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ORIGINAL ARTICLE

Assemblages of peracarid crustaceans in subtidal sediments from the Ría de Aldán (Galicia, NW Spain)

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Abstract Peracarid crustaceans inhabit many marine benthic habitats and are good indicators of environmental conditions. There is, however, a lack of information about diversity and distribution of peracarid crustaceans on the shallow subtidal sediments of the Galician rias. In the summer of 1997, 27 subtidal stations were sampled in the Ría de Aldán, a ria on the southern margin of the mouth of the Ría de Pontevedra (Galicia, NW Spain). A total of 16,191 peracarid individuals were collected, comprising 125 species belonging to five orders. Amphipods were dominant in number of species and individuals, followed by isopods and cumaceans. Multivariate analyses of these data indicated that depth and sediment granulometry were major determinants of distribution and composition of peracarid assemblages in the ria.

Keywords Peracarida · Soft-bottoms · Assemblages · Atlantic Ocean · Ría de Aldán

Introduction

Peracarid crustaceans are among the most diverse and numerically dominant organisms of soft-bottom benthic faunas (Fincham 1974; Dauvin et al. 1994; Prato and Biandiolino 2005). Peracarids also play an important role in structuring of benthic assemblages (Duffy and Hay 2000) and are important source of food for other benthic animals and fishes of commercial importance (McDermott 1987; Dauvin 1988a; Beare and Moore 1996). Distribution and abundance of peracarids inhabiting marine sediments are influenced by a number of abiotic factors, such as sediment composition (Parker 1984; De Grave 1999) and organic content (Robertson et al. 1989). Many peracarid species are also sensitive to hydrocarbon pollution and other perturbations and, therefore, their abundance and species diversity may serve as indicators of environmental conditions (e.g., Marques and Bellan-Santini 1990; Corbera and Cardell 1995; Gómez-Gesteira and Dauvin 2000; Guerra-García and García-Gómez 2004).

The Galician rias (NW Spain) are a special and complex kind of estuarine system and have a great economic and social importance due to the presence of fisheries, bivalve culture and shellfish resources (Nombela et al. 1995; Figueiras et al. 2002). The rias also have a large diversity of sedimentary habitats inhabited by a particularly rich benthic fauna (Cadée 1968; López-Jamar and Mejuto 1985). Peracarid fauna of the Galician rias, however, are little known and few studies have been devoted to describe diversity, distribution and composition of peracarid assemblages on their soft-bottoms (Anadón 1975; Sánchez-Mata et al. 1993).

Composition and distribution of soft-bottom benthos are well-known in many areas of the Galician coast (Viéitez and Baz 1988; Junoy and Viéitez 1989; Mazé et al. 1990; Palacio et al. 1991; Currás and Mora 1991). There is, however, a lack of studies in some small rias such as the Ría de Aldán. This ría is located on the mouth of the Ría de Pontevedra and shows a variety of subtidal sediments, ranging

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from gravel to mud, at depths of between 3 and 45 m. Thus, the main objectives of this paper were to characterize the composition and distribution of the peracarid fauna on the subtidal soft-bottoms of the Ría de Aldán as well as studying the influence of several environmental variables on the distribution patterns of peracarids. This will also provide baseline data for further comparative analyses.

Material and methods

Study area

The Ría de Aldán is situated on the southern margin of the mouth of Ría de Pontevedra, between 42°16′40′′–42°20′50′′N and 8°49′–8°52′W. This ria has 7 km length, 3.5 km width and has a maximum depth of 45 m; its mouth is oriented northwards. Mean salinity values are around 36 ‰ in outer areas of the ria and there is gradual increase in salinity from the inner to the outer part of the ria (Parada 2004). The small Aldán River flows into the inner area. Both East and West margins are made up of rocky substratum which alternates with sandy beaches. The ria is greatly influenced by strong oceanic hydrodynamism which reaches the inner areas and reduces the effect of freshwater input from the Aldán River. The ria is influenced by the growing practice of bivalve culture on rafts, mostly in the inner areas of the ria; these practices are supposed to contribute to the increase of the content of silt/clay and organic matter in those areas, such as it occurs in other Galician rías.

Sample collection and processing

The sampling programme comprised 27 stations which covered the full extent of the ria in order to provide sufficient information on the distribution of peracarids (Fig. 1; Table 1). Quantitative sampling was done during July–August 1997 using a Van Veen grab with a sampling area of 0.056 m^2. Five replicates were taken at each station, which accounted for a total area of 0.28 m^2. Samples were sieved through a 0.5 mm mesh, and fixed in 10% buffered formaldehyde solution for later sorting and identification of the fauna. An additional sediment sample was taken at each station to analyse granulometric composition, carbonates and organic matter content. The following granulometric fractions were considered: gravel (GR >2 mm), very coarse sand (VCS 1–2 mm), coarse sand (CS 0.5–1 mm), medium sand (MS 0.25–0.5 mm), fine sand (FS 0.125–0.25 mm), very fine sand (VFS 0.063–0.125 mm), and silt/clay (<0.063 mm). Median grain size (Q_{50}) and sort coefficient (S_0) (Trask 1932) were also determined for each sample. Temperature was also measured in sediment, surface water and bottom water. Sediment types were characterized according to Junoy (1996). Calcium carbonate content (%) was estimated by the treatment of the sample with hydrochloric acid. The total organic matter content (TOM, %) was estimated from the weight loss after placing samples in a furnace for 4 h at 450°C.

Data analysis

Several univariate measures were calculated for each sampling station: total abundance (*N*), number of species (*S*), the Shannon–Wiener diversity index (H′, as $\log_2$), and Pielou’s evenness (J). For any given site, species with ≥4% of total abundance were considered as dominant (Field et al. 1982). Peracarid assemblages were determined through non-parametric multivariate techniques as described by Field et al. (1982) using the PRIMER v5.0 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke and Warwick 1994). A similarity matrix was constructed by means of the Bray–Curtis similarity coefficient by first applying fourth root transformation on species abundance to minimise the contribution of the most abundant species. Differences in faunistic composition between sampling stations were tested using the one-way ANOSIM test. From the similarity matrix, classification of stations was done by cluster analysis based on the group-average sorting algorithm and an ordination by means of non-metric multidimensional scaling (nMDS). The SIMPER program was next used to identify species that greatly contributed to the differentiation of station groups. The species present in each group of stations were further classified according to the constancy and fidelity indexes (Glémarec 1964; Cabioch 1968).

The BIO-ENV procedure (belonging to the PRIMER package), and the canonical correspondence analysis (CCA, using the CANOCO v4.02, Canonical Community Ordination package; Ter Braak 1988) were used to research the possible relationship between peracarid distribution in the ria, and the measured environmental variables. The forward selection was used in the latter to detect which variables explained the most variance in the species data. All variables expressed in percentages were previously transformed by log $(x + 1)$.

Results

Sediments

Sediments were mainly sandy in most of the ria (Fig. 1; Table 1). Coarser sandy granulometric fractions were more prevalent at the mouth of the ria, and muddy bottoms were restricted to inner and sheltered areas. There was a decrease

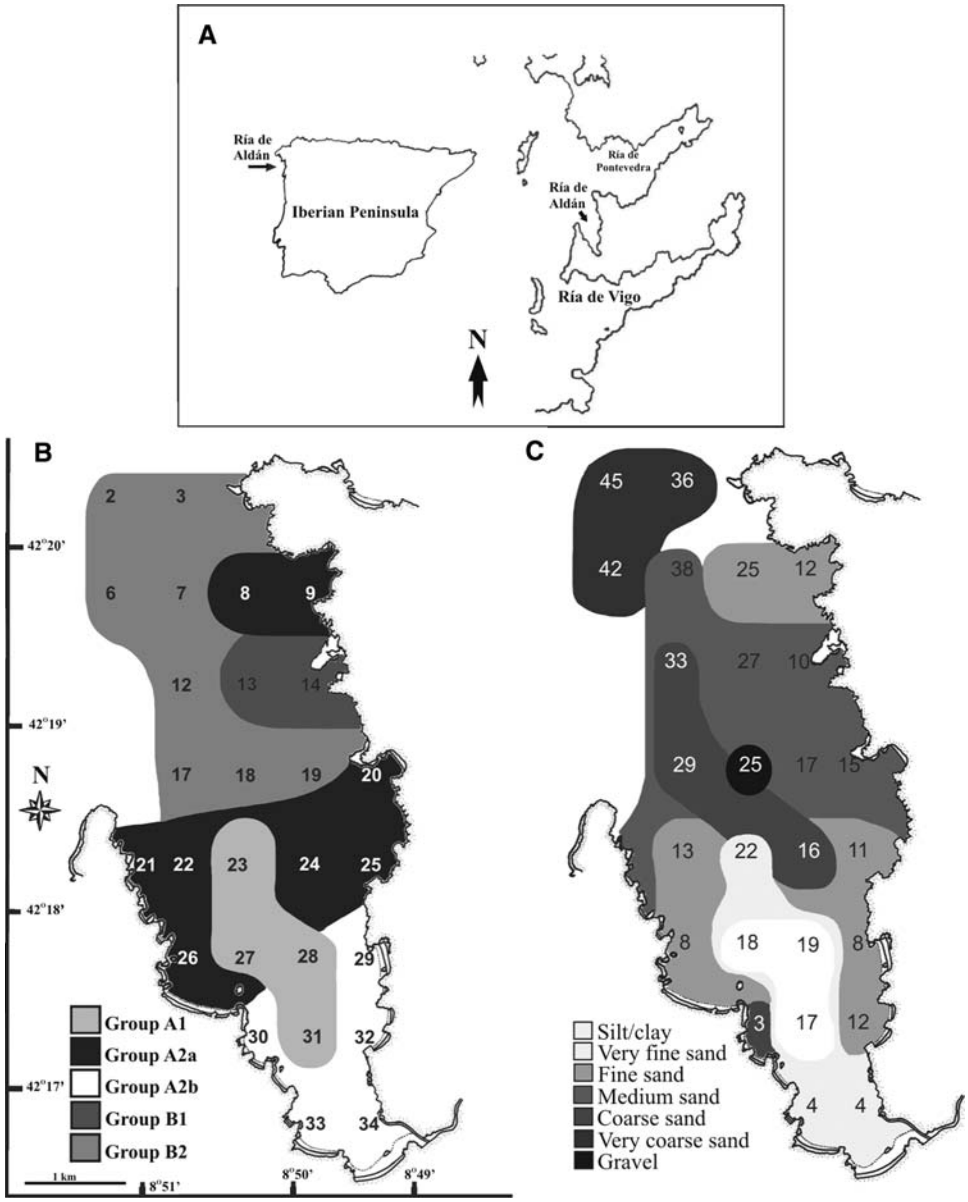


Fig. 1 **a** Location of the Ría de Aldán, **b** location of sampling stations and spatial distribution of peracarid assemblages in the ria as determined by multivariate analyses and **c** bathymetry (m) in numbers and sediment type in the ria

in grain size and an increase in organic content from the outer areas to the inner areas of the ria.

Peracarid fauna

A total of 16,191 peracarid individuals were collected, comprising 125 species of peracarids belonging to five orders. Amphipods were the best represented in total number of species (79) and individuals (73.4% of numerical abundance) followed by isopods (20 species and 2.6% abundance) and cumaceans (14 species and 2.7% abundance). Tanaids and mysids were less diverse in number of species (5 and 7, respectively). Tanaids comprised 20.6% of the total abundance, mostly due to the abundance of *Apseudes latreillii* (Milne-Edwards, 1828) in some sites. Values of univariate measures are shown in Table 2. The lowest abundance values were recorded at medium sand (St. 13, 171 individuals/m^2), while the highest numbers were recorded at muddy sand (St. 34, 12,229 individuals/m^2). Number of species varied between 15 (St. 13) and 38 (St. 29, fine sand); diversity ranged from 0.79 (St. 21, medium sand) and 4.26 (St. 32, fine sand). Evenness showed low values on sediments with a high dominance of *Siphonoecetes kroyeranus* Bate, 1856 (St. 21; *J*, 0.18), *Apseudes latreilli* (St. 22, 24, 34; *J*, 0.30–0.52) and *Gammarella fucicola* (Leach, 1814) (St. 33; *J*, 0.44).

The dominant species in terms of abundance were the tanaid *Apseudes latreillii* and the amphipods *Siphonoecetes kroyeranus*, *Photis longipes* (della Valle, 1893), *Gammarella fucicola*, Aoridae spp. (undetermined females),

Table 1 Position, depth, sediment and water temperature and sedimentary characteristics of sampling stations in the Ría de Aldán

Station	Position	Depth (m)	Surf temp (°C)	Bottom temp (°C)	Sed temp (°C)	Gravel (%)	Sand (%)	Silt/clay (%)	Q_{50} (mm)	Sediment type	S_0	Carbonates (%)	TOM (%)
2	42°20′15′′N, 8°51′15′′W	45	21.1	22.9	20.0	10.0	88.0	2.0	1.079	Very coarse sand	Moderate	73.9	2.6
3	42°20′15′′N, 8°50′45′′W	36	21.4	22.3	20.8	47.9	49.0	3.2	1.983	Very coarse sand	Moderate	89.8	2.6
6	42°19′45′′N, 8°51′15′′W	42	18.5	18.4	18.2	27.1	70.7	2.2	1.053	Very coarse sand	Poor	32.3	1.0
7	42°19′45′′N, 8°50′45′′W	38	17.0	17.7	17.4	0.3	97.4	2.4	0.485	Medium sand	Moderate	67.4	1.4
8	42°19′45′′N, 8°50′15′′W	25	22.1	21.4	19.6	0.1	97.0	2.9	0.211	Fine sand	Mod. well sorted	52.7	1.3
9	42°19′45′′N, 8°49′45′′W	12	18.7	18.6	17.9	0.2	96.8	3.0	0.202	Fine sand	Mod. well sorted	67.9	2.0
12	42°19′15′′N, 8°50′45′′W	33	18.1	18.6	17.2	18.4	79.5	2.1	0.869	Coarse sand	Moderate	38.2	0.7
13	42°19′15′′N, 8°50′15′′W	27	16.8	16.7	16.6	0.3	98.0	1.6	0.383	Medium sand	Moderate	40.8	1.1
14	42°19′15′N, 8°49′45′′W	10	17.3	17.4	17.0	0.8	96.5	2.8	0.391	Medium sand	Moderate	57.0	1.3
17	42°18′45′′N, 8°50′45′′W	29	19.9	21.2	20.2	13.5	84.2	1.8	0.623	Coarse sand	Moderate	32.6	0.5
18	42°18′45′′N, 8°50′15′′W	25	18.4	18.3	17.7	52.7	44.8	2.5	2.224	Gravel	Moderate	33.0	2.0
19	42°18′45′′N, 8°49′45′′W	17	18.4	18.1	17.1	0.5	96.1	3.4	0.331	Medium sand	Moderate	64.1	1.7
20	42°18′45′′N, 8°49′15′′W	15	18.7	18.7	17.6	0.8	95.3	3.9	0.300	Medium sand	Moderate	55.9	2.0
21	42°18′22′′N, 8°51′05′′W	4	21.1	20.8	20.2	2.3	93.2	4.5	0.290	Medium sand	Moderate	70.0	3.1
22	42°18′15′′N, 8°50′45′W	13	21.2	21.2	20.6	1.1	95.5	3.4	0.199	Fine sand	Mod. well sorted	55.2	1.9
23	42°18′15′′N, 8°50′15′′W	22	22.7	23.3	23.0	0.2	94.5	5.3	0.203	Muddy sand	Mod. well sorted	60.3	3.2
24	42°18′15′′N, 8°49′45′′W	16	20.6	21.4	21.4	21.6	74.2	4.2	0.919	Coarse sand	Moderate	65.5	2.5
25	42°18′15′N, 8°49′15′′W	11	21.2	21.5	21.6	0.1	96.7	3.2	0.192	Fine sand	Mod. well sorted	54.2	1.6
26	42°17′45′′N, 8°50′45′′W	8	21.4	21.2	21.7	0.7	92.7	6.6	0.142	Fine sand	Moderate	59.4	2.3
27	42°17′45′′N, 8°50′15′′W	18	17.1	17.3	17.3	6.0	34.8	59.2	0.050	Mud	Poor	33.8	9.0
28	42°17′45′′N, 8°49′45′′W	19	18.7	18.2	17.6	8.9	31.3	59.8	0.050	Mud	Poor	37.8	8.8
29	42°17′45′′N, 84°9′15′′W	8	17.9	18.2	18.2	8.8	87.2	4.0	0.210	Fine sand	Moderate	59.9	2.2
30	42°17′15N, 8°50′15′′W	3	21.6	21.5	23.5	5.8	92.9	1.4	0.868	Coarse sand	Mod. well sorted	41.9	0.7
31	42°17′15′N, 8°49′45′′W	17	22.5	22.5	19.5	4.1	26.6	69.4	0.040	Mud	Moderate	40.3	10.8
32	42°17′22′′N, 8°49′22′′W	12	17.5	18.7	18.4	3.9	93.6	2.5	0.195	Fine sand	Mod. well sorted	63.0	1.5
33	42°16′45′′N, 8°49′45′′W	4	21.0	21.9	27.3	29.8	56.5	13.3	0.230	Muddy sand	Bad	38.8	5.0
34	42°16′40′′N, 8°49′22′′W	4	21.3	22.9	21.2	8.1	86.4	5.6	0.317	Muddy sand	Poor	33.5	1.1

Bottom temp bottom water temperature, *surf temp* surface water temperature, *sed temp* sediment temperature, Q_{50} median grain size, S_0 sorting coefficient, *TOM* total organic matter

Microdeutopus versiculatus (Bate, 1856), *Guernea coalita* (Norman, 1868), *Perioculodes longimanus* (Bate and Westwood, 1868), *Leucothoe incisa* Robertson, 1892, *Ampithoe ramondi* Audouin, 1826 and *Ampelisca typica* (Bate, 1856), and the cumacean *Cumella* sp. The remaining peracarid taxa comprised less than 25% of the total abundance.

The most widespread species in the ria (at least found in 15 sampling sites) were the amphipods *Leucothoe incisa*, Aoridae spp., *Perioculodes longimanus*, *Photis longipes* and *Atylus vedlomensis* (Bate and Westwood, 1862), the isopods *Eurydice truncata* (Norman, 1868) and *Campecopea hirsuta* (Montagu, 1804), and the cumacean *Cumella* sp. (Table 3). About 55% of the species were only found in one to four sites.

Multivariate analyses

The ANOSIM test revealed significant differences in faunistic composition between all stations (global *R*, 0.865; *P*, 0.001), except between St. 2 and 17 (*R*, 0.148; *P*, 0.14), St. 17 and 19 (*R*, 0.108; *P*, 0.21), and St. 24 and 26 (*R*, 0.172; *P*, 0.05). The dendrogram obtained by cluster anal-

Table 2 Number of species (*S*), total abundance per m^2 and 0.28 m^2 (*N*), Shannon Wiener's diversity index (H′, log_2) and Pielou's evenness (*J*) for each sampling station in the Ría de Aldán

Station	Group	*S*	*N* (m^2)	*N* (0.28m^2)	H′	*J*
2	B2	17	336	94	3.11	0.76
3	B2	29	750	210	3.90	0.80
6	B2	16	275	77	3.54	0.88
7	B2	21	443	124	3.59	0.82
8	A2a	16	243	68	3.42	0.85
9	A2a	18	629	176	3.56	0.85
12	B2	29	796	223	3.88	0.80
13	B1	15	171	48	3.21	0.82
14	B1	16	436	122	2.33	0.58
17	B2	18	361	101	3.18	0.76
18	B2	33	3,071	860	3.47	0.69
19	B2	25	286	80	3.78	0.81
20	A2a	26	1,132	317	3.35	0.71
21	A2a	23	9,464	2,650	0.79	0.18
22	A2a	19	2,693	754	1.43	0.34
23	A1	20	361	101	3.68	0.85
24	A2a	29	2,814	788	1.46	0.30
25	A2a	26	671	188	3.96	0.84
26	A2a	29	1,386	388	3.68	0.76
27	A1	21	686	192	3.74	0.85
28	A1	30	1,025	287	3.85	0.79
29	A2b	38	5,389	1,509	3.20	0.61
30	A2b	30	1,639	459	3.32	0.68
31	A1	21	621	174	3.16	0.72
32	A2b	37	1,311	367	4.26	0.82
33	A2b	29	8,607	2,410	2.13	0.44
34	A2b	19	12,229	3,424	2.20	0.52

Cluster group to which each station belongs is also indicated

ysis showed the presence of two major groups of sites at a similarity level of 20% (Fig. 2): group A (finer sediments) and group B (coarser sediments). Group A was further subdivided into group A1 (St. 23, 27, 28, 31; mud) and group A2 (fine sand), the latter was subdivided into group A2a (St. 8, 9, 20, 21, 22, 24, 25, 26) and A2b (St. 29, 30, 32, 33, 34). Group B was subdivided in subgroup B1 (St. 13, 14; medium sand) and B2 (St. 2, 3, 6, 7, 12, 17, 18, 19; mostly coarse sand). nMDS ordination showed similar results to those of the dendrogram (Fig. 3). Relative abundance of peracarid orders in each assemblage is shown in Fig. 4.

Group A was located in the sheltered area of the ria. Subgroup A1 was constituted by muddy sites and had lower number of individuals and species than the other subgroups of A. The species that mostly contributed to similarities in A1 were *Harpinia pectinata* Sars, 1891, *Leucothoe incisa* and *Tanaissus lilljeborgi* (Stebbing, 1891), whereas *Metaphoxus simplex* Bate, 1857, *Harpinia pectinata* and *Microdeutopus armatus* Chevreux, 1887) were the most abundant species. Subgroup A2 was composed of sandy sediments (from muddy sand to coarse sand). The species which mostly contributed to characterize subgroup A2a (medium-fine sand) were *Perioculodes longimanus*, *Leucothoe incisa* (present in all stations), *Siphonoecetes kroyeranus* and *Apseudes latreillii*, the latter being the most abundant species. Subgroup A2b (fine-muddy sand) was located in the inner part of the ria and showed the highest number of individuals of all groups. This subgroup was characterized by *Photis longipes*, *Microdeutopus versiculatus* and *Gammarella fucicola*, which were present in all stations; those species and *Apseudes latreillii* were the most abundant.

Group B was located in the outer part of the ria. Subgroup B1 had less total abundance and number of species of peracarids than the other groups of the ría. Subgroup B2 showed the highest number of species of all groups; this subgroup was determined by *Guernea coalita*, *Haplostylus* sp. and *Eurydice truncata*, being *Apseudes latreilli* the most abundant species.

SIMPER analysis showed that *Guernea coalita*, *Haplostylus* sp. and *Siphonoecetes kroyeranus* explained most of dissimilarity between groups A2a and B2. *Guernea coalita*, *Siphonoecetes kroyeranus* and *Iphinoe trispinosa* (Goodsir, 1843) contributed greatly to the differentiation of B2 from B1. *Apseudes latreillii*, *Siphonoecetes kroyeranus* and *Lepidepecreum longicornis* (Bate and Westwood, 1862) differentiated group A2a from B1. Group A2a differed from A1 due to *Harpinia pectinata*, *Siphonoecetes kroyeranus* and *Metaphoxus simplex*. *Gammarella fucicola* and *Microdeutopus versiculatus* differentiated group A2a from A2b, whereas *Harpinia pectinata* and *Microdeutopus versiculatus* differentiated group A1 from A2b.

Species affinities

Cluster analysis done on the abundance data of the dominant species showed the existence of three major groups at similarity level of about 15% (Fig. 5). Group 1 included species mostly found in coarse sand (cluster group B2). Group 2 comprised species found in muddy and fine sand sediments. Subgroup 2a comprised species with higher abundance in muddy sediments (cluster group A1), while subgroup 2b was composed of species found in fine sand sediments (cluster group A2b). Group 3 included species mostly found in sediments composed of fine and medium sand (cluster group A2a).

Relation with environmental variables

The BIO-ENV procedure showed that the combination of gravel, very fine sand, silt/clay and depth had the highest

Table 3 List of the most abundant peracarid taxa in the Ría de Aldán (>30 individuals collected in total)

Species	Species code	Sites	2	3	6	7	8	9	12	13	14	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
		Group	B2	B2	B2	B2	A2a	A2a	B2	B1	B1	B2	B2	B2	A2a	A2a	A2a	A1	A2a	A2a	A2a	A1	A1	A2b	A2b	A1	A2b	A2b	A2b
Amphipoda																													
Abludomelita obtusata (Montagu, 1813)	*Abl obt*					11									4		11							168			82		
Ampelisca brevicornis (Costa, 1853)	*Amp bre*					7	7					4			129	14	100	64	71	71	57			4					
Ampelisca tenuicornis Lilljeborg, 1855	*Amp ten*				4		43	18	4									14	29	114		75	161	4					
Ampelisca typica (Bate, 1856)	*Amp typ*					25			11	7					57		50		39		211	14	39	68	7	57	32		
Ampithoe ramondi Audouin, 1826	*Amp ram*														4						4			29			64	607	21
Aoridae spp.	*Aor spp*			11	14	11		121	39	4		4	171		61		25		25	18	29		4	46	4	4	46	1121	
Atylus vedlomensis (Bate and Westwood, 1862)	*Aty ved*		4	43		25		4	36			75	21	29	4	4			7		4			11	14			4	
Autonoe cf. *spiniventris* (della Valle, 1893)	*Aut spi*					136			36	18		4			14					36			21						
Autonoe spp.	*Aut* spp			18									154		11										21				
Ceradocus semiserratus (Bate, 1862)	*Cer sem*			71									446																
Dexamine spinosa (Montagu, 1813)	*Dex spi*																							154			150	221	29
Gammarella fucicola (Leach, 1814)	*Gam fuc*												136	4										43	21		32	5382	364
Gammaropsis sp.				4	11				21			4	25								11		7	21	4				
Guernea coalita (Norman, 1868)	*Gue coa*		121	57	57	25			143		4	68	79	79	11				11						179				746
Harpinia pectinata Sars, 1891	*Har pec*																	61				136	129			29	7		
Leucothoe incisa Robertson, 1892	*Leu inc*		4		11		25	11	18			4	18		118	14	36	21	21	43	29	14	54	104	4	21	100	4	96
Maera grossimana (Montagu, 1808)													39										4			18		75	
Maera othonis (Milne-Edwards, 1830)	*Mae oth*			4					7				471									4	7			11			
Maerella tenuimana (Bate, 1862)	*Mae ten*		7						4			7							7		61		4	89			7	4	
Megaluropus agilis Hoek, 1889	*Meg agi*							25			21			4	7	79				57					4				
Megamphopus cornutus Norman, 1869	*Meg cor*			11					61					14			7		14		43				7				
Metaphoxus simplex Bate, 1857	*Met sim*																					64	71			243			
Microdeutopus armatus Chevreux, 1887	*Mic arm*																					71	182			89			
Microdeutopus versiculatus (Bate, 1856)	*Mic ver*																				4			843	107		111	404	171
Orchomene humilis (Costa, 1853)	*Orc hum*			18																					379				
Pariambus typicus (Kröyer, 1844)	*Par typ*										4		11				4	25	21		11	43	14						79
Perioculodes longimanus (Bate and Westwood, 1868)	*Per lon*						11	4			4				25	196	46	43	7	75	275		14	314	4		161	57	311
Photis longipes (della Valle, 1893)	*Pho lon*		7			11	4		7						200	46	25		111		179	18		2296	136	21	168	54	4296
Phtisica marina Slabber, 1769																								36	4		43	107	93
Pontocrates arenarius (Bate, 1858)	*Pon are*				11	4		100		4			4	4		107									32				

Table 3 continued

Species	Species code	Sites	2	3	6	7	8	9	12	13	14	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
		Group	B2	B2	B2	B2	A2a	A2a	B2	B1	B1	B2	B2	B2	A2a	A2a	A2a	A1	A2a	A2a	A2a	A1	A1	A2b	A2b	A1	A2b	A2b	A2b
Siphonoecetes kroyeranus Bate, 1856	*Sip kro*						39	61			261			7	29	8550	11			39	57			196	4		29		
Socarnes erythrophthalmus Robertson, 1892	*Soc ery*			14									504																
Stenothoe monoculoides (Montagu, 1815)	*Ste mon*			32																				7			43	11	129
Urothoe brevicornis Bate, 1862	*Uro bre*							82									32								432				
Urothoe elegans Bate, 1857	*Uro ele*							25							4	14		18	29		18			232	86		25		
Urothoe grimaldii Chevreux, 1895	*Uro gri*							32							282		75		7	32	18			86			7		
Urothoe marina (Bate, 1857)	*Uro mar*		64		25	36			157			43							4										
Isopoda																													
Campecopea hirsuta (Montagu, 1804)	*Cam hir*		29		36			4		4						43		4		11		4	68	14	14	7	7	4	11
Eurydice truncata (Norman, 1868)	*Eur tru*		14	64	7	29	39		46	43	4	21	11	4		4	4	4	7		14		4	4	7				
Exosphaeroma sp.	*Exo sp.*								4				32	7										14	93		7	4	
Microjaera anisopoda Bocquet and Levi, 1955	*Mic ani*			204									7																
Munna sp.															4													132	
Sphaeroma serratum (Fabricius, 1787)			7	7						4			4			7		4			4	4	4	29	7		25	4	4
Mysida																													
Haplostylus sp.	*Hap* sp.		14	14	7	29			79	39		79	7	18															
Cumacea																													
Bodotria pulchella (Sars, 1878)	*Bod pul*		4				4			7	4			4	4	4		4	25	18	4			57			7		
Cumella sp.	*Cum sp*			21	7						4		39					7	7	4	11	32	14	75		7	11	32	414
Eudorella truncatula (Bate, 1859)	*Eud tru*																	4				61	104			4	4		
Iphinoe serrata Norman, 1867	*Iph ser*																				14	32	4	25			11	143	118
Tanaidacea																													
Apseudes latreillii (Milne-Edwards, 1828)	*Aps lat*					29	14		21				689		132	11	2161	14	2289	18	232			321			39		5321
Leptochelia savignyi (Kröyer, 1842)	*Lep sav*																	4				11	21			50	4	43	
Tanaissus lilljeborgi (Stebbing, 1891)	*Tan lil*															207	71	36				43	25			14			

For comparative purposes, number of individuals in each station is expressed as individuals/m^2

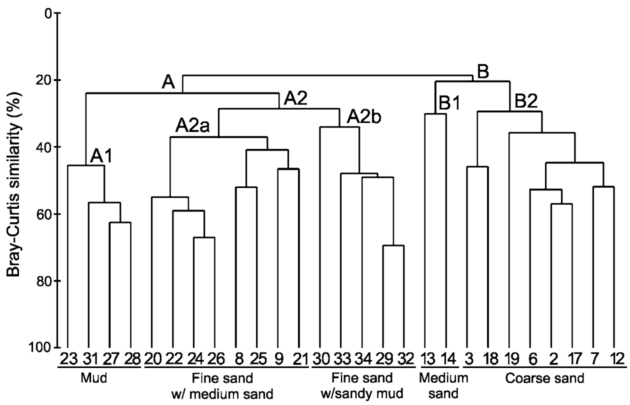


Fig. 2 Peracarid assemblages in the Ría de Aldán as determined by cluster analysis based on Bray–Curtis similarity coefficient

correlation with faunistic data (ρ_w 0.516). Very fine sand was the variable that alone showed the highest correlation (ρ_w 0.277), followed by depth (ρ_w 0.270) and fine sand (ρ_w 0.238).

The nMDS ordination of sites with superimposed values of the mentioned variables showed that stations appeared distributed from right to left following an increase in very fine sand and fine sand fractions in the sediment, accompanied by decreasing values of depth (Fig. 3).

The forward selection of CCA selected median grain size, silt/clay, sorting coefficient and depth as the variables explaining most of the variance in the species data (*P*: 0.002). Axes I and II were the most important in the CCA ordination, accumulating 21.2% of species variance and 27.9% of species-environment variance. Cluster groups with higher content of coarser granulometric fractions were distributed on the left of the ordination, while assemblages located in fine sand-mud were distributed on the right, following a gradient defined by a decrease in median grain size (Fig. 6).

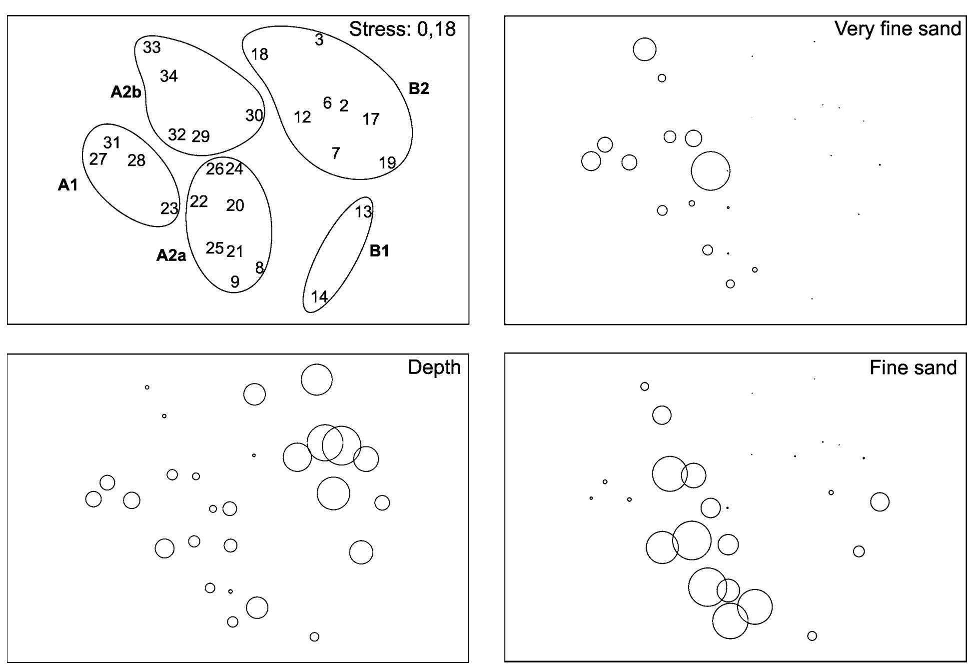
Discussion

Peracarid diversity

The peracarid fauna diversity of Ría de Aldán was higher than in other European temperate waters, having been recorded the typical species from shallow sediments of those waters (Dauvin et al. 1994; Conradi et al. 1997; Cunha et al. 1999). The total number of peracarid species founded at Ría de Aldán was 125, while Dauvin et al. (1994) reported 99 peracarid species from the western English channel (circalittoral suprabenthic coarse sand community), Cunha et al. (1999) reported 61 peracarid species from Ría de Aveiro (Portugal), and Conradi and López González (2001) reported 67 peracarid species from Algeciras Bay. Table 4 shows a comparison of the peracarid fauna between the Ría de Aldán and other nearby geographical areas.

The large peracarid diversity at Ría de Aldán was mainly due to the contribution of amphipods (79 species). For example, Garmendia et al. (1998) found 66 amphipod species in Ría de Ares-Betanzos, Conradi et al. (1997), recorded the presence of 53 amphipod species in Algeciras Bay, Parker found 26 subtidal amphipod species in Belfast Lough, Jimeno and Turon (1995) found 71 gammaridean amphipods along the Catalonian coast and Arresti et al.

Fig. 3 nMDS ordination of sampling stations showing groups determined by cluster analysis and ordination of sites with values of some environmental variables superimposed (very fine sand, depth and fine sand)



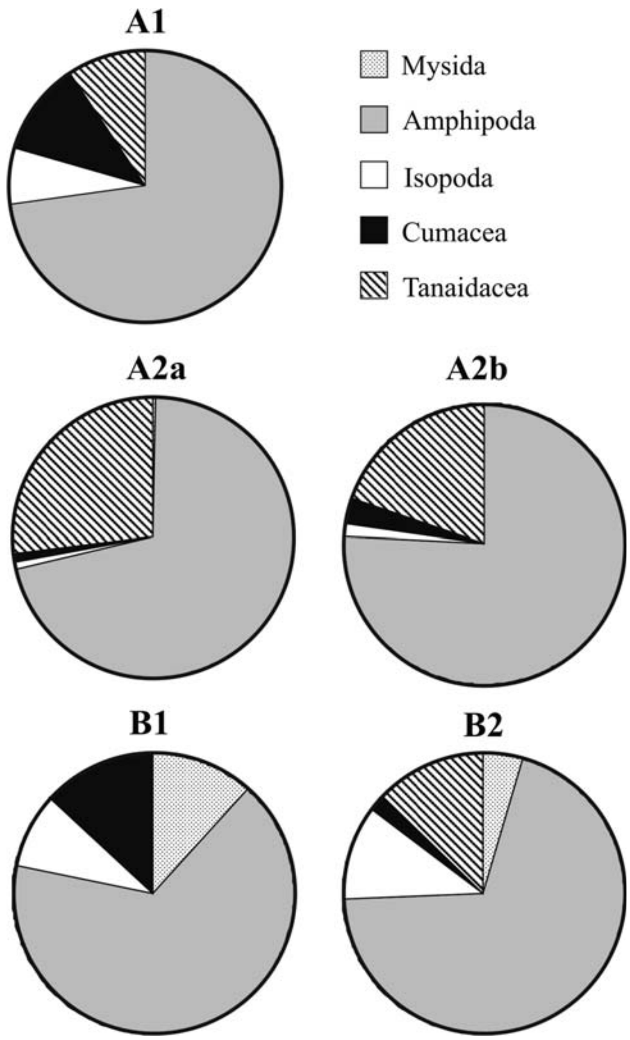


Fig. 4 Relative abundance (%) of each peracarid order in the groups of stations determined by multivariate analyses

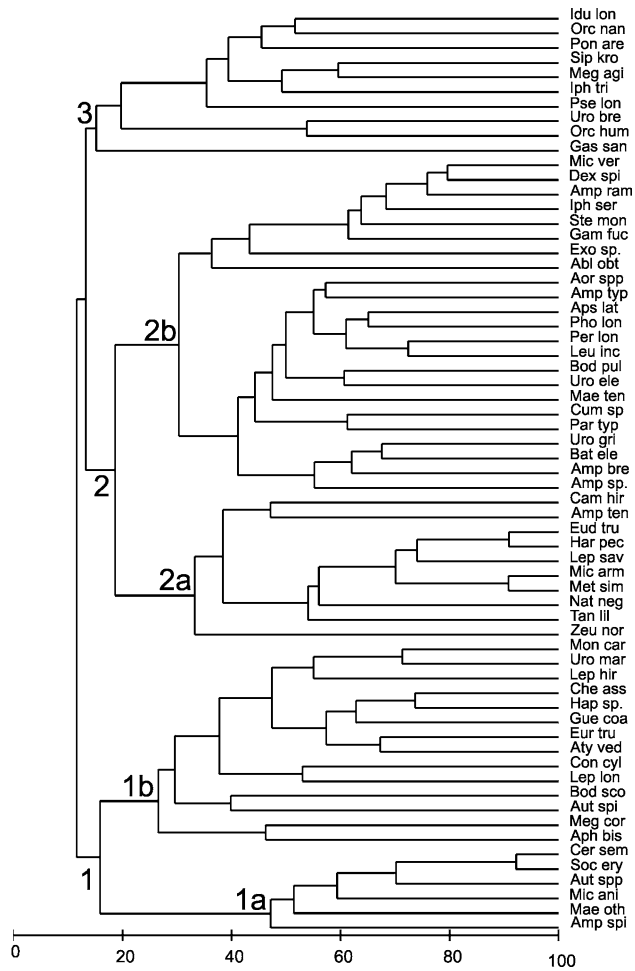


Fig. 5 Dendrogram based on cluster analysis showing the classification of species with a numerical dominance ≥4% at any given site. Species code are given in Table 3, except: *Amp* sp., *Ampelisca* sp.; *Amp spi*, *Ampelisca spinipes*; *Aph bis*, *Apherusa bispinosa; Bat ele*, *Bathyporeia elegans*; *Bod sco*, *Bodotria scorpioides*; *Che ass*, *Cheirocratus assimilis*; *Con cyl*, *Conilera cylindracea*; *Gas san*, *Gastrosaccus sanctus*; *Idu lon*, *Idunella longirostris*; *Iph tri*, *Iphinoe trispinosa*; *Lep hir*, *Leptocheirus hirsutimanus*; *Lep lon*, *Lepidepecreum longicornis*; *Mon car*, *Monoculodes carinatus*; *Nat neg*, *Natatolana neglecta; Pse lon*, *Pseudocuma longicorne*; *Orc nan*, *Orchomenella nana*; *Zeu nor*, *Zeuxo normani*

(1986) found 40 amphipod species in the Abra de Bilbao (País Vasco, Spain). Again, this gammaridean diversity was larger than in other similar areas, apart from the English Channel where Dauvin et al. (2000) reported 142 gammaridean amphipods.

Thus, the total number of species of the Ría de Aldán is high enough to consider those soft-bottoms as particularly rich in peracarids. Polychaetes and molluscs also show a high number of species in this ria (Lourido et al. 2006, 2008). This fact may be due to the granulometric heterogeneity existing in this area. Normally, heterogeneous sediments provide many microhabitats which may support a greater biodiversity of species than homogenous sediments do (Gray 1974).

The second peracarid groups in number of species were isopods and cumaceans; whereas, the former was more widespread, the latter was more abundant, both being found from gravel to muddy sediments. Isopods live in most marine habitats, being more diverse in the deep sea (Kensley 1998). Cumaceans can live in all kind of benthic habitats, mud, sand, gravel and on natural rock formations associated with algae or with sessile invertebrates (Alfonso et al. 1998). Nevertheless, other authors state that cumaceans may be more abundant with higher organic matter content and higher proportion of silt/clay in the sediment (Corbera and Cardell 1995).

In the Ría de Aldán, cumaceans showed their highest abundances in muddy sand, being *Cumella* sp. and *Iphinoe serrata* Norman, 1867 the most abundant species.

Mysids were poorly represented in our samples. This may happen due to the fact that mysids are sampled more

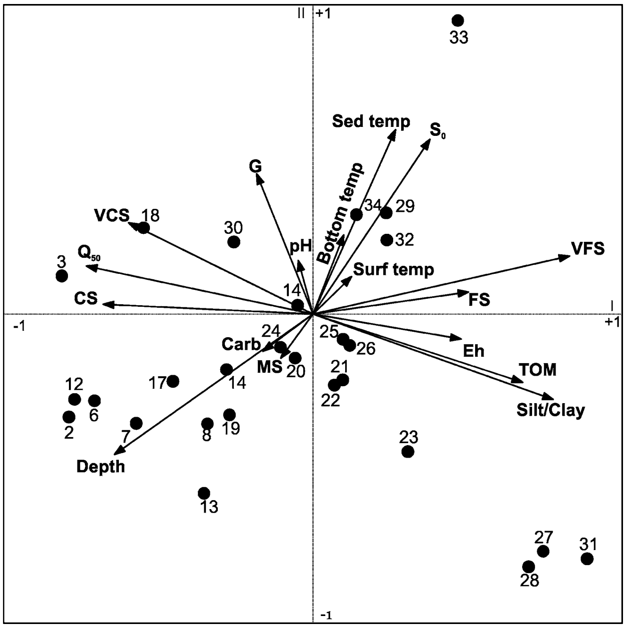


Fig. 6 Canonical correspondence analysis (CCA) ordination of stations and environmental variables relative to axes I and II for the Ría de Aldán. Gravel, G; very coarse sand, VCS; coarse sand, CS; medium sand, MS; fine sand, FS; very fine sand, VFS; median grain size, Q_{50}; sorting coefficient, S_0; bottom water temperature, bottom temp; surface water temperature, surf temp; sediment temperature, sed temp; calcium carbonate content, carb; total organic matter content, TOM

efficiently by using epibenthic sledges (Brandt 1995) rather than the grab used here. Tanaids showed a small number of species but a high number of individuals. This fact is due to the numerical dominance of *Apseudes latreillii* at some stations. Although this species may proliferate in conditions of organic enrichment (Grall and Glémarec 1997), content of organic matter was not high at stations where *Apseudes latreillii* was dominant. In the Ría de Aldán, this species showed a high number of individuals in different kind of sediments [1,490 individuals/m^2 in st. 34 (muddy sand), 641 in st. 24 (coarse sand) and 605 in st. 22 (fine sand)].

Peracarid assemblages and environmental conditions

Two major peracarids assemblages were determined in Ría de Aldán through multivariate analyses whose distribution agreed mostly with that of granulometric fractions. Similarly, the distribution of molluscan and polychaete assemblages in the Ría de Aldán also shows the same pattern (Lourido et al. 2006, 2008).

Groups A1 and A2b can be included within the ‘*Abra alba* community’ (Petersen 1918). This community has been reported along European coasts in different types of muddy sediments (Glémarec 1964; Cabioch 1968; Gentil et al. 1986; Carpentier et al. 1997) as well as in other Galician rias (Cadée 1968; Olabarría et al. 1998; Moreira et al. 2005). The most abundant peracarids in the muddy sediments of group A1 were *Metaphoxus simplex* (exclusive), *Harpinia pectinata* (constant) and *Microdeutopus armatus* (exclusive). Constant species of this group were *Eudorella truncatula* (Bate, 1859), *Tanaissus lilljeborgi*, *Leucothoe incisa* and *Leptochelia savignyi* (Kröyer, 1842). In group A2b (muddy sand and fine sand sediment), *Photis longipes* (constant), *Gammarella fucicola* (constant) and *Apseudes latreillii* had a high abundance (>1,500 individuals/m^2). *Dexamine spinosa* (Montagu, 1813) and *Phtisica marina* Slabber, 1,769 were constant and exclusive species of this group.

Faunal composition of group A2a (fine sand) can be ascribed to the *Venus gallina* community (Thorson 1957).

Table 4 Comparison of peracarid diversity between the Ría de Aldán (this work) and other nearby geographical areas (Galicia, Basque country and Portuguese coast)

	Amphipoda	Isopoda	Mysida	Cumacea	Tanaidacea	Total
Ría de Aldán (Galicia, Spain; this work)	79	20	7	14	5	125
Ría de Arousa (Galicia, Spain; López-Jamar 1982)	7	2	0	1	1	11
Ría de Ares-Betanzos (Galicia, Spain; Garmendia et al. 1998)	73	9	0	13	2	97
Ría de Foz (Galicia, Spain; Junoy and Viéitez 1988)	12	11	5	2	1	31
Miño Estuary (Galicia, Spain; Mazé et al. 1993)	8	5	1	0	0	14
Panxón (Ría de Vigo, Galicia, Spain; Anadón 1975)	24	8	2	0	0	34
Abra de Bilbao (Basque Country, Spain; Arresti et al. 1986)	40	0	0	0	0	40
Continental shelf (Basque Country, Spain; Martínez and Adarraga 2001)	40	5	3	18	1	67
Hendaya beach (Basque Country, Spain; San Vicente and Sorbe 2001)	19	3	12	5	0	39
Western Portuguese coast (Sousa Reis et al. 1982)	20	8	5	5	0	38
Albufeira and Obidos lagoons (Portugal; Rodrigues and Dauvin 1985)	36	0	5	4	0	45
Mondego Estuary (Portugal; Marques et al. 1993)	18	10	1	0	0	29
Ovar Channel (Ría de Aveiro, Portugal; Cunha et al. 1999)	26	6	9	1	2	44
Mira Channel (Ría de Aveiro, Portugal; Cunha et al. 1999)	30	9	12	3	2	56

In this community, *Siphonoecetes kroyeranus* (constant) and *Apseudes latreillii* (constant) were the most abundant species. Furthermore, *Bathyporeia elegans* Watkin, 1938 was constant and exclusive, *Ampelisca* sp. exclusive and *Perioculodes longimanus*, *Ampelisca brevicornis* (Costa, 1853) and *Leucothoe incisa* were constant.

The most abundant peracarid in group B1 (medium sand) was the amphipod *Siphonoecetes kroyeranus*. The characteristic species were *Eurydice truncata*, *Iphinoe trispinosa*, *Lepidepecreum longicornis* and *Pseudocuma longicorne* (Bate, 1858) (all constant) and the amphipod *Leucothoe spinicarpa* (Abildgaard, 1789) (exclusive). The mysid *Gastrosaccus spinifer* (Goës, 1864) (constant and elective) was also a typical species of this kind of sediment.

The coarse sandy sediments of group B2 has a fauna that could be included among the different varieties of the '*Branchiostoma lanceolatum-Venus fasciata* community' (Thorson 1957). Several authors have reported the presence of similar faunal associations in other areas of Galicia such as the Ría da Coruña (López-Jamar and Mejuto 1985), the Ría de Ares-Betanzos (Troncoso et al. 1993, 2005) and the Ensenada de Baiona (Moreira et al. 2005), and in other areas outside of Galicia, such as the Baie de Morlaix in the Manche Occidental (Dauvin 1988b).

Apseudes latreillii was the most abundant peracarid of this group. *Guernea coalita*, *Haplostylus* sp. and *Atylus vedlomensis* were constant species, while *Socarnes erythrophthalmus* Robertson, 1892 and *Ceradocus semiserratus* (Bate, 1862) and *Ampelisca spinipes* Boeck, 1861 were exclusive.

Among factors determining distribution of peracarids and composition of assemblages in sediments are temperature, stability of substrate, grain size, organic matter content, food availability, burrowing ability, the role of pollutants and diel activity changes determined by specific behavioural patterns (endogenous rhythms, predation, etc.) (Corbera and Cardell 1995; Weisshappel and Svavarsson 1998; Cunha et al. 1999). Grain size is, however, one of the most often reported (Robertson et al. 1989).

Our results suggest that sedimentary composition and a number of environmental gradients existing in the ria related to depth such as hydrodynamism, sedimentation, carbonates, organic matter and the presence of seaweeds are the major factors controlling peracarid spatial distribution. The number of species tended to be higher in fine sand and coarse sand assemblages than in muddy sediments. Similarly, Biernbaum (1979) reported higher number of species in coarse sand and Dauvin et al. (1994) found a high peracarid diversity in circalittoral coarse sands from the English channel. In the Ría de Aldán, total number of individuals is higher in muddy sand sediments than in other sediments. This fact can be due to the great variety of habitats present in sampling stations close to the river mouth which are, in addition, colonized by a number seaweeds. The presence of seaweeds increases the number of microhabitats and there are more ecological niches. Furthermore, seaweeds contribute to stabilize the sediment, food availability is greater than in naked sediments, and seaweeds give protection against a number of predators.

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