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Assemblages of the molluscan fauna in subtidal soft bottoms of the Ría de Aldán (north-western Spain)

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The composition and spatial distribution of the mollusc fauna on the subtidal soft bottoms of the Ría de Aldán (Galicia, north-western Spain) were studied by means of quantitative sampling and multivariate analyses. The faunal distribution was mainly conditioned by a sedimentary gradient that was defined by a decreasing grain size from the mouth towards the inner margins of the ría. Several assemblages were determined which could be defined according to the classic terms of 'community' and 'facies'. A '*Venus fasciata* community' and a 'facies of *Goodallia triangularis–Pisione parapari*' are present in coarser sandy sediments of the outer ría area. The communities characterized by '*Venus gallina*' and '*Tellina fabula–Tellina tenuis*' were found in the fine sand bottoms at the centre and margins of the ría. The shallower and muddier sediments in the inner ría showed a mix of typical species from the '*Abra alba*' and the '*Venus gallina*' communities, and in the Río Aldán's mouth could be distinguished a facies of a protected zone.

INTRODUCTION

Research on the macrobenthic communities of the Iberian Peninsula has been carried out by several authors, who have taken both a faunistic and an ecological descriptive approach. There has been an ongoing interest in the so-called 'rías' of Galicia (north-western Spain), which are a particular kind of estuarine system. The rías had their origin in flooded river valleys and have a high primary productivity due to upwellings and regular incoming of nutrients (Nombela et al., 1995). The great economic and social importance of these systems (e.g. fisheries, bivalve culture on rafts, shellfish resources) would greatly benefit from a scientific study of the environment, especially of the benthic communities, which have traditionally been considered as good indicators of the conditions of marine bottoms (Bellan, 1967, 1984; Pearson & Rosenberg, 1978; Gray & Mirza, 1979; Bellan et al., 1988; Warwick, 1988).

Frequent studies have also been made on the benthos living on soft substrata in recent years on the Galician coast (Viéitez & Baz, 1988; Junoy & Viéitez, 1989, 1990; Mazé et al., 1990; Palacio et al., 1991; Currás & Mora, 1991, 1992; Pérez Edrosa & Junoy, 1993). However, there is a lack of studies in some little rías, such as Ría de Aldán. The main objectives of this paper were to characterize the composition and distribution of the molluscan fauna on the subtidal soft bottoms of the Ría de Aldán and to study the influence of the measured environmental variables on the distribution patterns; thus providing a reference case study for future comparative studies on the ecology of the communities and evolution of assemblages. It will also be the baseline to investigate changes if they happen (possible risks due to human activities, oil spill, etc.).

MATERIALS AND METHODS

Study area

The Ría de Aldán is located on the southern margin of the mouth of the Ría de Pontevedra, between 42°16′40″–42°20′50″N and 8°49′–8°52′W. This ría has a maximum depth of 45 m and its mouth is oriented towards the north.

Sample collection

The sampling programme, which covers the extension of the ría to provide sufficient information on the distribution of the different species of molluscs, consisted of 27 stations (Figure 1). Quantitative sampling was carried out 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 formalin for later sorting and identification of the fauna. An additional sediment sample was taken at each station to analyse the granulometric composition, carbonates, and organic matter contents. 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 (Q_{50}) and sort coefficient (S_0) (Trask, 1932) were also determined for each sample. Sort coefficient was considered as $S_0=\sqrt{Q_{25}/Q_{75}}$, where Q_{25} and Q_{75} are the 25th and 75th percentiles. Sediment types were characterized according to Junoy (1996). Carbonate content (%) was estimated by treatment of the sample with hydrochloric acid, and the

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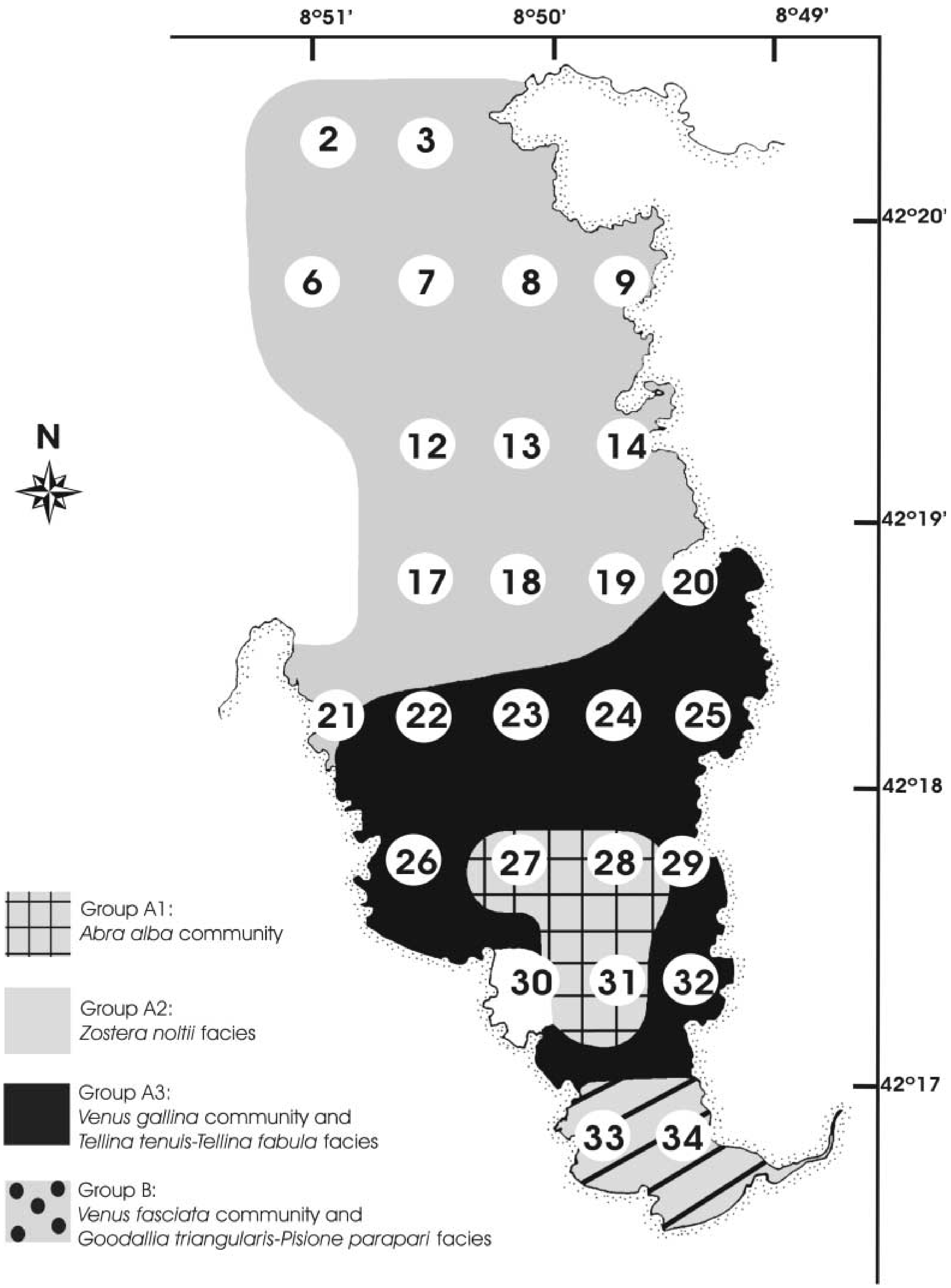

Figure 1. Locations of sampling stations in the Ría de Aldán and spatial distribution of molluscan assemblages in the ría as determined by multivariate analysis.

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Table 1. *Position, depth and sedimentary characteristics of sampling stations in the Ría de Aldán.*

Station	Position	Depth (m)	Gravel (%)	Sand (%)	Silt/clay (%)	Q_{50} (mm)	Sediment type	S_0	Carbonates (%)	TOM (%)
2	42°20′15″N 8°51′15″W	45	10.0	88.0	2.0	1.1	Very coarse sand	Moderate	73.9	2.6
3	42°20′15″N 8°50′45″W	36	47.9	49.0	3.2	2.0	Very coarse sand	Moderate	89.8	2.6
6	42°19′45″N 8°51′15″W	42	27.1	70.7	2.2	1.1	Very coarse sand	Poor	32.3	1.0
7	42°19′45″N 8°50′45″W	38	0.3	97.4	2.4	0.5	Medium sand	Moderate	67.4	1.4
8	42°19′45″N 8°50′15″W	25	0.1	97.0	2.9	0.2	Fine sand	Moderate well sorted	52.7	1.3
9	42°19′45″N 8°49′45″W	12	0.2	96.8	3.0	0.2	Fine sand	Moderate well sorted	67.9	2.0
12	42°19′15″N 8°50′45″W	33	18.4	79.5	2.1	0.9	Coarse sand	Moderate	38.2	0.7
13	42°19′15″N 8°50′15″W	27	0.3	98.0	1.6	0.4	Medium sand	Moderate	40.8	1.1
14	42°19′15″N 8°49′45″W	10	0.8	96.5	2.8	0.4	Medium sand	Moderate	57.0	1.3
17	42°18′45″N 8°50′45″W	29	13.5	84.2	1.8	0.6	Coarse sand	Moderate	32.6	0.5
18	42°18′45″N 8°50′15″W	25	52.7	44.8	2.5	2.2	Gravel	Moderate	33.0	2.0
19	42°18′45″N 8°49′45″W	17	0.5	96.1	3.4	0.3	Medium sand	Moderate	64.1	1.7
20	42°18′45″N 8°49′15″W	15	0.8	95.3	3.9	0.3	Medium sand	Moderate	55.9	2.0
21	42°18′22″N 8°51′05″W	4	2.3	93.2	4.5	0.3	Medium sand	Moderate	70.0	3.1
22	42°18′15″N 8°50′45″W	13	1.1	95.5	3.4	0.2	Fine sand	Moderate well sorted	55.2	1.9
23	42°18′15″N 8°50′15″W	22	0.2	94.5	5.3	0.2	Muddy sand	Moderate well sorted	60.3	3.2
24	42°18′15″N 8°49′45″W	16	21.6	74.2	4.2	0.9	Coarse sand	Moderate	65.5	2.5
25	42°18′15″N 8°49′15″W	11	0.1	96.7	3.2	0.2	Fine sand	Moderate well sorted	54.2	1.6
26	42°17′45″N 8°50′45″W	8	0.7	92.7	6.6	0.1	Fine sand	Moderate	59.4	2.3
27	42°17′45″N 8°50′15″W	18	6.0	34.8	59.2	0.1	Mud	Poor	33.8	9.0
28	42°17′45″N 8°49′45″W	19	8.9	31.3	59.8	0.1	Mud	Poor	37.8	8.8
29	42°17′45″N 8°49′15″W	8	8.8	87.2	4.0	0.2	Fine sand	Moderate	59.9	2.2
30	42°17′15″N 8°50′15″W	3	5.8	92.9	1.4	0.9	Coarse sand	Moderate well sorted	41.9	0.7
31	42°17′15″N 8°49′45″W	17	4.1	26.6	69.4	0.0	Mud	Moderate	40.3	10.8
32	42°17′22″N 8°49′22″W	12	3.9	93.6	2.5	0.2	Fine sand	Moderate well sorted	63.0	1.5
33	42°16′45″N 8°49′45″W	4	29.8	56.5	13.3	0.2	Muddy sand	Bad	38.8	5.0
34	42°16′40″N 8°49′22″W	4	8.1	86.4	5.6	0.3	Muddy sand	Poor	33.5	1.1

Q_{50}, median grain size; S_0, sort coefficient; TOM, total organic matter.

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

Station	Group	S	N	H′	J
2	B3	15	92	3.06	0.78
3	B2	26	546	2.77	0.59
6	B2	26	210	3.28	0.70
7	B3	16	146	2.71	0.68
8	B3	16	191	2.04	0.51
9	B1	9	167	1.02	0.32
12	B2	20	118	3.11	0.72
13	B3	17	314	2.64	0.65
14	B3	12	64	3.08	0.86
17	B2	20	229	2.99	0.69
18	B2	33	392	4.15	0.82
19	B2	22	1117	1.96	0.44
20	A3	30	514	3.50	0.71
21	B1	16	128	3.00	0.75
22	A3	29	240	3.60	0.74
23	A3	30	1427	1.06	0.22
24	A3	24	340	3.25	0.71
25	A3	22	222	2.77	0.62
26	A3	28	326	3.41	0.71
27	A1	30	1178	2.26	0.46
28	A1	24	610	2.69	0.59
29	A3	36	738	3.35	0.65
30	Ungrouped station	24	1382	0.83	0.18
31	A1	20	250	2.00	0.46
32	A3	33	636	3.02	0.60
33	A2	33	610	3.35	0.66
34	A2	43	1954	3.86	0.71

total organic matter content (TOM, %) was estimated from the weight loss after placing samples in a furnace for 4 h at 450°C (Table 1).

Data analysis

Total abundance (N), number of species (S), the Shannon–Wiener diversity index (H′, $\log_2$), and Pielou's evenness (J) are the several univariate measures that were calculated for each sampling station (Table 2). Molluscan 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 & Warwick, 1994). A similarities matrix between 27 sampling stations was constructed by means of the Bray–Curtis similarity coefficient by first applying fourth root transformation on species abundance to downweight the contribution of the most abundant species. The molluscan assemblages were investigated from this matrix by cluster analysis based on the group-average sorting algorithm, as well as an ordination by means of non-metric multidimensional scaling (nMDS). The SIMPER program was next used to identify species that greatly contributed to differentiate station groups (Table 4). The species present in each group of stations were further classified according to the constancy and fidelity indexes (Glémarec, 1964; Cabioch, 1968; Mora, 1980; Junoy, 1988; Currás, 1990; Garmendia, 1997; Moreira, 2003). For any given station group, species with more than 1% of the total specimens were considered as dominants (Junoy & Viéitez, 1990).

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 molluscan distribution in the inlet and the measured environmental variables. The forward selection was employed 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

In the Ría de Aldán, sediments are mainly of a sandy nature. Coarser sandy granulometric fractions are greater at the mouth and muddy bottoms are restricted to inner and sheltered areas. In the outer areas of the ría there is a decrease in grain size and an increase in organic content towards the inner areas of the ría.

The 27 samples analysed yielded a total of 14,141 individuals of molluscs belonging to 126 species, of which 60 were bivalves, 60 gastropods, five polyplacophorans and one scaphopod. Bivalves were the dominant group in terms of abundance (69.22%), followed by gastropods (29.58%) and polyplacophorans (1.19%). The bivalve *Mysella bidentata* (Montagu, 1803) and the gastropod *Caecum trachea* (Montagu, 1803) were the most abundant species in the ría, accounting for more than 50% of total molluscan abundance. The former was mainly found along a number of fine sediments (fine sand to mud) and the latter was found in coarser sandy sediments (coarse and medium sand).

Table 2 shows the values of univariate measures. Lowest abundance values were recorded at Station 14 (64 specimens) and Station 2 (92 specimens), while the highest were recorded at Station 34 (1954). The number of species fluctuated between 9 (Station 9) and 43 (Station 34), while diversity ranged between 0.83 (Station 30) and 4.15 bits (Station 18). Evenness showed low values on bottoms with a high dominance of *Goodallia triangularis* (Montagu, 1803), *M. bidentata* and *C. trachea* (Stations 9, 23, 30, respectively) and with a low diversity values. Number of species showed a positive

Table 3. *Results of the non-parametric Spearman's correlation coefficient of number of species evenness, abundance and diversity with sediment types.*

	GR	VCS	CS	MS	FS	VFS	Silt/clay
N	0.135	0.002	−0.161	−0.375	0.005	0.35	0.409*
S	0.373	0.102	−0.219	−0.404*	0.054	0.378	0.395*
J	0.33	0.397*	0.308	0.272	−0.123	−0.298	−0.164
H′	0.476*	0.327	0.09	0.016	−0.025	0.006	0.086

*, $P<0.05$; CS, coarse sand; FS, fine sand; GR, gravel; H′, Shannon–Wiener diversity index; J, Pielou's evenness; MS, medium sand; N, total abundance; S, number of species; VCS, very coarse sand; VFS, very fine sand.

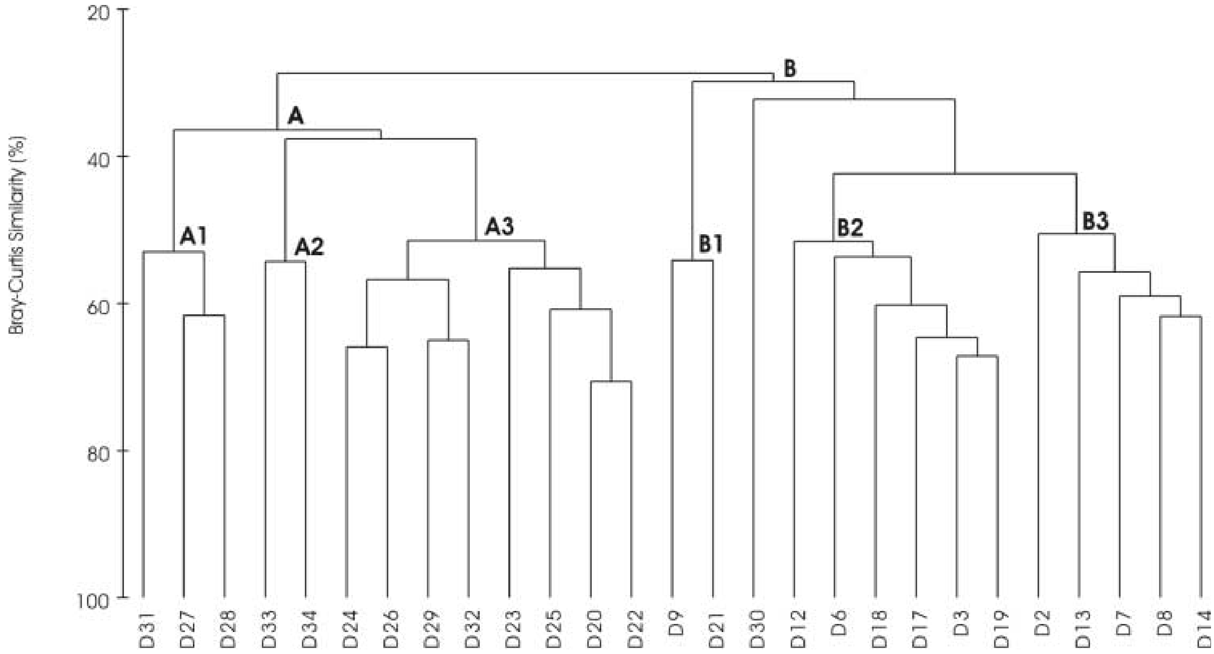

Figure 2. Molluscan assemblages in the Ría de Aldán as determined by cluster analysis based on Bray–Curtis similarity coefficient.

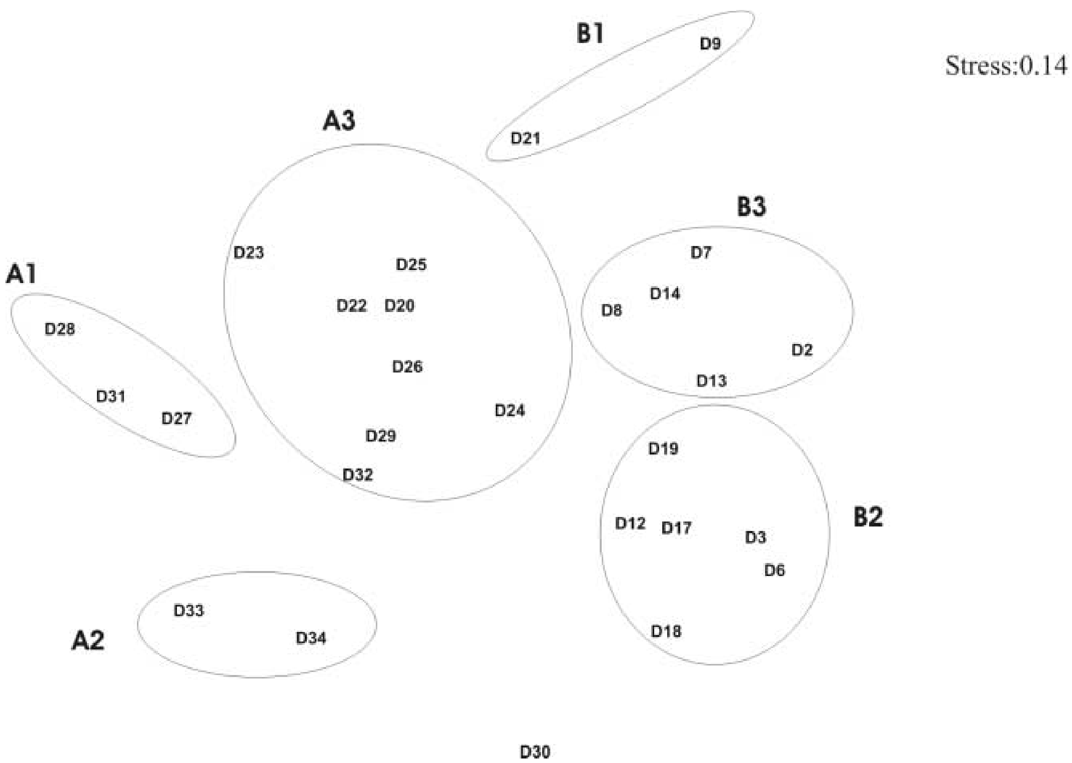

Figure 3. Non-metric multidimensional scaling ordination of molluscan assemblages in the Ría de Aldán.

correlation through non-parametric Spearman's correlation coefficient with silt/clay ($P<0.05$) and negative correlation with medium sand ($P<0.05$). Diversity was positively correlated with gravel ($P<0.05$), evenness with very coarse sand ($P<0.05$) and abundance with silt/clay ($P<0.05$) (Table 3).

Multivariate analysis

Cluster analysis revealed the presence of two large groups of stations (Figure 2): Group A, with subgroups A1 (Stations 27, 28, 31: mud bottoms), A2 (Stations 33, 34: sandy mud bottoms) and A3 (Stations 20, 22, 23, 25, 26, 29, 32: chiefly of fine sand, except Station 24 with

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Table 4. *Results of SIMPER analysis. Species were ranked according to their average contributions to dissimilarity between assemblages in the Ría de Aldán. Average abundance, ratio value (dissimilarity/standard deviation) and percentage of cumulative dissimilarity were also included.*

	Average abundance	Average abundance	Average dissimilarity	Dissimilarity/ SD	Cumulative %
Groups A1–A3 (average dissimilarity: 62.11)	Group A1	Group A3			
Thracia papyracea (Poli, 1791)	0.33	103.38	3.5	3.33	5.63
Thyasira flexuosa (Montagu, 1803)	250.33	4.88	3.39	3.11	11.09
Myrtea spinifera (Montagu, 1803)	19	0.38	2.34	3.77	14.87
Tellina fabula Gmelin, 1791	0.33	25.38	1.97	1.45	18.04
Tellina donacina Linnaeus, 1758	0.33	23.88	1.91	1.82	21.12
Tellina tenuis da Costa, 1778	0	36.75	1.7	1.24	23.85
Caecum trachea (Montagu, 1803)	0	8.75	1.53	1.38	26.32
Nucula nitidosa Winckworth, 1930	18.33	1.38	1.45	1.48	28.66
Corbula gibba (Olivi, 1792)	5	0.13	1.43	2.4	30.96
Groups A2–A3 (average dissimilarity: 61.28)	Group A2	Group A3			
Parvicardium exiguum (Gmelin, 1791)	0	250.5	3.28	6.8	5.36
Venerupis senegalensis (Gmelin, 1791)	6	172	2.34	2.46	9.19
Loripes lacteus (Linnaeus, 1758)	0.13	41	1.95	2	12.36
Bittium reticulatum (da Costa, 1778)	0	44.5	1.78	5.76	15.26
Tellina fabula Gmelin, 1791	25.38	0.5	1.59	1.46	17.86
Thracia papyracea (Poli, 1791)	103.38	47.5	1.55	1.87	20.38
Gibbula cineraria (Linnaeus, 1758)	0.13	12	1.45	3.32	22.75
Chamelea striatula (da Costa, 1778)	34.5	1.5	1.45	2.48	25.11
Caecum trachea (Montagu, 1803)	8.75	131	1.43	1.52	27.44
Leptochiton cancellatus (Sowerby, 1840)	3.5	28.5	1.39	1.7	29.7
*Turboella radiata (*Philippi, 1836)	0.5	47	1.33	1.86	31.87
Groups A3–B1 (average dissimilarity: 64.48)	Group A3	Group B1			
Goodallia triangularis (Montagu, 1803)	2	71	3.56	1.02	5.52
*Chamelea striatula (*da Costa, 1778)	34.5	0	3.35	3.98	10.71
Mysella bidentata (Montagu, 1803)	204	2	3.02	1.35	15.39
Tellina fabula Gmelin, 1791	25.38	0	2.63	1.58	19.47
*Dosinia exoleta (*Linnaeus, 1758)	14	0	2.55	3.51	23.42
Tellina tenuis da Costa, 1778	36.75	20.5	2.51	1.5	27.32
Caecum trachea (Montagu, 1803)	8.75	10	2.1	1.54	30.57
Groups A3–B2 (average dissimilarity: 67.70)	Group A3	Group B2			
Goodallia triangularis (Montagu, 1803)	2	75.83	2.63	1.67	3.88
Caecum glabrum (Montagu, 1803)	0.38	111.5	2.49	1.33	7.55

(*Continued*)

coarse sediments); and Group B, with subgroups B1 (Stations 9, 21: fine/medium sand), B2 (Stations 3, 6, 12, 17, 18, 19: coarse sediments) and B3 (Stations 2, 7, 8, 13, 14: mainly medium sand). The MDS ordination (Figure 3) showed similar results to those of the dendrogram, with an acceptable stress value (0.14).

Results of the SIMPER analysis are shown in Table 4. *Thracia papyracea* (Poli, 1791) and *Thyasira flexuosa* (Montagu, 1803) explained most of the dissimilarity between Groups A1 and A3. *Parvicardium exiguum* (Gmelin, 1791) and *Venerupis senegalensis* (Gmelin, 1791) contributed greatly to differentiate A2 from A3, and *G. triangularis* and *Caecum glabrum* differentiate Group A3 from B2. Group A3 differed from Group B1 due to *M. bidentata*, *Chamelea striatula* (da Costa, 1778) and *G. triangularis*. *Caecum glabrum* differentiates Group B2 from B1, and *G. triangularis* and *Diplodonta rotundata* (Montagu, 1803) differentiate Group B1 from B3. Differences between Groups B2 and B3 were mainly due to *C. glabrum*.

The BIO-ENV procedure (Table 5) showed that the best combinations of environmental variables through the highest correlations with faunistic data were those composed of very coarse sand/very fine sand/depth/redox potential (Eh)/TOM. Very fine sand and silt/clay were the variables with the best values when each variable was considered alone (ρ_w: 0.316 and 0.315 respectively).

The forward selection of CCA selected silt/clay, depth, sort coefficient, fine sand and gravel as the variables explaining most of the variance in the species data (P=0.005). Axes I and II were the most important in CCA ordination, accumulating 28.4% of the species variance and 35.6% of species–environment variance (Table 6). Content of very fine sand, silt/clay, coarse sand, TOM, Eh and median showed a strong correlation with axis I. The correlations with the other axes, however, were less significant. Sampling stations appeared distributed from the left to the right of axis I following an

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Table 4. *(Continued)*.

	Average abundance	Average abundance	Average dissimilarity	Dissimilarity/SD	Cumulative %
Groups A3–B2 (average dissimilarity: 67.70)	Group A3	Group B2			
Abra alba (Wood, 1802)	12.88	0	2.15	6.73	10.73
Caecum trachea (Montagu, 1803)	8.75	115.33	2.14	1.55	13.89
Tellina fabula Gmelin, 1791	25.38	0	2.12	1.63	17.02
Chamelea striatula (da Costa, 1778)	34.5	2.67	2.07	2.06	20.07
Clausinella fasciata (da Costa, 1778)	0	9.67	1.76	2.06	22.67
Nassarius reticulatus (Linnaeus, 1758)	6.88	0.33	1.66	2.53	25.12
Tellina tenuis da Costa, 1778	36.75	0	1.6	1.24	27.48
Thracia papyracea (Poli, 1791)	103.38	8.5	1.53	2.09	29.73
Retusa mammillata (Phillippi, 1836)	0	6.83	1.51	1.85	31.97
Groups B1–B2 (average dissimilarity: 74.85)	Group B1	Group B2			
Goodallia triangularis (Montagu, 1803)	71	75.83	3.43	1.59	4.58
Caecum glabrum (Montagu, 1803)	0	111.5	3.42	1.23	9.15
Nassarius reticulatus (Linnaeus, 1758)	14.5	0.33	3.41	4.3	13.7
Parvicardium scabrum (Philippi, 1844)	0	13.17	3.05	5.08	17.78
Caecum trachea (Montagu, 1803)	10	115.33	3.03	1.16	21.83
Bela nebula (Montagu, 1803)	3.5	0	2.74	8.03	25.5
Diplodonta rotundata (Montagu, 1803)	0	6.5	2.58	3.26	28.94
Mytilidae sp.	0	5.67	2.51	4.91	32.3
Groups B1–B3 (average dissimilarity: 62.56)	Group B1	Group B3			
Diplodonta rotundata (Montagu, 1803)	10.4	0	4.22	4.1	6.75
Goodallia triangularis (Montagu, 1803)	30.6	71	4	2.19	13.15
Dosinia exoleta (Linnaeus, 1758)	9	0	3.96	3.85	19.47
Montacuta ferruginosa (Montagu, 1808)	0	3	3.25	5.09	24.66
Caecum trachea (Montagu, 1803)	18.8	10	3.1	1.2	29.62
Lutraria lutraria (Linnaeus, 1758)	0	2	2.94	9.24	34.32
Groups B2–B3 (average dissimilarity: 56.94)	Group B2	Group B3			
Caecum glabrum (Montagu, 1803)	0.2	111.5	2.97	1.32	5.22
Mysella bidentata (Montagu, 1803)	0	15	2.75	3.63	10.05
Nassarius reticulatus (Linnaeus, 1758)	5.4	0.33	2.55	2.56	14.52
Parvicardium scabrum (Philippi, 1844)	0.2	13.17	2.36	2.44	18.67
Thracia papyracea (Poli, 1791)	55.4	8.5	2	1.88	22.17
Dosinia exoleta (Linnaeus, 1758)	9	4.67	1.85	1.42	25.42
Goodallia triangularis (Montagu, 1803)	30.6	75.83	1.76	1.16	28.5
Leptochiton cancellatus (Sowerby, 1840)	0.2	8.83	1.66	1.68	31.42

increase in content of fine sand and silt/clay (Figure 4). Thus, the different analysis suggested that the distribution of fauna in the study area is mainly related to grain size gradients.

Description of assemblages

The dominant species of each assemblage determined by the different multivariate techniques and their constancy and fidelity index values are shown in Table 7 and in Figure 1.

Group A1 has a muddy bottom and a high TOM content. The assemblage is numerically dominated by *T. flexuosa*, *M. bidentata*, *Abra alba* (Wood, 1802) and *Nucula nitidosa* Winckworth, 1930. This assemblage was characterized by the presence of *Odostomia acuta* Jeffreys, 1848, *Abra nitida* (Müller, 1776) and *Aporrhais pespelecani* (Linnaeus, 1758) (exclusive species), *Corbula gibba* (Olivi, 1792) and *Tellina serrata* Brocchi, 1814 (elective species). The dominance of some species affected diversity (2.00–2.26) and evenness (0.46–0.59) values.

Group A2 was characterized by its muddy sand and shallowest bottoms. This group has the higher total abundance per station and had a lower content of carbonates. The most abundant species were *P. exiguum*, *V. senegalensis* and *M. bidentata*. In spite of their common muddy nature, Station 33 was found to be poorer than Station 34 in terms of total abundance. This situation could be due to the more heterogeneous nature of the latter. Other characteristic species were *Bittium reticulatum* (da Costa, 1778), *Loripes lacteus* (Linnaeus, 1758) or *Lucinoma borealis* (Linnaeus, 1767).

Group A3 mainly comprised fine sandy stations, with higher values of carbonates. This assemblage has the highest total abundance value. Dominant species in terms of abundance were *M. bidentata*, *Thracia papyracea*, and in lower numbers *Tellina tenuis* da Costa, 1778 and *Chamelea striatula*. Other characteristic species were *Phaxas pellucidus* (Pennant, 1777) (elective) and *Tellina fabula* Gmelin, 1791 (preferential).

Table 5. *Best combinations of variables obtained through BIO-ENV analysis according to the values of the Spearman's rank correlation (ρ_w) for the Ría de Aldán.*

Number of variables	Correlation ρ_w	Best variable combination
5	0.580	VCS–VFS–depth–Eh–TOM
5	0.574	VCS–VFS–silt/clay–depth–Eh
5	0.569	GR–VFS–depth–Eh–TOM
5	0.568	FS–VFS–silt/clay–depth–Eh
5	0.567	FS–VFS–depth–Eh–TOM
5	0.563	GR–VFS–silt/clay–depth–Eh
5	0.561	GR–CS–VFS–silt/clay–depth
4	0.557	GR–VFS–silt/clay–depth
4	0.553	VCS–VFS–silt/clay–depth–Eh
4	0.552	GR–VFS–depth–TOM
3	0.525	VFS–depth–Eh
3	0.525	VFS–silt/clay–depth
3	0.524	VFS–depth–TOM
2	0.458	Silt/clay–GR
2	0.458	FS–silt/clay
2	0.45	VFS–Eh
1	0.384	VFS
1	0.354	Silt/clay
1	0.255	TOM
1	0.254	CS
1	0.232	FS
1	0.228	Q_{50}
1	0.217	Depth
1	0.206	Eh
1	0.188	S_0
1	0.182	Carb
1	0.177	VCS
1	0.176	MS
1	0.153	pH
1	0.119	GR
1	−0.05	Sed temp
1	−0.084	Bottom temp
1	−0.123	Surf temp
All 17 variables:	0.424	

Bottom temp, bottom temperature; carb, carbonates; CS, coarse sand; Eh, redox potential; FS, fine sand; GR, gravel; MS, medium sand; Q_{50}, median grain size; S_0, sort coefficient; sed temp, sediment temperature; surf temp, surface temperature; TOM, total organic matter; VCS, very coarse sand; VFS, very fine sand.

Table 6. *Summary of canonical correspondence analysis for the Ría de Aldán.*

Axes	I	II	III	IV	Total inertia
Eigenvalues	0.497	0.392	0.290	0.204	3.129
Species–environment correlations	0.976	0.985	0.961	0.990	
Cumulative percentage variance					
of species data	15.9	28.4	37.7	44.2	
of species–environment relation	19.9	35.6	47.1	55.3	
Sum of all unconstrained eigenvalues					3.129
Sum of all canonical eigenvalues					2.500

In Group B1 sediments had high carbonate values. Station 9 has fine sandy bottoms, while Station 21 has medium sandy bottoms, and higher values of diversity and evenness than in the other stations. The dominant species in this assemblage was *G. triangularis*. The only characteristic species in terms of fidelity were *Nassarius reticulatus* (Linnaeus, 1758), *Thracia papyracea* and *Tellina donacina* Linnaeus, 1758.

Group B2 has high values of diversity and evenness, and its sediment type is of coarse sand. This assemblage is characterized by high abundances of *Caecum glabrum*, *C. trachea* and *G. triangularis*, as well as by the presence of

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Table 7. *Median dominance (%), constancy and fidelity values for dominant species in each assemblage of the Ría de Aldán.*

	A1	A2	A3	B1	B2	B3
Leptochiton cancellatus (Sowerby, 1840)		2.22(Con/Acc)			2.30(Con/Occ)	
Turboella radiata (Philippi, 1836)		3.67(Con/Ele)				
Caecum imperforatum (Kanmacher, 1798)		1.22(Com/Occ)	1.59(VC/Occ)	6.78(Com/Occ)	26.49(Con/Occ)	11.65(Con/Occ)
Caecum glabrum (Montagu, 1803)					25.61(VC/Ele)	
Bittium reticulatum (da Costa, 1778)		3.47(Con/Exc)				
Calyptraea chinensis (Linnaeus, 1758)		2.54(Con/Acc)	1.59VC/Occ)			
Lunatia alderi (Forbes, 1838)						1.49(Con/Occ)
Nassarius reticulatus (Linnaeus, 1758)			1.25(Con/Occ)	9.84(Con/Occ)		3.35(FC/Occ)
Mangelia nebula (Montagu, 1803)				2.37(Con/Acc)		
Retusa mammillata (Phillippi, 1836)					1.57(Con/Ele)	
Retusa truncatula (Bruguière, 1792)		2.46(Com/Occ)				
Cylichna cylindracea (Pennant, 1777)				1.17(Con/Acc)		
Nucula nitidosa Winckworth, 1930	2.70(VC/Acc)					
Mytilidae sp.	1.42(VC/Acc)				1.32(Con/Occ)	
Loripes lacteus (Lamarck, 1818)		3.20(Con/Ele)				
Myrtea spinifera (Montagu, 1803)	2.80(Con/Pre)					
Thyasira flexuosa (Montagu, 1803)	36.85(Con/Pre)					
Diplodonta rotundata (Montagu, 1803)					1.49(Con/Acc)	6.44(Con/Acc)
Mysella bidentata (Montagu, 1803)	29.59(Con/Occ)	12.48(Con/Occ)	36.35(Con/Occ)	1.36(Com/Occ)	3.45(Con/Occ)	
Tellimya ferruginosa (Montagu, 1808)				2.34(Con/Pre)		
Digitaria digitaria (Linnaeus, 1758)				1.17(Com/Acc)		
Goodallia triangularis (Montagu, 1803)				48.14(Com/Occ)	17.42(Con/Acc)	18.96(Con/Acc)
Parvicardium exiguum (Gmelin, 1791)		19.54(Con/Ele)				
Parvicardium scabrum (Philippi, 1844)			1.92(VC/Occ)		3.25(Con/Acc)	
Lutraria lutraria (Linnaeus, 1758)				1.36(Con/Acc)		
Tellina donacina (Linnaeus, 1758)		1.76(Con/Occ)	4.33(Con/Occ)	4.75(Con/Occ)	2.72(Con/Occ)	9.29(Con/Occ)
Tellina fabula (Gmelin, 1791)			4.60(Con/Ele)			
Tellina tenuis (da Costa, 1778)		5.38(Con/Acc)	6.66(VC/Acc)	13.90(Com/Occ)		
Abra alba (Wood, 1802)	18.55(Con/Occ)	3.94(Con/Occ)	2.33(Con/Occ)			
Chamelea striatula (da Costa, 1778)	1.23(Con/Occ)		6.25(Con/Occ)			
Clausinella fasciata (de Costa, 1778)					2.23(Con/Ele)	
Dosinia exoleta (Linnaeus, 1758)		4.25(Con/Occ)	2.54(Con/Occ)		1.72(Com/Occ)	5.58(Con/Occ)
Venerupis senegalensis (Gmelin, 1791)		13.42(Con/Acc)	1.87 (FC/Aci)			
Thracia papyracea (Poli, 1791)		3.75(Con/Occ)	18.73(Con/Occ)	5.85(Con/Occ)	1.95(Con/Occ)	34.32(Con/Occ)

Acc, accessory; Aci, accidental; Com, common; Con, constant; Ele, elective; Exc, exclusive; FC, few common; Occ, occasional; Pre, preferential; VC, very common.

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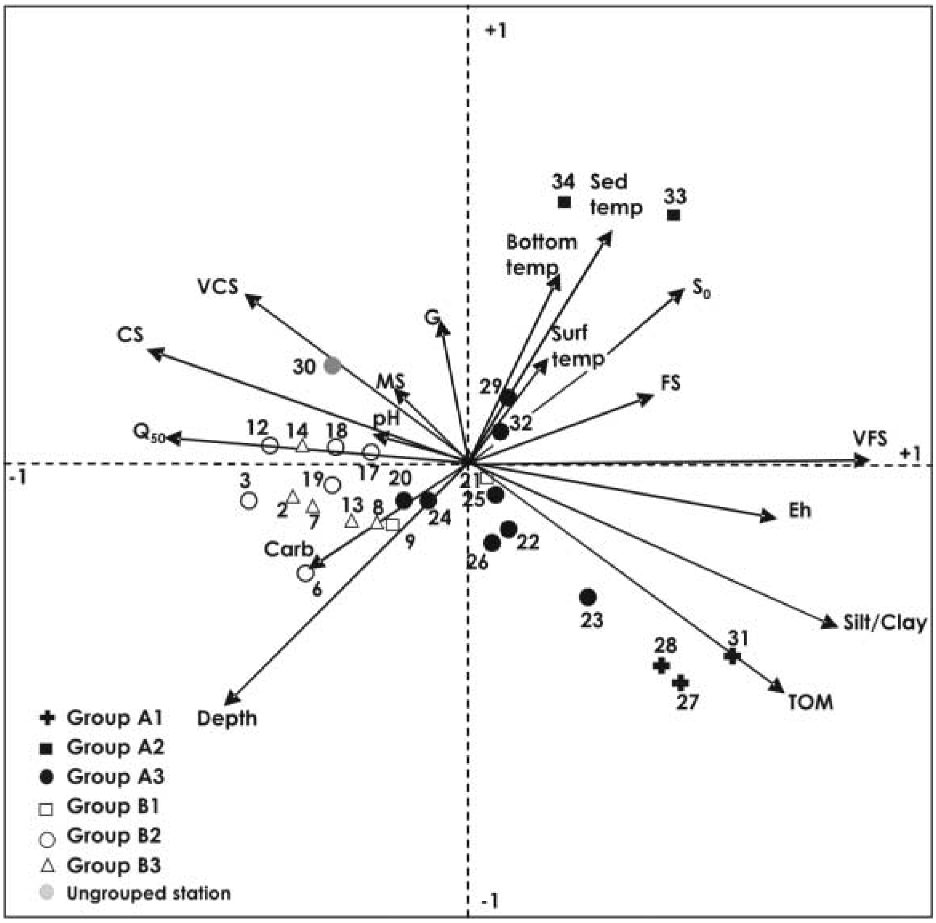

Figure 4. Canonical correspondence analysis ordination of stations and environmental variables relative to axes I and II for the Ría de Aldán.

Arcopagia crassa Pennant, 1777, *Retusa mammillata* (Philippi, 1836) and *Clausinella fasciata* (da Costa, 1778).

Group B3 included several species shared with Group B1 and B2, namely *G. triangularis*, *Thracia papyracea* and *Caecum trachea*. The lack of exclusive species and its global faunistic composition indicated transitional bottoms between coarser sandy stations and finer sandy stations.

DISCUSSION

The primary determining factor in the structuring of our communities seemed to be the grain size gradient, which was characterized by an increase in finer sandy fractions from the mouth of the ría towards the inner margins. The granulometry of the bottom is a consequence of the hydrodynamic regime in Galician rías: the presence of coarser sediments in the mouth is due to a stronger hydrodynamism (Troncoso et al., 1993) while a deposition of finer fractions occurs in inner, sheltered areas.

The molluscan assemblages in the Ría de Aldán determined by the different multivariate approaches (Figure 1) could be defined using the classic terms of 'community' and 'facies' (Petersen, 1918; Thorson, 1957). Thus, Group B 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 Ría da Coruña (López-Jamar & Mejuto, 1985), Ría de Ares-Betanzos (Troncoso et al., 1993) and Ensenada de Baiona (Moreira et al., 2005). These bottoms have clean coarse sediments with a high content of biogenic carbonates and are located at the outer areas of the rías where the hydrodynamism is stronger and does not allow the deposition of finer particles (Nombela et al., 1987). Although the studied area shared the presence of a number of typical species present in these bottoms (*Arcopagia crassa*, *Clausinella fasciata*), the high dominance of *Goodallia triangularis* would define the presence of a facies of this community mainly in Group B2 (*G. triangularis*, *Caecum trachea* and *Retusa mamillata* (Philippi, 1836)). This facies has been reported in Ensenada de Baiona (Moreira et al., 2005).

The fauna present in Group A3 agrees with the description of the '*Venus gallina* community' (Thorson, 1957), corresponding to the fine sand bottoms of the centre and inner margins of the ría in which the bivalve *Chamelea striatula* shows its greater abundance. There is an important presence of species which shows preference for fine sandy bottoms (*Mysella bidentata* and *Thracia papyracea*). In shallower stations of A3, the *Venus* community gave way to the *Tellina* community by a decrease in the abundance of *C. striatula* and *Thracia papyracea* and by an increase in the numbers of *Tellina tenuis* and *T. fabula*.

Even though Group A has some species typical of the '*Venus gallina* community', there is an important presence of several other species which show preference for the muddier sediments of Group A1 (*Abra alba*, *A. nitida*, *Nucula nitidosa*, *Corbula gibba*, *M. bidentata*). Thus, Group A1 could be considered as a mix between the already mentioned community and the '*Abra alba* community' of Petersen (1918). This situation agrees with the results shown by Sánchez-Mata & Mora (1999) for all groups of macrofauna in the Ares sector of the Ría Ares-Betanzos. On the other hand, the '*Abra alba*' community has been reported along European coasts in different types of muddy bottoms (Glémarec, 1964; Rees & Walker, 1983; Gentil et al., 1986; Lastra et al., 1988, Carpentier et al., 1997; Thiébaut et al., 1997) as well as in Galician rías (Cadée, 1968; Olabarría et al., 1998; Sánchez-Mata & Mora, 1999; Moreira et al., 2005; Troncoso et al., 2005).

The facies corresponding to Group A2 is determined by the dominance of *Parvicardium exiguum*, *Venerupis senegalensis*, *Bittium reticulatum* and *Loripes lacteus*. The last three species are present in a 'facies of *Zostera noltii*' in the Ensenada do Baño (Olabarría, 1995). In our case we do not have *Zostera noltii*, but there are seaweeds that work in the same way (food, shelter, etc.).

In general, mollusc distribution in sandy sediments of the outer and central part of the ría is similar to those observed in the Ría de Coruña (López-Jamar & Mejuto, 1985), Ensenada de Baiona (Moreira et al., 2005) and Ría de Ares-Betanzos (Troncoso et al., 2005). The transition between the '*Venus gallina*' and the '*Abra alba*' communities occurring in the inner areas of the Ría de Aldán has been also reported for several Galician rías (López-Jamar, 1981; Troncoso et al., 1993; Sánchez-Mata & Mora, 1999). Even though a number of communities or facies have been identified in the study area, we believe there is a continuum in the distribution of molluscs in the Ría de Aldán (the existence of a continuum implies that species are independently distributed along environmental gradients (Curtis, 1955)), based on the sedimentary and faunistic composition of assemblages and the distribution of dominant species, such as *M. bidentata*, *Caecum trachea*, *Thracia papyracea*, *Thyasira flexuosa* and *G. triangularis*. Differences in the abundances of these species probably reflect their ecological preferences and the environmental conditions found in the ría. Thus, co-existence or overlap between them in any given assemblage would be related to their response to the existing gradients (Mackie et al., 1995). In our case, variations in abundance of any given mollusc species across the different assemblages in Ría de Aldán would be conditioned by a grain size gradient.

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