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REPRODUCTIVE BIOLOGY OF THE MANTIS SHRIMP *ERUGOSQUILLA MASSAVENSIS* FROM PORT SAID, EGYPT.

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ABSTRACT

The reproductive biology of the mantis shrimp *Erugosquilla massavensis* inhabiting the Mediterranean Sea at Port Said was studied and compared to previous studies. A single reproductive period was observed for females that lasted from February to August. This was followed by a well-defined resting phase from September to November. The ratio of males and females was nearly equivalent (0.95 female: 1 male). Females outnumbered males in all months except during the reproductive season. Gonad indices as well as the number of females with developed cement glands were relatively high during the spawning season. The body size at which 50% of females were sexually mature was much smaller than that reported in a previous study (22.6 mm CL and 25.7mm CL respectively). Females responded to extensive exploitation by reaching maturity at a smaller size and by increasing fecundity. The mantis shrimp population in Port Said appears so far seriously heavily exploited and needs urgent management regulations for the maintenance of that valuable fishery resource.

INTRODUCTION

Studies on the reproductive biology of crustaceans provide essential information for understanding their reproductive pattern and strategies (Kawamura *et al.*, 1997). They are particularly important for species that have a fishery potential. Extensive studies have been carried out for a number of commercially economic species of stomatopods. The Japanese species *Oratosquilla oratoria* has been extensively studied since it is considered as the most exploited

stomatopod crustacean in the world (Hamano, *et al.* 1987; Ohtomi & Shimizu, 1991 ; Torisawa *et al.* 1998). At the same time, considerable attention has been given to the mantis shrimp *Squilla mantis* due to its obvious abundance in the Mediterranean waters. The annual sexual cycle of this species has been investigated and analysed to a considerable extent (Do-Chi, 1975 ; Giovanardi & Manfrin, 1983) and subsequently related to fishery studies (Abello & Sarda, 1989 ; Abello & Martin, 1993).

The different aspects of reproductive biology are important factors in determining the reproductive potential of a species, and in understanding the interaction between its population and the environment. *Erugosquilla massavensis* (Kossmann, 1880) is a common stomatopod species in the Mediterranean Sea at Port Said. Sallam (2000) carried out a comprehensive study of its reproductive cycle and demonstrated that females of this species mature at much smaller size than those inhabiting the Suez Canal as a result of the high fishing mortality exerted on them. On the other hand, El-Ganainy *et al.*, (2004) studied the population dynamics of this species and concluded that its fishery is subjected to heavy exploitation. Therefore, the aim of this paper is to follow up the adaptability of this species stock and to elucidate certain aspects of its reproduction, including sex ratio, seasonality of reproduction and fecundity.

MATERIALS AND METHODS

Specimens of *Erugosquilla massavensis* were collected monthly from the Mediterranean coast at Port Said during the period from August 2002 to July 2003. All shrimps were first sexed then measurements of the total wet body weight (TW) and carapace length (CL) were taken for each specimen. Females were dissected and developmental stages of the ovaries were categorized into four arbitrary stages (immature-maturing- mature- ripe) according to Do - chi (1975) and Sukumaran (1987). The cement glands of females which were reported to have a cyclic activity correlated to vitellogenesis (Deecaraman & Subramoniam,1983) were examined and their stages of development were recorded. No females carrying egg masses were sampled during the present study. Fecundity was therefore estimated as the total number of ripe ova in the ovaries (i.e. in their last stage of maturity). A subsample of the ovary was taken, weighed and the number of ova was counted. The remaining ovary was subsequently weighed and the total number of ova calculated.

Gonad Index (GI) was calculated for each female as follows:

$$GI = \frac{\text{Ovary wet weight}}{\text{Total wet body weight}} \times 100$$

RESULTS

Sex ratio:

Figure 1 shows the monthly variations in the sex ratio for *Erugosquilla massavensis* in Port Said. Females outnumbered males in all months except November and during February-April. Of the whole catch (1997 specimens), 974 were females (48.8%) and1023 were males (51.2%). Throughout the study, the total number of females was almost equivalent to the total number of males (0.95 female: 1 male). The ratio showed insignificant difference ($\lambda^{2} = 36.8$, d.f. = 11, $P > 0.05$).

Size at first sexual maturity:

The 974 female *Erugosquilla massavensis* examined, ranged in carapace length (CL) from 14.0 to 30.5 mm CL. Of these, 569 females were in sexually mature stage. The relationship between carapace length (CL) and the proportion of mature female (P) by 1 mm CL classes was calculated by fitting a logistic function to the size specific maturity data for females (Fig.2) as follows:

$P = 1/(1 + \exp[6.49 - 0.28\,CL])$ ($r^2 = 0.75$, $P<0.001$)

From this, the estimated size for 50% sexually mature females was 22.6 mm CL.

Seasonality of spawning and cement glands development:

The monthly variations in the percentage of sexually mature females (Fig. 3) shows a single reproductive period, lasting from February to August. 50% of females were mature during May - August. This period of reproductive activity was followed by a well-defined resting phase lasting from September to November. Development of cement glands also followed the same trend of gonadal maturation The annual changes in the percentage of female, with regard to the different maturation stages, (Fig. 4) demonstrated that females with immature, undeveloped ovaries (stage I) occurred all the year round and were most common between September-January. The beginning of the ovarian development (females in stage II) was observed to take place in December. The number of females increased regularly to reach their maximum in July and then declined to disappear completely during October and November. Females in stage III were seen mainly from February to August, with a

pronounced peak in June while females with ripe ovaries (stage IV) were only observed between April and June.

Gonad index:

The monthly changes in the mean gonad indices of females over the study period (Fig.5) were proved to be highly significant ($F = 20.94$, $d.f. = 11$, $P < 0.001$). A clear seasonal cycle was discernible for females. Gonad indices were relatively high during February – August that coincides with the peak percentage of females in spawning condition (Fig. 2). The values declined in September and retained their low levels till January. The highest mean G.I. recorded was 3.9 in June and the lowest was 0.3 between November and January.

Fecundity:

Table 1 shows the relationship between carapace length, total weight, gonad weight and number of ripe ova for females. The total number of ripe ova ranged from 80372 in a female of 18.1 mm CL with an ovary weight of 1.76g, to 217344 in a female of 29.7 mm CL with an ovary weight of 5.67g. Fecundity showed an obvious increase with increasing carapace length. A tendency for the heavier females to become more fecund was also observed.

DISCUSSION

The sex ratio of *E. massavensis* in Port Said waters showed the presence of an excess of females for most of the year. Nevertheless, the ratio of females to males decreased during the spawning season (February - April) (Fig.1). Departure from a 1:1 ratio has been observed in gonodactylids and has been attributed to increased mortality in males that experience higher mortality due to the cost of searching for a new cavity every time they breed (Caldwell, 1986). Males outnumbered females during the breeding season, when females were brooding their eggs and remained in their burrows. This pattern agrees with those observed in other stomatopod species (Hamano & Matsuura, 1987; Froglia & Giannini, 1989; Dittel, 1991; Wortham-Neal, 2002) and with previous studies on *E. massavensis* of the Mediterranean (Sallam, 2000 ; El-Ganainy *et al.*, 2004).

On the other hand, size at onset of females sexual maturity was observed to fall within the 15 mm CL size class (96 mm TL). The body size at which 50% of females were mature was estimated as 22.6 mm CL (125.1mm TL) compared to 25.7mm CL reported in a previous study (Sallam, 2000). It is therefore apparent that the

intensive fishing of this shrimp in Port Said exerts a serious stress over females thus resulting in their earlier maturation. The continuous high fishing mortality of this species at this area has led females to select for sexual maturity at such smaller size to ensure the persistence of the stock. Early maturation as a result of overfishing could be considered an appropriate response to the factors that might limit reproductive success. Similar pattern has been reported for the Japanese mantis shrimp *Oratosquilla oratoria* in Tokyo Bay (Ohtomi and Shimizu, 1991).

Breeding of *E. massavensis* in Port Said is clearly seasonal. The pattern of gonad maturation, supported by variations in the gonad indices of females, displayed a clear existence of an annual reproductive cycle. The breeding season extended from February-August and was followed by a well-defined resting phase from September to November. Such seasonal pattern is in agreement with most previous studies on other stomatopod species (Hamano, *et al.*, 1987 ; Torisawa *et al.*, 1998). In the meantime, synchronous development and activity of the cement glands with gonadal maturation of females was observed. Similar synchrony has been recorded in other stomatopod species (Do-chi, 1975; Deecaraman, 1983; Caldwell, 1986 ; Wartham-Neal, 2002). Caldwell (1991) reported that activity of cement glands in stomatopod crustaceans correlated to gonad maturation may be considered as a secondary sexual character and that their packed white appearance when fully developed, clearly visible through the exoskeleton, provides a convenient means of determining when females are ready to spawn.

Estimates of fecundity for females *E. massavensis* in this study were observed to be higher than those reported in a previous study (Sallam, 2000). It was also high if compared to estimates for other stomatopods (Giovanardi & Piccinetti Manfrin, 1983; Hamano *et al.*, 1987). The high fecundity of large stomatopod species has been reported to suggest extraordinarily high juvenile mortality (Reaka, 1979). Sallam (2000) proposed that the higher fecundity of females *E. massavensis* might be an adaptive response to the intensive exploitation of this species in this area. The high fishing mortality in the Mediterranean could have resulted in females selecting for higher fecundity in order to ensure the continuity of their existence. Similar adaptive response has been reported in several commercially exploited fish populations (Garrod & Horwood, 1984).

Despite the factors that could limit reproductive success, females *Erugosquilla massavensis* in Port Said area appeared to adapt

effectively to their surrounding environment and exhibited a fair ability in responding to exploitation. However, it is evident that the population of this species is heavily exploited and the regulation of its fishery appears to be an immediate necessity.

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Table 1. Variations in the mean number of ripe ova of female *E.massavensis* with carapace length, total weight and gonad weight; N = number of animals in each size class. M ± SD = mean ± standard deviation.

N	Size range C. L (mm)	Total weight (gm) T. wt min.	max.	M ± SD	Gonad weight (gm) G. wt min.	max.	M ± SD	No of ova min.	max.	M ± SD
2	18 - 21.9	16.1	16.5	16.3 ± 0.3	1.76	2.12	1.94 ± 0.2	80372	104996	92684 ± 17411.8
3	22 - 25.9	29.7	37.6	33.6 ±5.6	3.8	4.48	4.14 ± 0.5	132863	137945	135404 ± 3593.5
1	26 - 29.9	43.5			5.67			141312	217344	179328 ± 53762.7

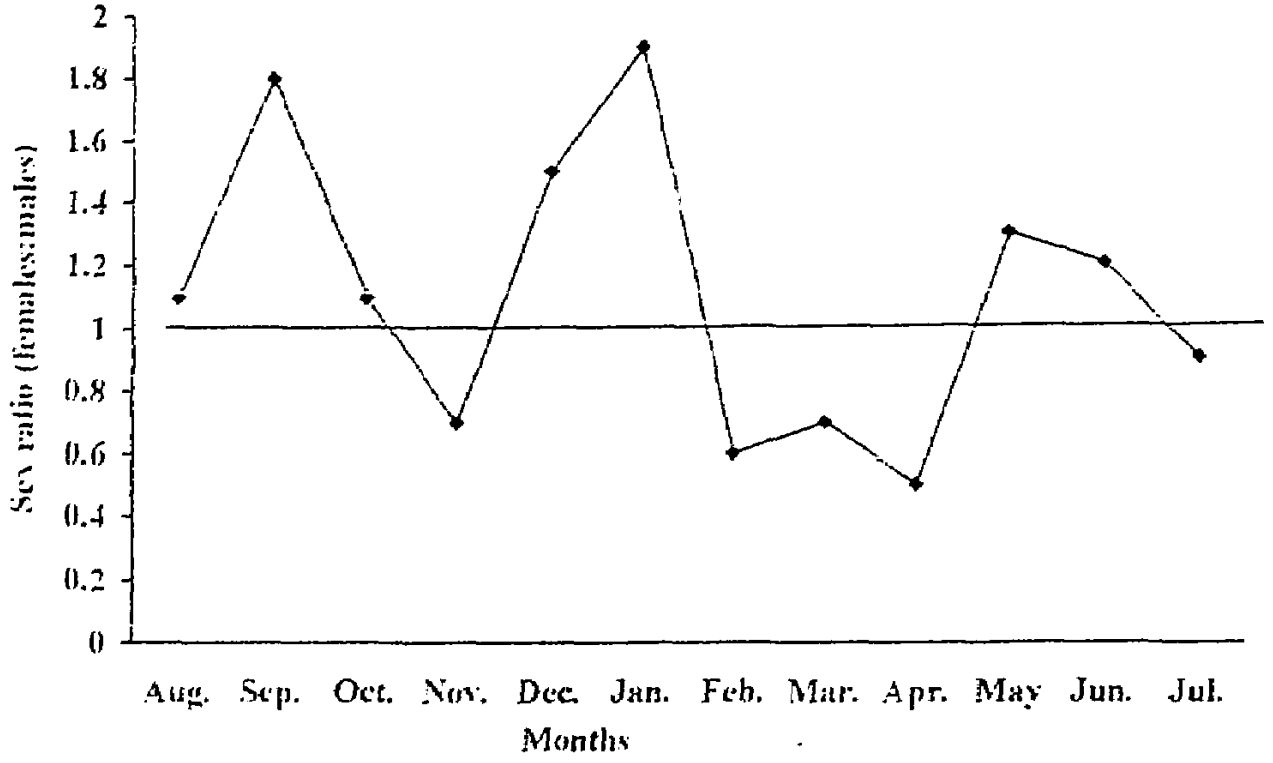

Fig. 1. Monthly variations in the sex ratio of *E. massavensis*. The line indicates a ratio of 1:1 (females:males)

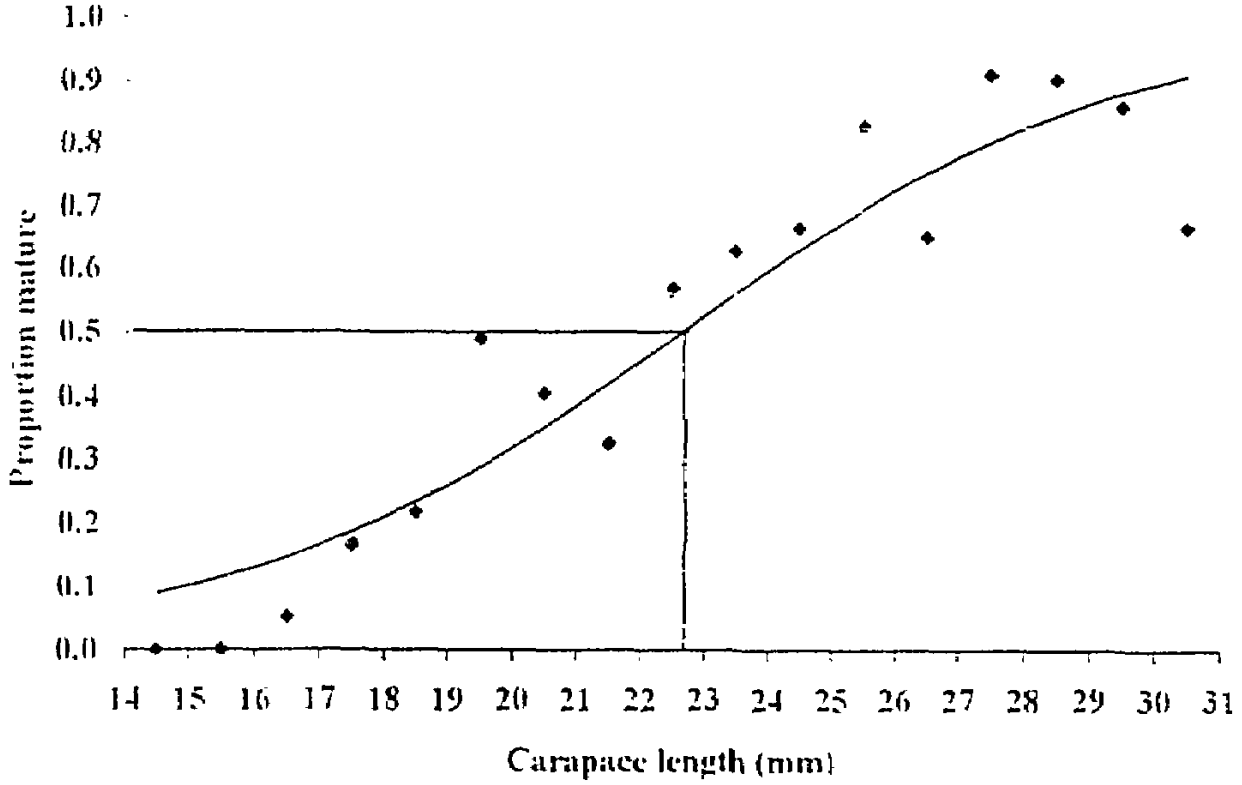

Fig.2. Logistic function fitting proportion of mature female to carapace length. The value of CL_{50} which corresponds to a proportion of 0.5 is indicated.

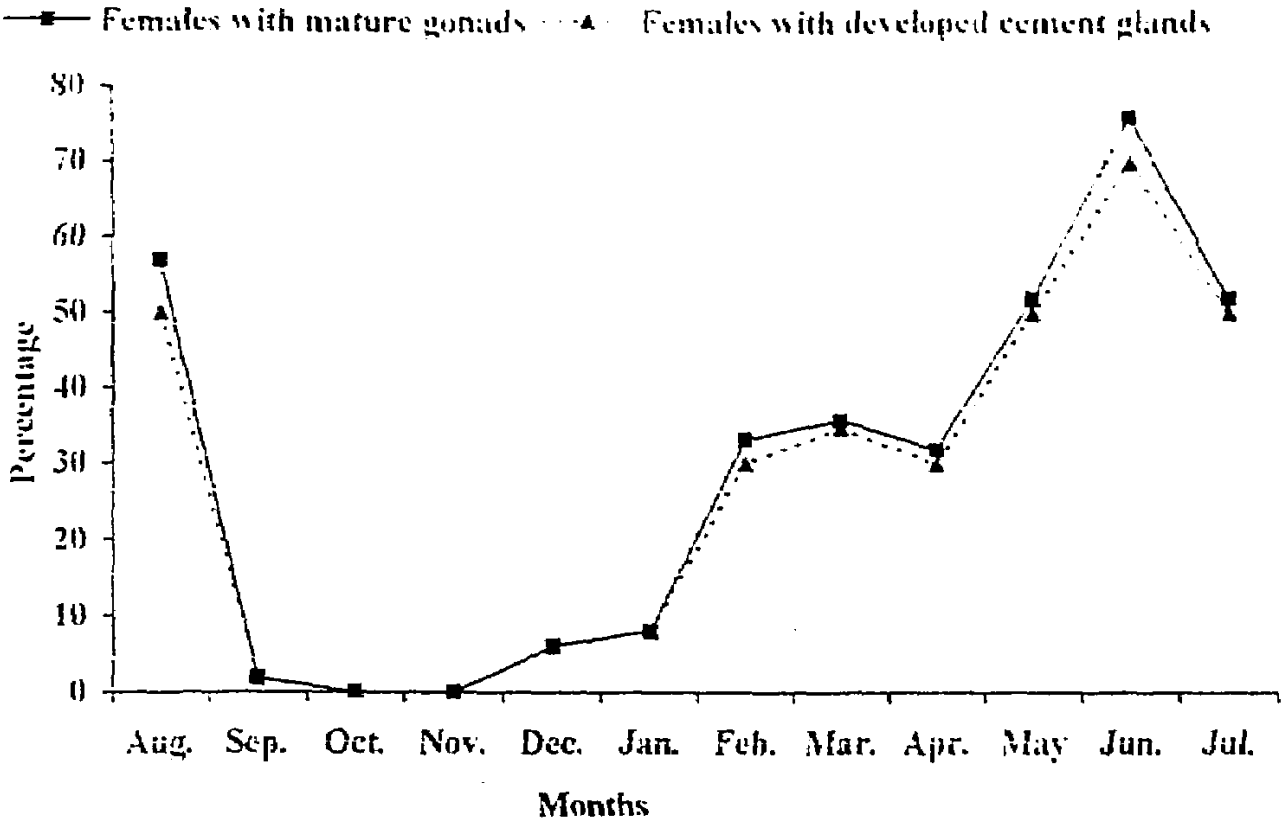

Fig.3. Monthly changes in the percentages of females with mature gonads and with developed cement glands.

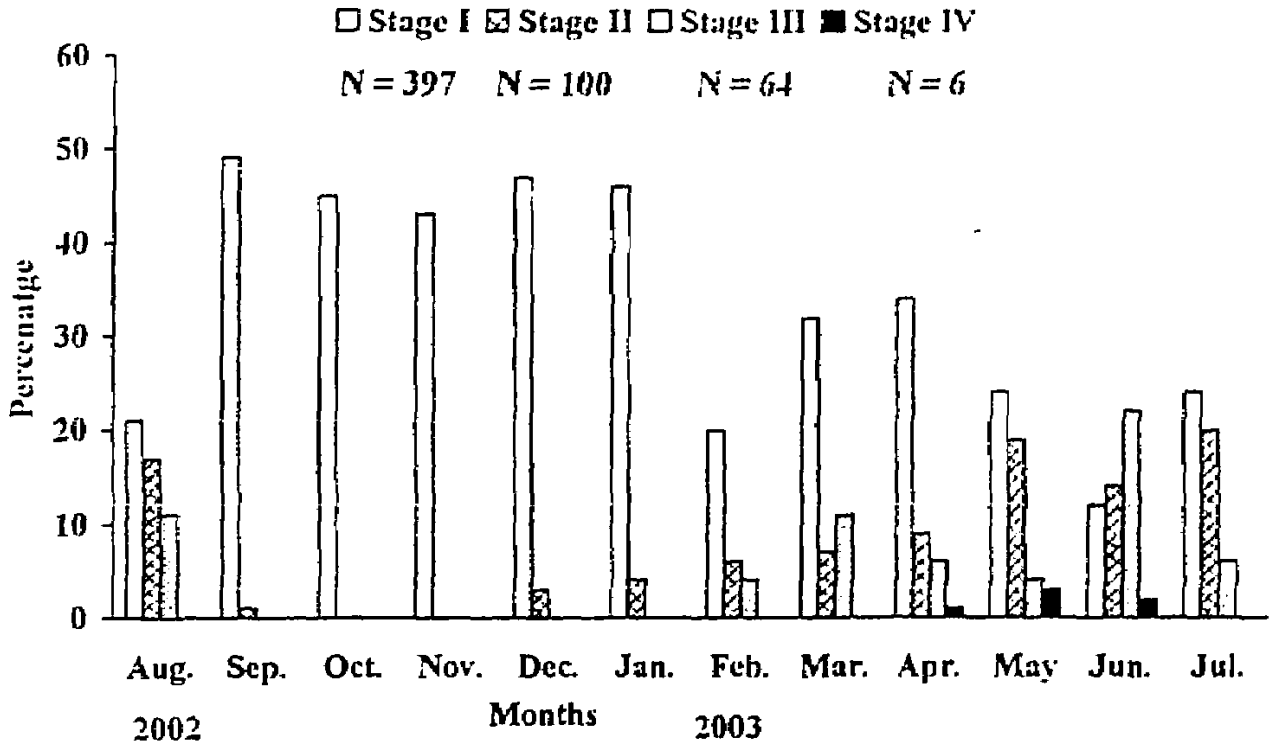

Fig. 4. Monthly variations in the percentages of females in each stage of gonad maturation. N, number of females examined in each stage.

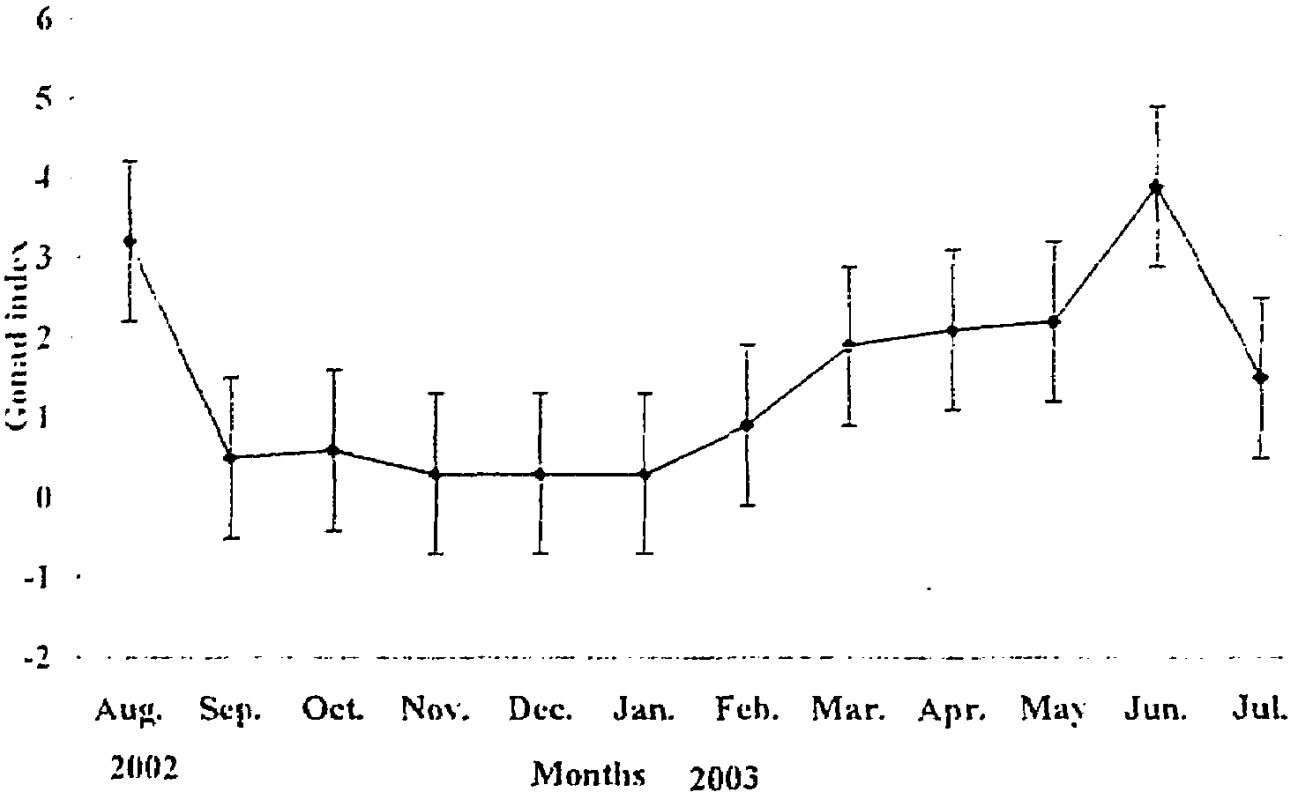

Fig. 5. Monthly changes in the gonad indices of females. Vertical lines indicate standard deviations.