With my best regards,

AGM

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Freshwater macroinvertebrate distribution in two basins with different salinity gradients (Guadalete and Guadaira river basins, south-western Spain)

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Abstract. This work reports the results of one year's sampling of aquatic macroinvertebrates in various streams with different salinity gradients. The study area was the headwaters of the rivers Guadaíra and Guadalete, located in the same geographical area in south-western Spain. The most interesting feature of the Guadaíra basin is the natural salinity of its waters due to the abundance of gypsum in its headwaters. Lithologically, the headwaters of the Guadalete basin flow over marls, clay, sandstone and limestone. Salinity values in most streams do not reach 1 mS cm^{-1}. At least at the levels of salinity found in the Guadaíra basin headwaters, the existence of a well-structured community of macroinvertebrates can be claimed. Of the groups studied, Diptera and Coleoptera showed the highest species richness, being distributed preferentially at the ends of the conductivity spectrum. Groups including taxa inhabiting waters of low salinty and taxa inhabiting waters with high salinity could be reliable indicators of salinity.

Introduction

Rivers with high levels of natural salinity are relatively frequent in the Mediterranean Basin. Consequently, we can expect to find both characteristic halophilic species (which can act as indicators of salinity), and the absence of others specifically adapted to water with little mineral content.

The study of saline basins enables evaluation of the impact of salinity on the fauna and provides knowledge of the natural communities of this type of system. Furthermore, it may allow the correct application to them of different water quality indices based on macroinvertebrate communities, since many species that act as indicators of pollution-free (especially organic-free) water may not be able to establish themselves in saline environments.

Hynes (1970) pointed out the value of comparative studies of rivers with normal salinity and naturally saline rivers of the same geographic area, so as to enable the characteristic features of saline stream communities to be determined. The present work reports the results of one year's sampling aquatic macroinvertebrates in various streams with different gradients of salinity of two basins in south-western Spain. The aims were as follows:

1. To show the preferences of macroinvertebrate taxa for different levels of salinity.
2. To characterize each group of streams (grouped according to their level of salinity) by their predominant taxa.
3. To attempt to elucidate whether the relationships between the streams grouped according to their varying levels of salinity were reflected by their macroinvertebrate communities.

Methods

The area chosen for the study was the headwaters of the rivers Guadaíra and Guadalete, located in the same geographical area in the south-western Spain (Fig. 1).

The most interesting feature of the Guadaíra basin is the natural salinity of its waters due to the abundance of gypsum in its headwaters; quarries near its source yield hydrated calcium sulphate ($CaSO_4 \cdot 2H_2O$) in excess of 80 per cent. Following a previous study (Gallardo and Toja, 1989) on the headwaters of this basin, seven stations were selected. Six of these were in the headwater zone of highest salinity, and the other (Alcaudete stream) where salinity values do not reach 1 mS cm^{-1}, due to a different geological nature (fine yellow sands).

Lithologically, the headwaters of the Guadalete basin flow over marls, clay, sandstone and limestone. Three stations were selected on these headwaters where salinity values do not reach 1 mS cm^{-1}, and another on the middle-high course of the main river (Algodonales) where there are natural saline springs that increase water salinity (Fig. 1).

All the stations sampled in both basins showed no notable levels of organic pollution.

Samples were taken between January 1988 and January 1989, twice-monthly at most of the stations, combining qualitative and quantitative methods (Gallardo, 1993). Each sample was measured for conductivity (in situ, with conductivity meter CRISON 522), chloride (volumetrically with silver nitrate and potassium chromate) and sulphate (colorimetrically with barium chromate and ammonium hydroxide), besides other physico-chemical parameters (Gallardo, 1991, 1993).

In an attempt to elucidate the salinity preference of the macroinvertebrate taxa, a matrix was constructed such that the conductivity variation range was divided into ten equal logarithmic classes. The number of specimens of each taxon obtained (by unit of effort) in the total sampling was assigned to each class. To allow for the different abundance of taxa (and because of the interest in the preference of each taxon for a determinate range of conductivity), the percentage of appearance of each taxon in each conductivity class was

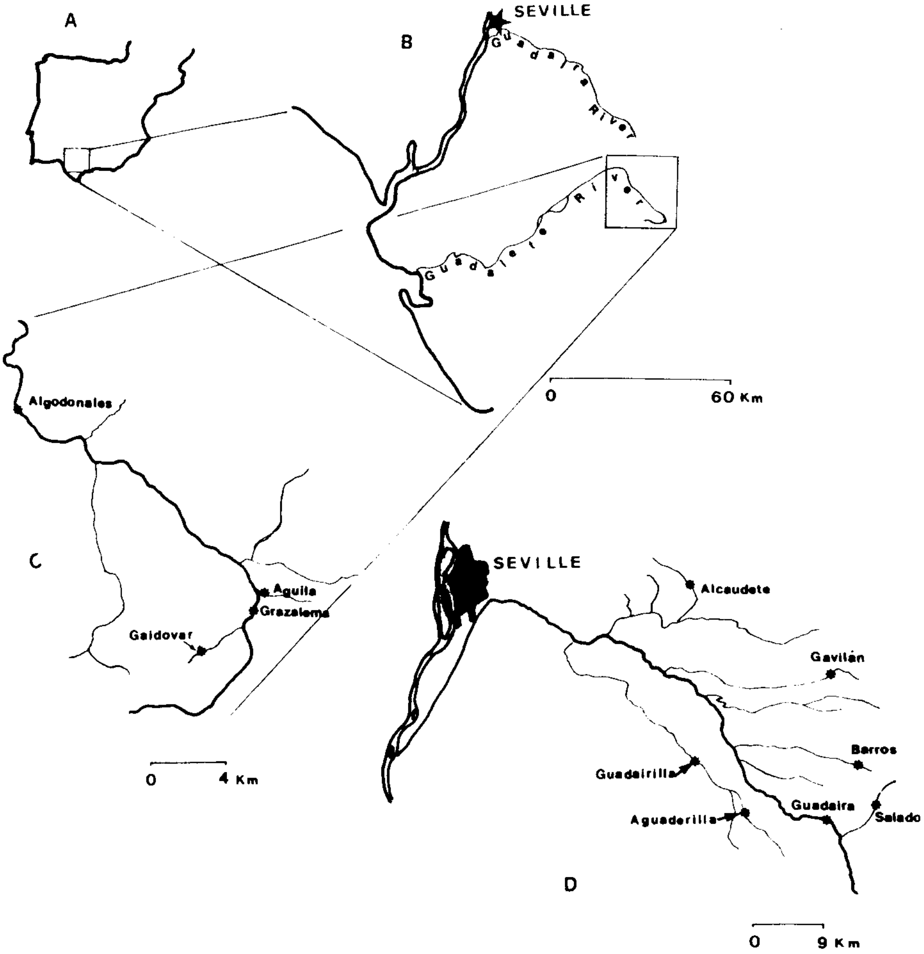

Fig. 1. (A) and (B): Location of the study area. (C) and (D): Situation of the sampling stations (*) in the Guadaíra and Guadalete basins, respectively. In (C), only the Guadalete basin headwater is drawn.

calculated (Guisande and Toja, 1987). Only those taxa appearing in at least three samples were considered in the construction of this matrix. For the remaining calculations, all taxa were considered.

To determine the relationships between the groups of stations according to their respective macroinvertebrate communities, Jaccard's coefficient of affinity (Margalef, 1977) was obtained.

Table 1. Chemical parameter values measured for one annual cycle (January 1988–January 1989) in the study area. Max: maximum value; min: minimum value; x: mean; SD: standard deviation; n: number of samples analysed; B/S: Barros and Salado streams; GRA: remaining saline streams of Guadaíra basin (Gavilán, Aguaderilla, and Guadairilla streams, and Guadaíra river); ALC: Alcaudete stream; ALG: Guadalete river in Algodonales; GTE: Guadalete basin headwaters (Aguila and Gaidovar streams, and Guadalete river in Grazalema).

		B/S	GRA	ALC	ALG	GTE
Conductivity (mS cm^{-1})	max =	14.6	6.2	0.8	1.3	0.9
	min =	3.6	1.0	0.2	0.8	0.2
	x =	8.5	3.0	0.4	1.1	0.5
	SD =	3.1	1.3	0.3	0.2	0.2
	n =	10	18	3	4	13
Chloride (mg L^{-1})	max =	7,277.5	1,295.7	149.1	280.4	74.5
	min =	1,260.2	202.3	28.4	134.9	21.3
	x =	4,082.5	656.7	71.0	181.0	35.5
	SD =	2,176.1	280.4	67.4	60.3	14.2
	n =	9	16	3	5	14
Sulphate (mg L^{-1})	max =	828.0	504.0	0	460.0	304.0
	min =	196.0	52.0	0	40.0	16.0
	x =	376.0	208.0	0	180.0	88.0
	SD =	224.0	124.0	0	168.0	92.0
	n =	10	18	3	5	14

Results

From the results of the chemical parameters measured, the six stations situated on the Guadaíra basin headwaters were separated into two groups. One comprised the Barros and Salado stream stations (where the highest conductivity, chloride and sulphate values were obtained), and the other, the four remaining stations. The latter had similar, high values of the three parameters, but lower values than those of the Barros and Salado streams (Table 1). The Alcaudete stream had conductivity values similar to those of the three stations of the Guadalete basin headwaters, with the total absence of sulphate. Algodonales had conductivity values between those of the Guadalete basin headwaters and the Alcaudete stream, and much higher chloride and sulphate values. The groups of stations can thus be ranked as follows (in decreasing order of salinity): (1) Barros and Salado streams; (2) the remaining four saline stations of the Guadaíra basin headwaters; (3) Algodonales; (4) Alcaudete stream; (5) the three stations of the Guadalete basin headwaters (Table 1).

Table 2 classifies the taxa found in the study area according to their distribution in the conductivity matrix.

In Barros stream, the station with highest salinity values (conductivity: 9.8–14.6 mS cm^{-1}, chloride: 4,863.5–7,277.5 mg L^{-1}, sulphate: 204–828 mg L^{-1}), no specimens of Ephemeroptera, Plecoptera and Trichoptera were collected. In Salado stream, the second most saline station, (conductivity: 3.6–8.6 mS cm^{-1}, chloride: 1,260.2–3,798.5 mg L^{-1}, sulphate: 196–728 mg L^{-1}) specimens of Ephemeroptera (*Baetis lutheri*, *Cloeon inscriptum*, *Cloeon simile*, *Caenis luctuosa*), Plecoptera (*Nemoura lacustris*, *Capnioneura mitis*, *Tyrrhenoleuctra minuta*) and Trichoptera (*Ithytrichia* sp., *Hydroptila* sp., *Hydropsyche exocellata*, *Hydropsyche pictetorum*, *Cheumatopsyche lepida*, *Mesophylax aspersus*) were collected.

Table 3 shows the number of taxa of each group present in each conductivity ranking according to the range including the value of this parameter measured when each taxon occurs in the maximum abundance. Table 4 shows the result (in percentages) of arranginging the rankings by groups into which the species had been classified ($\leq$ 1 mS cm^{-1} rankings 1 and 2; between 1.1 and 3.4 mS cm^{-1} rankings 3–5; $>$ 3.4 mS cm^{-1} rankings 6–10), and re-ordering the taxa of each group according to these three new rankings.

Figure 2 shows the relative abundance and the richness of each faunal group in each group of stations. Barros and Salado streams (B/S) presented a higher relative abundance of Diptera, Mollusca, Crustacea and Coleoptera. However, with regard to richness, Coleoptera, Diptera and Heteroptera were predominant. Mollusca presented a high value in relative abundance, while its species richness was very low. This was due to the contribution of *Mercuria confusa*, whose population in these two streams was 25.4 per cent of total macroinvertebrates. Similar results were obtained with Crustacea, where the populations of *Echinogammarus obtusidens* and *Atyaephyra desmarestii* reached 10.2 and 7.4 per cent of the total, respectively. With Coleoptera, species richness was much greater than abundance. In the remaining stations of the Guadaíra basin headwaters (GRA), there was a predominance of Diptera due to the size of the populations of *Simulium velutinum*, *Simulium pseudequinum* and *Simulium intermedium* (which between them totalled 51.4 per cent of total macroinvertebrates). The second most important group was Ephemeroptera due to the population of *Baetis lutheri* (comprising 21.3 per cent of total macroinvertebrates). Coleoptera and Diptera were the major groups in species richness.

The relative abundance of Diptera in Alcaudete stream (ALC) was outstanding, with a population of *Simulium velutinum* of 80.3 per cent. Diptera, Coleoptera and Ephemeroptera predominated in species richness. In Algodonales (ALG), Ephemeroptera was the most abundant group with *Baetis*

Table 2. Classification of the freshwater macroinvertebrates recorded in the study area according to their distribution in conductivity ranking.

HALOPHILIC (taxa distributed in conductivity values $\geq$ 3.4 mS cm^{-1}).
Crustacea: *Echinogammarus obtusidens*; Odonata: *Ischnura graellsi, Orthetrum nitidinerve*; Heteroptera: *Sigara selecta*; Coleoptera: *Hydroporus* sp., *Scarodytes halensis, Deronectes fairmairei, Potamonectes cerisyi, Berosus hispanicus*; Trichoptera: *Hydropsyche pictetorum*; Diptera: *Stratiomys* sp., *Nemotelus* sp., *Chrysops* sp.

EURYHALINE WITH HALOPHILIC TENDENCY (taxa distributed throughout conductivity ranking but with greater abundance at higher values).
Mollusca: *Mercuria confusa*; Crustacea: *Atyaephyra desmarestii*; Plecoptera: *Tyrrhenoleuctra minuta*; Heteroptera: *Sigara scripta*; Coleoptera: *Haliplus lineatocollis, Yola bicarinata, Laccophilus hyalinus*; Trichoptera: *Mesophylax aspersus*; Diptera: *Simulium pseudequinum, Bezzia* sp., *Stilobezzia* sp., *Oxycera* sp., *Chrysops caecutiens, Tabanus cordiger.*

EURYHALINE WITH HALOPHOBIC TENDENCY (taxa distributed throughout conductivity ranking but with greater abundance at lower values).
Ephemeroptera: *Baetis fuscatus, Baetis rhodani, Cloeon inscriptum, Cloeon simile*; Odonata: *Onychogomphus forcipatus*; Diptera: *Pericoma* sp.

HALOPHOBIC (taxa distributed in conductivity values $\leq$ 1 mS cm^{-1}).
Tricladida: *Dugesia (Dugesia)* sp.; Mollusca: *Lymnaea peregra, Pisidium* sp.; Crustacea: *Gammarus gauthieri*; Ephemeroptera: *Baetis alpinus, Baetis muticus, Baetis scambus, Centroptilum luteolum, Ecdyonurus aurantiacus, Ephemerella ignita, Paraleptophlebia submarginata, Habrophlebia lauta, Ephemera danica*; Plecoptera: *Isoperla bipartita, Perla marginata, Protonemura n.* sp., *Leuctra fusca, Leuctra geniculata, Leuctra maroccana*; Odonata: *Calopteryx* sp., *Onychogomphus uncatus, Cordulegaster boltoni*; Coleoptera: *Gyrinus dejeani, Orectochilus villosus, Elmis maugetii, Limnius* sp., *Riolus subviolaceus, Hydrocyphon* sp.; Megaloptera: *Sialis nigripes*; Trichoptera: *Hydropsyche infernalis, Hydropsyche instabilis, Hydropsyche punica, Polycentropus* sp., *Psychomyia pusilla, Sericostoma baeticum*; Diptera: *Dixa* sp., *Odontomyia* sp., *Atherix marginata, Atrichops crassipes.*

INDIFFERENT (taxa distributed throughout conductivity ranking without preference for any extreme values).
Mollusca: *Physella acuta, Lymnaea truncatula, Melanopsis dufouri*; Crustacea: *Procambarus clarkii*; Ephemeroptera: *Baetis lutheri, Caenis luctuosa*; Plecoptera: *Nemoura lacustris, Capnioneura mitis*; Heteroptera: *Sigara lateralis*; Coleoptera: *Hydraena subdepressa, Ochthebius dilatatus, Oulimnius rivularis*; Trichoptera: *Hydropsyche exocellata, Cheumatopsyche lepida*; Diptera: *Helius* sp., *Dicranota* sp., *Simulium velutinum, Simulium intermedium, Wiedemannia* sp., *Tabanus bromius.*

Table 3. Number of taxa of each group present in each conductivity ranking according to maximum abundance. 1 $\leq$ 0.6; 2 = 0.61–1.0; 3 = 1.1–1.6; 4 = 1.61–2.4; 5 = 2.41–3.4; 6 = 3.41–4.7; 7 = 4.71–6.4; 8 = 6.41–8.5; 9 = 8.51–11.4; 10 > 11.4 (values in mS cm^{-1}).

	1	2	3	4	5	6	7	8	9	10
Turbellaria	1	0	0	0	0	0	0	0	0	0
Mollusca	0	3	1	0	2	2	0	0	0	2
Crustacea	0	1	1	0	0	0	0	0	2	1
Ephemeroptera	0	10	5	0	1	0	2	2	2	0
Plecoptera	0	8	1	0	0	0	3	1	0	0
Odonata	2	4	2	0	0	0	0	0	4	0
Heteroptera	4	2	5	0	3	1	1	2	2	1
Coleoptera (larva)	3	9	2	0	1	1	0	2	1	5
Coleoptera (imago)	12	9	5	0	5	3	1	6	10	2
Megaloptera	0	1	0	0	0	0	0	0	0	0
Trichoptera	4	15	2	0	0	1	0	5	0	0
Diptera	3	8	3	0	1	1	4	4	2	10
Total	29	70	27	0	13	9	11	22	23	21

Table 4. Percentage of taxa of each group in the three conductivity rankings.

	$\leq$ 1mS cm^{-1}	1.1–3.4mS cm^{-1}	> 3.4mS cm^{-1}
Turbellaria	100	0	0
Mollusca	30	30	40
Crustacea	20	20	60
Ephemeroptera	45.4	27.3	27.3
Plecoptera	61.5	7.7	30.8
Odonata	50	16.7	33.3
Heteroptera	28.6	38.1	33.3
Coleoptera (larva)	50	12.5	37.5
Coleoptera (imago)	39.6	18.9	41.5
Trichoptera	70.4	7.4	22.2
Diptera	30.6	11.1	58.3

lutheri as the numerically best-represented species (with 30.4 per cent of total macroinvertebrates) and Diptera (*Simulium pseudequinum* was the most abundant species with 22.9 per cent of the total). Finally, in the streams of the Guadalete basin headwaters, Ephemeroptera predominated, with *Baetis*

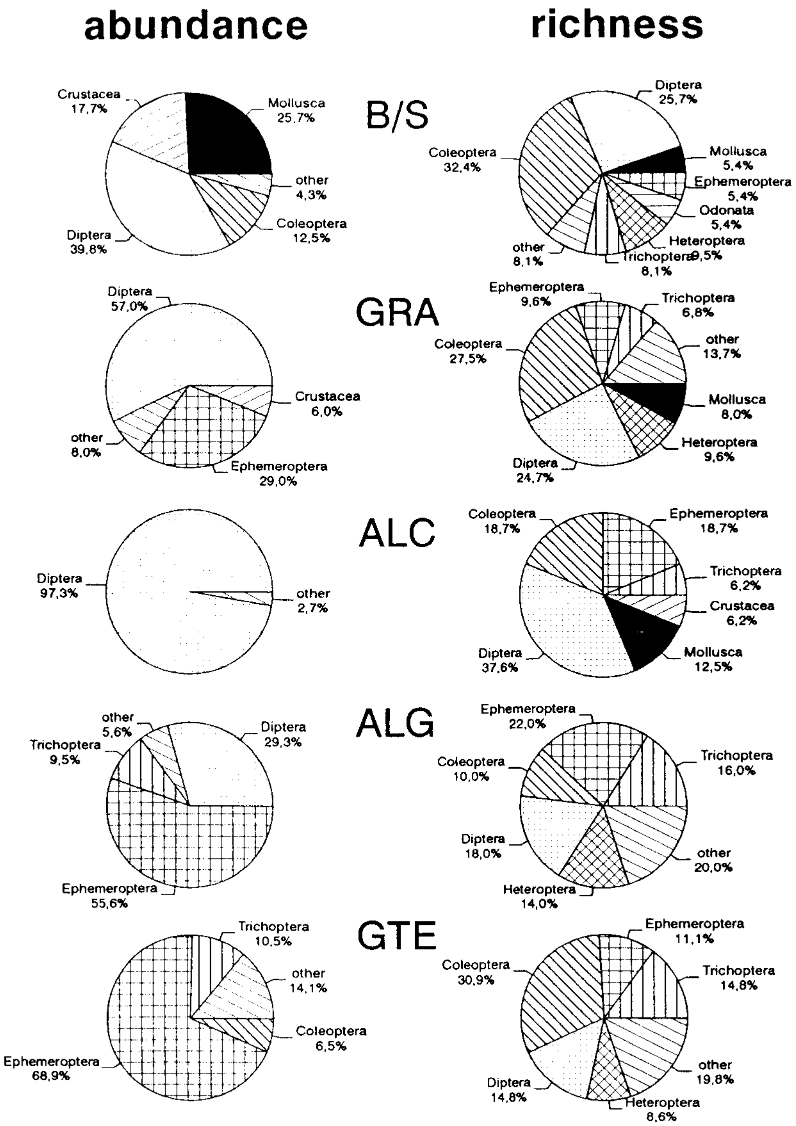

Fig. 2. Relative abundance (individuals per unit effort) and richness of macroinvertebrates found in each group of stations. B/S, GRA, ALC, ALG and GTE as in Table 1. Coleoptera include individuals collected in larval and imago stages.

rhodani the most abundant species (with 29.8 per cent of total macroinvertebrates), while Coleoptera predominated at higher taxonomic levels.

In summary, it can be seen that Diptera (mainly species of Simuliidae) are relatively more abundant at stations with a level of salinity from very

Table 5. Richness, relative abundance (individuals per unit effort) and diversity (H) for each group of stations. B/S, GRA, ALC, ALG and GTE as in Table 1.

	B/S	GRA	ALC	ALG	GTE
Richness	74	72	16	50	162
Relative abundance	432.4	161.2	263.5	105.4	489.6
Diversity	2.50	2.36	0.72	2.35	2.82

Table 6. Jaccard's coefficient of affinity (J) calculated for the groups of stations from their macroinvertebrate communities. B/S, GRA, ALC, ALG and GTE as in Table 1.

	B/S	GRA	ALC	ALG	GTE
B/S	*	0.44	0.15	0.23	0.22
GRA		*	0.19	0.26	0.21
ALC			*	0.20	0.05
ALG				*	0.17
GTE					*

high (B/S) to medium (ALG), or at stations such as Alcaudete stream that, although having normal salinity, suffer the stress of a high variability in discharge (temporality). With regard to richness, at all the stations, Diptera and Coleoptera were the best-represented groups, the latter generally with higher diversity.

Table 5 shows the richness, relative abundance and Shannon-Weaver diversity index (H) (Margalef, 1977) of the five groups of stations. Barros and Salado streams and the remaining stations of the Guadaíra headwaters had a very similar richness, although the relative abundance in the former group was greater. Alcaudete stream and Algodonales were the two groups with lowest richness, and the group of the Guadalete basin headwaters the highest. With regard to diversity, the values found were similar, except in Alcaudete stream.

Jaccard's coefficient of affinity (Table 6), calculated from the communities inhabiting the various groups of stations, demonstrates the similarity between the communities of Barros and Salado streams and those of the other stations of the Guadaíra basin headwaters (J = 0.44). Next come the values of comparison between the communities of these two groups of stations and Algodonales (J = 0.23 and 0.26, respectively). The values comparing the stations of the Guadalete basin headwaters with Barros and Salado streams (J = 0.22) and with stations of the Guadaíra basin headwaters (J = 0.21) are possibly due to the fact that the taxa are indifferent to salinity, and thus are found in streams at both ends of the conductivity range. Finally, very low values were found comparing Alcaudete stream with Barros and Salado streams (J = 0.15) and with the stations of the Guadaíra basin headwaters (J = 0.19), despite the fact that they all belonged to the same basin.

Discussion

Comparing these results with those obtained by other authors, it must be remembered that in different geographical areas the correlations between environmental variables and species may vary due to diverse interactions between the variables themselves (Cuppen, 1986). Such interactions can be seen in the two headwaters studied, even though very close together (Gallardo, 1993). Some of the data obtained coincide with those of other authors: species of the genus *Sigara* and larvae of *Haliplus* are characteristic of marsh environments of south-western Spain, where chloride concentrations of up to 26 g L^{-1} may be reached (Montes and Ramirez, 1981); *Mercuria confusa*, *Potamonectes cerisyi*, and *Berosus* sp. are predominant in a stream of south-eastern Spain having similar characteristics to those of the Guadaíra headwaters (conductivity 9.2–13.5 mS cm^{-1}) (Ortega *et al.*, 1991); *Baetis lutheri* is tolerant to the salinity in waters of north-eastern Spain (Puig, 1981); and *Hydropsyche exocellata* is an indicator of stream stretches degraded by the effect of salinity in basins close to those of this work (González del Tánago and Garcia de Jalón, 1987). Halophobic species such as *Ephemerella ignita* are affected negatively by the salinity in central European waters (Ortlepp *et al.*, 1991). However, Heuss (1966) found *Lymnaea peregra*, *Ephemera danica* and *Paraleptophlebia submarginata* in waters with salinity levels higher than those of the Guadaíra headwaters. The permanence of running water in the stream during the whole year perhaps could be a factor having a greater effect on the distribution of most of the taxa in the area studied, rather than the salinity. So, the latter species cited were collected only in streams with some flow even at low water. Barros and Salado, together with most of the streams of the Guadaíra basin, have no summer flow, and, in fact, the majority dry up during this period (Gallardo, 1993).

Heuss (1966) found six species of Plecoptera in a saline stream (conductivity 5.7–9.8 mS cm^{-1} and chloride 2,151–3,600 mg L^{-1}), two of which (*Nemoura erratica* and *Isoperla grammatica*) were able to complete their larval cycle. In Sicily, Ravizza and Gerecke (1991) found *Protonemura ruffoi* in waters with 7.5 mS cm^{-1} of conductivity, and young nymphs of *Leuctra* and *Nemoura* at 6.5 and 9 mS cm^{-1}, respectively. These latter authors stated that no species of Plecoptera is able to tolerate levels of conductivity higher than 10 mS cm^{-1}, which fully coincides with our results. Plecoptera were not collected in two saline rivers in Australia (Williams *et al.*, 1991). Moreover, according to these authors, plecopteran nymphs have never been found in any Australian saline lake (i.e. at a salinity > 3 g L^{-1}).

In the study area, an association made of *Mercuria confusa*, *Bezzia* sp., *Helius* sp., and *Echinogammarus obtusidens* was related with the most saline waters of the Guadaira basin (Gallardo, 1993). Williams *et al.* (1991) no found apparent relationship between salinity and community composition. On the contrary, the insect composition resembles that in other Australian rivers.

Short *et al.* (1991) found that species richness increases with decreasing environmental salinity. The present work shows (Table 5) that high levels of natural salinity do not hinder the development of well-structured communities of macroinvertebrates (as also shown by the diversity values).

The results obtained in the calculation of Jaccard's coefficient of affinity demonstrate the similarities between the different macroinvertebrate communities, depending on the different groups into which the stations are ranked according to their salinity levels. This shows such communities to be good indicators of these different salinity gradients.

Of all the macroinvertebrate groups collected during this work (except those Heteroptera and Coleoptera in an imago stage which could abandon the medium when the environmental conditions become adverse), Plecoptera, Coleoptera and Diptera were the best distributed through the conductivity spectrum (Table 4). Both halophilic and halophobic specimens were included, with a lower number of species having euryhaline or indifferent characteristics. However, as Plecoptera species are unable to develop above a particular salinity value (ranking 8), and because of the low number of species appearing compared with that of Coleoptera and Diptera, these latter two groups are those shown to be the best indicators of saline streams (Gallardo, 1991; Gallardo and Prenda, 1994.

The Appendix lists the taxa represented by at least three samples collected in the study area throughout the annual cycle. This work does not include either Chironomidae or Oligochaeta. With regard to Oligochaeta, Prenda and Gallardo (1992) found no trends among the species of the Guadaíra basin, all being indifferent to salinity.

Conclusions

In conclusion, it may be stated that in the study area there are many taxa that are halophilic or euryhaline which appear to prefer a high salinity (Table 2).

However, we cannot be sure that they are really halophilic rather than simply tolerant to salinity. The results seem to show that the presence or absence of flow throughout the year is the most important factor in permitting particular species to establish (or not) in the streams of the Guadaíra basin, favouring those that have less rigid requirements and a life-cycle short enough to be able to develop totally. Nevertheless, salinity must obviously have a very important role as a second factor determining the inhabitability of its waters.

At least at the levels of salinity found in the Guadaíra basin headwaters, the existence of a well-structured community of macroinvertebrates can be claimed. Of the groups studied, Diptera and Coleoptera (in larval stage) showed the highest species richness, being distributed preferentially at the ends of the conductivity spectrum. Groups including species inhabiting waters with low salinity and others inhabiting waters with high salinity could be good indicators of salinity.

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Appendix

Vmax: maximum value of each chemical parameter in which the taxa have been found; Mab: value of each parameter in which the taxa have been found in the highest abundance; x: mean value of each parameter, considering only those sampling and dates in which each taxon has been found; l: larva; i: imago; *: without data; **: there were several maximal abundance data.

	Conductivity (mS cm^{-1})			Chloride (mg L^{-1})			Sulphate (mg L^{-1})		
	Vmax	Mab	x	Vmax	Mab	x	Vmax	Mab	x
Platyhelmintes									
Turbellaria									
Tricladida									
Dugesiidae									
Dugesia (Dugesia) sp. Girard	0.8	0.5	0.5	74.5	24.8	31.9	304	16	108
Mollusca									
Gastropoda									
Hydrobiidae									
Mercuria confusa (Frauenfeld)	14.6	10.1	5.9	7277	4863	2577	828	248	280
Physidae									
Physella acuta (Draparnaud)	3.6	3.6	1.7	2556	2556	838	248	248	108
Lymnaeidae									
Lymnaea peregra (Müller)	0.9	0.7	0.7	42.6	24.8	28.4	88	88	80
Lymnaea truncatula (Müller)	3.6	3.6	0.9	2556	2556	504	264	248	104
Thiaridae									
Melanopsis dufouri Férussac	14.6	2.9	3.9	7277	731	1349	828	184	292
Planorbidae									
Planorbarius corneus (L.)	3.2	0.4	1.1	1296	42.6	497	176	36	80
Ancylidae									
Ancylus fluviatilis Müller	1.3	0.7	0.6	160	24.8	39	304	88	88
Lamellibranchiata									
Sphaeriidae									
Pisidium sp.	0.9	0.7	0.6	42.6	24.8	28	304	88	124
Arthropoda									
Crustacea									
Decapoda									
Atyidae									
Atyaephyra desmarestii (Millet)	8.6	8.4	2.8	3798	3447	660	728	264	192
Astacidae									
Procambarus clarkii (Girard)	8.6	1.6	2.6	3798	319	816	380	64	128
Amphipoda									
Gammaridae									
Echinogammarus obtusidens Pink. and St.	14.6	7.5	7.0	7277	*	3340	828	728	340
Gammarus gauthieri S. Karaman	0.9	0.7	0.7	31.9	24.8	24.8	264	88	144
Insecta									
Ephemeroptera									
Baetidae									
Baetis alpinus Pictet	0.7	0.2	0.4	31.9	24.8	28.4	88	16	48
Baetis fuscatus L.	6.2	1.1	2.6	784	181	362	504	64	200
Baetis lutheri Müller-Liebenau	8.4	3.0	2.7	2556	785	561	504	204	216
Baetis muticus L.	0.9	0.5	0.6	74.5	24.8	35.5	264	16	88
Baetis rhodani Pictet	6.2	0.6	1.0	785	31.9	110	504	264	132
Baetis scambus Eaton	0.9	0.2	0.6	42.6	42.6	31.9	304	32	104
Centroptilum luteolum (Müller)	0.8	0.5	0.6	74.5	24.8	42.6	80	48	48
Cloeon inscriptum Bengtsson	8.4	0.9	2.6	3447	21.3	955	264	67.4	132
Cloeon simile Eaton	8.6	0.9	5.0	3798	21.3	1910	728	76	348
Procloeon concinnum (Eaton)	1.3	0.9	0.9	280	21.3	106	304	76	140
Oligoneuriidae									
Oligoneuriopsis skhounate Dak. and Giud.	1.2	1.2	1.0	181	142	153	460	184	236
Heptageniidae									
Ecdyonurus aurantiacus Burmeister	0.9	0.7	0.8	31.9	24.8	24.8	304	88	156
Ecdyonurus gr *forcipula*	1.2	1.1	0.9	181	181	106	460	64	224

	Conductivity ($mS\ cm^{-1}$)			Chloride ($mg\ L^{-1}$)			Sulphate ($mg\ L^{-1}$)		
	Vmax	Mab	x	Vmax	Mab	x	Vmax	Mab	x
Ephemerellidae									
Ephemerella ignita (Poda)	0.8	0.8	0.5	42.6	35.5	31.9	264	148	88
Caenidae									
Caenis luctuosa (Burmeister)	8.6	0.4	2.3	3798	42.6	518	728	36	184
Leptophlebiidae									
Choroterpes picteti (Eaton)	3.3	0.6	1.6	792	31.9	334	264	264	160
Paraleptophlebia submarginata (Steph.)	0.8	0.8	0.5	74.5	74.5	35.5	148	80	64
Habrophlebia lauta Eaton	0.8	0.6	0.5	42.6	31.9	31.9	264	264	92
Ephemeridae									
Ephemera danica Müller	0.8	0.8	0.5	74.5	74.5	39	80	80	48
Plecoptera									
Perlodidae									
Isoperla bipartita Aubert	0.8	0.8	0.5	42.6	35.5	31.9	148	148	80
Perlidae									
Perla marginata (Panzer)	0.8	0.3	0.5	74.5	31.9	35.5	304	36	92
Nemouridae									
Protonemura n sp.	0.8	0.2	0.5	74.5	24.8	35.5	80	16	40
Nemoura lacustris Pictet	4.8	**	2.3	1374	**	543	504	**	228
Capniidae									
Capnioneura mitis Despax	4.8	4.1	2.7	1374	1374	568	504	196	288
Leuctridae									
Leuctra fusca (L.)	0.8	0.6	0.6	74.5	31.9	39	264	264	104
Leuctra geniculata Stephens	0.9	**	0.7	31.9	**	28.4	304	**	172
Leuctra maroccana Aubert	0.8	0.8	0.5	74.5	74.5	42.6	80	80	36
Tyrrhenoleuctra minuta (Klapalek)	8.4	8.4	4.4	2556	1260	1292	504	444	292
Odonata									
Calopterygidae									
Calopteryx sp.	0.8	**	0.7	74.5	**	42.6	88	**	60
Coenagrionidae									
Ischnura graellsi Rambur	8.6	8.4	6.9	3798	3447	2627	728	264	368
Gomphidae									
Gomphus pulchellus Selys	1.3	**	1.1	280	**	160	160	**	84
Onychogomphus forcipatus (L.)	8.6	**	2.4	3798	**	682	380	**	176
Onychogomphus uncatus (Charpentier)	0.8	**	0.6	74.5	**	35.5	264	**	88
Cordulegasteridae									
Cordulegaster boltoni Morton	0.8	**	0.5	74.5	**	35.5	80	**	40
Libellulidae									
Orthetrum nitidinerve (Selys)	8.6	8.4	8.2	3798	3447	3621	728	264	456
Heteroptera									
Hydrometridae									
Hydrometra stagnorum (L.)	1.3	0.4	0.8	160	42.6	78.1	264	36	112
Gerridae									
Gerris cinereus (Puton)	3.3	0.9	2.0	792	21.3	309	304	76	224
Gerris lacustris (L.)	1.3	0.4	0.6	160	42.6	81.6	40	36	36
Gerris najas (De Geer)	0.9	*	0.5	42.6	31.9	31.9	304	304	80
Gerris thoracicus Schummel	6.2	0.6	2.7	547	31.9	245	504	264	268
Corixidae									
Micronecta meridionalis (Costa)	3.2	0.9	1.3	671	21.3	185	256	76	100
Parasigara sp.	0.5	0.4	0.5	42.6	42.6	31.9	48	36	32
Sigara lateralis (Leach)	3.2	**	2.3	1090	**	554	264	**	212
Sigara scripta (Rambur)	10.1	3.2	6.0	6780	1090	3216	248	156	220
Sigara selecta (Fieber)	14.6	10.1	10.8	7277	4863	5591	828	248	400
Naucoridae									
Naucoris maculatus F.	0.9	0.6	0.6	42.6	31.9	31.9	264	264	124
Nepidae									
Nepa cinerea L.	8.6	**	3.4	3798	**	1310	380	**	156
Notonectidae									
Notonecta maculata F.	3.6	0.4	1.6	2556	42.6	873	248	36	120

	Conductivity (mS cm^{-1})			Chloride (mg L^{-1})			Sulphate (mg L^{-1})		
	Vmax	Mab	x	Vmax	Mab	x	Vmax	Mab	x
Coleoptera									
Haliplidae									
Haliplus lineatocollis l (Marsham)	14.6	*	5.5	7277	31.9	1864	828	304	380
Haliplus lineatocollis i (Marsham)	10.1	10.1	3.6	4863	4863	1502	248	248	136
Gyrinidae									
Gyrinus dejeani i Brullé	0.7	*	0.5	31.9	31.9	28.4	304	304	124
Orectochilus villosus l (Müller)	0.8	0.7	0.6	35.5	24.8	28.4	264	88	128
Dytiscidae									
Yola bicarinata l (Latreille)	14.6	9.8	4.3	7277	5396	1850	828	204	220
Hydroporus basinotatus i Reiche	1.1	0.3	0.5	1296	31.9	209	176	36	56
Hydroporus lucasi i Reiche	1.6	1.1	0.7	1296	1296	288	176	176	60
Hydroporus sp. l	8.4	3.6	5.1	2556	2556	1537	444	248	304
Graptodytes varius i (Aubé)	8.6	0.5	3.2	3798	24.8	1282	380	48	148
Scarodytes halensis l (F.)	14.6	14.6	11.5	7277	7277	6486	828	828	424
Deronectes fairmairei l (Leprieur)	14.6	9.8	10.6	7277	5396	5559	828	204	356
Deronectes fairmairei i (Leprieur)	9.8	3.6	3.4	5396	2556	1321	304	248	188
Potamonectes cerisyi i (Aubé)	14.6	10.1	9.4	7277	4863	5052	828	248	340
Potamonectes clarki i (Wollaston)	3.1	**	1.4	635	**	185	304	**	132
Laccophilus hyalinus l (De Geer)	8.4	8.4	3.7	3447	3447	1150	444	264	232
Hydraenidae									
Hydraena andalusa i Lagar and Fresneda	0.8	0.3	0.5	74.5	31.9	42.6	80	36	56
Hydraena capta i Orchymont	0.9	0.3	0.5	42.6	31.9	28.4	76	36	44
Hydraena cordata cordata i Schaufuss	0.8	0.4	0.5	74.5	42.6	42.6	80	36	48
Hydraena subdepressa i Rey	4.1	4.1	2.3	2556	1374	994	248	196	140
Hydraena gaditana i Lagar and Fresneda	0.8	0.3	0.5	74.5	31.9	35.5	80	36	40
Ochthebiidae									
Ochthebius dilatatus i Stephens	14.6	14.6	7.0	7277	7277	3607	828	828	328
Helophoridae									
Helophorus sp. i	3.2	3.2	1.3	1090	1090	380	156	156	56
Berosidae									
Berosus hispanicus l Küster	14.6	10.1	9.1	7277	6780	4874	828	240	392
Berosus hispanicus i Küster	10.1	8.4	8.0	6780	3447	4100	728	264	304
Hydrobiidae									
Anacaena sp. i	8.4	0.6	3.4	3447	31.9	887	728	264	264
Laccobius atratus i Rottenberg	10.1	8.4	6.2	4863	3447	2783	264	264	180
Laccobius atrocephalus i Reitter	8.4	8.4	3.6	3447	3447	887	728	264	228
Limnebiidae									
Limnebius sp.i	3.6	3.2	2.2	2556	1090	909	248	156	144
Elmidae									
Elmis maugetii l Latreille	0.9	0.2	0.6	74.5	24.8	31.9	304	16	92
Elmis maugetii i Latreille	0.8	0.3	0.5	74.5	31.9	35.5	80	36	40
Esolus sp. l	1.2	1.2	0.9	181	142	99.4	184	184	116
Limnius sp. l	0.9	*	0.6	35.5	31.9	28.4	304	304	92
Limnius sp. i	0.9	0.3	0.7	35.5	31.9	28.4	148	36	88
Oulimnius rivularis l (Rosenhauer)	3.6	3.6	1.1	2556	2556	305	304	248	116
Oulimnius rivularis i (Rosenhauer)	4.1	**	1.2	1374	**	302	196	**	76
Riolus subviolaceus l (Müller)	0.8	0.2	0.5	74.5	24.8	39	148	16	64
Riolus subviolaceus i (Müller)	0.8	0.3	0.5	74.5	31.9	35.5	88	36	48
Helodidae									
Hydrocyphon sp. l	0.8	0.2	0.4	74.5	24.8	42.6	80	16	44
Megaloptera									
Sialidae									
Sialis nigripes Pictet	0.8	0.5	0.6	74.5	24.8	42.6	264	48	108
Trichoptera									
Rhyacophilidae									
Rhyacophila munda McLachlan	1.2	0.2	0.6	142	24.8	46.1	264	16	104

	Conductivity (mS cm^{-1})			Chloride (mg L^{-1})			Sulphate (mg L^{-1})		
	Vmax	Mab	x	Vmax	Mab	x	Vmax	Mab	x
Hydroptilidae									
Ithytrichia sp.	7.5	0.2	1.9	74.5	24.8	39	728	16	180
Hydroptila sp.	8.4	0.2	1.7	3447	24.8	380	304	16	132
Hydropsychidae									
Hydropsyche exocellata Dufour	8.4	3.2	3.1	3447	671	1132	460	256	244
Hydropsyche infernalis Schmid	0.8	0.8	0.4	74.5	74.5	39	80	80	36
Hydropsyche instabilis (Curtis)	0.8	0.8	0.5	74.5	74.5	35.5	80	80	40
Hydropsyche pictetorum Bots.and Schmid	3.6	**	3.2	2556	**	1164	256	**	208
Hydropsyche punica Malicky	0.9	0.9	0.6	74.5	95.8	35.5	304	76	100
Cheumatopsyche lepida (Pictet)	8.4	3.2	3.8	3447	671	1225	264	256	204
Polycentropidae									
Polycentropus sp.	0.9	0.5	0.5	280	25	53.2	264	48	72
Psychomyidae									
Psychomyia pusilla (F.)	0.9	0.9	0.7	42.6	21.3	31.9	264	76	128
Limnephilidae									
Mesophylax aspersus (Rambur)	8.4	7.5	3.8	1374	*	802	728	728	292
Allogamus sp.	0.8	**	0.4	35.5	**	31.9	148	**	68
Sericostomatidae									
Sericostoma baeticum Pictet	0.8	0.5	0.5	74.5	24.8	31.5	80	16	40
Diptera									
Tipulidae									
Tipula sp.	6.2	0.4	1.8	2556	42.6	376	504	36	152
Limoniidae									
Helius sp.	14.6	9.8	4.7	7277	5396	2119	828	204	224
Dicranota sp.	8.4	0.4	2.4	2556	42.6	579	504	36	180
Psychodidae									
Pericoma sp.	9.8	0.2	1.6	5396	24.8	712	264	16	92
Dixidae									
Dixa sp.	0.8	0.2	0.4	74.5	42.6	49.7	80	32	48
Culicidae									
Culex sp.	1.1	0.4	0.8	1296	42.6	454	176	36	96
Simuliidae									
Simulium (E.) velutinum (S.Abreu)	14.6	3.2	3.5	7277	1090	1186	828	156	220
Simulium (W.) pseudequinum Séguy	8.4	4.8	3.4	1260	611	564	504	504	252
Simulium (W.) sergenti sergenti Edw.	3.3	0.8	2.1	792	135	461	460	460	268
Simulium (S.) intermedium Roubaud	8.4	4.8	2.4	2556	611	511	504	504	212
Ceratopogonidae									
Bezzia sp.	14.6	10.1	3.5	7277	6780	1282	828	240	212
Stilobezzia sp.	14.6	10.1	4.9	7277	6780	2822	828	240	224
Stratiomyidae									
Stratiomys sp.	14.6	9.8	8.6	7277	5396	3216	828	204	408
Odontomyia sp.	0.9	0.2	0.5	74.5	24.8	35.5	304	16	88
Nemotelus sp.	14.6	9.8	9.5	7277	5396	4682	828	204	408
Oxycera sp.	14.6	10.1	6.7	7277	6780	3493	828	240	244
Empididae									
Hemerodromia sp.	1.2	0.2	0.7	142	42.6	71	184	32	76
Wiedemannia sp.	4.8	0.2	1.9	2556	42.6	593	504	32	188
Tabanidae									
Chrysops caecutiens (L.)	8.6	8.4	5.2	3798	3447	1825	728	264	320
Chrysops sp.	14.6	14.6	11.0	7277	7277	5836	828	828	444
Tabanus bromius (L.)	14.6	10.1	5.2	7277	6780	2591	828	240	300
Tabanus cordiger (Meigen)	14.6	8.6	5.9	7277	3798	2009	828	380	348
Athericidae									
Atherix marginata (F.)	0.9	0.2	0.6	74.5	24.8	31.9	304	16	88
Atrichops crassipes Meigen	0.9	*	0.7	74.5	31.9	35.5	304	304	112
Muscidae									
Limnophora sp.	6.2	0.6	1.9	547	31.9	160	504	264	212

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