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Corophium multisetosum (Amphipoda: Corophiidae) in Canal de Mira, Portugal: some factors that affect its distribution

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Abstract

The population of *Corophium multisetosum* (L.) from Canal de Mira, Ria de Aveiro, Portugal, was sampled seasonally from December 1985 to September 1986, as part of a larger survey of the benthic invertebrate macrofauna. Its distribution along the channel exposes the species to a range of salinities from freshwater to above 30‰. A principal components analysis, using the physical and chemical parameters of the sediment as variables and sampling stations as operational taxonomic units, indicated that abundance is negatively correlated with salinity, depth, and the occurrence of sediments rich in particles below 125 μm and rich in organic matter. Abundance is positively correlated with temperature. The distribution of the species does not seem to be affected by the occurrence of sediment grades between 125 and 1 000 μm. Paired-choice salinity experiments indicated that *C. multisetosum* prefers salinities within the range 2.5 to 10‰. In multi-choice experiments concerning sediment grade, amphipods did not show any significant preference within the 125 to 500 μm range, although the 125 μm grade was chosen less frequently. The influence of temperature on the overall distribution of *C. multisetosum* is discussed.

Introduction

Species of the genus *Corophium* Latreille are well known inhabitants of European estuaries. For a background on habit, life cycle and environmental preferences of some of the more common species, the reader is referred to Meadows and Reid (1966), Fish and Mills (1979) and Meadows and Campbell (1972, p. 279–280).

Corophium multisetosum has been found on the higher reaches of estuaries, where salinities range from 1.5 to 6‰ (Stock 1952, G. M. Spooner in Ingle 1963). Though rarely recorded on the Portuguese coast, its presence is known from the Sado and Mondego estuaries, (Marques and Bellan Santini 1985). During 1985 and 1986, an ecological survey of the benthic invertebrate macrofauna of Canal de Mira, Ria de Aveira, Portugal (Fig. 1), was undertaken. The study indicated that *C. multisetosum* was distributed over most of the length of the channel, with densities from some to a few hundred ind. m^{-2}; however, it was extremely abundant (>80 000 ind. m^{-2}) in one particular site. Salinity conditions ranged from freshwater to well above 30‰. This paper describes the distribution of *C. multisetosum* in Canal de Mira in relation to some environmental parameters, as well as the results of experiments to determine the preferences exhibited concerning salinity and sediment composition.

Materials and methods

Distribution

A total of 40 sampling stations, 20 subtidal and 20 intertidal, were distributed over 13 transects along Canal de Mira. These were spaced at 1.5 km intervals (Fig. 1). According to transect width, 1 to 5 stations were allocated to each. Transects were numbered from north to south and stations, within each transect, from west to east. Thus, Stn 5.4 is the fourth station from west of Transect 5. Seasonal sampling took place in December 1985 (autumn), March (winter), June (spring) and September (summer) 1986. Subtidal stations were sampled using a van Veen grab with an area of 0.05 m^2 and for intertidal stations, a hand operated Birge-Eckman grab of the same area. Three random replicates were taken at each station. Samples were sieved in bags of 1 mm nylon net, and all biological material was later sorted at the laboratory. Sediment temperature at 2.5 and 10 cm depth, and the pH and salinity of interstitial water were recorded. Sediment samples obtained with a corer were analyzed for granulometric composition and organic matter content. Details of sampling methods can be found in Moreira et al. (unpublished). Data obtained underwent

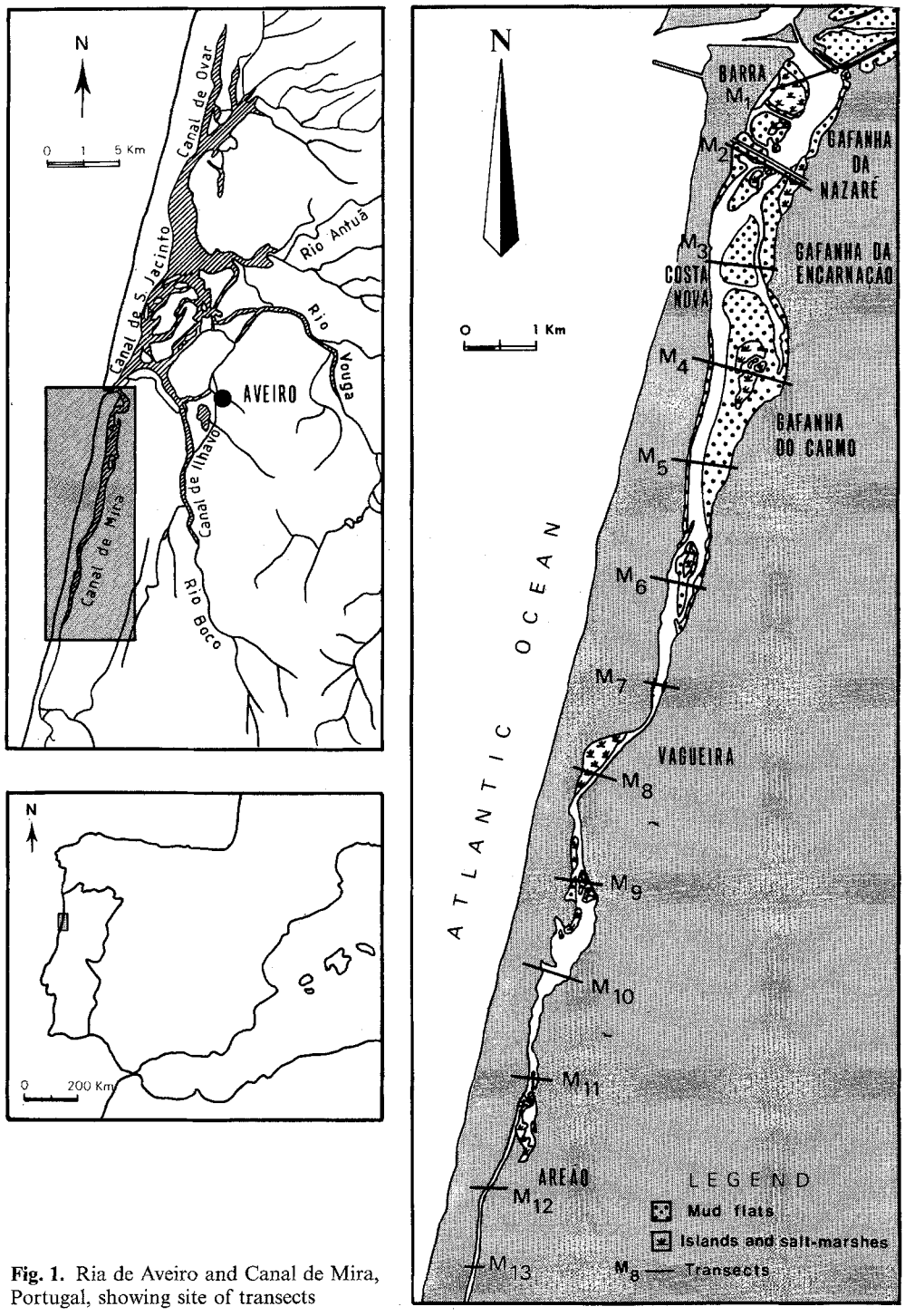

Fig. 1. Ria de Aveiro and Canal de Mira, Portugal, showing site of transects

principal components analysis (PCA) using sampling stations as operational taxonomic units in the space of sediment variables. Percentages of the granulometric fractions were submitted to the angular transformation. Eigenvalues and eigenvectors of a matrix of correlation between variables were computed after centering and reduction to unit variance (Legendre and Legendre 1979).

Salinity and substrate preferences

All amphipods and substrates used in tests were collected at Stn 11.1, which is assumed to represent the natural habitat of *Corophium multisetosum* (L.) in Canal de Mira.

For salinity experiments, a double-choice apparatus, similar to that described by McLusky (1970), was used.

Details of the methodology can be found in the same paper. The following pairs of salinities were tested: 0+2.5, 2.5+5, 5+10, 10+15, 15+20, 20+25, 25+30, 30+35. Two series of experiments were conducted which differed in the acclimatization salinities that amphipods underwent prior to experimentation, i.e., (A) 5‰ and (B) 25‰. Results thus obtained were subjected to a Chi-square goodness-of-fit test, assuming the null hypothesis that there is no difference between the number of amphipods in each division, i.e. that they do not make a significant choice.

Experiments relating to substrate grade were run in the apparatus described by Barnes et al. (1969). The 500, 250 and 125 μm grades were used. It was not possible, due to the sediment composition, to use grades above and below these values. A multi-choice experiment was conducted in which each grade and a mixture of the three in equal volumetric proportions were offered simultaneously, the substrates being randomly distributed in the apparatus. The duration of the experiment was 1 h and three replicates were used. The numbers of burrowed amphipods from each substrate were submitted to a Chi-square interaction test (Sokal and Rholf 1969). This design of the Chi-square goodness-of-fit test allows evaluation of heterogeneity among replicates, as well as the result of each replicate, and the combined result of the three replicates. The null hypothesis ist, once again, that the amphipods do not make any significant choice.

The significance level in all statistical tests was 5%.

Results

Distribution

The abundance of *Corophium multisetosum* varies considerably along the channel and throughout the year (Table 1). The species was very abundant at Stns 10.1, 10.2 and 10.3 and, especially, at Stn 11.1, where a density of over 80 000 ind. m^{-2} was recorded in December 1985. Transect 11 lies in the meso/oligohaline portion of the channel, where salinity remains below 5‰ during most of the year. Salinity values taken at the surface and bottom of the deepest point of Transects 10 and 11, at high and low water, are shown in Table 2. Maximum and minimum values recorded from Transect 11 ranged from 12 to 13‰ in September 1986 (at high water) to 0‰ in March 1986 (at high and low waters). Values recorded from Transect 10 were considerably higher.

The first two components of the PCA account for 42.5% of the total variance. Variable axes and stations were projected upon the plane of ordination defined by these components (Fig. 2). To facilitate reading, variables and stations are represented in different scales. However, since the axes of each component are isotropic, both in the ordination of variables and stations, the difference in scale does not affect the representation of the spatial relationships among stations and variables. At each station, the annual mean density of *Corophium multisetosum* was plotted. When analyzing Fig. 2, the reader must keep in mind that closeness between stations reflects similar environmental conditions. The angle between any two variable axes is a measure of their correla-

Table 1. *Corophium multisetosum*. Density at 40 sampling stations from Canal de Mira; mean annual density (ind. m^{-2}) and mean salinity (‰) recorded at transect

Stn	Density (ind. m^{-2})				Mean density	Mean salinity
	Dec.	Mar.	Jun.	Sep.		
1.1	0	33	0	0	8	28.7
1.2	0	0	0	0	0	
1.3	0	0	0	0	0	
2.1	0	0	0	0	0	25.0
2.2	0	0	0	0	0	
2.3	0	0	0	0	0	
2.4	0	0	0	0	0	
2.5	0	0	0	0	0	
3.1	0	0	0	20	5	24.4
3.2	0	7	7	7	5	
3.3	7	0	0	153	40	
3.4	133	7	0	20	40	
3.5	7	0	0	27	8	
4.1	13	40	0	0	13	20.6
4.2	0	0	0	0	0	
4.3	0	0	0	0	0	
4.4	0	0	0	0	0	
4.5	0	0	0	0	0	
5.1	0	0	0	0	0	18.9
5.2	0	0	0	0	0	
5.3	127	7	20	20	43	
5.4	13	7	7	207	23	
6.1	7	73	13	47	35	16.0
6.2	0	7	0	0	2	
6.3	13	13	0	153	45	
6.4	0	13	0	67	20	
7.1	53	120	113	27	78	12.9
7.2	7	73	0	0	20	
7.3	40	353	7	40	110	
8.1	0	33	7	0	10	12.5
9.1	7	200	167	0	93	10.9
9.2	0	100	20	0	30	
9.3	7	7	133	0	37	
10.1	240	846	3573	0	1165	6.5[a]
10.2	40	2307	2047	0	1098	
10.3	227	0	5567	0	1448	
11.1	84493	827	21880	12920	30030	2.6[a]
11.2	33	47	0	0	20	
12.1	7	113	20	0	35	0.1
13.1	0	0	7	0	2	0.1

[a] See Table 2

Table 2. Seasonal readings of water salinity (‰) taken at the surface (S) and bottom (B) of the deepest point of Transects 10 and 11, at high (HW) and low (LW) water

Transect	Dec.		Mar.		Jun.		Sep.	
	S	B	S	B	S	B	S	B
10 HW	5.3	2.1	1.0	0.0	3.5	3.8	11.0	18.9
LW	8.0	8.0	0.0	0.0	2.3	2.5	16.8	20.9
11 HW	3.2	4.2	0.0	0.0	0.2	0.2	12.3	13.1
LW	1.0	1.0	0.0	0.0	0.5	0.8	2.7	2.7

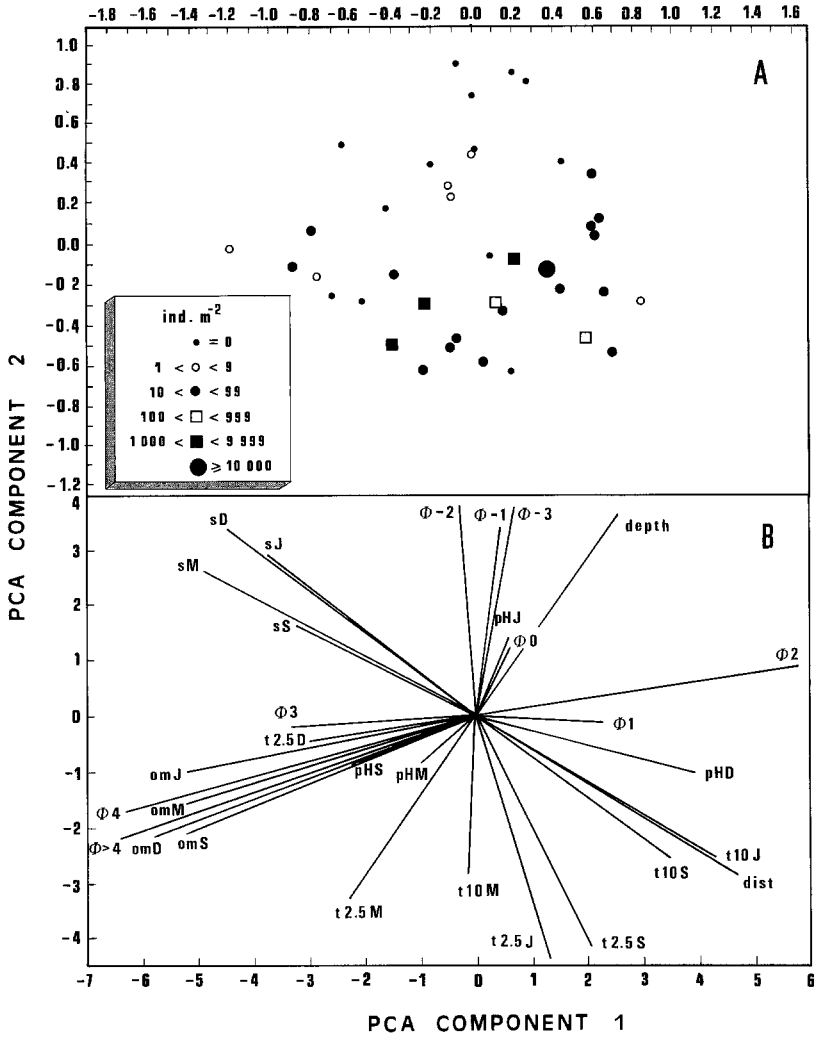

Fig. 2. Ordination of (A) stations and (B) sediment variables on the plane defined by Components 1 and 2 of PCA. Mean annual density of *Corophium multisetosum* is plotted at each station. $\Phi > 4$ to $\Phi - 3$: sediment grades; s: salinity; *t*2.5: temperature at 2.5 cm; *t*10: temperature at 10 cm; pH: pH; om: organic matter; dist: distance from mouth; D: December; M: March; J: June; S: September

tion: a 0° angle means perfect positive correlation; one of 180° means perfect negative correlation; and one of 90° means independence.

By inspection of Fig. 2 it can be seen that the occurrence of *Corophium multisetosum* is negatively correlated with salinity, with coarser grain sizes, $\Phi 0$ to $\Phi - 3$ (1 000 to 8 000 μm), and with depth. Grain sizes $\Phi 0$ to $\Phi - 3$ and depth are positively correlated with each other. While salinity and grades $\Phi 0$ to $\Phi - 3$ are slightly positively correlated, salinity and depth change independently. Fig. 2 also illustrates that *C. multisetosum* does not seem to discriminate between different compositions of sediments made up, mainly, by grain sizes below $\Phi 0$ (1 000 μm) and above $\Phi 3$ (125 μm). It appears, however, to avoid sediments with high levels of grades $< \Phi 3$ (125 μm) and rich in organic matter. It is also interesting to note the positive correlation, especially in June and September 1986, between sediment temperature and species abundance. The water longitudinal temperature profile of Canal de Mira is typical of estuaries in the temperate zone (Moreira et al. unpublished): temperature rises upstream in spring and summer and declines from the mouth inward in autumn and winter. Temperatures, varying from 20° to 24 °C, were recorded at Transects 10 and 11 in June and September, while values from 7° to 15 °C were found in December and March. In the sediment, recorded values ranged from 17° to 22 °C and from 9° to 14 °C, respectively.

Salinity and substrate preferences

The number of individuals in each salinity, within each pair of salinities, was not constant over time. As can be seen from Fig. 3, total Chi-square for each series reaches its maximum value after 120 min. Discrimination between salinities is thus at its maximum. Further analysis will be based on the results obtained after 2 h of experimentation (Fig. 4).

Individuals acclimatized to 5‰ S exhibited a highly significant preference, above 15‰, for the lower salinity. Between 5 and 15‰ S they preferred the lower salinity, although the preference was not significant. Amphipods acclimatized to 25‰ S significantly preferred the lower salinity between 10 and 25‰. Below 2.5‰ S they significantly chose the higher of the two. From 2.5 to 10‰ S they appeared to prefer the lower salinity, although the choice was not significant. Above 25‰ S amphipods did not make a consistent

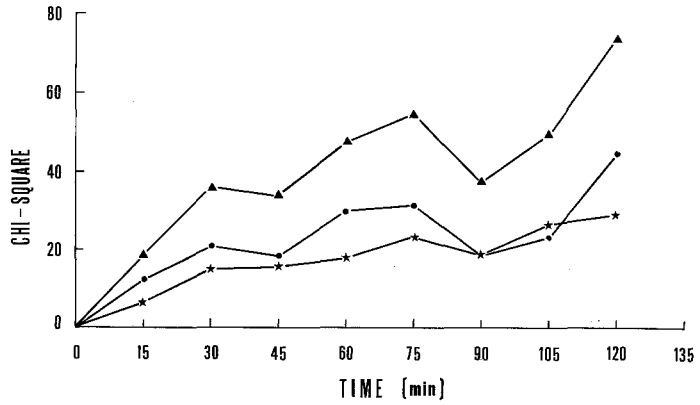

Fig. 3. Evolution of total Chi-square over time in salinity paired choice experiments. ●: 5‰ and ⋆: 25‰ acclimatization series; ▲: combined result for the two series

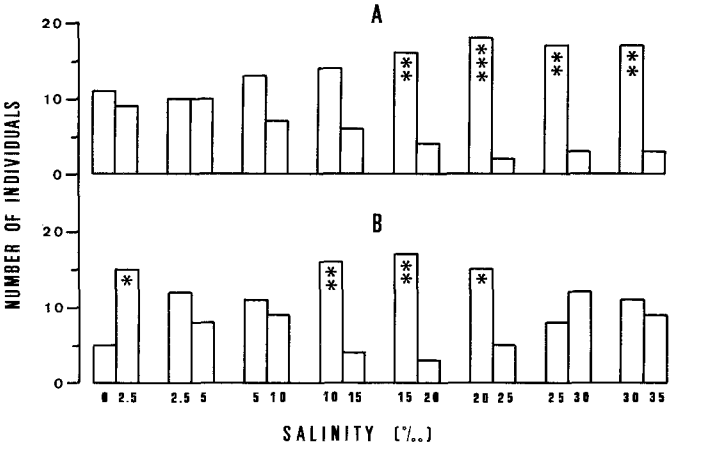

Fig. 4. *Corophium multisetosum*. Numbers in each alternative salinity after 120 min. Specimens acclimatized to A: 5‰ and B: 25‰. Results of Chi-square tests are * $p<0.05$; ** $p<0.01$; *** $p<0.001$

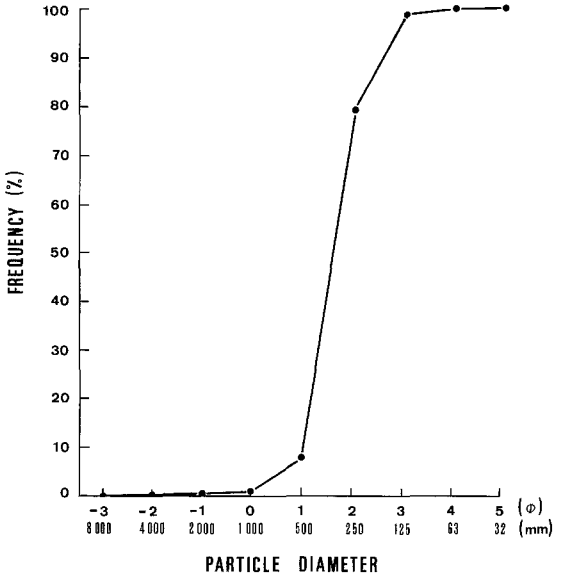

Fig. 5. Granulometric analysis of sediment from Stn 11.1

Table 3. *Corophium multisetosum*. Numbers in each substrate in three replicates and interaction Chi-square test

Replicate	Soil grade (μm)				*n*	df	Chi-square	*p*
	500	250	125	Mixture				
1	7	16	4	13	40	3	9.000	<0.050
2	9	12	7	12	40	3	1.800	ns
3	16	9	6	4	35	3	9.457	<0.025
Total					115	9	20.257	<0.025
Combined	32	37	17	29		3	7.539	ns
Heterogeneity						6	12.718	<0.050

choice. These results suggest that *Corophium multisetosum* prefers salinities within the range 2.5 to 10‰ S.

Granulometric analysis of the sediment of Stn 11.1 is expressed in Fig. 5. The 500, 250 and 125 μm grades form 6.8, 71.7 and 19.4% of the sediment, which gives a total value of 97.9%. Frequency of grades below 125 μm is 1%.

The results of the multi-choice tests with substrates are shown in Table 3, together with the interaction Chi-square test. Taking the individual replicates, *Corophium multisetosum* made a significant choice in Replicate 1, prefering the 250 μm grade and the mixture, and in Replicate 3, prefering the 500 μm grade. In Replicate 2 the choice was not significant. The heterogeneity Chi-square is significant, showing that choices in the whole set of three replicates are not homogeneous, cancelling out to give a non-significant combined Chi-square, although close to significance ($\chi^2_s = 7.539$, $p<0.10$). In all replicates *C. multisetosum* appeared to avoid the finer grade.

Discussion and conclusions

Under experimental conditions *Corophium multisetosum* is able to recognize and choose between two alternative salinities. Although individuals acclimatized to 25‰ S did not show any consistent preference above 25‰, taking the results of the two series *C. multisetosum* clearly prefers salinities from 2.5 to 10‰. The highest densities observed in Canal de Mira occurred in Transects 10 and 11, within the salinity range which amphipods selected in the experimental tests. These values differ from those obtained for *C. volutator* by McLusky (1970), this species selected salinities between 10 and 30‰ and exhibited a clear trend towards 20‰.

Using sediment grades from the *Corophium multisetosum* habitat in multi-choice experiments, it was not possible to detect a significant choice within the range 500 to 125 μm. The heterogeneity Chi-square value may in itself be the result of a difficult choice for a specific grade within the range. However, *C. multisetosum* seems to avoid the 125 μm grade. In the same kind of experiments but using a wider range, Meadows (1964c) has shown that *C. volutator* is able to choose among the various grades, selecting the finer.

To rule out any other factor, substrate choice experiments would need to be conducted using different grades of an inert material. In some initial experiments, substrates

were offered that were made up of particles obtained by grinding sand in a mill, followed by treatment with hydrogen peroxide to remove all organic matter. However, only a small proportion of amphipods were willing to burrow. Such rejection has also been detected in *Corophium volutator* and *C. arenarium* (Meadows 1964a, b) and is probably a consequence of a reaction to the lack of organic film surrounding grains.

These results never-the-less support the hypothesis that the distribution of *Corophium multisetosum* is independent of the composition of sediment-grades between 1 000 and 250 μm. The 125 μm grade probably has some negative influence on the distribution of the species. It remains to be tested whether the presence of grades below 125 μm is a limiting factor for the species, as field evidence seems to point out.

Temperature seems to be correlated with *Corophium multisetosum* abundance (see Fig. 2), especially in spring and summer. This may be a consequence of an independent correlation between: (1) salinity, which definitely affects abundance of this species, and distance from the mouth of Canal de Mira; and (2) temperature in the hottest months and distance from the mouth. However, it is evident that *C. multisetosum* is able to withstand the higher temperatures recorded in Canal de Mira during the hottest months. Quantitative data regarding species abundance seems to be scarce. Stock (1952), refering to densities of 2 000 ind. m^{-2}, considers it a common species in its type locality in the Netherlands, while Cazaux and Labourg (1973) state that this is a very abundant species in fish culture ponds in the Arcachon basin, France, with 1 000 to 1 500 ind. m^{-2}. For *C. volutator*, the highest record is 40 000 ind. m^{-2} (Segestrale 1959) and other published peak values range from 2 000 (Gee 1961) to 28 000 ind. m^{-2} (McLusky 1968). The population of *C. multisetosum* from Ria de Aveiro, reaching over 80 000 ind. m^{-2}, is undoubtedly the highest yet recorded from near the southern limit of this species. These relationships suggest that the geographic distribution of *C. multisetosum* depends on temperature in a way not realized before, and that its classification as a cold temperate species (Lincoln 1979) will probably have to be reconsidered.

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