Fecundity of the spider crab *Mithraculus forceps* (Decapoda, Mithracidae) from the northeastern coast of the state of São Paulo, Brazil

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ABSTRACT. Fecundity is one of the most important parameters in studying the reproductive output of Pleocyemata decapods, especially because of its relationship to the efficiency of population replacement. Knowledge of fecundity provides basic elements for understanding the reproductive strategies, dynamics, and evolution of a given population. The present investigation provides informations on fecundity, egg size, egg loss, and the relationship between fecundity and selected environmental features, for the spider crab *Mithraculus forceps* (A. Milne Edwards, 1875). Ovigerous crabs were collected each month during 2000, by SCUBA diving, at Couves Island (23°25'25"S, 44°52'03"W) on the northeastern coast of the state of São Paulo, Brazil. A total of 40 ovigerous females with egg in early development (initial stage) and 28 final stage eggs were obtained and analyzed. Mean fecundity, from eggs of the initial stage, was 402.8 ± 240.1 eggs, ranging from 60 to 1,123 eggs. Sizes of females ranged from 9.4 to 14.0 mm carapace width. Mean egg size was 0.56 ± 0.06 mm diameter. A 20.33% rate of egg loss was estimated by comparing the fecundities of batches of eggs in early and late development (40 initial batches and 28 final stages batches). There were no significant relationships between the water temperature or salinity and variations in fecundity. As in most brachyuran species, *M. forceps* showed a strong conservative relationship between fecundity and body size.

KEYWORDS. Reproduction, reproductive output, Brachyura, *Mithraculus forceps*, Ubatuba.

RESUMO. Fecundidade do caranguejo-aranha *Mithraculus forceps* (Decapoda, Mithracidae) do litoral norte do Estado de São Paulo. A fecundidade é um dos parâmetros mais importantes no estudo do potencial reprodutivo dos decápodes Pleocyemata, em especial por sua relação com a reposição de indivíduos na população. Informações acerca da fecundidade providenciam elementos importantes para a compreensão das estratégias reprodutivas, dinâmica e desenvolvimento de uma determinada população. Este trabalho estudou a fecundidade, tamanho dos ovos, perda de ovos durante a incubação e as relações entre a fecundidade e alguns determinados fatores ambientais para o caranguejo-aranha *Mithraculus forceps* (A. Milne Edwards, 1875). Fêmeas ovígeras foram amostradas de janeiro a dezembro de 2000, por meio de mergulho autônomo, na região da Ilha das Couves (23°25'25"S, 44°52'03"W), litoral norte do Estado de São Paulo, Brasil. Foi capturado um total de 68 fêmeas ovígeras, das quais 40 com ovos em estágio inicial de desenvolvimento e 28 com ovos em estágio final. A fecundidade média para o total de massas de ovos analisadas foi de 402,8 ± 240,1 ovos, variando de 60 a 1123 ovos. O tamanho das fêmeas variou de 9,4 a 14,0 mm de largura de carapaça. O tamanho médio dos ovos foi de 0,56 ± 0,06 mm de diâmetro. Foi estimada uma taxa de 23,33% de perda de ovos durante a incubação por meio da comparação do número médio de ovos em estágios inicial e final de desenvolvimento. Não foi possível detectar correlação entre a fecundidade de *M. forceps* e a variação dos valores de temperatura e salinidade. A exemplo do que se observa para a maior parte das espécies de Brachyura, *M. forceps* também é caracterizado por apresentar uma relação bastante conservativa entre o tamanho do corpo e o número de ovos produzidos por desova.

PALAVRAS-CHAVE. Reprodução, potencial reprodutivo, Brachyura, *Mithraculus forceps*, Ubatuba.

The Order Decapoda is a highly diversified group whose members show many adaptations to various lifestyles. Their evolution involves an important innovation, unique among malacostracans: the emergence of pleopodal incubation, with eclosion typically occurring in the zoeal stage. This strategy characterizes the suborder Pleocyemata, which includes the brachyuran crabs (Saint-Laurent, 1979; Santos & Negreiros-Fransozo, 1997). The species of the superfamily Majoidea, well known concerning their larval development, show abbreviated metamorphosis. In this sense, Fransozo & Hebling (1982) noted a great degree of specialization in this superfamily compared with other Brachyuran groups, and they suggested this specialization may be partly responsible for the large number of species in this taxonomic group.

Fecundity studies may provide important information on the rate of replacement in a natural population. This information allows a better understanding of the reproductive strategies, dynamics, and evolution of a given population (García-Montes *et al.*, 1987). In crabs, fecundity is traditionally measured as the number of eggs produced in each clutch, and it is described as a function of body size (Corey & Reid, 1991). However, according to Steachey & Somers (1995) and Luppi *et al.* (1997) it is convenient to distinguish fecundity estimates according to the stage of egg production, i.e., 1) potential fecundity, as the number of oocytes stored in the ovaries; 2) realized fecundity, as the number of extruded eggs attached to the pleopod setae; and 3) actual fecundity, represented by the number of released larvae.

Egg size can be viewed as one of the most important reproductive variables, which determines whether the relatively constrained brood mass is partitioned into many small or few large eggs, thus resulting in much greater variation in fecundity than in brood mass for equivalent-size crabs (Hines, 1982). Ecological and evolutionary consequences of these apparent variations have not been examined for closely related species in similar habitats (Hines, 1988).

Reproductive output per brood is strongly correlated with body size among brachyuran crabs. According to Hines (1982) and Henmi (1989), a lack of relationship between body size and fecundity may have several causes, such as individual variation in egg production, seasonal food availability, and multiple spawnings, in addition to natural egg loss.

Brachyuran crabs usually carry their eggs attached to the pleopodal setae, forming a partially exposed mass of eggs, as occur with *Stenorhynchus seticornis* (Cobo, pers. obs.). The peripheric layers of eggs may be vulnerable to damage from various sources, i.e., pathogenic and parasitic agents (SHIELDS, 1991), long periods of incubation that increase egg loss by rubbing against the substrate (TALBOT, 1991), and even active removal during grooming or under stressful conditions (NORMAN & JONES, 1993). The impact of egg mortality during the incubation period may act as a causal factor, thus contributing to the dynamics of crabs' population cycles. However, the exact significance of this impact remains poorly understood, in particular as to how it affects the sensitivity of these animals' responses to the range of environmental factors.

Along the Brazilian coast, the genus *Mithraculus* White, 1847, is represented by three species, *M. coryphe* (Herbst, 1801), *M. forceps* (A. Milne Edwards, 1875), and *M. sculptus* (Lamarck, 1818). The geographical range of *M. forceps* is limited to the Western Atlantic, from North Carolina, U.S.A. to Santa Catarina, Brazil. This crab is commonly found on hard substrata under rocks and coral heads, from the intertidal down to 100 meters deep (MELO, 1996). According to PENHA-LOPES *et al*. (2005), *M. forceps* has a great potencial for aquaculture, with short larval duration and survivorship, when fed on newly hatched *Artemia* nauplii. Nevertheless, a large number of juveniles must be produced at low cost, allowing aquaculture-raised animals to compete with wild caught animals in the aquarium trade market, which can be an alternative to minimize the effects of wild harvest on the coral reef ecosystems.

This investigation provides information about the fecundity of a population of the spider crab *M. forceps* at Couves Island, on the northeastern coast of the state of São Paulo, Brazil, including data on egg size and loss.

MATERIAL AND METHODS

Monthly collections were made from January to December 2000, at Couves Island, northeastern coast of São Paulo, Brazil (23°25'25"S, 44°52'03"W). Crabs were collected by SCUBA diving, with catch per unit effort of 4 hours each month. The specimens were individually packed in plastic bags and transferred frozen to the Laboratório de Biologia Marinha – LabBMar/IBB-UNITAU. After that, the ovigerous females were identified, measured at their largest carapace width (CW) and grouped into 1 mm-CW size classes, as indicated by COBO (2005).

The egg masses were detached from the pleopodal setae, and the eggs were counted under a microscope stereoscope with a manual counter. A sample of 5 eggs was taken from each batch, and the egg diameters were measured using an ocular micrometer scale under a microscope stereoscope.

Early and late egg stages of embryo development were identified according to BOOLOOTIAN *et al*. (1959) and OKAMORI & COBO (2003), modified for this species as follows (1) initial stage: early development; yolk occupying the whole internal volume of the eggs; no evidence of cleavage or cellular differentiation; (2) final stage: late development; reduced amount of yolk; embryo differentiated, showing visible segmentation of limbs and large developed eyes.

Temperature and salinity data were provided by LabMet, Instituto Oceanográfico, Universidade de São Paulo. Luminosity data were provided by the Instituto Agronômico de Campinas–IAC, Ubatuba. The relationship among environmental features and fecundity was estimated by regression analysis. A 5% statistical significance level was considered (ZAR, 1999).

RESULTS

During the study period, a total of 68 egg masses were obtained: 40 in the initial stage and 28 in the final stage of embryonic development. The estimated mean fecundity was 375.5 ± 211.8 eggs, ranging from 60 to 1,123 eggs. The mean fecundity of the females with eggs in different developmental stages is presented in Table I. There were no significant differences between the fecundity of these stages of embryo development (t= 2.025; p= 0.026). However, the mean fecundity of early developmental eggs was 23% higher than the final ones.

The size-specific fecundity of early eggs was assessed by the regression analysis and could be expressed by the power function Egg Number = $0.13.CW^{3.28}$ ($r^2 = 0.68$); the fecundity of late-developmental eggs was Egg Number = $5.46.CW^{1.68}$ ($r^2 = 0.17$) (Fig. 1). The general mean egg size was 0.51±0.06 mm diameter, and there were no significant differences between clutches of initial and final embryo stages (t= -0 827; p= 0.412). No significant differences were detected among the mean monthly fecundities (F=2.27; p=0.016) (Fig. 2). The range of fecundity showed no relationship to the variations of the selected environmental factors (Tab. II). Multiple regression analysis also detected no relationship among fecundity variation and water temperature and salinity (F=0.2317; p=0.8791). The body size of females showed no significant variation among the analyzed months (H=23.3; p=0.016).

Table I. Egg number and ovigerous female size of the spider crab *Mithraculus forceps* in each analyzed embryonic stages at Couves Island, Ubatuba, state of São Paulo, Brazil.

Egg stage	Number of clutches	Number of eggs	Mean female size (mm)
initial	40	402.8±240.2	10.9±1.4
final	28	320.9±196.2	10.9±1.5

Table II. Relationships among fecundity of the spider crab *Mithraculus forceps* and selected environmental parameters, i.e. water temperature, salinity and luminosity, at Couves Island, Ubatuba, state of São Paulo, Brazil (r^2; p<0,05).

	Water temperature	Salinity	Luminosity
r^2	0.0457	0.0273	0.0653
p	0.5045	0.6078	0.4228

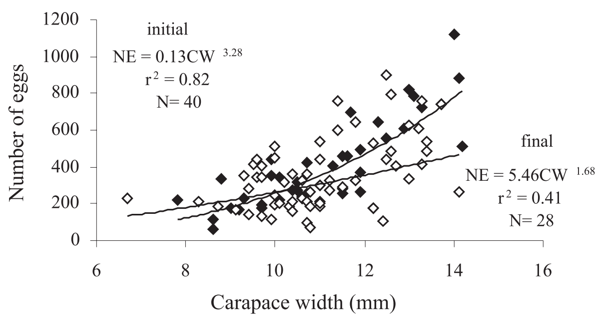

Fig. 1. *Mithraculus forceps* relationship between egg number and crab size (carapace width) (initial, open diamonds; latter, close diamonds) at Couves Island, Ubatuba, state of São Paulo, Brazil.

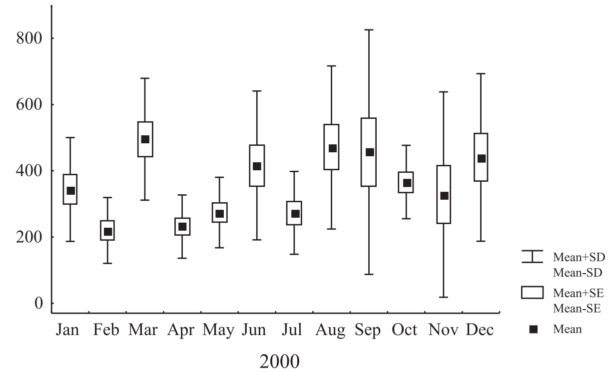

Fig. 2. *Mithraculus forceps* box-whisker plot of the fecundity (monthly average) at Couves Island, Ubatuba, state of São Paulo, Brazil.

DISCUSSION

Fecundity is often recognized as an important parameter to measure the reproductive output of species or even populations (MANTELATTO & FRANSOZO, 1997). The spider crab *M. forceps* seems to be part of those crabs which have low fecundity per brood, and egg number can vary, among crab species, from less then 5,000, described for *Aratus pisonii* (H. Milne Edwards, 1837) in Jamaica (WARNER, 1967) to more than 4,000,000, as reported by HAYNES *et al.* (1976) for *Chionoecetes opilio* (Fabricius, 1788) on the Gulf of Saint Lawrence, Canada.

Reproductive output per brood for brachyuran crabs is strongly correlated with body size and weight within a species (see HINES, 1982, HARTNOLL, 1985) and the size of eggs (RABALAIS, 1991). In this study, the brood size of *M. forceps* showed a conservative relationship to body size, as it has been observed for most brachyuran species (see CHOY, 1988). However, there were some examples of lack of relationship between body size and fecundity for *M. forceps*, specially regarded to final egg stages, which may have several causes. Some of these causes are proposed by GUTIÉRREZ & ZÚÑIGA (1976) who pointed out that large female *Cancer borealis* Stimpson, 1859 may be senescent and produce fewer or smaller eggs. SAINT-MARIE (1993) suggested that primiparous females may be less fecund than females carrying a second clutch, but some females fertilize the second egg clutch with sperm stored from the first mating. SHIELDS (1991) proposed that temperature may influence the brood size. However, to find the main causes of lack of relationship between body size and fecundity in *M. forceps* further field and laboratory studies are required.

The mean number of eggs produced did not change significantly over the months, probably because of the lack of relationship between fecundity and the selected environmental features. The availability of food and some tolerance for environmental changes could explain the maintenance of *M. forceps* egg production, which remained almost constant over the study period. Maintenance of fecundity throughout the annual cycle was reported by OKAMORI & COBO (2003) for another spider crab, *Stenorhynchus seticornis* (Herbst, 1877), from the same area as the present study, suggesting a latitudinal pattern. As mentioned by SASTRY (1983), it is still unknown how, or to which extent, environmental features may constrain reproductive strategies. However, it is imperative that the populations adjust their life cycles to the prevailing conditions.

According to BRYANT & HARTNOLL (1995), the majoid crabs have larger eggs than most other brachyurans. For *M. forceps*, egg size was similar to that observed by OKAMORI & COBO (2003) for *S. seticornis*, a spider crab as small as *M. forceps*. However, HINES (1991) stated that egg size seems not to vary as a function of body size; also, variations in egg size have been recorded for some brachyurans. Crustacean egg production and development may be constrained, at least in part, by climatic conditions. In general, the influence of climate is more evident for those species inhabiting cold waters: they have much longer embryogenic periods than do crabs living in warmer waters. The lack of relationship between environmental features and the fecundity of *M. forceps* is not surprising; the same was also reported for *S. seticornis*, in the same region (OKAMORI & COBO, 2003).

As suggest by SHIELDS (1991), most species of crab show some variation in their reproductive ecology at both intraspecific and interspecific levels. Interspecific variations may be controlled by many factors, including climatic regime, habitat, and some biological constrains. Features of the embryonic and larval stages of crabs lend themselves to studies of environmental sensitivity.

Intraspecific changes in fecundity of *M. forceps* result especially from variation in body size. However, certain environmental conditions, such as the availability of food for adults, may have some importance in the reproductive output of this crab.

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