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## Monitoring of marine benthic communities and taxonomic resolution: an approach through diverse habitats and substrates along the Southern Iberian coastline

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**Abstract** Studies conducted along the southern Iberian coastline validate macrobenthic community analyses at taxonomic levels higher than that of species. Twelve studies on littoral benthic communities, carried out by the same research team, were selected spanning both a variety of sampling strategies (spatial, temporal, spatio-temporal) and substrate/habitat types (sediment, rock, algae). In order to establish differences between the results obtained at the taxonomic levels of species, family and order, similarities among stations were calculated using Spearman's coefficient for ranges. A subset of three studies was selected to investigate possible differences in 'best-explaining' environmental variables with taxonomic level. The environmental variables selected at species level were the same as those found at levels of family and order. It is concluded that studies at the different levels of taxonomic resolution (species, family, order) lead to similar results both with regard to relative community distributions and the environmental variables associated with these. The importance of this result for monitoring similar benthic communities is discussed.

**Keywords** Taxonomic resolution · Benthic communities · Southern Iberian Peninsula

### Introduction

The analysis of zoobenthic communities as a tool to assess ambient water quality is a complex and fine-consuming procedure. Ideally, the analysis should proceed to the species level. However, in many taxa species identification is complex and laborious (see Gaston 2000, and references therein). Additionally, some taxa require specialised methods of sampling and sample treatment. With sufficient time and resources all these problems may be overcome, but unfortunately results have to be achieved within ever-shorter timescales. This has led to many instances where the more classical approaches such as physico-chemical water analyses were considered more favourable.

Ways to simplify community analyses have been studied extensively in recent years (Resh and Unzicker 1975; Stephenson and Cook 1977; Ellis 1985; Ferraro et al. 1989; Sale and Guy 1992; Smith and Simpson 1993; James et al. 1995; Somerfield and Clarke 1995; Balmford et al. 1996a, b; Vanderklift et al. 1996). The general tendency in these studies has been to analyse potential information loss when data from a taxonomic level higher than that of species were used, and to calculate the cost–benefit relationships of analyses performed at different taxonomic levels. In other studies which mainly focussed on the detection of impacts on the marine environment, it has become evident that in many groups of benthic organisms changes in community composition can be detected at levels above that of species (Herman and Heip 1988; Warwick 1988a, b; Ferraro and Cole 1990; Gray et al. 1990; Warwick et al. 1990; Warwick and Clarke 1993; De Grave and Whitaker 1999; Pagola-Carte et al. 2001; Sánchez-Moyano et al. 2004). Even where environmental perturbations were relatively weak and remained undetectable by univariate methods (such as diversity indices) at species level, multivariate analyses at higher taxonomic levels could reveal such effects (Warwick 1993). In general, the

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majority of these studies have given comparable results for different taxonomic levels. This may be due to the fact that there are substantially fewer species but nevertheless more higher taxa in the marine environment than on land (Vincent and Clarke 1995). This may contribute to a greater similarity across taxonomic groupings in marine ecosystems.

We carried out a number of studies along the southern Iberian coastline to determine temporal and spatial patterns of macrobenthic communities within a wide range of environmental conditions (natural, polluted, environmentally stressful), habitats and substrate types. In the present study, we evaluated whether the use of different degrees of taxonomic resolution (species, family and order) affects the results of ordinations and the resulting organism–environment relationships. For this purpose we selected 12 studies: 11 of them had been carried out within the Bay of Gibraltar (southern Spain) on sediment macrofauna (Estacio 1996) and on algal-associated or epiphytic fauna (Sánchez-Moyano 1996), whereas 1 study on rocky littoral macrofauna (Fa 1998) covered a larger spatial scale, the southern Iberian Peninsula. We thus wanted to include a variety of methodologies, habitats and substrate types. We evaluated whether the environmental variables explaining the observed distributions remain the same at each level of taxonomic resolution.

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## Methods

Details of the 12 studies are outlined in Fig. 1 and Table 1. Studies N1–N5 (Estacio 1996) analysed the temporal variation of macrobenthic communities at five locations within the Bay of Gibraltar, differing in environmental and granulometric characteristics, whilst study N6 (Estacio 1996) analysed the spatial distribution of sediment macrofauna within the same bay.

Study N7 was carried out within the Saladillo Harbour, south of Algeciras, an area with high levels of urban and sewage discharge (Estacio et al. 1997); the effects of these effluents on the macrofauna were compared with regard to the hydrodynamism experienced inside and outside the harbour. Study N8 was carried out to investigate the effects of algal density on the associated macrofauna in a *Caulerpa prolifera* Forskaal meadow located within the port of San Felipe, La Línea (Sánchez-Moyano 1996; Sánchez-Moyano et al. 2001a, b). Study N9 analysed the spatial variation of the epiphytic communities on the alga *Halopteris scoparia* (L.) Sauvageau within the Bay of Gibraltar as a consequence of varying environmental conditions (Sánchez-Moyano 1996; Sánchez-Moyano et al. 2000). Study N10, carried out in the estuary of the Palmones river in 1994, sought to analyse community distributions along the entire estuarine zone of influence (15 stations). Study N11, also carried out in the estuary of the Palmones river, evaluated the spatial distribution of sediment communities at

four sampling stations located at varying distances from the river mouth (one exterior and three interior stations), and included the temporal variations observed over the period 1992–1997 (Estacio et al. 1999).

Study N12 was a large-scale distributional study of the intertidal macrofauna along the southern Iberian Peninsula (Fa 1998), from Vila Nova de Milfontes on the Portuguese Atlantic coast to La Manga del Mar Menor on the Spanish Mediterranean coast, spanning an approximate distance of 1,500 km. A total of 20 different locations along the coast were sampled using a fixed belt-transect method and all macrofaunal species, their abundances and zonations were noted.

In all these studies, specimens were determined and quantified at the taxonomic levels of species, family and order as these are the most commonly used (Clarke and Warwick 2001).

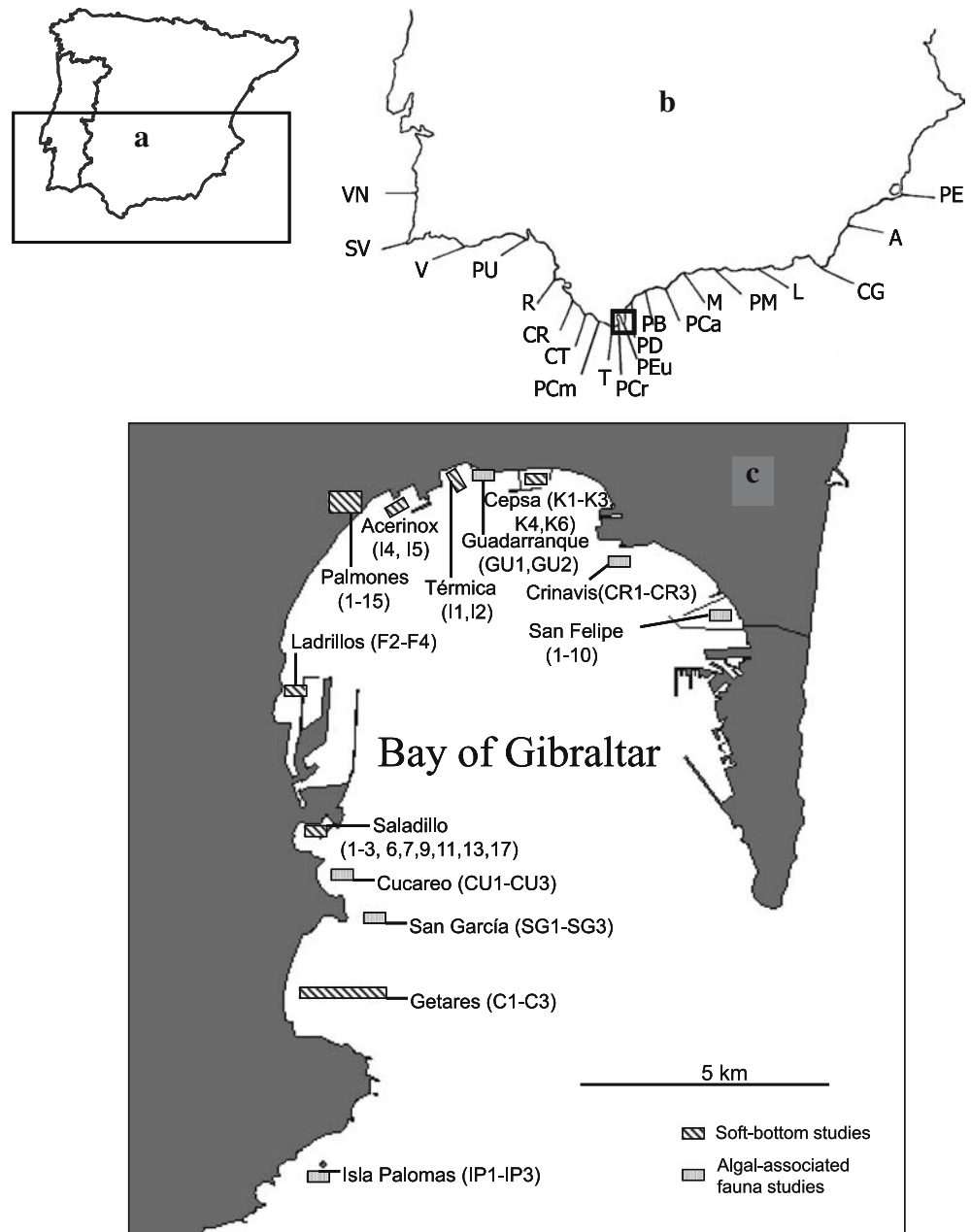
Following a root–root transformation, abundance data for each study and taxonomic level were analysed using the Bray–Curtis index of similarity (Bray and Curtis 1957). The percentage similarities obtained from the similarity matrices at each taxonomic level were contrasted within each study using Spearman's rank-correlation coefficient using the RELATE programme from the PRIMER statistical package.

Non-metric multi-dimensional scaling (nMDS) ordinations were obtained from the initial similarity matrices which allowed the visual assessment of the results obtained at each of the three taxonomic levels investigated. This analysis was selected as it is particularly sensitive to both spatial and temporal variations in community structure (Clarke 1993).

In studies N2 and N6–N12 the composition of the various taxa and their contribution to the results obtained were analysed. In each case the number of species, families and orders were quantified, as were the number of families containing only one species (unispecific) and those containing more than one species (multispecific). In the latter case the number of multispecific families dominated by a single species (>70% of the total abundance for the family) was also noted. At the level of order we recorded how many contained only a single family (unifamilial orders) and how many of these were unispecific or contained a single dominant species. In the same way the number of multifamilial orders was also quantified, again noting how many of these families were dominated by a single species each. Data on families and orders represented by either a single species or by a dominant one are expressed as percentages (*S*) of the total number of families and orders present, and as abundance percentages (*A*) of the total number of organisms at each taxonomic level.

The programme SIMPER from PRIMER was used to establish which taxa contributed to more than 70% of the differences found between groups of periods or stations following similarity analysis. These representative taxa were further analysed to quantify the percentage of unispecific or single-species dominated families and or-

**Fig. 1** **a** Map of the Iberian Peninsula; **b** sampling stations for study N12; **c** sampling zones for the studies N1–N11



ders so as to help determine the causes of the similarities between results across the three taxonomic levels.

Additionally, for studies N6, N7 and N9, we analysed the influence of the various environmental variables on the distribution of organisms at each of the three taxonomic levels. Table 2 shows the environmental variables considered in these studies. This was carried out by canonical correspondence analysis (CCA; Ter Braak 1986, 1990), a form of analysis based on a unimodal response model that constrains the ordination axes to be linear combinations of the environmental variables that maximize the dispersion (variance) of sample or species scores. In the ordinations, stations were represented as points and statistically significant environmental vari-

ables (after a Monte-Carlo permutation procedure) as arrows.

## Results

Studies on temporal variations in community composition (N1–N5; Fig. 2)

The results of the nMDS, the corresponding stress values, and the relevant Spearman rank-correlation coefficients (Table 3, study type: temporal) indicate high levels of similarity across all taxonomic levels regardless of sediment type or environmental conditions. The

**Table 1** Characteristics of the sites studied

Key	Location	Comparative elements	Site	Habitat	Study type	Zonation	Substrate	Depth (m)	Environmental perturbations	Methodology
N1	Getares Beach	Oct 1992–Sept 1993	C1	Marine	Temporal	Subtidal	Fine sand	5	None detected	Five samples/period
N2	Los Ladrillos	Aug 1992–Sept 1993	F2	Marine	Temporal	Subtidal	Mud	5	Urban waste	or station with
N3	Acerinox	Oct 1992–Sept 1993	I4	Marine	Temporal	Subtidal	Muddy sand	5	Industrial waste	an 0.05 m <sup>2</sup> van
N4	Power plant	Oct 1992–Sept 1993	II	Marine	Temporal	Subtidal	Medium-grained sand	5	Industrial waste	Veen grab
N5	CEPSA refinery	Aug 1992–Sept 1993	K4	Marine	Temporal	Subtidal	Sandy mud	5	Industrial waste	(abundance/m <sup>2</sup> ; type A)
N6	Bay of Gibraltar	Getares Saladillo Los Ladrillos	C1, C2, C3 S1 F2, F3, F4	Marine	Spatial	Subtidal	Fine sand Mud Mud, Mud, Muddy sand	5, 15, 30 5 5	Dredged Urban waste Urban waste	
		Acerinox Power plant	I4, I5 II, I2				Muddy sand Muddy sand Medium sand, muddy sand	5, 15 5, 15	Industrial waste Industrial waste	
		Cepsa	K1, K2, K3, K4, K6				Coarse sand, 1, 2 and 3; muddy sand, 4,6	5, 15, 30, 5, 5	Industrial waste	
N7	El Saladillo Harbour	Internal area External area	E1, E2, E3, E6, E7 E9, E11, E13, E17	Marine	Spatial	Subtidal	Mud	3	Urban waste	
N8	San Felipe Wharf	Coverage 25–50% Coverage 50–75% Coverage > 75%	4, 10 3, 5, 7, 9 1, 2, 6, 8	Marine	Spatial	Subtidal	Coarse sand <i>Caulerpa prolifera</i>	5, 5, 5, 8 5	Urban waste	Five 15x15x5 cm <sup>3</sup> quadrats/station (abundance/m <sup>2</sup> )
N9	Bay of Gibraltar	Crinavis Guadarranque Cucareo San García Isla Palomas Ext–Int. gradient	CR1, CR3 GU1, GU2 CU1, CU2, CU3 SG1, SG2, SG3 IP1, IP2, IP3 15 stations	Marine	Spatial	Subtidal	<i>Halopteris scoparia</i>	5, 5 3, 5 3,4,5 5, 8, 10 5, 8, 10 0.5–4	Urban/industrial Urban/industrial Urban waste None detected None detected Urban/industrial	Four replicate samples of algae/station (abundance/100 g dry weight of algae) Type A
N10	Palmones Estuary	Ext–Int. gradient	15 stations	Estuarine	Spatial	Subtidal	Variable		Urban/industrial	Type A
N11	Palmones Estuary	Ext–Int., 92–97	1, 2, 3, 4	Estuarine	Spatial/ temporal	Subtidal	Variable	0.5–4	Urban/industrial	Type A
N12	Southern Iberian Peninsula	Atlantic–Mediterranean gradient	20 stations	Marine	Spatial	Intertidal	Rock	0	Variable	Twelve 1x0.25 m <sup>2</sup> gridded quadrats along a fixed-belt transect

**Table 2** Environmental variables considered in the studies N6, N7 and N9

Variable		N6	N7	N9
Sediment	Granulometry	+	+	-
	Organic carbon	+	+	-
	Organic content	+	+	-
	Total nitrogen	+	+	-
	Carbonates	+	+	-
	Hydrocarbons	-	+	-
	Oils	-	+	-
	Phosphates	-	+	-
	Humectation	-	+	-
	Hydrodynamism	+	-	+
Water	$T(^{\circ})$ max.-min.	+	+	+
	Sedimentation load	+	-	+
	Organic materials in sedimentation	+	-	+
	Solids in suspension	+	-	+
	Organic materials in suspension	+	-	+
	Nutrients	-	+	-
	Chlorophylls	-	+	-
	pH	-	+	-
	Visibility	-	+	-
	DO and BOD	-	+	-
	Hydrocarbons-oils	-	+	-
	Agitation	-	+	-

highest correlation coefficients were always obtained between species and families, and the lowest between species and orders.

Studies on spatial variations in community composition (N6–N10 and N12; Fig. 2)

Again high similarities were obtained at all three levels of taxonomic resolution with regard to the nMDS, stress values and Spearman's rank-correlation coefficients (Table 3, study type: spatial) which furthermore are of the same order as those obtained for the temporal studies. As for studies N1–N5, the highest correlations were generally obtained between species and families, and the lowest between species and orders.

Studies on spatio-temporal variations in community composition (N11; Fig. 2)

The nMDS ordinations and stress values obtained for both stations and sampling periods in the Palmones estuary, again show high levels of similarity at each of the taxonomic resolutions, as evidenced by the Spearman's rank-correlation coefficient between matrices, although in this case the highest correlation coefficients were obtained between species and order (Table 3, study type: spatio-temporal).

Composition and abundance of taxa at different taxonomic levels

The results of studies N2 and N6–N12 show that there were generally more single-species than multispecies

families (N6 being the only exception). Moreover, a large proportion of multispecies families were dominated by a single species that accounted for over 70% of the total abundance (Table 4). Families containing either a single or overwhelmingly dominant species comprised 71–96% of all the families present, with abundances ranging from 66 to 99% of the total number of collected organisms.

The number of single-family orders was also higher than that of orders encompassing two or more families (except for studies N7, N9 and N11—see Table 5). Within these single-family orders, a great number were unispecific or dominated by a single species, and even in multifamilial orders, the greater number corresponded to single-species dominated groups. Thus, single-species and/or single-species dominated orders comprised between 66 and 87% of the total number of orders, with abundances ranging from 34 to 99% of the total abundances.

Contribution of the various taxa to similarity

Using the programme SIMPER (from the PRIMER package), we obtained in each case the taxa that best discriminated between the groups of stations or sampling periods identified in the multivariate analyses.

Unispecific and single-species dominated families were superior in numbers (79.6–93.1%; Table 6). A similar result was found for orders (range 55.5–80%).

Relationship between environmental variables and taxonomic resolution

For study N6 (infaunal macrobenthic distributions in the Bay of Gibraltar) the CCA indicated a similar distribution of stations independent of taxonomic level (Fig. 3a). The environmental variables that best explained the observed community distributions were the same at all taxonomic levels, although one factor, depth, had no influence at the level of order. At all three taxonomic levels, stations clustered according to one of three environmental variables: those influenced by clay and organic carbon content (E1, F2, F3, and F4), those where the sediment had a high sand content (C1, C2, C3 I1 and I4), and finally stations that had high levels of coarse material and carbonates (K1, K2, K3 and K4).

The same pattern was found in study N7, carried out in the Saladillo Harbour. High similarities were obtained among CCA ordinations at different taxonomic levels (Fig. 3b): stations located closest to sewage effluents within the harbour (1, 2 and 3), separated from those more distant from the pollution foci (6 and 7) or located outside the harbour (9, 11, 13 and 17). The environmental variables that best explained the community distributions were the same for all three taxonomic categories. However, with decreasing taxonomic resolution the degree of differentiation between the more



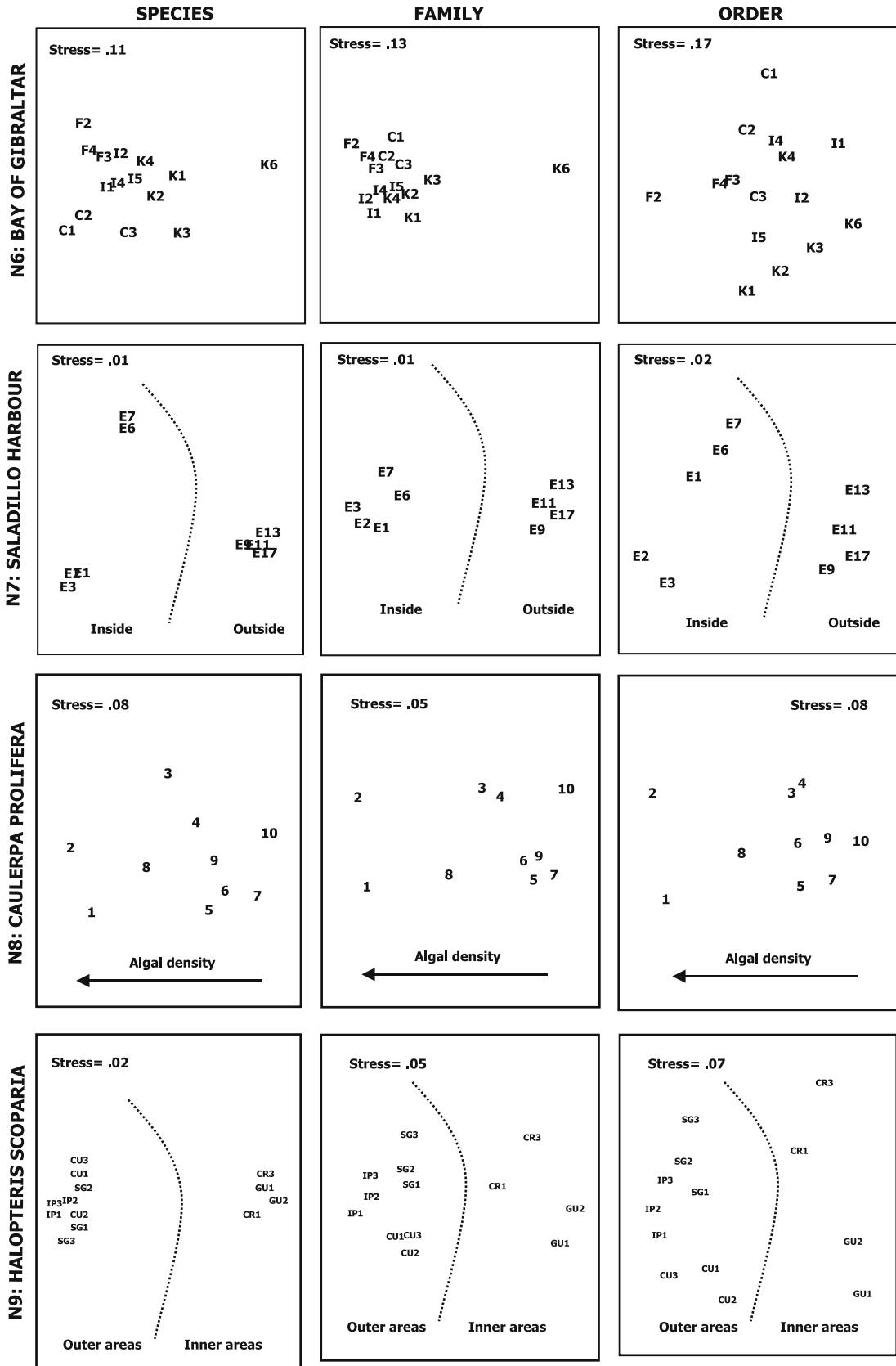
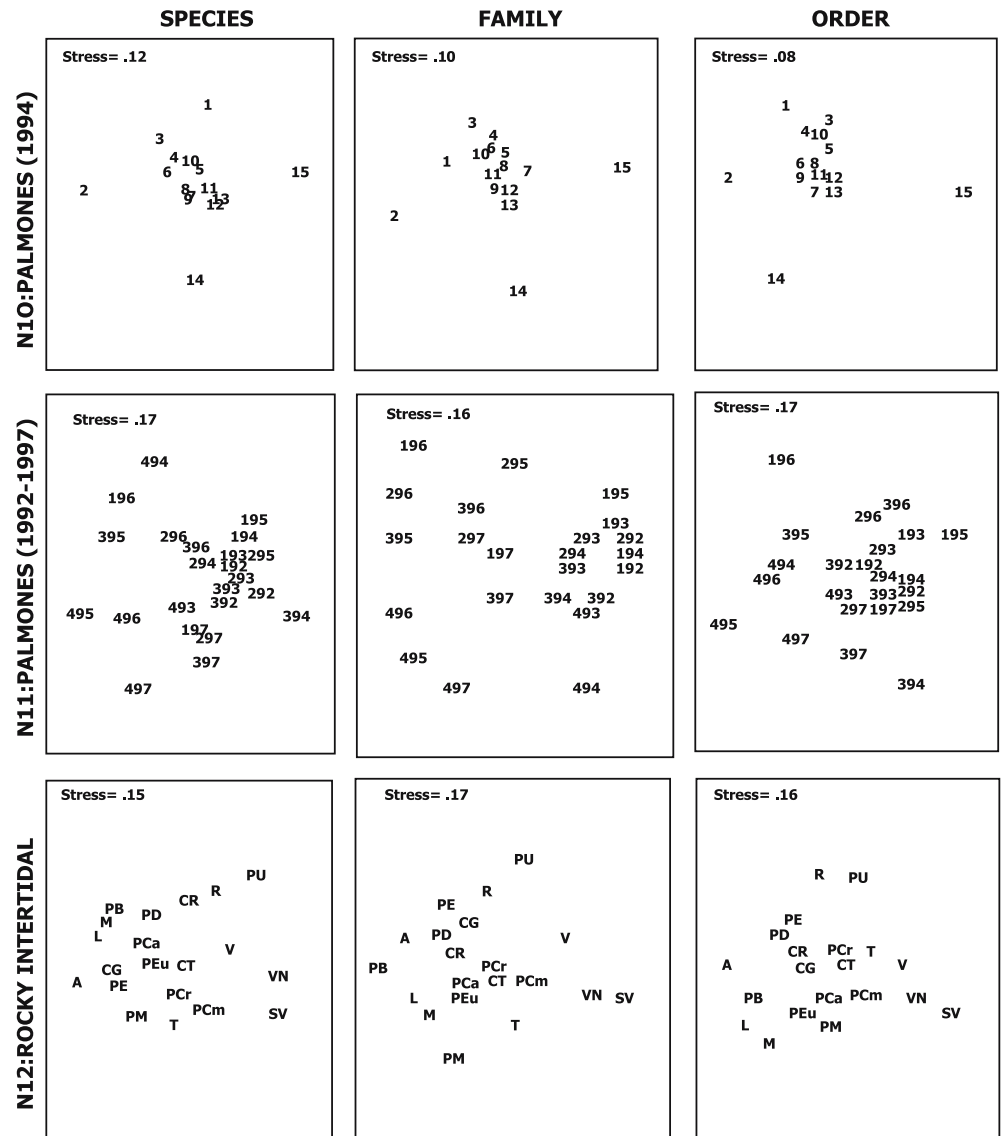


Fig. 2 (Contd.)



Fig. 2 (Contd.)



abundances were aggregated under a single taxon blurring the difference found at the species level.

In the CCA ordinations for the spatial variation of epiphytes on *Halopteris scoparia* (study N9: Fig. 3c), all ordinations showed the same separation of stations along axis 1. Stations located at the more external zones of the Bay (IP—Palomas Island, SG—San García Point and CU—Cucareo inlet) were separated from those located more interiorly (GU—Guadarranque, CR—Crinavis shipyard). The external zones are exposed to higher levels of hydrodynamism and water renewal due to their proximity to the strong currents in the Straits of Gibraltar, whilst in the inner part of the Bay, lower levels of water movement, coupled with contamination from urban and port areas, industries and river estuaries serve to differentiate the sites. At the level of family and order, external stations were grouped closer to each other leading to greater discrimination between internal zones. As in study N6, differences that were apparent at the

species level, were blurred at higher taxonomic levels. Nonetheless, the responses at different taxonomic levels were, in general terms, similar, although at the level of order hydrodynamism was found to have no determining influence.

## Discussion

In all evaluated studies, which covered a diverse spectrum of habitats, environmental conditions, coastal zones and substrate types, the results obtained at different taxonomic levels were very similar. The environmental variables identified as primary structuring factors in the selected studies (N6, N7 and N9) were the same across different taxonomic levels, although there was some information loss at the level of order and family.

The potential importance of alternative taxonomic levels other than that of species has been treated previ-



**Table 3** Correlations between results obtained at each of the three taxonomic levels for all of the studies

Study number: location (substrate type)		Pairings	<i>N</i>	<i>R</i> (Spearman's)	<i>P</i>
Study type: temporal	N1: Getares (sta. C1) (fine sand)	Species–Family	66	0.846	< 0.0001
		Family–Order	66	0.774	< 0.0001
		Species–Order	66	0.658	< 0.0001
	N2: Los Ladrillos (sta. F2) (mud)	Species–Family	78	0.953	< 0.0001
		Family–Order	78	0.911	< 0.0001
		Species–Order	78	0.883	< 0.0001
	N3: Acerinox (sta. I4) (mud/sand)	Species–Family	66	0.929	< 0.0001
		Family–Order	66	0.776	< 0.0001
		Species–Order	66	0.762	< 0.0001
	N4: Guadarranque (sta. I1) (medium-grained sand)	Species–Family	91	0.865	< 0.0001
		Family–Order	91	0.785	< 0.0001
		Species–Order	91	0.751	< 0.0001
	N5: Cepsa (sta. K4) (sandy mud)	Species–Family	91	0.905	< 0.0001
		Family–Order	91	0.785	< 0.0001
		Species–Order	91	0.751	< 0.0001
Study number: location (habitats–substrates)		Pairings	<i>N</i>	<i>R</i> (Spearman's)	<i>P</i>
Study type: spatial	N6: Bay of Gibraltar (marine–sediment)	Species–Family	120	0.94	< 0.0001
		Family–Order	120	0.86	< 0.0001
		Species–Order	120	0.82	< 0.0001
	N7: Saladillo Harbour (marine–sediment)	Species–Family	36	0.987	< 0.0001
		Family–Order	36	0.955	< 0.0001
		Species–Order	36	0.952	< 0.0001
	N8: <i>Caulerpa prolifera</i> meadows (marine–algae)	Species–Family	45	0.960	< 0.0001
		Family–Order	45	0.924	< 0.0001
		Species–Order	45	0.861	< 0.0001
	N9: <i>Halopteris scoparia</i> meadows (marine–algae)	Species–Family	78	0.982	< 0.0001
		Family–Order	78	0.927	< 0.0001
		Species–Order	78	0.909	< 0.0001
	N10: Palmones Estuary (1994) (Estuarine–sediment)	Species–Family	105	0.974	< 0.0001
		Family–Order	105	0.961	< 0.0001
		Species–Order	105	0.933	< 0.0001
N12: Southern Iberian coastline (intertidal–rock)	Species–Family	190	0.860	< 0.0001	
	Family–Order	190	0.906	< 0.0001	
	Species–Order	190	0.770	< 0.0001	
Study number: area (period)		Pairings	<i>N</i>	<i>R</i> (Spearman's)	<i>P</i>
Study type: spatio-temporal	N11: Palmones Estuary (1992–1997)	Species–Family	253	0.66	< 0.0001
		Family–Order	253	0.58	< 0.0001
		Species–Order	253	0.79	< 0.0001

**Table 4** Number of unispecific and multispecific families in the selected studies

Study	Unispecific families	Multispecific families (families species-dominant)	<i>S</i> (%)	<i>A</i> (%)
N2	39	23 (16)	88	90
N6	64	92 (47)	71	86
N7	39	27 (22)	92	98
N8	62	23 (20)	96	66
N9	92	46 (36)	93	79
N10	49	19 (9)	84	97
N11	57	25 (15)	88	97
N12	39	15 (10)	91	99

Figures in brackets refer to the number of families with a single dominant species

*S* Percentage of unispecific and single-species dominated families, *A* percentage of abundance of unispecific and single-species dominated families

**Table 5** Number of unifamilial orders (figures in brackets refer to unispecific or single-species dominated) and multifamilial (figures in brackets refer to orders dominated by a single species) in the selected studies

Study	Unifamilial order (unispecific-dominant)	Multifamilial order (ordered species-dominant)	<i>S</i> (%)	<i>A</i> (%)
N2	19 (12)	11 (8)	66	78
N6	28 (26)	23 (15)	80	52
N7	10 (10)	14 (11)	87	96
N8	21 (19)	13 (7)	76	42
N9	20 (15)	23 (11)	60	34
N10	23 (19)	11 (7)	76	97
N11	16 (15)	16 (7)	69	91
N12	16 (13)	13 (9)	76	99

*S* Percentage of unispecific and single-species dominated orders, *A* percentage of abundance of unispecific and single-species dominated orders

**Table 6** Percentage of unispecific or single-species dominated families and orders that contribute to differentiate ( $\geq 70\%$ ) the groups highlighted by similarity analysis

Study	Family (%)	Order (%)
N2	91.3	69.2
N6	81.8	76.9
N7	93.1	72.7
N8	92.4	77.2
N9	79.6	73.9
N10	88.8	80
N11	81.5	55.5
N12	75	62.5

ously by numerous authors and has been tested in a variety of habitats, both terrestrial and marine, and on selected types of organisms such as insects (Kaesler et al. 1978; Waterhouse and Farrel 1985; Cain et al. 1992), fish (Kaesler and Henricks 1979; Dawson-Shepherd et al. 1992; Sale and Guy 1992), fauna associated with algal and seagrass meadows (Smith and Simpson 1993; Sánchez-Jerez and Ramos-Esplá 1996), meiofauna (Heip et al. 1988; Herman and Heip 1988; Ferraro and Cole 1992) and benthic macrofauna (Warwick 1988a, b; Ferraro and Cole 1990, 1992; Gray et al. 1990; Warwick et al. 1990; Somerfield and Clarke 1995).

Cost–benefit analyses for studies performed at different taxonomic levels are necessary to justify the use of taxonomic levels other than species (Green 1979; Kennelly and Underwood 1984; Ferraro et al. 1989; Kingston and Riddle 1989). Clearly, studies carried out at higher taxonomic levels may lower the high costs of biological studies by reducing the degree of specialist intervention (Ferraro and Cole 1990) and the time required to analyse samples.

Moreover, identification to species level can generate greater error than that to the level of higher taxa (Ellis and Cross 1981). From biological and statistical viewpoints the limitation to higher taxa may be preferable to incorrect species identification (Green 1979). In addition, the ecology of many species is little known, so the information they provide is very limited (James et al. 1995).

The restriction to higher levels of determination may allow for extending the study area, for analysing higher numbers of samples per site and time (Warwick 1993; Warwick and Clarke 1993) or for completing a study within a much shorter time period. A further benefit of this approach is to create an alternative form of data reduction to the commonly employed method of excluding rare species (usually those contributing less than 5% of the total abundance—Clarke and Warwick 2001) prior to statistical analysis. Although not included in this study, results obtained from dataset reduction by rare species removal or by limitation to higher taxonomic levels were very similar.

The use of levels of taxonomic determination above that of species may be sufficient to detect impacts on

organisms (Edwards et al. 1975; Kaesler et al. 1978). Although Ferraro and Cole (1990) indicated that the species level would be most sensitive for the evaluation of pollution impacts, variations in abundance of macrobenthic species in response to small perturbations may be hard or impossible to detect due to the large range of variability (Stull et al. 1986).

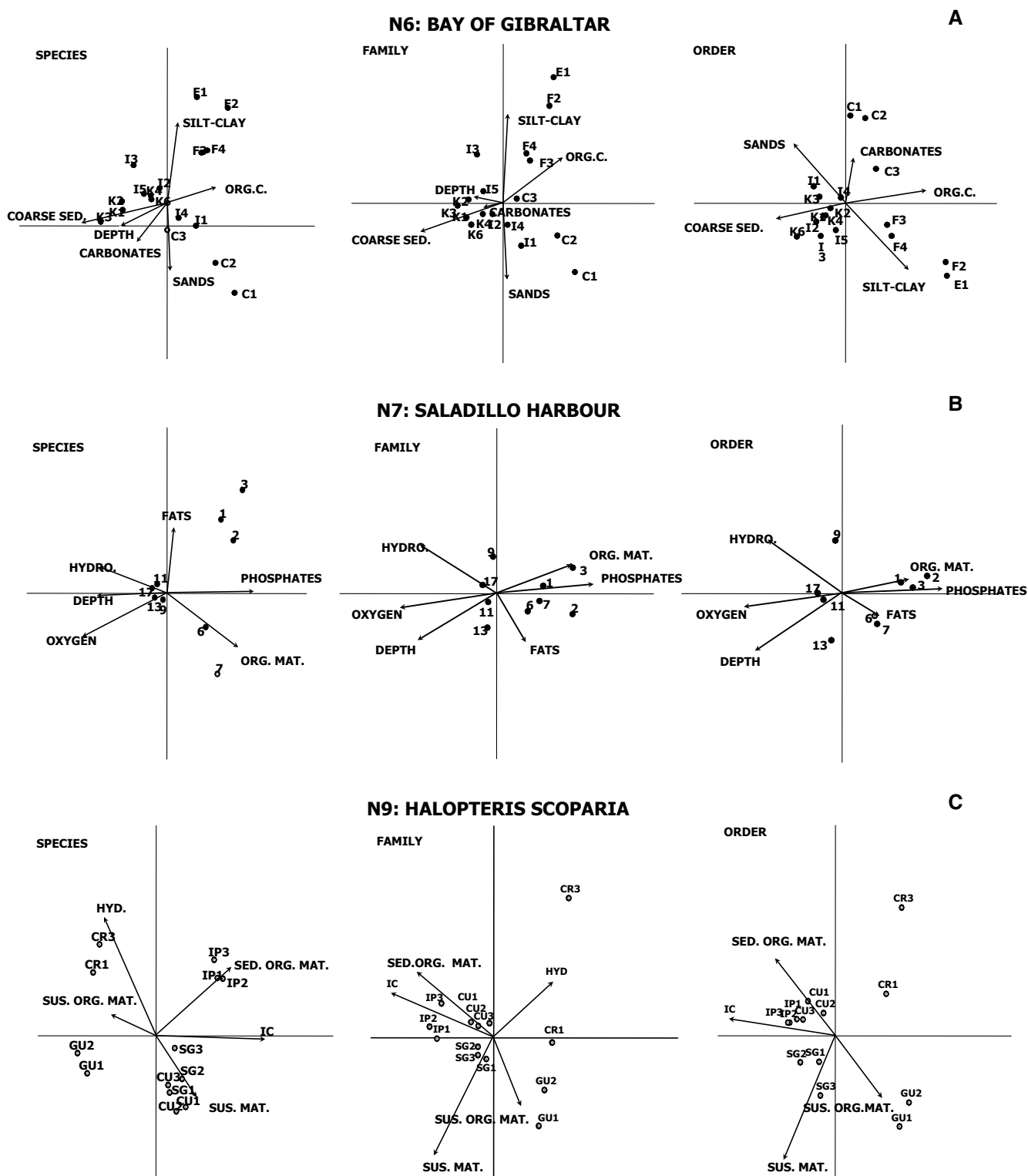
According to Warwick (1988b) natural environmental variation has a greater effect on macrofaunal assemblages at the species level, whereas anthropogenic impacts do so at higher taxonomic levels. In contrast, James et al. (1995) suggested that in natural situations, the spatial distributions of macrofaunal communities remained the same irrespective of whether they were analysed at the family or species level. In this sense, the aggregation of species into higher taxonomic groups reduces the natural variability in species abundances, and may therefore improve the chances of detecting less-obvious impacts.

In some instances changes in the degree of taxonomic resolution had no influence on the results of community analyses via diversity measures (Waterhouse and Farrel 1985; Ferraro and Cole 1990, 1995) or multivariate techniques (Somerfield and Clarke 1995).

In the present study, we found that interpretations arrived at from different taxonomic levels are very similar, as shown by the Spearman rank-correlation coefficients and nMDS ordinations. Correlations were consistently higher, however, between analyses at species and family levels. Thus, the use of higher taxonomic levels would be justified for the analysis of macrobenthic community data from various habitats (marine, estuarine, intertidal, infralittoral) and substrates (rocky, sediment, algal). Moreover, consistent results across taxonomic levels were obtained from localities under both environmental perturbations (N2–N5, N6–N10 and N11) and natural conditions (N1 and N12), supporting the results obtained by James et al. (1995). There was also consistency across taxonomic levels when intertidal systems (N12) were compared with more diverse ones such as estuaries (N10 and N11), a result also described by Somerfield and Clarke (1995). Finally, the similarities between results obtained in studies at a local scale (N1–N10 and N12) and at a broad-scale (N11) illustrates the applicability of these treatments across a wide range of spatial scales, as proposed by Balmford et al. (1996a, b).

In contrast to Somerfield and Clarke (1995) who obtained higher stress values with decreasing taxonomic resolution, our results showed no important variations in stress between species, family or order.

James et al. (1995) showed that results obtained at differing taxonomic levels depended on the number of species per family and the species-abundance distributions. Thus, a single species in each family will produce identical results at both taxonomic levels. Very similar results should be obtained if only a few species are present in each family and these are in turn dominated numerically by a single species.



**Fig. 3** Graphical representations of the CCA analyses obtained at each of the three selected taxonomic levels for studies N6, N7 and N9. The significance of these ordinations were assessed by means of a Monte Carlo permutation test

The latter was the case in the studies N2 and N6–N12: the families and orders which aggregated the majority of species and abundances were indeed the

major contributors to the groupings obtained in each study. Our results are consistent with those of Herman and Heip (1988); they found that the information con-

tained in species abundances was conserved, albeit partially, when these were aggregated into higher taxonomic groupings.

Graphical representations of the CCA ordinations at each level of taxonomic resolution show how communities are primarily structured by the same subset of environmental variables. Study N6 showed high levels of similarity between the distribution of stations at each level of resolution and the best explaining environmental variables. However, decreasing taxonomic resolution creates a greater level of similarity between internal stations (I and K—which are physically close to each other) and a greater differentiation between the three main groups of stations (internal, external—C, and harbours—F and E).

The results of the same analyses for study N7 again reflected high similarities between the three taxonomic groups studied, but some differences were also present. While there were two clear groups (harbour interior and exterior), sites exposed to high contaminant levels within the harbour showed greater similarities at higher taxonomic levels. This means that whilst differences between outer and inner sites were still present, the gradient associated with pollution was less defined at the family and order levels.

Hydrodynamism was not selected as an important environmental factor at the level of order in study N9, possibly due to species-specific hydrodynamic requirements within the same taxonomic group. This is particularly evident when orders such as amphipods are important to determine the overall community structure (Sánchez-Moyano and García-Gómez 1998).

We conclude that, at least for the systems studied, data analysis at higher taxonomic levels, particularly that of family, retains important ecological information whilst having the added advantage of being more robust with regard to the vagaries of species-level taxonomy.

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