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DISTRIBUTION OF INTERTIDAL ISOPODS IN RELATION TO GEOGRAPHICAL CHANGES IN MACROALGAL COVER IN THE BAY OF BISCAY

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The distribution of intertidal isopods with respect to algal species was investigated over a range of 250 km on the shores of north Spain. A survey of 25 localities included three zones with a distinct composition of algal species: a western zone comprising shores facing Atlantic waters and the outer part of the Bay of Biscay; a narrow transition zone (about 70 km in length); and an eastern zone extending to the inner part of the Bay of Biscay. Thirty two isopod species were collected, 11 of which were present in high densities. Response to geographical change was observed to occur clearly in three species, *Ischyromene lacazei*, *Idotea pelagica* and *I. baltica*, and to a lesser degree in *I. granulosa*; the former two and the latter two were abundant in the eastern and western zones respectively. All four species were found to be closely associated with macroalgae species which display geographical changes in abundance (*e.g. Laminaria ochroleuca* and *Corallina elongata*). In addition, *Idotea* species were found to inhabit a reduced number of algal species compared with other European shores. Spanish shore of the Bay of Biscay probably constitutes the geographic limit of the distribution of the four species. A sampling artefact might also be responsible to some extent for the patterns of distribution observed. Differences in the physico-chemical properties of sea water along the coast and circulation of coastal waters are not thought to influence the distribution of isopods.

INTRODUCTION

A conspicuous change in the composition of intertidal macroalgal-dominated communities occurs on the shores of northern Spain (Fischer-Piette, 1957; Van den Hoek, 1975; Anadón & Niell; 1981; Anadón, 1983). Two distinct areas, western and eastern, can be clearly recognized in relation to their algal cover, with a narrow separation zone of about 70 km between them (Anadón, 1983). In the transition zone there is a coexistence of both groups of algal species and alternate dominance on short shore distances are the major features (Anadón & Fernandez, 1986).

Despite extensive studies on the change of macroalgal species (Fischer-Piette, 1957; Anadón & Niell, 1981; Anadón, 1983; Fernández & Niell, 1983; Anadón & Fernández, 1986), little is known about the change in animal species. A variation in the composition of the fauna associated with macroalgal belts would be expected, either in response to the factors affecting algal distribution or as a consequence of the change in the dominant algal species. Isopods are normal constituents of the fauna inhabiting rocky shores where they have been collected in a great variety of environments, ranging from supralittoral rock crevices (*Ligia* spp.) (Carefoot, 1973; Koop & Field, 1980) to intertidal and subtidal communities (*e.g. Idotea* spp.) (Naylor, 1955, 1972; Salemaa, 1979). Habitats where the presence of isopods has been reported include mussel beds, lichens, boulders, freshwater streams, brackish water pools, rock crevices, algae and among barnacles, ascidians and sponges (Harvey, 1968; Holdich, 1970, 1976; Jansen, 1971; Carefoot, 1973; Jones, 1974; Healy & O'Neill, 1984). The presence of isopods in macroalgal-dominated communities is well documented in all tidal levels, often being the dominant faunistic group (Holdich, 1968, 1970; Jansson & Matthiesen, 1971; Nicotri, 1980; Healy & O'Neill, 1984). Variations in the presence and abundance of isopod species might therefore be utilized as an indicator of the existence of geographical changes in the structure of animal communities. In this paper, we report the change in abundance and composition of the isopod assemblage in the eastern, western and transition zones in a survey including 250 km of shore line. The vertical distribution of the isopods and the relationship between changes in the isopod populations and changes in the macroalgal communities are examined.

THE SHORE

Changes in the physico-chemical properties of sea water along the shore have been described (US Naval Oceanograhic Office, 1967, Treguer *et al.*, 1979; Fraga *et al.*, 1982) though the effect on individual species is unknown. The changes include warmer water surface temeperatures towards the inner part of the Bay of Biscay during summer and the existence of summer upwelling conditions on the outermost portion of Spanish shore of the Bay. No substantial differences in topography, tidal regimes and weather conditions appear to exist between different portions of the shore.

The western zone ranges from the shores facing the open Atlantic to a mid-point on the shores of the Bay of Biscay. This zone is characterized by the dominance of *Ascophyllum nodosum* in mid-tidal levels on sheltered shores; *Fucus serratus*, *Himanthalia elongata* and *Chondrus crispus* in lower levels on semi-exposed and exposed shores. [Authorities for scientific names of algae are given in Parke & Dixon (1976) and for isopods in Table 1.] *Laminaria ochroleuca* occurs subtidally throughout the zone and, locally also appears at the lower tide levels (Anadón, 1983; Fernández *et al.*, 1983). These algal species are frequently found on other western European shores (Lewis, 1964). The eastern zone ranges towards the inner part of the Bay of Biscay and the previous species are respectively substituted by *Fucus vesiculosus* on sheltered shores; by *Bifurcaria bifurcata*, *Corallina elongata* and *Gelidium latifolium* on exposed ones; and by *Cystoseira baccata* and *Saccorhiza polyschides* subtidally (Anadón & Niell, 1981; Anadón, 1983; Fernández & Niell, 1983). With the exception of *G. latifolium*, the species of this second group are present on the total length of the shore. There is no evidence that changes in environmental parameters exist in the transition zone, and the topography of the shore remains the same.

METHODS

Twenty five localities were visited, most of them at least twice, in late spring and summer of 1977. These localities included shores over 250 km along northern Spain (see Figure 1). This range is the same as that studied by Anadón (1983) and includes representative localities of the western zone (sites 1-4); transition zone (sites 5-13) and eastern zone (sites 14-25). In each locality an area of 50x50 cm was cleared of algae in each of the macroalgal-dominated belts. Samples of the same size of *Mytilus* sp. and *Chthamalus* sp. were also taken in some localities. The lichen *Lichina pygmaea* was sampled only when it was found to form extensive patches. The height on the shore of each quadrat sampled was recorded. Samples were collected by scraping clear the rock substrate, placed in plastic bags and transported to the laboratory as soon as possible. The samples were frozen (-16°C) until they were sorted. All the material collected was washed with freshwater and the isopods were separated from the algae by strong agitation of the algae. Isopods were identified to species whenever possible and counted. For those localities where two or more samples of each community were collected, mean values were considered for analysis. Numerical data are presented only for common species. The spatial distribution of isopods was divided into three components: distribution in the geographical range, with 25 localities examined; distribution in the tidal range, where heights were grouped into 7 divisions of 0·5 m each; and distribution in relation to dominant seaweed and herbivore species, with 16 communities examined (including 13 macroalgal-dominated belts, 2 herbivore-dominated belts and 1 *Lichina pygmaea* dominated belt).

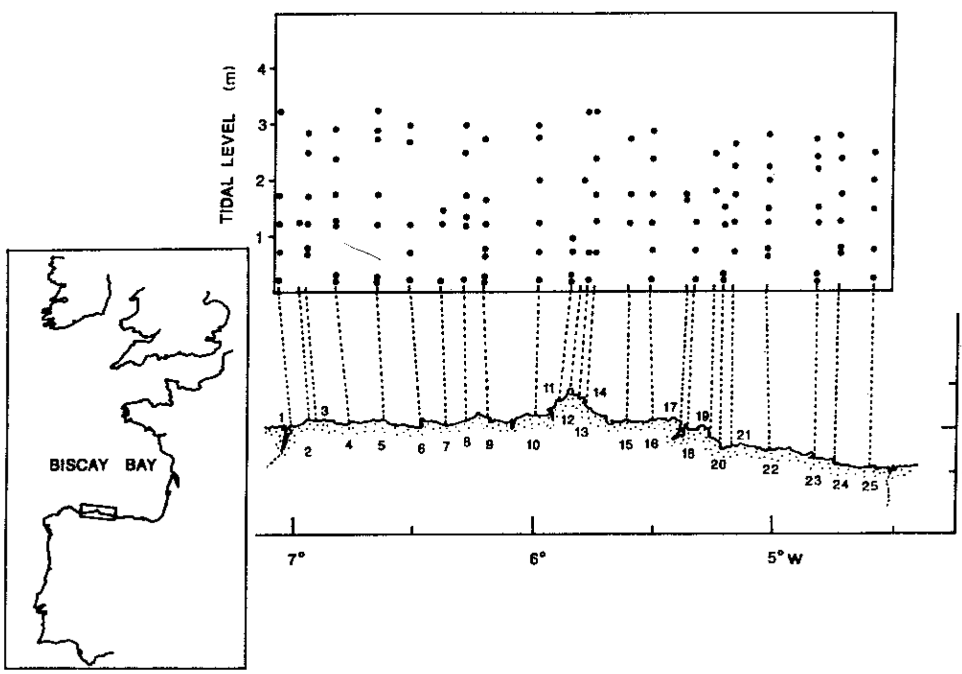

Figure 1. Map of the zone studied. Dots in the upper rectangle indicate samples taken in each locality and their heights on the shore.

RESULTS

A total of 32 species was identified (Table 1). Due to problems in the identification of some specimens (mainly juveniles) of the genus *Cymodoce* the two species, *C. truncata* and *C. emarginata*, were designated as *Cymodoce* spp. in the Tables. Most of the isopod species were encountered infrequently or in low numbers. Therefore only the 11

Table 1. *Isopods found on the shores of northern Spain*

Subjective abundance index: 1, presence; 2, rare; 3, common; 4, fairly abundant; 5, very abundant. Pc, *Pelvetia canaliculata;* Li, *Lichina* sp., Pa, *Patella + Chthamalus;* My, *Mytilus* sp., Lt, *Lithophyllum tortuosum;* Fs, *Fucus spiralis;* Fv, *Fucus vesiculosus;* An, *Ascophyllum nodosum;* Ce, *Corallina elongata;* Fs, *Fucus serratus;* Bb, *Bifurcaria bifurcata;* Ge, *Gelidium* sp.; He, *Himanthalia elongata;* Cc, *Chondrus crispus;* Lo, *Laminaria ochroleuca;* Sc, *Saccorhiza polyschides+Cystoseira baccata*

Species	Pc	Li	Pa	My	Lt	Fs	Fv	An	Ce	Fs	Bb	Ge	He	Cc	Lo	Sc
Ancyroniscus bonnieri Caullery & Mesnil												1				
Anthura gracilis (Mont.)											1	1				1
Arcturella dilatata G.O.Sars											1	1				1
Arcturella damnoniensis (Stebbing)											1					
Arcturella sp.																1
**Campecopea hirsuta* (Mont.)		5	5			3	3		1	1	1					1
Cirolana cranchi Leach											1					
Cyathura carinata Norman & Stebbing																1
Cymodoce rubropunctata (Grube)												1				1
**Cymodoce* sp.							1		3	3	4	5		4	2	3
**Dynamene bidentata* (Adams)	5	1	1	4		5	5	2	3	5	4	5	3	4	4	4
**Dynamene magnitorata* Holdich							1		3	2	3	5	1	3	4	5
Dynamene edwarsi (Lucas)							1		1			1	1			
Gnathia maxilaris Mont.											1	1			1	
Gnathia vorax (Lucas)											1	1				
Gnathia sp.									1		1					
**Idotea baltica* Pallas							1		1	1	1	1		3	3	2
Idotea emarginata Fab.														1		
**Idotea granulosa* Rathke							1		1	2	1	2	3	4	2	1
**Idotea pelagica* Leach							1		3		1	1	1	1		
**Ischyromene lacazei* Racovitza					1				4	1	3	1	1	1		1
Jaera albifrons Leach							1		1							
Jaera prehirsuta Forsman							2		5							
Jaera forsmani Bocquet							1									
Ligia oceanica (L.)	4					1										
Munna kroyeri Goodsir											1	1				1
**Parathura nigropunctata* Lucas							1		1	1	2	2		2	1	2
Sphaeroma rugicauda Leach							1								1	
Sphaeroma serratum (Fab.)								1							1	
**Synisoma acuminatum* (Leach)							1				1			1	1	4
**Synisoma lancifer* (Leach)									1	1	1	2		2	3	2
Zenobiana prismatica Risso											1					

* Species whose distribution was investigated

abundant species, marked in Table 1, were used to study the variation in isopod abundance in relation to the geographical change.

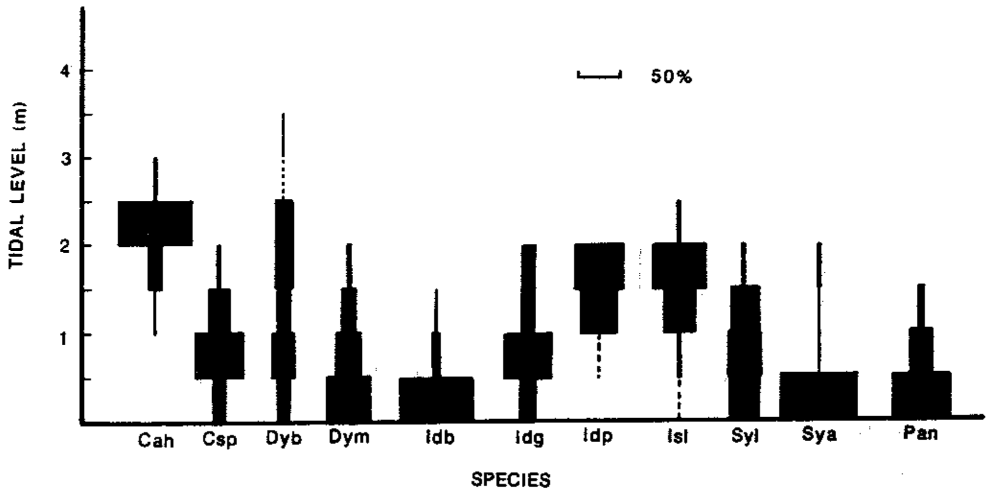

Figure 2. Vertical distribution of isopods on rocky shores of North Spain. Expressed as percentage of total specimens collected. Cah, *Campecopea hirsuta*; Csp, *Cymodoce* sp., Dyb, *Dynamene bidentata*; Dym, *Dynamene magnitorata*; Idb, *Idotea baltica*; Idg, *Idotea granulosa*; Idp, *Idotea pelagica*; Isl, *Ischyromene lacazei*; Syl, *Synisoma lancifer*; Sya, *Synisoma acuminatum*; Pan, *Paranthura nigropunctata*

A clear vertical pattern was shown by most of the isopod species (Figure 2), with marked differences between them. Differences are evident between species of the same genus, as shown by genus *Idotea*, with *I. baltica* appearing in the lowest levels, *I. pelagica* in upper levels and *I. granulosa* in the mid-zone. Differences between species of genus *Dynamene* and *Synisoma* are also evident (see Figure 2). Three species were found to show a clear preference for the upper levels of the shore, *Campecopea hirsuta*, *I. pelagica* and *Ischyromene lacazei*. These, together with *Ligia oceanica* are the only strictly intertidal species. All others appeared in communities that extend subtidally. *Dynamene bidentata* had the widest tidal range, occuping all heights examined.

Geographical distribution of the isopods is summarized in Figure 3. *Dynamene bidentata* appeared to be the most widespread species in all three distribution components. Moreover, this species was usually collected in high densities. The cosmopolitan nature of genus *Dynamene* on European shores has been pointed out by Holdich (1970, 1976) and no additional comments will be made here. *Dynamene magnitorata*, *Idotea granulosa* and *Cymodoce* species also appeared widely distributed and, locally, in high densities (see Figure 3). Only three species showed a clear segregation in abundance in their geographical ranges: *Idotea pelagica*, *I. baltica* and *Ischyromene lacazei*, though all three species were present in most localities of the range studied. *Idotea baltica* occurred in high densities only in the western zone, while the two other species appeared abundant in the eastern zone and locally in the transition zone. Higher abundance in western and transition zones was also found in *I. granulosa*, though the pattern is not very clear due to the low density of this species at all localities. The patterns of distribution of the remaining species appear to be independent of geographical change, although local differences in abundance are evident for some species (*e.g. Campecopea hirsuta* and *D. magnitorata*).

Distribution in relation to macroalgae is given in Table 2. The species that exhibited segregation in their geographical ranges were for the most part sampled on algal

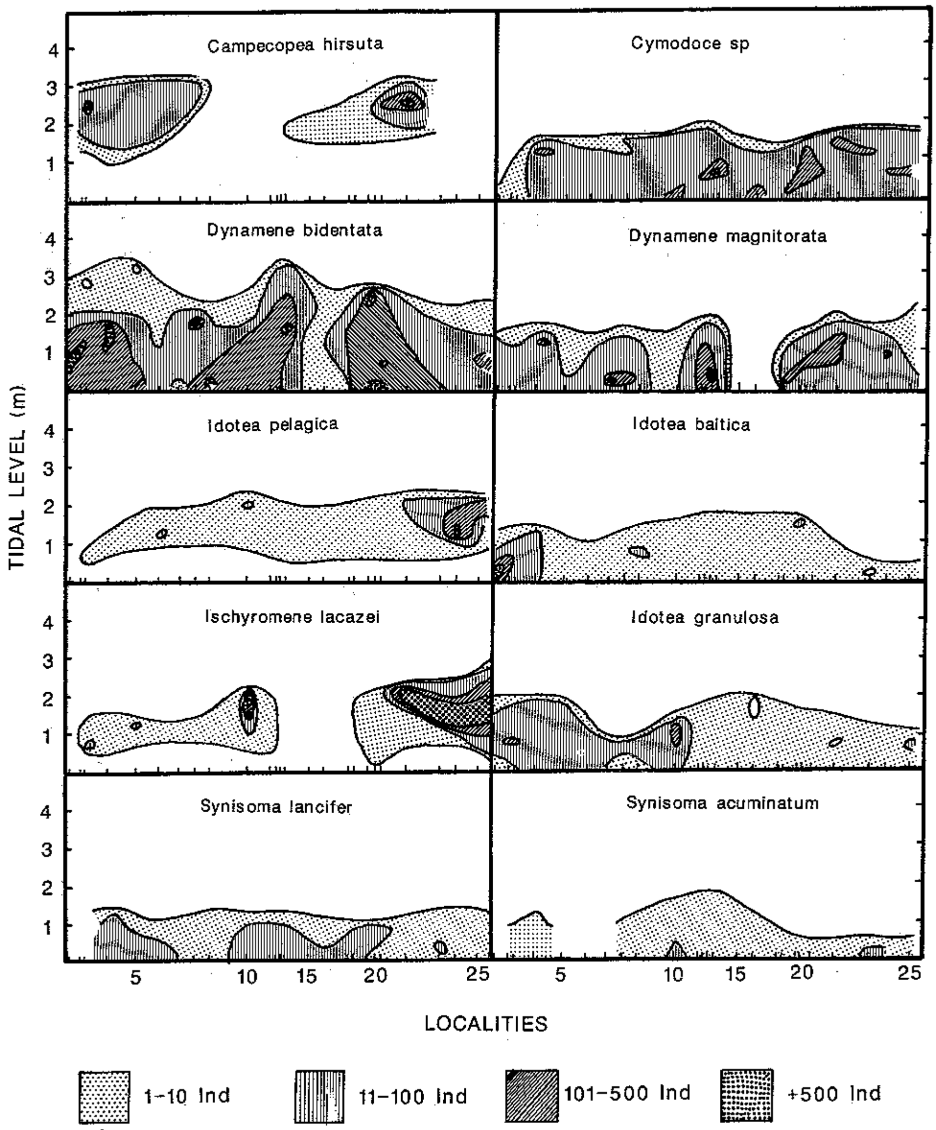

Figure 3. Geographical distribution of isopods in the Bay of Biscay Samples are grouped in arbitrary abundance classes. Representation of *Paranthura nigropunctata* has been omitted due its low and homogeneous abundance throughout the zone in lower levels. Number of specimens per sample (50x50 cm)

species that also displayed a geographical change in abundance. Thus, 84% of specimens of *I. baltica* were collected on *Laminaria ochroleuca*; 90% of *I. pelagica* and 61% of *I. lacazei* on *Corallina elongata*; and 66% of *I. granulosa* on *Himanthalia elongata* and *Chondrus crispus*. The most widespread species, *D. bidentata*, was collected in large numbers in 12 of the 16 belts considered and its presence recorded in two others. This species was absent in samples taken in areas dominated by the marine lichen *L. pygmaea* and the crustose algal *Lithophyllum tortuosum*. The highest abundances were recorded in Fucaceae-dominated communities, largely *Fucus vesiculosus* and *F. spiralis*.

Table 2. *Distribution of isopods in intertidal belts. Percentage of total individuals collected*

Belt	Cah	Csp	Dyb	Dym	Idb	Idg	Idp	Isl	Pan	Sya	Syl
Pelvetia canaliculata			0.01								
Lichina sp.	0.03										
Patella-Chthamalus	0.87		+								
Mytilus sp.			0.02								
Lithophyllum tortuosum								0.18			
Fucus spiralis	0.06		0.20								
Fucus vesiculosus	0.04		0.12		+	0.03	+		0.02	0.02	
Ascophyllum nodosum			0.02	+							
Corallina elongata	+	0.09	0.01	0.05	0.01	0.05	0.90	0.61	0.03		+
Fucus serratus		0.09	0.19	0.03	0.03	0.07		+	0.07		0.01
Bifurcaria bifurcata		0.13	0.06	0.12		0.07	0.07	0.16	0.15	0.05	0.05
Gelidium sp.		0.44	0.06	0.18	0.01	0.05	+	0.02	0.12		0.12
Himanthalia elongata			0.10	+		0.30	0.02	0.03			
Chondrus crispus		0.10	0.07	0.12	0.08	0.36	+	+	0.24	0.04	0.22
Laminaria ochroleuca		0.05	0.08	0.24	0.84	0.04			0.13	0.03	0.37
Saccorhiza-Cystoseira		0.10	0.06	0.26	0.02	0.05			0.24	0.87	0.23

Abbreviations as in Figure 2.

The distribution of two species which were oberved throughout the range studied was not considered. *Paranthura nigropunctata* had a wide distribution, in all three components, but was always collected in very low densities (in most cases with less than 10 specimens per sample), associated with the sediment fraction in macroalgal-dominated belts, with preference for the lower tidal levels. This species has been found to be abundant subtidally on other European shores, between macroalgae and seagrass beds (Wagele, 1982). No differences in its abundance distribution was observed in the areas examined in the present study. *Ligia oceanica* showed problems of a very different nature. This species was observed to be abundant in high tidal levels and in the supralittoral zone in all localities visited. However due to its habits, like other species of the same genus, is considered as a transition form between marine and terrestrial isopods (see Carefoot, 1973; Koop & Field, 1980). Because *L. oceanica* is cryptic during the day and active only at night, the method of sampling used was not satisfactory for this species and so the distribution of this isopod was not investigated.

DISCUSSION

Although at least 32 isopod species inhabited the macroalgal communities examined, only 11 species were present in consistently high densities. Isopods were abundant in all macroalgal-dominated communities and were occasionally collected in high densities in the lichen *L. pygamaea* and in the herbivore-dominated zones. Nevertheless, strong differences in distribution and abundance exist between them. Geographical changes in abundance were clearly observed in three species, *I. baltica*, *I. pelagica* and *I. lacazei*. Distribution of these species might be due to a number of factors including: (i) a direct response to the same environmental factors (if any) originating the change in algal cover, (ii) a response to distribution of macroalgae on which animals live and, (iii) a sampling artefact.

Changes in the physico-chemical properties of sea water have been described towards the inner part of the Bay of Biscay and include temperature, salinity and nutrient concentrations (US Naval Oceanographic Office, 1967; Treguer *et al.*, 1979; Fraga *et al.*, 1982). The ranges of fluctuation of temperature and salinity appear to be irrelevant in the control of the observed patterns of distribution since they are much lower than animals are able to survive without apparent damage (Naylor, 1955; Harvey *et al.*, 1973). The differences in the physical parameters in the three zones are not thought to affect the distribution of the isopods. Models of circulation and movement of coastal water masses might influence the distribution of the species by limiting the dispersion of spores (algae) or juveniles (isopods). Free-swimming juveniles have been reported in some species of isopods (Holdich, 1968, 1970; Jansson & Matthiesen, 1971; Salemaa, 1979; Tully & O'Céidigh, 1986) and their distribution might be influenced by water movement. Circulation of coastal waters only, however, appears to be insuffıcent to explain why some species with free-swimming juveniles have a restricted distribution (*Idotea* spp.) while others are widely distributed (*Dynamene* spp.). Any other environmental factor which might influence the distribution of algae (and isopods) in the Bay of Biscay is unknown.

Absence of suitable habitats in some localities also appears to be a plausible explanation for the observed changes. In the present study *I. baltica* was collected in *Laminaria ochroleuca*, a species limited to the western zone (Anadón, 1983). High percentages of *I. pelagica* and *I. lacazei* were found on *Corallina elongata*. Although this seaweed appears in the whole geographical range studied, it is only dominant on the very exposed shores of the eastern zone (Fernández & Niell, 1983). Finally, *I. granulosa*, which appeared in larger numbers in the western zone, was frequently sampled (two-thirds of the total of sampled individuals) in *Himanthalia elongata* and *Chondrus crispus*, both of them appearing in higher densities in the western and transition zones (Anadón, 1983; Anadón & Fernández, 1986). Species with a broader distribution or collected in communities not affected by geographical changes did not exhibit differences in their abundance in the two zones.

In marked contrast with the results of the present study, the species displaying geographical changes in abundance have been found to inhabit a richer variety of habitats on other shores. *Idotea baltica* has been frequently sampled in either sublittoral or intertidal environments inhabiting a great variety of substrates, including *Fucus vesiculosus*, *Ascophyllum nodosum*, *Cladophora*, floating drift weeds and decaying algae (Naylor, 1955; Jansson & Matthiesen, 1971; Strong & Daborn, 1979; Tully & O'Céidigh, 1986). *Idotea pelagica* is usually found inhabiting open shores exposed to strong wave action (Naylor, 1955; Sheader, 1977; Healy & O'Neill, 1984), where it is collected among barnacles, mytilids, stunted fucoids and *Corallina*. *Idotea granulosa* has been collected in a great variety of macroalgal-dominated communities (including *Gigartina*, *Fucus spiralis*, *F. vesiculosus* and *F. serratus* among others) on shores with moderate wave action (Naylor, 1955; Healy & O'Neill, 1984). *Idotea* species are considered to be 'northern species' (Naylor, 1972; Healy & O'Neill, 1984) and the southern limit in the distribution of these species appears to be the Spanish shore of the Bay of Biscay (Naylor, 1972). The reasons for the limited substrates on which the species were collected in the present study are not known. Habitats found to harbour huge populations on other coasts abound in the study zone and were regularly sampled but were not found to contain significative numbers of *Idotea* species. The absence of *Idotea* species from these habitats might be related to any kind of restrictions imposed on the isopods in the limit of their distribution. The likelihood that these species are eliminated by competition with other isopods inhabiting macroalgae on shores of North Spain has not been investigated. On the other hand, distribution of *Ischyromene lacazei* is poorly known. This species appears to have a 'southern distribution' (Harrison & Holdich, 1982) and the sampled populations probably are near to the northern limit for the species. No record of this species exists for the shores of northern Europe.

A final possibility is that the observed patterns of distribution are a consequence of a sampling artefact. Populations of some species of isopods have been found to display marked seasonal cycles in abundance (Holdich, 1968, 1970; Heath & Khazaeli, 1985). For a given species, differences in the timing of peak abundances on different sections of the shore or a prolonged sampling period in which populations in different localities are sampled in different stages of the abundance cycle, might readly originate patterns of distribution identical to those shown in Figure 3 for *Idotea* and *Ischyromene* species The importance of this problem, if it exists, is unknown and additional research is needed in this area.

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