

# Reproductive aspects of the rose shrimp *Parapenaeus longirostris* (Lucas, 1846) in the Gulf of Cadiz (southwestern Iberian Peninsula)

I. Sobrino<sup>1</sup> and T. García<sup>2</sup>

<sup>1</sup> Estación Oceanográfica de Cádiz, Instituto Español de Oceanografía, Puerto Pesquero, s/n, Apdo. 2609. E-11006 Cádiz, Spain. E-mail: ignacio.sobrino@cd.ieo.es

<sup>2</sup> Centro Oceanográfico de Málaga, Instituto Español de Oceanografía, Puerto Pesquero, s/n, Apdo. 285. E-29640 Fuengirola, Málaga, Spain. E-mail: teresa.garcia@ma.ieo.es

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## ABSTRACT

*Parapenaeus longirostris* (Lucas, 1846) is an abundant penaeid species which inhabits the Eastern Atlantic, from Portugal to Angola, and the Mediterranean Sea. This species is of great interest to fishermen in the Spanish waters of the Gulf of Cadiz. The present study on the reproductive cycle of *P. longirostris* was based on the analysis of monthly commercial samples and fisheries research surveys carried out in this region.

The species shows two spawning peaks throughout the year, the first peak occurring in late spring and the second one in the autumn. The larger mature females mainly spawn in the spring, whereas smaller adult females spawn in autumn. Females' cephalothorax length (CL) at first maturity was between 21.5 and 22 mm CL. In males the joining of the two sections of the petasma takes place at between 12 and 15 mm CL, being always separated at sizes lower than 11 mm CL. The size at which 50 % of males have a joint petasma was estimated at 12.9 mm CL. The spermatophoric mass on the coxae of the fifth pereopods was present from a size of 13 mm CL, the size at first maturity being estimated at 14.8 mm CL. The conditioning factor is related more to growth events than to ovarian maturation, and a relationship was found between them. Relative fecundity was estimated at 7 486 eggs/g of female, with fecundity ranging from 21 410 to 186 856 eggs. Females at the stage of both advanced ovarian development and readiness to spawn occurred at depths greater than 100 m.

**Keywords:** *Parapenaeus longirostris*, shrimp, reproduction, Gulf of Cadiz, southwestern Iberian Peninsula.

## RESUMEN

**Aspectos sobre la reproducción de la gamba blanca *Parapenaeus longirostris* (Lucas, 1846) en el golfo de Cádiz (suroeste de la península Ibérica)**

La gamba blanca *Parapenaeus longirostris* (Lucas, 1846) es un peneido abundantemente distribuido en el Atlántico oriental –desde Portugal hasta Angola– y en el Mediterráneo, y constituye un recurso primordial para un importante sector pesquero en aguas del golfo de Cádiz. Para ampliar el conocimiento sobre su ciclo reproductivo se muestrearon mensualmente las capturas comerciales y se consideraron de nuevo muestras obtenidas en otras campañas de investigación desarrolladas en la zona.

En el ciclo se distinguen dos máximos de puesta al año: el primero al final de primavera y el segundo en otoño. Las hembras más grandes realizan la puesta fundamentalmente en primavera, mientras que las de tamaños menores lo hacen en otoño. La talla de primera madurez en las hembras se sitúa entre 21,5 y 22 mm de longitud del cefalotórax (LC). En los machos, la unión de las dos piezas del petasma tiene lugar cuando

los ejemplares alcanzan entre 12 y 15 mm LC, permaneciendo aun separadas en todos los individuos de menos de 11 mm LC; la talla a la que el 50 % de los machos tiene el petasma totalmente formado fue estimada en 12,9 mm LC. La masa espermática en las coxas del quinto par de pereopodos está presente a partir de 13 mm LC, calculándose la talla de primera madurez en 14,8 mm LC. El factor de condición está más relacionado con el crecimiento en sí que con la maduración. La fecundidad relativa fue estimada en 7486 huevos por gramo de ejemplar hembra, encontrándose valores entre 21 410 y 186 856 huevos. La puesta tiene lugar a partir de 100 m de profundidad.

**Palabras clave:** *Parapenaeus longirostris*, gamba, reproducción, golfo de Cádiz, suroeste de la península Ibérica.

## INTRODUCTION

The rose shrimp *Parapenaeus longirostris* (Lucas, 1846) is one of the three species included in this genus, which inhabits the Atlantic Ocean (Pérez-Farfante and Kensley, 1997). It has a wide geographic distribution, from the eastern Atlantic north of Spain (Olaso, 1990) to the southern waters of Angola (Crosnier, De Bondy and Lefevre, 1968), as well as in the Mediterranean and its adjacent seas (Thyrrhenian, Adriatic, Aegean, and the Sea of Marmara) (Karlovac, 1949; Maurin, 1960; Massutí, 1963, Audouin, 1965).

The bathymetric range of the rose shrimp in the Gulf of Cadiz is between 28 m and 650 m (Sobrino, 1998), similar to that described by different authors in the Mediterranean: 40-500 m (Audouin, 1965), 20-750 m (Tom, Gorem and Ovadia, 1988), 100-500 m (Ardizzone *et al.*, 1990). However, in the African Atlantic waters, this species seems to present a more restricted bathymetric range. It is found between from 20-400 m in the Gulf of Guinea, according to Sobrino and Fernández (1991), and between 50-500 m off the Congo (Crosnier *et al.*, 1970), as well as in the rest of tropical Africa (Crosnier and Forest, 1973). In Senegalese waters, it has not been recorded at depths over 500 m (Lopez Abellan, pers. com.), whereas in Mauritanian waters; its range is from 50-400 m (Diop, pers. com.). Finally, Sobrino and De Cardenas (1996), did not find this species at depths of more than 400 m in the waters off Angola.

The greatest densities, in terms of biomass, have been recorded by different authors between 100 and 300 m depth. In the Mediterranean, Frogliá (1982) found its greatest abundance between 200 and 350 m, whilst Ardizzone *et al.* (1990) found the highest densities in the range of 150-350 m. Crosnier *et al.* (1970) registered the greatest densities in the waters off Congo, between 200 and 300 m, while Sobrino and De Cardenas (1996)

found them concentrated in shallower waters (100-200 m).

This species is the main target species of a large fishing fleet working in the Eastern Atlantic. The principal fishing grounds are to the south of Spain and Portugal (Pestana, 1991, Sobrino *et al.*, 1994), as well as in areas off Morocco, Mauritania, Senegal, Guinea-Bissau, Gabon and Angola (Cervantes and Goñi, 1986; Cervantes *et al.*, 1991, Sobrino and García, 1991; 1992a,b). In spite of the fact that this species has a high economic value, research on its reproductive aspects in the Atlantic is scarce. The main objective of the present paper is to describe the some aspects related to this species' reproduction in the Gulf of Cadiz, such as its reproductive cycle, fecundity, and reproductive behaviour.

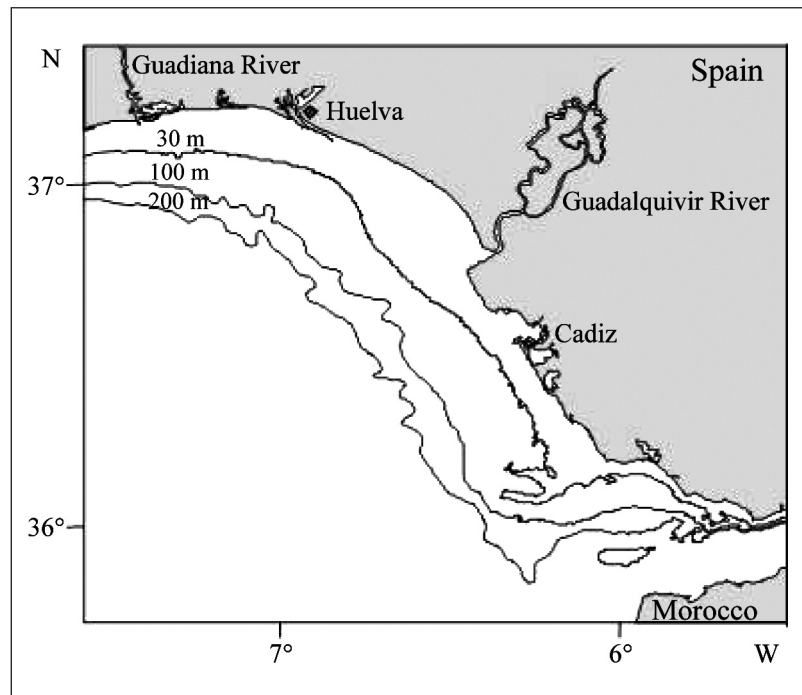
## MATERIALS AND METHODS

The information used to elaborate the present study originates from two different sources: one, from monthly sampling (stratified by commercial categories) of the commercial landings in the ports of Huelva; Sanlúcar and Puerto Santa María (southern Spain), and the other, from fishery research surveys carried out in the shelf and slope region between the meridians 6° 15' W and 7° 20' W; beyond this, the composition of the seabed varies in such a manner as to make trawling operations impossible (figure 1). The methods applied and the parameters measured were the following:

Cephalothorax length (CL), taken from the ocular orbit to the posterior margin of the cephalothorax (0.1 mm); sex; weight (0.1 g); and the maturity stage, according to the following scale:

- Females: A four-stage maturity scale based on the macroscopic observation of the gonad (size and colouring) has been applied

Figure 1. Spanish South Atlantic Region (Gulf of Cadiz)



(Sobrino, 1998). This scale was validated by visualising through microscopic observation the gonads of specimens from sizes ranging between 18.4 and 26.7 mm. The gonad samples were extracted from three different levels (cephalic lobe, abdominal lobe to the level of the first segment and the abdominal lobe to the level of the fifth segment). The samples were embedded in hydroxyethyl methacrylate and stained with toluidine blue.

- Males: A maturity scale of two stages was applied (immature and mature) based on the presence or absence of spermatic mass in the coxae of the fifth pair of pereopods. The formation of the petasma (separate or joint) was, moreover, followed as a secondary sexual characteristic (Demestre, 1990).

The size-weight relationship by sex has been tested with a one way ancova fitted to a power function ( $\text{Weight} = a \text{ CL}^b$ ).

The detection of the spawning season was done by analysing the evolution of the different maturity stages. In the case of females, they were treated in two different size ranges, from 20 to 25 mm and those over 25 mm. Within the first range of sizes, the specimens that were maturing for the first time were included. In this manner, by eliminating specimens smaller than 20 mm, the errors produced by

the inclusion of virgin stages are decreased; however, in the second range of sizes, those specimens which possibly had realised a previous spawning process were included. The specimens which were at stages III and IV were considered potentially mature.

For the condition factor study, the indices applied were those described by Le Cren (1951) ( $\text{FC}_1$ ) and defined by Kartas and Quignard (1984) ( $\text{FC}_2$ ).

$$\text{FC}_1 = \frac{\text{WF}}{a \text{ CL}^b}$$

$$\text{FC}_2 = \frac{\text{WF}}{\text{CL}^3} 10^n$$

where WF corresponds to fresh weight, CL to the cephalothorax length, a and b to the parameters of the size-weight relationship and, n corresponds to the exponential value used to reduce the decimal numbers.

The relation between condition factor and maturity has been analysed, testing its variations with size and with regard to its maturity stage by means of one-way anova, and examining its inequalities with the Bonferroni test.

The size at first maturity has been estimated in females by analysing the specimens during the detected spawning season, comparing immature spec-

imens (stage I) with mature ones (stages III and IV). The sexually developing specimens (stage II) were not considered due to the growth processes, which occurs during gonadal maturation (Sobrino and García, 1994). The fraction of mature individuals by size intervals were fitted to a logistic function by means of a least-squares fit, previously doing a logarithmic transformation to a linear fit:

$$p_i = 1 - \frac{1}{1 + e^{A + B \text{CL}}} \Rightarrow \ln \frac{p_i}{1 - p_i} = A + B \text{CL}$$

where,  $p_i$  is the percentage of mature specimens in the size interval  $i$ ; CL is the cephalothorax length (mm) and A, B the constants of the equation, and thereby, estimating with these equations, size at first maturity ( $L_{50}$ ) and size at massive maturation ( $L_{90}$ ).

In the case of males, the immature specimens were comparing with the mature ones, and the separate petasma with the joined petasma.

The fecundity study was done with 46 females in advanced maturity stages (III and IV) covering a wide size range (from 21.8-34.2 mm CL). The collected individuals were conserved in buffered formaldehyde at 10% (Guitart, González and Reyes, 1982). Once in the laboratory, data on the measurements of CL (to the mm), total weight (to a hundredth gram precision) and gonadal weight (to a thousandth gram precision) were taken. All the samples of the gonads were taken from first abdominal segment because no morphological differences were observed in the histological study of the different sections of the ovary, as described in similar studies (Cummings, 1960; Martosubroto, 1974; Rodríguez, 1981). The samples of 0.1 g were fixed in Gilson's fluid modified by Simpson (1951), and maintained during a minimum of one month to achieve a complete segregation of the oocytes (by dissolving connective tissue). During the preservation period, the samples were agitated periodically to facilitate the oocyte segregation. The oocytes were totally separated from the ovary and the connective tissue by means of laboratory needles under a binocular microscope. Once completely segregated, the oocytes were conserved in 100 ml of buffered formaldehyde at 4% for their eventual count and measurement.

The volumetric method of Martosubroto (*op. cit.*) was used to estimate the total number of oocytes in a sample. The sample was homogenised

through a magnetic agitator and an aliquot of 5 ml was extracted from the sample. All the opaque oocytes in the aliquot were counted and measured through a profile projector.

The absolute fecundity defined as the total number of oocytes shed by a female during a spawning event (Bagenal, 1975; Khmeleva and Goloubev, 1986) was estimated using the equation  $F = X A$ , where X is the number of oocytes in the 5 ml aliquot and

$$A = \frac{20 (\text{Gonad weight})}{\text{Sample weight}}$$

In order to study the relationship between absolute fecundity with the somatic variables, such as size or total weight, different models were tested (linear, potential and exponential functions). The model, which showed the highest regression coefficient ( $r^2$ ), was chosen as the most appropriate.

The relative fecundity is defined as the number of oocytes shed in one spawning event by gram of the specimen. Nikolsky (1969), Alheit and Alegre (1986), and Balguerías Guerra (1995) indicate that one fraction of ovary weight to fresh weight in fish can vary considerably in relatively short time periods, depending on the degree of hydration of oocytes. Consequently, this can cause an important source of bias in the estimation of relative fecundity. Nevertheless, in *P. longirostris* the weight of the gonad represented a maximum 6-7% of the total weight, and consequently, it cannot be considered important in the estimation of relative fecundity.

For reproductive behaviour in relation to spatial coverage, we have used the data collected in different research trawl surveys carried out in the study area. Since 1993, a total of eight surveys were conducted: two surveys during autumn 1993 and 1998, and the remaining during end of winter beginning of spring. All the surveys were carried out on board the R. V. *Cornide de Saavedra*. A random stratified sampling for depth was applied in the surveys and using a cod end of 20 mm. The trawls had a standard duration of one hour (figure 1).

## RESULTS

Table I presents the number of specimens sampled from the commercial landings (monthly sam-

Table I. Sampled specimens with indication of source (commercial landing and survey) and year

Sex	Commercial 1994	Survey							
		03-1993	10-1993	03-1994	03-1995	04-1996	02-1997	11-1997	03-1998
Females	2 903	254	500	232	747	927	776	528	881
Males	2 128	455	455	611	758	570	678	479	627

pling, Gulf of Cadiz), as well as, from the different research surveys.

The ancova analysis showed significant differences in the size-weight relationship by sex ( $p < 0.05$ ). The results obtained in the fits by sex are shown in table II.

### Evolution of Maturity

The histological observations of the different sections of the ovary did not show differences with regard to type and amount of present oocytes. It can be concluded that the oogenesis occurred independently and simultaneously in the different gonadal sections. On the other hand, there were clear differences between the proportion of previtellogenic oocytes and vitellogenic oocytes in the different maturity stages assigned with the macroscopic observations. There was a great similarity between them from the histological point of view in stages III and IV. This led us to treat jointly both stages.

Figure 2 shows the seasonal distribution of the different maturity stages, monthly, by sex and size class. Two spawning peaks occur; the larger females (CL > 25 mm) contribute to the first spawning peak during late spring (June), whereas, during autumn (October), the whole female spawning population (including females of sizes below 20 mm) contribute to the most important spawning peak. The males, however, remain mature throughout the year.

### Condition Factor

The condition indices corresponding to the different size ranges were estimated (figure 3a). The anova test showed inequality between the means with respect to Le Cren's index ( $FC_1$ ). However, when applying the Bonferroni test, the means did not show differences until attaining a size of 28 mm CL; but, over this size range, the

means were significantly different. The results obtained in the anova with the Kartas and Quignard index ( $FC_2$ ) showed differences in the mean values. All the mean values were different (Bonferroni test), showing a continuous decrease of these values at increasing sizes (figure 3a). These results indicate a greater independence in relation to size with Le Cren's index ( $FC_1$ ), and thus are considered as the most suitable for this analysis.

The mean values of both indices in relation to the maturity stage are shown in figure 3b. Le Cren's index ( $FC_1$ ) increases significantly different with the maturity stage. However, Kartas and Quignard's index ( $FC_2$ ) maintains significant similar values ( $p > 0.05$ ). These results show the relationship between maturity and the  $FC_1$ , as well as the absence of relationship between the  $FC_2$  index and the ovarian maturation.

From the results obtained, Le Cren's index was selected for the temporal evolution analysis due to its positive relationship with maturation, as well as, its independence with size.

The monthly evolution of this index presents two peaks, one occurring in April-May and another one in November. A major decrease is observed in December (figure 4), showing a different situation to the one obtained with the maturity stages (figure 2). Due to these discrepancies, the monthly evolution by maturity stage has been represented only for females (figure 5a). The same maturity stage tendencies appear. Analysis of variance shows significant differences of the  $FC_1$  value for stage I between the different months. This can be an anomalous situation if this index was to be only representative of the maturity stage. Thus, we consider that this index is more related to growth events (possibly related to seasonal moults) than to ovarian maturation.

In the case of males (figure 5b), an evolution similar to that of females is observed throughout the year. This verifies the greater relationship of this index with growth events rather than with its reproductive seasonally.

Table II. Parameter estimates by sex in the cephalothorax length CL (mm)-weight (g) relationship (Weight = a CL<sup>b</sup>; r<sup>2</sup> coefficient of determination)

Sex	a	b	r <sup>2</sup>	n
Males	2.269 10 <sup>-3</sup>	2.563	0.910	2535
Females	1.911 10 <sup>-3</sup>	2.636	0.891	1095

**Size at first maturity**

Based on the knowledge of the spawning season of females, the estimation of the values for the maturation function has been made with the values obtained during the spawning period. In the case of

males, due to their possibility of spawning throughout the year, the data acquired are from commercial landings of every month, as well as, those obtained during the survey of March, 1998.

Table III presents the values obtained both from females and males. Size at first maturity for females was 22.2 mm CL, while for males, this value was 15 mm CL, with certain variations in function of the data source.

In males, the union of the two pieces of the petasma takes place between 12 and 15 mm CL. These are always separated in sizes lower than 11 cm CL. The size at which 50 % of males have a joint petasma was estimated at 12.9 mm CL. The sper-

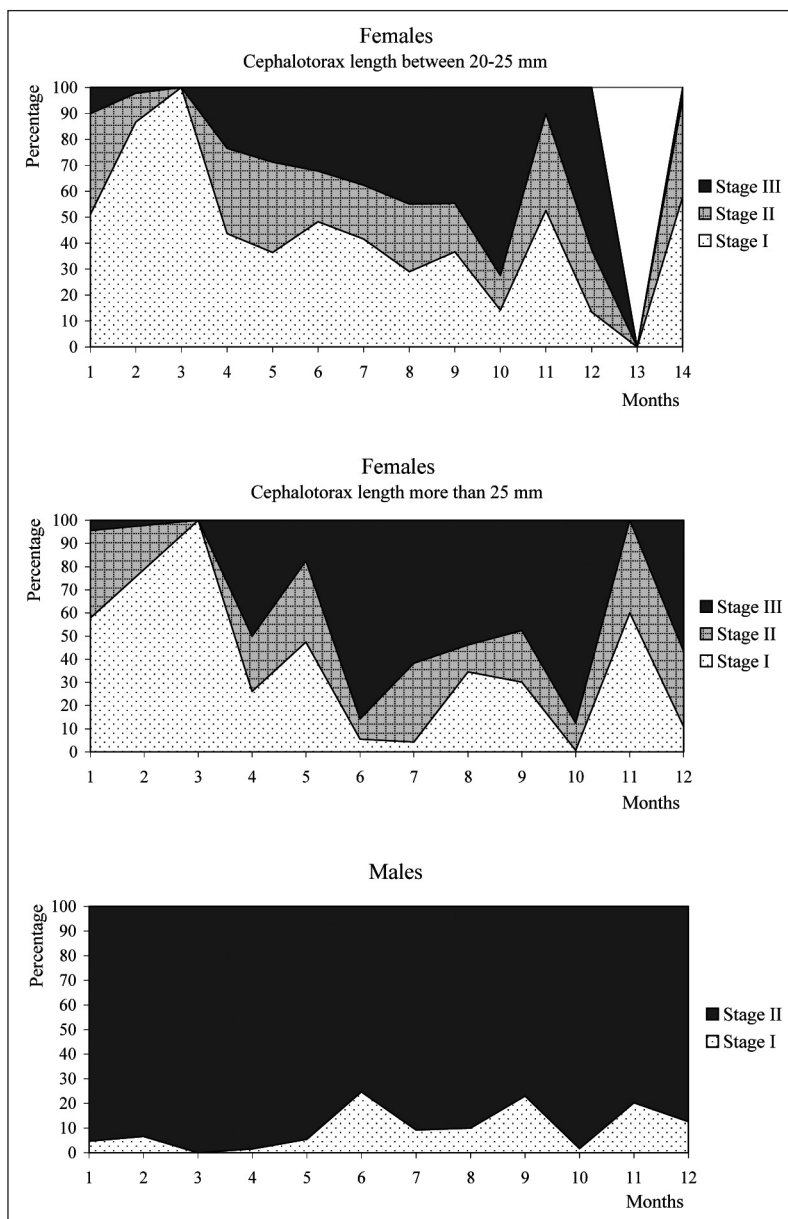


Figure 2. Evolution of female and male maturity stages

Table III. Maturity curves parameters for males and females from commercial landings and surveys

Parameters	Commercial		Survey 1993 Males	Survey 1994 Males	Hemipetasma joined
	Females	Males			
a	-6.25	-17.74	-12.6	-21.21	-20.76
b	0.28	1.10	0.79	1.44	1.60
L <sub>50</sub>	22.2	16.2	15.9	14.7	12.9
L <sub>90</sub>	30	18.2	18.7	16.3	15.2
r <sup>2</sup>	0.86	0.71	0.83	0.90	0.91
n	2903	2128	455	611	627

matophoric mass on the coxae of the fifth pereopods was present from a size of 13 mm CL. The size at first maturity was estimated at 14.8 mm CL (figure 6; table II).

**Fecundity**

Absolute fecundity varied from 21 410 eggs for a female of 25.4 mm CL and 186 856 for a female of

34.2 mm CL. The total mean value was 87 766, registering a rather high standard deviation of 34 079, resulting in a coefficient of variation of 39 %. The mean relative fecundity for *P. longirostris* was 7,486 eggs/g, with values ranging from 2 048 eggs/g and 13 371 eggs/g (table IV).

The relationship of size and weight with absolute fecundity was fitted to a linear function, although very little differences existed between the determination coefficients. Fecundity increases propor-

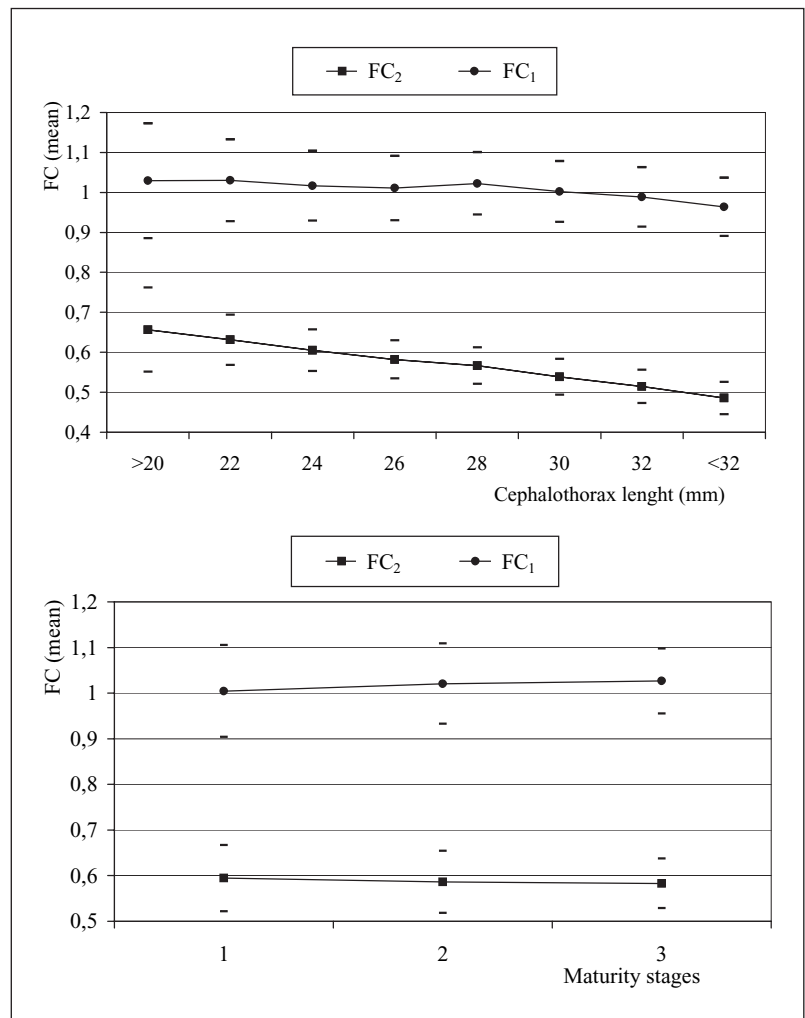


Figure 3. Condition factor by cephalothorax length and by maturity stages for females. Mean values ( $\pm$  standard deviation)

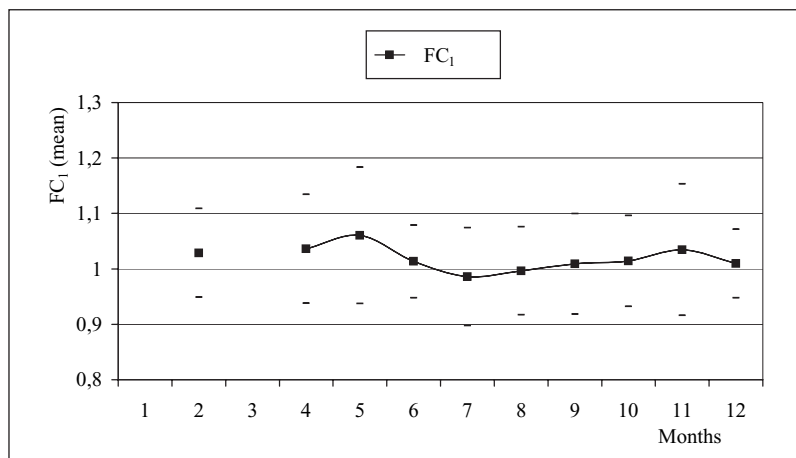


Figure 4. Monthly evolution of condition factor for females. Mean values ( $\pm$  standard deviation)

tionally to size as shown in figure 7a, increasing approximately 10 000 eggs for each mm of CL. Figure 7b shows the equation obtained from the weight to absolute fecundity relationship. Fecundity is directly proportional to body weight, increasing approximately 9 500 eggs per gram ( $b = 9\,528.02$ ).

Figure 8 shows the size frequency distribution of the diameter of the oocytes measured in this study. It presents a unimodal distribution with values ranging from 120 and 390  $\mu$ m and a mean size of 250  $\mu$ m.

### Spatial reproductive behaviour

The percentage of maturity stages of individuals potentially mature of each depth stratum sampled in the surveys is represented in figure 9. It can be observed that in the shallow strata (less than 100 m), females in advanced stages of maturation are practically non-existent; thus, the major fraction is composed of immature specimens. This situation varies with depth, producing an increase of mature females in the deeper bathymetric strata. In the

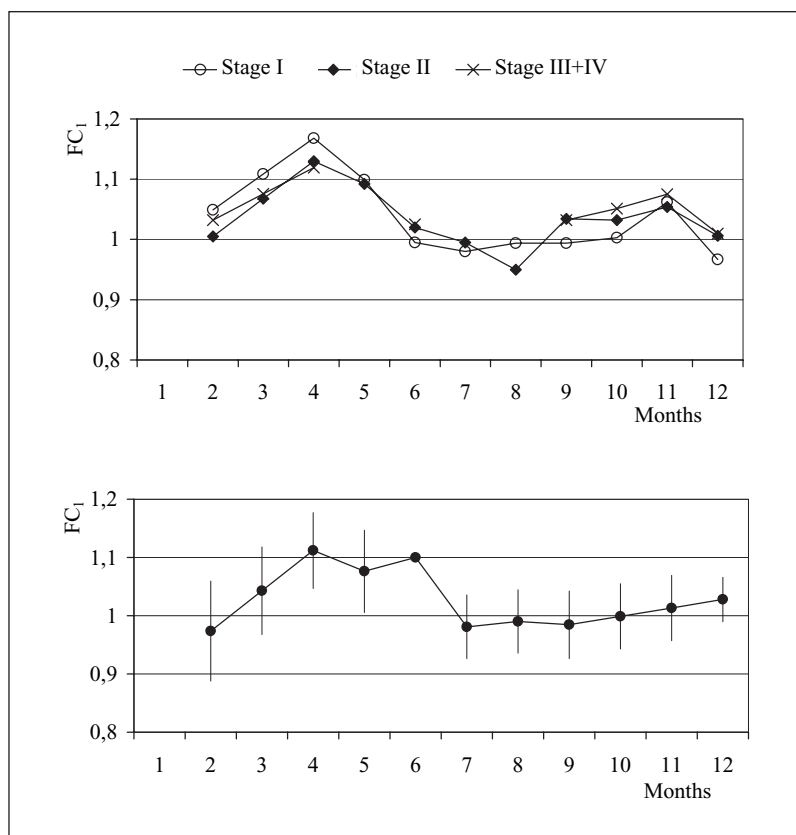
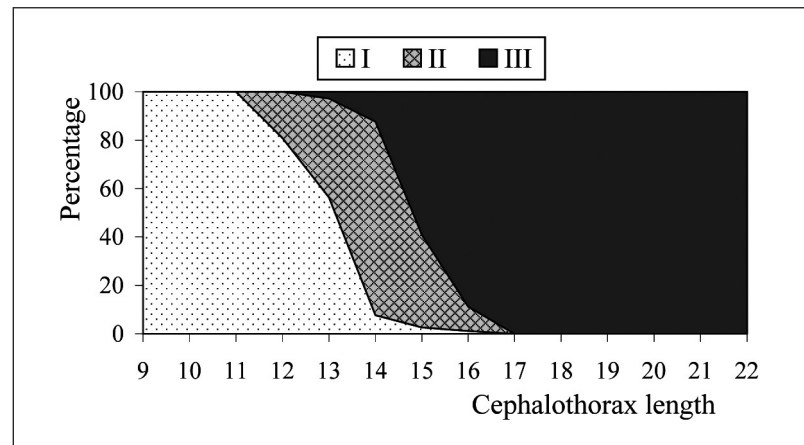


Figure 5. Monthly evolution of condition factor ( $FC_1$ ) by maturity stages for females (a) and males (b). Mean values ( $\pm$  standard deviation)



Figure 6. Evolution of the joining of the two pieces of the petasma and presence of the spermatophoric mass on the coxae of the fifth pereopods by cephalothorax length. (I): Separated petasma. Spermatophoric mass no present. (II): Joint petasma. Spermatophoric mass no present. (III): Joint petasma. Spermatophoric mass present



case of males, the only strata in which immature specimens are present is in the shallow stratum (less than 100 m). In the rest of the deeper strata, practically the whole male population is mature. No differences were observed in the surveys carried out during March (non-reproductive period) in comparison with those carried out during October (spawning period).

## DISCUSSION

In the histological examination of the gonads at advanced stages of maturation, only on one occasion we did detect the presence of peripheral corpuscles, which are related to spawning events, as observed by other authors (Medina *et al.*, 1996; Tom, Goren and Ovidia, 1987; Yano, 1988). The implementation of maturity scales based on the macroscopic observation of the gonads has been used widely in different penaeids –Ragonese and Bianchini (1995) in *Aristaeomorpha foliacea* (Risso, 1827); Rodríguez (1985) in *Penaeus kerathurus* (Forsk., 1775); Sardá and Demestre (1987) in *Aristeus antennatus* (Risso, 1816)–, as well as, on the present species (Ribeiro-Cascalho and Arrobas, 1983, 1987; Sobrino and García, 1994). However, as Cummings (1960) points out, “the ripe stage can

be distinguished from the nearly ripe stage only by the presence of a characteristic margin of peripheral rod-like bodies”. For this reason, although the macroscopic examination of the gonads always find mature females throughout the whole year, a continuous spawning cannot occur as other authors indicate, because spawning events should happen in determined periods of the year.

*P. longirostris* follows a reproductive pattern of two spawning peaks in the study area. The first one, occurring in late spring corresponds to individuals of higher ages, and the other one, in autumn, in which these older individuals spawn together with those that spawn for the first time. This is a similar situation as observed by Ribeiro-Cascalho and Arrobas (1983, 1987) south of Portugal, and by Sobrino and García (1994) in the Atlantic waters off Morocco. These authors obtained two spawning peaks (June and October), similar to the findings off the Gulf of Cadiz. Similarly, Crosnier *et al.* (1970) defined a spawning peak between April and May and less important one between September and October for this species in the waters off Congo.

The studies carried out in the Mediterranean show certain differences among them. Held (1954) describes one sole spawning peak between April and November in Tunisian waters, while Drobisheva

Table IV. Relative and absolute fecundity values by size (mm) and weight range (g). (sd): standard deviation

	Cephalothorax Length	Total Weight	Gonadal Weight	Absolute Fecundity no.	Relative Fecundity no.
Maximum	34.20	20.18	1.69	186 856	13 371
Minimum	21.80	6.72	0.27	21 410	2 048
Mean	26.74	11.54	0.79	87 766	7 486
sd	2.60	2.77	0.27	34 079	1 902

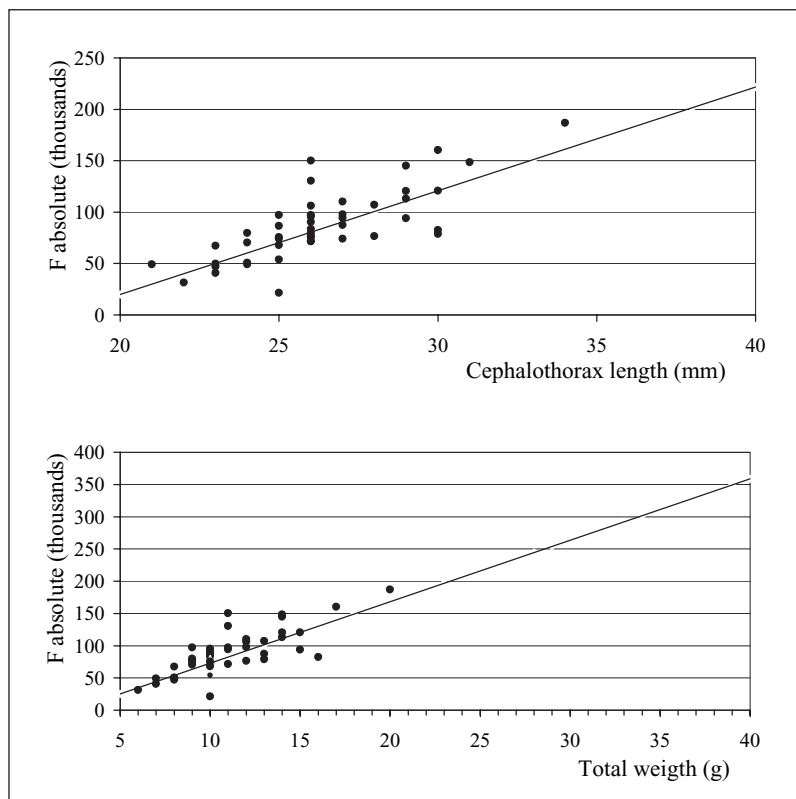


Figure 7. Relationship between absolute fecundity and cephalothorax length ( $a = 18\,201$ ;  $b = 10\,090$ ) and between absolute fecundity and total weight ( $a = 22\,194$ ;  $b = 9\,528$ )

(1970) only finds mature females in spring in the Egyptian coast. In the coasts of Italy, Levi, Andreoli and Giusto, 1995; D’Onghia, Maiorano and Mastrototaro (1998) describe a continuous spawning throughout the year, using a scale of macroscopic observations of the female gonads. Finally, Tom, Goren and Ovadia (1988), in the waters off Israel, relates oogenesis with the temperature and distinguishes different reproductive periods in function of depth. In shallow waters (between 47-73 m), the reproductive activity is continuous, while in

deeper waters, spawning ceases during the period from June to August.

In the Gulf of Cadiz area, this species presents two spawning peaks over the year, one in the late spring and another in early autumn. This hypothesis is supported by the size frequency distributions obtained from the surveys. In the trawl surveys, a cod-end cover was used; thus, the catch was representing all the size fractions of the population. On the other hand, the whole bathymetric range in which this species is present (30-700 m) was cov-

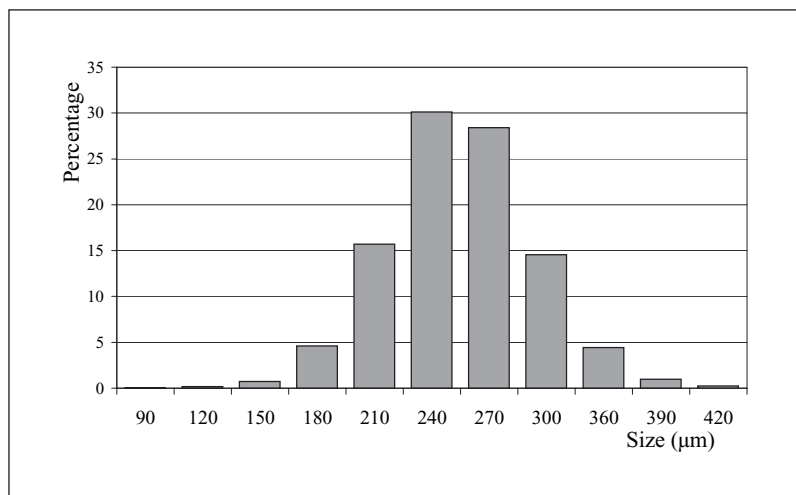


Figure 8. Oocyte size distribution

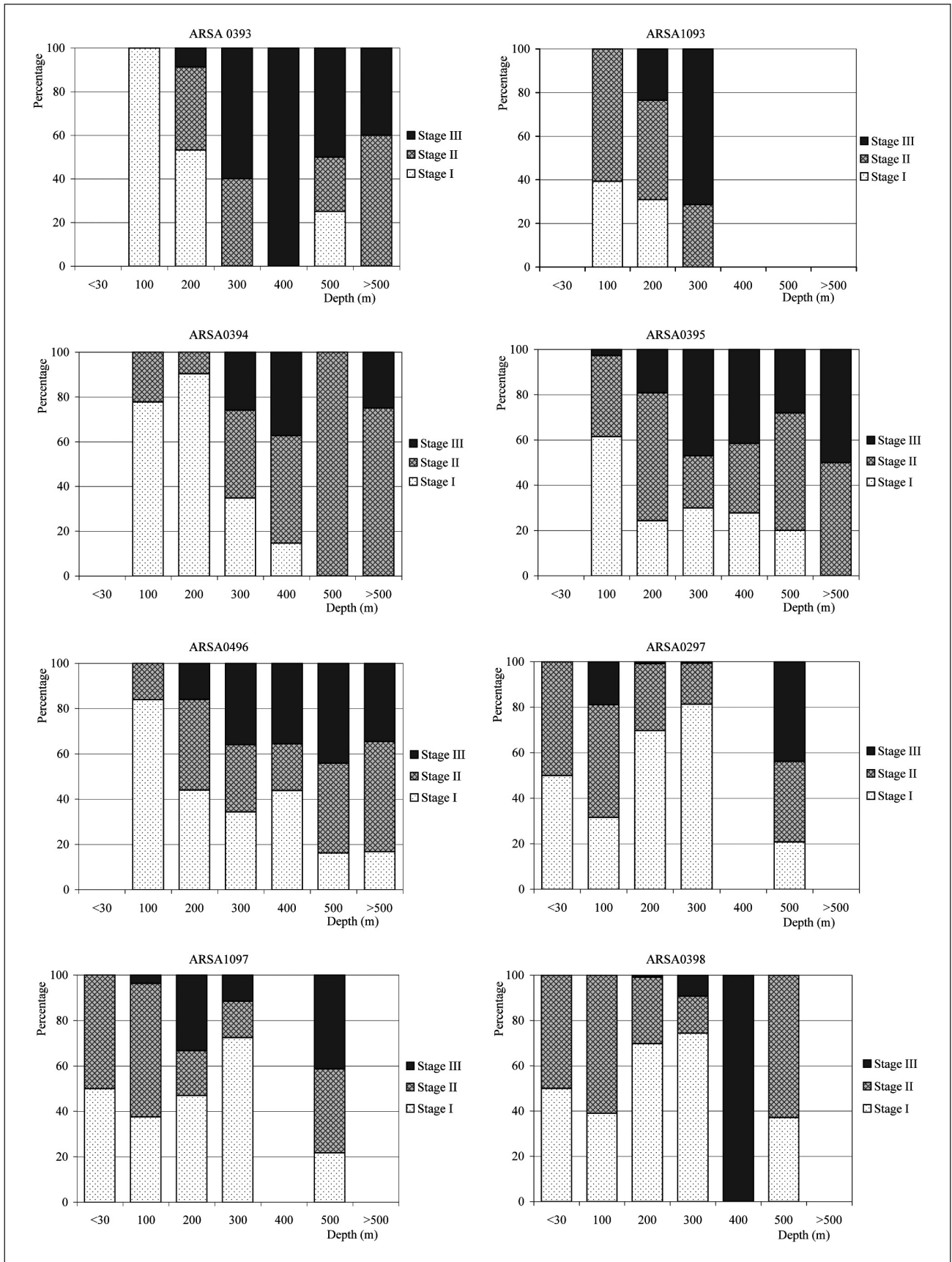


Figure 9. Proportion of sexual maturity stages in females by depth stratum

ered. The size distributions have a first and clear normal component. The mean size varied in function of the season in which the surveys were carried out. The mean size corresponds to a cohort. This situation would not be the case if a continuous spawning were occurring, in which the size distributions would be characterised by the presence of microcohorts.

The value of size at first maturity for the present study is noticeably lower than those obtained in other areas by other researchers. Ribeiro-Cascalho and Arrobas (1987) estimate a size at first maturity of 26 mm CL off southern Portugal, while Sobrino and García (1994), in Moroccan Atlantic waters, obtained values ranging from 24.5 to 27.7 mm CL. In the Gulf of Guinea, based on the results of a survey Sobrino and Fernández (1991), a size at first maturity of 25.5 mm CL has been estimated, although these authors pointed out that the non-exploited characteristic of this resource could have an influence on the reproductive behaviour of this species. However, Crosnier *et al.* (1970) calculated a size at first maturity of 22 mm in the waters off Congo, a very similar value to the estimate of Sobrino and Cardenas (1996) in the waters off Angola (21.6 mm), and of De Ranieri, Mori and Sbrana, 1998 in Mediterranean waters (21.5 mm CL).

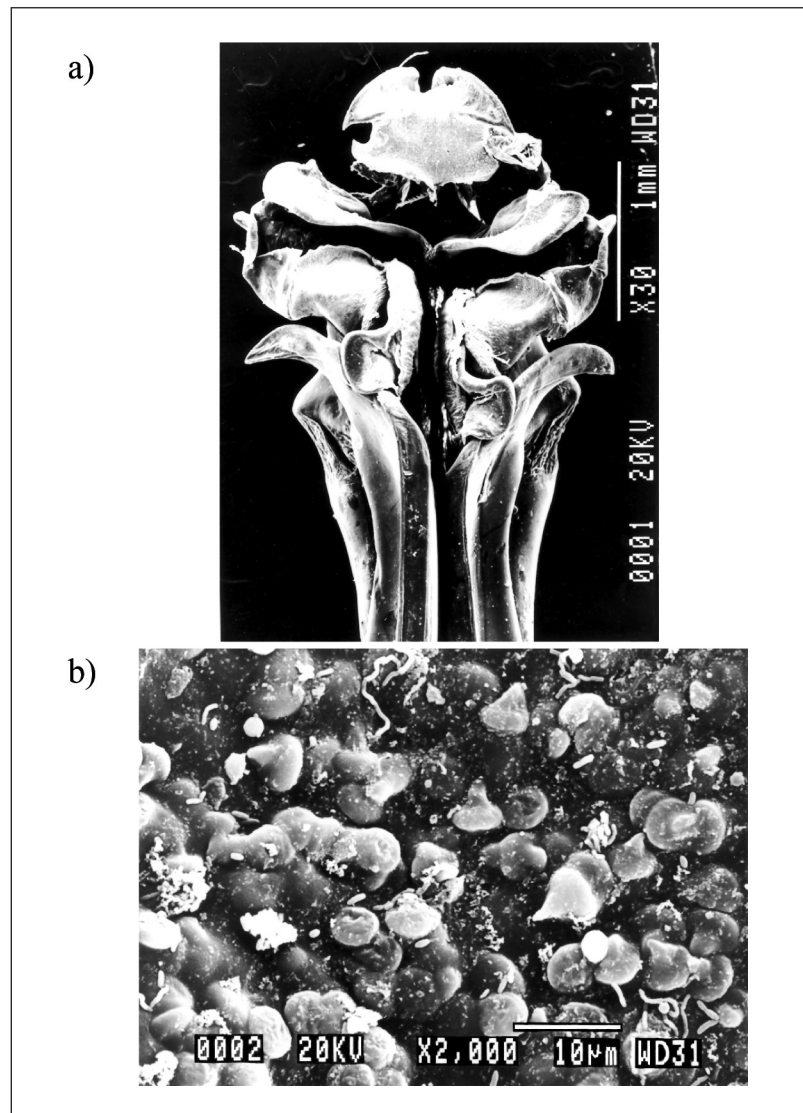
In the case of males, the absence of such studies makes it impossible to carry out a comparative analysis. Nevertheless, it would be logical for males to have a lower size at first maturity than females, due to their lower growth rates. Likewise, the size at formation of the petasma of 12.9 CL and the size at first maturity of 14.8 CL is in agreement with the function that the petasma fulfils. Heldt (1938) pointed out that the petasma's role in *P. longirostris* is to transfer spermatid mass, illustrated with a photograph, which depicts the spermatid mass in the extreme of the petasma. However, Pérez-Farfante (1982) casts doubt on this function, because he had never observed it in thousands of specimens examined of the species *Parapeneus politus* Smith, 1881. Without any doubt, the fixation of spermatid mass in the petasma is rather weak, and consequently, can be lost during the strain caused by the fishing procedure. Thus, the possibility of observing males with spermatid mass in the petasma is rather unlikely. In our case, after the examination of several thousand specimens from the Spanish South Atlantic, as well as, from the African Atlantic, only one male presented spermatid mass (figure 10).

The absolute fecundity values obtained for *P. longirostris* were highly variable. This fact was already remarked by Khmeleva and Goloubev (1986), who observed that many crustaceans have highly variable absolute fecundity values, even in females of similar size. Our estimates are lower than those of Heldt (1938), who estimated 150 000 to 400 000 eggs for Tunisian waters, and more in agreement with the estimates of De Ranieri, Mori and Sbrana (1998), who found 24 000-205 000 eggs in the northern Tyrrhenian Sea.

With regard to the size of oocytes, those found in the present study fall within the range found by other authors, such as Crosnier *et al.* (1970), who found a mean size of 280  $\mu$ m, while Heldt (1938) reported a mean size of oocytes close to be spawning that ranged from 230 to 238  $\mu$ m for Tunisian waters. Lastly, Tom, Goren and Ovadia (1988) defined a mean oocyte size ranging from 272-300  $\mu$ m in the waters off Israel.

The reproductive behaviour of this shrimp in relation to its bathymetric distribution shows a clear segregation of the different maturity stages. Females in advanced stages of maturity or imminently spawning are found at depths of more than 100 m. In shallower bottoms, these females are practically absent. This behaviour has been described for other areas. In the Mediterranean (Tyrrhenian Sea), Mori, Belcari, and Biagi, 1986 localised the reproductive zone in bottoms between 150 and 300 m, while in the Gulf of Guinea, it is at depths of more than 200 m (Sobrino and Fernández, 1991), and in the waters off Angola, they are concentrated between 100 and 400 m in depth (Sobrino and De Cárdenas, 1996). However, these results differ from those of Tom, Goren and Ovadia (1988), who found, in the waters off Israel, constant spawning activity at depths from 47-73 m, relating this to the water temperature, and suggesting that the temperature of 16°C could be the cut-off for a decline of spawning activity. In the Gulf of Cadiz, within the bathymetric range in which mature females are found (100-400 m), the water temperature varies from 16.5°C at depths from 100-200 m, decreasing over these depths to 14°C at 300 m and to 13°C at greater depths. These results are more in line with those proposed by Ghidalia and Bourgois (1961), who found a correlation between the abundance of shrimp and the water temperatures, suggesting a minimum temperature of 13.5°C and optimal temperatures between 14 y 15°C.

Fig 10. Spermatic mass (sm) in the extreme of the petasma (a). Spermatic mass in detail showing the presence of spermatozoids (arrow head) (b)



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