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Study of a population of *Calcinus tubularis* (Crustacea, Diogenidae) from a shallow *Posidonia oceanica* meadow

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Abstract: A population of the hermit crab *Calcinus tubularis* from a shallow *Posidonia oceanica* meadow in the SE of Spain has been studied. The results show a prevalence of small specimens, an egg-laying period extending from May to October (maximum in August), with a resting period during the winter months. The sex ratio is in favour of females during the spawning period. The first spawns occur in females with a cephalothoracic shield length of 0.7-0.9 mm. The mean number of eggs carried by a female is 30 and their mean size is 0.31 mm. The recruitment to the zone occurs from October to March (mainly in November-January). The relative growth is similar in both sexes, with no change between the juvenile and adult stages. The chelipeds show a slight sexual dimorphism. The ocular peduncles show a remarkably strong negative allometric growth.

Résumé : Une population du Paguridé *Calcinus tubularis* a été étudiée dans un herbier peu profond de *Posidonia oceanica* du sud-est de l'Espagne. Cette population est dominée par de petits individus. La période de ponte se situe entre mai et octobre (maximum en août) et le recrutement entre octobre et mars. Le sex-ratio est en faveur des femelles pendant la période de ponte et la première ponte se produit chez de jeunes femelles ovigères ayant une longueur du bouclier céphalothoracique de 0,7-0,9 mm. Le nombre moyen d'œufs portés par femelle ovigère est de l'ordre de 30, avec un diamètre moyen de 0,31 mm. La croissance relative des mâles et des femelles est similaire, sans discontinuités entre les phases de développement juvénile et adulte. Un faible dimorphisme sexuel a été observé pour les chélipèdes. Une allométrie négative de la croissance relative des pédoncules oculaires a été mise en évidence chez cette espèce.

Keywords: *Calcinus tubularis*, Decapoda, biology, relative growth, Mediterranean Sea.

Introduction

Infralittoral *Posidonia oceanica* (L.) Delile beds represent an important shelter for many Mediterranean sea animals and harbour a very complex biological community (Harmelin, 1964; Templado, 1984). Within this community the Decapoda are an important group, but they have been studied by only a few authors. The development, annual evolution of population structure and dynamic of some dominant decapods species from the leaves or rhizomes strata have been analysed by Ledoyer (1966), Vadon (1981) and García Raso (1990). The last study, carried out in the Spanish Mediterranean Sea, analyzed the structure of the community and demonstrated the strong dominance of two hermit crabs, *Cestopagurus timidus* (Roux, 1930) and *Calcinus tubularis* (Linnaeus, 1767). We have already studied the biology of *Cestopagurus timidus* (Manjón-Cabeza and García Raso, 1994), so to complete our

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knowledge of this taxocoenosis we investigated the biology of *Calcinus tubularis*.

Calcinus tubularis, belonging to the family Diogenidae, is a typical mediterranean species (Zariquiey Álvarez, 1968) living on rocky, coralligenous and calcareous bottoms and in *Posidonia* beds (Forest, 1966; García Raso, 1982, 1990) presenting a clear heterochely (typical in the Diogenidae species), the left cheliped being bigger than the right. On the other hand, it is the only hermit crab inhabiting *Vermetus* tubes (Amouroux, 1974; Holthuis, 1977; Zibrowius, 1978).

Biological studies of hermit crabs are scarce, especially growth studies, probably because it is difficult to measure the length of their partially and slightly calcified body, and also because their growth is conditioned by the size of available shells (Bush, 1930; Blackstone, 1986 a, b; Lancaster, 1988). Thus, in the case of the Spanish Mediterranean species, the previously cited work (Manjón-Cabeza and García Raso, 1994) and an abstract about *Diogenes pugilator* (Roux, 1829) (Guillen Nieto, 1992) are the only papers found.

Material and Methods

Specimens of the small hermit crab *C. tubularis* were sampled in a well-established *Posidonia oceanica* meadow growing on a sandy bottom with a few rocks, off Genoveses beach in the Cabo de Gata-Nijar Natural Park, Almería (S.E. Spain).

Samples were collected directly by SCUBA divers every two months over two years, 1986 and 1987 (the June 87 sample was not collected due to bad sea conditions), at depths ranging between 3 and 7 metres. Sampling areas were always larger than 900 cm^2 and rhizome heights were approximately 20 cm (García Raso, 1990).

In the laboratory the *Posidonia* leaves and rhizomes were separated and washed over a three-sieve column (smallest mesh size: 0.5 mm). This method also retained the postlarvae or megalopae of *C. tubularis*, which were not included in the study but which provided information about the recruitment period. The leaves and rhizomes were dried at 105° C for 48h, after separating the fauna. For comparison purposes, the density of specimens for month referred to a sample of 1000 g dry weight.

In the relative growth study, the anatomical structures were analysed with a VID V computer program that processed stereoscopic microscope images taken by video camera, with a measurement error of 0.001 mm. Five dimensions were measured: cephalothoracic shield length (CL); cephalothoracic shield width (CW); propodus length of the larger cheliped (QL); propodus width of the larger cheliped (QW) and the length (EL) and width (EW) of the ocular peduncle.

To test whether the relative growth rhythm differ significantly between the sexes, the confidence interval of the regression slopes ($P < 0.001$) were determined.

In the population structure study, the cephalothoracic shield length has been used as a size reference, because the carapace is not sufficiently calcified and so the total length cannot be used.

Fecundity was estimated from ovigerous females, with intact spawn, collected during the maximum spawning months.

In order to study the population structure the specimens were grouped in size classes, calculated according to the highest and lowest sizes (Christensen, 1983).

Results

A total of 1215 specimens were collected during the 11 months of sampling, but only 1075 (the specimens in good condition) were studied. The evolution of the monthly density (total and referring to 1000 g of dry weight of substrate), together with the number of ovigerous females, through the cycle are represented in Table 1.

Table 1. Monthly density of *Calcinus tubularis* from a *Posidonia* bed off Genoveses beach.
DW: Posidonia dry weight.
N: number of specimens in a sample.
N/1000: number of specimens in 1000 g DW.
OF/1000: number of ovigerous females in 1000 g DW.
(The values referring to 1000 g of dry weight of substrate have been rounded off)

Tableau 1. Abondance mensuelle de *Calcinus tubularis* d'un herbier de Posidonies au large de la plage de Genoveses.
DW : poids sec de substrat (Posidonies).
N : nombre de spécimens dans un échantillon.
N/1000 : nombre de spécimens dans 1000 g de poids sec de substrat (DW).
OF/1000: nombre de femelles ovigères dans 1000 g DW.
(Les valeurs rapportées à 1000 g de poids sec ont été arrondies)

DATE	DW	N	N/1000	OF/1000	SEX RATIO
26/03/86	949.7	104	110	0	3.10
23/05/86	753.0	146	194	1	1.63
21/07/86	925.6	43	46	7	0.38
17/09/86	1223.8	60	49	5	0.12
13/11/86	1051.6	51	48	0	3.50
08/01/87	1643.6	155	94	0	0.78
05/02/87	1371.9	83	61	0	3.27
10/04/87	1372.7	79	58	0	1.78
25/08/87	953.3	134	141	48	0.18
07/10/87	1013.6	199	196	1	0.87
15/12/87	1204.3	161	134	0	2.44

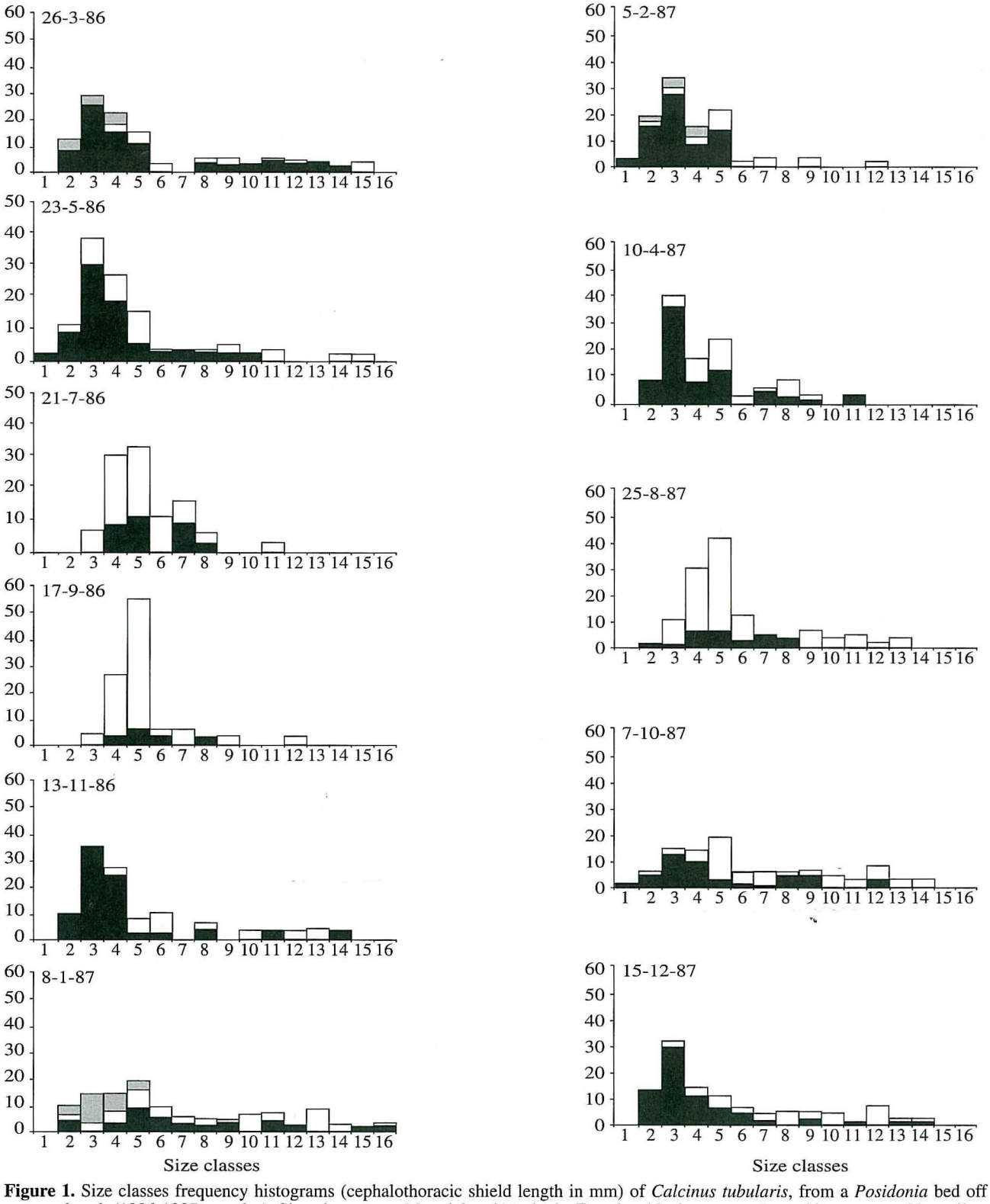

Figure 1. Size classes frequency histograms (cephalothoracic shield length in mm) of *Calcinus tubularis*, from a *Posidonia* bed off Genoveses beach (1986-1987 samples). Size classes: see Material and Methods. Females: black areas, males: white areas, and juveniles: grey areas.

Figure 1. Histogrammes de fréquence des classes de taille (basées sur la longueur du bouclier céphalothoracique en mm) de *Calcinus tubularis* dans 1 000 g de poids sec de substrat (DW), d'un herbier de *Posidonia* au large de la plage de Genoveses (échantillons de 1986-1987). Classes de taille : voir Material and Methods. Femelles, en noir ; mâles, en blanc ; juvéniles, en gris.

As we were working with a natural population of a species never studied before, the relationship between size and age was unknown. So, 16 size classes of cephalothoracic shield length (CL) were considered with a class interval of 0.13 mm:

Size class 1: 0.60-0.729 mm. Size class 9: 1.64-1.769 mm.
Size class 2: 0.73-0.859 mm. Size class 10: 1.77-1.899 mm.
Size class 3: 0.86-0.989 mm. Size class 11: 1.90-2.029 mm.
Size class 4: 0.99-1.119 mm. Size class 12: 2.03-2.159 mm.
Size class 5: 1.12-1.249 mm. Size class 13: 2.16-2.289 mm.
Size class 6: 1.25-1.379 mm. Size class 14: 2.29-2.419 mm.
Size class 7: 1.38-1.509 mm. Size class 15: 2.42-2.549 mm.
Size class 8: 1.51-1.639 mm. Size class 16: 2.55-2.680 mm.

The size frequency histograms (Fig. 1) show a clear prevalence of specimens less than 1.25 mm CL. Thus, the evolution of the average size follows a pattern close to the one drawn for the minimum size distribution (Fig. 2).

The bimonthly evolution of size distribution (males and females) is shown in Fig. 1.

The sex ratio (Table 1) is clearly in favour of females during the maximum spawning period. The spawning period extends from May to October, with a maximum in August. The first spawn occurs in the females belonging to size class 2, whereas 50% or more of the females are ovigerous in size class 3 (during the maximum spawning period). The mean number of eggs carried by a female is 30 ($\sigma = \pm 10.9$), their mean size being 0.31 mm ($\sigma = \pm 0.23$). The correlation between size (CL) and number of eggs (N) carried by an ovigerous female is significant and follows the equation $N = -27.1 + 48.3$ CL, $r = 0.94$.

Recruitment into the zone studied (by specimens which belong to the previously defined class size 1-3) occurs from October to March (Fig. 1), and is maximum from November to January, about four months after the period of maximum spawning (Table 1).

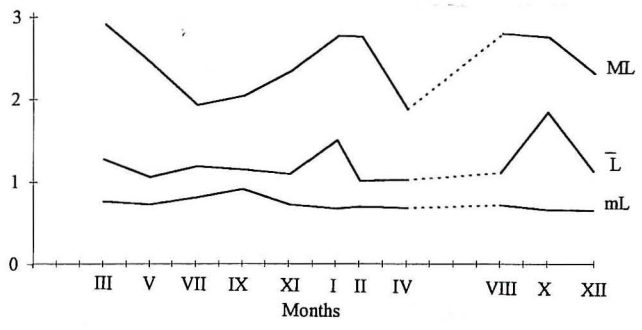

Figure 2. *Calcinus tubularis* (samples as in Fig.1): Seasonal variations in cephalothoracic shield length in mm (CL). ML: maximum, L̄: average and mL: minimum.

Figure 2. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Variations saisonnières de la longueur du bouclier céphalothoracique en mm (CL) ; ML : longueur maximum ; L̄ : longueur moyenne ; mL : longueur minimum.

In the area studied *C. tubularis* inhabits an extensive range of gasteropod shells, mainly *Clanculus jussieui* (Payraudeau, 1826), *Hinia incrassata* (Müller, 1776) and *Columbella rustica* (Linné, 1758) and rarely *Vermetus* tubes (only 1 specimen).

Relative growth

The equations ($Y = bX + a$) obtained in the study of relative growth are shown in Figs. 3 to 7.

1. The relationship between cheliped length and cephalothoracic shield length (QL-CL) (Fig 3) is isometric in males $b = 1.004 \pm 0.30$ and slightly negative in females, $b = 0.80 \pm 0.08$.

2. The relationship between length of the ocular peduncle and cephalothoracic shield length (EL-CL) (Fig. 4) shows no differences in the growth rhythm. The slopes are not different (males $b = 0.89 \pm 0.12$, females $b = 1.04 \pm 0.08$).

3. The relationship between cephalothoracic shield width and length (CW-CL) (Fig. 5) is isometric in both cases (males: $b = 0.91 \pm 0.08$, females $b = 1.04 \pm 0.04$).

4. The relationship between cheliped width and length (QW-QL) (Fig. 6): although there is slight sexual dimorphism, the cheliped is slightly wider in females (with the consequence of a different Y-intercept or "a" value, with a 65% confidence interval), no differences have been detected between the slopes of the growth curves between the sexes. Males: $b = 0.95 \pm 0.15$, females: $b = 0.93 \pm 0.09$.

5. The relationship between ocular peduncle width and length (EW-EL) shows (Fig. 7) a slight sexual dimorphism, with a clear negative allometric growth in both sexes (males: $b = 0.60 \pm 0.02$, females $b = 0.40 \pm 0.01$).

Discussion

The strong hydrodynamic conditions existing in the shallow area studied (mainly during the second year) produces differences between the cycles analysed, but the maximum number of specimens is located during the winter period (the end of autumn to the beginning of spring) and during the spawning period in summer (the end of spring to the beginning of autumn).

In the area studied there is a clear dominance of small individuals in the shallow bottoms studied (3-7 m) (Figs. 1 and 2) and a greater density of specimens on deeper sea-beds (-9 m) (García Raso, 1990). These observations and the maximum size of the species (referred to by Zariquiey Álvarez, 1968) could support the hypothesis that while recruitment is general in the shallow meadow studied, the larger specimens make vertical migrations and would prefer deeper sea-beds, where hydrodynamic conditions are more calm.

Regarding reproduction, both *Calcinus tubularis* and *Cestopagurus timidus*, the two dominant species in

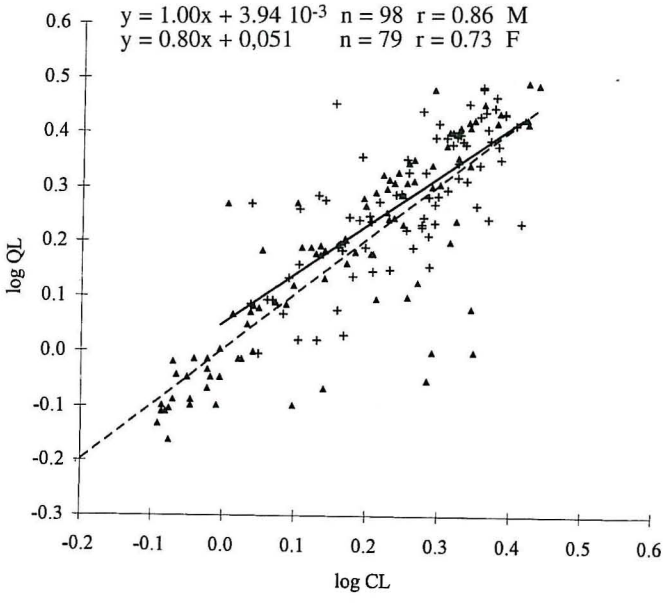

Figure 3. *Calcinus tubularis* (samples as in Fig. 1): Relationship between big cheliped length in mm (QL) and cephalothoracic shield length in mm (CL). Males (M) (▲ and discontinuous line), females (F) (+ and continuous line).

Figure 3. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Relations entre la longueur du grand chélipède en mm (QL) et la longueur du bouclier céphalothoracique en mm (CL) chez les mâles (M) (▲ et ligne discontinue) et les femelles (F) (+ et ligne continue).

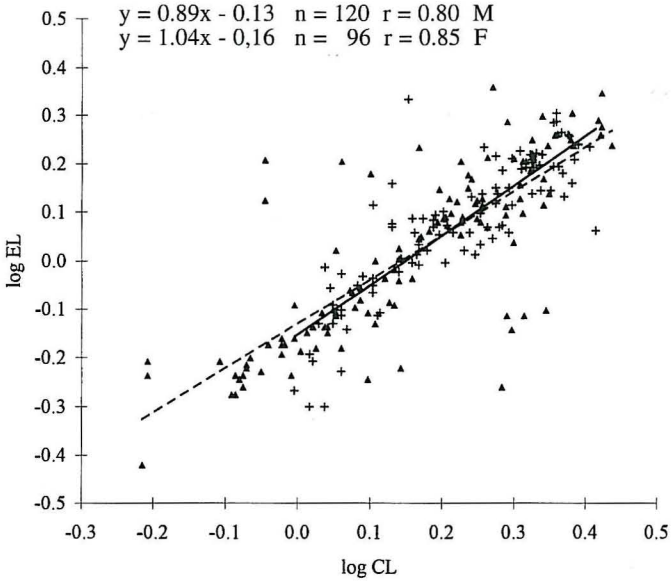

Figure 4. *Calcinus tubularis* (samples as in Fig.1): Relationship between the length of the ocular peduncle in mm (EL) and cephalothoracic shield length CL (in mm). Males (M) (▲ and discontinuous line), females (F) (+ and continuous line).

Figure 4. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : relations entre la longueur du pédoncule oculaire en mm (EL) et la longueur du bouclier céphalothoracique en mm (CL) chez les mâles (M) (▲ et ligne discontinue) et les femelles (F) (+ et ligne continue).

Posidonia oceanica meadows (Manjón-Cabeza and García Raso, 1994), show preferences for R strategies, but they also display clear differences: *C. tubularis* has only one spawning period with a maximum in August, a recruitment period about four months after spawning, and a resting interval during winter months. *C. timidus* has two maximum spawning periods, then two recruitment periods about three months after spawning (Manjón-Cabeza and García Raso, 1994) and a shorter resting time.

In laboratory conditions, Pike and Williamson (1960) hatched *C. tubularis* in July, and reported that it is possible to find all larval stages (five zoeal stages and the megalopa) in the plankton in September and October (two-three months later). This is in accordance with our results. The time between spawning and recruitment to the zone by juveniles belonging to size class 2 was longer in *C. tubularis*, which has 5 stages of zoea, than in *C. timidus* which has only 4 (Pike and Williamson, 1960; Dechancé and Forest, 1958).

In both species, sexual maturity is found in very small-sized individuals and *Calcinus tubularis* carries more eggs (30) than *Cestopagurus timidus* (16 to 20 according to Pessani and Premoli, 1993; Manjón-Cabeza and García Raso, 1994). On the other hand, the eggs of the Diogenidae *C. tubularis* are slightly smaller than those of *C. timidus* (Bouvier, 1940; Zariquiey Álvarez, 1968; Manjón-Cabeza and García Raso, 1994), which is the species having the smallest egg size recorded in the Paguridae (Pike and Williamson, 1960).

The clear dominance of small sized and ovigerous females from July to September and their decrease in number later on, could be a consequence of death or of migration (probably to deeper zones) of larger specimens after the reproductive period. These movements related to reproduction habits, search for shells, etc (Hazlett, 1981; 1983; Tomlinson, 1960; Rebach, 1969; Fotheringham, 1975; Stachowitsch, 1979) are known in other pagurids. On the other hand, our data are in accordance with those of Amouroux (1974), from Banyuls-sur-Mer, who reports that the ovigerous females of *C. tubularis* are abundant during June to August, at 2-5 m depth on rocky bottoms, and disappear from the area after the summer.

Both sexes show similar patterns of relative growth of the cheliped in *C. tubularis*, without allometric changes between the juvenile and adult stages. This could indicate that the chelipeds play essentially a similar role in behaviour, in both sexes. However, there is a slight sexual dimorphism (the

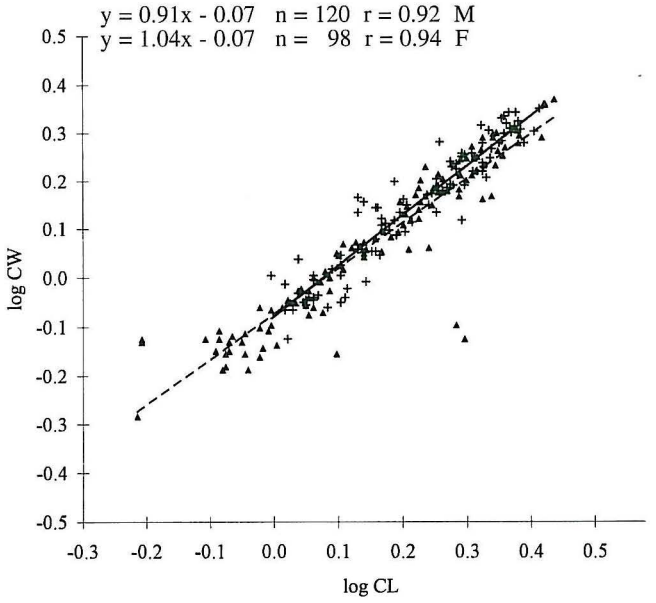

Figure 5. *Calcinus tubularis* (samples as in Fig. 1): Relationship between cephalothoracic shield width in mm (CW) and length in mm (CL). Males (M) (▲ and discontinuous line), females (F) (+ and continuous line).

Figure 5. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Relations entre la largeur du bouclier céphalothoracique en mm (CW) est sa longueur en mm (CL) chez les mâles (M) (▲ et ligne discontinue) et les femelles (F) (+ et ligne continue).

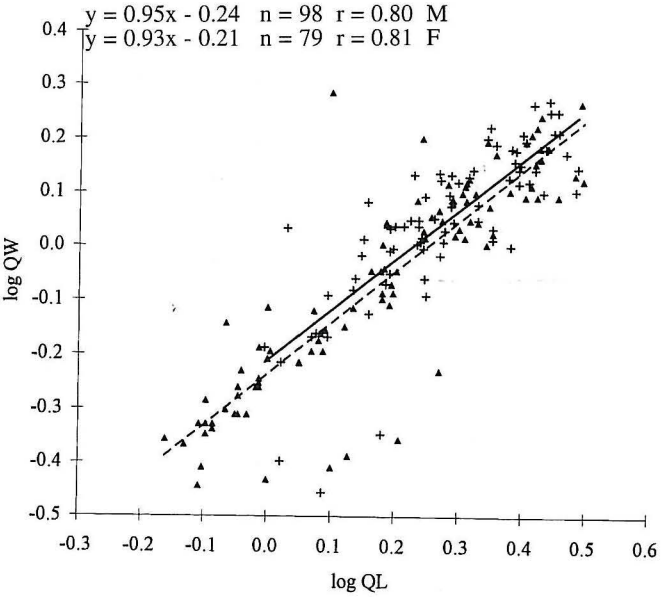

Figure 6. *Calcinus tubularis* (samples as in Fig. 1): Relationship between big cheliped width in mm (QW) and length in mm (QL). Males (M) (▲ and discontinuous line, females (F) (+ and continuous line).

Figure 6. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Relations entre la largeur du grand chélipède en mm (QW) et la longueur en mm (QL) chez les mâles (M) (▲ et ligne discontinue) et les femelles (F) (+ et ligne continue).

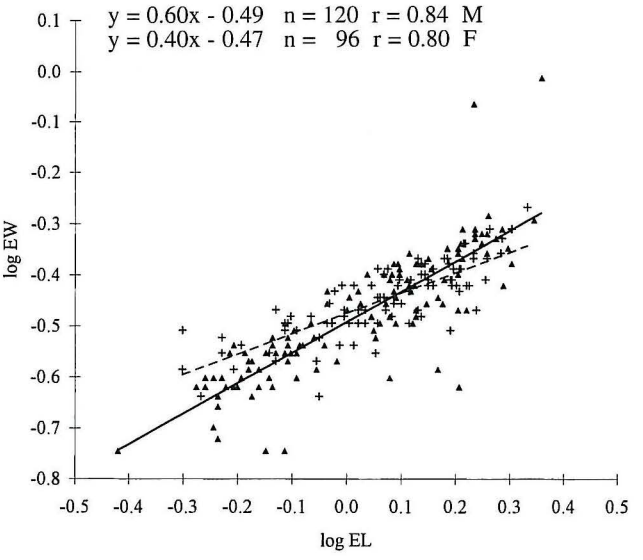

Figure 7. *Calcinus tubularis* (samples as in Fig. 1): Relationship between the ocular peduncle width in mm (EW) and length in mm (EL). Males (M) (▲ and discontinuous line, females (F) (+ and continuous line).

Figure 7. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Relations entre la largeur en mm (EW) du pédoncule oculaire en mm et la longueur (EL) chez les mâles (M) (▲ et ligne discontinue) et les femelles (F) (+ et ligne continue).

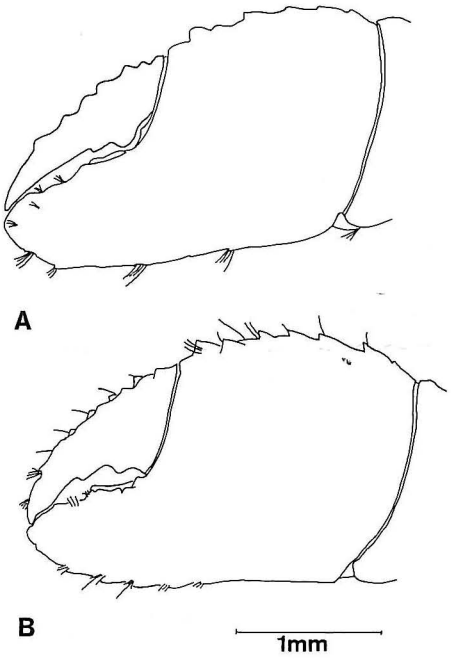

Figure 8. *Calcinus tubularis* (samples as in Fig. 1): Sexual dimorphism of the big cheliped. A: males, B: females. Scale: 1 mm.

Figure 8. *Calcinus tubularis* (mêmes échantillons que pour la Fig. 1) : Dimorphisme sexuel du grand chélipède des mâles (A) et des femelles (B). Echelle : 1 mm.

cheliped in females is slightly wider than in males of similar size, Fig. 8) which appears early in juvenile stages, and it must be correlated with different behaviour patterns (Hartnoll, 1982). This pattern of relative growth of the cheliped is different in males of other decapods, such as in the hermit crabs *Diogenes pugilator pugilator* (Roux) (Codreanu & Balcesco, 1968) and *C. timidus* (personal data), and in Brachyura (Hartnoll, 1982).

The ocular peduncle grows longer and thinner with age. This strong negative allometric growth (width-length relationship) is noticeable and can be detected even with the naked eye.

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