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Studies on reproduction of the mullet *Mugil platanus* Günther, 1880 (Actinopterygii, Mugilidae) from the Mar Chiquita coastal lagoon, Argentina: Similarities and differences with related species

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Abstract

The aim of the present study is to provide the first results on the reproductive biology of *Mugil platanus*, from the Mar Chiquita coastal lagoon (Argentina). To address this topic, we employed mainly female gonads, at both microscopic and macroscopic levels. The following stages of oocyte development were observed: (A) oogonias, (B) primary growth oocyte, (C) cortical alveolus stage, (D) yolked oocytes, and (E) atretic follicle. Also five of the seven stages of gonad maturity were macro and microscopically stated. The potential fecundity ranged between 1,002,026 and 2,548,769 yolked oocytes, with a mean of around 1,800,000 oocytes. The length at first maturity (L_{50}) was 450.6 total length (TL) and 367.7 standard length (SL) for females, 436.3 TL and 354.9 SL for males, showing a late sexual maturity for both sexes. Seasonal changes in gonadosomatic index (GSI) of females were observed. The mean GSI was ≤ 1 during six months of the year (January, June–October). Two modes in the ovarian maturation were observed, the most important in April–May and a secondary one in November–December. Both modes, correlated with the CPUE values, are indicative of the mullet migration from the coastal lagoon towards the sea for spawning. Differences and similarities have been found between *Mugil platanus* and other mugilid species (*Mugil cephalus*, *Mugil curema*, *Liza aurata*, *Liza abu*, *Liza argentea*, *Myxus elongatus*, and *Valamugil cunnesius*), from the reproductive point of view. The length at first maturity obtained for *M. platanus* is higher than in other mugilid species and when a relationship between maximum length and L_{50} is established the percentage corresponding to *Mugil platanus* is 75%, while the others range between 50 and 61%.

Keywords: Fish reproduction, gonad histology, fecundity, Mugilidae, *Mugil platanus*

Introduction

Fish species of Mugilidae occur in both coastal marine and brackish waters from all tropical and temperate seas (Nelson 2006). Conservative morphological features make identification of mullet species difficult. Recently, in order to clarify the controversy regarding the taxonomic status of the striped mullet *Mugil platanus*, in relation to the cosmopolite *Mugil cephalus*, a comprehensive analysis using sequences of the mitochondrial gene cytochrome *b*, landmark-based morphometry and meristic data have been performed (González Castro et al. 2008). The demonstrated discontinuity in geographic distribution and the mitochondrial DNA, morphometric and meristic

analysis allow these authors to consider *Mugil cephalus* and *Mugil platanus* as valid allopatric nominal species.

The striped mullet *Mugil platanus* is the only mugilid of permanent presence in Argentina, with a wide distribution along the coast, coastal lagoons and some fresh water beds (Cousseau et al. 2005; González Castro 2007). However, the white mullet *Mugil curema* Valenciennes, 1836 has been occasionally captured (González Castro et al. 2006).

Mugil platanus is commercially exploited not only in the south of Brazil (Vieira & Scalabrin 1991), but also in Samborombón Bay, Argentina (González Castro 2007). It is a gonochoristic and ovuliparous species, which shows high fecundity and migratory

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behaviour with reproduction purposes (Godinho et al. 1988; Esper et al. 2001). Based on Vieira and Scalabrin (1991), Vieira (1991) presents a hypothetical model for the life history of *M. platanus* from Lagoa dos Patos (Brazil). The author relied mainly on the temporal-spatial distribution of larval–juvenile recruitment (measured by CPUE) and adult captures (in reproductive migration), relating these data with different environmental variables (temperature, salinity, direction of coastal marine currents). González Castro et al. (2009a) proposed a hypothetical model for adult stocks of the same species, based not only in CPUE of adults and environmental data but also on gonadosomatic index, the allometric growth coefficient b and border analyses of otoliths. Both models basically agree and are complementary, for, as Vieira (1991) indicates, ‘The following model describes the early-life movements of *M. platanus*’, whereas the González Castro et al. (2009a) model is based on the adult stock.

The Mar Chiquita coastal lagoon is located in the Buenos Aires province, 32 km NE of the Mar del Plata city. It is a shallow estuary (0.4–3 m deep) separated from the sea by a littoral line of dunes with an inlet joining it to the ocean. It is 25 km large and 5850 ha (Isla 1995), and is considered a World Biosphere Reserve by the Coordination Council of the Man and Biosphere Program (MaB) of UNESCO (Iribarne 2001). Temperature and salinity in this estuary are extremely variable. Diurnal variations of surface temperature are strongly dependent on sun irradiance, with peaks of maximum temperature between 3 and 4 pm. Salinity fluctuates over a wide range between 0 and 36 ups, and it is extremely variable and influenced by the fresh water volume present in the lagoon, the tide, and the wind direction/intensity (Reta et al. 2001). The fish composition of Mar Chiquita has been studied during the last decade and several fish species have been reported to make extensive use of the lagoon, in a permanent, seasonal or occasional way (Díaz de Astarloa et al. 2000; Figueroa et al. 2000; Cousseau et al. 2001; González Castro et al. 2006). Moreover, González Castro et al. (2009b) not only analysed the composition and relative abundance of the fishes of Mar Chiquita coastal lagoon, in relation to their spatial and temporal distribution, but also evaluated the relative contribution of some environmental variables over the abundance/distribution patterns of the main fishes species. These authors found shoals of *Mugil platanus* in the nearby mouth of the lagoon, comprising adult specimens in advanced maturation stage.

It is well known that reproductive biology and ecological requirements are essential for aquaculture

and efficient management of the stocks. However, no reproductive studies of *Mugil platanus* have been conducted in Argentina, and are scarce for the rest of South America (Vieira & Scalabrin 1991; Andrade-Talmelli et al. 1994; Romagosa et al. 2000; Esper et al. 2001).

The aim of the present study is to provide the first results on the reproductive aspects of *Mugil platanus*, in the Mar Chiquita coastal lagoon. This analysis includes: ovarian development, oocyte diameter distribution, estimates of potential fecundity, length at first maturity and gonadosomatic index. Moreover, similarities and differences on the reproductive biology between *Mugil platanus* and other mugilids are discussed.

Materials and methods

Fish samples

Striped mullet samples were collected monthly between 2000 and 2006 in the Mar Chiquita coastal lagoon, Argentina (Figure 1). However, the frequency sampling was irregular during the 2000–2004 period, due to logistic troubles and adverse climatic conditions. Three 25-m long, 1.5-m high monofilament gill nets with 120, 68 and 57 mm mesh size were employed. The different mesh sizes used allowed the capture of a wide total length range of specimens as was demonstrated by Cousseau et al.

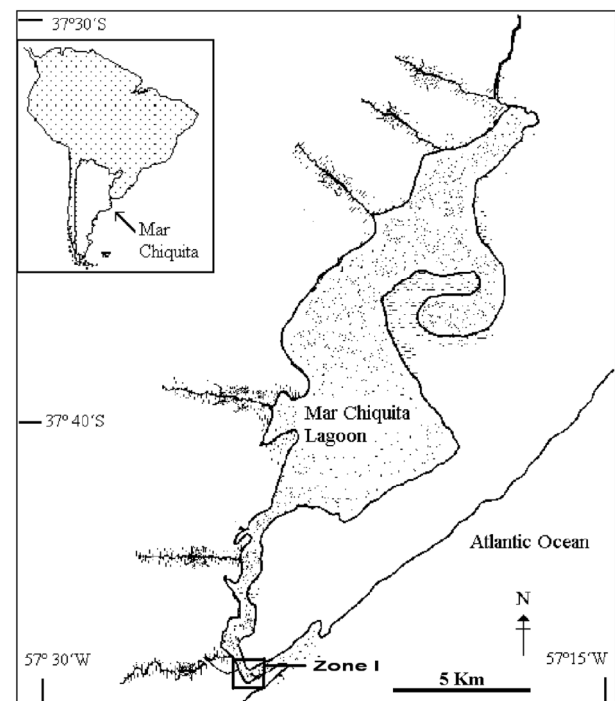


Figure 1. Map of Mar Chiquita coastal lagoon.

(2001). Water temperature ($^{\circ}\text{C}$) and salinity data were registered monthly, in the Zone 1 near to the mouth of the lagoon in the sea (Figure 1), using an alcohol thermometer and a Hydrobios[®] refractometer, respectively.

Each fish was measured to total (TL) and standard lengths (SL) to the nearest mm, and weighed to 0.1 g with a Metler Toledo[®] electronic balance. Total weight (TW), ovary weight and macroscopic maturity stages were recorded for each fish sampled ($n = 950$). A macroscopic maturity scale of seven stages was employed for both sexes: (1) virginal, (2) immature, (3) incipient maturity, (4) advanced maturity, (5) spawning, (6) spent and (7) resting (Christiansen & Cousseau 1971). The ovaries sampled were separated and fixed in 10% formalin.

Laboratory analysis of preserved samples

Histological preparations. A portion of tissue of the fixed ovaries was removed, dehydrated in ethanol, cleared in xylol and embedded in paraffin. Tissue samples were sectioned at 4 μm , stained with Harry's haematoxylin followed by eosin counterstain. Histological classification of ovaries was adapted from Mayer et al. (1988) and the terminology used in the description of oocyte stages was based on Wallace and Selman (1981).

Whole preserved oocytes. Formalin preserved samples (ovaries in stage 4) were used to obtain the oocyte size frequency distributions. After fixation, 24 ovaries in advanced maturity (< specimens collected between 2004 and 2006) were stored for 3–5 days in ethanol 70 $^{\circ}$. A total of 110 oocytes per ovary were removed from the anterior, middle and posterior parts of gonads, placed in water, and the longest axis was measured with an ocular micrometer.

Potential fecundity estimation, Gonadosomatic index and length at first maturity (L_{50})

The potential fecundity (PF) was estimated employing 24 ovaries in advanced maturity (stage 4), stored in ethanol 70 $^{\circ}$ after fixation. These ovaries showed no evidence of recent spawning (no post-ovulatory follicles were observed). The procedure used was to remove three pieces of ovary of approximately 0.1–0.2 g each, from the anterior, middle and posterior parts of the gonad. Later each sample was rehydrated, weighed with an analytical balance (± 0.0001 g) and yolked oocytes counted. Consequently, PF was estimated as the product between the mean number of yolked oocytes per ovary gram (Y_0/g) and the ovary weight (Ow).

A potential model was fitted to the relationships between PF-standard length and PF-total weight, according to Kartas & Quignard (1984). Gonadosomatic Index (GSI%), estimated as gonad weight divided by body weight ($\times 100$), was analysed in relation to the annual cycle and stages of maturity.

To estimate length at first maturity, 381 males and 529 females were analysed for maturity stage determination. Later, individuals were classified as immature or mature (macroscopic stage 3 or higher) and grouped in 1-cm length classes. A logistic model was fitted to the proportion of mature individuals by total length class using the maximum likelihood method, and also an asymptotic test for equality of coefficients was performed (Kendall & Stuart 1967).

Results

Stages of oocyte development

During the period analysed the following stages were observed: (A) oogonias, (B) primary growth oocyte, (C) cortical alveolus stage, (D) yolked oocytes, and (E) atretic follicle (Table I; Figure 2).

Gonad maturity stages

Five of the seven stages of gonad maturity were macro- and microscopically stated during this study.

1. Virginal. Very small ovaries, less than 1 g of weight, translucent with a thin tunic (capsule). At the microscopic level only oogonias (Figure 2A) and incipient primary growth oocytes were observed. Few specimens were found in this stage, probably due to the mesh size of the gill-nets employed.
2. Immature. This stage was observed practically during the whole year. Swollen small ovaries, with weights between 1 and 3 g. Pink colour and thin tunic. At microscopic level primary growth oocytes (Figure 2B) with compact and organized lamellar structure were observed.
3. Incipient maturity. Ovaries reach weights of 10–20 g, and can attain the third part of the abdominal cavity. Colour from pale yellow to dark yellow. Ovaric arteries can be observed. Two stages of oocyte development occur at the microscopic level: primary growth oocyte and cortical alveoli oocyte (Figure 2C).
4. Advanced maturity. Ovaries attain half to three-quarters of the abdominal cavity with weights between 30 and 280 g. Colour dark yellow to orange with prominent ovaric artery. Oocytes were discernible to naked eye. Histology reveals

Table I. Descriptions of each stage of oocyte development and atretic follicles.

Stage	Microscopic characteristics
A. Oogonias	Small cells, with 4–7 μm diameters. Large nucleus of central location rounded and with lax chromatin, surrounded by scarce cytoplasm. These cells were only observed in virginal or immature specimens.
B. Primary growth oocytes	Larger than oogonias (50–250 μm diameter). With polyhedral shapes and rounded-central nucleus. These cells showed 1–9 prominent nucleoli and basophilic cytoplasm.
C. Cortical alveoli	In this stage of development, the endogenous vitellogenesis starts. With diameters between 200 and 300 μm , the oocytes begin to lose their basophilic characteristics. Nucleus still large and with peripheral nucleoli. Small vesicles, called cortical alveoli, appear first, surrounded the nucleus and then dispersed throughout the cytoplasm. The radiata zone is visible and also the follicular layer (granulosa and teca cells).
D. Yolked oocytes	Oocytes of 350–700 μm diameter. Eosinophilic yolk protein granules present throughout the cytoplasm. Although less frequent, lipid vesicles are observed dispersed between the yolk granules. Zona radiata thick, striated and highly eosinophilic. The follicular cells become notorious.
E. Atretic follicle	Characterized by autolysis of follicular components and the presence of phagocytes inside the follicles.

primary growth (scarce) and yolked oocytes (Figure 2D,E).

- Resting. Ovaries showed a thick tunic (Figure 2F), more flaccid than the other stages, colour reddish or greyish with weights between 4 and 10 g. Primary growth oocytes were observed and, eventually, some nest of oogonias.

No spawning (stage 5) or spent females (stage 6) were detected during the study period.

Frequency distribution of oocyte diameters

The size distribution of formalin-preserved oocytes was bimodal (Figure 3), with one mode in 0.1 mm corresponding to unfolled oocytes (primary growth), and a second group between 0.35 and 0.75 mm diameters with a mode in 0.5 mm confirmed by yolked oocytes.

Potential fecundity (PF)

The PF ranged between 1,026,000 and 2,548,000 yolked oocytes with a mean of around 1,800,000 ($\pm\text{SD}$) oocytes, estimated for 24 females between 410 and 475 mm standard length (SL). The number of yolked oocytes per gram of ovary was 13,201 in average, ranging between 7440 and 25,758.

A potential relationship was fitted between PF and SL, with a tendency to increase fecundity with the body size. A similar model was fitted to the relationship PF versus total weight (data not shown). Although r^2 values were not high (0.53 and 0.44, respectively), high Pearson correlation coefficients between fecundity–standard length

and fecundity–total weight indicate that potential fecundity was size-dependent (Table II). It is noticeable that females in advanced maturity with total length minor of 500 mm (414 mm SL) were not observed, thus indicating the large size of mature females.

Length at first maturity (L_{50})

Comparison of the logistic models estimated for the relationship between the proportion of mature individuals and the length class (Figure 4) and also the asymptotic test for equality of coefficients showed significant differences between sexes ($P < 0.05$), with L_{50} values of 439 mm total length (TL) and 454 mm TL obtained for males and females, respectively. This result suggests that males of *M. platanus* mature at a smaller size than females. The smallest maturing female was 420 mm TL while the smallest male in mature condition was 390 mm TL. 100% maturity was attained at 510 mm TL in females and at 490 mm TL in males (Figure 4).

Ovarian cycle and capture per unit effort (CPUE)

Analysis of the annual gonad cycle showed four of the seven maturity stages employed for *M. platanus* (Figure 5). The co-occurrence of resting and incipient/advanced maturity stages in adult specimens of this species is noticeable. Two peaks of maturity were observed during the annual cycle for 2004–2006, the principal one in April–May and the second in November–December (Figure 5). The peak of July 2006 constituted by specimens in incipient maturity, was not considered because most of the individuals had a high proportion of atresia, thus

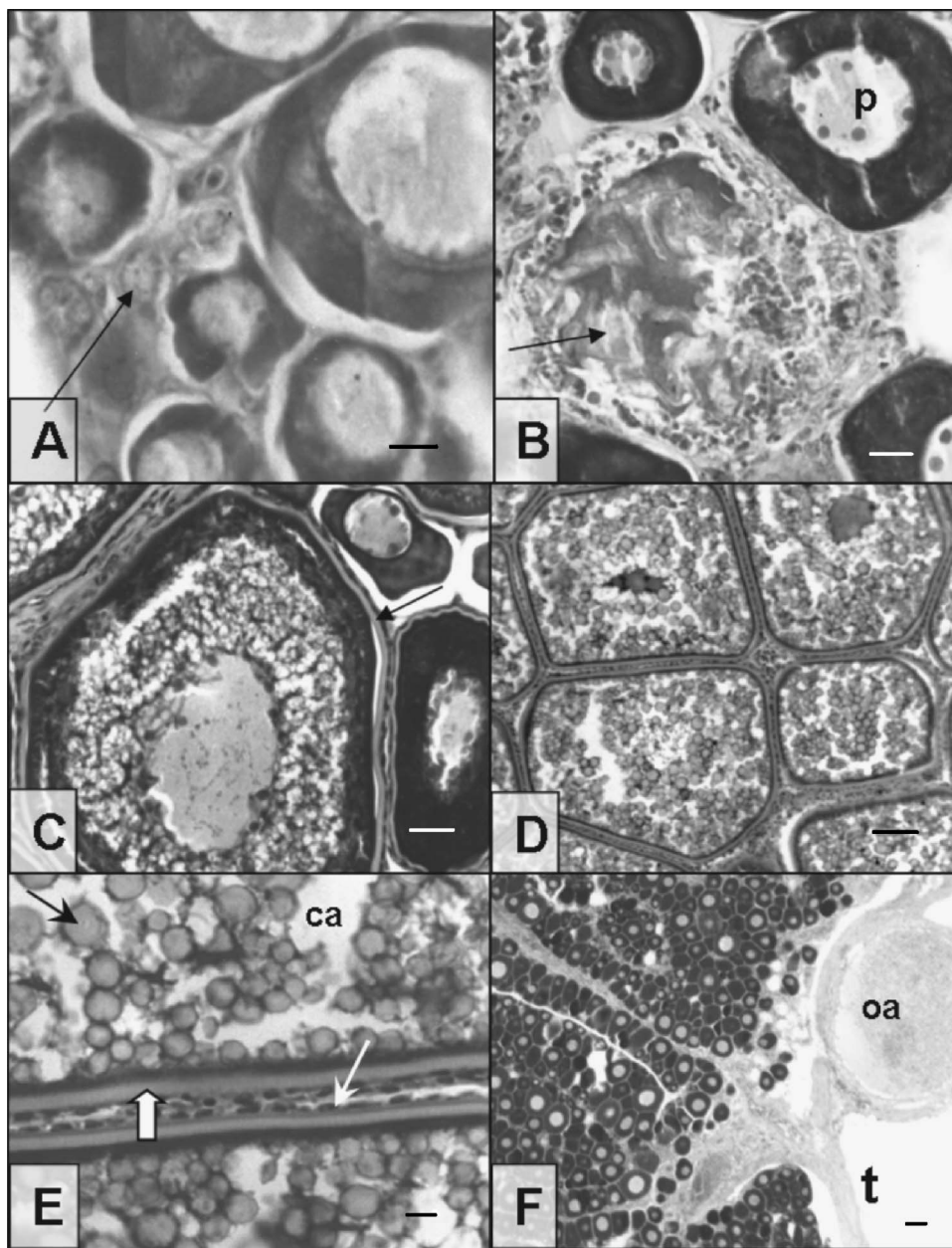


Figure 2. **A**, oogonias (arrow); **B**, atretic follicle (arrow) and primary growth (p) oocytes; **C**, cortical alveoli stage oocyte (arrow); **D**, yolked oocytes; **E**, details of a yolked oocyte (black arrow: yolk granule; ca: cortical alveoli; white thick arrow: radiata zone; white thin arrow: follicular cells); **F**, resting ovary (t: tunica; oa: ovarian artery). Scale bars: A, 10 μm ; B, 10 μm ; C, E, 20 μm ; D, F, 100 μm .

they may represent non-migrant specimens. Resting females were basically registered during 2005–2006 (Figure 5), with peaks in April–May 2005 and June–July 2006. Juveniles were recorded along the year, but with two modes in autumn and summer (Figure 5).

The relative abundance of *Mugil platanus* between 2005 and 2006 (when the major fishing effort was done) was estimated by the capture per unit effort (CPUE) and plotted against salinity and water temperature (Figure 6). For both years, it can be observed that the highest CPUE values occur

between April and May. After that, the CPUE values decreased, which may be explained by the sudden drop in water temperature in the region that seems to trigger the reproductive migration of *Mugil platanus* from the lagoon to the sea.

Gonadosomatic index (GSI)

Mean values of GSI estimated for each maturity stage in females showed significant differences as revealed by ANOVA ($P = 0.00$; $F = 2.6$). The

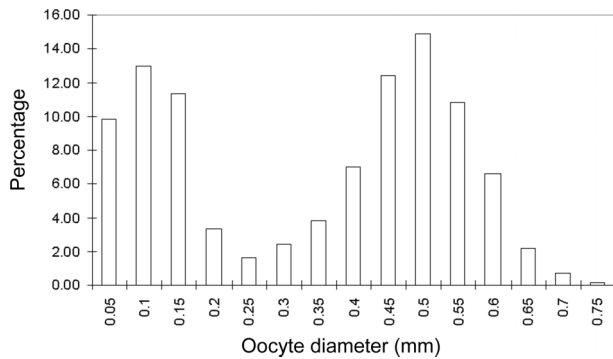


Figure 3. Frequency distribution of oocyte diameters ($N = 3100$ oocytes measured).

Table II. Pearson correlation coefficients, with significance values, for the morphological variables and fecundity of *Mugil platanus* in Mar Chiquita coastal lagoon from 2004 to 2006. SL: standard length; TW: total weight; FEC: potential fecundity.

	SL	TW	FEC
SL			
Pearson correlation	1	0.942(**)	0.745(**)
Sig. (2-tailed)		0.000	0.000
TW			
Pearson correlation	0.942(**)	1	0.683(**)
Sig. (2-tailed)	0.000		0.000
FEC			
Pearson correlation	0.745(**)	0.683(**)	1
Sig. (2-tailed)	0.000	0.000	

**Correlation is significant at the 0.01 level (2-tailed).

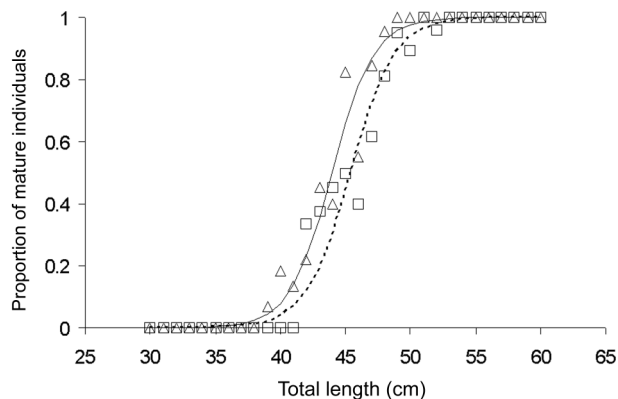


Figure 4. Proportion of mature individuals observed for each length classes of *Mugil platanus*. Females (open squares): $L_{50} = 45.40$ cm; $N = 495$. Males (open triangles): $L_{50} = 43.95$ cm; $N = 373$.

mean GSI was ≤ 1 during 6 months of the year (January, June–October), but it increases during the ovarian maturation attained between February–May and November–December (Figure 7). In the advanced maturity stage, females showed ovaries

well-developed (40–200 g of ovary weight), reaching GSI values between 1.8 and 15.7 (data not shown).

Discussion

Recently, González Castro et al. (2009a) presented the first hypothetical model for the life history of the adult stock of *Mugil platanus* from Mar Chiquita Coastal Lagoon. The present work represents the first contribution about the reproductive biology of this species in Argentina.

It is evident that mugilids, after its resting and maturing periods in coastal lagoons, estuaries or related environments, perform its reproductive migration towards the sea (Wijeyaratne & Costa 1988; Vieira & Scalabrin 1991; Ibáñez & Gutiérrez-Benitez 2004; Fazli et al. 2008; Kendall & Gray 2008; González Castro et al. 2009a).

At present there is no information about location of the *Mugil platanus* spawning areas, corroborated with suitable histological evidence (hyaline oocytes/post-ovulatory follicles). According to Vieira and Scalabrin (1991), this species becomes fully sexually developed during its migration and reproduction would occur in offshore waters between North of Río Grande do Sul and North of Santa Catarina, principally between May and August at water temperatures of 19–21°C. These authors indicated that the sudden drop of temperature between March and June triggers the reproductive migration of the striped mullet, at least from Los Patos lagoon. Also, Vieira et al. (2008) indicated that near-zero salinity at the estuarine area along several months during strong El Niño events could lead to higher spatial dispersion of the maturing mullet during their migration to the ocean, resulting in smaller shoals of individuals and consequently, lower catches by artisanal fishermen. In the present work the decrease of temperature below 20°C from March to August, when it started to recover again was corroborated. Accordingly, the highest CPUE occur in April–May, while the sudden drop in temperature was observed in May–June. Therefore this environmental variable could be the factor that starts the reproductive migration of *Mugil platanus* from Mar Chiquita coastal lagoon towards the sea.

The L_{50} values estimated for males (43.9 cm TL) and females (45.4 cm TL) of *Mugil platanus* were higher than that reported for females of the same species (412 mm TL $N = 109$) in Baía de Paranaguá, Brazil (Esper et al. 2000). This variation may be related to different causes: the dissimilar sample size used in both works, population intraspecific variation due to genetic/environmental factors, or 'fishery pressure' (Vazzoler 1996) which is higher in Brazil

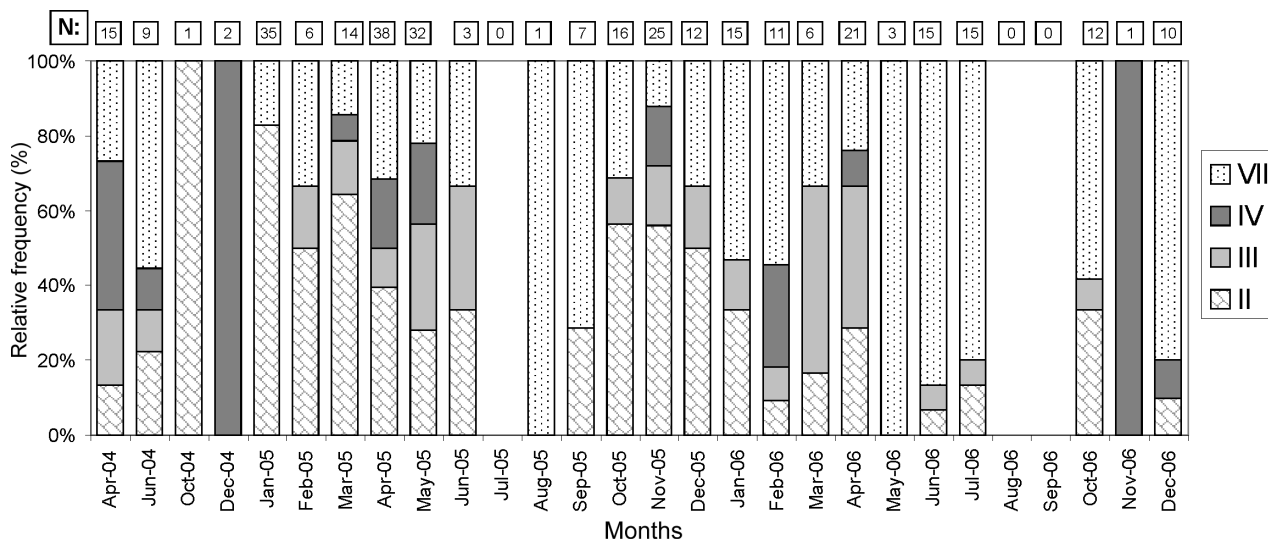


Figure 5. Monthly percentage contributions of the different gonadal development stages observed in females of *Mugil platanus* between 2004 and 2006. Virginal stage was not considered here. $N = 325$.

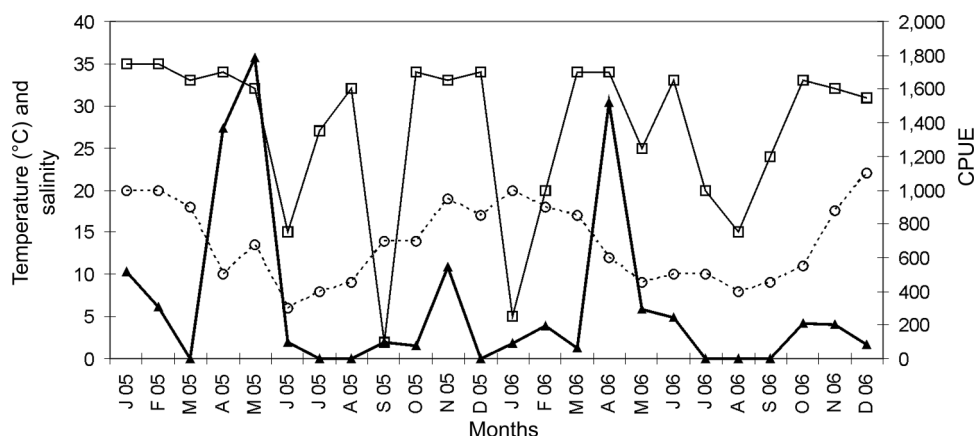


Figure 6. Captures per unite effort (CPUE, in kg/h) and relationships with temperature and salinity obtained for *Mugil platanus* during 2005–2006 for Mar Chiquita coastal lagoon. Black triangles: CPUE; open squares: salinity; open circles with dotted line: water temperature.

than in the surveyed area. Comparison between these values and those obtained for other mugilids indicate that *Mugil platanus* L_{50} shows notoriously higher sizes at sex maturation (Table III). When a relationship between maximum length and L_{50} was established for these species, the highest percentage corresponded to *Mugil platanus* (75%).

The PF estimates ranged between 1,026,000 and 2,548,000 oocytes/female, with a mean value of 1,840,000. Romagosa et al. (2000) analysed females of *Mugil platanus* in the Cananea lagoon (Brazil), obtaining fecundity values between 550,800 and 2,360,000 oocytes, with a mean of 1,040,692 oocytes. The lower values obtained by the Brazilian authors could be due to the fact that they estimated PF by counting oocytes higher than 470 μm diameter; in the present work we include vitellogenic

oocytes higher than 400 μm diameter in PF estimation.

The frequency distribution of oocytes diameters indicates that *Mugil platanus* is a two-group synchronic spawner (*sensu* Vazzoler 1996) or a group-synchronous *sensu* Wallace and Selman (1981). This implies that mature females of this species have two batches of oocytes at the same time: a fairly synchronous group of larger oocytes (defined as a ‘clutch’) and a stock of smaller oocytes from which the clutch is recruited (Figure 3). Accordingly, it is noticeable that, at least for the species summarized in Table III, all mugilids shared a bimodal oocyte distribution (which implies that these species are total spawner or partial spawner with annual determinate fecundity, in accordance with the classification of Hunter et al. (1992)) and a migratory behaviour

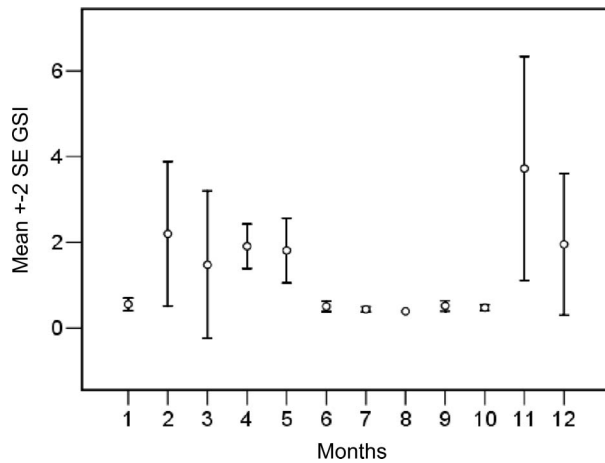


Figure 7. Monthly variation of the mean gonadosomatic index (GSI), based on an annual cycle. Bars denote standard error (SE).

thus suggesting/reflecting a conservative reproductive pattern, from an evolutionary point of view. The sizes measured for yolked oocytes were similar in the species summarized, usually ranging between 300 and 700 μm of diameter (Table III). The variation in the data observed for the works dealing with *Mugil cephalus* could be related with the sampling time in the reproductive season. Su & Kawasaki (1995) recorded oocytes with a range of 600–900 μm by collecting specimens during the spawning season; in comparison, Silva & De Silva (1981) registered oocytes between 360 and 648 μm , but the samples were collected inside the Negombo Lagoon, prior to the reproductive migration.

Analysis of the data concerning the spawning period (Table III) showed that normally, most mugilid species reproduce in autumn–winter. Under this approach, the spawning would occur in a suitable epoch allowing larvae to use the higher temperatures of spring–summer to migrate backward, feed and grow.

The GSI data obtained for the species compared in Table III ranged between 0.8–9.0% (maturing specimens) and 5.0–40.0 (mature individuals) (data not shown). The GSI individual values obtained for the present work (advanced maturity stage specimens) ranged between 1.8 and 15.7% and were registered in April–May and November–December. These values were similar between the compared species, with the exception of the highest GSI value (40.0%) obtained by Ibáñez-Aguirre & Gallardo Cabello (2004) for *Mugil cephalus* mature specimens.

The presence in Mar Chiquita lagoon of adult specimens in resting stage during the whole year, in co-occurrence with females in advanced maturity (April–May, November–December) is remarkable.

Esper et al. (2001) mentioned the presence of specimens in a macroscopic stage called by the authors as B1 (incipient maturity) along the study period (1985–1986), but omit the dynamics of resting specimens. However, Chang et al. (2004) investigated the Sr:Ca ratios in otoliths of *Mugil cephalus* of Taiwan; they showed that the migratory environmental history of the mullet beyond the juvenile stage consists of 2 types. In Type 1 mullet, the high Sr:Ca ratios indicated that they migrated between estuary and offshore waters but rarely entered the freshwater habitat. In Type 2 mullet, the low Sr:Ca ratios indicated that the mullet migrated to a freshwater habitat. Most mullet collected nearshore and offshore were of Type 1, while those collected from the estuaries were a mixture of Types 1 and 2. The mullet spawning stock consisted mainly of Type 1 fish. These facts could explain the co-occurrence of resting/advanced maturity stages found in the present work.

There is no reference in Brazilian literature about the existence of females of *Mugil platanus* in advanced sexual maturity during November–December. Although in a small number of specimens, we observed this fact uninterruptedly during 2004–2006. Chang et al. (2000), based on recruitment and hatching date studies of *Mugil cephalus* juveniles for the Tanshui estuary (Taiwan), suggest that two reproductive populations would coexist: a resident (that would reproduce locally) and a migrant one. This hypothesis could explain the two maturity peaks observed for the Mar Chiquita lagoon, the main in April–May and the minor in November–December, and the coexistence of resting and maturity stages. However, if this hypothesis is true, spent females (with recent post ovulatory follicles) should be found in the nearby region of the lagoon. No ovaries have ever been found in this maturation stage.

Another hypothesis may be the arriving of migrant adults from higher latitudes than the Mar Chiquita coastal lagoon; taking into account that *Mugil platanus* inhabit at least until 43° S (Cousseau et al. 2005; González Castro et al. 2008) it is expected that southern populations, that inhabit under dissimilar environmental conditions (i.e. water temperature, sea currents, winds), performed its reproductive migration at a different epoch compared with the mullets of Mar Chiquita lagoon.

Therefore, to corroborate some of these hypotheses, future studies should include information about migration of *M. platanus* from the Mar Chiquita lagoon (obtained for example by means of mark-recapture methods, or Sr:Ca ratios), as well as histological analysis of gonads of the southern populations of this species.

Table III. Reproductive parameters comparison between different species of Mugilidae. (FL: fork length).

Author	Species	Locality	L50 (mm)			Annual potential fecundity			Oocyte diameter distribution	Reproductive period
			Female	Male	Average	Range	Average	Range		
Present work	<i>M. platanus</i>	Mar Chiquita lagoon, Argentina	450	436	1,800,000	1.0–2.5 × 10 ⁶		Bimodal (400–700 μm)	Jun–Sept?	
Romagnosa et al. 2000	<i>M. platanus</i>	Canancia lagoon, Brazil	–	–	1,040,000	0.55–2.36 × 10 ⁶		Bimodal (300–600 μm)	Aug–Oct	
Silva & De Silva 1981	<i>M. cephalus</i>	Negombo lagoon, Sri Lanka	315	340	–	0.45–4.8 × 10 ⁶		Bimodal (360–648 μm)	Jan–May	
Su & Kawasaki 1995	<i>M. cephalus</i>	Taiwan, western coast	–	–	–	0.51–3.0 × 10 ⁶		Bimodal (600–900 μm)	Nov–Jan	
Ibáñez-A. & Gallardo- C. 2004	<i>M. cephalus</i>	Gulf of Mexico, Mexico	377	373	–	0.54–1.48 × 10 ⁶		–	Nov–Feb	
Mc Donough et al. 2005	<i>M. curema</i> <i>M. cephalus</i>	South Carolina estuaries, EEUU	278 325	274 275	–	0.08–0.38 × 10 ⁶		–	Feb–May Nov–Jan	
Hotos et al. 2000	<i>Liza aurata</i>	Klisova lagoon, Greece	–	–	–	0.08–1.41 × 10 ⁶		Bimodal (550–850 μm)	Aug–Nov	
Fazli et al. 2008	<i>Liza aurata</i>	Caspian sea, Iran	260 (FL)	–	451,963	0.11–1.47 × 10 ⁶		–	Oct–Dec	
Ünlü et al. 2000	<i>Liza abu</i>	Tigris River, Turkey	127 (FL)	124 (FL)	21,641	0.012–0.056 × 10 ⁶		Bimodal (300–500 μm)	March?	
Ergene 2000	<i>Liza ramada</i>	Akgöl- Paradeniz Lagoons, Turkey	–	–	–	0.12–0.44 × 10 ⁶		Bimodal? (410–590 μm)	Dec–Feb	
Kendall & Gray 2008	<i>Liza argentea</i>	Lake Macquarie and St. Georges Basin, Australia	207 (FL)	180 (FL)	321,206	0.16–0.55 × 10 ⁶		Bimodal (400–600 μm)	Mar–Nov?	
Wijeyaratne & Costa 1988	<i>Myxus elongatus</i> <i>Valamugil cummesius</i>	Negombo lagoon, Sri Lanka	255 (FL) 160	230 (FL) 169	726,636	0.42–1.16 × 10 ⁶ 0.08–0.14 × 10 ⁶		Bimodal (300–600 μm) Bimodal	Jan–Mar? May–Aug?	

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