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ECOLOGY AND TAXONOMY OF THE GENUS *EURYDICE* (ISOPODA: CIROLANIDAE) FROM SAND BEACHES ON THE IBERIAN PENINSULA

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Quantitative sampling for the genus *Eurydice* (Isopoda: Cirolanidae) was conducted on 25 sand beach sites along the Atlantic coast of the Iberian Peninsula. Five species were recorded intertidally: *Eurydice affinis*, *E. pulchra*, *E. naylori* sp. nov., *E. lusitaniensis* sp. nov. and *E. spinigera*. Physical data collected were used to construct an index of exposure to rank each site. The distribution of intertidal *Eurydice* sp. is described in relation to exposure to wave action and to tidal level. Peak abundance of *E. affinis*, *E. pulchra* and *E. naylori* occurred most frequently between mean high water neap (MHWN) and mean tide level (MTL). Whilst *E. affinis* occurred over a wide range of exposure, *E. naylori* exhibited a marked preference for exposed sites and *E. pulchra* was only recorded from sheltered and semi-exposed sites. Surf plankton collections revealed the presence of *E. lusitaniensis*, but as only two specimens were collected, its ecology remains unknown. The zoogeographical distribution of the genus on North Atlantic and Mediterranean coasts is briefly reviewed.

INTRODUCTION

Isopods of the family Cirolanidae dominate the upper shore of sandy beaches in most temperate and tropical regions (Bruce, 1986) and are represented by members of the genus *Eurydice* at this level of the shore on European North Atlantic coasts (Wolff, 1966; Jones & Naylor, 1967; Dexter, 1988). Of nine species of *Eurydice* recorded from this region, *Eurydice pulchra* Leach, *E. affinis* Hansen, and *E. naylori* sp. nov. are found predominantly in littoral sand. *Eurydice rotundicauda* Norman may also possibly be regarded as an intertidal species, for although the type specimen was dredged subtidally during the Porcupine expedition (Norman, 1906), it has since been taken from intertidal sand at Arguin in south-west France (Salvat, 1962) and at Chios, Greece (Jones, 1969). *Eurydice spinigera* Norman and *E. dollfusi* Monod have also been collected intertidally, although the vertical distribution of these species extends into the sublittoral and both species are more frequently collected below mean low water springs (MLWS) (Soika, 1955a,b; Jones, 1970b; Jones & Naylor, 1967). *Eurydice lusitaniensis* sp. nov. caught in surf plankton during the present study may also be subtidal. *Eurydice caeca* Hansen, *E. grimaldii* Dollfus, *E. truncata* Norman and *E. inermis* Hansen are offshore species (Jones & Naylor, 1967).

Eurydice pulchra occurs between the tidemarks from Norway and the outer Baltic, to northern Morocco (Soika, 1955a) and is therefore towards the southern end of range on the Iberian coast. *Eurydice affinis* occurs predominantly on the Atlantic coasts of southern Europe, as well as in the Mediterranean (Soika, 1955a). Records from Anglesey in North Wales, represent the northern limits of the distribution of this species (Jones & Naylor, 1967). Similarly, *E. spinigera* ranges down the Atlantic coast of southern Europe and into the Mediterranean (Soika, 1955a), but has been taken as far north as the southern North Sea (Holthuis, 1950). Although predominantly a Mediterranean species (Soika, 1955a), *E. dollfusi* has recently been reported from the Atlantic coast of southern Portugal (D.A.J., personal observations). *Eurydice naylori* was collected from the northern coast of Spain to south-west Portugal during this study. The offshore species, *E. inermis* and *E. truncata* have been recorded in plankton samples from the southern coast of Portugal (Pierpoint, 1992).

The ecology of European *Eurydice* spp. has been studied on sand beaches in the UK (Jones & Naylor, 1967; Jones, 1970a,b; Fish, 1970), in south-west France (Salvat, 1966, 1967), in the Mediterranean (Monod, 1926, 1930, 1953), and in the Aegean (Jones, 1969). *Eurydice affinis, E. pulchra* and *E. spinigera* have been recorded from Iberian beaches during habitat surveys (Costa et al., 1986; Saldahna, 1983; Calvário, 1984; Sousa Reis et al., 1982; Marques et al., 1988; Weber, 1985), and during studies on community structure and faunal associations (Cancela de Fonseca & Magalhaes, 1987; Rodrigues & Quintino, 1987). The sites at which each of these surveys were conducted have been included in the present work. Unfortunately, specimens of *Eurydice* spp. from most previous studies are unavailable, but collections by Dexter (1988) who surveyed 58 intertidal habitats on the Portuguese coast were made available to the authors and include specimens of *E. affinis, E. spinigera* and of *E. pulchra*, some of which are *E. naylori*. Other collections made available by Professor L. Cancela de Fonseca have also subsequently been found to include both *E. pulchra* and *E. naylori*. Accurate ecological baseline data is essential for environmental monitoring or habitat assessment programmes, but species of *Eurydice* exhibit very different behaviour (Naylor, 1972) and habitat preferences (Jones, 1970a,b). Hence, it is necessary to identify species of *Eurydice* on beaches and to separate ecological preferences for co-occurring closely similar species.

Jones (1970b) identified the importance of exposure to wave action in determining the density and distribution of *E. pulchra* and *E. affinis* in the UK. However, Eleftheriou & Nicholson (1975) found that it is not possible to assess exposure using sediment characteristics alone and attempted to assess exposure using faunal indices and certain physicomorphological features (slope, fetch and angle of exposure, sediment texture and sorting). McLachlan et al. (1981) found significant correlations for abundance with grain-size and slope, but not with wave action estimates, suggesting that it is not wave action directly, but steep slopes and coarse sands which limit fauna. Although exposure to wave energy has been shown to exert the greatest influence either directly or indirectly, on the distribution and abundance of sand beach fauna, it appears necessary to consider the interaction of several physical beach parameters when attempting to assess the degree of exposure to wave energy. The present study uses an exposure index (modified after McLachlan, 1980, 1983) with seven measured factors to quantify the exposure at each sample site. This index takes into account the interaction of wave action, surf zone width, beach slope, particle size, percentage of fine sand, depth of reduced layers and presence of animals with stable burrows allowing beaches in different regions to be compared directly.

Dexter (1988) found much of the Portuguese coastline to be composed of reflective beaches with coarse sediment (median particle size (Md) >500 µm), and a sparse infauna. However, the northern and western coastline of the Iberian Peninsula as a whole, includes a wide range of sand beach habitats experiencing a wide range of exposure to wave action. Quantitative infaunal samples were taken at four shore levels on 25 sand beaches on the Atlantic coast of Spain and Portugal, together with surf plankton hauls at 16 sites. Two new species of *Eurydice* are described and differences in zonation and habitat choice for all intertidal species have been determined.

MATERIALS AND METHODS

Sample sites

Quantitative studies were made on 25 sand beaches on the north and west coasts of the Iberian Peninsula (Figure 1). These were selected to include sites surveyed by Dexter (1988) and to encompass a wide range of exposure to wave action and sediment grain-size.

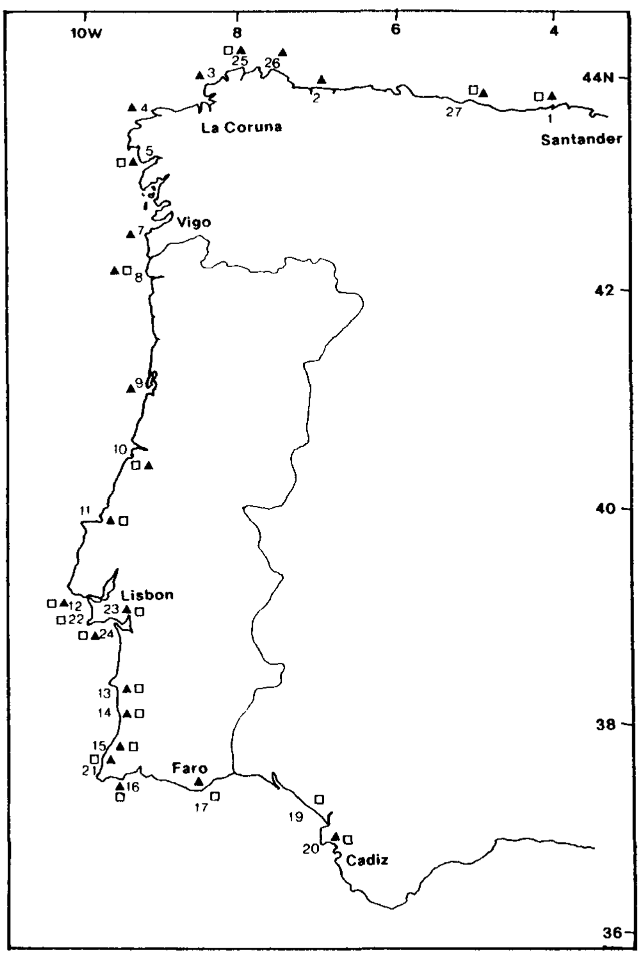

Figure 1. Sand beach sampling sites in Spain and Portugal: ▲, beaches at which *Eurydice* spp. were present in intertidal sand; □, surf plankton samples were taken.

Physical measurements

The profile of each beach was surveyed along a transect between mean low water (MLW) and mean high water (MHW) using a staff and level. Admiralty tidal predictions for Spain and Portugal were used to determine tidal levels. At MTL on each beach ~150 g of sediment was taken from the upper 15 cm of sand, preserved in 5% formalin and stored and analysed later for particle size using the standard sieve method (Buchanan, 1971) to estimate median particle size and the percentage of fine sand contained in each sample. Wave height was measured together with surf zone width. Animals with stable burrows were noted as present or absent on each beach, and the depth of reduced layers measured. These seven factors were used to calculate wave exposure for each site where *Eurydice* spp. were found in intertidal sand using the Exposure Index (EI) proposed by McLachlan (1980). As a reduced layer was rare the EI was modified by adding a value of 1 if no reduced layer was present in the upper 15 cm of sand and a value of 0 if a reduced layer was present. McLachlan (1983) worked with more sheltered beaches where a reduced layer was common and ascribed a range of 0–4 depending on depth of layer.

The present EI produced values of 0–6 for sheltered, 7–9 for semi-exposed, and 10–16 for exposed sand beaches. Correlation between median particle size, mean slope and beach exposure rating were tested. As slope and sediment data did not closely fit a normal distribution, Spearman's ranked correlation coefficient (r_s) was used to calculate a t-value which was tested for significance at (n–z) degrees of freedom.

Biological sampling

At each beach, samples were collected from stations between MHW of the last tide and MLW. A stratified random sampling strategy was followed with stations located at four levels: MHWS – MHWN, MHWN – MTL, MTL – MLWN and MLWN – MLWS. Three replicate samples were taken at each level using a 25x25 cm quadrat, removing all sand to 15 cm depth. Each sample was sieved through a 10 μm nylon screen and material retained preserved in 5% buffered formalin.

Samples were also taken from the surf zone at night. Free-swimming organisms were attracted by the light of a 12 V waterproof torch and captured using a hand-net with a mesh size of 300 μm (Naylor, 1972). Samples were taken using this method from 16 sites (Figure 1) either at LW or HW, and sampling effort was standardized by 'fishing' for 20 min on each occasion. These samples were also preserved in buffered 5% formalin and stored in plastic bottles.

All samples were later sorted, firstly removing all macrofauna and then further separating any *Eurydice* spp. *Eurydice* were identified, separated by species and counted using a Wild M3Z (x6·5–40 zoom) binocular microscope. The remaining macrofauna were preserved but are not considered in this report. Specimens were dissected and mounted using polyvinyl lactophenol/lignin pink to aid identification whenever necessary. Drawings were made from slides, using a Wriekart viewer.

Species population densities are expressed as numbers m^{-2} and are means of three replicates at each station. Habitat preference was investigated by comparing the median exposure ratings of the beaches from which each species was found in intertidal sand.

A Kruskal-Wallis test was used to test whether the median values were significantly different from each other. Pairwise comparisons were then carried out using the test by Dunn, to determine which species preferred beaches with significantly different exposures. Details of both statistical tests are given by Whitaker (1990). The parametric Kruskal-Wallis test was also used to determine whether there were significant differences between population densities of each species at beach levels where each species was most abundant.

RESULTS

Physical data

Location

The distribution of sampled beaches is shown in Figure 1 and their physical characteristics are summarized in Table 1. Preliminary surveys of 34 beaches were conducted and quantitative data collected on 22 of these beaches. Using the beach type classification of Short & Wright (1983), 12 sites are dissipative, four reflective and three intermediate. The three remaining sites sheltered from wave action are classified as protected (Table 1).

Table 1. *Location of beaches containing intertidal species of* Eurydice *together with physical characteristics and maximum densities of each species (m^{-2}).*

Site	Name	Location	Type	Md (µm)	Ms	EI	*Eurydice* (m^{-2}) *E. affinis*	*E. pulchra*	*E. naylori*
1	Mogro	43°26′N 04°00′W	P	280·4	0·024	6	213·3	42·7	5·3
2	Arano	43°30′N 07°00′W	D	299·1	0·036	9	240·0	5·3	0·0
3	Cobros	43°31′N 08°15′W	D	430·3	0·035	14	10·7	0·0	0·0
4	Balares	43°14′N 08°55′W	D	1235·8	0·076	10	0·0	0·0	5·3
5	San Francisco	42°45′N 09°04′W	I	282·5	0·057	6	5·3	0·0	0·0
7	America	42°07′N 08°52′W	D	251·5	0·041	8	208·0	10·7	0·0
8	Viana	41°40′N 08°50′W	D	247·3	0·031	10	0·0	0·0	42·7
9	Aveiro	40°36′N 08°45′W	P	491·6	0·290	5	37·3	5·3	0·0
10	Fig. da Foz	40°04′N 08°54′W	D	216·6	0·024	10	0·0	0·0	149·3
11	Baleal	39°22′N 09°22′W	D	242·8	0·030	10	21·3	0·0	16·0
12	Covo Vapor	38°40′N 09°15′W	R	186·3	0·089	3	26·7	69·3	0·0
13	São Torpes	37°56′N 08°45′W	D	291·7	0·074	9	144·0	0·0	0·0
14	Molfontes	37°43′N 04°45′W	P	418·6	0·048	5	0·0	5·3	0·0
15	Amoreira	37°24′N 08°50′W	D	312·7	0·020	12	16·0	0·0	5·3
16	Meia-Praia	37°06′N 08°35′W	R	433·4	0·080	8	16·0	5·3	0·0
20	Luz	36°36′N 06°20′W	I	201·2	0·120	2	42·7	0·0	0·0
21	Corduarma	37°06′N 08°55′W	D	352·6	0·050	13	26·7	0·0	213·3
23	Trafaria	38°40′N 09°20′W	R	374·7	0·229	6	1525·3	5·3	0·0
24	Arrábida	38°28′N 09°09′W	R	844·0	0·097	8	5·3	0·0	0·0
25	Forna	43°45′N 07°50′W	D	196·6	0·036	8	552·0	440·0	24·0
26	Area Longa	43°45′N 07°36′W	I	228·4	0·062	5	314·7	106·7	0·0
27	Espesa	43°27′N 05°20′W	D	316·7	0·028	10	26·7	0·0	16·0

D, dissipative; I, intermediate; P, protected; R, reflective. EI, Exposure index; Md, median particle size; Ms, mean slope.

Temperature and salinity

Over the period of sampling (July – September 1991) sand temperatures within the upper 15 cm at midday ranged from 12°C (site 26: 27 September 1991) to 38 °C (site 15: 30 July 1991). Salinity was not measured, but coastal water ranges from 36·4‰ in the south to 35·5‰ in the north of Portugal (C.G. Martins, personal communication).

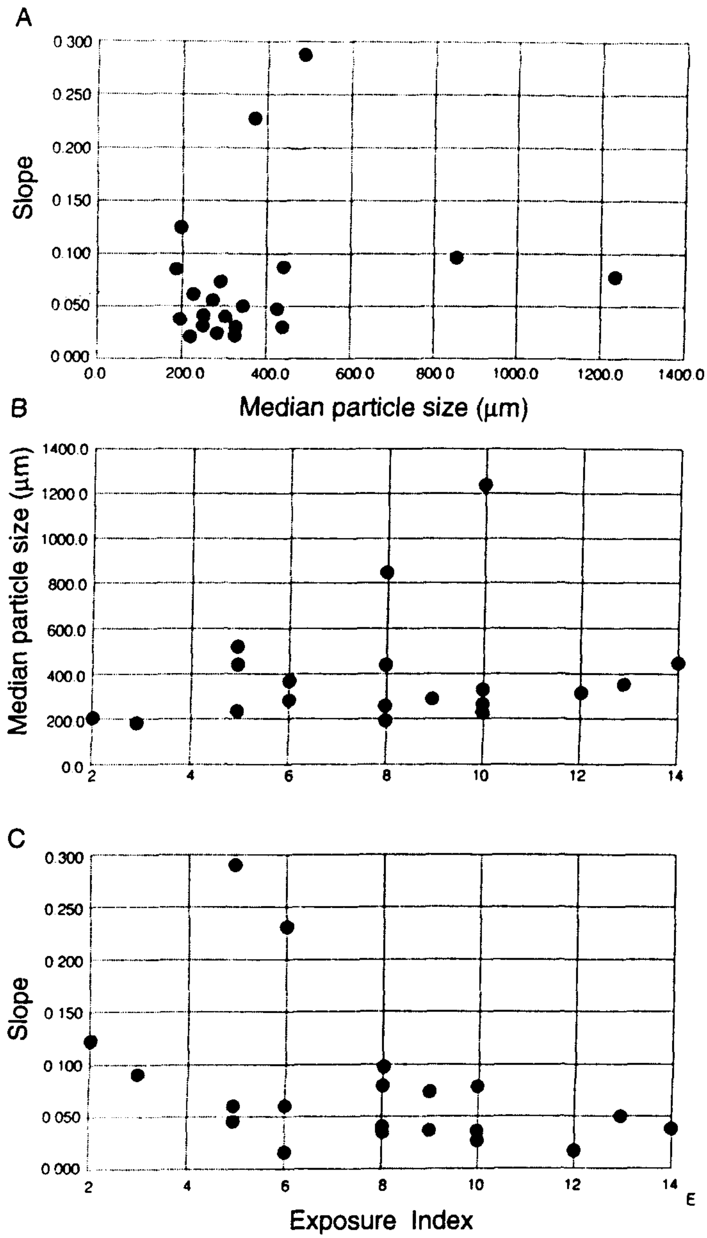

Figure 2. (A) Median particle size for beaches (see Table 1) plotted against mean slope of the same beaches (r_s=0·210); (B) median particle size of beaches plotted against Exposure Index (see Table 1) (r_s=0·187); (C) mean beach slope plotted against Exposure Index (r_s=0·468).

Sediment and beach profiles

Median particle sizes taken at MTL at each site are given in Table 1. Thirteen of the beaches were composed of medium sand (Md 250–500 μm), seven of fine sand (125–250 μm), and two of coarse or very coarse sand (50–2000 μm). Mean beach slopes plotted from measured profiles are given in Table 1 and plotted against median particle size in Figure 2A. There is no significant correlation between these factors (r_s=0·210; t=0·9606; df=20).

Exposure

The calculated Exposure Index (EI) values for sites containing intertidal *Eurydice* spp. are given in Table 1. The most exposed sites (EI >10) are dissipative beaches with relatively shallow intertidal slopes (mean 0·035, range 0·02–0·076) located mainly on the Atlantic coasts of western Portugal (beaches 8, 10, 11, 15, 21; Figure 1) and north-west Spain (beaches 3, 4, 27). The most sheltered sites (EI <6) are represented by a range of different habitats throughout the study area: beaches protected by headlands (5, 20, 26); pocket beaches at the mouths of rivers (12, 14, 23); and beaches protected by vegetated sand bars (1, 9). These beaches have steeper profiles (mean 0·1265, range 0·024–0·290).

The remaining six sites (EI 7–9) are classed as semi-exposed, consisting of dissipative, reflective and intermediate beach types, found on all coasts, but sheltered from prevailing northerly and north-westerly wind and wave action (beaches 2, 7, 13, 16, 24, 25) (mean slope 0·061, range 0·036–0·097). If median particle size is plotted against exposure rating for each beach (Figure 2B) there is a nonsignificant correlation (r_s=0·187; t=0·8513; df=20). This is because some protected estuarine beaches (9, 14) and semi-exposed reflective beaches (16–24) are composed of coarser sediment than more exposed sites. However, when beach slope is plotted against exposure (Figure 2C) a significant correlation is found (r_s=0·468; t=2·368; df=20) at the 5% confidence level. Thus beach profiles become less steep as exposure to wave action increases.

SYSTEMATICS

Order ISOPODA
Family CIROLANIDAE
Genus *Eurydice* Leach, 1815

Restricted synonymy: *Eurydice* Leach, 1815: 354, 370; Jones, 1971: 201; Brusca, 1973: 203; Bruce, 1986: 11.

Eurydice naylori sp. nov. (Figures 3A,B,E & F; 4–6)

Material examined

Two hundred and thirty-five males, 306 females, 149 juveniles, intertidal from beaches on the Atlantic coast of Spain and Portugal, collected by C.J.P. Amoreira 37°24′N 08°35′W, 3 September 1991.

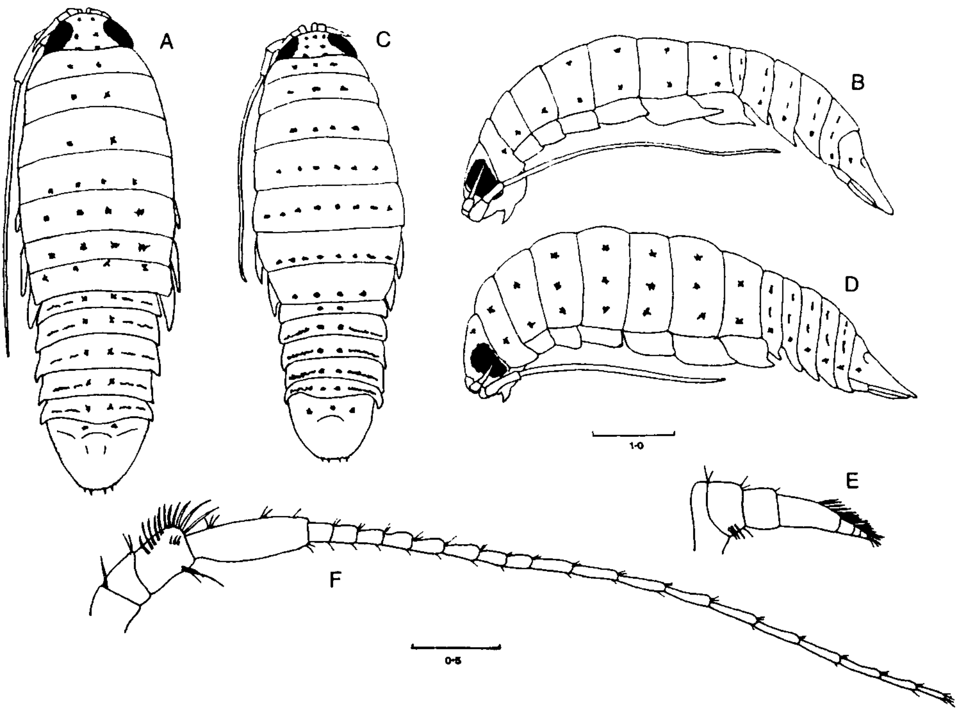

Figure 3. *Eurydice naylori.* Male holotype from Amoreira beach, Portugal: (A&B) dorsal and lateral views; (E) antennule; (F) antenna. *Eurydice pulchra* male from the same beach: (C&D) dorsal and lateral views.

Type material

Male holotype (4·4 mm), British Museum (Natural History) (BM (NH)) 1996: 105. Forty male and female paratypes Amoreira 3 September 1991, BM (NH) 1996: 106–125 (106, male (4·8 mm) dissected, three slides).

Description of male holotype

Body about three times as long as wide, dorsal surface patterned with black chromatophores, eyes large extending to dorsal edge of cephalon when viewed laterally, pereonites 4–6 longest and subequal; posterior margins of coxae 5–7 visible in dorsal view; pleonites all visible.

Frontal lamina elongate and narrow with spear-shaped anterior tip, clypeus triangular, strongly produced and projecting. Mandibular palp second article with nine setae, article three with 11. Maxillule inner ramus with three strong distal plumose spines and two short simple setae, outer ramus with 12 stout spines. Maxilla with truncate inner ramus bearing three plumose setae and three simple setae distally; inner and outer lobes of outer ramus bearing seven and five distal setae respectively. Maxilliped article 6 bearing ten long setae; article 5, nine setae; article 4, eight setae; article 3, two setae; and article 2, nine setae; articles 5, 6 with row of fine setae on lateral margins.

Antennule reaching posterior of eye, second peduncular article just shorter than third and half length of first flagellar article, bearing four setae on posterior and two

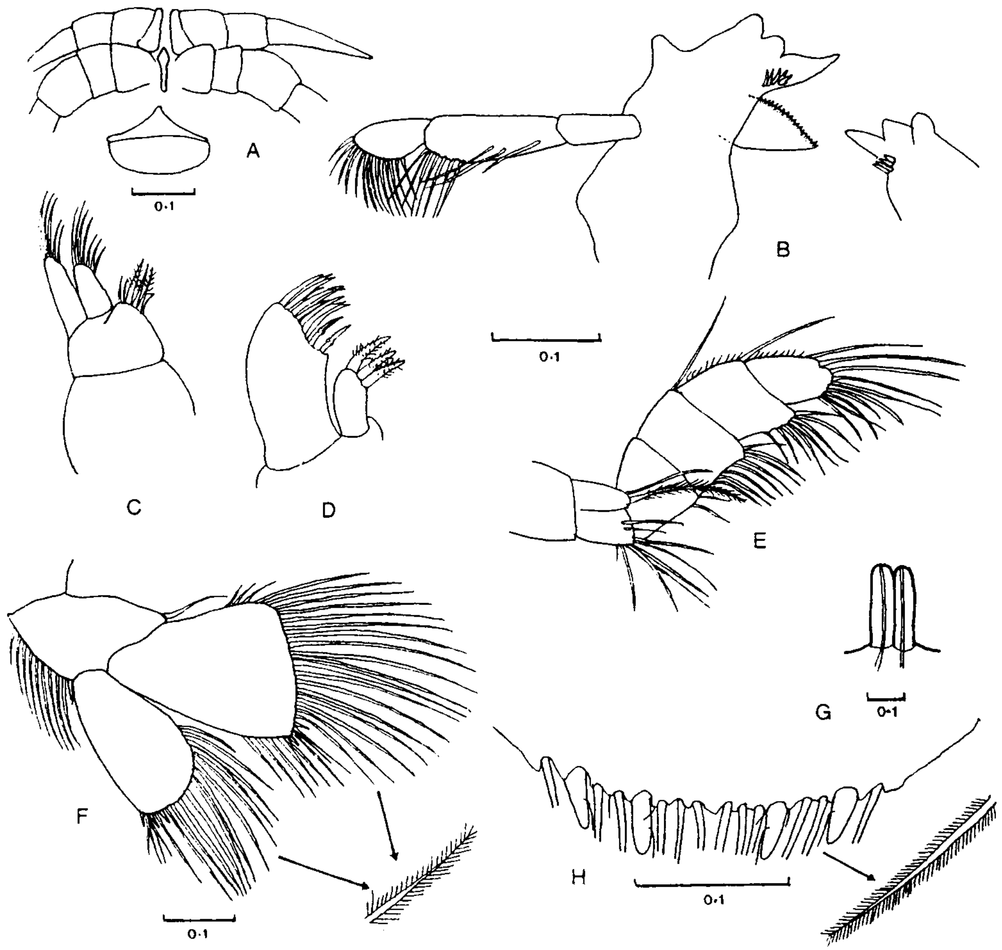

Figure 4. *Eurydice naylori*. Male holotype: (A) frontal lamina and clypeus. Male paratype: (B) left and right mandibles; (C) maxillule; (D) maxilla; (E) maxilliped; (F) uropod; (G) penes; (H) telson hind margin.

setae on anterior margin; flagellum of four articles, article 2 twice length of either article 3 or 4. Antenna reaching pleonite 2 peduncular article 4 equal to combined length of articles 1–3, article 3 bearing a row of 11 stout curved setae on anterior margin and two other groups of three simple setae; article 4 with groups of 3, 2, 1 setae on anterior margin, antennal flagellum with 19 articles.

Coxae 2–7 with posterior free margins pointed, those of coxae 6 and 7 extended, former by up to one third of coxal length, forming a sharp point.

Pereopods 1–3 similar and ambulatory, 5–7 also similar with ischium to propodus setose and flattened. Pereopod 1 propodus with nine setae on superior margin, five spines and five setae on inferior margin, inferior margin of merus with six spines and a single seta, ischium with seven setae on inferior margin. Pereopods 2–3 increasingly spinose and setose. Pereopod 4 with carpus and merus subequal, with groups of setae and spines on inferior and superior margins, at least one spine on inferior margin of both articles almost equal to length of article. Pereopod 5 shorter than pereopod 7, pereopod 6 longest. Pereopod 7 propodus with groups of 3, 2, 2, 4 spines on inferior margin and 1, 1, 2 spines plus six setae on the superior margin, carpus with groups of four spines + 1 seta, 3, 3 spines on inferior margin and two submarginal groups of two spines, and groups of four spines + 4 setae, 2 + 2, 2 + 2, 1 + 2 on the superior margin. Merus with groups of 2, 3, 3 spines on inferior, three single submarginal and 3, 1, 1, 1 spines on superior margin which is moderately setose. Ischium bearing groups of 2, 3, 2, 1, 2 spines on inferior and a distal group of four amongst eight setae on superior margin. Basis with three groups of setae 6, 6, 2 on inferior margin. Penes present on sternite 7 elongate three times longer than wide.

Pleotelson 1·1 times broader than long with gently rounded lateral margins terminating in a slightly rounded serrated posterior margin, more than one third of telson width, with 12 plumose setae and four blunt spines. Uropod projecting slightly beyond posterior margin of pleotelson; peduncle lateral margin bearing nine setae and a single spine; exopod about twice as long as broad and 85% length of endopod, with three spines on posterolateral angle and 13 plumose setae on posterior margin; endopod posterior margin truncate with 18 plumose setae, lateral margin with four setae and distolateral angle bearing two short spines. Pleopods elongate and rounded, endopod of pleopod 5 without setae. Pleopod 2 with appendix masculina proximal to the midpoint of the medial margin of endopod and is 86% of length of endopod; appendix masculina medially narrowed with broad apex bearing slightly curved narrow mediodistal process, median margin with cuticular scales also found on distolateral margin.

Additional characters

In larger males (5·2–5·6 mm TL) the apical point on the appendix masculina becomes increasingly straightened.

Female

Similar to male but body broader and more convex and antennal flagellum shorter, reaching to posterior of pereonite 6.

Colour

In formalin white with black chromatophores on dorsal and ventral surfaces.

Remarks

There are several other intertidal species of *Eurydice* with posteroventral points on coxae 6–7 in the region, but most appear to be restricted to the Mediterranean Sea (Jones, 1969; Kussakin, 1979). *Eurydice naylori* may be separated from *E. dollfusi* as this species lacks posteroventral points on coxae 2–5; *E. longispina* Jones has pronounced posteroventral points on coxae 1–5 and a distinctive curved spine opposing the dactylus of pereopods 1–6; *E. valkanovi* Bascesco has a curved appendix masculina bearing a recurved apical point; *E. racovitzai* Bascesco has two apical points on the appendix masculina (Kussakin, 1979). Atlantic coast species from Portugal (Dexter, 1988) may be separated using similar criteria. However, as *E. pulchra* overlaps with *E. naylori* and the

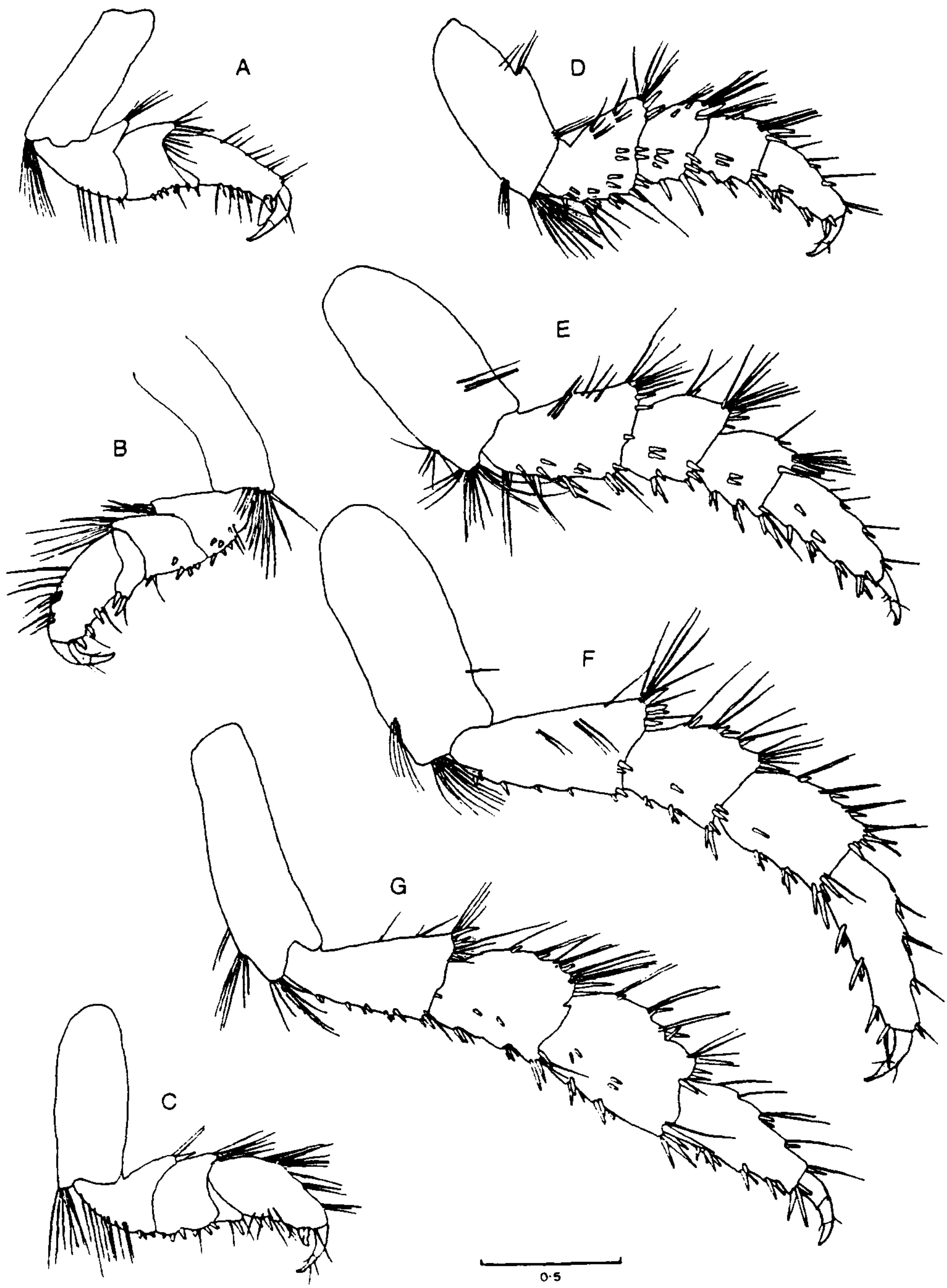

Figure 5. *Eurydice naylori*. Male holotype: (A–G) pereopods 1–7 respectively.

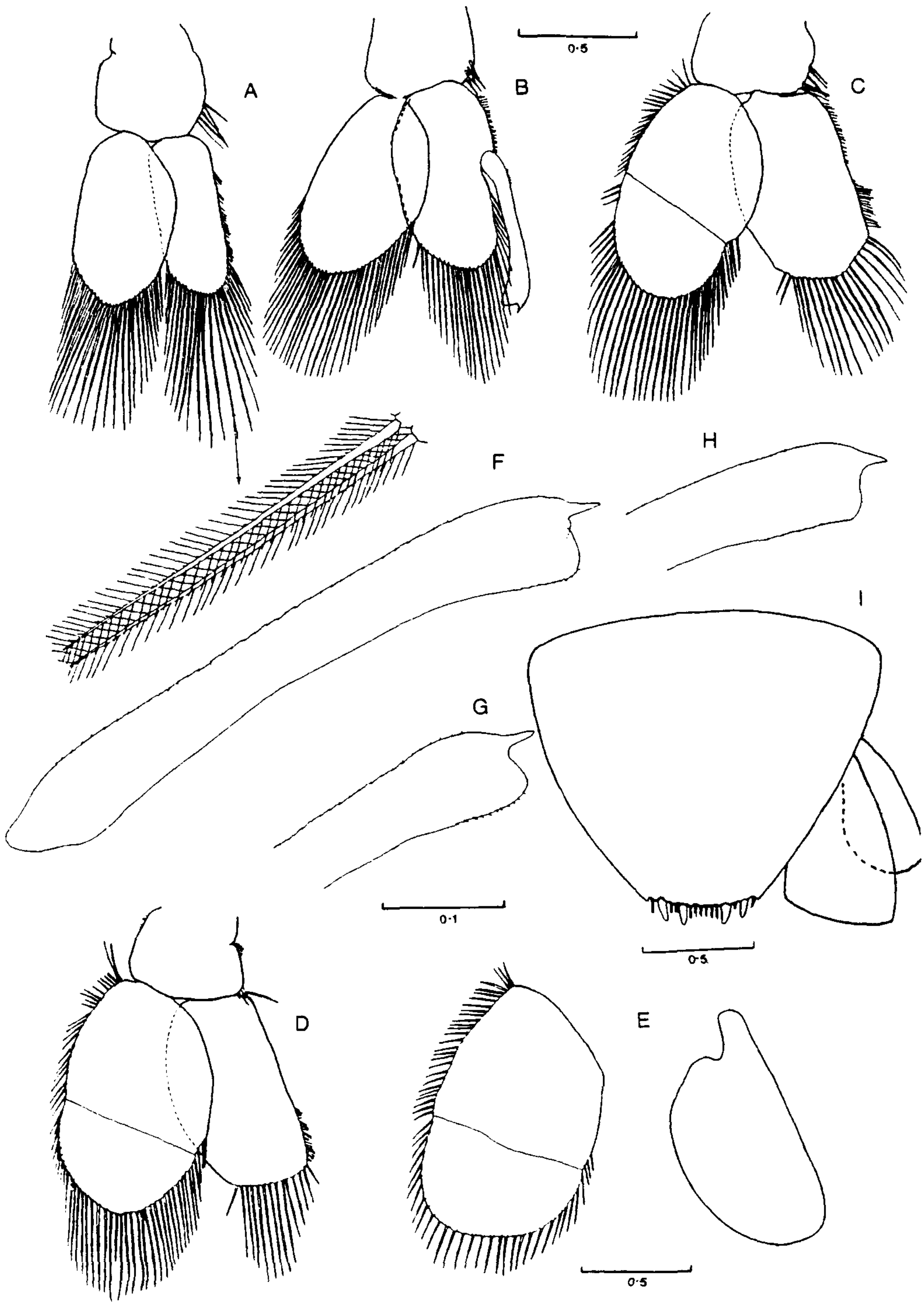

Figure 6. *Eurydice naylori*. Male paratype: (A–E) pleopods 1–5; (F) appendix masculina, male 5·6 mm total length (TL); (G) same for male 5·2 mm TL; (H) same for male holotype 4·4 mm TL; (I) pleotelson and uropods.

species can co-occur on the same beaches, this has led to past misidentification (Dexter, 1988; L. Cancela de Fonseca, personal communication). The most obvious character separating *E. naylori* from *E. pulchra* is the extended posteroventral point on coxa 6 of the former species (Figure 3). Other obvious distinguishing characteristics include the length of the antennule in *E. naylori* which reaches to the rear of the eye, but only to the centre in *E. pulchra*; the antenna which extends beyond the thorax in *E. naylori* together with differences in the setation and proportions of penduncular articles between species (Figure 3). The telson is 1·25 times broader than long in *E. pulchra* which has a shorter (70% length) endopod and appendix masculina with a curved apical point. The setation and spination of the pereopods also differs between the species.

Distribution

Atlantic coasts of Spain and Portugal from Mogro in the north to Corduarma in the south in exposed sandy beaches (see section on Ecology).

Etymology

This species is named after Professor E. Naylor in recognition of his contribution to marine sciences, especially in the field of crustacean behaviour.

Eurydice lusitaniensis sp. nov. (Figures 7 & 8)

Material examined

Two males (one dissected) in surf plankton at Amoreira, Portugal 37°24′N 08°35′W collected by C.J.P., 3 September 1991.

Type material

Male holotype (6·0 mm) Amoreira BM (NH) 1996: 126. Male paratype (4·8 mm; dissected, four slides) Amoreira BM (NH) 1996: 127.

Description of male holotype

Body less than three times longer than broad, chromatophores on dorsal and ventral surfaces, eyes small and rounded, not reaching dorsal margin of head when viewed laterally, pereonite 4 longest, only posterior margin of coxae 7 visible in dorsal view; all pleonites visible.

Frontal lamina elongate and narrow, clypeus triangular and projecting ventrally. Mandibular palp with six setae; three marginal, on second article and ten on third article. Maxillule inner ramus with three strong distal plumose spines, outer ramus with 11 stout spines. Maxilla with truncate inner ramus bearing six plumose setae and one simple seta distally; inner and outer lobes of outer ramus bearing six and three distal plumose setae. Maxilliped with article 6 bearing nine strong setae and a row of short setae on the lateral margin; article 5, six setae; article 4, seven setae; article 3, one seta; article 2, three setae; endite with two simple and one plumose setae.

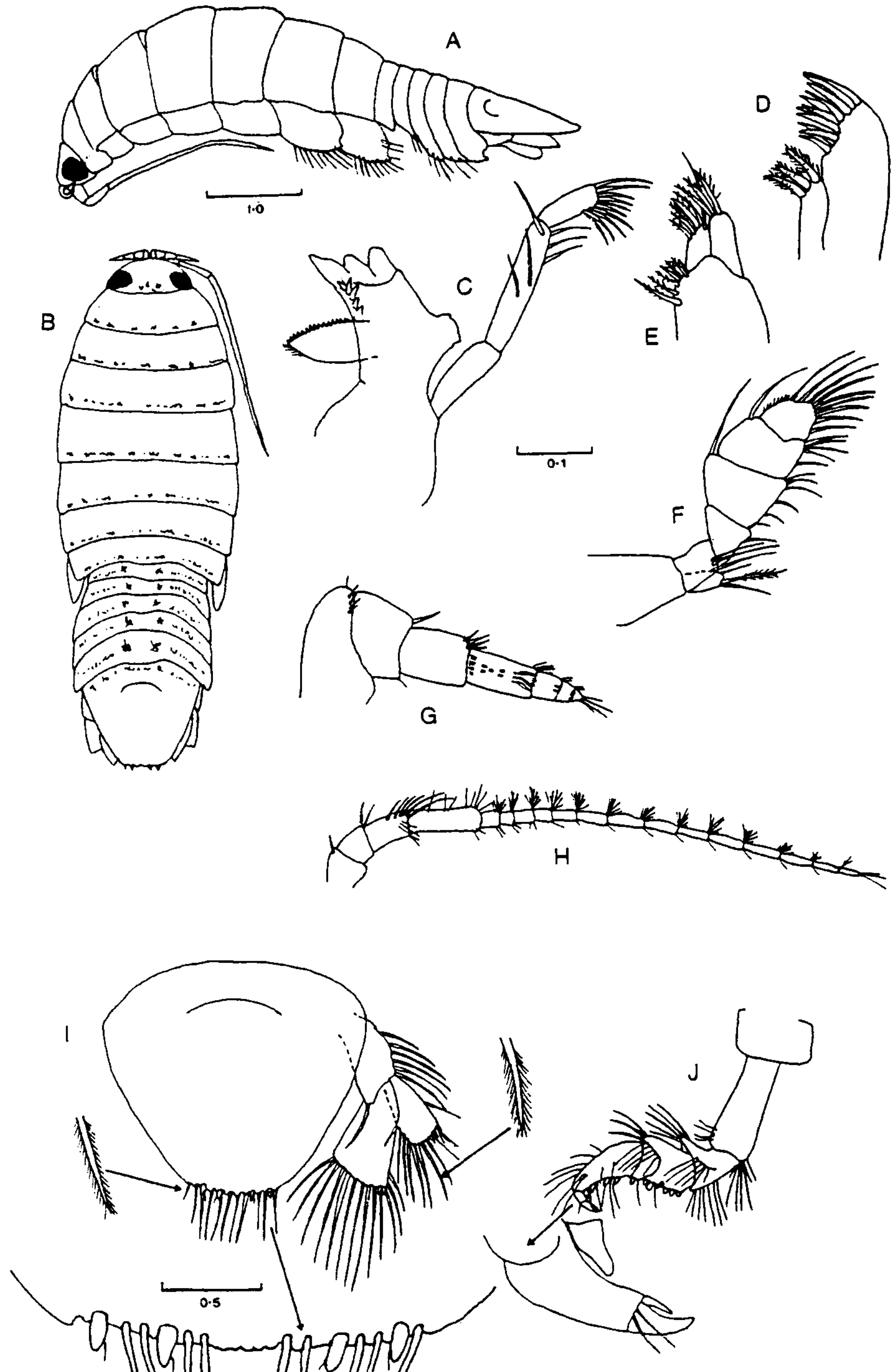

Figure 7. *Eurydice lusitaniensis*. Male holotype Amoreira, Portugal: (A&B) lateral and dorsal views. Male paratype: (C) left mandible; (D) maxillule; (E) maxilla; (F) maxilliped; (G) antennule; (H) antenna; (I) pleotelson and uropods; (J) pereopod 1.

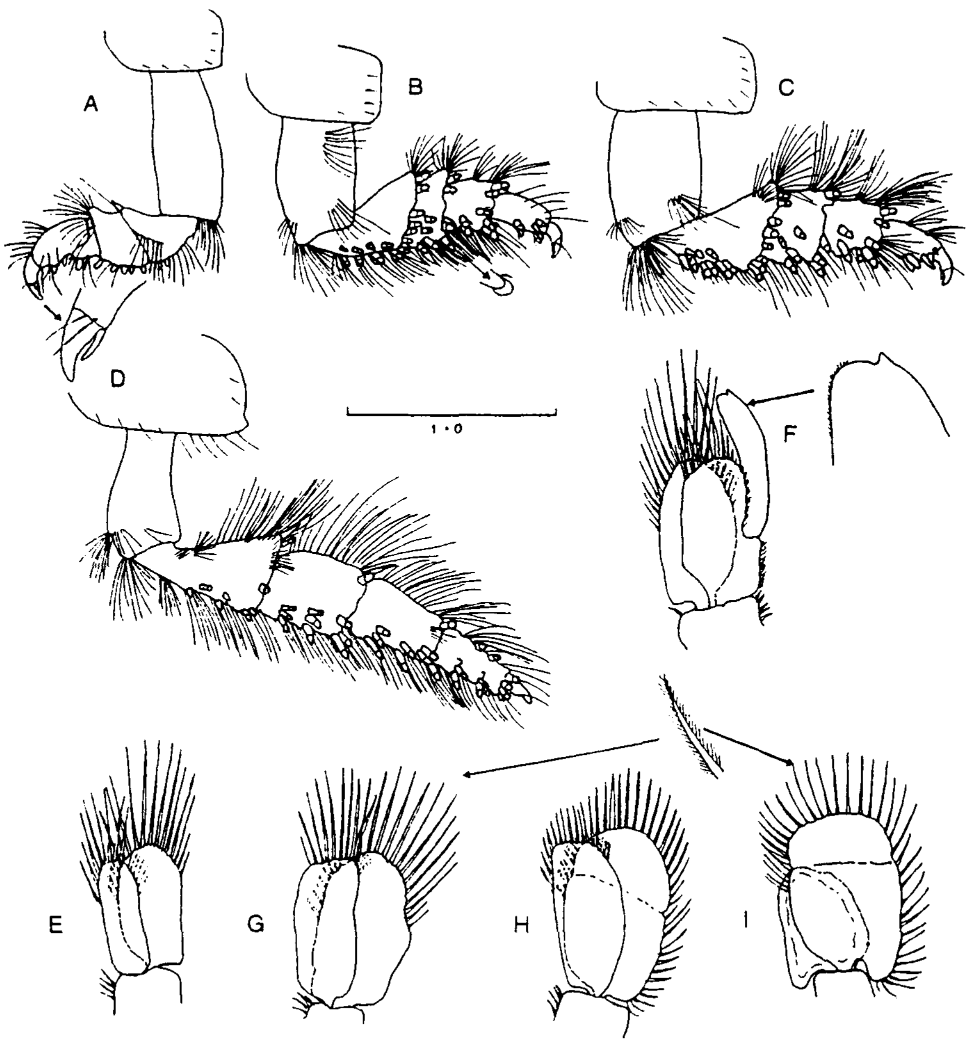

Figure 8. *Eurydice lusitaniensis*. Male paratype: (A–C) pereopods 3–5; (D) pereopod 7; (E–I) pleopods 1–5.

Antennule short, not reaching centre of eye, third peduncular article longest, subequal to length of first flagellar article, bearing four setae distally on anterior margin; flagellum of four articles, article 1 longer than combined length of articles 2–4. Antenna short, not reaching beyond pereonite 4 with peduncular article 4 equal to combined length of articles 2–3; peduncular article 3 with a row of six curved setae on anterior margin and a group of four setae on dorsal surface; article 4 with groups of 1, 2, 5 setae on anterior margin; antennal flagellum with 14 articles.

Coxae 1–5 with posteroventral free margins bluntly pointed, those of coxae 6–7 with posterior margins indented and bearing small points on the posteroventral angles; ventral margins of coxae 6–7 setose. Epimera on pleonite 2 reduced to narrow elongate point, epimera on pleonite 5 terminating in a hooked point, epimera 2–4 setose.

Pereopods 1–3 similar and fossorial, 4–7 increasing in length and strongly spinose and setose. Pereopod 1 with five setae on superior margin and two submarginal spines, four spines and three setae on inferior margin of propodus; dactylus with strong subapical spine; inferior margin of merus with five blunt spines, one submarginal spine, and a single seta; ischium with seven setae on inferior margin, six setae on outer lateral surface and five distal setae on superior margin. Pereopods 2–5 increasingly setose and spinose. Pereopod 4 propodus with a group of three blunt club-shaped spines on inferior distal margin and further group of two medially on margin. Carpus with seven club spines, merus with nine spines, ischium with 17 spines. Pereopod 7 propodus with four terminal club spines, groups of 3, 2 spines on the inferior margin and 1, 1 on superior margin; carpus with 3, 2, 3 spines on inferior and a single distal spine on superior margin; merus with 3, 3, 3 spines on inferior and one club and one pointed spine on superior margin; ischium with 2, 1, 1 spines on inferior and one pointed and one club spine on superior margin. Both margins of all articles heavily setose.

Pleotelson 1·1 times broader than long with curved lateral margins terminating in a slightly rounded serrated posterior margin one third width telson, and bears 11 plumose setae and four blunt spines. Uropod just projecting beyond posterior margin of pleotelson; lateral margin of peduncle bearing six plumose setae; exopod twice as long as broad, less than two thirds length of endopod, with three spines on posterolateral angle and eight plumose setae on posterior margin; endopod triangular, posterior margin bearing ten plumose setae and two spines on posterolateral margin, lateral margin with 2 plumose setae. Pleopods with margins setose except for endopod pleopod 5. Pleopod 2 with appendix masculina arising proximal to the midpoint of the medial margin of endopod and is of same length as endopod and hence exceeds apex of endopod by 50% of its length; appendix masculina broad and curved with rounded apex bearing small mediodistal process, distolateral margin bearing short cuticular scales.

Female

Unknown.

Colour

Yellowish brown with black chromatophores in formalin.

Remarks

The heavily setose and spinose pereopods of *E. lusitaniensis*, bearing club-end spines, appear unique among European *Eurydice* spp., as does the hooked epimera of pleonite 5 and broad shaped appendix masculina with reduced apical process. The reduced epimera on pleonite 2 are also seen in *E. dollfusi*, but this species has a narrow straight pleotelson posterior margin. Similarly, marginal setae are present on the coxae of *E. racovitzai*, but this species also has posteroventral points on the coxae. There are no other Mediterranean (Kussakin, 1979) or North African species (De Grave & Jones, 1991) in which the appendix masculina projects so far beyond the endopod apex.

Table 2. *Night plankton hauls. The total number of* Eurydice *spp. collected in night surf plankton hauls is given for each site at which sampling was carried out. The percentage of the total for each species is then given.*

Site	Total	*E. affinis*	*E. pulchra*	*E. naylori*	*E. spinigera*	*E. lusitaniensis*
1	120	52·5	47·5	0·0	0·0	0·0
5	0	0·0	0·0	0·0	0·0	0·0
8	23	4·4	0·0	95·6	0·0	0·0
10	153	0·0	0·0	100·0	0·0	0·0
11	41	26·8	0·0	73·2	0·0	0·0
12	70	48·6	51·4	0·0	0·0	0·0
13	14	64·3	0·0	28·6	7·1	0·0
14	87	0·0	66·7	0·0	33·3	0·0
15	371	10·5	0·3	85·2	3·5	0·5
16	129	0·8	34·1	0·0	65·1	0·0
17	3	33·3	66·7	0·0	0·0	0·0
19	1	0·0	0·0	0·0	100·0	0·0
20	9	100·0	0·0	0·0	0·0	0·0
21	35	0·0	0·0	100·0	0·0	0·0
22	*			*	*	
23	11	100·0	0·0	0·0	0·0	0·0
24	66	100·0	0·0	0·0	0·0	0·0
25	348	9·2	88·2	2·6	0·0	0·0
27	22	4·5	0·0	95·5	0·0	0·0

*, the sample taken at site 22 was badly preserved but the specimens of the species marked with an asterix were present.

Distribution

Atlantic coast of Portugal at Amoreira taken in surf plankton using a light at night.

Etymology

This species is named after the region in which it was discovered.

ECOLOGY

Geographical distribution of species

Of the five species of *Eurydice* collected from the intertidal zone of beaches during this study, *Eurydice affinis*, *E. pulchra*, *E. naylori* and *E. spinigera* were taken both in sand and surf samples, whilst *E. lusitaniensis* was only taken in surf samples (Table 2). *Eurydice affinis*, *E. spinigera* extend along the Algarve onto the southern Atlantic coast of Spain where *E. dollfusi* has previously been reported. Highest densities of *E. affinis* (1525 m^{-2}) were taken at Trafaria (Table 1), but this species was common throughout the region. *Eurydice pulchra* reached highest densities in northern Spain (106–440 m^{-2}), whereas *E. naylori* was most abundant on southern Portuguese Atlantic beaches (149–2131 m^{-2}), but both species extend over the same geographical range (Table 1).

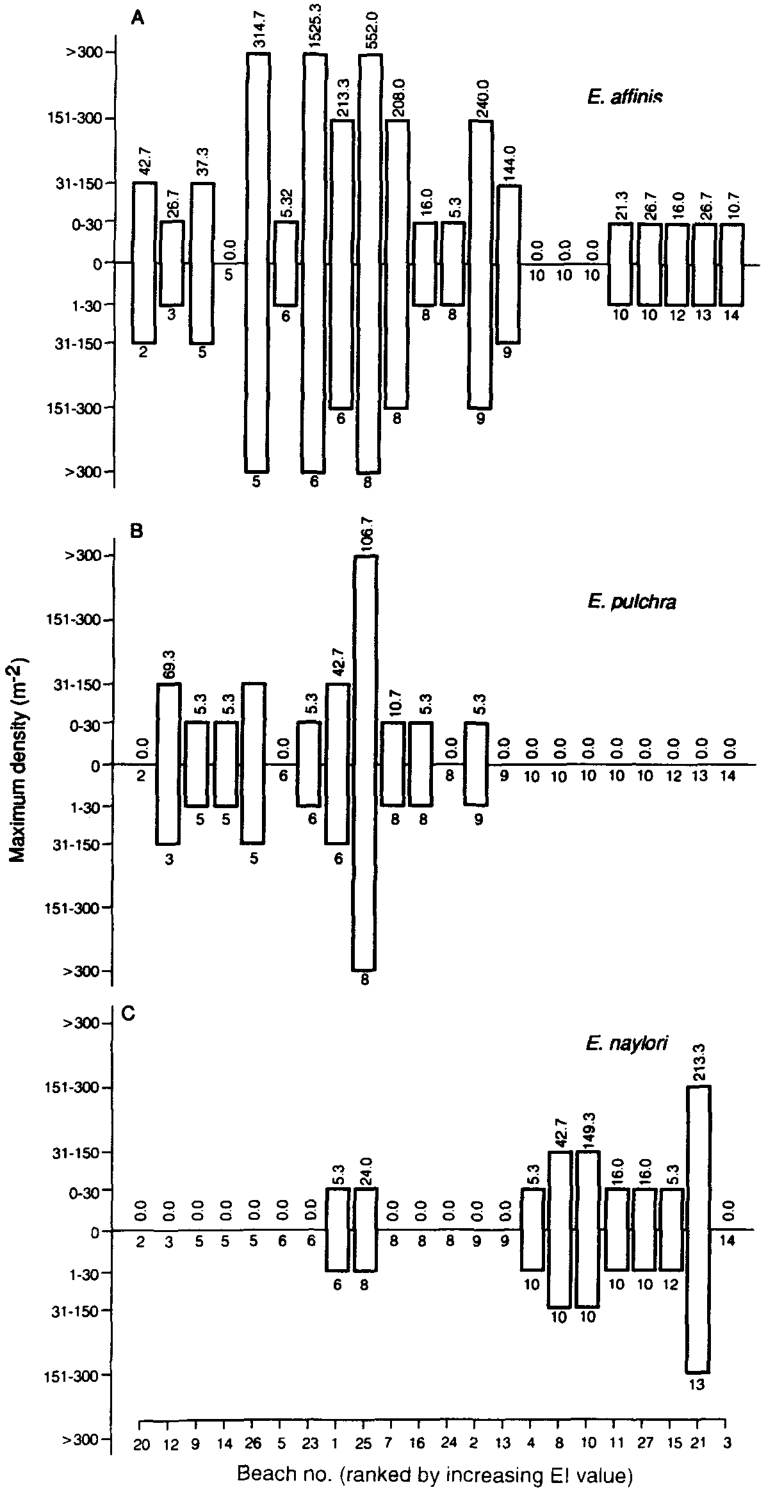

Figure 9. Densities m^{-2} for intertidal *Eurydice* spp. on beaches listed in Table 1 ranked by increasing Exposure Index: (A) *Eurydice affinis*; (B) *Eurydice pulchra*; (C) *Eurydice naylori*.

Distribution in relation to exposure

Densities of the common intertidal species *E. pulchra, E. naylori* and *E. affinis* are plotted in Figure 9 for beaches ranked by exposure using the Exposure Index. This shows that whilst *E. affinis* (Figure 9A) occurs over a wide range of exposures (EI 2–14), *E. pulchra* (Figure 9B) and *E. naylori* (Figure 9C) exhibit distinct exposure preferences. *Eurydice pulchra* is only present on sheltered and semi-exposed beaches of EI <9, whereas *E. naylori* is generally confined to exposed beaches (EI >10). The two species only coexist at sites 1 (EI 6) and 25 (EI 8) where *E. naylori* formed <13% of the density attained by *E. pulchra* (Table 1).

A Kruskal-Wallis test (Whitaker, 1990) used to determine whether the median exposure value differs for beaches containing each species (*E. affinis*, EI 8; *E. pulchra*, EI 6; *E. naylori*, EI 10) demonstrates (P=0·011) that at least one median value is significantly different from others. Pairwise comparisons (Dunn cited in Whitaker, 1990) reveal that whilst exposure values for *E. pulchra* and *E. naylori* are significantly different at the 5% level, neither species can be separated from *E. affinis* on the basis of exposure. Thus *E. naylori* prefers more exposed beaches than *E. pulchra* and the two species were mutually exclusive on 17 out of 19 beaches surveyed, and in 10 out of 12 surf hauls taken. *Eurydice affinis*, however, regularly coincides with both species (Table 1).

Vertical zonation

Table 3 shows the tidal levels at which peak densities of each species occurred on the beaches surveyed quantitatively. Although all species of *Eurydice* were found at all four tidal levels, peak densities of each species occurred most frequently at tidal level 2 between HWN and MTL. A Kruskal-Wallis test for differences in the level at which each species attains peak density failed to reveal any significant differences between species.

Table 3. *The tidal levels at which peak species densities occur at each site. Where peak abundance occurred between two levels, data is not included.*

Species	Level 1	Level 2	Level 3	Level 4
E. affinis	0	15	3	0
E. pulchra	0	6	2	1
E. naylori	0	4	2	1

DISCUSSION

It is perhaps surprising that a common macrofaunal inhabitant of Iberian Atlantic sand beaches, *Eurydice naylori* should have remained undetected until recently, although its similarity to *E. pulchra* has undoubtedly led to previous misidentification (Dexter, 1988). The use of the morphological criteria given in the present work, in particular the pointed coxae 6–7, should now allow rapid identification under low magnification. The ability to separate *E. naylori* from *E. pulchra* is particularly important, as the ecology of these species is so distinct. *Eurydice naylori* populates exposed sand beaches, in particular dissipative beaches on the Atlantic coast of Portugal, whilst *E. pulchra* dominates on semi-exposed and sheltered beaches receiving significantly less exposure to wave action.

Studies on *Eurydice* spp. from the Aegean Sea demonstrate similar ecological separation of this genus. *Eurydice czerniavsky* Bascesco and *E. pontica* (Czerniavksy) are restricted to exposed beaches, whilst *E. longispina* and *E. rotundicauda* preferentially occupy sheltered sites (Jones, 1969). In South Wales *E. pulchra* populations dominate those of *E. affinis* at more exposed sites, yet in Spain and Portugal this species occurs over a wider range of exposure than either *E. pulchra* or *E. naylori*. As *E. affinis* reaches its northern geographical limit in the UK it is probable that temperature rather than exposure allows *E. pulchra* to compete more successfully in northern Europe.

Comparisons of population densities are possible between Iberian, UK (Jones & Naylor, 1967) and French beaches (Salvat, 1966, 1967). *Eurydice affinis* reaches maximum densities in Iberia (Trafaria, Portugal, 1525 m^{-2}; Oxwich, UK, 1250 m^{-2}; La Vigne, France, 709 m^{-2}). Conversely, maximum densities for *E. pulchra* in Iberia are 440 m^{-2} (Forna), 924 m^{-2} at La Vigne, 5760 m^{-2} in South Wales and 7280 m^{-2} on St Kilda, Scotland (Scott, 1960). These changes in densities of individual species are likely to reflect temperature control of reproductive potential throughout the geographical range of each species (Salvat, 1966; Jones, 1970a).

Six intertidal or immediate sublittoral species of *Eurydice* have now been recorded from the Atlantic coast of the Iberian peninsula: *E. pulchra, E. affinis, E. naylori, E. spinigera, E. dollfusi* and *E. lusitaniensis*. This last species, although taken only in surf plankton, is likely to be intertidal or nearshore in distribution, as it possesses dorsal and ventral chromatophores and spines on the posterior margin of the pleotelson (Soika, 1955a; De Grave & Jones, 1991). Only *E. pulchra, E. affinis* and *E. spinigera* extend north into the UK, and *E. clymeneia* Monod, *E. pulchra* and *E. mauritanica* De Grave & Jones, occur on the north-west Atlantic coast of Africa. More extensive speciation has occurred within the Mediterranean and Black Seas with seven species, *E. pontica, E. dollfusi, E. rotundicauda, E. czerniavsky, E. valkanovi, E. longispina, E. affinis* and one subspecies, *E. dollfusi-mari-nigri* (Jones, 1969; Kussakin, 1979). Further subspecies of *Eurydice* may occur on the southern and eastern border of the Mediterranean (Dexter, 1986), and a thorough taxonomic review of the genus in the region is long overdue.

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