Suprabenthic assemblages from Catalan beaches: zoological groups

T. Munilla
M. J. Corrales
C. San Vicente
Universitat Autònoma de Barcelona. Laboratori de Zoologia
08193 Bellaterra (Barcelona). Spain

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Abstract

An analysis of the zoological groups captured with suprabenthic sledges at a depth of 1 m (sampled area 50 m^2), has been carried out on 13 Catalan beaches (NE of Spain) with varying profile, exposure, and granulometry. A total of 22104 specimens, belonging to 10 different zoological groups, were obtained (mysids, amphipods, cumaceans, isopods, tanaidaceans, decapods, exuviae of cirripeds, copepods, pycnogonids, and teleosts). The great majority were arthropods and crustaceans, 94.2% being peracarids. The mean density was 34 ind.m^{-2} and the mean concentration of organic matter 2.89% of the AFDW sediments. Mysids, accounting for 59.9%, constitute the most important group in the Catalan suprabenthos at 1 m depth, followed by amphipods (28.7%). The same groups are also dominant at 5 and 10 m depths on the reflective Masnou beach (86.2% mysids and 8.8% amphipods). In view of the data obtained, we conclude that, at a depth of 1m, the observed faunistic differences are related to the degree of exposure, sand size, and dissipative-reflective character of the analyzed beaches.

Moreover, beaches near to the rivers (but not next to) are more dense than remote ones. The hydrodynamics is the basic factor controlling distribution, both vertical and horizontal, of the suprabenthic communities on beaches.

Finally, the data of this study are compared to those of the Atlantic suprabenthos obtained from other biotopes. The chief conclusion is that density values decrease with depth.

Key words: suprabenthos, Catalan beaches, North-western Mediterranean, zoological groups.

Resumen. *Suprabentos de playas catalanas: grupos zoológicos*

Se analizan los grupos zoológicos capturados con trineos suprabentónicos a 1 m de profundidad en 50 m^2 de 13 playas catalanas de distintos tipos de perfil, exposición y granulometría. Se han obtenido 22104 individuos pertenecientes a 10 grupos zoológicos diferentes (Misidáceos, Anfípodos, Cumáceos, Isópodos, Tanaidáceos, Decápodos, mudas de Cirrípedos, Copépodos, Picnogónidos y Teleósteos). El 95.4% son Artrópodos, el 95.05 son Crustáceos y el 94.2% son Peracáridos. La densidad media es de 34 indiv./m^{-2} y la concentración media de la materia orgánica es del 2.89% del Pssc (oscila entre 1.4 y 6.2).

Los Misidáceos, con el 59.9%, constituyen el grupo más importante del suprabentos catalán a 1 m de profundidad, seguido por los Anfípodos, con el 28.7%. Los mismos grupos también dominan en el conjunto de 5 y 10 m de profundidad de la playa reflectiva del Masnou (86.2 % de Misidáceos y 8.8% de Anfípodos).

A la vista de los datos obtenidos se concluye que, a 1 m de profundidad, las diferencias faunísticas observadas están relacionadas con el grado de exposición, con la granulometría y con el carácter disipativo-reflectivo de las playas analizadas.

Por otro lado, las playas cercanas a los ríos (pero no junto a su desembocadura) son más densas que las lejanas, siendo la hidrodinámica el factor fundamental que controla la distribución del suprabentos de playas, tanto horizontal como verticalmente.

Finalmente, se comparan datos del presente estudio con otros del suprabentos atlántico obtenidos en otros biotopos submarinos. La principal conclusión es que la densidad decrece con la profundidad.

Palabras clave: suprabentos, playas catalanas, Mediterráneo noroccidental, grupos zoológicos.

Introduction

Suprabenthic fauna, often also called hyperbenthos or demersal benthic zooplankton, includes small swimming animals, mainly crustaceans, which live directly above the sediment and can migrate on a daily or seasonal basis (Brunel et al., 1978). The dominant group is the peracarids, although the community also includes pycnogonids, euphausids, decapods, copepods and teleosts. Most of these species constitute an important food source for demersal fishes (Sorbe, 1981; 1984; Kleppel et al., 1980; Mauchline, 1982; Dauvin, 1988; Brown & Mclachlan, 1990). Many species in these groups are detritivorous, feeding on organic matter from the sediment, thus constituting intermediate elements in the food chains (Mauchline, 1980; Sorbe, 1984; Dauvin et al., 1994).

A number of suprabenthic studies have been carried out in the infralittoral and circalittoral regions by Hesthagen (1970) (Meteor and Josephine Seamounts, European Atlantic), Brunel et al. (1978), Saint Marie & Brunel (1985) (Bay of Fundy and Gulf of St. Lawrence, north west Atlantic, Canada), Boysen (1975) (Kiel Bight, Germany), Kaartvedt (1985, 1989), Buhl-Jensen (1986), Buhl-Jensen & Fossa (1991) (Norwegian and Swedish coasts), Hamerlynck & Mees (1991), Mees & Hamerlynck (1992), Mees et al. (1993) (Dutch and Belgian estuaries and deltas), and Wang & Dauvin (1994) (Seine Bay). In spite of this extensive bibliography, few papers consider beaches to a depth of 5 m: Hamerynck & Mees (1991), Mees & Hamerlynck (1992), Cattrijse et al., 1993, and Mees et al. (1993) reported data about the intertidal zone and between 2 to 10 m depth of the Voor Delta, The Netherlands. On non-European beaches, Clutter (1967) investigated the mysids of La Jolla, California, Wooldridge (1983, 1989) and Cockcroft (1979) studied the eastern zone of Cape Town, although the last mentioned author used 1.5 cm mesh nets causing great loss of information concerning smaller specimens, and Webb (1987) studied the diet as well as the vertical and horizontal migrations of mysids in Algoa Bay, South Africa. In Spain, few studies have been made in the Guipuzcoa Atlantic estuaries (San Vicente et al., 1990) and at the Mediterranean beaches of Creixell (San Vicente & Sorbe, 1993; San Vicente, 1996, Munilla & San Vicente, in press) and Roses (Munilla & Corrales, 1995).

The aim of this study is to determine the relative importance (percentages and densities) of the zoological groups on different type of beaches. This objective is prior to carrying out a later study about to specific biodiversity.

Materials and methods

During 1995, diurnal samples were taken once (during spring or summer) from 11 Catalan beaches (l'Estartit, Pals, la Fosca, Platja d'Aro, s'Agaró, Santa Cristina, el Masnou, Castelldefels, Cambrils, El Trabucador, L'Aluet), along a transect 100 m in length, parallel to the coastline, and at a depth of 1 m (Figure 1). A suprabenthic sledge with an aperture of 50 x 20 cm and 1 m long, with a 500 μm net, was used. This sledge was manually pushed with the aid of two rods fitted to the lower part of the frame. El Masnou beach was also sampled at 5 and 10 m, using another sledge with a 50 x 50 cm aperture and a net similar to that already descri-

Figure 1. Location of the Catalan beaches sampled. Black circle: mouth of River Ebro.

bed. This sledge was towed from a Zodiac with the help of Scuba-divers who opened and closed the net at the beginning and at the end of sampling. They also measured the length of the hauls on the sea floor and supervised the correct running of the haul.

Both sledges have the advantage of collecting all the macrofaunal specimens swimming over the soft bottom, because these specimens are forced into the net by a curved attachment on the lower front part of the frame, which also avoids contamination by sediment.

The area sampled at each bathymetric level was 50 m^2, the minimum qualitative sampling area being 35 m^2 (San Vicente & Sorbe, 1993). The collected samples were fixed in 4% formaldehyde diluted with sea-water, and they were subsequently preserved in 70% ethanol for later selection and counting. Sediment was also taken from the top 10 cm of the sea-bed in order to analyse its granulometry (column of 7 sieves) and estimate the organic matter content, expressed as percentage of dry weight without ash (AFDW). The distance from the stations to the coastline was also measured with the aid of a marked line. Samples were taken in calm water conditions in order not to unstabilise the sampler and to fill the sledge with sediment. The impact on the beaches was negligible. Segregation of beach types according to exposure grade and dissipative-reflective character can be seen in Brown & Mclachlan, 1990.

Table 1. Characteristics of the sediments from the Catalan beaches sampled.

Beach	Median of sand size (in mm)	Mean of sand size (in mm)	Organic matter (%)	
El Masnou	1.555	1.121	5	Coarse and
Platja d'Aro	1.046	0.781	1.4	very coarse
Sta. Cristina	1.004	0.805	2.5	sand
Mean	1.202	0.929	2.97	
Cala la Fosca	0.392	0.286	2.5	
Platja de Pals	0.370	0.292	1.6	
S'Agaró	0.352	0.268	1.4	Medium
L'Estartit	0.327	0.214	2.5	sand
L'Aluet	0.325	0.220	2.1	
Barra del Trabucador	0.309	0.199	5.1	
Mean	0.346	0.240	2.53	
Castelldefels	0.232	0.182	2.5	
Rosas	0.195	0.184	2.3	Fine
Creixell	0.194	0.148	6.2	sand
Cambrils	0.192	0.147	2.5	
Mean	0.203	0.164	3.67	

Results and discussion

In order to give the broadest possible view of the Catalan suprabenthos, this section also includes the data obtained by San Vicente & Sorbe (1993) and by Munilla & Corrales (1995) concerning the beaches of Creixell and Roses, respectively.

With reference to granulometry, table 1 and figure 2 show the segregation of three groups of beaches according to their sand size characteristics (coarse and very coarse sand, medium sand and fine sand).

Therefore, from a total of thirteen beaches, at a depth of 1 m, we have obtained 22104 specimens belonging to 10 taxonomic groups (Table 2), taking the cirriped moults as a separate one. In spite of the proved efficiency of the sledge, 984 specimens belonging to infaunal or pelagic groups were also captured (polychaetes, gastropods, bivalves, platyhelminths, jellyfishes, etc.).

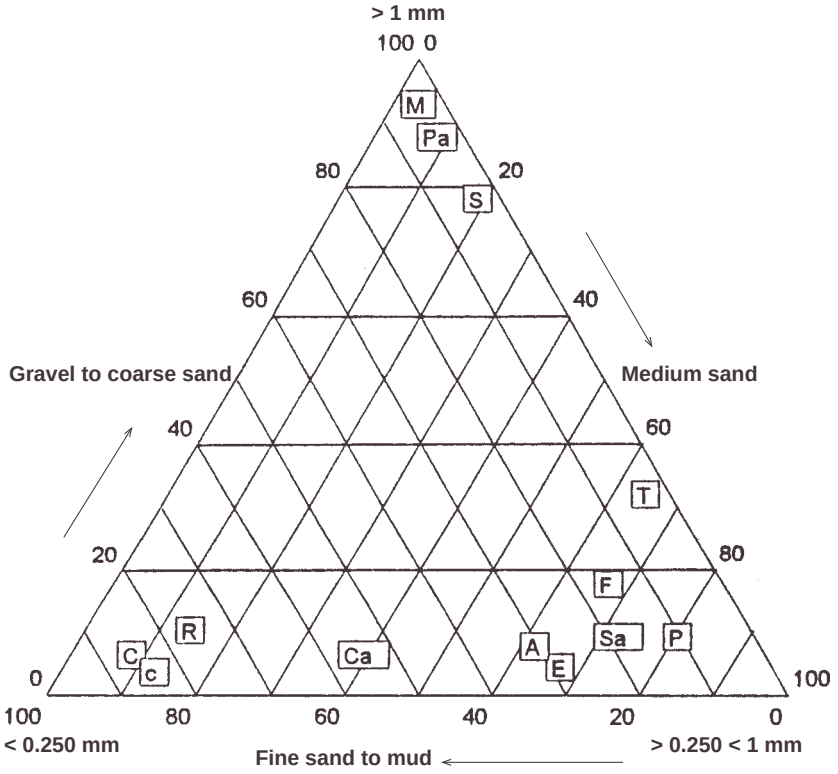

Figure 2. Triangular graph of the sand size sediment data from Catalan beaches analysed at 1 m depth. **R**: Roses; **E**: l'Estartit; **P**: Pals; **F**: la Fosca; **Pa**: platja d'Aro; **Sa**: s'Agaró; **S**: Sta. Cristina; **M**: el Masnou; **Ca**: Castelldefels; **C**: Creixell; **c**: Cambrils; **T**: Trabucador; **A**: l'Aluet.

Table 2. Percentages of the suprabenthic groups from the Catalan beaches. Dist: distance to the coast line (in m).N: number of specimens. D: density (ind.m^{-2}). Beach types: VS-very sheltered, S-sheltered, SE-semiexposed, E-exposed, R-reflective, D-dissipative, I-intermediate. C.M.: Cirriped moults. All the samples were captured in spring or summer except that of Creixell (mean of three months in winter from 1991).

Beaches	Type	Dist	Mys	Amph	Cum	Iso	Tan	Dec	C.M.	Cop	Pyc	Tel	N	D
Roses	S-D	20	27.0	23.3	1.7	7.3		3.1	4.5	16.7		11.8	288	5.8
L'Estartit	SE-D	25	77.2	19.7	0.7			0.7	1.7				1930	38.6
Pals	E-D	20	61.5	24.2		0.8							117	2.3
La Fosca	S-D	60	12.9	82.0	0.9			1.4	1.4	1.4			217	4.3
Platja d'Aro*	E-R	8		19.4		3.2			6.4				31	0.6
S'Agaró	S-ID	15	44.5	29.9	3.9	3.9		0.8	7.9	0.4		0.8	254	5.1
Sta. Cristina*	SE-R	4	89.7	5.8	0.2				3.8				583	11.6
El Masnou*	E-R	4	2.0			0.2				0.2			504	10.0
Castelldefels	E-D	52	88.6	2.2	8.2	0.1			0.9		0.1		1856	37.1
Creixell	E-D	50	81.9	5.9	8.6	0.2		0.6		1.5	0.4		960	19.3
Cambrils	E-D	48	37.3	55.7	2.0	0.7		0.9	0.8	1.1	1.3	0.2	6250	125.0
El Trabucador	E-D	45	98.7	0.7	0.3	0.3							3931	78.6
L'Aluet	VSD	125	43.3	37.6	0.3	4.6	0.8	0.02		4.5	0.02		5183	104.0
Mean			59.9	28.7	1.9	1.5	0.2	0.4	0.7	1.7	0.41	0.21	1700	34.0

*Beaches with sand-size bigger than 500 microns.

As shown in table 2, almost all the specimens were arthropods and crustaceans, most of them being peracarids (94.2%). The mean density was 34.0 ind.$^{-2}$ ± 41.96 ($P<0.0001$) ranging between 0.6 and 125, and the mean organic matter in sediment was 2.89% (oscillating between 1.4 and 6.2).

The dominant suprabenthic group at 1 m on Catalan beaches is mysids (59.9%), followed by amphipods (28.7%) These two groups together therefore account for more than 88% of all the specimens captured. Moreover, the 5 m and 10 m data of el Masnou beach show a total dominance of mysids.

On the other hand, there are four clear type of beaches on the Catalan coast: very sheltered, exposed-reflective, exposed-dissipative and sheltered-dissipative.

In the light of the data obtained (see tables 2, 3 and 4), we can say that at a depth of 1 m:

Table 3. Characteristics of the Catalan beaches sampled groups. **SE** semiexposed; **E** exposed; **S** sheltered; **VS** very sheltered; **D** dissipative; **R** reflective.

	Type of beaches					
	SE	**E**	**S**	**VS**	**D**	**R**
Number of beaches sampled	2	7	3	1	10	3
Mean density ind.m^{-2}	25.1	39	5.1	104	46.1	7.2
Zoological groups mean	4.5	5	7.3	8	6.2	3.3
Mysids (%)	83.5	52.9	28.1	43.3	59.3	30.6
Amphipods (%)	12.7	15.4	45.1	37.6	27.1	8.5
Cumaces (%)	0.5	2.7	2.2	0.3	2.6	0.1
Isopods (%)		0.8	3.7	4.6	1.8	1.1

Table 4. Very important suprabenthic groups on main beach types of Catalan coast. H*: Hendaya beach (0.20 cm depth, 650 m^2 sampled, exposed-dissipative beach type, Biscay Gulf, data of the annual mean, after San Vicente, 1996). Types of beaches: **E-D**: exposed-dissipative; **S-D**: sheltered-dissipative; **E-R**: exposed-reflective; **VS**: very sheltered.

		Type of beaches			
	H*	**E-D**	**S-D**	**E-R**	**VS**
Number of beaches sampled	1	5	3	2	1
Percentage of peracarids	96.2	95.8	77.3	12.4	86.6
Mean density Ind./m^2	82.8	52.5	5.1	5.3	104
Number of zoological groups	8	5.8	7.3	3	8
Mysids (%)	72.6	72.5	28.1	1	43.3
Amphipods (%)	3.7	18.8	45.1	9.7	37.6
Mean distance to the coast line	2	43	31	6	125
Sand size (mm)	< 0.5	< 0.5	0.5	> 0.5	< 0.5
Location		Sout of Barcelona	Costa Brava	North of Barcelona	Àlfacs Bay

— The very sheltered Aluet beach is the most dense (in specimens) and diverse (in zoological groups) of all the beaches, because its sediments are the most stable (there are hardly any waves); mysids and amphipods were equidominant groups.
— Dissipative beaches are considerably more dense and somewhat more diverse (in zoological groups) than reflective beaches.
— Exposed-dissipative beaches are intermediate in densities and zoological groups number, with superdominance of mysids.
— Sheltered beaches, of the dissipative type, are the least dense and the most diverse in zoological groups, with slight dominance of amphipods.
— Exposed and reflective coarse sand beaches , wehere sediment particle size is greater than 500 microns, are considerably poorer in suprabenthic fauna than beaches with a smaller grain diameter. The community is mainly formed by infaunal non-arthropod groups, which are removed from the sediment by the waves and captured by the sledge.
— The beaches near to rivers (but not next to them) have denser fauna than the remote ones; their density is proportional to the flow of the river. In fact, the beaches in the province of Tarragona, near to the wide River Ebro (Cambrils, El Trabucador and L'Aluet- Alfacs Bay), are the densest of all those sampled (mean density 102 ind.m^{-2}); l'Estartit and Castelldefels beaches, near to the Ter and LLobregat short rivers respectively, have a moderate density (38 ind.m^{-2}) and the other beaches remote from the rivers are less dense (7.4 ind.m^{-2}).

The reflective-exposed beach model (el Masnou, table 5), prospected at 1 m, 5 m and 10 m, reveals the existence of two communities, as is the case in dissipa-

Table 5. Number of individuals /percentages of the suprabenthic groups from el Masnou beach at 1m, 5m and 10 m depth. Others: no suprabenthic groups.

	Depth		
Groups	**1 m**	**5 m**	**10 m**
Mysids	10/2	6300/88.1	3476/80.7
Amphipods		487/6.9	507/19.4
Cumaces		124/1.8	112/2.6
Tanaidaces		5/0.1	
Isopods	3/0.6	9/0.13	1/0.03
Decapods		66/0.9	37/0.8
Cirr.moults		8/0.1	
Copepods	1/0.2	37/0.6	3/0.06
Teleostei		20/0.3	
Others	488/96.8	78/1.12	173/4.01
Number of individuals	504	7035	4309
Density ind.m^{-2}	10	141	86.2

tive beaches (Munilla & San Vicente, in press). The first is at 1 m, with major hydrodynamic stress and markedly impoverished suprabenthos. The second (5 to 10 m zone) is calmer and more abundant in detritus; here the suprabenthic communities are located, having similar characteristics at both bathymetric levels (denser and more diverse than at 1 m, with a total dominance of mysids). On dissipative beaches, contrarily, such populations are well established at a depth of 1 m.

With regard to the environmental parameters, hydrodynamics is the key factor controlling the density and distribution of macroinfaunal communities on beaches (Brown & Mclachlan, 1990); the same seems to occur with the suprabenthic ones. This factor distributes organic matter along the coastline, both horizontally (the beaches nearest the Ebro big river are the densest, since they benefit from the detritus brought by this river) and vertically (reflective beaches are denser and more diverse at deeper levels than at 1 m, since organic matter is more stable at greater depths).

On the other hand, table 6 compares the data from the beaches sampled with data of other Atlantic suprabenthic assemblages, obtained from estuaries (San Vicente et al., 1990), the Seine bay (Wang & Dauvin, 1994), Kiel Bight (Boysen, 1975), the continental shelf at various depths (Sorbe, 1984; Dauvin et al., 1994), from the slope (Elizalde et al., 1993) and from the Cap Ferret underwater canyon (Dauvin et al., 1995). The chief conclusion is that density decreases with depth. The data from the coves are affected by pollution and the data from the Roscoff shelf are related to coarse sand grain. The mean density at Catalan beaches show a similar status to data of estuaries, with dominance of mysids. Densities are

Table 6. Percentages and mean density of main suprabenthic diurnal groups from distincts biotopes sampled between 0 and 50 cm on the sediments. **E.G.**: Estuaries of Guipuzcoa, after San Vicente et al., 1990. **C.b.**: Catalan beaches, present study. **S.B.**: Seine Bay, after Wang & Dauvin, 1994. **K.B.**: Kiel Bay, after Boysen, 1975. **C.S.** 30 m. and **C.S.** 90-180 m: Continental Shelf of Arcachon, after Sorbe, 1984. **C.S.** 75 m.: Continental Shelf of Roscoff, after Dauvin, 1994. **S.CF.**: Slope Cap Ferret, after Elizalde et al., 1993. **CF.C.**: Cap Ferret Canyon, after Dauvin et al., 1995.

Biotope **Depth (m)**	**E.G.** **1-3**	**C.b.** **1**	**S.B.** **8-13** **Pol.**	**K.B.** **7-33** **Pol.**	**C.S.** **30**	**C.S.** **75***	**C.S.** **90-180**	**SCF** **425-1043**	**CF.C** **3060**
Mysids	76.2	59.9	53.3	13.6	28.8	25.0	42.4	11.8	0.4
Amphipods	8.6	28.7	2.1	4.4	67.9	67.6	16.1	23.3	16.0
Eufaus.					0.6		29.3	4.7	
Isopods	5.1	1.5		0.6	0.1		0.5	53.7	57.8
Cumaces	1.6	1.9	41.4	38.6	1.4		3.7	4.7	17.9
Decapods	3.5	0.4	3.9	2.7	1.0	2.4	6.8	1.0	0.8
D:ind./10m^3	2050	1700$^+$	21	157	872	20	458	260	48

*coarse sand. Pol: polluted coves. + 5 m^2~/m^3.

more or less similar between estuaries of Guipuzcoa (2050), and the Schelde estuary (1748, Mees & Hamerlynck, 1992). The fauna of estuaries and beaches is very dense compared to those of bays, because the alochtonous detritus are more important in the formers and the polluted status of the bays.

In short, we can say that mysids clearly predominate in estuaries, beaches and the bay of Seine (only diurnal samples), while mysids and amphipods predominate on the continental shelf and isopods are the principal suprabenthic group on the slope and in the underwater canyons, although cumaces are present in large numbers in the Seine bay (dominant group in the Kiel Bight), as are Euphausiacea in the remote shelf.

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Patrones espaciales de tamaño y mortalidad del roble (*Quercus robur* L.) en un bosque del litoral de Cantabria

Vicente Rozas
Universidad de Oviedo. Departamento de Biología de Organismos y Sistemas
Catedrático Rodrigo Uría. 33071 Oviedo. Spain

José A. Fernández Prieto
Instituto de Recursos Naturales y Ordenación del Territorio
Independencia, 13. 33004 Oviedo. Spain

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Resumen

La descripción e interpretación de los patrones espaciales de los árboles permite extraer conclusiones sobre los factores que condicionan tanto el establecimiento de las cohortes como su variación temporal. En el presente trabajo se analizan las distribuciones espaciales de tamaño y mortalidad del roble (*Quercus robur* L.) en dos parcelas de bosque. Obtenemos evidencias significativas de agregación para las clases de tamaño pequeñas y de distribución aleatoria en la clase de tamaño mayor. La disponibilidad de espacios abiertos parece ser el principal factor que condiciona la regeneración, estructura y mortalidad en las poblaciones de roble. Una de las poblaciones estudiadas se habría originado sin limitación de espacios abiertos, presentando poca organización espacial y un patrón aleatorio de la mortalidad, lo cual es indicativo de una escasa incidencia de la competencia intraespecífica. En otra población, que corresponde a una parcela de bosque maduro con escasos espacios abiertos, la regeneración del roble está asociada a «fase de claro», formándose grupos compuestos por árboles de tamaños similares y en distintas fases de madurez. En este caso, la mortalidad de roble tiene lugar predominantemente dentro de los grupos formados por árboles de poca talla y está, al menos en parte, causada por competencia intraespecífica.

Palabras clave: patrones espaciales, dinámicas de poblaciones, *K* de Ripley, autocrrelación espacial, mortalidad, competencia intraespecífica, *Quercus robur* L..

Abstract. *Spatial patterns of tree size and mortality of pedunculate oak (* Quercus robur *L.) in a forest of the Cantabria lowlands*

Quantitative spatial analysis provide inferences on tree population dynamics. Spatial patterns of pedunculate oak (*Quercus robur* L.) in two forest plots were analysed in this work. Significative evidences of clumping for trees of smaller sizes and a random pattern for larger-sized ones were given. This results would be related to self-thinning occurrence. Open space availability seems to be the main factor that drive the structure evolution and the regeneration and mortality processes within oak populations. In one of the studied stands, poor spatial arrangement and random mortality are linked to oak populations developed in open space, and there are evidences of scarce intraspecific competition. In the other studied