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Distribution of *Brachionus* species in Spanish mediterranean wetlands

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Abstract

In this study 200 zooplankton samples were collected (1979–1980), from 57 different wetlands in coastal Mediterranean Spain (CMS) and examined for the occurrence of *Brachionus* species. Data on 17 separate physical and chemical features of these water bodies were obtained from samples collected at the same time. Ten different *Brachionus* species were found in these wetlands, but only six occurred frequently enough to allow further examination of their distributional patterns using multivariate discriminant analysis. To separate these species, three analyses were performed using the 17 physical and chemical parameters, or their ratios. Three discriminant functions accounted for 80% or more of the among species variance. Separation of species occurred on each discriminant function which could be attributed to a reduced number of parameters. These were mainly temperature, sulphate, chloride, alkalinity and alkaline earths.

Introduction

Coastal wetlands in Mediterranean Spain frequently have large rotifer populations whose biomass can exceed that of other zooplankton. *Brachionus* and *Synchaeta* are two genera characteristically found in this area. Many species of the genus *Brachionus* are cosmopolitan [Pejler, 1977] and some have genetically different ecotypes, which apparently permits the occupation of a variety of environments [Serra & Miracle, 1983, 1985]. Nevertheless, a differential distribution of species belonging to the same genus is likely to occur [Hutchinson, 1978].

The physical and chemical parameters of wetlands in coastal Mediterranean Spain (CMS) have been described by López [1983]. Such abiotic information could prove useful in separating closely al-

identify the more important ecological factors that affect species distribution.

The study area

The study area was a narrow band of brackish wetlands along the Mediterranean Spanish coast consisting of coast marshes, lagoons, springs and salt fields (Fig. 1). The wetlands were categorized into seven distinct groups (wetland types I to VII) by Lopez [1983], using physical and chemical parameters. These wetland types could be recognised on the basis of mineralization (freshwater inflow, marine influence, evaporation) and eutrophication (Table 1).

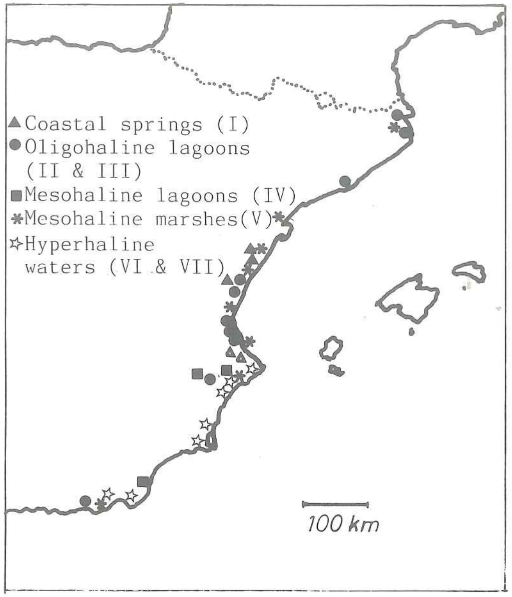


Fig. 1. Outline of the Spanish Mediterranean coast indicating the main sampling stations and their wetland type (I–VII). Only one sampling station of each type is indicated when they lie close together.

(50 μm mesh net) were collected from 57 different locations in CMS. Samples for the determination of 17 physical and chemical parameters were taken at the same time [López, 1983]. Zooplankton samples were counted with an inverted microscope and relative frequency was determined for each species.

Three multidiscriminant analyses [Cooley & Lohnes, 1971; Green, 1971] were performed with six groups of samples. These groups consisted of those samples containing each of six *Brachionus* species that occurred in $>5\%$ of cases. The samples were defined by the logarithmic transforms of 16 physical and chemical parameters and pH, which was not transformed (Table 3). The first analysis (no. 1) was made with groups consistingin all samples in which the *Brachionus* species defining the group was present. The second analysis (no. 2) was similar to the first, except that a few samples were excluded from the three groups defined by the more common species, *B. angularis, B. plicatilis* and *B. quadridentatus.* Samples were excluded when the species which defined the group was rare in that sample (i.e. $<2\%$), and other *Brachionus* species were dominant. The third analysis (no. 3) was like the second, except that the six major chemical parameters and total Fe and Mn were replaced by five ratios derived from the original data (Table 4).

Results and discussion

General distribution

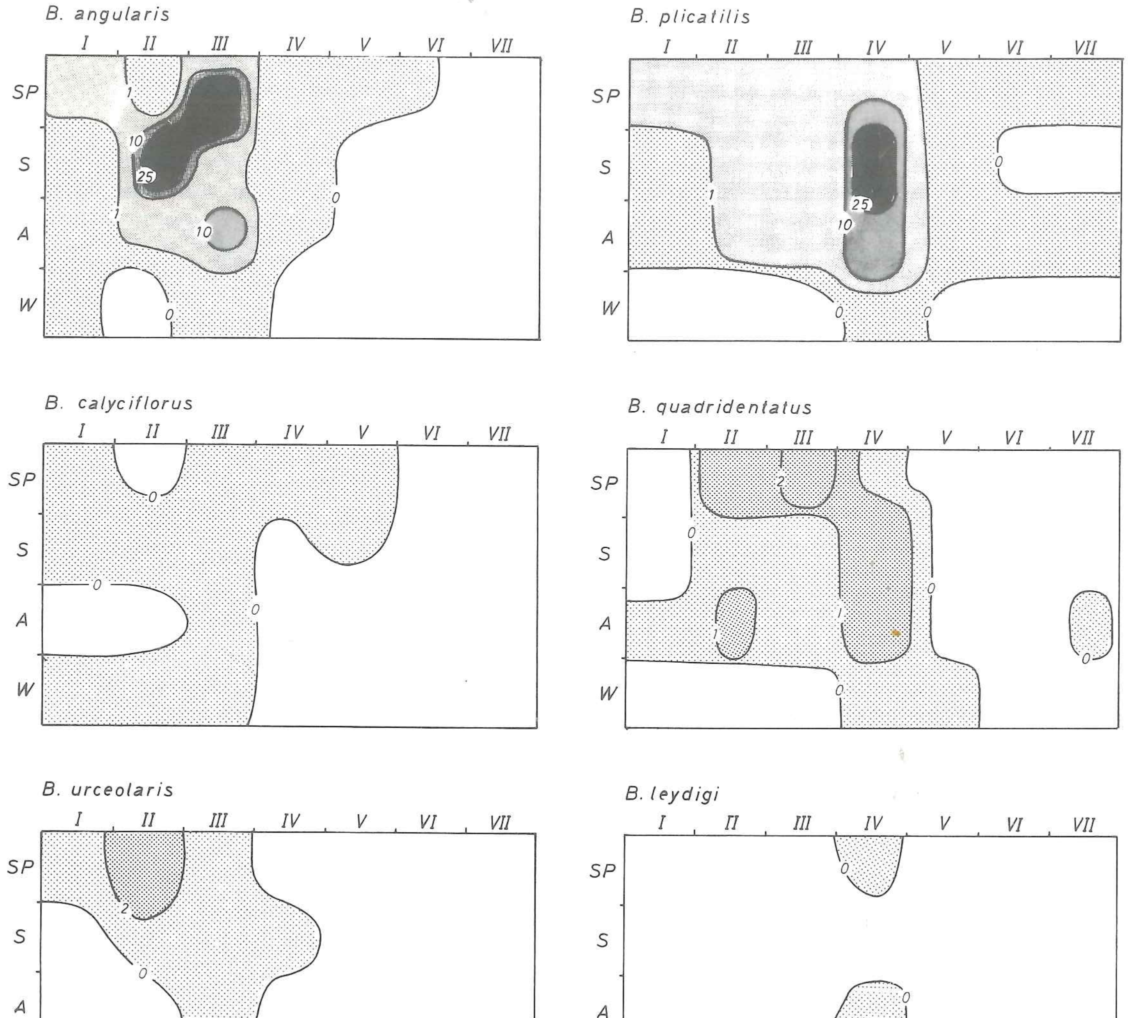
Ten species of *Brachionus* were found in CMS wet-

Table 1. Occurrence and frequency of *Brachionus* species as a function of total zooplankton in CMS wetlands characterised by their mineralization parameters and trophic state (i.e. reactive + acid labile phosphorus). Wetland types (I – VII) are arranged along a gradient of increasing influence of marine waters as follows: I- Subterranean freshwater springs near the coast, with high relative concentrations of Ca^{2+}; II- Hypereutrophic freshwater coastal lagoons, with an important sewage inflow; III- Eutrophic freshwater coastal lagoons; IV- Sulphated coastal lagoons of intermediate salinity, with significant evaporation rates; V- Brackish water marshes; VI- Hyperhaline salt marshes and abondoned salt fields; VII- Artificially regulated hyperhaline salt fields.

Wetland type	Occurrence (percent)	Mean frequency (percent)	Conductivity (μS cm^{-1})	Alkalinity (meq l^{-1})	Ca^{2+} (meq l^{-1})	$Cl^-:SO_4^=:Al$	$Na^+:Mg^{2+}:Ca^{2+}$	PO_4^{3-} (μmol l^{-1})
I	47.60	4.17	3372	4.1	10.7	8: 2:1	2:0.6:1	0.17
II	73.68	21.96	2820	2.7	4.4	7: 4:1	4:2.0:1	2.06

lands. They are, in order of importance, *B. plicatilis, B. angularis, B. quadridentatus* (mainly *brevispinus* and *cluniorbicularis* forms, but also *quadridentatus, rhenanus* and *fulleborni*), *Brachionus calyciflorus* (mainly *anuraeiformis* and *pala* forms, but also *dorcas* and *amphiceros*), *Brachionus urceolaris, Brachionus leydigi* (forms *leydigi* and *tridentatus*), *Brachionus bidentatus, Brachionus rubens, Brachionus bennini* and *Brachionus variabilis.*

Percentage occurrence of the genus *Brachionus* in wetlands I to VII are shown in Table 1. In general, the genus showed clear preference for coastal lagoons (wetland types II, III and IV). They occurred in springs and marshes (I, V), but tended to avoid hyperhaline systems (VI, VII).



As a group, the ten *Brachionus* species showed a slight preference for spring and avoided winter. *Brachionus* were found in 47% of spring samples, 42% of summer samples, 43% of autumn samples and 32% of winter samples. However, percent occurrence in summer samples may have been overestimated because some water bodies had dried up and the total number of samples was smaller than in other seasons. The six main species showed rather different distributions in relation to wetland type and season (Fig. 2). *Brachionus angularis*, for example, occurred most often in oligohaline coastal lagoons where freshwater inflow was important (II, III), although it tolerated a wide range of salinities (0.5 to 24‰). On the other hand, *B. plicatilis* occurred most often in waters of intermediate salinity and showed a clear preference for sulphated coastal lagoons (IV) whose ionic ratios were more similar to those of inland endoreic lagoons than brackish waters. However, *B. plicatilis* is the most widespread of these species, having been found in both oligo- and hyperhaline waters ranging from 0.5 to 88.6‰ salinity. Two species, *B. calyciflorus* and *B. urceolaris*, occurred mainly in oligohaline coastal waters (I, II & III), but in relatively low numbers. *B. urceolaris* showed the most well defined salinity limits, from 0.5 to 8.6‰. *Brachionus quadridentatus* had a similar distribution to that of *B. plicatilis*, except that it was much more restricted to lagoons (II, III and IV). *Brachionus leydigi* resembled *B. quadridentatus* in its distribution, but it was almost exclusively a winter resident, except among lagoons of group IV where it was more persistent.

Discriminant analysis

Analyses one and two

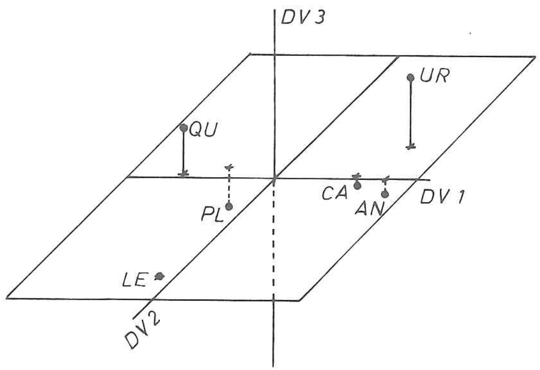
Only six species (Table 2) occurred frequently enough (5% of samples) to be used in the discriminant analysis. Results from the first two discriminant analyses (Nos. 1 and 2) using the 17 environmental parameters (Table 3) were very similar. Analysis No. 2, in which a few samples were eliminated from consideration (see Material and methods), had slightly more conclusive results, and these are reported here (Table 3, Fig. 3). The first three discriminant functions accounted for slightly more than 80% of the among-species variance. Discriminant function I accounted for 34.3% of the among-species variance and was largely a function of SO_4^{2-} concentration. Discriminant function I was well correlated with all the major constituents of water salinity and separated the three oligohaline species (*B. angularis, B. urceolaris. B. calyciflorus*) from the other three species (*B. quadridentatus, B. plicatilis* and *B. leydigi*). The latter three species appear to prefer those lagoons of group IV where

Table 2. Mean values of several physical and chemical parameters at which six species of *Brachionus* occurred in CMS wetlands.

Parameters	*Brachionus* species					
	angularis	*plicatilis*	*calyciflorus*	*urceolaris*	*leydigi*	*quadridentatus*
Conductivity (mS cm^{-1})	4.76	15.81	8.31	3.92	9.63	10.10
Temperature (°C)	20.83	20.46	21.12	23.87	15.32	20.15
Alkalinity (meq l^{-1})	3.95	4.40	3.72	3.59	4.08	4.71
Cl^- (meq l^{-1})	36.99	221.96	77.61	18.58	168.35	81.77
SO_4^{2-} (meq l^{-1})	15.47	46.20	20.29	14.20	36.23	36.69
Ca^{2+} (meq l^{-1})	9.33	26.23	10.16	6.93	18.66	15.75
Mg^{2+} (meq l^{-1})	12.02	48.39	15.98	7.29	40.33	22.63

Table 3. The first three discriminant function coefficients from analysis No. 2, showing the relative contribution of 17 physical and chemical parameters to the separation of *Brachionus* species in CMS wetlands. The structure coefficients, or correlations between the discriminant functions and these physical and chemical parameters, are indicated in parentheses. Coefficients over ±0.3 and ±0.5, respectively, have been underlined.

	Discriminant functions					
	I		II		III	
Percentage of variance	34.3		26.5		19.5	
Parameters:						
Conductivity	0.304	(−0.69)	−0.271	(−0.22)	0.172	(0.13)
Temperature	−0.039	(0.23)	−0.729	(−0.92)	0.344	(0.65)
pH	0.162	(0.21)	0.107	(−0.28)	−0.098	(0.43)
Alkalinity	−0.064	(−0.43)	0.031	(0.20)	0.034	(−0.25)
Cl^-	−0.293	(−0.73)	0.407	(−0.03)	−0.605	(−0.04)
SO_4^{2-}	−0.800	(−0.79)	−0.040	(−0.09)	0.482	(0.18)
Ca^{2+}	−0.073	(−0.71)	−0.115	(0.14)	−0.040	(−0.19)
Mg^{2+}	−0.013	(−0.71)	0.248	(−0.04)	−0.056	(−0.02)
Na^+	0.203	(−0.69)	−0.177	(−0.02)	0.278	(0.00)
K^+	0.114	(−0.55)	−0.198	(−0.09)	−0.068	(−0.09)
O_2	0.062	(0.43)	−0.068	(−0.05)	0.309	(0.52)
NO_2^-	−0.009	(−0.06)	0.058	(0.32)	−0.020	(−0.12)
NO_3^-	−0.005	(−0.04)	−0.002	(0.43)	0.098	(−0.31)
Si	−0.072	(−0.34)	−0.148	(−0.40)	0.005	(0.43)
PO_4^{3-}	−0.069	(0.07)	0.172	(−0.14)	0.065	(0.46)
Total Fe	0.186	(−0.14)	0.019	(0.14)	−0.114	(−0.25)
Total Mn	−0.206	(−0.55)	−0.100	(0.19)	0.185	(−0.14)



evaporation rate and continental influence is high. The continental influence on CMS wetlands means that bicarbonate, calcium and sulphate levels are high, especially in the southern part. So, when evaporation rates are high, calcite and gypsum are precipitated; conductivity increases, but the relative proportion of sulphates and carbonates decreases. This phenomenon differentiates the lagoons of group IV from those of groups II and III, which have smaller Cl^-/SO_4^{2-} and Cl^-/alkalinity ratios (Table 1).

Discriminant function II (26.5% of the variance), which separates *B. leydigi* from the other species (Fig. 3), is largely a function of temperature and is also correlated with NO_3^- (Table 3). Dis-

19.5% of the variance, is more difficult to interpret. It is related to an inverse relationship between Cl^- and SO_4^{2-}, but temperature and surface oxygen are also involved (Table 3). It is also positively correlated with phosphate (reactive plus acid labile phosphorus). The most eutrophic lagoons (group II) showed the smaller Cl^-/SO_4^{2-} ratios are the higher surface oxygen and phosporus concentrations (Table 1). Oligohaline waters in CMS wetlands, with a higher rate of inflow than evaporation, have small Cl^-/SO_4^{2-} ratios. This ratio becomes higher as evaporation rates increase. The Cl^- and SO_4^{2-} relationship may separate *B. urceolaris* from other species, especially from *B. plicatilis* (Fig. 3). Moreover, *B. urceolaris* was the species which showed the greatest preference for less mineralized and more eutrophic waters.

Analysis three

The first three functions of the third discriminant analysis (No. 3) accounted for 86% of the among-species variance (Table 4). The results of this analysis were similar to that of the second. Discriminant function I (40.85% of variance) is largely a function of the Cl^-/SO_4^{2-} ratio, but temperature was also important.

This is to be expected from the evaporation and precipitation phenomena described above for sulphate rich waters. This function accounts for separation of the same three species (i.e., *B. angularis, B. urceolaris* and *B. calyciflorus*) from the other three, as the first discriminant function of analysis 2.

The second discriminant function (II), accounted for 26.70% of the variance and separated *B. leydigi* from the other species, as in analysis No. 2. Once again temperature was important, but the ratio of alkalinity to $Ca^{2+} + Mg^{2+}$, which related to calcite precipitation, also had a strong influence. Throughout its winter occurrence, *B. leydigi* preferred those oligo-mesohaline lagoons with low alkalinity/$Ca^{2+} + Mg^{2+}$ ratios.

As in analysis No. 2, discriminant function III (18.45% of variance) also separated *B. urceolaris* from the other species. Both Cl^- and SO_4^{2-} were involved again, but as the ratio Cl^-/SO_4^{2-}. Temperature, oxygen and phosphate also showed rather high positive correlations.

Table 4. The first three discriminant function coefficients from analysis No. 3, showing the relative contribution of 13 physical and chemical parameters and ratios to the separation of *Brachionus* species in CMS wetlands. The structure coefficients, or correlations between the discriminant functions and these physical and chemical parameters, are indicated in parentheses. Coefficients over ±0.3 and ±0.5, respectively, have been underlined.

	Discriminant functions					
	I		II		III	
Percentage of variance	40.85		26.70		18.45	
Parameters:						
Conductivity	$\underline{-0.392}$	(−0.04)	−0.167	(0.36)	0.079	(−0.42)
Temperature	$\underline{0.482}$	$\underline{(\ 0.52)}$	$\underline{-0.508}$	$\underline{(-0.51)}$	$\underline{0.550}$	$\underline{(\ 0.64)}$
pH	0.100	(0.17)	0.038	(0.23)	−0.063	(0.29)
O_2	0.060	(0.10)	0.022	(0.11)	0.275	(0.43)
NO_2^-	0.015	(−0.18)	0.104	(−0.18)	−0.038	(−0.06)
NO_3^-	−0.050	(−0.13)	0.019	(−0.05)	0.090	(−0.24)
Si	−0.089	(−0.19)	−0.170	(−0.25)	0.113	(0.35)

Discussion

On the basis of the results described above, there appears to be a real separation among the six *Brachionus* species studied, and a relatively small number of ecological factors are sufficient to account for their differential distribution. These are, in order of importance, sulphate, temperature, chloride, alkalinity relative to total alkaline earths, conductivity and O_2.

The CMS wetlands studied represent only a fraction of the geographical range of the genus *Brachionus* and the physical and chemical factors examined in this study are not exhaustive. Biotic factors such as trophic relationships, competition and predation were not considered. However, the genus seems to have evolved to match the abiotic environmental heterogeneity and a preference for specific conditions is evident. *B. plicatilis* is known to attain peak densities in waters of high alkalinity [Walker, 1981]. The alkalinities of waters in the present study are far less than those considered high by Walker [1981], but we have recorded a tendency for *B. plicatilis* to inhabit lagoons of group IV, which have relatively higher alkalinities than the other waterbodies studied (Table 1).

When other geographical areas are considered, similar distributions are seen. For example, on the Iberian peninsula as a whole *Brachionus* species appear to be important only in steppe lagoons or shallow highly mineralized endoreic waters. In such habitats the main species are *B. plicatilis* and *B. quadridentatus*, the former being much more frequent than the latter [Miracle, 1982]. In the present study, these two species were the most closely related species, showing a clear preference for lagoons of group IV, i.e., those most closely related to inland endoreic waters. In other environments (e.g., Karst and alpine lakes and reservoirs) *Brachionus* is only a minor component of the zooplankton community. Only *B. calyciflorus* and *B. urceolaris* are posed by Epp and Winston [1977]. Furthermore, the latitudinal distribution of the genus *Brachionus*, centred in the tropics [Green, 1972; Pejler, 1977], indicates their ancient origin. In a southern temperate region, such as the Iberian peninsula, the genus *Brachionus* is important in older environments such as coastal and steppe wetlands and it plays only a minor role in post-glacial or recent man-made aquatic systems.

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