

Influences of the reproductive cycle on condition of marine catfishes (Siluriformes, Ariidae) in a coastal area at southeastern Brazil

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Synopsis

Marine catfishes use estuaries and bays as part of their life cycle for spawning and feeding purposes, respectively. We compared three species of the family Ariidae in two different environmental conditions: a relatively stable bay site and an estuarine site, which differ in their magnitudes of environmental fluctuation to investigate effects of spawning on condition. We found differences in the parameter b (slope) and in the y -intercept (a) among species and sexes. The parameter a varied inversely with b , and thus is not a good indicator to express fish condition. Condition factor did not differ between the two sites for species and sexes when we consider the pooled data. Overall condition was associated with reproductive process, and was high before the reproductive season, decreasing during the spawning period in the estuary, then increasing when fish move to the bay (April–August). Temporal segregation in the reproductive period and small-scale movements between the estuary and the bay are the probable mechanisms to optimize the use of the area by the three species.

Introduction

Marine catfishes are widely distributed in shallow coastal and brackish tropical waters, in semi-closed areas such as estuaries and bays. In Sepetiba Bay, a semi-closed area on the southeastern Brazilian coast, this family is represented by five species (Araújo et al. 1998a, b): *Sciadeichthys luniscutis* (Valenciennes 1840), *Genidens genidens* (Valenciennes 1839), *Cathorops spixii* (Agassiz 1829), *Netuma barba* (Lacépède 1803) and *Bagre marinus* (Mitchill 1814). The first three species are by far the most abundant ariids in the area. These ariid species are an important component of the bay's ecosystem, but very little is known about their condition and reproductive strategy. Overall, their life history involves migration to lower reaches of estuaries to spawn, males brood care by oral incubation for approximately 2 months, the

early juvenile development occur in bays and estuaries, followed by a further migration to coastal zones when adult (Araújo 1988).

Fish condition indicates health and can be related to ecological processes and life history, so environmental conditions and the reproductive cycles are key processes in determining the allotment of the energy budget by fishes (Patterson 1992, Winters & Wheeler 1994, Vila-Gispert & Moreno-Amich 2000). Additionally, parental care has tended to evolve in fishes occupying environments that are spatially and temporally unpredictable for zygotes and young; the selection, guarding and tending of a spawning site by parental fish reduces the danger to the zygote of that unpredictability (Krebs & Davies 1981, Wootton 1990). In marine catfish parental care is shown by males which take care of fertilized eggs and the early juveniles in estuarine areas (Barbieri et al. 1992).

We chose the Guarda River estuary, one of the largest freshwater contributors to Sepetiba Bay and a spawning area used by marine catfishes (Gomes et al. 1999), as one of our study sites. The other site was the inner zone of Sepetiba Bay, a comparatively more stable environment, where changes in physico-chemical variables are less noticeable. The marine catfishes in the two areas belong to the same population (Azevedo et al. 1999), because of the proximity of the sites (ca. 10 km), the absence of barriers, and the ability of these species to move over these relatively small distances.

The gonadosomatic index (GSI) is a common method of describing the relative size of the gonads. A change in GSI may result from a change in the mass of either the gonads or the soma, or may arise because there is an allometric relationship between gonadal and somatic mass (Wootton 1990). Movements and choice of a breeding site and parental care require the allocation of time and may also be energetically costly. Time and energy spent on such behaviour are not available for activities that would directly increase the investment in gamete production or contribute to somatic growth maintenance. During the breeding season, both males and females of some species show significant depletion of their somatic energy stores (Diana & MacKay 1979, Wootton 1990).

In this study we compared the condition factor and GSI between two sites to test the ability of catfishes to move over such small distances during the spawning period and to determine whether there is segregation between spawning and non-spawning individuals with different condition. Additionally, we analyzed the parameters of the length–mass relationship and compared them to fish condition. Specifically, we addressed the following questions: (1) do fishes move over small distances during the reproductive period between the bay and the estuary? and (2) what are the influences on fish condition in the two areas in reference with segregation of spawning and non-spawning individuals?

Materials and methods

Study area

Sepetiba Bay is a 520 km² coastal embayment area with a wide communication with the sea, in Rio de

Janeiro State (22°54′–23°04′S; 43°34′–44°10′W) in southeastern Brazil (Figure 1). Several rivers and small tributaries drain into the Bay, with seawater dilution being more noticeable in the inner Bay. Discharges usually peak in late spring and summer and drop in winter, reflecting the pattern of rainfall. Bottom salinity is quite stable, ranging between 27 and 34‰ most of the year. The climate is tropical with temperature ranging between 20 and 30°C. The maximum depth is 30 m, near the sea connection, but most of the Bay has an overall mean depth of 5 m. Substrate is mainly mud flats with patches of gravel and sand; tidal amplitude is 1.5 m. There is a large muddy formation exposed at low tide in the inner Bay. Major anthropogenic influences in this region include industrial and domestic effluent discharges into the bay brought by channels from the outskirts of Rio de Janeiro City.

Sampling

We collected fishes in monthly samplings in the Guarda River estuary and inner zone of Sepetiba Bay, between October 1998 and September 1999. In the Guarda River estuary, we collected fishes using gill nets (30 m × 2 m, 40 mm mesh). In the Bay, we made collections with a 12 m long otter trawl, with 25 mesh net in the arms and 12 mm mesh at the cod end.

We preserved all collected fishes in 10% formalin. We measured each specimen for total length (L_t) (± 1 mm) and weighed for body mass (± 1 g). We assigned ovary maturity stages according to Vazzoler (1981) and Araújo et al. (1998a, b). We removed the gonads, determined sex and weighed them (GW) to 0.01 g. We excluded immature individuals or those whose sizes were smaller than the mean size at first maturity (L_{50}) to eliminate influences of body size or stage in gonadal development on the mass of the gonad relative to the body mass. In total, we examined 355 fishes of the three species: 168 *S. luniscutis* (74 females and 94 males), 127 *G. genidens* (75 females and 52 males) and 60 *C. spixii* (41 females and 19 males). We measured the following environmental variables at each sampling occasion: oxygen concentration (mg l⁻¹), water temperature (°C), transparency (cm), salinity (‰) and depth (cm).

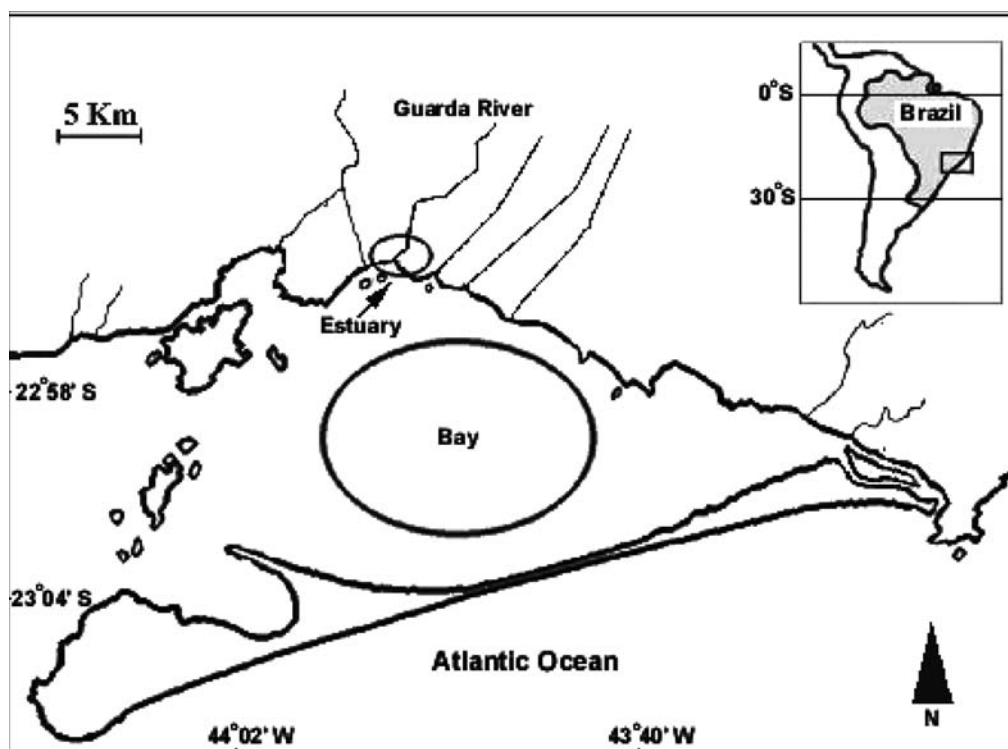


Figure 1. Study area – Sepetiba Bay, showing the two sampling sites: (a) Estuary of Guarda River, and (b) inner Bay.

Data analysis

We log transformed masses and lengths and fitted the resulting linear relationship by the ordinary least squares regression using W as the dependent variable. The length–mass relationship is $W = aL^b$, where W is the round weight in g, L the total length in cm, and a and b are parameters to be estimated. We calculated condition factor with a Fulton-type equation: $K = (W - W_g) * L^{-1}$, where W is the fish mass; W_g is the gonad mass; L is the total length. We used the GSI as a complementary index of the condition. We calculated this index for each fish, using the equation $(100 * \text{gonad mass} * \text{body mass}^{-1})$, where GW and W represent gonad and somatic masses, respectively. We used one-way analysis of variance to compare environmental variables, condition factor and GSI means between sites and months. We used a Tukey test (*a posteriori*) to compare for significant differences among months.

Results

Environmental conditions

Temperature was comparatively higher in the estuary where seasonal changes were more marked than in the Bay (Figure 2). Transparency was always higher in the Bay than in the estuary with no clear seasonal changes over the study period. Salinity and depth differed significantly between the estuary and the Bay, with comparatively lower values being recorded in the estuary. Dissolved oxygen showed a narrow range of variation and was comparatively lower in the estuary, but did not differ significantly ($p > 0.05$) between the two sites.

Water temperature ranged from 17 to 28°C in the Bay, vs. 26–34°C in the estuary (Figure 2). Increasing temperature occurred from October reaching a peak in January in the estuary (34°C) and in February–March (26°C) in the Bay; the

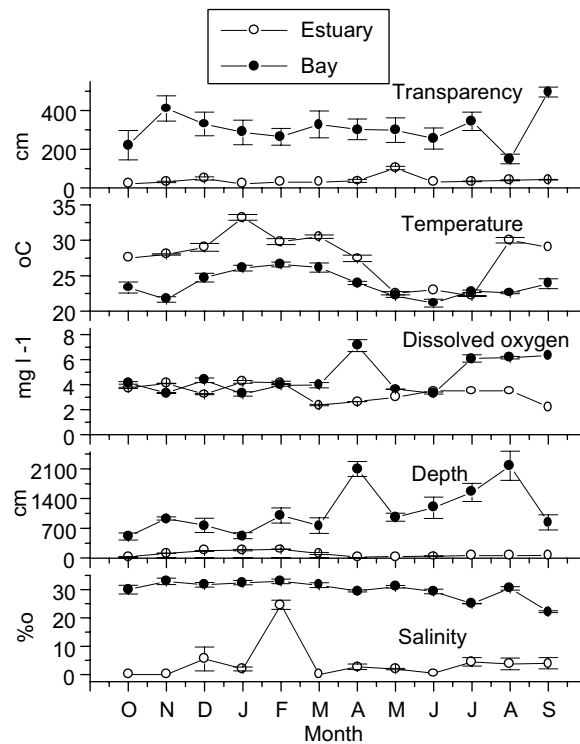


Figure 2. Means (+ standard error, - vertical bars) for environmental variables in the two sampling sites in the Sepetiba Bay, October 1998–September 1999.

lowest mean values in both sites were 22°C in June and July. Transparency ranged from 200 to 450 cm in the Bay vs. 15–100 cm in the estuary. Lowest transparencies were closely associated to lowest depths being recorded in the estuary in opposition to highest records in the Bay. Most salinities in the estuary were close to 0.5‰ due to the predominance of freshwater in the estuary, although high variations were shown as result of tidal influence, reaching in some occasion up to 24‰; on the other hand, these values were more stable in the Bay, ranging from 24 to 36‰. Overall, higher temperature, lower dissolved oxygen and wider salinity variation in the estuary suggest a more stressful situation in this site compared to the Bay.

Parameters of the length–weight relationship

There are remarkable differences in the parameter b (slope) and in the y -intercept (a) among species and sexes (Table 1). *S. luniscutis* showed lower a than *G. genidens* and *C. spixii*. Parameter a for

males *S. luniscutis* was comparative higher than for females; the opposite was found for *G. genidens* and *C. spixii*, with parameter a for males being comparatively lower than for females.

We found positive allometry for female *S. luniscutis*, coinciding with the lowest parameter a . We found isometry for males of all species. We detected negative allometry for female *G. genidens* and for female *C. spixii*. *S. luniscutis* reaches a larger size than the other two species, which seem to show the same size structure. Overall, *C. spixii* gains less mass as it grows, while *S. luniscutis* gains comparatively more mass, reaching the maximum mass later.

Condition factor

For the pooled data, condition factor did not change between the Bay and the estuary for any species or sex (Table 2). When we consider each site separately, we detected differences in condition among months, although both sexes of the three

Table 1. Regression parameters (a, b) of the ln-transformed length weight relationship in each studied population (n = sample size).

Species	Sex	n	Total length (mm) Min–Max	b (slope)	a (the y-intercept)
<i>S. luniscutis</i>	Males	94	190–410	2.96	-11.42
	Females	74	186–418	3.31*	-13.29
<i>G. genidens</i>	Males	52	175–364	3.01	-11.68
	Females	75	141–366	2.91*	-11.13
<i>C. spixii</i>	Males	19	174–301	2.99	-11.59
	Females	41	155–302	2.38*	-8.25

*Significant departure from 3 (p < 0.01).

Table 2. F-values and post hoc comparisons from ANOVA for condition factor between the bay and the estuary for each species and sexes (ns = not significant).

Species	Sex	F	Post hoc comparisons
<i>S. luniscutis</i>	Males	1.54	ns
	Females	1.46	ns
<i>G. genidens</i>	Males	1.88	ns
	Females	0.39	ns
<i>C. spixii</i>	Males	0.56	ns
	Females	2.60	ns

species were not recorded during all sampled months. This may be due to movements between the two sites, or even to other regions outside the sampled area. Marine catfishes were more abundant in the samples from spring to early autumn; we did not find any *C. spixii* from May to September. Overall, *S. luniscutis* concentrates in the estuary in September and October, being recorded

in both sites in November to February, moving away from the estuary to the Bay in March to August. *G. genidens* uses both sites in October to April, and the Bay in the remaining period, while *C. spixii* uses both sites in October to March, living in the study area from May to September.

Female *S. luniscutis* in the estuary showed higher condition in September, decreased in October, and reached the lowest values from December to February. Then they move from the estuary to the Bay where they are recorded in best conditions from February to August (Figure 2); males showed slightly similar seasonal condition variation but they were not recorded in the estuary in November and January. Female *G. genidens* in the Bay showed lower condition from October to February and higher condition from March to September (Figure 3). Male *G. genidens* in the Bay showed two monthly peaks (November and August) but an increasing trend was detected from lower values between October and February, to

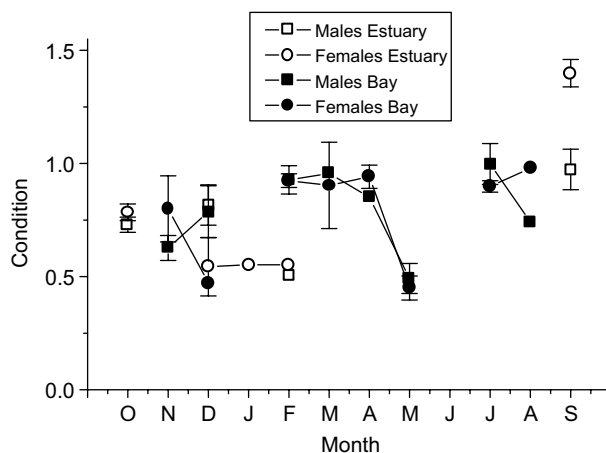


Figure 3. Condition factor for *S. luniscutis* by sexes in the two sites (estuary and bay) in the Sepetiba bay. Values are means ± SE.

Table 3. *F*-values and *post hoc* comparisons from ANOVA for condition factor among months, by sites and sexes (*n* = sample size).

Species	Sex	<i>n</i>	Site	<i>F</i>	<i>Post hoc</i> comparisons
<i>S. luniscutis</i>	Males	74	Estuary	2.42ns	
		20	Bay	2.75ns	
	Females	47	Estuary	23.96**	September > October; December–February
		27	Bay	0.78ns	
<i>G. genidens</i>	Males	17	Estuary	0.57ns	
		35	Bay	13.00*	August; November > January–December
	Females	25	Estuary	2.84ns	
		50	Bay	3.05**	September > October–December
<i>C. spixii</i>	Males	5	Estuary	2.15ns	
		14	Bay	1.44ns	
	Females	14	Estuary	3.12ns	
		27	Bay	1.61ns	

higher values, from March to September. Both sexes of *G. genidens* occurred in the estuary from October to April, with lowest values between January and March. We caught *C. spixii* only from October to April, with higher condition in October–January in both sites and lowest values in February and March (Table 3; Figure 4).

Gonadosomatic index

For the pooled data, GSI was higher for female *S. luniscutis* and for female *G. genidens* in the estuary when compared to the Bay ($p < 0.01$; Table 4). We recorded *S. luniscutis* exclusively in the estuary in September and October, where they reach the highest GSI, and in the Bay in March to June, where they reached the lowest values (Figure 5).

G. genidens showed GSI peaks in the estuary in December to February for females and in January for males. From April to September we recorded this species only in the Bay, where it showed low GSI (Figure 6). We recorded *C. spixii* from October to April, mainly in the Bay; we found the highest GSI values in October in both sites for females (Table 5, Figure 7).

Overall GSI in estuaries was always higher than in the Bay, and these differences were more accentuated for females for all species; the only exception was found for male *G. genidens*, which showed higher GSI in the Bay (Table 6). Condition factor was slightly higher for females than males, and differences were found between the two sites. Males showed comparatively higher values in the Bay, females in the estuary. Condition for male *G.*

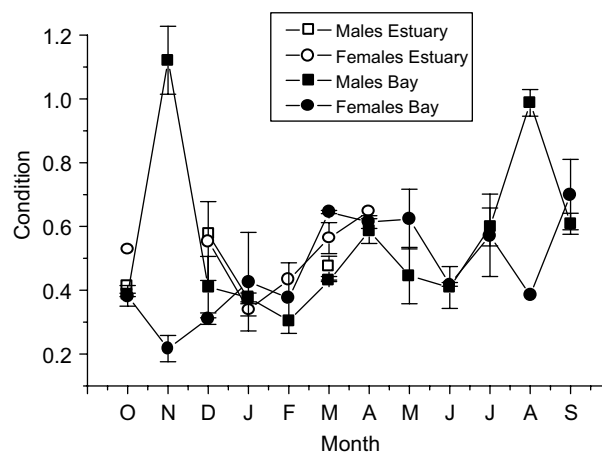


Figure 4. Condition factor for *G. genidens* by sexes from the two sites (estuary and bay) in Sepetiba Bay. Values are means \pm SE.

Table 4. *F*-values and *post hoc* comparisons from ANOVA for GSI between the bay and the estuary for each species and sexes (*n* = sample size; ns = not significant).

Species	Sex	<i>n</i>	<i>F</i>	<i>Post hoc</i> comparisons
<i>S. luniscutis</i>	Males	94	39.67**	ns
	Females	74	66.94**	Estuary > Bay
<i>G. genidens</i>	Males	52	0.83	ns
	Females	75	22.38**	Estuary > Bay
<i>C. spixii</i>	Males	19	0.03	ns
	Females	41	1.9	ns

genidens showed higher values in the Bay, and was nearly the same in both sites for females. For *C. spixii*, similar to *S. luniscutis*, females showed higher condition in the estuary while males in the Bay (Table 6; Figure 8).

Discussion

Condition of the three species of marine catfishes in Sepetiba Bay depends more on the reproductive cycle than environmental constraints. Condition was high at the beginning of the spawning period, when fishes moved to the estuary, decreased during the spawning season when the species were in the estuarine area, and then increased as they moved to the bay. The parameters of the length–mass relationship (slope and intercept) varied inversely and changed among species and sexes, are thus not good predictors for condition.

The present study did not show a clear difference in overall condition of marine catfishes between the two sites, although we detected some interspecific and inter-sex differences. Overall condition was high at the beginning of the reproductive season, when fishes moved to the estuary, decreasing during the spawning period, when they are in the estuarine area, and then increasing as they move to the Bay. Therefore, the main variation in condition follows the seasonal reproductive cycle, linked to movements of the marine catfish between the Bay and the estuary. This pattern of condition influenced by the reproductive process which took place in Sepetiba Bay included some missing data over the monthly samples, as these species performed small scale movements between the estuary and the Bay, with part of the fish population not being well represented during all the study period. Environmental conditions in the two sites differed substantially. In the estuary, wider variations in salinity and dissolved oxygen plus comparatively higher temperatures characterize this site as a more harsh condition. The marine catfishes are by far the dominant species in the estuary (Gomes et al. 2001). Predators and general competitors tend to occupy deeper areas in the Bay. Since estuaries are well known as one of the most productive of all aquatic ecosystems, marine catfishes could take advantage of such an environment because they are very well adapted to such systems due to their freshwater origins. On the other hand, while they use the estuarine area

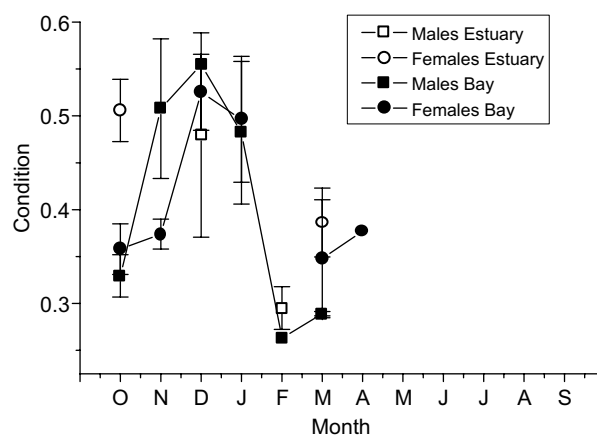


Figure 5. Condition factor for *C. spixii* by sexes from the two sites (estuary and bay) in Sepetiba Bay. Values are means \pm SE.

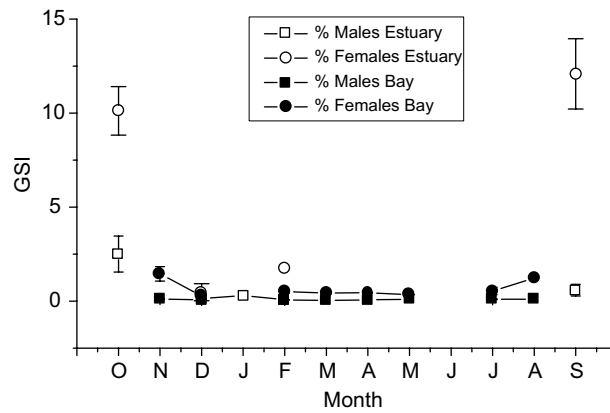


Figure 6. GSI for *S. luniscutis* by sexes in the two sites (estuary and bay) in Sepetiba Bay. Values are means \pm SE.

for reproduction they do not take advantage of the estuary for increasing condition via feeding since they allot most their energy budget to spawn.

Male *S. luniscutis* and *C. spixii* had lowest condition in the estuary and the main reason is starvation during oral incubation. Gomes et al. (2001) found male *C. spixii* and *S. luniscutis* brooding in the estuary and this behaviour was confirmed in other areas in south and southeastern Brazil by several workers (Araújo 1988, Barbieri et al. 1992, Araújo et al. 1998a, b). Males showing better condition in the Bay are expected since the Bay is used as a feeding area. *G. genidens* seems to differ from the other two species in reproductive strategy, since it showed higher GSI in January and February; additionally, we found no indica-

tion of incubation for male *G. genidens* in the estuary, although we did observe expansions of the oral cavity. Therefore, it is reasonable to suppose that it spawns in some area other than the Guarda River estuary.

The GSI for females was always higher than for males, as marine catfishes produce one of the largest eggs among teleosts, while their testis are comparatively low in mass. The overall higher GSI in the estuary, mainly for *S. luniscutis* and *C. spixii*, is consistent with the hypothesis that these marine catfishes use the estuarine environment for spawning purposes, and the bays as feeding areas. Peaks in condition recorded for females *S. luniscutis* in September in the estuary and peaks of GSI in September and October indicate that this

Table 5. F-values and *post hoc* comparisons from ANOVA for GSI among months, by sites and sexes (n = sample size).

Species	Sex	n	Sites	F	Post hoc comparisons
<i>S. luniscutis</i>	Males	74	Estuary	4.09**	October > December
		23	Bay	0.93ns	
	Females	47	Estuary	3.4*	September, October > December-February
		27	Bay	1.8ns	
<i>G. genidens</i>	Males	17	Estuary	9.59**	October; December > March
		35	Bay	2.26**	January > April–August
	Females	25	Estuary	2.12ns	January–February > October; December; March–April
		50	Bay	0.45ns	
<i>C. spixii</i>	Males	5	Estuary	1.15ns	September–October > December–March
		14	Bay	1.22ns	
	Females	14	Estuary	16.49**	October > March
		27	Bay	1.51ns	October > November–September

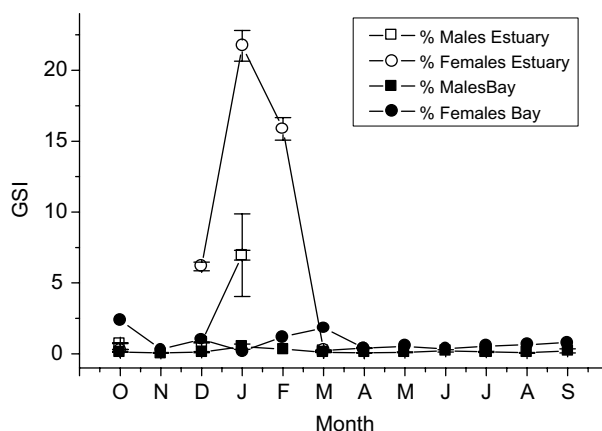


Figure 7. GSI for *G. genidens* by sexes in the two sites (estuary and bay) in Sepetiba Bay. Values are means \pm SE.

species reaches its best condition at the beginning of the reproductive period, which takes place in early spring, with condition falling sharply after spawning. Seasonal changes in condition, with minimum values just after spawning, have been often observed in fish species (Bengtsson 1993). It is apparent that females can start to recondition after the spawning season, as they do not take care of the eggs as the males do. High condition for females of *G. genidens* in September in the Bay and a peak of GSI in January indicate a completely differentiated strategy of allocation energy to somatic growth and reproduction when compared to *S. luniscutis* and *C. spixii*. Marine catfishes are very well known for their freshwater origin and their estuarine dependence for spawning purposes, being classified as 'semi-anadromous' species

(Dando 1984). Different periods in GSI peaks found in this work suggest temporal segregation in the spawning period, with *S. luniscutis* and *C. spixii* peaking in September and October and *G. genidens* in January and February. This mechanism of segregation could be a strategy to optimize juvenile survival by avoiding inter-specific competition and allowing coexistence of this species in the Bay.

The size structure of the examined populations indicated that *S. luniscutis* is the largest species with size varying between 186 and 418 TL, followed by *G. genidens* (141–366 mm TL) and *C. spixii* (155–302 mm TL). Searching in the estuary allowed us to catch large fishes, which migrate to this area during the reproductive period. This suggests that a selective sample or the population

Table 6. Means and SD for GSI and condition factor for marine catfishes by sexes and sites in the Sepetiba Bay (n = sample size).

Species	Sex	Site	GSI mean + SD	CF mean + SD	n
<i>S. luniscutis</i>	Males	Estuary	0.234 + 0.11	0.759 + 0.27	74
		Bay	0.082 + 0.05	0.838 + 0.20	20
	Females	Estuary	12.89 + 7.65	0.934 + 0.36	47
		Bay	0.779 + 0.75	0.834 + 0.31	27
<i>G. genidens</i>	Males	Estuary	0.129 + 0.07	0.471 + 0.11	17
		Bay	0.164 + 0.17	0.564 + 0.23	35
	Females	Estuary	8.330 + 10.56	0.498 + 0.17	25
		Bay	1.063 + 2.31	0.498 + 0.22	50
<i>C. spixii</i>	Males	Estuary	0.150 + 0.06	0.369 + 0.16	5
		Bay	0.143 + 0.06	0.427 + 0.15	14
	Females	Estuary	10.90 + 0.08	0.480 + 0.11	14
		Bay	6.57 + 0.07	0.413 + 0.13	27

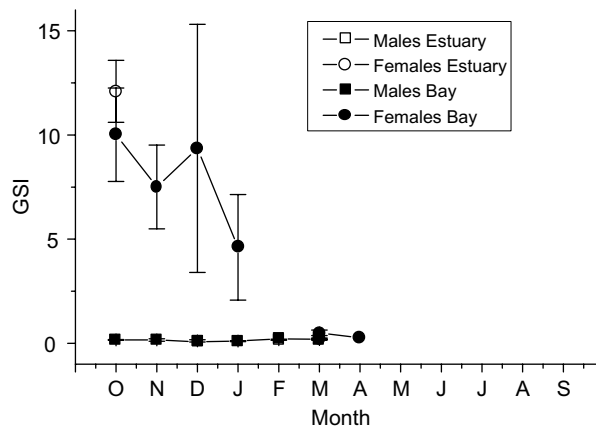


Figure 8. GSI for *C. spixii* by sexes in the two sites (estuary and bay) in Sepetiba Bay. Values are means \pm SE.

length structure may strongly influence the estimation of the length–weight relationship. We found differences in the parameter b (slope) and in the y -intercept (a) among species and sexes. As we found isometry for males of all three species, this indicates the males do not change form as they grow. On the other hand, female *S. luniscutis* tend to gain more mass during ontogenetic development, while female *G. genidens* and female *C. spixii* tend to gain comparatively less mass. The parameter a (y -intercept) of the length–weight relationship has been used to express condition (Bolger & Connolly 1989) and it has been frequently referred as condition factor (Braga 1986, Barbieri & Verani 1987). In this work it did not prove to be applicable, because it showed low or null correlation with the condition factor. Godinho (1997) also found no significant correlation between the parameter a and the condition factor. This is a clear indication that the parameter is influenced by others factors such as food availability or gonad development, which can limit its use as an indicator of fish condition.

Additionally, there was a high negative correlation between the a (y -intercept) and b (slope). This is commonly attributed to their covariance (Weisberg 1985, cited in Godinho 1997) and to the high correlation between body mass and length. The comparison of condition between groups using y -intercepts is only valid when the slopes are equal (Le Cren 1951), but this situation is not commonly observed (Bolger & Connolly 1989). On the other hand, the slope has also been used to

express condition. According to Godinho (1997) and Vila-Gispert & Moreno-Amich (2001), b (body form) can only be used to express condition when the y -intercepts of the groups to be compared are the same. However, even in these cases it does not seem to be a good indicator of condition, because the body mass difference between fish of the same size in each group is not constant for different lengths. During the reproductive months, b changed due to the increase in weight of the females' ovaries whereas juvenile females tend to maintain their weight, and this contributes to higher b values. Higher values of b can also be due to the higher percentage of small fish in the sample and smaller b , the higher percentage of large fish (Godinho 1997). This size structure of the sample does not necessarily represent the population structure because of collecting gear selectivity, but it does show how a population structure may influence b . We suggest that a careful examination of the data set and the assumption for using intercept or slope as population parameters and not for indicate condition, since this last use should be made in the context of each approach in order to avoid misleading conclusions.

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