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Reproductive biology of the marine catfish, *Genidens genidens* (Siluriformes, Ariidae), in the Jacarepaguá Lagoon system, Rio de Janeiro, Brazil

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Synopsis

Genidens genidens was sampled at the Jacarepaguá Lagoon system (23° S, 43° W), Rio de Janeiro State, Brazil, using cast nets and beach seines, to study its reproductive biology. Spawning period extended from October to February, but was more intense from December to January, coinciding with high surface water temperature and low salinity in the area. After spawning, males mouthbrood the eggs for two to three months until development is completed. Mean length at first maturity for females was approximately 180 mm TL, and at 250 mm TL, all females were mature. Batch fecundity was very low, ranging from 7 to 30 eggs for fish with 170 mm TL (37.0 g TW) to 228 mm TL (104.0 g TW), respectively, and was linearly related to fish total length and total weight. Sexual dimorphism starts after sexual maturity, with females having relatively longer pelvic fins than males. Both sexes exhibited very low condition during the spawning season, probably due to changes in feeding activity related to the reproductive cycle. A strong predominance of males during the main spawning/brooding period suggests that females migrate from the area after spawning is completed.

Introduction

The marine catfish, *Genidens genidens* (Valenciennes), occurs along the east coast of South America, from Guyana to Argentina, and is one of the most common catfish species along the Brazilian coast (Figueiredo & Menezes 1978). It inhabits shallow coastal waters with muddy or sandy bottoms and is especially abundant in estuaries and coastal lagoons (Volcker & Andreata 1982, Araújo 1983, Chao et al. 1985, Andreata et al. 1989). In the Jacarepaguá Lagoon system in southeastern Brazil a small-scale cast net fishery exploits this species commercially, but no catch records are presently available.

Despite its wide distribution and abundance along the Brazilian coast, little is known about the reproductive biology of this catfish. Previous studies have reported distribution, abundance and movements (Silva 1982, Mishima & Tanji 1981, 1983a, Araújo 1983), feeding habits (Mishima & Tanji 1982, Araújo 1984) and aspects of fisheries (Reis 1986a). Mishima & Tanji (1983b, 1985) described the reproductive biology of several species of Ariidae in a lagoon-estuarine system in southeastern Brazil, but the small number of *G. genidens*

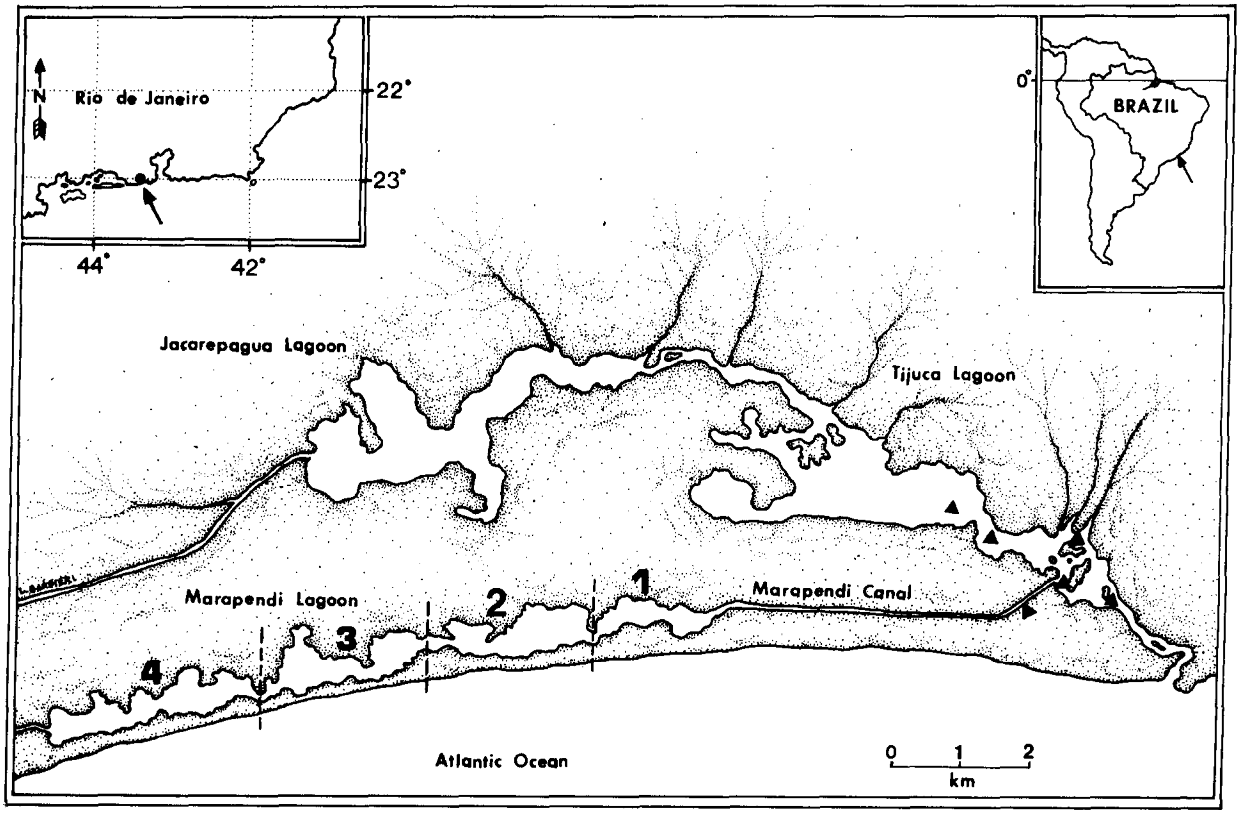

Fig. 1. Map of the study area, Jacarepaguá Lagoon system, Rio de Janeiro State, Brazil. The black triangles represent fixed stations in the Tijuca Lagoon and Marapendi canal. Areas 1–4 represent longitudinal strata used for the stratified random sampling design in the Marapendi Lagoon.

sampled prevented detailed studies on spawning periodicity, fecundity and brood care. The aim of this paper is to present additional information on the reproductive biology of *G. genidens*, including results on spawning, fecundity, brood care, sexual dimorphism, fish condition and sex ratio.

Study area

The Jacarepaguá Lagoon system (Fig. 1) represents a group of interconnected shallow, brackish water basins situated along the coast of Rio de Janeiro State (23° S, 43° W), in southeastern Brazil. The system's only communication with the adjacent ocean is made through a narrow channel 50 m wide and 4–5 m deep situated at the eastern side of the Tijuca Lagoon. Marginal vegetation consists primarily of fringing mangroves (*Rhizophora mangle, Languncularia racemosa* and *Avicennia* spp.) and sea grass beds (*Ruppia maritima*). No major rivers drain into the system; land drainage is through small creeks and canals.

Surface water temperature followed a regular seasonal cycle during the sampling period (Fig. 2). Lowest values were recorded from late fall to early winter (May–June) and highest values during the summer (December–February). As expected for tropical latitudes, the annual temperature range was generally small (20.8° C–31.2° C). Due to the small inlet and reduced inflow of oceanic waters, salinity fluctuations in the system were mainly related to seasonal variations in rainfall. Lowest values were recorded from late spring to early summer (November–February) when heavy summer rains usually increase land drainage. Further information on the system's fish community and details on the environmental conditions of individual lagoons

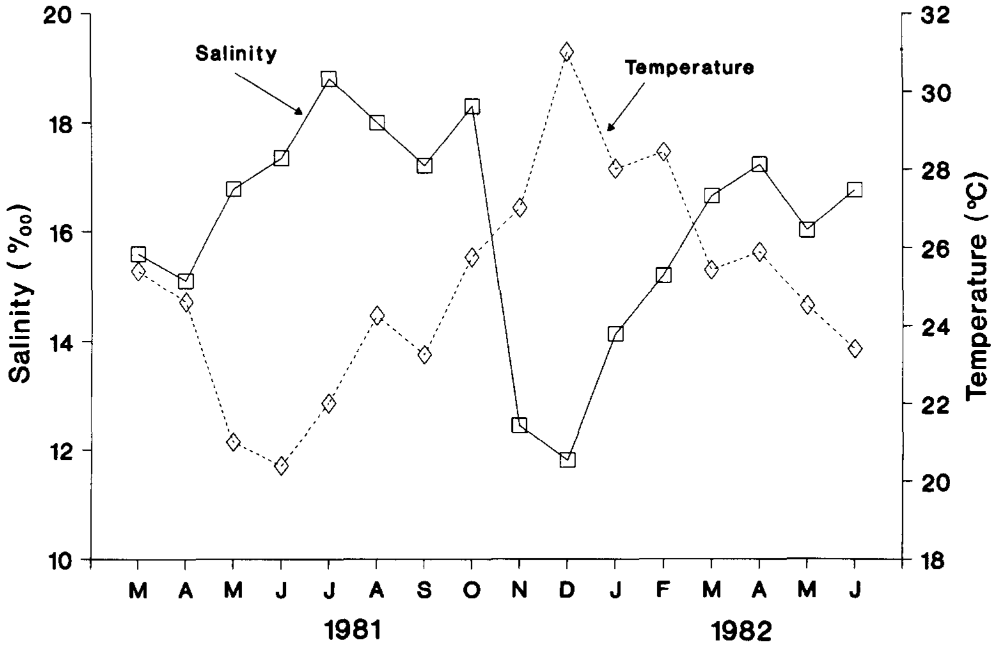

Fig. 2. Monthly distribution of surface water temperature, and surface salinity in the Jacarepaguá Lagoon system from March 1981 to June 1982.

can be found in Volcker & Andreata (1982) and Andreata et al. (1989).

Materials and methods

Between July 1980 and June 1982 a total of 1166 specimens of *G. genidens* was sampled at the Tijuca and Marapendi Lagoons using cast nets and beach seines. At the Tijuca Lagoon and Marapendi Canal (Fig. 1) six fixed stations were sampled weekly using a 2 mm diameter cast net with 20 mm bar mesh size. At the Marapendi Lagoon a stratified random sampling design was used with the total area divided into four longitudinal strata (Fig. 1, areas 1–4) and three cross-sectional substrata (north shoal, channel and south shoal). Six randomly assigned stations were then sampled every two weeks in each area using the same cast nets described above and a 5 m long, 1.4 m high, 15 mm bar mesh size beach seine. From March 1981 to June 1982 surface water temperature and salinity were also recorded at each station.

Individuals were processed fresh, for total length (TL), measured from snout to the end of the caudal fin, total weight (TW), gonad weight (GW), and sex. We also measured pelvic fin length (PL = distance from the fin base to its farthest tip), on 49 females and 54 males. Ovary maturity stages were assigned as: I, immature/resting; II, developing; III, ripe/spawning, and IV, spent, according to Vazzoler (1981). Batch fecundity was estimated by counting the total number of mature (hydrated) eggs in both ovaries. Only fish showing no signs of previous spawning were used for batch fecundity estimates. The number of eggs or embryos in the mouth of brooding males was also recorded, although we do not discard the possibility that some eggs or embryos might have been expelled by brooding males at the time of capture. Gonadosomatic indices (GSI) were calculated for individual fish as:

$$GSI = 100\ (GW/(TW-GW).$$

The mean length at first maturity (L_{50}) for females was determined by the 10 mm length interval when 50% of the individuals captured during the spawn-

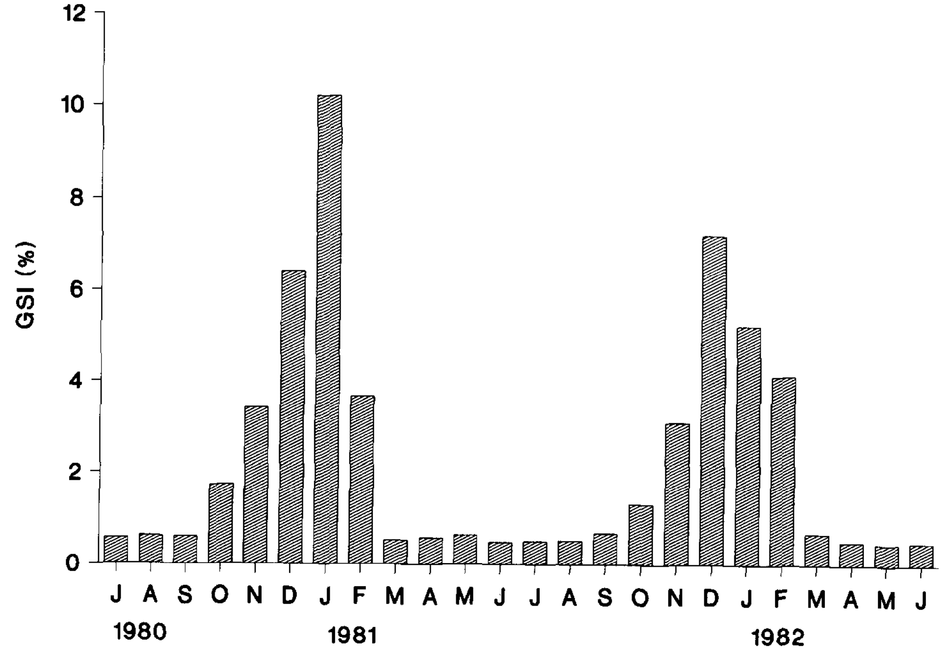

Fig. 3. Monthly distribution of the mean gonadosomatic index (GSI) for female *Genidens genidens* in the Jacarepaguá Lagoon system (July 1980–June 1982, N = 346).

ing period were mature (gonad stages II–IV as defined above). For analysis of fish condition, a modified version of Fulton's condition factor (Bolger & Connoly 1989) was determined for individual fish as:

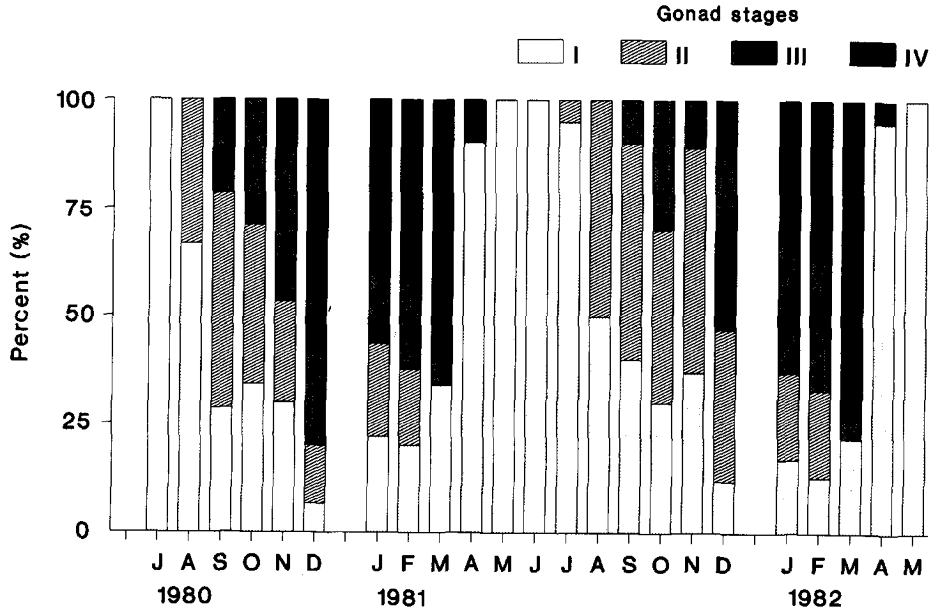

Fig. 4. Monthly frequency distribution of gonad maturity stages for female *Genidens genidens* in the Jacarepaguá Lagoon system (July 1980–May 1982, N = 814).

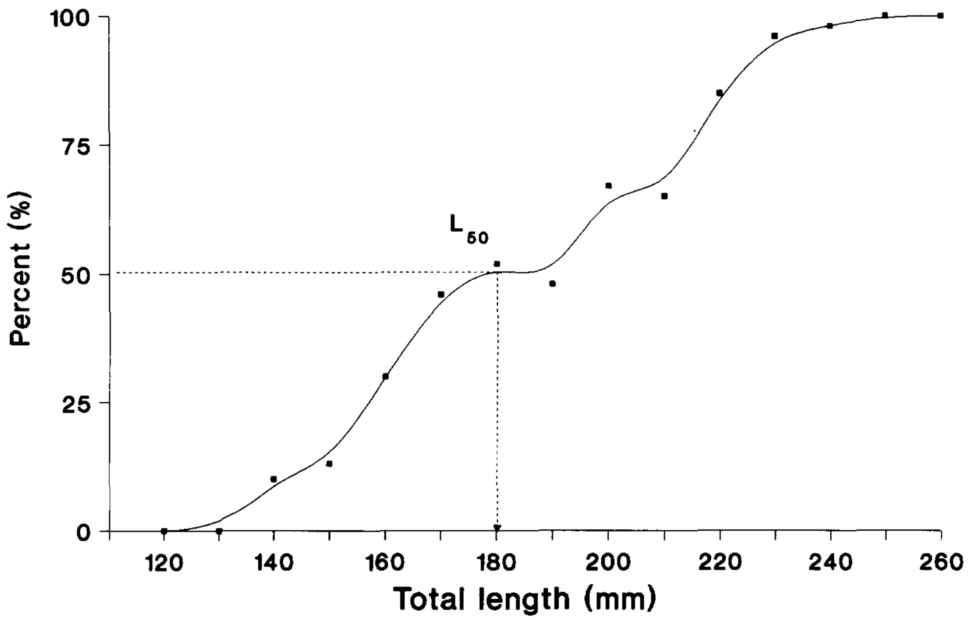

Fig. 5. Proportion of mature female *Genidens genidens* by 10 mm total length class intervals during the spawning season. L_{50} represents the mean size of first maturity (N = 346).

$$K' = (TW-GW)/TL^3.$$

The use of gonad-free body weight in estimating K′ attempts to reduce biases associated with variations in total weight caused by changes in gonad weight instead of somatic weight.

Statistical analyses were performed using the Statistical Analysis System (SAS 1988). All regressions were calculated by standard procedures (Draper & Smith 1981). Original data were sometimes $\log_{10}$ transformed to meet the assumptions of statistical models.

Results

Spawning periodicity and size-at-maturity

Spawning period for *G. genidens* was determined by the monthly mean gonadosomatic index (Fig. 3), and by the monthly frequency distribution of gonad maturity stages for females (Fig. 4). During both reproductive seasons GSI values began to increase in October and reached maximum values in December–January coincident with high water temperatures and low salinity in the area (Fig. 2). Frequency of gonad maturity stages agree well with GSI results. Gonad maturation started in August and increased in September and October, but it was not until November–December that we captured females with spent ovaries, indicating no actual spawning before November. The proportion of ripe and spent fish from January–April indicates that spawning continued at least until March.

Females began to mature at approximately 140 mm TL (Fig. 5), attaining the mean length at first maturity (L_{50}) at 180 mm TL, and at 250 mm TL all individuals were mature.

Based on the L_{50} and assuming knife-edge maturation at this length, females were then classified as small (140–180 mm TL) or large (> 180 mm TL) and the monthly mean GSI for each group reanalyzed. In both years larger females began spawning one to two months earlier and seemed to have a more protracted reproductive period than smaller females.

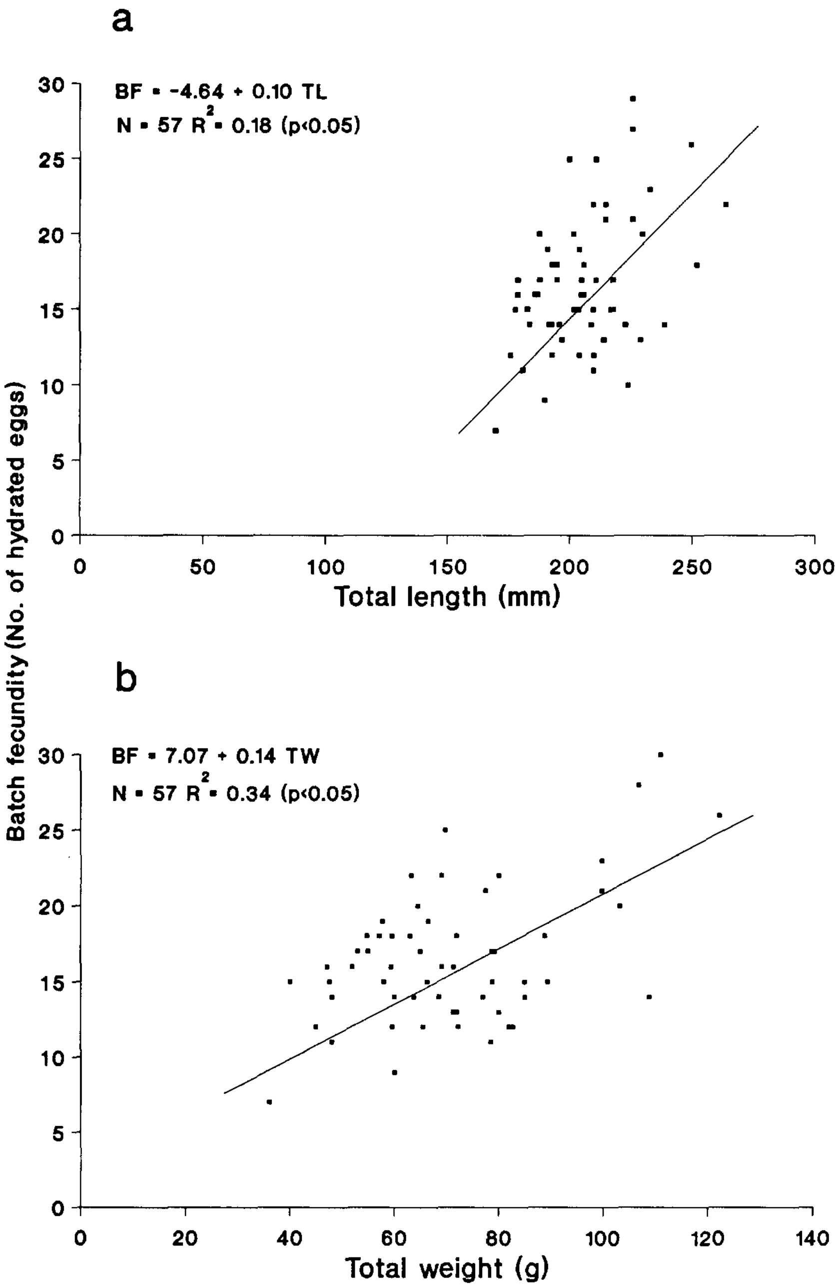

Fig. 6. Relationship between batch fecundity and (a) total length and (b) total weight for *Genidens genidens* in the Jacarepaguá Lagoon system.

Fecundity

Three size classes of eggs can be found in the ovaries of a ripe female *G. genidens*. Large golden-yellow eggs (ca. 8–13 mm diameter), which have undergone hydration and represent the group to be actually shed at each spawning event; an intermediate group of smaller yolky, more opaque eggs (ca. 4–7 mm diameter) which will eventually develop and be spawned later in the spawning season; and a large stock of small undeveloped oocytes (1–3 mm diameter). For batch fecundity analysis we consid-

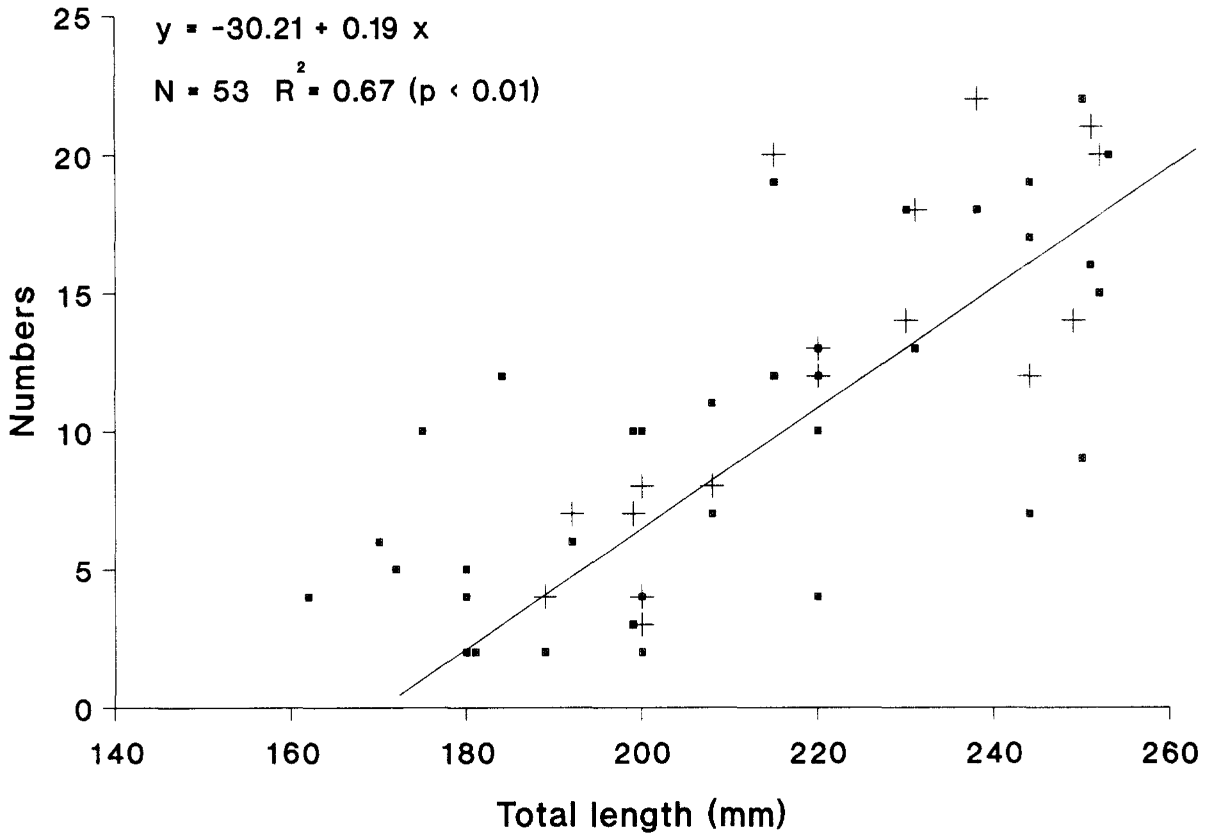

Fig. 7. Relationship between the number of eggs (small squares) or young (crosses) incubated by male *Genidens genidens* and its total length.

ered only the large, hydrated eggs. Batch fecundity ranged from 7 to 30 eggs for fish with 170 mm TL (37.0 g TW) to 227 mm TL (104.0 g TW), respectively, and was linearly related to both fish total length and total weight (Fig. 6a, b).

Brood care

In *G. genidens,* as reported for other ariids, only males mouthbrood. All the eggs, embryos or young within a batch carried by an individual male were at the same stage of development, although one or two unfertilized (or not developed) eggs were sometimes found together with normal eggs.

During the spawning season mature males showed an expansion of the hyoid region which formed a 'second chin' in the fish, probably to increase the space available to carry eggs or young. Although this presumed adaptation for mouth brooding has been observed in other species of Ariidae (Merriman 1940, Ward 1957, Dmitrenko 1970, Reis 1986b), no evidence is presently available on how it is related to the physiological alterations experienced by the fish during its reproductive cycle.

The relationship between the number of eggs or embryos incubated by an individual male and its total length was calculated for the 53 brooding males captured during the entire sampling period (Fig. 7). Despite the large variation ($R^2 = 0.67$) the regression was highly significant ($p < 0.01$), indicating that the number of eggs or young carried by a single male tends to increase linearly with fish length.

Brooding males ranging from 162 to 249 mm TL were captured from November to April. During the beginning of the spawning season (November–

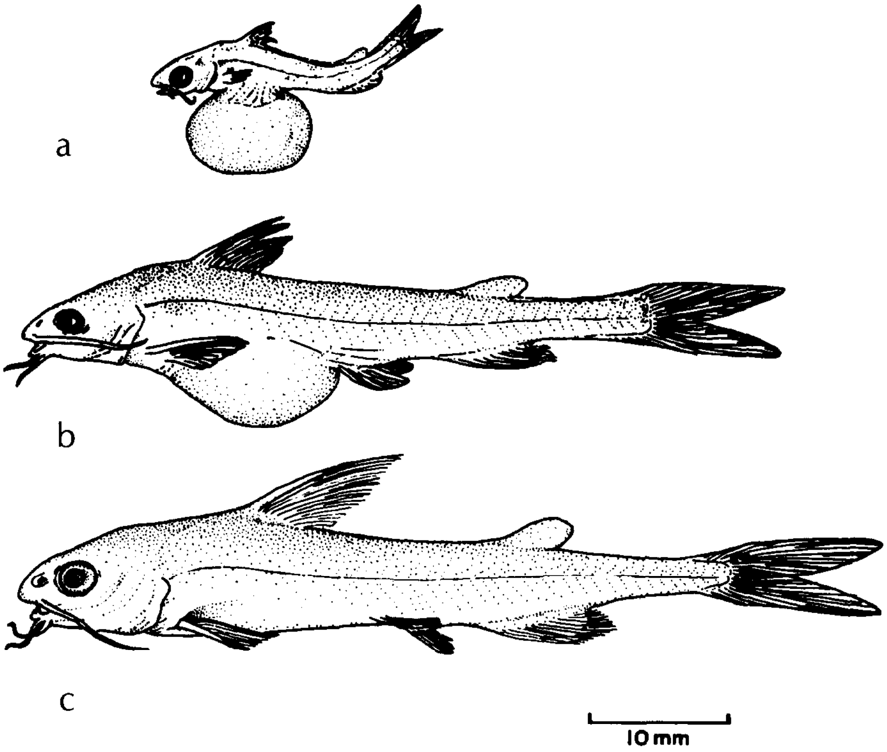

Fig. 8. Embryos and a juvenile of *Genidens genidens* at three developmental stages: a – free embryo at 25 mm TL; b – free embryo at 45 mm TL; c – free-swimming young at 55 mm TL.

December) all brooding males were carrying eggs. In January and February, the proportion of egg-carriers decreased and about half of the individuals were incubating young. At the end of the spawning season (March–April) only a small proportion of brooding males were carrying eggs. Also during this last period 162 free-swimming young ranging from 46 to 60 mm TL were caught. Although the exact incubation period could not be determined, our results suggest it lasts two to three months.

Some embryos and young obtained from brooding males were brought to the laboratory and kept in an aquarium for observations on their development and swimming ability. At 25 mm TL (Fig. 8a) the young have all the fins formed and most of the fundamental characters of the adult can be easily distinguished. Even though the young seem well-developed at this point, they do not swim well due to the large yolksac, which averages 80% of their total weight. At 45 mm TL (Fig. 8b), about half of the yolk has been absorbed and the young can swim for short periods, resting frequently on the bottom. When it reaches 55 mm TL (Fig. 8c), the yolksac has been completely absorbed and the young has only a longitudinal ventral scar due to the fusing of the abdominal walls. At these stages it swims with no apparent difficulty.

Fish condition

Variations in the physical state of *G. genidens* throughout the reproductive cycle were assessed through the distribution of the monthly mean condition factor (K′) for adult males and females (Fig. 9). Both sexes showed low body condition during the spawning/brooding season with the lowest values of K′ recorded for the period February–March. During most of the brooding season (December–March), the condition of males was noticeably less than that of females, and although no detailed stomach content analysis was performed, exam-

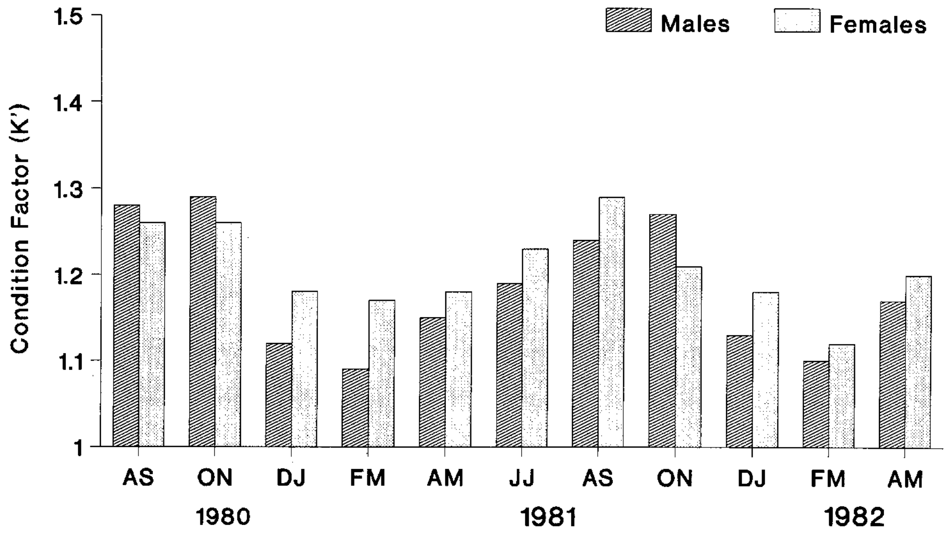

Fig. 9. Bimonthly distribution of the mean body condition factor (K′) for adult male and female *Genidens genidens* in the Jacarepaguá Lagoon system (August 1980–May 1982, N = 756).

ination of the digestive tract of brooding males showed empty stomachs and intestines, suggesting that they fast while brooding.

Sexual dimorphism

Sexual dimorphism in *G. genidens* is related to the relative size of the pelvic fins. Adult females have longer pelvic fins than adult males, but no major differences in fin shape or any clasper-like thickening of the fins were observed. The relationship between pelvic fin length and fish total length is presented in Figure 10 for males and females. Because a plot of residuals showed a strong curvilinear trend even after data were log-transformed, analysis of covariance of pelvic length on total length and sex was performed separately for small (120–180 mm TL) and large (> 180 mm TL) fish. Slopes between sexes were homogeneous for both size classes, but large fish showed a highly significant difference in mean pelvic length between sexes ($N = 67$; $F = 278.06$; $p < 0.01$), indicating that females start having longer pelvic fins at the size they reach sexual maturity.

Sex ratio

Chi-square tests were used to verify the hypothesis of 1 : 1 sex ratio for *G. genidens* during the sampled period (Table 1). A highly significant predominance of males was observed during January–February in both years and in March–April 1981, corresponding to the spawning/brooding season of *G. genidens* in the area. During the rest of the sampling period no significant differences from the expected 1 : 1 sex ratio were found.

Discussion

Spawning season and fecundity

The spawning period of *G. genidens* in the Jacarepaguá Lagoon system seems to represent the general pattern observed for other ariid catfishes. Previous studies have shown that ariids generally have a single annual spawning period corresponding to the warm season or associated with high water temperatures (Dmitrenko 1970, Yañez-Arancibia et al. 1976, Rimmer & Merrick 1983, Rimmer 1985a). Several species have also been reported incubating eggs and young or having maximum gonadal development in areas or periods of low

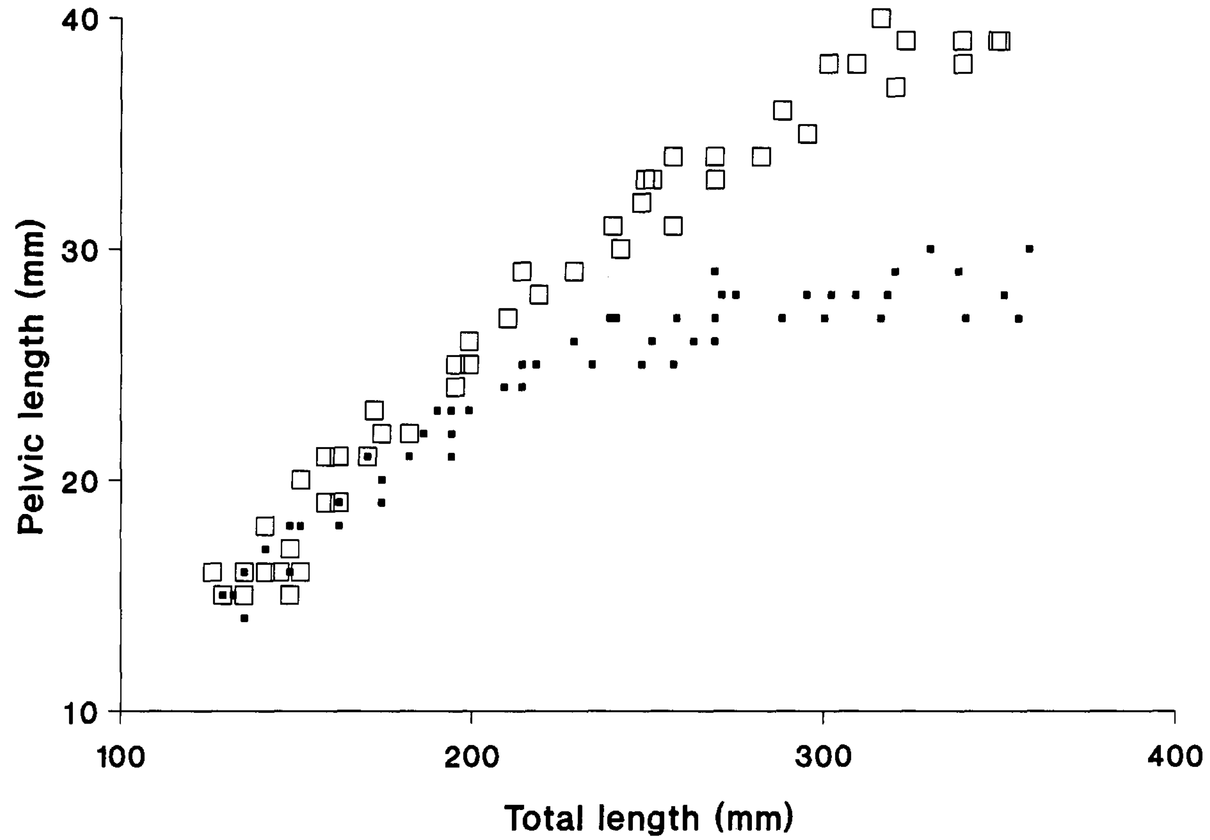

Fig. 10. Relationship between pelvic fin length and fish total length for male (small squares, N = 54) and female (large squares, N = 49) *Genidens genidens*.

salinity (Gunter 1947, Yañez-Arancibia et al. 1976, Araújo 1983, Rimmer & Merrick 1983, Reis 1986b).

The earlier onset and later cessation of spawning exhibited by larger females of *G. genidens* also has been reported for *Arius spixii* (Etchevers 1978). It suggests that during a given spawning season older females are capable of spawning a greater number of times than the younger ones. Because older females are also more fecund (Fig. 6a, b), their investment in reproduction seems to be much greater than might be inferred by batch fecundity alone. The observed increase in batch fecundity with fish length and weight, and the corresponding increase in the number of incubated eggs and embryos with brooding male length (Fig. 7) suggests, as pointed out by Coates (1988), that pairing during spawning occurs between fish of approximately equivalent size.

Although in most teleosts fecundity is expected to increase as a cube function of fish length (Bagenal 1978), the linear relationship observed in *G. genidens* seems to represent a general pattern among ariid catfishes (e.g., Etchevers 1978, Mishima & Tanji 1985, Rimmer 1985a, Reis 1986b, Coates 1988). Coates (1988) attributed this deviation to a positive correlation between egg size and fish length, since the expected cubic relationship assumes that egg size remains constant and does not vary directly with fish size. However, results reported for other species in the family contradict this interpretation. Rimmer (1985a) and Reis (1986b) found no significant relationship between egg size and fish length for two ariid species. Nevertheless, both authors found a significant linear relationship between batch fecundity and fish length. An alternative hypothesis could be that because ariids produce one of the largest eggs among teleosts (Wallace & Selman 1981), large increases in fecundity might be limited by space available in the body cavity (see discussion on fish condition below) and by the amount of maternal resources allotted to yolk production in each spawning event. If we consider the large investment ariids direct to individual eggs, and that larger females have larger batch fecundity and spawn more times during a given spawning season, it is not surprising that batch fecundity does not increase as a power function of fish length. Furthermore, ariids are mouthbrooders and reproductive success depends not only on the total number of eggs produced by females but also on the numbers of eggs incubated by males (Reis 1986b). Our results with *G. genidens* showed that larger males are able to incubate more eggs, but the relationship between the number of incubated eggs and length of the brooding male is linear (Fig. 7). In this case, an exponential increase in batch fecundity would not represent a corresponding increase in reproductive success.

Fish condition

The sharp decrease in condition exhibited by *G. genidens* during its spawning/brooding season is probably related to changes in feeding activity throughout its reproductive cycle. Reis (1986b) found that the proportion of specimens of *Netuma barba* with full or partially full stomachs was maximum during the beginning of gonadal maturation, decreasing towards the spawning season. According to Rimmer & Merrick (1983) the mature ovaries of many ariids take up most of the body cavity, compressing the stomach and intestine and preventing feeding during the period just prior to spawning. In males, emaciation seems to be related to fasting during the brooding period (Rimmer 1985b, Reis 1986c). As the incubated eggs or young occupy the whole oropharyngeal cavity, males probably cease feeding completely during the incubation period.

Sexual dimorphism

Secondary sex characters in ariids usually involve differences related to the size, shape and thickening of the pelvic fins (Lee 1937, Merriman 1940, Luengo 1973, Rimmer & Merrick 1983, Rimmer 1985a). Although we do not know how or if the longer pelvic fins of adult female *G. genidens* are used in the spawning activity, several authors have related sexually dimorphic characters in ariids to reproductive mechanisms (Lee 1937, Dmitrenko 1970, Rimmer 1985a). According to Oppenheimer (1970) morphological adaptations that increase

Table 1. Bimonthly number of males and females and Chi-square values for the sex ratio of *Genidens genidens* in the Jacarepaguá Lagoon system during the period July 1980 to June 1982. * = $p < 0.01$.

Bimester	Year	Number of males	Number of females	Total	Chi-square value
Jul–Aug	1980	35	23	58	2.48
Sep–Oct		69	69	138	–
Nov–Dec		120	110	230	0.43
Jan–Feb	1981	50	17	67	16.25*
Mar–Apr		18	3	21	10.70*
May–Jun		38	24	62	3.16
Jul–Aug		7	10	17	0.53
Sep–Oct		29	25	54	0.30
Nov–Dec		16	24	40	1.60
Jan–Feb	1982	118	45	163	32.69*
Mar–Apr		14	12	26	0.15
May–Jun		1	2	3	0.35
Whole period		515	364	879	24.58*

spawning efficiency have evolved in the non-parental sex of mouthbrooders. The fact that sexual dimorphism in *G. genidens* starts at the time females reach sexual maturity reinforces the hypothesis that it might be involved with reproductive mechanisms.

Sex ratio

Although variations in sex ratio have been reported in ariid catfishes, most of the species previously studied have shown a higher proportion of females in the stock (Etchevers 1978, Reis 1986b). The only results that agree with the predominance of males observed in *G. genidens* were presented by Rimmer (1985a) for *Arius graeffei* in Australia. However, that author analyzed the sex ratio only for the pooled data set and presented no information on its variation during the reproductive cycle.

Two hypotheses can be formulated for the predominance of males observed during the spawning/brooding season of *G. genidens* in the Jacarepaguá Lagoon system. The first is that females start migrating from the spawning grounds after spawning is completed, leaving brooding males behind. This seems to be the pattern exhibited by other ariids during their reproductive cycle in estuarine habitats (Reis 1986b). The second possible explanation is that brooding males, usually exhibiting signs of emaciation and low body condition, may be more vulnerable to the sampling gear thus causing bias in our sex ratio results.

Reis (1986b) pointed out two mechanisms influencing the stock-recruitment relationship in *Netuma barba:* (a) the number of eggs produced by females and (b) the number of incubated eggs, which is directly related to the number of males. This principle might be extended to *G. genidens* and to other species of Ariidae. Maintaining a 1 : 1 sex ratio during the spawning season is probably more important for these catfishes than for species where male participation in reproduction is limited to egg fertilization. Even though fecundity in ariids is low by teleost standards (Rimmer & Merrick 1983), male brood care minimizes offspring mortality during the most vulnerable developmental stages, increasing the chances for juveniles to reach maturity. However, because both sexes are so closely related to reproductive and recruitment success, recruitment is likely to be highly density-dependent and thus sensitive to even small increases in fishing mortality (Coates 1988). Therefore, we suggest that management practices directed to ariids, especially those concerning the effect of parental stock size on recruitment, should consider appropriate fishing mortality schedules to protect not just spawning females, but also brooding males. A closed or restricted fishing season during the spawning/brooding period is strongly recommended.

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