Observations on the biology of the burrowing mud shrimps Callianassa tyrhena and C. candida (Decapoda: Thalassinidea)

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Populations of the burrowing shrimps Callianassa tyrhena and C. candida were studied on tidal flats in the Northern Adriatic Sea. Biometric analysis showed a sexual dimorphism in both species, especially in the size of the propodus of the major cheliped. Slight differences between the two species in the shape of the propodus and telson were not statistically significant. Size frequency distributions revealed the presence of large animals during all seasons; recruitment by juveniles was observed only in September. Few ovigerous females were found in May and June. The parasitic isopod Ione thoracica and the parasitic cirriped Parthenopea subterranea infected only C. tyrhena.

KEYWORDS: Callianassa tyrhena, Callianassa candida, relative growth, population, Adriatic Sea, Parthenopea subterranea, Ione thoracica.

Introduction

The Thalassinidea (Decapoda) are among the most common burrowing organisms in littoral and sublittoral sediments; they are found—sometimes in very high densities—from the intertidal zone down to at least the shelf break, and occur in all types of environments from brackish or euryhaline to stenohaline.

In the Mediterranean Sea Callianassa tyrhena (Petagna, 1792) and C. candida (Olivier, 1792) are the most common members of the family Callianassidae. Both remain herein assigned to Callianassa sensu lato, pending generic reassignments of Mediterranean species in line with the restricted definition of Callianassa that was proposed by Manning and Felder (1991).

Callianassa tyrhena occurs in the Eastern Atlantic from the North Sea and the Kattegat to Mauritania, and is common in the entire Mediterranean Sea (Holthuis, 1991). This shrimp is found in the intertidal and shallow subtidal zones, where it burrows into sandy substrata.

Callianassa candida has also been treated under the junior synonym C. pontica Czerniavsky, 1884 or C. pestae de Man, 1928. So far, it has been reported from the Mediterranean Sea and the Black Sea. This species can often be found together with C. tyrhena and Upogebia pusilla in the same habitat, but occurs higher in relation to tidal level and in more muddy sediments. In addition, this species is also common in coarse sand or mud under stones in the intertidal and shallow subtidal, and has
been found in sandy silt or mud in 6 to 9 m depth (Thessalou-Legaki and Zenetos, 1985; Dworschak, 1987, 1992).

This study describes the comparative biometry and the population structure of these species and provides information on the infestation of C. tyrrhena by two crustacean parasites.

Material and methods

The present study was carried out at a tidal flat in the Bay of Strunjan near Piran, Slovenia (Northern Adriatic Sea) between September 1983 and September 1986. Here, the sediment consisted of a silty fine sand (median diameter between 64 and 107 μm) and only C. tyrrhena was encountered. Additional observations were made between May 1985 and May 1988 at Lido di Starnazzo, a tidal flat near Monfalcone, Italy. Here, the sediment is a medium sand to silty very fine sand with median diameter between 91 and 233 μm (Dworschak, 1987). At this site, C. candida occurs in the upper intertidal, while C. tyrrhena can be found near the low water line. Animals were collected with a 'yabby pump' similar to that described by Manning (1975) and either transported alive to the laboratory in Vienna or fixed immediately in 4% buffered formaldehyde–seawater. Animals were identified with the key provided by Saint Laurent and Božič (1976). C. tyrrhena is sometimes parasitized by the bopyrid isopod Ione thoracica (Montagu, 1808) and the rhizocephalan cirriped Parthenopea subterranea (Kossmann, 1874). All infestations were recorded. Damaged, regenerating, and parasitized specimens were omitted from allometric growth analysis and right/left ratios.

The following parameters were determined in all animals:

- sex, based on the presence (female) or absence (male) of the first and second pleopods;
- total length (TL in mm) from the tip of the rostrum to the end of the telson, in a Petri dish on graded paper;
- carapace length (CL in mm) from the tip of the rostrum to the end of the carapace using sliding callipers or, in small animals, a dissecting microscope with a scaled and calibrated eye-piece;
- side (right/left) of the major cheliped;
- palm length of the propodus of the major cheliped (PLma in mm) in the middle line from the carpus to the insertion of the dactylus;
- palm width of the major cheliped (PWma in mm) in the middle of the propodus, ventral to dorsal margin;
- telson length (LT in mm); and
- maximum telson width (WT in mm)

Additional measurements included:

- wet weight (ww in g) to a precision of 0.01 g in 33 specimens;

Prior to statistical analysis, data were tested using Kolmogorov-Smirnov tests. Data fulfilled the assumption of normal distribution; therefore parametric statistics were used. Data on C. tyrrhena were pooled for Lido di Starnzano and Strunjan. In all cases untransformed data were used. Regression analyses on relative growth were performed using the computer program REGRANS (Pezzuto, 1993a). This program detects transition points using iterative standard least squares regression and examination of the total residual sum of squares.
## Results

**Measurements related to growth**

*Carapace length.* This is linearly related to total length. There is no significant difference between males and females in both species (*C. tyrrhena*: ANCOVA, $F_{1,300} = -0.0898$, $p > 0.05$; *C. candida*: ANCOVA, $F_{1,165} = 0.7558$, $p < 0.05$). The formulae for the relation between TL and CL (for males and females combined) are:

- *C. tyrrhena*: $CL = 0.2403 \times TL + 0.8173$; $n = 388$; $r = 0.9641$
- *C. candida*: $CL = 0.2517 \times TL + 0.1844$; $n = 81$; $r = 0.93$

*Wet weight.* In *C. tyrrhena* this is correlated to total length by approximately the third power:

$$\log\,ww = 2.875 \times \log\,TL - 4.65; \quad n = 33, \quad r = 0.976$$

The pattern of occurrence for right- or left-handed shrimp is summarized in table 1. In most cases, right-handed shrimp prevailed in the samples of *C. tyrrhena* from Strunjan. More variation in the location of the major cheliped occurred in samples of this species taken at Lido di Staranzano. When individuals from all months are combined, animals from Strunjan more often had the major cheliped on the right side than did those from Lido di Staranzano (table 1). The difference in the right/left ratio between the two sites is statistically significant ($\chi^2 = 4.3$, $p < 0.001$). A nearly equal left to right ratio of major cheliped occurrence was observed in *C. candida*.

### Table 1. Major cheliped ratio and degree of infestation by parasites of *C. tyrrhena* and *C. candida* from Strunjan and Lido di Staranzano.

<table>
<thead>
<tr>
<th>Date, Location</th>
<th>Species</th>
<th>Major Cheliped Ratio (right/left)</th>
<th>Sex Ratio (f:m)</th>
<th>Parasitism (% of total) with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Females/Males/Both sexes</td>
<td></td>
<td>Ione/Parthenopea</td>
</tr>
<tr>
<td>20 September 1983 Strunjan</td>
<td><em>C. tyrrhena</em></td>
<td>2.5/0.8/1.3</td>
<td>0.5</td>
<td>0/4.8</td>
</tr>
<tr>
<td>13 June 1984</td>
<td></td>
<td>2/2.8/2.3</td>
<td>0.9</td>
<td>3.2/16.1</td>
</tr>
<tr>
<td>9 September 1984</td>
<td></td>
<td>0.8/1.2/1.0</td>
<td>0.9</td>
<td>3.8/26.9</td>
</tr>
<tr>
<td>17 September 1985</td>
<td></td>
<td>1.4/2.1/1.8</td>
<td>0.5</td>
<td>0/12.5</td>
</tr>
<tr>
<td>17 September 1986</td>
<td></td>
<td>1.5/2.8/2.2</td>
<td>0.5</td>
<td>3.3/0</td>
</tr>
<tr>
<td>All samples</td>
<td></td>
<td>1.5/1.8/1.7</td>
<td>0.7</td>
<td>1.7/10.3</td>
</tr>
<tr>
<td>2 May 1985</td>
<td>All samples</td>
<td>1.0/2.0/1.2</td>
<td>2.6</td>
<td>3.2/4.8</td>
</tr>
<tr>
<td>26 May 1986</td>
<td></td>
<td>3.3/2.5/3.0</td>
<td>2.3</td>
<td>11.5/0</td>
</tr>
<tr>
<td>13 April 1987</td>
<td></td>
<td>0.9/0.6/0.8</td>
<td>1.7</td>
<td>5.9/1.9</td>
</tr>
<tr>
<td>9 May 1988</td>
<td></td>
<td>0.9/1.7/1.0</td>
<td>5.5</td>
<td>6.0/2.0</td>
</tr>
<tr>
<td>All samples</td>
<td></td>
<td>1.0/1.2/1.1</td>
<td>2.4</td>
<td>6.0/2.5</td>
</tr>
</tbody>
</table>

*C. candida*:

<table>
<thead>
<tr>
<th>Date, Location</th>
<th>Species</th>
<th>Major Cheliped Ratio (right/left)</th>
<th>Sex Ratio (f:m)</th>
<th>Parasitism (% of total) with</th>
</tr>
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<td></td>
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<td>Females/Males/Both sexes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 May 1985</td>
<td><em>C. candida</em></td>
<td>0.5/1.3/0.7</td>
<td>2.4</td>
<td>0/0</td>
</tr>
<tr>
<td>26 May 1986</td>
<td></td>
<td>0.8/1.0/0.9</td>
<td>2.2</td>
<td>0/0</td>
</tr>
<tr>
<td>All samples</td>
<td></td>
<td>1.0/0.8/0.9</td>
<td>3.1</td>
<td>0/0</td>
</tr>
</tbody>
</table>
*Palm length.* This is linearly related to carapace length. A transition point (X) of \( CL = 12.0 \text{ mm} \) in males and \( CL = 12.3 \text{ mm} \) in females was calculated for *C. tyrrenha* using REGRANS. However, the slopes of the regression line for animals \( \geq X \) did not differ significantly from zero in males \( (t_{349} = 0.44, p > 0.05) \). In females, a comparison of the sum of the squared residuals obtained for the data as a whole against the sum of squared residuals for the lines at the left side and at the right side of the transition point shows no statistically significant difference \( (F_{2,160} = -0.1326, p > 0.05) \). Therefore, the transition points could not be accepted. Only one regression line for each sex was drawn over the whole size range, see figure 2.

Due to the small sample size, no transition point determination was performed in *C. candida*. The regression lines for males and females are shown in figure 3.

Covariance analysis showed that the slopes of the regression lines PLma:CL do not differ significantly (males: \( F_{[1,133]} = 0.194, p > 0.05 \); females: \( F_{[1,176]} = 1.60, \text{ df} = P > 0.05 \) between *C. tyrrenha* and *C. candida* of both sexes, while the intercepts showed a significant difference (males: \( F_{[1,133]} = 11.73, p < 0.005 \); females: \( F_{[1,177]} = 25.0, p < 0.001 \)). Palms in both sexes are slightly longer in *C. candida* versus *C. tyrrenha* specimens of the same carapace length.

Both slopes (*C. tyrrenha*: ANCOVA, \( F_{[1,247]} = 102.1, p < 0.001 \); *C. candida*: \( F_{[1,61]} = 6.41, p < 0.02 \)) and intercepts (*C. tyrrenha*: ANCOVA, \( F_{[1,249]} = 216.3, p < 0.001 \); *C. candida*: \( F_{[1,62]} = 73.2, p < 0.001 \)) of the regressions PLma:CL differ significantly between sexes in both species.

*Palm width.* This is linearly related to carapace length. A transition point of \( CL = 12.0 \text{ mm} \) in males, and \( CL = 12.2 \text{ mm} \) in females was calculated for *C. tyrrenha* using REGRANS. As the slopes of the regression lines for animals \( \geq X \) did not differ from zero (males: \( t_{40} = 1.32, p > 0.05 \); females: \( t_{65} = -1.63 \)) the transition points could not be accepted. Therefore, only one regression line each for all sizes was drawn in figure 4 for both males and females.

Due to the small sample size, no transition point determination was performed in *C. candida*. The regression lines for males and females are shown in figure 5.

Both slopes (*C. tyrrenha*: ANCOVA, \( F_{[1,240]} = 85.68, p < 0.001 \); *C. candida*:...
Fig. 2. *C. tyrhenensis*: regressions of palm length (PLma) on carapace length (CL) for male (PLma = 0.809 CL – 1.607, n = 110, r = 0.943) and females (PLma = 0.339 CL + 1.645, n = 141, r = 0.665).

Fig. 3. *C. candida*: regressions of palm length (PLma) on carapace length (CL) for males (PLma = 0.76 CL – 0.084, n = 26, r = 0.741) and females (PLma = 0.375 CL + 2.027, n = 39, r = 0.747).
**Fig. 4.** *C. tyrrhena*: regressions of palm width (PWma) on carapace length (CL) for males (PWma = 0.657 CL - 1.10, n = 106, r = 0.933) and females (PWma = 0.297 CL + 1.343, n = 138, r = 0.684).

**Fig. 5.** *C. candida*: regressions of palm width (PWma) on carapace length (CL) for males (PWma = 0.531 CL + 0.207, n = 26, r = 0.688) and females (PWma = 0.289 CL + 1.456, n = 39, r = 0.687).
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$F_{[1,61]} = 4.58, \ p < 0.05$ and intercepts ($C. \ tyrhena$: ANCOVA, $F_{[1,241]} = 199.54, \ p < 0.001$; $C. \ candida$: $F_{[1,62]} = 44.15, \ p < 0.001$) of the regressions PWma:CL differ significantly between sexes in both species.

No significant difference in both the slopes (males: $F_{[1,128]} = 1.91, \ p > 0.05$; females: $F_{[1,173]} = 0.03, \ p > 0.05$) and intercepts (males: $F_{[1,129]} = 1.48, \ p > 0.05$; females: $F_{[1,174]} = -0.0005, \ p > 0.05$) exists between the regressions PWma:CL in $C. \ tyrhena$ and $C. \ candida$ of both sexes.

**Telson length.** This is linearly related to carapace length. There is no significant difference between males and females in both species. The regression lines (for males and females combined) are shown in figure 6. There is a significant difference in the slopes between $C. \ tyrhena$ and $C. \ candida$ (ANCOVA, $F_{[1,292]} = 28.03, \ p < 0.001$). Telson length increases more strongly with increasing size in $C. \ tyrhena$ than in $C. \ candida$ (figure 6).

**Telson width.** This is linearly related to telson length. There is no significant difference between males and females in either species. The regression lines are shown in figure 7. There is no statistical significant difference in the slopes of $C. \ tyrhena$ and $C. \ candida$ (ANCOVA, $F_{[1,298]} = 1.81, \ p > 0.05$), whereas the intercepts differ significantly (ANCOVA, $F_{[197]} = 136.97, \ p < 0.01$).

The relation between telson width and telson length (WT/LT) ranged from 0.55 to 1.3 (mean = 0.8, SD = 0.008) in $C. \ tyrhena$ and from 0.43 to 1.21 (mean = 0.678, SD = 0.119) in $C. \ candida$. The difference between the two species is not statistically significant (ANOVA, $F_{[1,300]} = 1.98, \ p > 0.05$).

**Demographics**

The size frequency distribution of males, females, and ovigerous females collected in population samples at Strunjan and Lido di Staranzano are shown in figures 8.
Fig. 7. Regressions of telson width (WT) on telson length (LT) for \( C. \) tyrrhena \((WT = 1.150 \times LT + 0.387, n = 240, r = 0.922)\) and \( C. \) candida \((WT = 1.251 \times LT + 0.906, n = 61, r = 0.942)\).

and 9, respectively. Individuals of \( C. \) tyrrhena ranged in size from 7 to 65 mm total length and 2 to 16.6 mm carapace length. \( C. \) candida individuals ranged from 11 to 67 mm total length and 2.9 to 18 mm carapace length. Sex ratios at both sites were seasonally variable (table 1B). Sex ratios were strongly male-biased in Strunjan (female: male ratio = 0.48 to 0.9), whereas in Lido di Staranzano in both \( C. \) tyrrhena (female: male ratio = 2.25 to 5.25) and \( C. \) candida (female: male ratio = 2.2 to 2.44), females outnumbered males in all samples. For \( C. \) tyrrhena, the difference in the sex ratio between the two sites is statistically significant \((\chi^2 = 7.3, p < 0.001)\).

No ovigerous females were present in the samples from Strunjan (figure 8), and only a few were found in the samples of \( C. \) tyrrhena (one and two in May 1985 and 1986, respectively) and \( C. \) candida (one in May 1986) from Lido di Staranzano (figure 9). The smallest ovigerous females had a CL of 10.2 mm and 12.4 mm in \( C. \) tyrrhena and \( C. \) candida, respectively.

Parasites
The degree of infestation of \( C. \) tyrrhena by \( Parthenopea \) subterranea is summarized in table 1. Animals at Strunjan were infected to a higher degree (up to 26.9%) than those at Lido di Staranzano (up to 4.8%). The size of the infested shrimps ranged from 38 to 59 mm total length. The sex ratio of parasitized animals was male: female = 1:1.18. The size of the externa varied according to its development; mature externae reached 9 × 10 × 7 mm in size, and most of these contained multicellular eggs. No nauplii were observed. In 84% of the cases, the mantle aperture was on the left side of the host animal. Most of the parasitized animals showed only a single externa on the ventral side of abdominal segment 2; in two cases, a second, but
Fig. 8. Size frequency histograms (carapace length CL in mm) for the Strunjan samples of *C. tyrrenha*. m: males; f: females.

smaller externa was also present a few mm away on the ventral side of the second abdominal segment.

The degree of infestation of *C. tyrrenha* by *Ione thoracica* is summarized in table
Fig. 9. Size frequency histograms (carapace length CL in mm) for the samples of *C. tyrhena* (left) and *C. candida* (right) from Lido di Staranzano. m: males; f: females; shaded: ovigerous females.

1. Animals at Lido di Staranzano were infested to a higher degree (up to 11.5%) than those at Strunjan (up to 3.8%). The size of the infested shrimp ranged from 31 to 57 mm total length. The sex ratio of parasitized shrimps was male:female =
1:3.75 female. In most cases (71%), the bopyrid was found to reside in the left branchial chamber.

None of the more than 100 specimens of *C. candida* collected at these and other sites was infested by *Parthenopea subterranea* or *Ione thoracica*.

**Discussion**

In the present study both palm length and palm width varied greatly in relation to carapace length. No obvious change in the relative growth of the chelae could be detected. In addition, the transition points of CL (around 12 mm) calculated by REGRANS for *C. tyrrhena*, which should indicate the point of maturation, were well above the size of the smallest ovigerous female captured (CL = 10.2 mm). Infestation by parasites is known to influence secondary sexual characters (e.g., Reverberi, 1942b). This cause for the wide variations can be excluded, as allometric analyses were performed only with unparasitized animals. An obvious change in allometry of the major cheliped with increasing size in *C. tyrrhena* (under the name *C. laticauda* Otto, 1821) was observed in a population from the Gulf of Naples by Reverberi (1942b). He showed three phases in the growth of the major cheliped. In both sexes the degree of allometric growth is the same up to a length of 38 mm total length; males show a higher allometric coefficient than females from this size on, with a decreased allometric coefficient in all animals larger than TL = 60 mm. In other callianassids, e.g., in *Callianassa subterranea* (Montagu, 1808) from the North Sea (Rowden and Jones, 1994), *Callichirus major* (Say, 1818) and *Sergio mirim* (Rodrigues, 1971) from Brazil (Rodrigues, 1983, 1985), *Neotrypaea californiensis* (Dana, 1854) from Washington (Dumbauld *et al.*, 1997), and *Lepidophthalmus louisianensis* (Schmitt, 1935) from the Gulf of Mexico (Felder and Lovett, 1989), only two phases have been detected in the allometric growth of the major cheliped.

Telson shape differs slightly between both species; it is somewhat shorter in *C. candida* than in *C. tyrrhena*. This character has, therefore, also been given in keys (Saint Laurent and Božič, 1976) to distinguish between the two species. The present study, however, shows a great overlap in the dimensions of the telson. In addition, no statistical difference existed between the two species in the telson width/length ratio. The shape of the meral hook of the major cheliped and especially the fringe of setae on the outer uropod are much more useful characters in distinguishing between the two species (see figures in Saint Laurent and Božič, 1976).

The bopyrid *Ione thoracica* has been reported as a parasite on *C. tyrrhena* from the Mediterranean and the North Sea and also infests *C. subterranea* (see summary in Bourdon, 1968). The infestation levels of *C. tyrrhena* by *Ione thoracica* were of the same order of magnitude as those reported for *C. subterranea* from the North Sea (Rowden and Jones, 1994).

*Parthenopea subterranea* was described originally from Naples by Kossmann (1874) as a parasite of *C. subterranea*. Later, Boschma (1927) mentioned that the host was not *C. subterranea* but *C. stebbingi* Borradaile, 1903. The latter name, however, is partly a junior synonym of at least two species, namely *C. tyrrhena* and *C. candida* (see Dworschak, 1992). Caroli (1931) and Reverberi (1942a,b) reported the rhizocephalan to occur in the Gulf of Naples on *C. laticauda*, which is a junior synonym of *C. tyrrhena*. Although *C. subterranea* is known from the Gulf of Naples, the specimen sent to Kossmann was most probably *C. tyrrhena*. According to Höeg and Lützen (1985), the type specimen of *Parthenopea subterranea* is probably lost. Therefore the identity of the host cannot be clarified with certainty. Besides the
records from the Gulf of Naples, Popov (1929) reported \textit{P. subterranea} on \textit{C. subterranea}. In the Black Sea, according to more recent literature only \textit{C. truncata} Giard and Bonnier, 1890 and \textit{C. candida} [= \textit{C. pontica}, = \textit{C. pestae}] occur (e.g. Băcescu, 1967, Güth, 1980, Mikashavidle, 1981). Hoeg and Lützen (1985) further reported one record of \textit{P. subterranea} on \textit{Calocarisides coronatus} (Trybom, 1904) from the Skagerrak. Isaac and Moyse (1990) list \textit{Parthenopea subterranea} as occurring ‘On \textit{Callianassa subterranea}. In Scandinavia, probably in British Isles too’. Their figure (8.15), however, is identical with that in Hoeg and Lützen (1985), showing \textit{P. subterranea} on \textit{Calocarisides coronatus}. Extensive material of \textit{C. subterranea} from Scotland and the North Sea obtained during ecological studies showed no sign of parasitization by \textit{P. subterranea} (R. J. A. Atkinson, personal communication; A. A. Rowden, personal communication).

Size frequency distributions have been presented for a number of callianassids, e.g. \textit{Callianassa subterranea} (see Witbaard and Duineveld, 1989, Rowden and Jones, 1994), \textit{C. filholi} A. Milne Edwards, 1878 (see Devine, 1966), \textit{C. kraussi} Stebbing, 1900 (see Forbes, 1977), \textit{C. arenosa} Poore, 1975 (see Coleman, 1981), \textit{C. japonica} Ortmann, 1891 (see Tamaki and Ingle, 1993), \textit{Trypaea australiensis} Dana, 1852 (see Hailstone and Stephenson, 1961), \textit{Lepidodenthalus louisianensis} (see Felder and Lovett, 1989; Felder and Griffis, 1994), and \textit{Callichirus islagrande} (Schmitt, 1935) (see Felder and Griffis, 1994).

In the present study, no distinct modes could be identified in the size-frequency histograms both for \textit{C. tyrhena} and \textit{C. candida}. For other callianassids, a life span between two and four years has been reported, e.g. \textit{C. subterranea} lives for two to three years (Rowden and Jones, 1994), \textit{C. kraussi} for three years (Forbes, 1977), \textit{C. filholi} for three or possibly four years (Devine, 1966), \textit{Trypaea australiensis} for two years (Hailstone and Stephenson, 1961), and \textit{Lepidodenthalus louisianensis} for between two and two and a half years (Felder and Lovett, 1989). A detailed analysis of growth rates was presented for \textit{Sergio mirim} by Pezzuto (1993b) and shows that this species lives for four years. Recently, Dumbauld et al. (1997) reported a life span of four to five years for \textit{Neotrypaea californiensis}.

Only few ovigerous females were collected in the present study. Ovigerous females of \textit{C. tyrhena} have been collected in the Adriatic Sea in July, and in the Aegean Sea in August (Dworschak, 1992). Thessalou-Legaki and Zenetos (1997) sampled ovigerous females of \textit{C. tyrhena} on the west coast of Greece between March and June.

Various sex ratios have been reported for callianassid shrimp. Devine (1966) found a male:female ratio of 0.5 for \textit{C. filholi}; the population of \textit{Sergio mirim} investigated by Pezzuto (1993b) was female biased (male:female = 0.75) as was that of \textit{Neotrypaea californiensis} (male:female = 0.47) studied by Dumbauld et al. (1997). For \textit{C. subterranea}, Witbaard and Duineveld (1989) reported a population in the North Sea in which females outnumbered males (mean male:female = 0.71), while Rowden and Jones (1994) found a male biased population sex ratio (mean male:female = 1.9) at their North Sea site. The latter authors argue that deviation from equal sex might also be related to sampling gear efficiency. Collecting with a yabby pump certainly has severe limitations, as the pumps might selectively sample the population. The different sex ratios observed at Strunjan and Lido di Staranzano for \textit{C. tyrhena}, however, cannot be explained by the selectivity of the pump alone, as gear and operator were the same at the two sites, and the sediment composition and burrowing depth were also similar (Dworschak, unpublished data). These differences in population structure are therefore probably due to other factors.
Further sampling with quantitative methods and a detailed data analysis is required in order to clarify the different population structures and parasite infestation rates between the two sites and the two species; this approach will also be necessary to estimate the growth rates and reproductive patterns of *C. tyrrhena* and *C. candida*.

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