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Changes in population structure and body dimensions of two xanthid crabs: A long-term study in a single boulder-shore

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Abstract
Two xanthid crab species were studied during 29 months over a period of 14 years between 1986 and 1999 all in exactly the same boulder shore. One of the crab species studied was the xanthid, *Eriphia verrucosa* (Forskåll, 1775) with 60 specimens, the other species, *Xantho poressa* (Olivi, 1792), with 155 specimens. A significant change in numbers of both males and females of *E. verrucosa* was noticeable between 1986 and 1996 with a marked drop in numbers between these years. In 1997 male numbers increased again to almost their previous numbers in the population during 1986. The population of *X. poressa* declined significantly towards the end of the study period. Numbers of both genders peaked in spring and again, in summer. There was generally a decline in numbers of both crab species during autumn and winter. Thus, the average capture during the seasons was highest in spring for males of both *E. verrucosa*, and *X. poressa*. The body dimensions: mass, carapace length (CL) and width (CW) were measured in both xanthids. The aim of this long-term study was to determine whether temporal changes in the population structure and allometric changes in the dimensions of these crabs took place. Only such long-term observations could reveal these changes in population.

Keywords Decapoda, Brachyura; Xanthidae; *Eriphia*; *Xantho*; Eastern Mediterranean; population ecology, sex ratio; allometric dimensions; long-term study.

1 Introduction

The stony (or rocky) beaches are quite unique in that they are ideal in sheltering many crab species. Thus, more crab species occur in the mid-littoral area of stony beaches (Griffin, 1971). Abele (1974) found the highest number of decapod crab species inhabited the rocky intertidal zone (78 species). Similar findings are reported by Beck (1995) who found that the habitat structural complexity and the availability and size of refuges, regulate to some extent the population size. The structure of the crab assemblage studied in this pebble shore was previously described (Warburg et al., 2007). Likewise, the population structure and body dimensions were followed for several years (Warburg et al., 2011).

The main objective of this study is to find any long-term changes in a crab population inhabiting a single pebble shore. Following both population structure and dynamics as well as sex ratio in two xanthid crabs, can yield valuable data which can not otherwise be evaluated only in a study over a long period of time. Another important aspect of this study was to determine whether temporal allometric changes took place in the dimensions of both xanthids.

2 Materials and Methods

The study site is a stony shore consisting of pebbles (1-5cm), cobbles (5-10cm) and boulders (>10cm) situated on sandy, silt, and gravelly substrate on a rocky sea shore at the western slopes of Mt. Carmel, Haifa, in a small, shallow bay partly protected from the south by a concrete wall (of the Israel Oceanographic Institute, Shiqmona), and from the north-west by a rocky shelve (Warburg and Schwartz, 1993; Warburg et al., 2007).

The size of the study area was 20 x 20m. The study was conducted at low tide. Two of us worked their way each from opposite corners turning over all cobbles and boulders collecting the crabs from underneath. Throughout this long-term study, the same sampling technique was used. During low tide many crabs remained under boulders, cobbles, or pebbles situated on a sandy, gravelly substrate. Small cobbles are known to move more frequently with the tide than larger ones (Fukui and Wada, 1986). During diurnal low tide periods most small and medium sized crabs selected cobbles as refugia from predation (Navarette and Castilla, 1990; Richards, 1992). Temperature ranged between 16-28^{0}C during the study period 1986-1999, and salinity was around 6.4%. The tidal range was up to 25cm. Usually sampling was carried out at intervals over one month thus not affecting sampling method (Chapman and Underwood, 1996).

The crabs were then taken for a 20min drive to the laboratory to be measured: maximum carapace width (CW) and length (CL) were measured to the nearest 0.05 mm with a Vernier Caliper, and mass (±0.01mg) with a Mettler electronic balance. The crabs were sexed, registered and were released within a few days into a similar area adjacent to the study site.

The study was conducted during 29 months over a period of 14 years between 1986 and 1999 all in exactly the same site. Crabs were sampled monthly sometimes fortnightly on 44 collecting trips. This long-term study was not aimed as such and in 1986 it was just a plain population analysis. After a break of 10 years the study was resumed and was continuous between 1996 and 1999.

Data obtained during 1986 could not be used here to compare the relationships between body dimensions. since they were given in size classes rather than in actual measures. Because of the value of these data they are included in this report in spite of the 10 years that have elapsed between 1986 and 1996 when the study was resumed. During 1998 only a single month was studied.

Population structure, sex ratio and body dimensions are described in two xanthid species: *Eriphia verrucosa* (Forskåll, 1775) and *Xantho poressa* (Olivi, 1792)

E. verrucosa was more abundant in the lower intertidal level (Flores and Paula, 2001). This is an aggressive crab in both its intra- and inter-specific encounters. Consequently, it was largely found alone under a stone (Warburg and Schwartz, 1993).

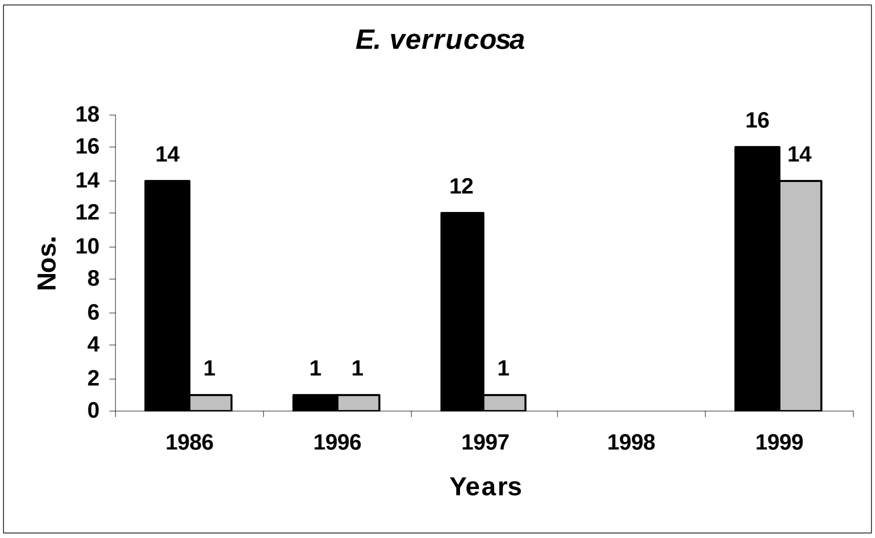
Analysis of data included also analysis of numbers captured during different seasons rather than monthly captures. Statistical treatment of the data consisted of regression analysis.

3 Results

3.1 Changes in number of male and females

The changes in numbers of male and females *E. verrucosa* and *X. poressa* captured during the study period are shown in Fig. 1.

The number of *E. verrucosa* declined markedly in the 10-year interval between 1986 and 1996 (Fig. 1). In 1997 there was a marked increase in number of males which continued in 1999. Likewise, female *E. verrucosa* showed a marked increase in numbers in 1999. The highest number of *X. poressa* (112) was in 1986 (see Fig. 1). From 1996 onwards the number of both male and female *X. poressa* declined (Fig. 1)



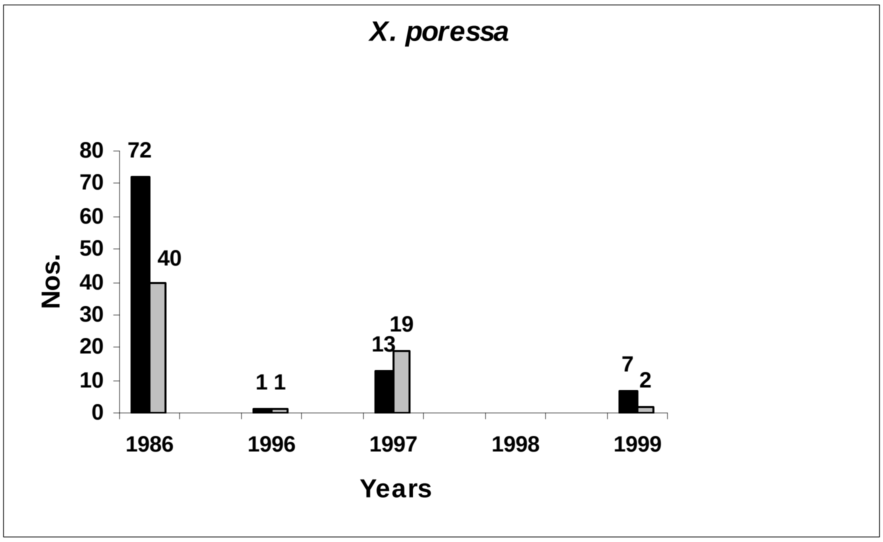


Fig. 1 Changes in population structure of *E. verrucosa* and *X. poressa* captured during the study period. Male (black); female (gray).

3.2 Changes in sex ratio

The changes in sex ratio in *E. verrucosa* and *X. poressa* during the study period are given in Fig.2. The sex ratio in *E. verrucosa* was during all but one year female-biased ranging between 47-93% females in the population (Fig. 2). In *X. poressa* it ranged between 41-78% females in the population (Fig. 2).

3.3 Seasonal changes in number

The seasonal changes in number of *E. verrucosa* and *X. poressa* males and females are illustrated in Fig. 3. The average numbers of the two xanthids captured was highest during Spring for *E. verrucosa* males (n=21) dropping during Summer (n-12)(see Fig. 3). *E. verrucosa* females have not shown any seasonal preferences In *X. poressa* numbers of both genders peaked in Spring and Summer (Fig. 3).

3.4 Yearly changes in average dimensions

Yearly changes in average dimensions (CL, CW and mass) of male and female *E. verrucosa* and *X. poressa* over the years, are shown in Fig. 4 and in Fig. 5 respectively.

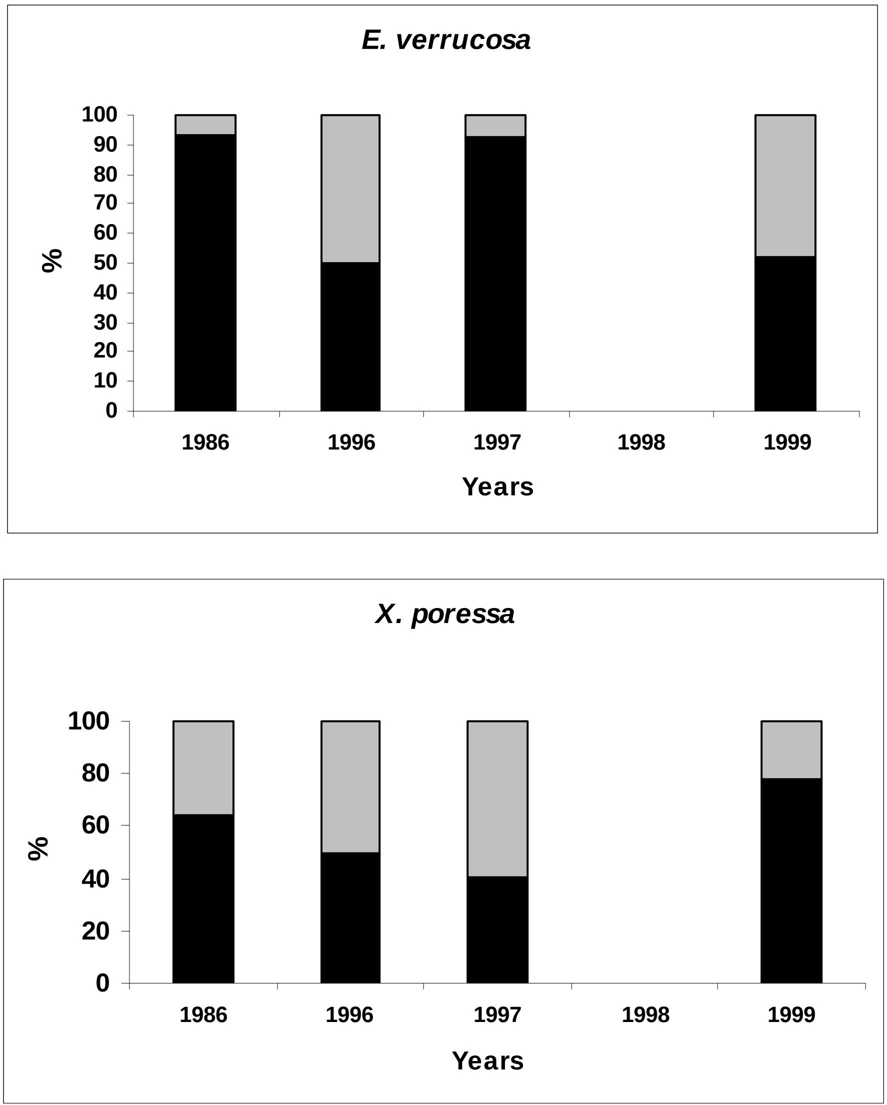
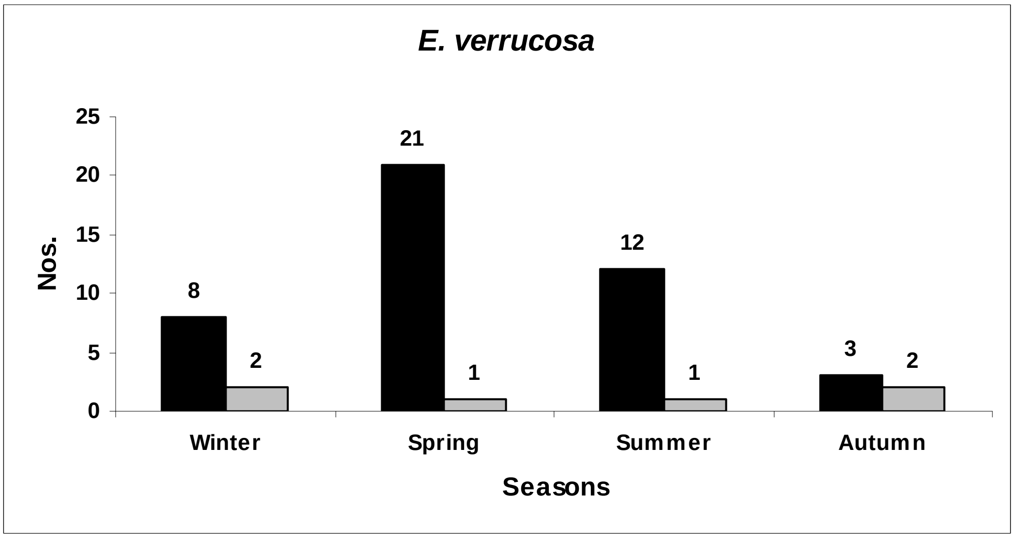


Fig. 2 Changes in sex ratio in *E. verrucosa* and *X. poressa* during the study period. Male (black); female (gray).

In *E. verrucosa* both males and females have shown a decline in both allometric measurements (CL, CW) in spite of the marked increase in mass peaking in 1999 (see Fig. 4). Longer and wider male *E. verrucosa* were found in 1999, whereas females were heavier in 1996. In *E. verrucosa*, significant correlation between either mass, CW and years (R^2=0.8201, and R^2=0.6141, respectively)(see Fig. 4).

In *X. poressa*, both genders have shown a gradual increase in size (CL, CW & mass) over the years peaking in 1999 (Fig. 5). This means that the crabs captured during 1999, were significantly larger. Both male and female *X. poressa*, have shown a significant correlation between either mass, CW and CL with the study years was noticed (see Fig. 5).



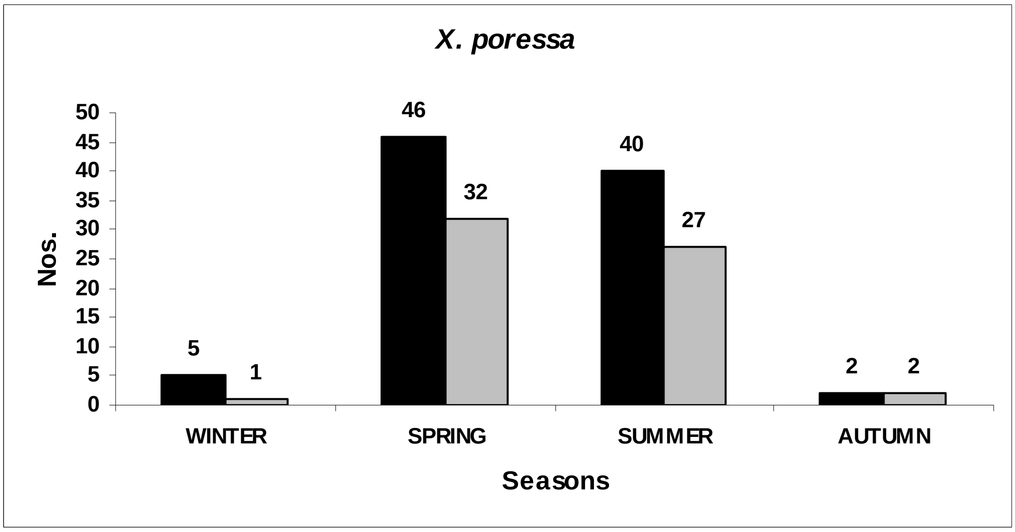


Fig. 3 Seasonal changes in number of male (black) and female (gray) *E. verrucosa* and *X. poressa*

3.5 Monthly changes in body dimensions

Monthly changes in body dimensions of *E. verrucosa* and of *X. poressa* are illustrated in Figs. 6 & 7 respectively. In *E. verrucosa* males there was a significant correlation between monthly changes in either mass, CL or CW (R^2=0.9402, R^2=0.8295 and R^2=0.8676, respectively), meaning that larger crabs are found in winter (Fig. 6).

In female *X. poressa* a positive relationship was found in monthly changes of all three dimensions (mass R^2=0.8848, length R^2=0.7668, and width R^2=0.7316). Larger specimens of both genders were found in winter (Fig. 7).

3.6 Relationships between body dimensions

Relationships between body dimensions (mass, CL, CW) of *E. verrucosa* and *X. poressa* are shown in. (Figs. 8, 9). *E. verrucosa*, CW and CL were significantly correlated (R^2=0.9431 linear) (Fig. 8). In *X. poressa*, there was a significant correlation between mass and either CL R^2=0.8533, and CW R^2=0.8614 (Fig. 9).

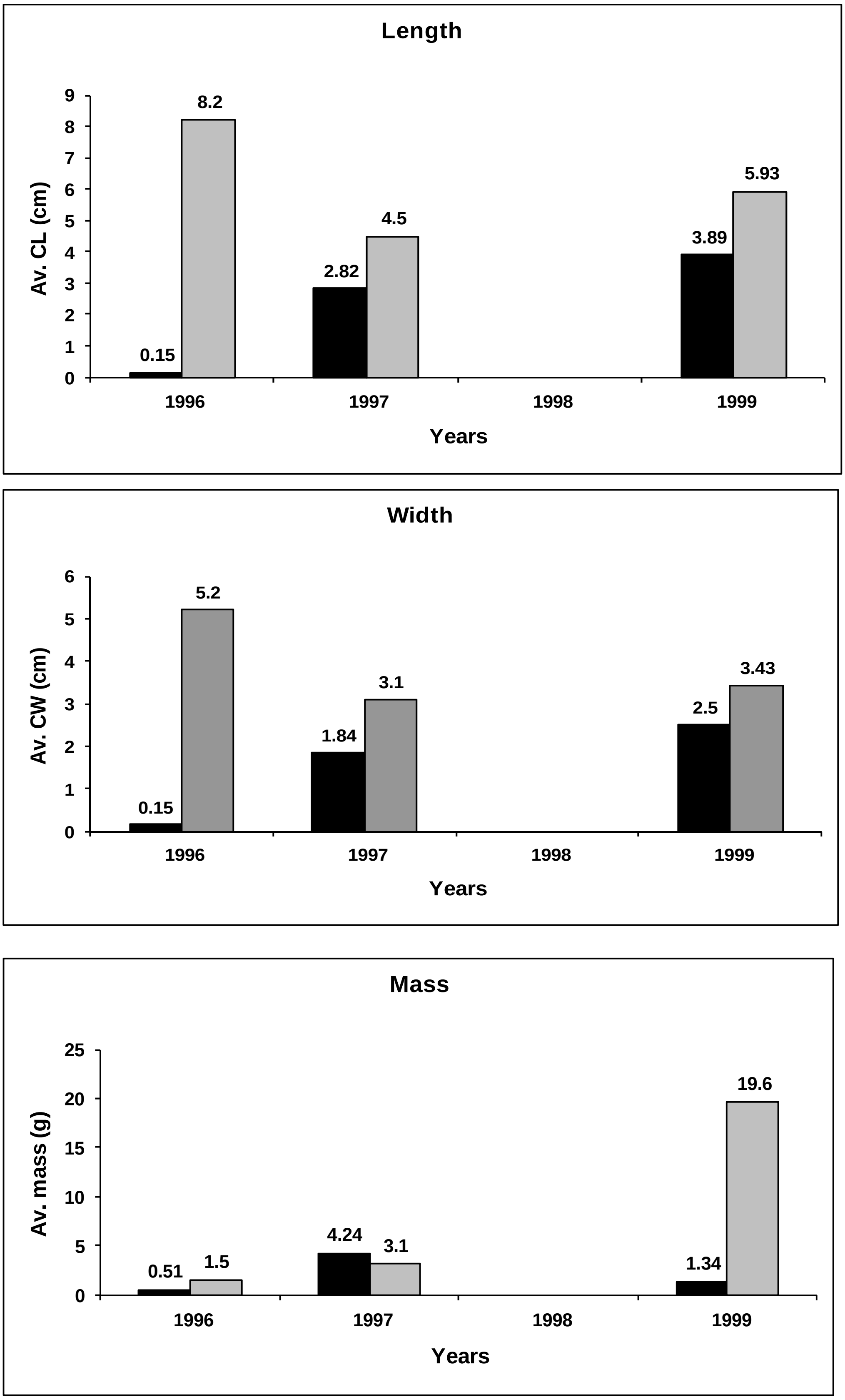


Fig. 4 Yearly changes in average dimensions (CL, CW and mass) of male and female *E. verrucosa*. Male (black); female (gray).

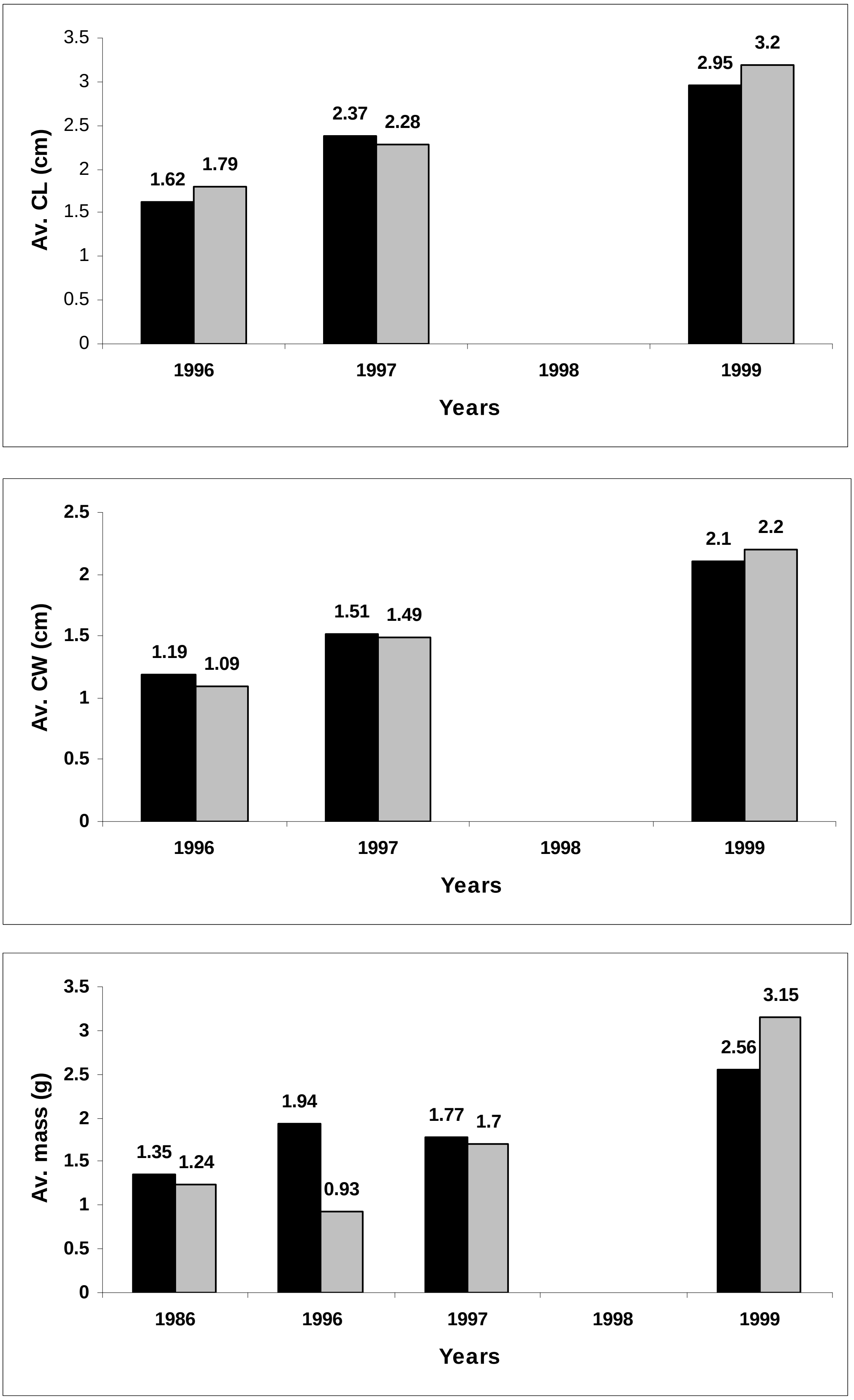


Fig. 5 Yearly changes in average dimensions of male (black) and female (gray) *X. poressa*.

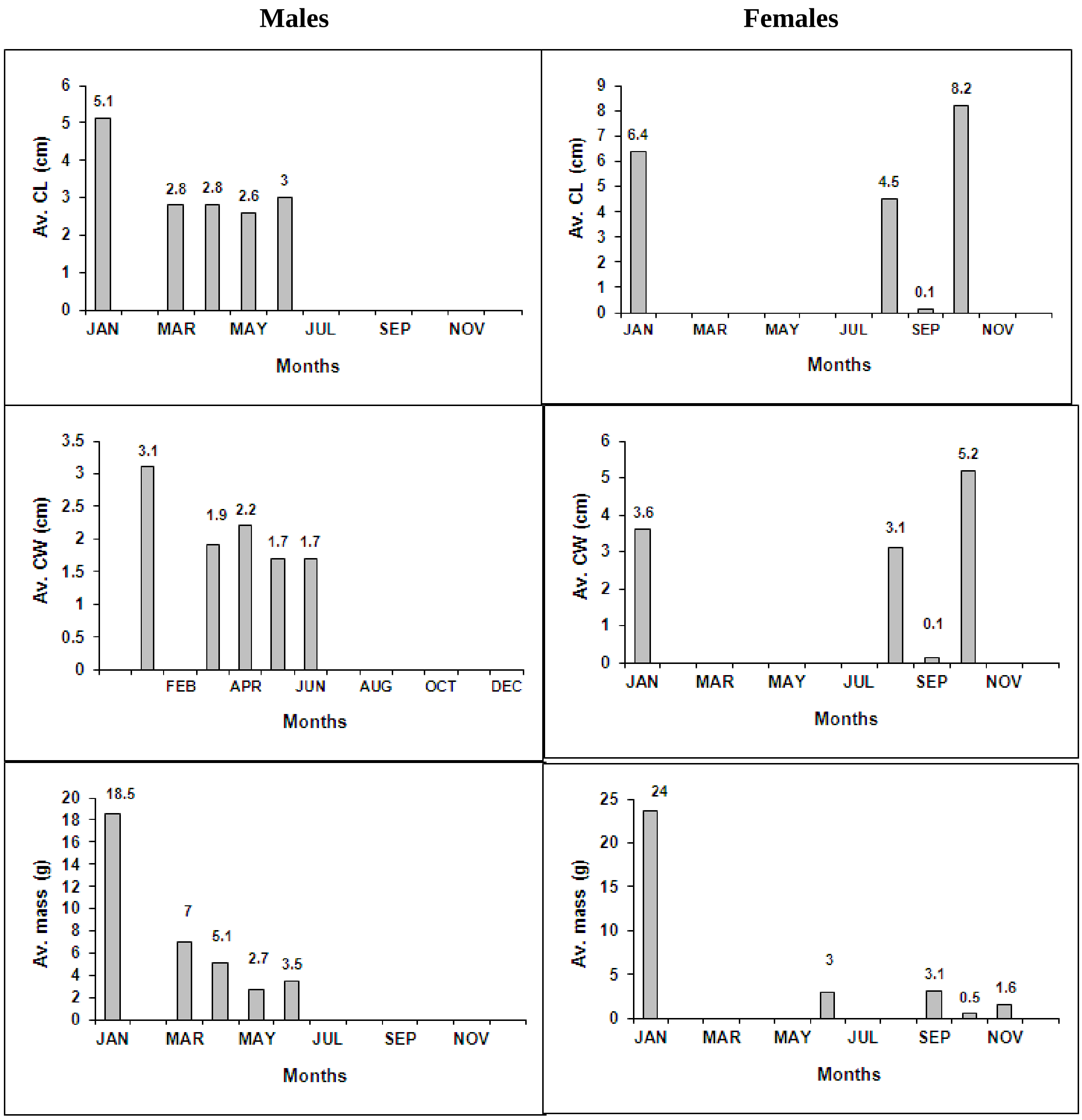


Fig. 6 Monthly changes in body dimensions of male and female *E. verrucosa*

4 Discussion

4.1 Population structure and numbers

We describe here the changes in population structure and the population fluctuations over the years in the two xanthid species studied. What can cause fluctuation in population size as we have found here? These could be naturally-occurring fluctuations and are not necessarily a consequence of any event that occurred in recent years. Indeed there has been no marked environmental change that took place in the study site.

What can cause fluctuation in population size as we have found here?

(1). Predation. A new predator preying on any phase in the life cycle of the crabs.

(2). Changes in recruitment rate. This can be caused by changes in ambient conditions such as temperature (maximum, minimum or range), salinity or substrate affecting any stage in crabs' metamorphosis. Abele (1974) found that temperature, salinity ranges, and tidal exposure were of less significance than was the substrate. It was observed that the duration of the zoeal stage in *Eriphia* is modified by salinities (Fransozo and Negreiros-

Fransozo, 1986). No such changes in salinity, temperature siltation or substrate were record in this site over the years. There is evidence that low winter temperatures reduced the number of. brachyuran species (Mantellato and Fransozo, 2000). Willason (1981) concluded that physical factors such as salinity and siltation restrict settlement and survivorship (in grapsids).

(3). A change in the availability of food at any phase in the crabs' life cycle. As an example, *Eriphia* is largely a predator of crustaceans and molluscs (Vannini, 1987). It breaks the mollusc's shell by clipping away the shell's lip (Zipser and Vermeij, 1978; Vannini and Gherardi, 1988). Any decline in mollusks populations will affect their availability and will almost certainly have an effect on the population size of *Eriphia*.

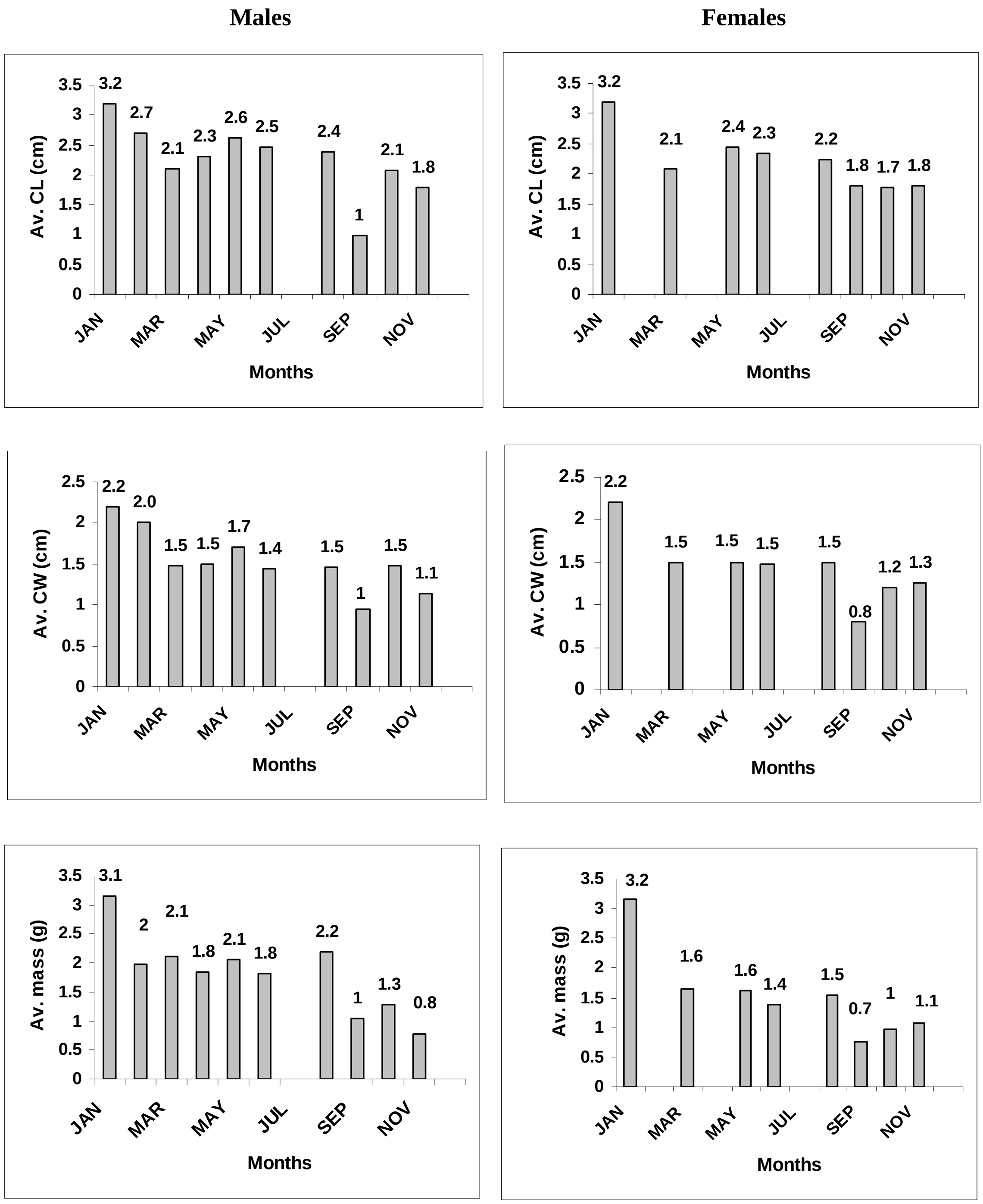


Fig. 7 Monthly changes in average dimensions of males and females of *X. poressa*

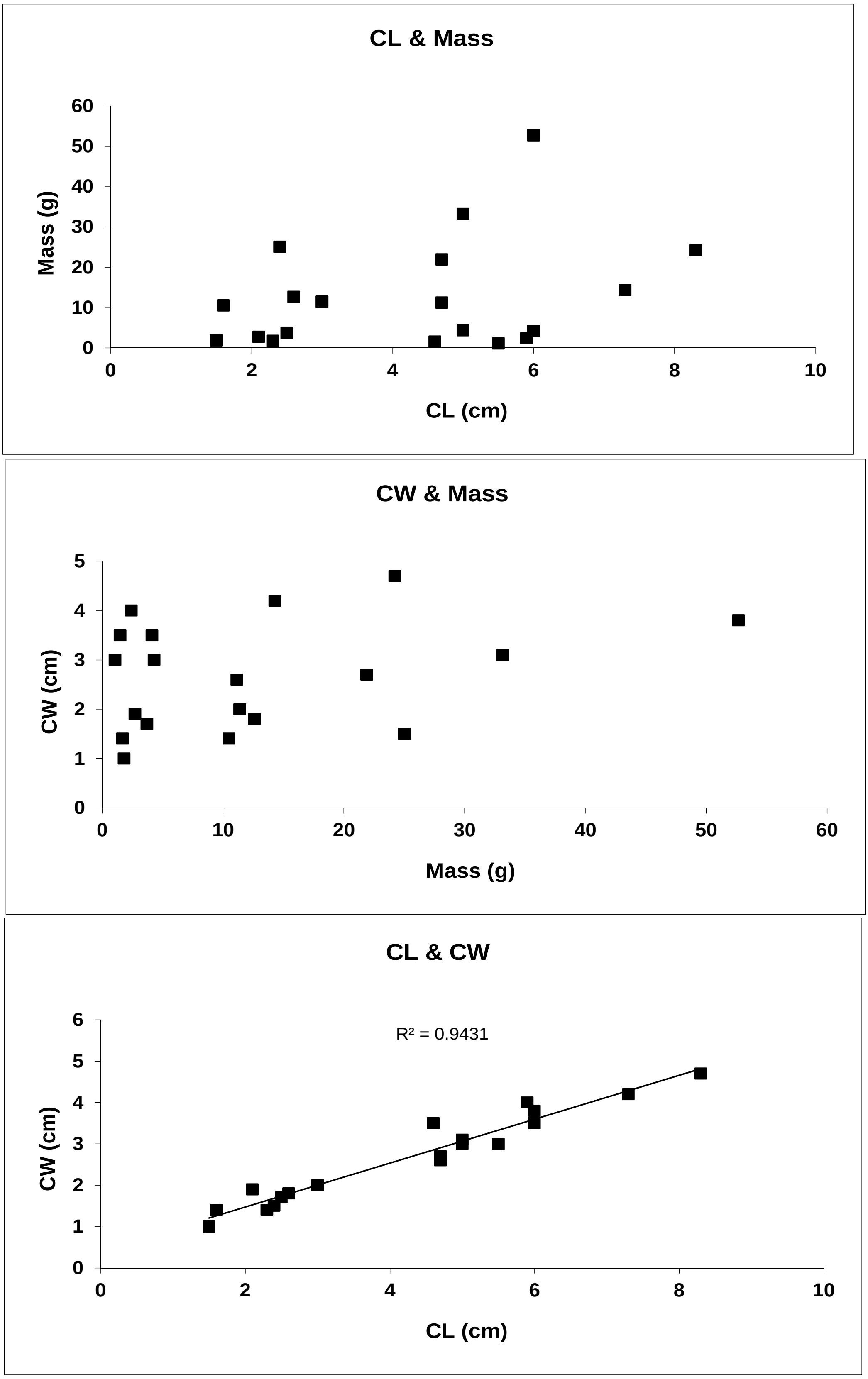


Fig. 8 Relationships between body dimensions of *E. verrucosa*.

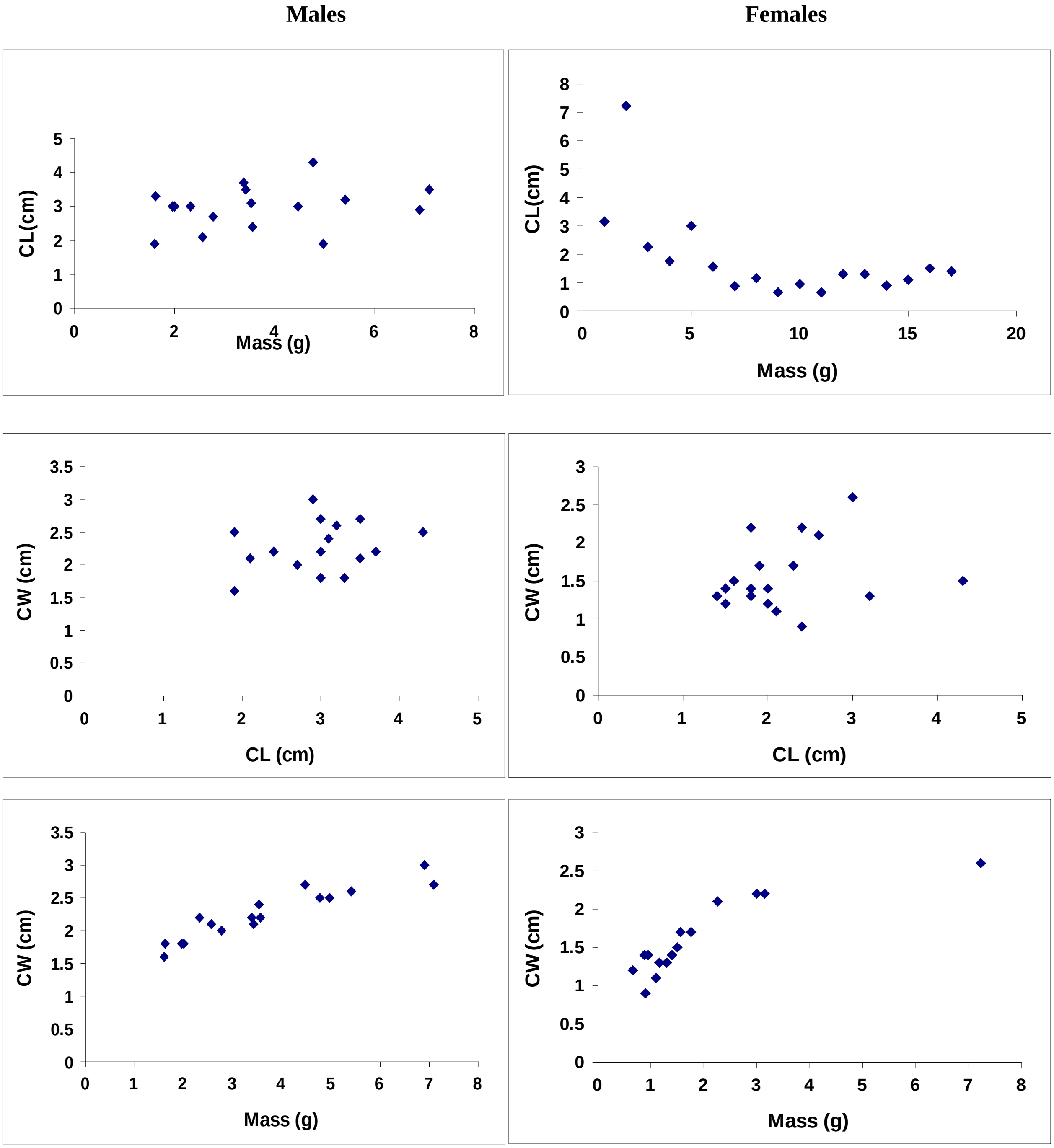


Fig. 9 Relationships between body dimensions of *X. poressa*

The decline in *X. poressa* populations since 1986 could have resulted from a number of different causes. Stevcič (1979) studied the ecology of *X. poressa* which he found frequently under stones 20-30 cm in diameter on a substrate of pebbles, sand and mud in the intertidal zone and in the shallow sub-littoral zone. In that zone *X .poressa* is subject to great variation in temperatures and salinities. Since, apparently, no major ambient change took place in the habitat itself, it is possible that a stage of the life cycle like the zoea larvae were somehow affected and consequently fewer megalops settled successfully in that specific habitat. As a result, recruitment of adult *X. poressa* crabs dropped.

We have also described here the annual variations in sex ratio and population structure. Similar variations were recorded by Flores and Negreiros-Fransozo (1999b) where, during six months, the sex ratio was biased towards the male, and during the rest of the year the M:F sex ratio was 1:1. In *E. verrucosa,* De Goes and Fransozo (2000) found that the sex ratio was biased towards the males which is similar to our findings. What can cause a change in sex ratio? Perhaps differential mortality of either gender. This can happen especially in crabs of commercial value where larger females are selected. Another cause could be differential predation on either gender. Although theoretically possible we found no evidence of such phenomenon. We have also describe here the annual variations in sex ratio and population structure.

4.2 Changes in dimensions of crabs

Most studies on xanthids dealt with populations structure and fluctuations in numbers and only a few studied dimensions of crabs. *X. poressa* has a carapace width (CW) between 3-4.3 cm with a maximum recorded CW in a male was 5.1 cm and a minimum 0.89 cm (Števčić, 1979).

4.2.1 Yearly changes in allometric measures

There are several long-term studies in which growth and changes in size classes were studied in grapsid or xanthid (Table 1). Some on them were samples throughout a period others at intervals (as in the present study extending over 16 years: 1984-1999). These studies are largely based on monthly sampling (and measuring) with occasional bimonthly or fortnightly measures (Table 1). Yearly temporal changes in body dimensions were taken either on consecutive years or not (see Table 1). This may be significant in trying to interpret any long-term temporal changes in dimensions. Thus, CL was measured during two subsequent years in the grapsids *Hemigrapsus sanguineus* (De Haan, 1853) and *H. penicillatus* (De Haan, 1853). (Fukui, 1988), as well as in *P. transversus* (Flores and Negreiros-Fransozo, 1999b). CW was measured for three years in sequence in the grapsid *Aratus pisonii* (H. Milne Edwards 1837) (Diaz and Conde ,1989).

In most studies only CW was measured, in a few also CL and in two studies all three parameters were measured, mass included (Table 2).

4.2.2 Monthly changes in allometric measures

Monthly temporal changes in either CL, CW or body mass were taken either on consecutive months (in 60% of the studies) or not (see Table 2). This is of significance largely in constructing size frequencies for population studies.

4.2.3 Relationships between allometric measures

Significant correlation between CL and CW were described in the grapsids *Goniopsis cruentata* (Latreille, 1802; Cobo and Fransozo, 1998), and *P. transversus* (Flores and Negreiros-Fransozo, 1999a). A similar significant correlation between CL and CW was found in *Trapezia ferruginea* Latreille, 1825 (Finney and Abele, 1981)

5 Conclusions

There appears to be a cyclic oscillation in population numbers as well as in sex ratio in both xanthids. Males appear to peak during spring and females during winter

Large *E. verrucosa* females were found during 1986 and 1999 whereas the largest males were seen in 1999. In both males and females *X. poressa,* significantly larger crabs were captured in 1999 and there was a gradual increase in dimensions of crabs captured during the study period. This indicates that apparently no smaller crabs of this latter species were recruited into this population. This is supported by evidence from capture rates

(Warburg et al., 2007). To conclude, there does not seem to be a simple explanation for the decline in the *X. poressa* population over the years.

Table 1 Frequency and pattern of sampling and duration of measuring body dimensions in some xanthids

					Duration		
			Pattern	**Frequency**	**Years**	**Months**	
Trapezia ferruginea	Latreille, 1828		N			4	Finney & Abele 1981
Eriphia smithi	McLeay, 1838					16	Vannini & Gherardie 1988
E. gongara	(Fabricius,	1781)	C	monthly	4		De Góes & Fransozo 2000
E. verrucosa	Forskåll, 1755		N			18	Present study
Xantho poressa	(Olivi, 1792)		N			28	Števčić 1979
X. poressa					5		Reuschel & Schubart 2006
X. poressa						18	Present study

Pattern: C: consecutive years; N: not in sequence

Table 2 Allometric measuremens in some xanthid crabs

Species	CW	CL	Mass	Source
Panopeus herbsti (Milne-Edwards)	+			McDonald 1982
Eurypanopeus depressus (S.I.Smith, 1869)	+			McDonald 1982
Xantho poressa	+			Števčić 1979
X. poressa	+	+	+	Reuschel & Schubart 2007
X. poressa	+	+		Reuschel & Schubart 2007
X. poressa	+	+	+	Present study
Eriphia smithi	+	+		Vannini & Gherardi 1988
E. gonagra	+			De Góes & Fransozo 2000
E. verrucosa	+	+	+	Present study

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