Fecundity of *Macrobrachium acanthurus* Wiegmann, 1836 (Decapoda: Palaemonidae) in a tropical coastal lagoon subjected to human impacts (Macaé, Brazil)

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RESUMO: Fecundidade de *Macrobrachium acanthurus* Wiegmann, 1836 (Decapoda: Palaemonidae) em uma lagoa costeira tropical sujeita a impactos antrópicos (Macaé, Brasil). Esta pesquisa foi realizada na lagoa Imboassica (Macaé, RJ), lagoa costeira urbana sujeita a impactos antropogênicos, como lançamento de esgotos domésticos, aterro de suas margens e aberturas artificiais da barra de areia que a separa do oceano. Várias pesquisas têm se desenvolvido nesta lagoa no sentido de desenvolver um plano de manejo que leve em consideração seus usos múltiplos. Este trabalho aborda o efeito das aberturas de barra sobre *Macrobrachium acanthurus*, através da fecundidade da espécie e a densidade de fêmeas ovígeras após eventos freqüentes de abertura. A fecundidade de *M. acanthurus* foi estimada utilizando 65 fêmeas, coletadas com tarrafa, rede de arrasto e gaiolas tipo covo, durante o período de junho de 1995 a julho de 1997, período em que ocorreram quatro aberturas. A espécie apresentou alto potencial reprodutivo, com número médio de ovos por fêmea de 8438, variando entre 1054 e 17093 ovos. A fecundidade apresentou relação direta e positiva com o peso e com o comprimento das fêmeas, e a melhor estimativa foi obtida entre o peso seco da massa de ovos e o número de ovos. Foram detectadas diferenças no tamanho e no peso dos ovos nos diferentes estágios de desenvolvimento, sendo os mais pesados quando em estágio intermediário e os maiores em estágio final de desenvolvimento. Os valores de salinidade apresentaram grande oscilação, variando em função dos eventos de abertura artificial da barra de areia. O aumento da salinidade após estes eventos e com o fechamento da barra da lagoa pode constituir um estímulo para a migração da espécie desde áreas mais interiores para desova. Por outro lado, a grande freqüência das aberturas artificiais da barra ocorridas neste período parecem ser prejudiciais à população, pois ocasionaram acentuada diminuição no número de fêmeas ovígeras.

Palavras-Chave: *Macrobrachium acanthurus*, Palaemonidae, fecundidade, lagoa costeira, impacto antrópico

ABSTRACT: Fecundity of *Macrobrachium acanthurus* Wiegmann, 1836 (Decapoda: Palaemonidae) in a tropical coastal lagoon subjected to human impacts (Macaé, Brazil). This work was performed at Imboassica lagoon (Macaé, RJ), an urban coastal lagoon subject to anthropogenic impacts, such as the inflow of untreated domestic sewage, landfilling in its margins and artificial openings of the sandbar that separates it from the ocean. Many studies have been done in this lagoon to develop a management plane to it. This research aimed to evaluate the sandbar openings effects on *Macrobrachium acanthurus* after frequents events of breaching, through its fecundity and ovigerous females density. The fecundity of *Macrobrachium acanthurus* was based on 65 females, collected with throwing net, dragnet and traps, from June 1995 to July 1997. The species had a great reproductive potential, with an average number of eggs per female of 8438, ranging from 1054 to 17093. The fecundity had a positive relationship with the weight and length of the females, and the adjustment between the dry weight of the egg mass and the number of eggs was the best estimate. We detected differences of length and weight in the eggs throughout their development, the greatest weight being registered in intermediate stages of development and the greatest length in the final stages of development. Salinity had great oscillations, due to the events of sandbar openings. The higher salinity after

this events and with the closing of sandbar could act as a migration signal for the hatching in the lagoon, but the frequency of sandbar openings that occurred in this period seems to be harmful to the population, since there was a decline in the ovigerous females number.
Key-words: *Macrobrachium acanthurus*, Palaemonidae, fecundity, coastal lagoon, human impact

Introduction

Palaemonidae of the genus *Macrobrachium* are considered as descendants from marine ancestors, which later migrated to freshwater regions (Jalihal *et al.*, 1993; Álvarez & Villalobos, 1997). Nowadays this genus exhibits freshwater adapted species, called continental, especially in lotic environments, and other designated as coastal species, with larval stages salinity dependent and which therefore migrate to estuaries and other areas close to the ocean to lay their eggs (Coelho & Ramos-Porto, 1985; Fonseca, 1995). Smaller and abundant eggs characterize the coastal (or littoral) species (Coelho & Ramos-Porto, 1985), and according to Albertoni (1998a) *Macrobrachium acanthurus* is classified as typical coastal species.

Macrobrachium acanthurus is found from North Carolina (EUA) to Rio Grande do Sul (Gomes-Correa, 1977; Bond-Buckup & Buckup, 1989; Fonseca, 1995; Camacho *et al.*, 1997; Bond-Buckup & Buckup, 1999) and its habitat is water bodies close to coastal zones, with few currents and salinity between 0 and 15 ppt. It is popularly known as "cinnamon shrimp" in the southern area of Brazil (Bond-Buckup & Buckup, 1989), and "cinnamon shrimp, freshwater shrimp or pitu" in the southeast and northeast of the country. It is found in all hydrographic basins of the State of Rio de Janeiro (Fonseca, 1995), is an important species in the fisheries of the area (Oliveira *et al.*, 1955; Albertoni, 1998a), reaching a great size (18 cm of total length), and for this reason has a great potential for use in commercial farms (Valenti, 1985).

In coastal lagoons of Rio de Janeiro State, studies about the biology of Palaemonidae is almost nonexistent. The knowledge about its reproductive biology is an important step aiming to a possible increase in its management and exploitation in natural environments, and it would be very useful for future studies of reproductive strategies and life histories of this species (Corey & Reid, 1991).

Imboassica lagoon is separated from the sea by a sand barrier about 50 m wide. The surroundings are partially occupied by residential areas and, sometimes, during the rainy season, inundation of these areas occurs (Branco *et al*, 1997). An artificial opening (by human action) of the sand barrier then causes drastic drop in the water level and sea water entrance. These modifications involve substantial change in salinity levels and in the biotic communities (Albertoni *et al.*, 1999; Palma-Silva, 1999; Palma-Silva *et al.*, 2000).

The present study aimed to evaluate the fecundity of *Macrobrachium acanthurus*, through an estimating of the number of eggs per female, and to investigate the variation in size and weight between the development stages of the eggs. We also analyzed the periods with highest reproductive effort of the species, relating it to the impact of frequent artificial breachings of the lagoon's sandbar on the populational stratum of reproductive females.

Material and Methods

Imboassica lagoon is located on the northern coast of the State of Rio de Janeiro, Brazil (22° 50' S; 44° 42' W) in the urban zone of municipality of Macaé. Its present area is 3.26 Km^2 and a medium depth of 1.1 m (Panosso *et al.*, 1998). The regional climate is subhumid, with a maximum mean temperature of 29.9° C in February (summer) and a minimum mean temperature of 25.4° C

in July (winter). Annual precipitation varies between 800 and 1200 mm (RADAMBRASIL, 1983). After an artificial sandbar breaching in May 1995, during this research, four another events took place, November 1995, April 1996, November 1996 and January 1997. The influence of the frequency of this process of artificial breaching of the sandbar over this population was evaluated, throught the frequency of ovigerous females and salinity variation during the studied period.

The mean number of eggs of *M. acanthurus* was calculated from 65 females, using all development stages of them. The samplings were performed monthly, with dragnets, casting nets, and traps, with baits, placed close to the macrophyte stands, from June 1995 to July 1997. For each sample date, in two consecutive nights were used 10 traps (placed during night period, and chicken or cow liver was used as bait), ten 50 meters drags, and ten catches with casting net, all of them at night, beggining one hour after sunset. The species was identified according Wood (1974), Gomes-Corrêa (1977), Rodriguez (1980) and Fonseca (1995).

After the sampling, the females were kept in ice, and in the laboratory the total lenght (TL = from the tip of rostrum to the tip of telson) and weight (W) were recorded for each specimen. The difference between the weight of the female with and without the egg mass was considered to be the weight of the egg mass (Müller & Carpes, 1991). The individual eggs mass were preserved in a solution of alcohol 70%. For an easier interpretation of the results the eggs were morphologically characterized and classified as follows, adaptaded from Corey & Reid (1991) :

a- initial development (ID) => eggs without eyespots;

b- intermediate development (InD) => eggs with developing eyespots; and

c- final development (FD) => eggs with developed eyespots and detectable appendages.

The difference in the number of eggs in each development stage was tested (ANOVA). Since *M. acanthurus* carried high number of eggs, their number, weight and length were measured according to Corey & Reid (1991). The eggs were air dried until constant weight and weighed in a digital scale (0.1 mg). From each egg mass three subsamples were taken, with around 100 eggs, weighted and counted, for the determination of the number of eggs in each subsample and of the mean weight of the eggs. This weight and count were used for the estimate of the number of eggs in each female. From each subsample of eggs an aliquot of at least 10 eggs was taken, and the longest and shortest diameters of each egg (including the chorionic membrane) were measured under a compound microscope with a camera lucida. Data were analysed by regression for allometric plots ($y=ax^b$) of reproductive variables versus TL and W. Comparisons between the length, width and weight of the eggs were tested (Sokal & Rohlf, 1979).

Results

The salinity values oscillate throughout the period of study, due to the events of sandbar breachings (Fig. 1). An increase in the number of ovigerous females was observed three months after the sandbar breaching, in both intervals under study. However, after the third breaching the number of females dropped. Therefore, considering all periods, there is a trend for the decrease in the number of ovigerous females after frequent events of sandbar breachings.

The fecundity of *M. acanthurus* was based on 65 ovigerous females, and their frequency distribution of size was normal and unimodal (KS, d= 0.0539; $p<0.05$) varied from 76.18 to 112.02 mm (94.10 + 7.51 mm) (Fig. 2). There was no significant difference between the mean number of eggs in each development stage (ANOVA, $p> 0.05$), and all stages were used for the fecundity estimative.

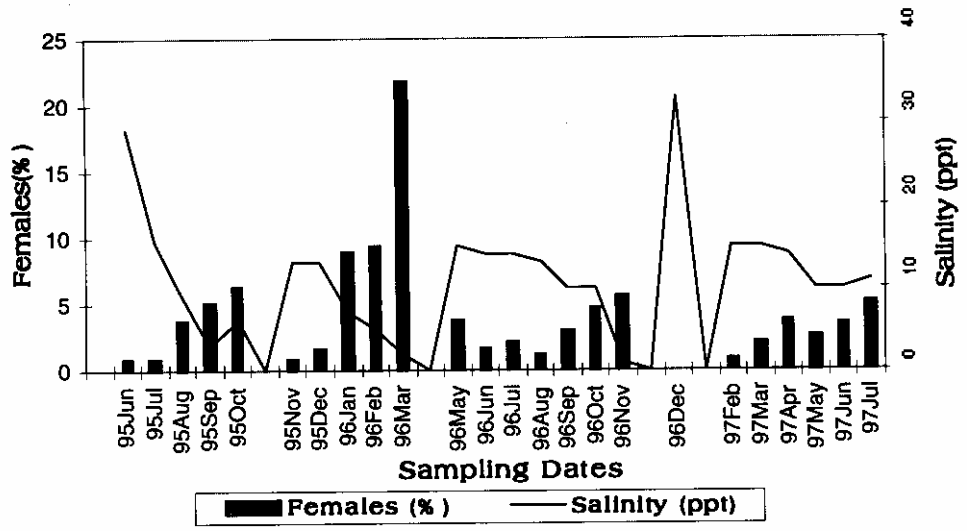

Figure 1: Frequency of ovigerous females of *Macrobrachium acanthurus* and salinity variation in relation of sandbar breachings at Imboassica lagoon, from June 1995 to July 1997 (arrows shows sandbar openings).

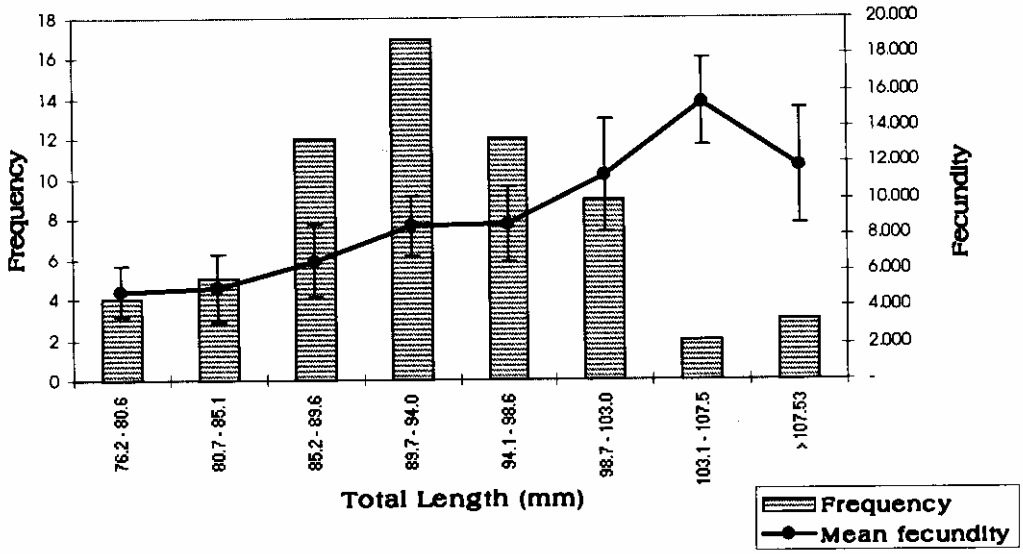

Figure 2: Frequency distribution and mean fecundity of *Macrobrachium acanthurus* ovigerous females at Imboassica lagoon, between June 1995 and July 1997.

The females exhibited a great number of small eggs, and the mean of total number of eggs per female was 8,437 ± 3,129, ranging from 1,054 (female with 79.34 mm TL) to a maximum of 17,093 (female with 107.46 mm TL). The linear regression curves (non-transformed data), adjusted between the TL of the females and the total number of eggs estimated for each female, and the wet and the dry weight of the eggs had a high significance ($p < 0.001$) (Fig. 3). The fecundity-total length relationships of females showed an increase in number of eggs produced with increasing female size. This condition was supported by the high r^2 coefficient.

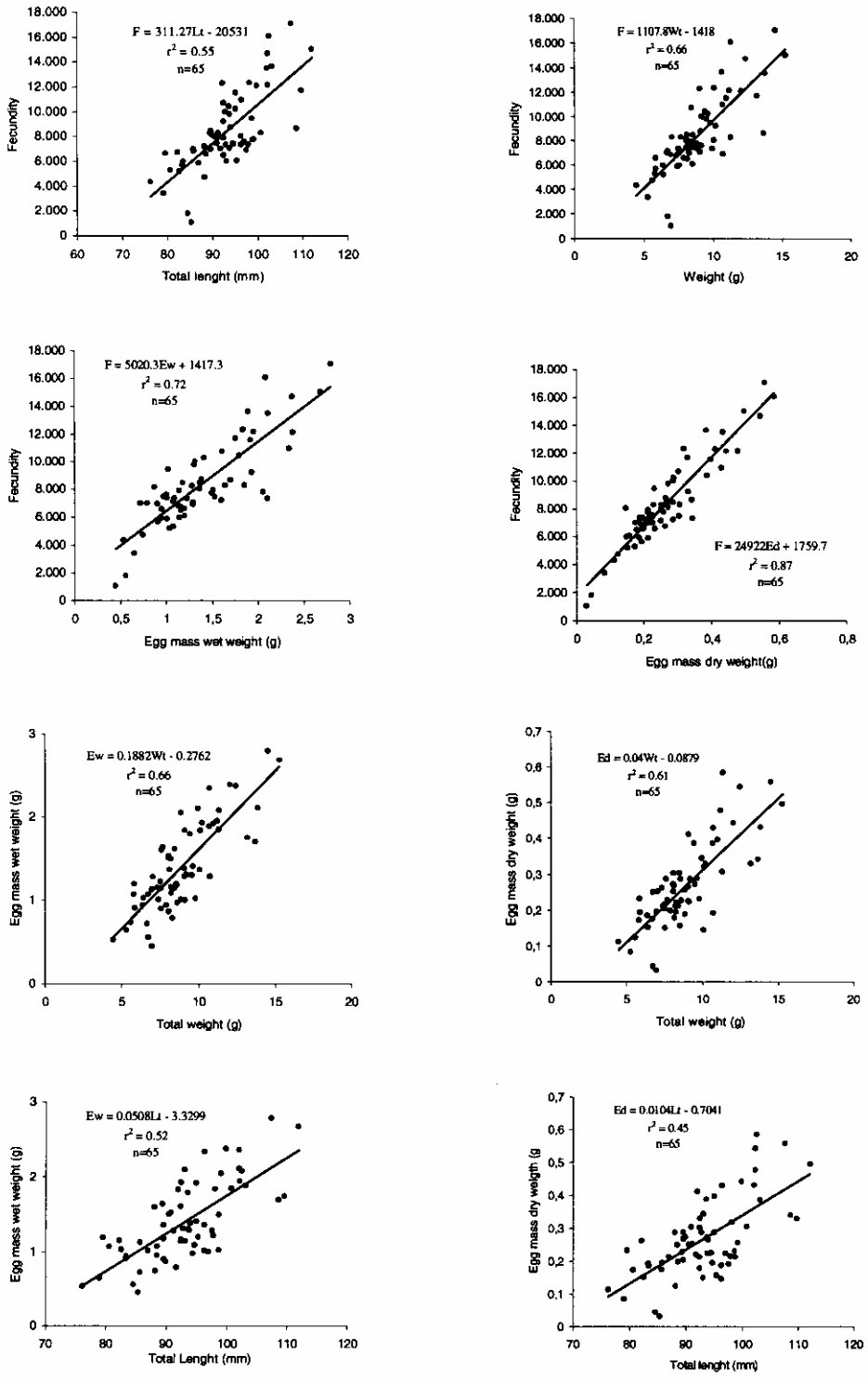

Figure 3: Linear regressions between biometric measurements of ovigerous females, egg numbers and egg mass weight of *Macrobrachium acanthurus*. (F= fecundity; Lt= Total length ; Wt= Total weight; Ew= Egg mass wet weight; Ed= Egg mass dry weight).

The classification of the egg masses development stage in three categories regarding the allowed for the comparison of the variation that may occur in their size and weight. A total of 712 eggs were measured and they have a slightly oval shape, with mean length of 0.605 + 0.052 mm (0.525 to 0.712mm) and mean width of 0.489 + 0.051 mm (0.227 to 0.602 mm) .

The biometric measurements for each eggs stage (ID, InD, FD) were compared (ANOVA). The FD was significant larger ($p < 0.001$) (0.625 + 0.045 mm) than the other ones (ID 0.575 + 0.023 mm, and InD 0.587 + 0.033 mm). The width of the different stages of development did not exhibit a statistically significant difference ($p > 0.05$) (ID 0.487 + 0.025 mm, InD 0.450 + 0.033 mm, and FD 0.50 + 0.053 mm), and the mean weight of the eggs in the InD showing the higher weight ($p < 0.01$) (0.0359 + 0.003 g), with 0.0261 + 0.0041 g for ID and 0.0317 + 0.0026 g for FD.

Discussion

The reproductive cycle of several species of crustaceans is measured by the presence of ovigerous females in different times of the year (see Corey & Reid, 1991). At Imboassica lagoon, ovigerous females of *M. acanthurus* were captured in almost all months of the year, the exceptions being the months in which the artificial breaching of the sandbar took place (November 1995, April 1996, and January 1997), when they disappear completely, due to the drastic drop in the water level, the dragging of individuals by the water flow to the ocean, and the intensive fishing to which the species is subjected when it is restricted to a few pools. In November 1996 the capture was done before sandbar breaching.

The reappearance of the species in the lagoon is linked to the restoration of the water column, and the connection of the water in the lagoon with the Imboassica stream, where the non-reproductive population is supposed to reside. The events of sandbar breachings determining the migration and survival of adults are unpredictable and aperiodic, since the sandbar breachings occur haphazardly, determined by the pluviometric regime of the area and not according to specific seasons, which would allow the organisms to establish egg-laying patterns.

After the sandbar breaching, the salinity of the lagoon gradually drops as the water level rises. This may be a positive factor for the migration of reproductive adults towards the mesohaline areas and the laying of the eggs. However, after the third consecutive interval between breachings, the number of ovigerous females decreased, showing the negative effects of successive and high frequency sandbar breachings, preventing the reestablishment of the population.

Some authors have reported the need for brackish water for the larval development of *Macrobrachium* species (Horne & Beisser; 1977; Moreira, 1994; Bueno & Rodrigues, 1995). In a laboratory culture, Dobkin (1972), achieved good rates of survival and metamorphosis for *M. acanthurus* in salinities of 23.5 and 35 ppt, and survival in salinity of 12 ppt, postulating that the survival and adaptation of the larvae to salinity may vary among populations from different geographic regions. Moreira *et al.* (1986), mentioned *M. acanthurus* as a species with narrow limits for survival of the first larval stages (14 to 20 ppt). Brailovsky & Galera (1997), in laboratory experiments, found that the maximum salinity tolerated by *M. acanthurus* was 25 ppt, and may have flexibility of adaptation to different salinities. The data of larval abundance quoted by Albertoni *et al.* (1999), at Imboassica lagoon, show that larvae of *M. acanthurus* were found in salinities ranging from 1 to 16 ppt, without, however, survival or growth data of these larvae.

The maintenance of salinities values in the months after the breaching and closing of the sandbar probably acts as a signal detected by the adults for their migration and the hatching. The comparative analysis of the abundance of ovigerous females, after the three artificial breachings, indicate that successive events of breaching may be harmful to the species, as seen in the last period when the number of females had a sharp decline.

In previous study, Albertoni (1998b) postulated the possibility of use this lagoon for intensive culture of some shrimp species, among these *M. acanthurus*, including studies for the management of sandbar openings, with planning of favorable periods to the development of fisheries resources, both of freshwater and marine origin, and prevent high levels of eutrofication in the lagoon. Considering the results of abundance of *M. acanthurus* ovigerous females, the management of sandbar openings must consider the frequency of this events to avoid damage to this population.

Williamson (1972) ponders that the size and number of eggs may indicate the development mode of many species of *Macrobrachium*. Species found in interior freshwaters have short larval stages, and few, large eggs, and coastal species have smaller and abundant eggs (Coelho & Ramos-Porto, 1985). *Macrobrachium acanthurus* is classified by Jalihal *et al.* (1993) as a species with prolonged or normal type of development with more than 10 larval stages and numerous and small eggs.

According Shakuntala (1977), among many factors that regulate the number of eggs carried by a crustacean, the size of female seems to be the most important one. Several authors have found that the number of eggs in species of Palaemonidae, particularly in the genus *Macrobrachium*, exhibits a significant positive correlation with the size of the female (Paiva & Barreto, 1960; Shakuntala, 1977; Bond & Buckup, 1982; Ching & Velez Jr., 1985; Valenti *et al.*, 1986; 1989; Corey & Reid, 1991; Mashiko *et al.*, 1991; Müller & Carpes, 1991; Müller *et al.*, 1996; Souza & Fontoura, 1996).

In studies of crustacean fecundity, mostly authors estimate it with eggs in all stages of development (Modlin, 1980; Walker & Ferreira 1985; Prager *et al.* 1990; Cracco & Fontoura, 1995, among others), and others use the early stage of eggs, to avoid effects of egg loss during incubation by parasitism or predation (Mashiko *et al.*, 1991; Reid & Corey, 1991; Mantelatto & Fransozo, 1997; among others). Carpenter (1983) showed that for *Paratya curvirostris* there was no difference between the number of newly laid eggs per female and the number of eggs per female close to hatching, indicating no losses during development. In this research, we use all stages for the fecundity estimate, since there was no statistical differences in the mean number of eggs among the three stages. The fecundity of *M. acanthurus*, expressed as number of eggs per female, is directly related to the size and weight of the females, and the size and weight of the eggs exhibit some variation related to the stage of development that they reached.

Camacho *et al.* (1997) quotes for *M. acanthurus* in Mexico an average production of 3,500 eggs, and Corey & Reid (1991) quote 14,599 eggs for this species captured in Florida. Both authors did not mentioned size of females neither the development stages of eggs. Valenti *et al.* (1989) found for the population from São Paulo, an individual mean fecundity of 8,929 eggs, ranging from 740 to 17,769 eggs, in a range of female size of 60 to 140 mm, in all development stages of eggs. The positive linear relationship between the weight of the females and the number of eggs, is also referred to by some authors, as Shakuntala (1977), Valenti *et al.* (1989) and Müller & Carpes (1991).

These values indicate the great reproductive potential of *M. acanthurus*, and the average (8,248) and maximum (17,093) values of eggs by female found in this research are close to the values found by these authors. The fecundity has a direct, positive relationship with the size and weight of the females, and the adjustments made with the total length and total weight allow for an estimate of the number of eggs per female.

The quoted size of the eggs for *M.acanthurus* ranges from 0.5 to 0.6 mm of diameter (Gomes-Corrêa, 1977), and according Jalihal *et al.* (1991), 0.40 to 0.65 x 0.55 to 0.95 mm and brownish eggs characterizes the group where this species is found. Corey & Reid (1991) mentioned that the eggs tend to increase in weight and volume in the course of development.

The results obtained for *M. acanthurus* in this research show that there is a significant increase in the weight between the initial and intermediate stages of development, with a later decrease when the eggs are in the final stage of development, close to the hatching. The difference in weight between the intermediate and final stages may be explained by the change of environmental material, and some uptake of stored material from the eggs, for *M. acanthurus* hatches as zoea, and the first steps of the larval stages, nauplius and mysis, are embryonic, with uptake of stored nutrients while still inside the egg.

Through the results obtained in this research, we conclude that *M. acanthurus* is a species with a potential use for food production in this region, and frequent sandbar breachings are harmful to its re-establisment at Imboassica lagoon

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