TEMPORAL DYNAMICS OF FEEDING AND REPRODUCTION OF THE DAMSEL FISH (*Stegastes fuscus)*

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ABSTRACT: This study reports on the feeding and reproductive dynamics of the damsel fish, *Stegastes fuscus* (Osteichthyes: Perciformes: Pomacentridae) in the rocky coastal reefs of Búzios, Rio Grande do Norte, Brazil. Water temperatures and rainfall data were registered and fish were captured on a monthly basis during one year. Fish body weights and lengths were measured and the stomachs were removed and classified according to their degree of fullness. The gonads were weighed, examined for sex determination and maturation was determined based on macroscopic inspections. A higher frequency of females (78%) was registered in relation to males (22%). The lowest degree of stomach fullness was observed in August and the highest in January. Only 2.49% of the fish had empty stomachs and the rest 97.51% had mainly macroalgae in their stomachs. The period from February to August was associated to a long phase of gonadal resting in males and females. Two peaks of partial spawning were registered during January and September/October.

KEY-WORDS: Feeding. Reproduction. Biological rhythm. Environmental parameters. Pomacentridae.

DINAMICA TEMPORAL DE ALIMENTAÇÃO E REPRODUÇÃO DO PEIXE-DONZELA, *Stegastes fuscus*

RESUMO: O presente trabalho relata sobre a dinâmica de alimentação e reprodução do peixe-donzela, *Stegastes fuscus* (Osteichthyes: Perciforemes: Pomacentridae), nos arrecifes rochosos de Búzios, Rio Grande do Norte, Brasil. A temperatura da água e os dados de pluviosidade foram registrados e os peixes foram capturados mensalmente durante o período de um ano. Os peixes foram medidos, pesados, dissecados, as gônadas foram removidas, pesadas e examinadas para identificação do sexo. Foi realizada a avaliação macroscópica dos estádios de maturação gonadal. Os estômagos foram removidos e classificados em relação ao grau de enchimento. Foi registrada uma maior freqüência de fêmeas (78%) em relação aos machos (22%). O menor grau médio de repleção dos estômagos ocorreu no mês de agosto e o maior ocorreu no mês de janeiro. Apenas 2,49% dos peixes apresentaram estômagos vazios enquanto que 97,51% de indivíduos apresentaram estômagos com alimento, principalmente as macroalgas. O período de fevereiro a agosto foi associado a um longo período de repouso gonadal de ambos os sexos. Dois picos de desova foram registrados durante janeiro e setembro/outubro.

PALAVRAS-CHAVE: Alimentação. Reprodução. Ritmos biológicos. Parâmetros ambientais. Pomacentridae.

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1 INTRODUCTION

The species that inhabit coral reefs are strongly influenced at low tides by external factors such as temperature, luminosity, and rainfall, among others (Klumpp, Mckinnon and Daniel, 1987; Cleveland and Motgomery, 2003). These effects are due to the low volume of water in these areas, which are usually trapped in tide pools. Thus, it is expected that tropical fish communities living in tide pools are influenced by external factors which vary throughout the year. Fishes show a wide adaptive radiation in their foraging habits and marine fish populations exhibit annual changes in their feeding pattern (Lison De Loma et al. 2000) and reproductive dynamics (Richardson, Harrison and Harriott, 1997; Asoh 2003; Picciulin et al., 2004; Araújo and Chellappa, 2002). Effects of temperature, luminosity and rainfall on annual distribution and population structure have been detected in marine fish (Gibson, Ansell and Robb, 1993; Schwamborn and Ferreira, 2002). However, few studies have dealt with tropical reef fish (Schwamborn and Ferreira, 2002; Osório, Rosa and Cabral, 2006)

Fishes in the equatorial regions are more influenced by rainfall and are less subjected to variations in temperature and photoperiod, since they are practically constant all around the year (Volpato and Trajano 2006). Thus, fishes in the equatorial regions are useful for investigating the influence of the dry and rainy periods on fish biology, since other intervening factors are rather reduced.

The damselfish, *Stegastes fuscus* (Cuvier 1830), (Osteichthyes: Perciformes: Pomacentridae), which occurs in tide pools located in the coastal reefs in northeastern Brazil was investigated in the present study. The objective of this study was to investigate the sex ratio, the size structure of males and females, the degree of stomach fullness and gonadal development in a coral reef population of *S. fuscus* in order to understand the temporal dynamics of feeding and reproduction. An attempt was made to correlate the spawning season of this species with rainfall, one of the environmental factors known to modulate the duration and timing of the spawning period of tropical fish.

2 MATERIAL AND METHODS

2.1 Study area and sample collection

The study area is located in the South Atlantic Equatorial Zone. Samples of damselfish *S. fuscus* were captured from the tide pools located in reef formations (approximately 3 km in extension), in Búzios Beach, Nizia Floresta, Brazil (06º00’40’’S; 35º 06’38’’W) (FIG. 1). In the collection site there were other co-occurring fish species pertaining to Pomacentridae, Serranidae, Lutjanidae, Haemulidae and Scianidae. The benthonic macroalgal flora of this area included Rhodophyta, Chlorophyta and Ochrophyta with dominance of *Hypnea musciformis* (Rhodophyta), *Gracilaria* spp (Rhodophyta), *Solieria filiformis* (Rhodophyta), *Gelidium coarctatum*

(Rhodophyta) and *Padina* gymnospora (Ochrophyta) (Marinho-Soriano, Carneiro and Soriano, 2009).

Fish were captured on a monthly basis during the lowest daytime tides, from September 2004 to August 2005. The observations on fish occurrence were made at low tide periods, which is when they are most influenced by variations over the course of the year. Water temperatures (°C) were recorded monthly in the field when the fish were captured. Rainfall data (mm) was obtained from the Meteorological Station of the Universidade Federal do Rio Grande do Norte (UFRN), Natal, Brazil.

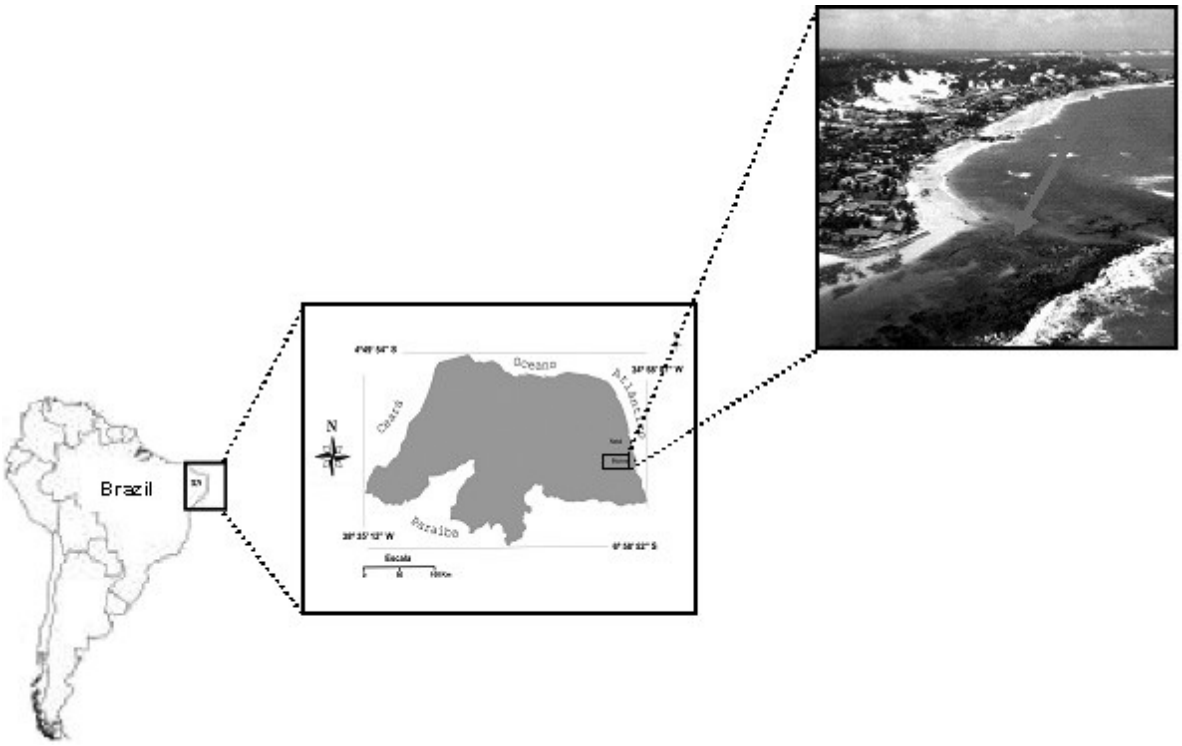

FIGURE 1 - Study area: Búzios Beach, Nísia Floresta, RN, Brazil (The arrow indicates the collection site).

Fish were captured with a 0.5 cm mesh hand net, 90 min before and 90 min after peak low tide. The collected specimens were placed in plastic bags and packed in ice in a thermal container and were then transported to the Laboratory for immediate inspection. The voucher specimens are deposited in the fish collection of the Museum of the Departamento de Oceanografia e Limnologia, Universidade Federal do Rio Grande do Norte, Brazil.

2. 2 Measurements

The total body mass (TW) of each fish was registered to the nearest 0.001 g. The fish were then measured to obtain standard (SL) and total (TL) body lengths to the nearest 0.1 cm. The gonads were examined to identify sex. Gonadal development stages

were determined macroscopically according to classification of Asoh (2003). Gonadosomatic index (GSI) was calculated as the ratio between gonad mass and total body mass for females (Wootton, Evans and Mills, 1978).

2.3 Estimation of the degree of fullness of stomachs

The stomachs were removed and their degree of fullness were classified according to Berg (1979): 0 (empty), 1 (up to 25% full), 2 (between 25% and 75% full) and 3 (between 75% and 100% full). To estimate these percentages, the food contents were accumulated at the bottom of the stomach and then this filled region was estimated in relation to total stomach volume. Stomach contents were identified using identification manuals for macroalgae and Diatomaceae (Werner, 1977; Reviers, 2006; Marinho-Soriano, Carneiro and Soriano, 2009).

2.4 Statistical analyses

Monthly analysis of male and female frequencies was performed to obtain the sex proportion. Mean values were compared by ANOVA in order to assess the variations considering month, sex and seasonality (dry and rainy). Tuckey test was used for testing differences between particular pairs of means. The repletion index was square root transformed. The Goodman's test was used to verify the proportions between the numbers of fish (Goodman 1965), while χ^2 was used to test for differences in the frequency of males and females along the year and in the dry and rainy seasons. Significance was attributed at 5% level.

3. RESULTS

3.1 Rainfall and water temperature

During the study period, northeastern Brazil experienced six months of dry season from September, 2004 to February, 2005. During the dry season the rainfall varied from a maximum of 44.0 mm to a minimum of 2.0 mm, with a mean (±sd) rainfall of 18.33 mm (± 17.39 mm). The rainy season was from March to August, 2005, during this period the rainfall varied from a maximum of 752.0 mm to a minimum of 90.0 mm, with a mean rainfall of 307.83 mm (± 274.52 mm). There was a significant difference between the rainfall levels during the dry and rainy seasons ($t = 2.578$; $p=0.0275$).

The water temperature varied from a maximum of 36°C in March, 2005 to a minimum of 25°C in July, 2005. During the dry season the mean water temperature was 32.67ºC (± 1.21ºC), with a maximum of 34.5ºC to a minimum of 31ºC. During the rainy season the mean water temperature was 30.58ºC (± 4.65ºC) with a maximum of 37ºC to a minimum of 26ºC. There was no significant difference between the water temperature during the dry and rainy seasons ($t = 1.259$; $p=0.2366$).

3.2 Total body length, body mass and sex proportion

The frequency of individuals by standard length classes showed a normal distribution. Males and females ranged from 3.0-4.5 to 10.5-12.0 cm length classes (FIG. 2a). There were significant differences in the number of males and females throughout the study period, except for the months of July and August (FIG. 2b). There was a higher proportion of females (78%) than males (22%) in the total sample (n= 562) ($\chi^2 = 35.75$).

The length-mass relation was not different for males and females and indicated that mass increment is positively allometric in relation to total length. The length and mass was correlated by an exponential curve (r = 0.9876 for females and r =0.9911 for males). (FIG. 3

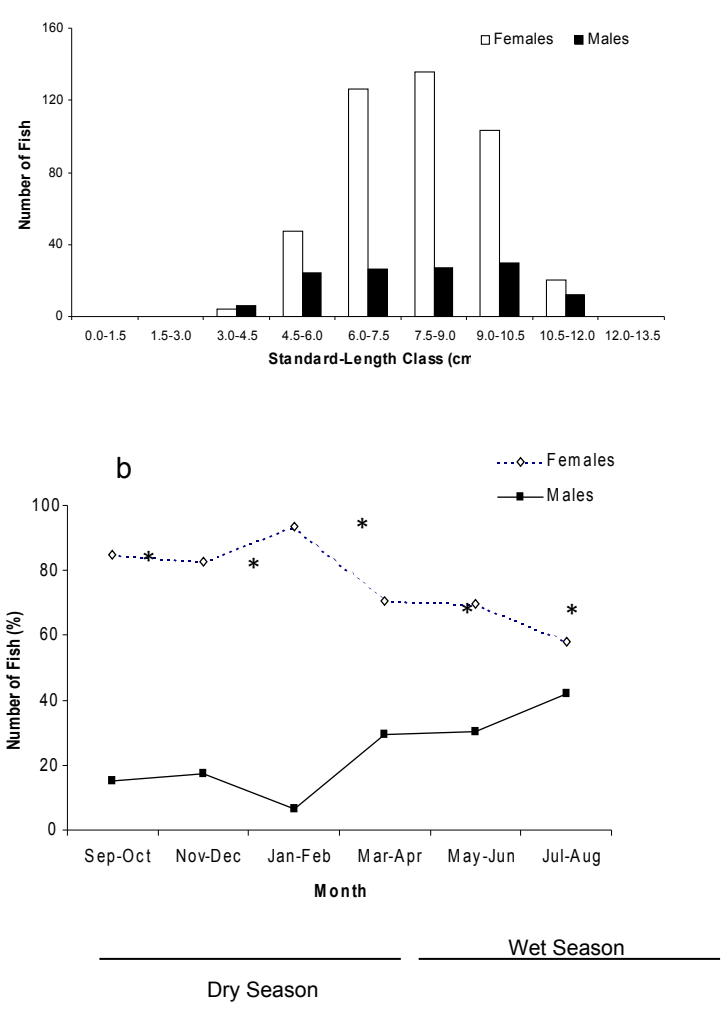

FIGURE 2 - Class frequency of occurrence (a) and monthly variation in percentage of occurrence (b) of males and females of *Stegastes fuscus* in the coastal rocky reefs of Búzios Beach during 2004 to 2005 (Asterisks indicate significant differences).

The total length of fish was more distinct between the sexes at the beginning of the dry season (FIG. 4a; F = 0.43; p=0.83). The fish were significantly larger in March and April than in the other months (F = 2.38; p=0.04) (FIG. 4a). However, standard length of fish varied between the sexes and the months. In the months of July-August and November- December, the females were significantly larger than the males (FIG. 4b; F = 3.24; p=0.007). The females captured in March-April and July-August had higher mean standard length compared to the other months. The males captured in March-April were the largest and those captured in November-December were the smallest. Body mass was equally affected in relation to sex and month (FIG. 4c; F = 2.75; p=0.02). The females had greater body mass than the males in January-February, whereas the male body mass was the highest in March-April (FIG. 4c).

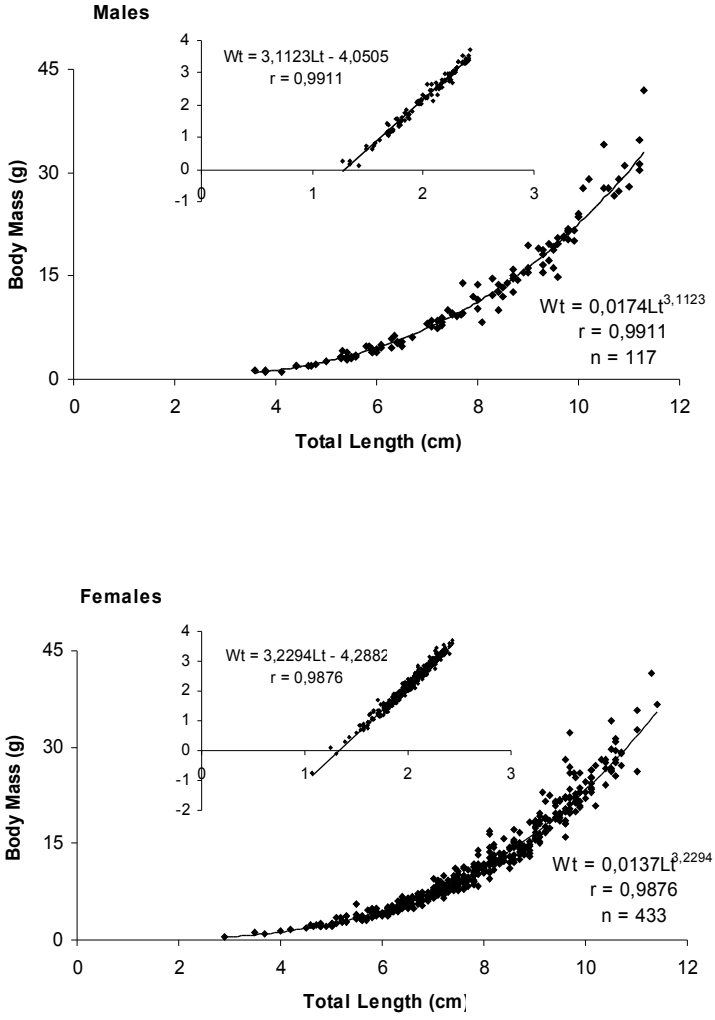

FIGURE 3 - Relation between body length and body mass in males and females of *Stegastes fuscus.*

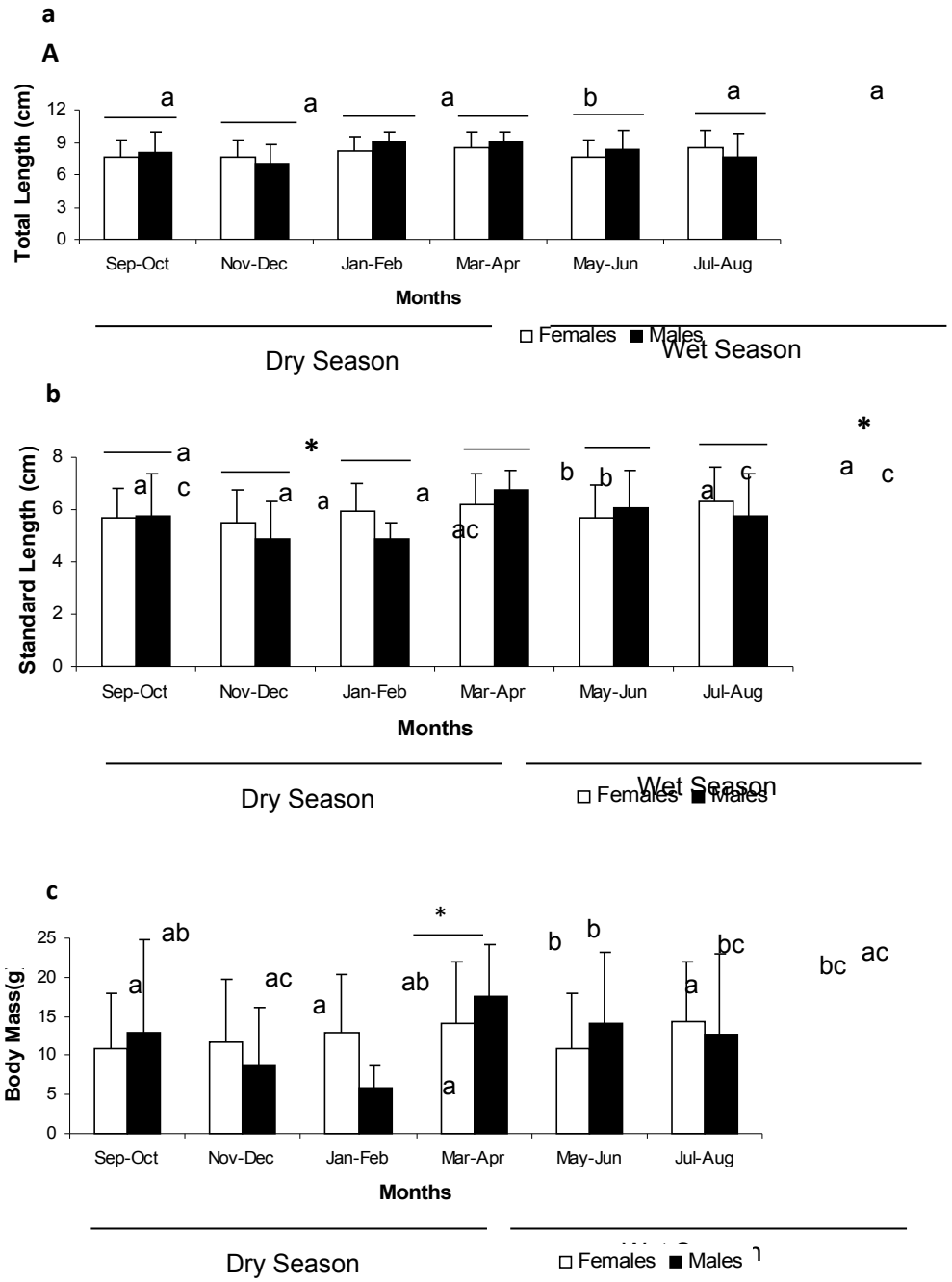

FIGURE 4 - Size (total length, standard length and body mass) of *Stegastes fuscus* in relation to sex and seasonal variation during 2004 to 2005. Measurements indicated in similar simple letters were not significantly different among themselves (comparison across the months). The asterisks indicate significant differences between the sex, when compared during the same period.

3.3 The degree of fullness of stomachs

Of the 562 specimens examined, a low proportion (14; 2.49%) had empty stomachs, whereas 548 (97.50%) specimens had stomach contents consisting mainly of

macroalgae (*Gelidium* sp., *Grasilaria* sp. and *Padina* sp.), benthonic diamatoceae and organic debris. The highest frequencies of empty stomachs occurred from August-December, whereas the highest frequencies of stomachs with food occurred from January to July. The stomach fullness did not change throughout the year. The lowest mean repletion level (1.59) was in August, and the highest (2.29) occurred in January (FIG. 5).

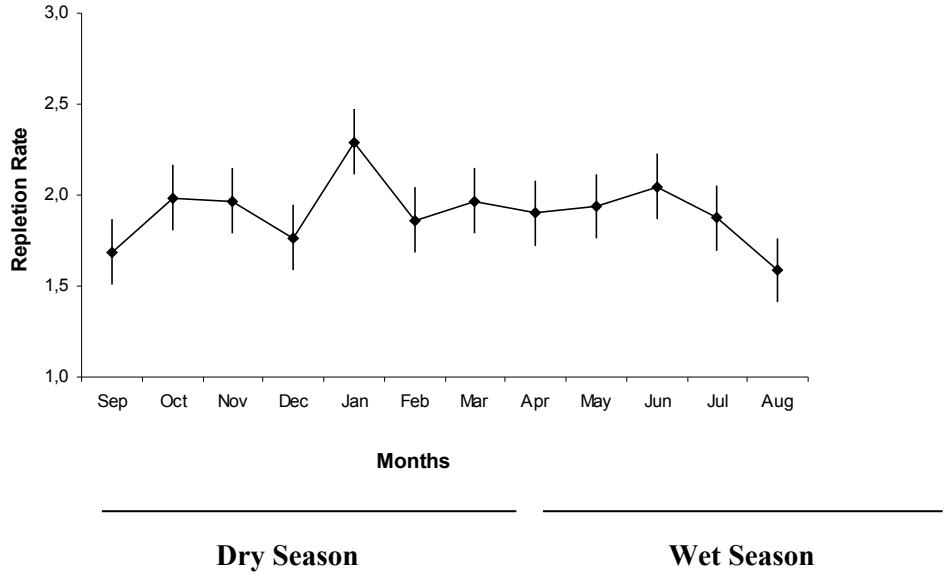

FIGURE 5 - Mean monthly values for degree of stomach fullness in *Stegastes fuscus* (for pooled sex).

Repletion index of fish varied over the months (FIG. 6). No correlation was observed between fish size (standard length, total length and body mass) and repletion index, regardless of sex and season ($r = 0.45$, $p>0.05$, $n = 6$). Repletion index did not differ between males and females ($F = 0.38$; $p=0.54$), despite the variations observed over the months ($F = 2.22$; $p = 0.05$) (FIG. 6).

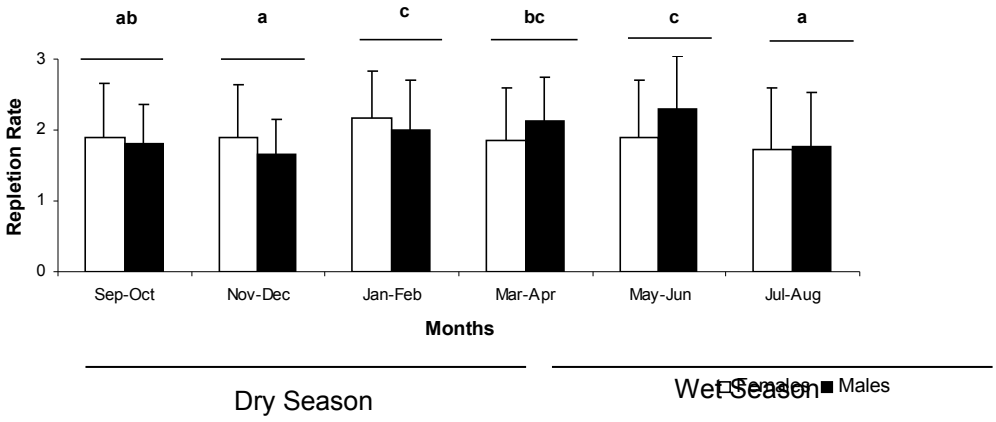

FIGURE 6 - Stomach repletion rate in *Stegastes fuscus* according to sex, season and across months during 2004 to 2005. The grouping of horizontal lines indicate similar

indices and simple letters above the lines indicate significant differences (medium with the same letter, however they were not significantly different among themselves).

3.4 Macroscopic aspects of gonads and GSI

Five stages of gonadal maturation (immature, developing, mature, spent and resting) were identified: The gonadosomatic index (GSI) of females was high in September, 2004 and in January, 2005. The period between February and August, 2005 was associated to a gonadal inactivity period. Females with developing and resting gonads predominated in the rainy season (FIG. 7a; FIG. 8). The highest mean GSI values coincided with the lowest temperatures (FIG. 7b).

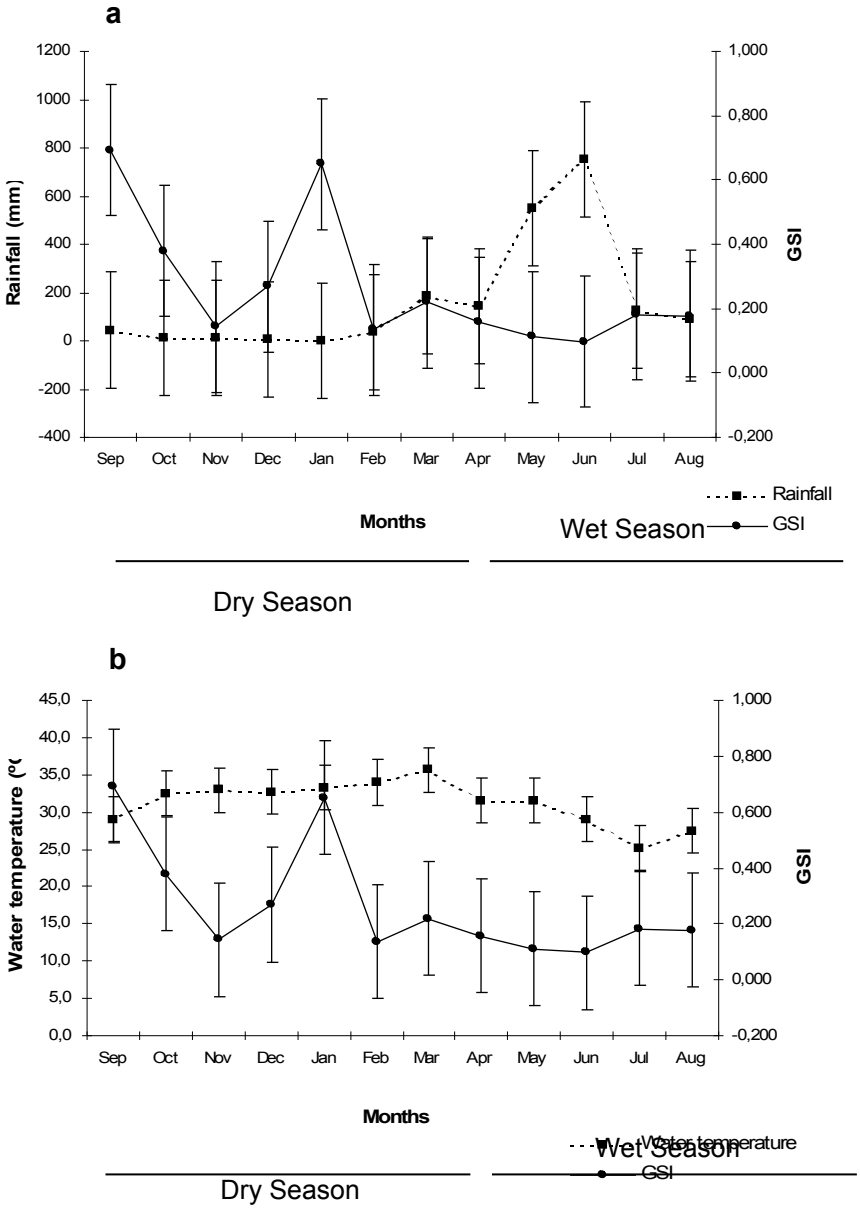

FIGURE 7 - Monthly mean values of (**a)** rainfall and GSI (**b)** water temperatures and GSI in females of *Stegastes fuscus* during the period of 2004 to 2005.

Though gonadal development did not vary much throughout the year, the gonadal development profiles of males and females were different between one another in both dry and rainy seasons (FIG. 8). The females were predominately with developing gonads, whereas the males, for the most part, were juvenile and with immature gonads.

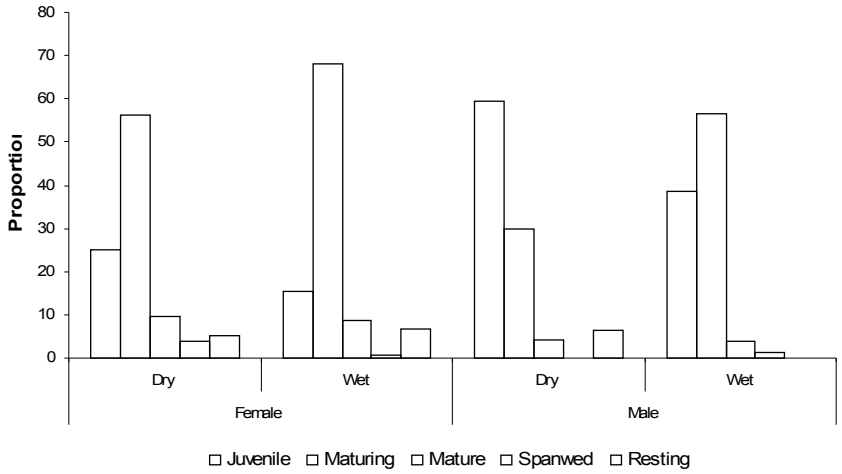

FIGURE 8 - Fish proportion in relation to sex, gonadal status, dry and rainy season in *Stegastes fuscus.*

4. DISCUSSION

The dynamics of reproduction of *S. fuscus* is associated mainly to rainfall, which is expected for fish populations in an equatorial region. Both males and females of this species showed positive allometric growth. Though the classical sex ratio is a balanced one, usually being 50% of males and 50% of females (Nikolsky, 1969), the proportion between males and females was different from 1:1 in the present study and females were predominant during most of the months. This is possibly due to the behavior of these individuals since territoriality is common among pomacentrids during the reproductive phase. Males guard the eggs in territories before and after they hatch, thus keeping off the predators and unwanted female intruders. Male care also includes ventilation of eggs, cleaning of territory and discarding dead eggs, and these activities occupy about 25% of their time (Petersen, 1995). This behaviour, possibly results in potential coasts for the territorial males, which include lack of food availability during parental care (Tabata, 1995; Blazquez, Zanuy and Piferrer, 1998; Gaillard et al., 2004), predation risks from bigger fishes, mortality difference between the sexes and ambient temperature (Hatcher, 1981; Carpenter, 1986; Klumpp and Polunin, 1989).

The difference in territorial distribution between S *fuscus* males and females, as well as for other species, has been reported (Munro, 1976). In this study S *fuscus*

males were distributed predominately along the outer edges of the reefs, which are deeper, while the females were found in shallower areas.

Populational stratification could be another factor responsible for the unbalanced sex ratio of this species. The predominance of males of *S. diencaeus* in Barbados appears to be related to specific exigencies of males and females, resulting from environmental resources, like appropriate sites for breeding territories, proximity to cleaning stations and search for cleaning agents, depending on the parasitic loads (Cheney and Côté, 2003). Thus, a possible populational stratification appears to be a more adequate explanation to justify the difference observed in sex ratio and such intra-specific variation is a common characteristic among reef fishes (Nemtzov, 1997; Sikkel, Herzlieb and Kramer, 2005).

Seasonal variation in relation to the body size, food intake and gonadal development of *S. fuscus* was observed, with variations associated to rainfall. The mass-length equation indicates how much one variable changes in association with the variation of the other. In this context, the relation between body mass and length of *S. fuscus* showed slightly higher values compared to the value reported by Bohnsack and Harper (1989). This difference may be explained by the fact that smaller fish (from 3 to 8 cm in furcal length) were used, whereas in the present study the size range of fish was larger (2.9 to 11.4 cm).

Differences in the mass-length relation between sexes have been reported for several fish species (Le Cren, 1951), and are a consequence of the higher energy expenditure of females during gonadal maturation (Wootten, 1995). Even though the fish in the present study were predominately in the immature and developing gonadal phases, the expected marked effect of sex on the weight-length relation did not occur. One explanation for this finding is that, although female energy expenditure in producing gonads is greater, *S. fuscus* males spend energy defending their territory and protecting the territory (Itzkowits, Ludlow and Haley, 2000; Sikkel, Herzlieb and Kramer, 2005). Coasts of territorial defense by males may be equivalent to expenditure of energy by female on gonadal development, which could explain the similarity in the mass-length curves of males and females.

This study confirms the herbivorous nature of *S. fuscus* in accordance with Ferreira et al. (1998) and Osório, Rosa and Cabral, (2006). There was no difference between the sexes in stomach repletion rates, though there was a higher rate between January and June. The increased ingestion may be related to the reproductive phase. This association may lead to accumulation of sufficient energy to complete the gonadal development. On the other hand, the higher repletion level may result from greater food availability. That is, reproduction may be associated with the period of greater food supply, which would guarantee not only adult development, but also offspring survival. This profile coincides partially with the higher *S. fuscus* length patterns found in March-April and July-August. There was a predominance of larger specimens in the rainy season, which seems to be a response more associated to food availability than to

reproduction. The food supply is greater in the rainy season and therefore, in the dry period, the larger specimens must search for other feeding sites, which would explain the size variation of the fish collected in this study.

Considering the gonadal development phase of *S. fuscus,* the females were mainly in developing stages and the males in the immature or developing stages. That is, the females were in a more advanced stage of gonadal development than the males. The action of external influences has been considered as important spawning synchronizers, for example, in *Chromis dispilus* (Tzioumis and Kingsford, 1995). The different gonadal development phases between *S. fuscus* males and females suggest that there must be some acceleration mechanism for males or a delay mechanism for females that synchronizes the spawning period in this species. However, rainfall had no effect on overall gonadal development. Since temperature and photoperiod duration are relatively constant throughout the year in the study area, other environmental stimuli may have had an influence. In tropical regions the rainy and dry seasons seem to be the most important in regulating fish reproduction (Volpato and Trajano, 2006; Chellappa et al., 2009). This association was not clearly found in this study. The spawning of *S. fuscus* occurred mainly in the dry season (September and February), whereas the initial gonadal development stages predominated in the rainy season.

The spawning season observed in this study is slightly different to those reported for pomacentrids from other geographical regions. Sale (1977) reported a 5-9 month spawning season duration for pomacentrids, with multiple, weekly or monthly frequencies, promoting a wide dispersion. In the northeast Caribbean, *Chronis cyanea* spawn in April, *Microspothodon chrysurus* in March, *S. fuscus* in January, June and September, and *S. leucostictus* in September (Erdman, 1976) In the Red Sea, the numerous pomacentrid species, with their varied spawning behavior, reproduce from March-April to September (Fischelson, Popper and Aviador, 1974).

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