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EXTERNAL FACTORS DETERMINING THE REPRODUCTIVE PERIODICITY IN A TROPICAL POPULATION OF THE HAIRY CRAB *PILUMNUS VESPERTILIO* (DECAPODA: BRACHYURA: PILUMNIDAE)

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ABSTRACT. **–** *Pilumnus vespertilio* is probably the most abundant brachyuran inhabiting the pebble and rocky areas of Mozambique. However, several aspects concerning its biology remain poorly known. The influence of temperature and rainfall on the reproductive activity of this crab were investigated. Samples were taken from January to December 2002 in the pebble area of Inhaca Island, Mozambique. Pearson correlations revealed that both temperature and rainfall were positively associated with the relative frequency of ovigerous females. However, multiple regression models showed that temperature is the main factor controlling the reproductive activity of this species in the study area.

KEY WORDS. **–** *Pilumnus vespertilio*, Reproduction, Temperature, Rainfall, Inhaca Island, Mozambique.

INTRODUCTION

Reproduction in brachyurans is extremely diversified (Hartnoll & Gould, 1988). Breeding may take place year-round (continuous pattern) or be restricted to few months (discontinuous pattern). As stated by Sastry (1983), the reproductive characteristics of a species or population are a result of the interactions between various exogenous and endogenous factors. In particular reference to tropical brachyuran species, it is generally thought that in tropical regions reproduction occurs year-round due to stable environmental parameters (Negreiros-Fransozo et al., 2002).

The determination of breeding periods is the result of a complex interaction of endogenous and exogenous factors, allowing both intra and interspecific variations regarding the duration of the reproductive season (Sastry, 1983). The breeding period is defined as the time interval during which ovigerous females may be found in a population (Cobo, 2002a).

Moreover, length of the breeding period is also correlated to vertical position in intertidal crustaceans (Sastry, 1983), and semiterestrial brachyuran crabs species living in higher intertidal substrate may usually show a well-defined breeding season (Emmerson, 1994; Flores & Negreiros-Fransozo, 1998, Cobo, 2002a, b).

The recognition of external factors controlling reproduction in brachyuran crabs can be achieved by means of sampling along a time interval including more than a single breeding period, e.g. data obtained from long-term population studies, or through comparisons between closely related species when equivalent information is available (Flores & Negreiros-Fransozo, 1998).

Pilumnid crabs are the most abundant and important organisms inhabiting the pebble, rocky and crevice substrates (Almaça, 1987, 1990). Due to their high abundance, pilumnid crabs may significantly contribute to the energy flow in marine environments, as they have been reported to be consumed by fish and seabirds. Moreover, they may contribute to the ecological balance in rocky habitats through the release of billions of planktonic larvae that can serve as both predators and prey for other species. Most studies already carried out on these crabs rely on larval development (Spivak & Rodriguez, 2002; Ng, 2002; Clark & Paula, 2003).

Pilumnus vespertilio (Fabricius, 1793) is a small crab inhabiting the lower eulitoral, rocks and crevices areas of Inhaca Island, southern Mozambique. It occurs widely in the Indo-Pacific region (Jones, 1997). But nothing is known about the reproductive biology of this species in Mozambique.

This study provides information on the breeding periodicity of *Pilumnus vespertilio* at Inhaca Island, southern Mozambique, based on the monthly frequency variation of ovigerous females and evaluates the association between the breeding intensity and the environmental parameters of temperature and rainfall.

MATERIALS AND METHODS

Sampling was carried out from January to December 2002. Crabs were found under coral debris and rocks at Inhaca Island, southern Mozambique (26º00´S and 33º00´E). All aspects concerning the fauna, flora, physical parameters and topographic structure of Inhaca Island can be found in Guerreiro et al. (1996) and Paula et al. (1998). Each month, crabs were collected by hand during spring low tide and standardized full moon periods, through a catch effort performed by two people, during 1 hour, covering an area of 300 m^2, always during low tides. All specimens were kept individually in plastic bags and preserved in 70% ethanol until further processing. In the laboratory, each crab was measured for carapace width (CW) and the presence of egg masses in females was recorded. The monthly frequency of ovigerous females crabs was determined based on the percentage of breeding females within the overall adult female sample.

The monthly average values of water temperature and rainfall were provided by the local meteorological institute (INAM-Instituto Nacional de Meteorologia). The degree of association between ovigerous crabs and the environmental parameters was evaluated using the Pearson´s correlation (Zar, 1999). Student t-test was employed to compare the mean size of non-ovigerous and ovigerous females. In order to assess the relative importance of each environmental parameter, a multiple regression analysis was performed, in which temperature and rainfall were assigned as independent variables. The significance of the multiple linear models obtained was tested in an ANOVA, and the regression coefficients; β_0 (constant), β_1 (temperature) and β_2 (rainfall) were estimated (Zar, 1999). All statistical tests were performed using ORIGIN 6.0.

RESULTS

A total of 514 females were obtained of which 359 were non-ovigerous and 155 ovigerous during the study period. Ovigerous females (minimum, maximum, mean ± SD) (8.0, 30.8 and 18.13 ± 5.61 mm CW) were larger than non-ovigerous females (5.0, 28.5, 16.28 ± 7.45 mm CW) $t = 18.6$, $p < 0.05$. Breeding intensity during the study period showed considerable variations (Fig. 1). *Pilumnus vespertilio* showed a continuous reproductive pattern with highest proportions of ovigerous females being recorded in March (55.6%), October (61.8%), November (64.3%) and December (71.4%) respectively.

The temperature ranged from 20.3ºC in July to 29.3ºC in January, (Fig. 2A) while the rainfall varied from 5.0 mm^3 (June) to 296.7 mm^3 (November) (Fig. 2B). The percentage of ovigerous females was positively correlated with temperature (Pearson´s correlation, $r = 0.78$, $p < 0.05$) and rainfall (Pearson´s correlation, $r = 0.69$, $p < 0.05$). The analysis of variance of the multiple linear regression models demonstrated their validity (Table 1), and the estimates of the regression coefficients are shown (Table 2). From these,

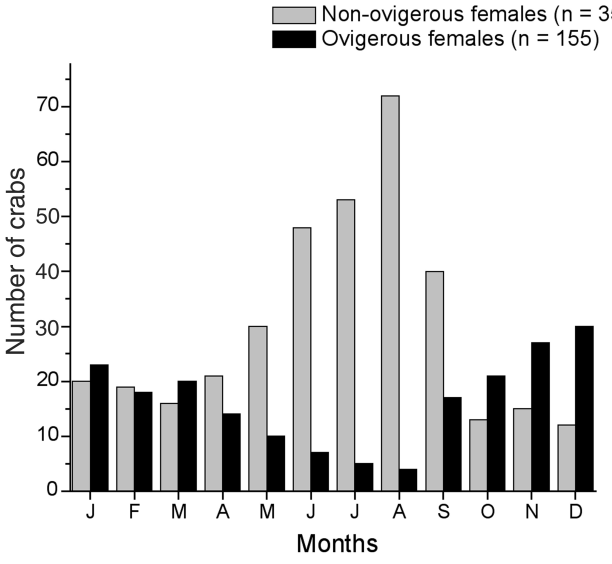

Fig. 1. Monthly frequency variation of females of *Pilumnus vespertilio* collected at Inhaca Island from January to December 2002.

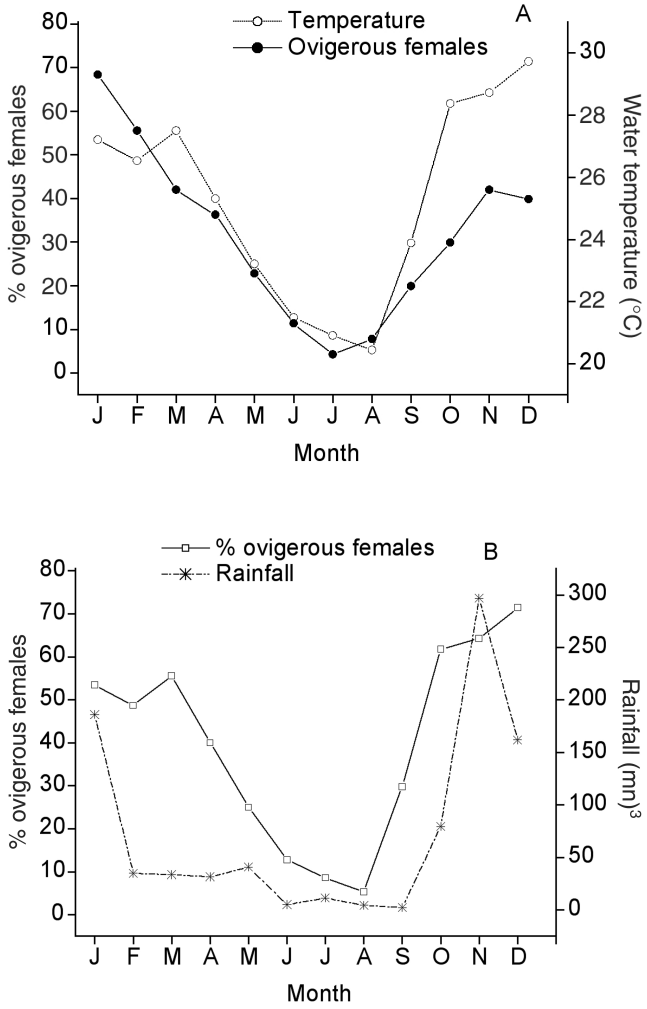

Fig. 2. Line graphs showing the association between ovigerous females and water temperature (A) and rainfall (B).

Table 1. Analysis of variance for the multiple regression $Yj = \beta_{0+} \beta_1 X_1 j + \beta_2 X_2 j + \varepsilon$ for *Pilumnus vespertilio* sampled at Inhaca Island in 2002; where Yj is percentage of ovigerous females and the independent variables X_1 and X_2 are temperature and rainfall, respectively.

Source of variation	MS	SS	Df	F-ratio
Model	2792.86	5582.725	2	110.764*
Error	25.214	226.93	9	
Total			11	

* $p < 0.05$; H_0: $\beta_1 = \beta_2$

Table 2. Regression coefficients´ (bi) estimates, standard error and t-values for the multiple linear regression $Y_j = \beta_{0+} \beta_1 X_1 j + \beta_2 X_2 j + \varepsilon$ for *Pilumnus vespertilio* coleected at Inhaca Island in 2002; where Y_j is percentage of ovigerous females and the independent variables X_1 and X_2 are temperature and rainfall, respectively.

Regression coefficients	Estimate	SE	t-value	p
Constant (β_0)	199.933	26.416	7.548	0.000
Temperature (β_1)	10.097	1.186	8.515	0.0000
Rainfall (β_2)	-0.064	0.035	1.828	0.101^{ns}

ns = not significant

temperature seems to be the main factors controlling the reproductive periodicity of this species.

DISCUSSION

There are many different reproductive patterns among brachyurans often related to environmental variations. Such variations may be explained as a genotypic response to environmental conditions, in order to maximise reproductive success under favourable conditions (Sastry, 1983).

The variation in the monthly frequency of ovigerous females of *Pilumnus vespertilio* during the study period indicates that this crab follows a continuous reproductive pattern. This has been observed in several brachyurans of both tropical and subtropical regions, which are subjected to a narrow range of environmental parameters throughout the year (Rodriguez et al., 1997; Costa & Negreiros-Fransozo, 2003; Lardies et al., 2004).

A continuous recruitment pattern and a stable size frequency distribution contribute to the maintenance of population size (Conde & Diaz, 1989).

A number of abiotic and biotic factors such as temperature, day-length, food availability, rainfall, tidal regime photoperiod have been pointed out to be the major modulators of reproduction in crustaceans (Meusy & Payen, 1988; Morgan & Christy, 1995; Flores & Negreiros-Fransozo, 1998). As stated by Sastry (1983), it is possible that they may differentially affect female gametogenesis as well as other stages of the reproductive cycle. Generally, reproduction takes place within the narrowest environmental range of conditions, compared to those suitable for survival or even growth of a species. For example, many brachyuran crabs release gametes or larvae on nocturnal maximum-amplitude high tides when adults, embryos, or larvae are least likely to be seen by predatory fishes and are most likely to be transported away from reefs and nearshore coastal areas that generally harbor more predators than offshore waters (Morgan & Christy, 1995)

Temperature and rainfall are correlated to the occurrence of ovigerous females. Sastry (1983), Costa & Negreiros-Fransozo (2003) and Sampedro et al. (2003) argued that temperature may act as a metabolic and biochemical and hormonal modulator, triggering the process of ecdysis, mating and gonad development. At the same time, it was recently shown that under low temperatures the degree of maturation of oocytes is low, leading to a longer period of incubation (Yamaguchi, 2001; Christy, 2003; Lardies et al., 2004). Spawning in the rainy season may also provide a selective advantage to intertidal brachyuran populations since periods of higher rainfall can cause changes in the salinity of water and promote increased of nutrient concentrations. This favours the development of planktonic larvae, by increasing primary productivity of the seawater (Mantelatto et al., 2003).

Multiple regression models suggest that water temperature is the main factor controlling the reproductive activity of *Pilumnus vespertilio* at Inhaca Island. According to Moura et al. (2000), breeding in summer, when temperatures are higher and phytoplankton more abundant, would shorten development time, larval predation and competition for food. Rodriguez et al. (1997) states that within a tolerant range, temperature mostly affects duration of larval stages, and this in turn affects dispersal and gene flow interactions with coastal physical processes.

This study constitutes the first account of the reproductive biology of *Pilumnus vespertilio* in Mozambique. Further studies on gonad maturation, larval ecology and population dynamics are needed for a better understanding of the biological cycle of this crab.

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LITERATURE CITED

Almaça, C., 1987. Crabs of the *Sabellaria alveolata* (Linnaeus, 1767) community. Egg number and population size in *Pilumnus hirtelus* (Linnaeus, 1761) and *Porcellana plathycheles* (Pennant, 1777). *Arquivos do Museu Bocage*, **1**: 19-32.

Almaça, C., 1990. Structure and interactions in the crab community inhabiting sabelariid colonies at Praia de Ribeira de Ilhas (Ericeira, Portugal). *Arquivos do Museu Bocage*, **1**: 505-519.

Christy, J. H., 2003. Reproductive timing and larval dispersal of intertidal crabs: the predator avoidance hypothesis. *Revista Chilena de Historia Natural*, **76**: 177-185.

Clark, P. F. & J. Paula, 2003. Descriptions of ten xanthoidean (Crustacea: Decapoda: Brachyura) first zoeas from Inhaca Island, Mozambique. *Raffles Bulletin of Zoology*, **51**: 323-378.

Cobo,V.J., 2002a. Breeding of the spider crab *Mithraculus forceps* (A. Milne Edwards) (Crustacea, majidae, Mithracinae) in the southeastern Brazilian coast. *Revista Brazileira de Zoologia*, **19**: 229-234.

Cobo,V. J., 2002b. Breeding period of the arrow crab *Stenorhyncus seticornis* from Couves Island, southeastern Brazilian coast. *Journal of the Marine Biological Asssociation of the United Kingdom*, **82**: 1031-1032.

Cobo, V.J. & A. Froansozo, 2003. External factors determining breeding season in the red mangrove crab *Goniopsis cruentata* (Latreille) (Crustacea, Brachyura, Grapsidae) on the São Paulo State northern coast, *Brazil. Revista Brazileira de Zoologia*, **20**: 213-217.

Conde, J. E. & H. Diaz, 1989. The mangrove tree crab *Aratus pisonii* in a tropical coastal lagoon. *Estuarine Coastal and Shelf Science*, **28**: 639-650.

Costa, T. M. & M. L. Negreiros-Fransozo, 2003. Population biology of *Uca theyeri* Rathbun, 1990 (Brachyura, Ocypodidae) in a subtropical South American mangrove area: Results from transect and catch-per-unit-effort techniques. *Crustaceana*, **75**: 1201-1218.

Emmerson, W. D., 1994. Seasonal breeding cycles and sex ratio of eight species of crabs from Mgazana, a mangrove estuary in Transkei, South Africa. *Journal of Crustacean Biology*, **14**: 568-578.

Flores, A.A.V & M. L. Negreiros-Fransozo, 1998. External factors determining seasonal breeding in a subtropical population of the shore crab *Pachygrapsus trasnversus* (Gibbes, 1850) (Brachyura, Grapsidae). *Invertebrate Reproduction and Development*, **34**: 149-155.

Guerreiro, J., S. Freitas., P. Pereira., J. Paula. & A. Macia. 1996. Sediment macrobenthos of mangrove flats at Inhaca Island, Mozambque. *Cahiers de Biologie Marine*, **37**: 309-327.

Hartnoll, R.G. & P. Gould. 1988. Brachyuran life history strategies and the optimization of egg production. *Zoological Symposium*, **59**: 1-9.

Jones, D.A., 1997.Infraorder Brachyura. In: M. Richmond (Ed), *A Guide to the Seashores of Eastern Africa and the Western Indian Ocean Island*. Sida/Department for Research Cooperation, SAREC. Pp. 222-237.

Lardies, M.A., J. M. Rojas & I. S. Wehrtman, 2004. Breeding and population structure of the intertidal crab *Petrolistes laevigatus* (Anomura: Porcellanidae) in central-southern Chile. *Journal of Natural History*, **38**: 375-388.

Mantelatto, F. L. M., F. C. R. Faria & R. B. Garcia, 2003. Biological aspects of *Mithraculus forceps* (Brachyura: Mithracidae) from Anchieta Island, Ubatuba, Brazil. *Journal of the Marine Biological Association of the United Kingdom*, **83**: 789-791.

Meusy, J. & G. G. Payen. 1988. Female reproduction in malacostracan crustacea. *Zoological Science* **5**: 217-265.

Morgan, S. G. & J. H. Christy. 1995. Adaptive significance of the timing of larval release by crabs. *The American Naturalist*, **145**: 457-478.

Moura, N. F. O., P.A. Coelho-Filho. & P. A. Coelho, 2002. Population structure of *Goniopsis cruentata* (Latreille, 1803) in the Paripe estuary, Brazil. *Nauplius*, **8** : 73-78.

Negreiros-Fransozo, M. L., A. Fransozo. & G. Bertini. 2002. Reproductive cycle and recruitment of *Ocypode quadrata* (Decapoda, Ocypodidae) at a sandy beach in southeastern Brazil. *Journal of Crustacean Biology*, **22**: 157-161.

Ng, P. K. L., 2002. On the identity of *Pilumnus cristimanus* A. Milne Edwards, 1873, and the status of *Parapilumnus* Kossman, 1877 (Crustacea: Decapoda: Brachyura), with description of a new species from rubble beds in Guam. *Micronesica*, **34** : 209-226.

Paula, J., I. Pinto., I. Guambe., S. Monteiro., D. Gove & J. Guerreiro, 1998. Seasonal cycle of planktonic communities at Inhaca Island, southern Mozambique. *Journal of Plankton Research*, **20**: 2165-2178.

Rodriguez, A., P, Drake, & A. M. Arias.1997. Reproductive periods and larval abundance of the crabs *Panopeus africanus* and *Uca tangeri* in a shallow inlet (SW Spain). *Marine Ecology Progress Series*, **149**: 133-142.

Sampedro, M.P., E. González-Gurriaran & J. Freire, 2003. Moult cycle and growth of *Maja squinado* (Decapoda: Majidae) in coastal habitats of Galicia, north-west Spain. *Journal of the Marine Biological association of the United Kingdom*, **83**: 995-1005.

Sastry, A. N., 1983. *Ecological aspects of reproduction*. In: Vernberg, W. B. (ed.), The Biology of Crustacea, Vol. 8. Environmental Adaptations. Academic Press. Pp. 197-270.

Spivak, E. D. & A. Rodriguez, 2002. *Pilumnus reticulatus* Stimpson, 1860 (Decapoda: Brachyura: Pilumnidae): a reaprisal of larval characters from laboratory reared material. *Scientia Marina*, **66**: 5-19.

Yamaguchi, T., 2001. Incubation of eggs and embryonic development of the fiddler crab, *Uca lactea* (Decapoda, Brachyura, Ocypodidae). *Crustaceana*, **74**: 449-458.

Zar, J. H., (1999). *Biostatistical Analysis*. New Jersey, Prentice Hall, Upper Seddle River, 4th Edition, 930 pp.