May to October, with peaks in May and August. In the eastern Gulf of Mexico Houde (1977), based on the abundance of eggs and larvae, proposed a spawning season extending from February to September with a peak from April to August (see Finucane and Vaught 1986). Houde also reported that the primary spawning area was located in coastal waters from Tampa Bay to just south of Fort Myers (see Finucane and Vaught, 1986). Fuss *et al.* (1969) suggest a spawning period from March to August with a marked peak in June in Florida. A similar pattern was reported by Kemmerer (1977) in the northern Gulf of Mexico. According to Hildebrand (1963) *O. oglinum* spawns during May and June in North Carolina. Smith (1994) reported ripe and recently spawned females from a purse seine sampled in June in North Carolina. Prest (1971) indicated an April - July spawning season in the St. Petersburg area (Florida). Larvae were observed off south Texas during August and September (Finucane *et al.* 1978). Herrema *et al.* (1985) collected *O. oglinum* in spawning condition off St. Lucie, Florida, from February through May and in August. Whitehead (1985) suggests that *O. oglinum* spawns from March to July in Venezuela, while Bigelow *et al.* (1963) report spawning in May - June. Somewhat different findings were reported by Vega-Cendejas *et al.* (1997) from thre Campeche Bank, where *O. oglinum* apparently spawns from July to December and individuals with ripe gonads were found throughout the year. Spawning seems to takes place in nearshore shelf waters in depths between 10 - 30 meters (Prest 1971, Houde 1977, Harvey *et al.* 2003). We collected females with hydrated ovocytes in depths ranging from 5 - 15 meters in locations between 0.5 - 1 miles from shore. In Puerto Rico, as in many other countries, clupeids are among the most important fishbait species, and in many areas the beach seine is the main gear responsible for most of the landings reported. The vulnerability of the thread herring, redear sardine, false pilchard, and other clupeids and carangids to the beach seine was critical, mainly due to the nature of the inshore movements of their schools where the beach seine usually operated. The elimination of that fishing gear certainly was a crucial step towards the conservation of such an ecologically and economically important group of species.

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