

METADIAPTOMUS CHEVREUXI (COPEPODA: CALANOIDA: DIAPTOMIDAE) AND LEPTESTHERIA MAYETI (BRANCHIOPODA: CONCHOSTRACA: LEPTESTHERIIDAE), TWO AFRICAN FRESHWATER CRUSTACEANS RECORDED IN MAJORCA

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ABSTRACT

In the course of a faunistic intensive prospection of small temporary freshwater pools in the sub-steppic zone of Majorca (Balearic Islands), two crustaceans characteristic of the arid regions of north Africa were recorded, namely *Metadiaptomus chevreuxi* (Calanoida: Diaptomidae), and *Leptestheria mayeti* (Conchostraca: Leptestheriidae). Information about their morphology, habitat and ecology is presented, together with some biogeographical comments of their presence so far from north Africa.

INTRODUCTION

Temporary freshwater bodies of the sub-steppic and steppic zones of the world are the habitat of greatly diversified crustacean communities. There anostracans, notostracans, conchostracans, diaptomid copepods and cladocerans are the most characteristic taxa (GAUTHIER, 1928; ALONSO, 1985a, 1985b; THIERY, 1986). This fauna has an accentuated degree of endemism or restricted distribution in spite of its potential for passive dispersal (resting eggs, ephippiums), acquired as a result of adaptations to temporarily dried habitats. This has opened a new point of view on freshwater crustacean Biogeography (FREY, 1982; DUMONT, 1980; ALONSO, 1987). This point of view is now fully accepted, and contrasts with that which considers the cosmopolitanism of the species belonging to the major freshwater crustacean taxa (BIRGE, 1918).

The Majorcan temporary biota has not been studied until a short time ago. In fact, there are

only four bibliographic references on this subject, some of them very bare. The first one is very old (LUIS SALVADOR, 1871) and refers to the finding of *Triops* (= *Apus*) *cancriformis* and *Branchipus stagnalis* (= *B. schaefferi*) in Majorca. The work of MARGALEF (1953) has been the most accurate intent of tipification of the Majorcan water bodies, but references to temporary waters are scarce and reduced to findings of some relevant organisms (i.e. *Triops cancriformis* and *Branchipus schaefferi*). It was not taken in mind the importance and extension of these environments on Majorca until the work of LLORENS (1979), who reported the presence of the Zsoetion alliance in some freshwater temporary pools of the southern part of the island. Later, MAYOL (1977) reported *Triops cancriformis* (Bosc 1801) and the conchostracan *Leptestheria dahalacensis* (Rüppel 1837) from the same localities.

The aim of this work is to refer the existence of two crustacean species with a great biogeographical value in Majorca, namely the diaptomid *Metadiaptomus chevreuxi* Guerne & Richard 1894, and the conchostracan *Leptestheria mayeti*

Simon 1885. These two taxa are restricted to zones with less than 400 mm of annual rainfall (GAUTHIER, 1928; THIERY, 1986; RAMDANI, 1986) and, up to date, they were only known from arid and semi-arid zones of north Africa, Mesopotamia and Arabia. In Majorca they have been collected in 22 small temporary freshwater bodies placed in the semi-arid region.

MATERIAL AND METHODS

Sampling was done qualitatively, specially among the aquatic vegetation. Samples were collected with a plankton net of 40 micrometers mesh size, preserved in 4 % formaldehyde and analyzed under microscope. Drawings were done with camera lucida.

Study area

The survey was done in the semi-arid part of the island, in the area known as Marina de Lluçmajor (fig. 1). This zone is a platform 90 m.a.s.l. originated by sub-aerial exposure of a Messinian

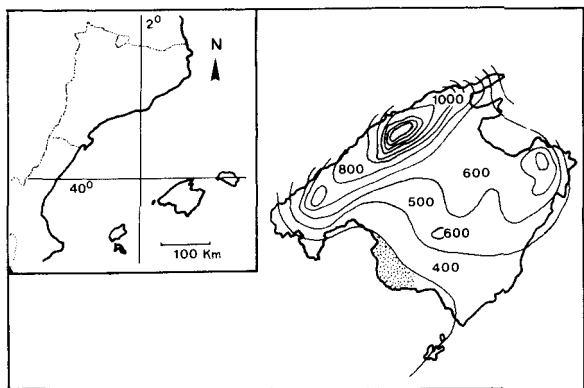


Figure 1.- Regional distribution of annual rainfall in Majorca (from JANSÁ, 1985). Dotted area indicates the restricted zone where *Leptestheria mayeti* and *Metadiaptomus chevreuxi* have been registered.

Distribución de la precipitación anual en la isla de Mallorca (tomado de JANSÁ, 1985). La zona punteada indica el área de distribución conocida de los taxones *Leptestheria mayeti* y *Metadiaptomus chevreuxi* en la isla.

Table 1.- Some limnological parameters of 22 temporary pools studied in the semi-arid region of Majorca. Algunos parámetros limnológicos de 22 balsas temporales estudiadas en la región semi-árida de Mallorca.

Parameter	X	Range
pH	8.66	(7.15-9.65)
Cond. ($\mu\text{S}/\text{cm}$)	703.93	(363.90-1,826.50)
HCO_3^- (meq/l)	1.92	(1.02-4.76)
CO_3^{2-} (meq/l)	0.12	(0.00-0.34)
Cl^- (mg/l)	74.46	(24.11-241.11)
Ca^{++} (mg/l)	35.87	(24.05-56.91)
Mg^{++} (mg/l)	4.62	(1.95-9.97)
Na^+ (mg/l)	35.41	(14.02-140.01)
K^+ (mg/l)	7.04	(1.95-10.95)

coral reef (POMAR et al., 1983). Ulterior diagenetic processes have originated impermeable soil profiles («Caliche») that form small pools (Pomar, pers. com.), reaching 40-500 m² and 30-60 cm deep. Flooding period spreads from October to May in mean. Waters are clear, but they can be moderately muddy at the beginning of the rainy period, when the pools flood. This is a result of the lack of macrophyte development, that do not fix the sediment, which is consequently removed by animals (mainly Triops). The values of some limnological parameters of these waters are presented in table 1.

RESULTS

Leptestheria mayeti Simon 1885 (figs. 2,3)

Shell outline is elongated in males; rostrum with an apical hook in both males and females; postabdomen with regularly distributed dorsal spinules, all roughly of the same size. It closely resembles *Leptestheria dahalacensis* (Rüppel, 1837), however it can be easily differentiated by: a) the number of legs with modified epipodites for egg-carrying in females (two in *L. mayeti* instead 4-5 in *dahalacensis*); b) the situation of the first abdominal tergite armed with a dorsal row of spines (the first one just before postabdomen in *dahalacensis*, or some tergites behind in *mayeti*).

The Majorcan population was first referred by MAYOL (1977) as *Leptestheria dahalacensis* and re-

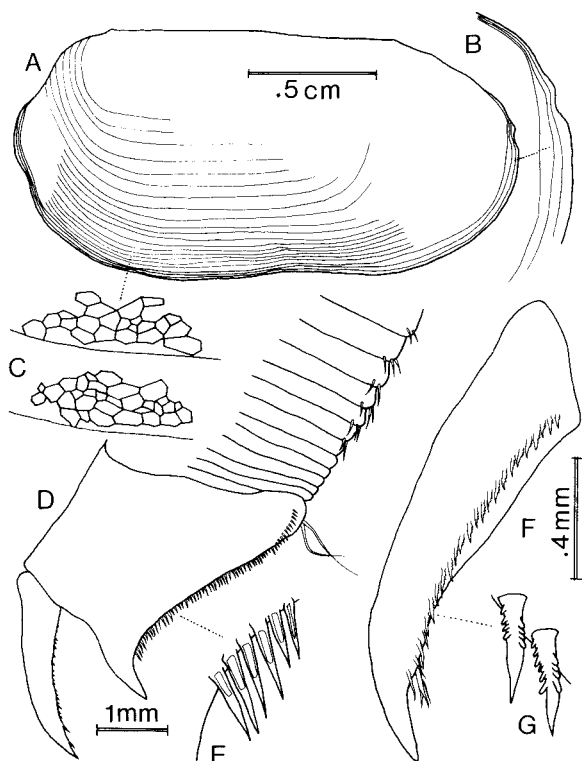


Figure 2.- *Leptestheria mayeti* Simon 1885. Male from Llucmajor, Majorca. A, left valve; B, postero-dorsal corner of left valve, detail; C, detail of the valve sculpture between the growth lines; D, last abdominal somites and post-abdomen; E, postabdomen dorsal denticulation, detail; F, terminal claw of postabdomen, inner side; G, detail of the post-abdominal claw denticulation.

Leptestheria mayeti Simon 1885. Macho procedente de Llucmajor, Mallorca. A, valva izquierda; B, detalle del extremo postero-dorsal de la valva izquierda; C, detalle del esculpido de las valvas entre las líneas de crecimiento; D, últimos terguitos abdominales y post-abdomen; E, detalle de la denticulación de la región dorsal del post-abdomen; F, garra terminal del postabdomen vista por su cara interna; G, detalle de la denticulación de la garra terminal del post-abdomen.

taken by ALONSO (1985b). In ALONSO (1986) a good drawing of female *L. mayeti* is given again under the name *L. dahalacensis*.

Populations develop from the first days of flooding. Naupliar stadium was recognized one day after first flooding (1110186). First post-naupliar stadium was recorded seven days after first flooding (length: 4.29 mm), but empty valves less than 1.98 mm were recorded as well. So, probably, larval development takes less than seven days. Data on growth of a single population stu-

died during last 1986-87 are given in table 2. It reflects a maximum relative body size increase at the beginning, as should be expected for a species adapted to habitats of unpredictable duration. Maximum length recorded was 10.8 mm for males (10/04/87), and 8.9 mm for females (6103187). Valvar growth has been isometric in both males and females:

Males: $H = 0.57 = 0.41 L$ ($r = 0.95$; $n = 43$),
Females: $H = 0.31 = 0.45 L$ ($r = 0.91$; $n = 44$),

where H: height, and L: length of shell (cm).

Table 2 summarizes the growth pattern of a single population of *L. mayeti* studied during the last 1986-87. When the sample size was great enough, standard error of mean was calculated for confidence intervals as high as $p < 0.01$. The values obtained were very low and allow us to suspect that the population studied was composed by only one cohort, with egg eclosions concentrated the first days after flooding. Copulatory behaviour was observed during all of the flooding period. Largest individuals had very dark valves and were covered by filamentous algae.

Leptestheria mayeti was only known from north African temporary freshwater bodies of the arid and semi-arid zones (less than 400 mm annual rainfall) (GAUTHIEK, 1928; THIERY, 1986). DADAY (1923) considered this species as endemic of the Moghreb. There, it lives in clear or muddy, moderately mineralized waters (30-500 $\mu\text{S}/\text{cm}$; 1.0-3.6 meq/l total alkalinity), with a very characteristic aquatic vegetation (*Marsilea pubescens*, *Glyceria fluitans*, *Damasonium alisma*, *Scirpus maritimus*, *Isoetes velata*, *Ranunculus aquatilis*, *Heleocharis palustris* and filamentous algae as *Spirogyra* and *Oedogonium* (THIERY, 1986).

Metadiaptomus chevreuxi Guerne & Richard 1894 (figs. 4, 5)

This diaptomid was previously recorded from the arid zones of north Africa, Arabia and Mesopotamia (GAUTIER, 1928; KIEFER, 1978; DUMONT, 1980; RAMDANI, 1986). GAUTHIER (1928) considers this species as typical of the steppic zone of north Africa (annual rainfall less than 300 mm). RAMDANI (1986) considers it a typical Saharian species. The Majorcan populations corres-

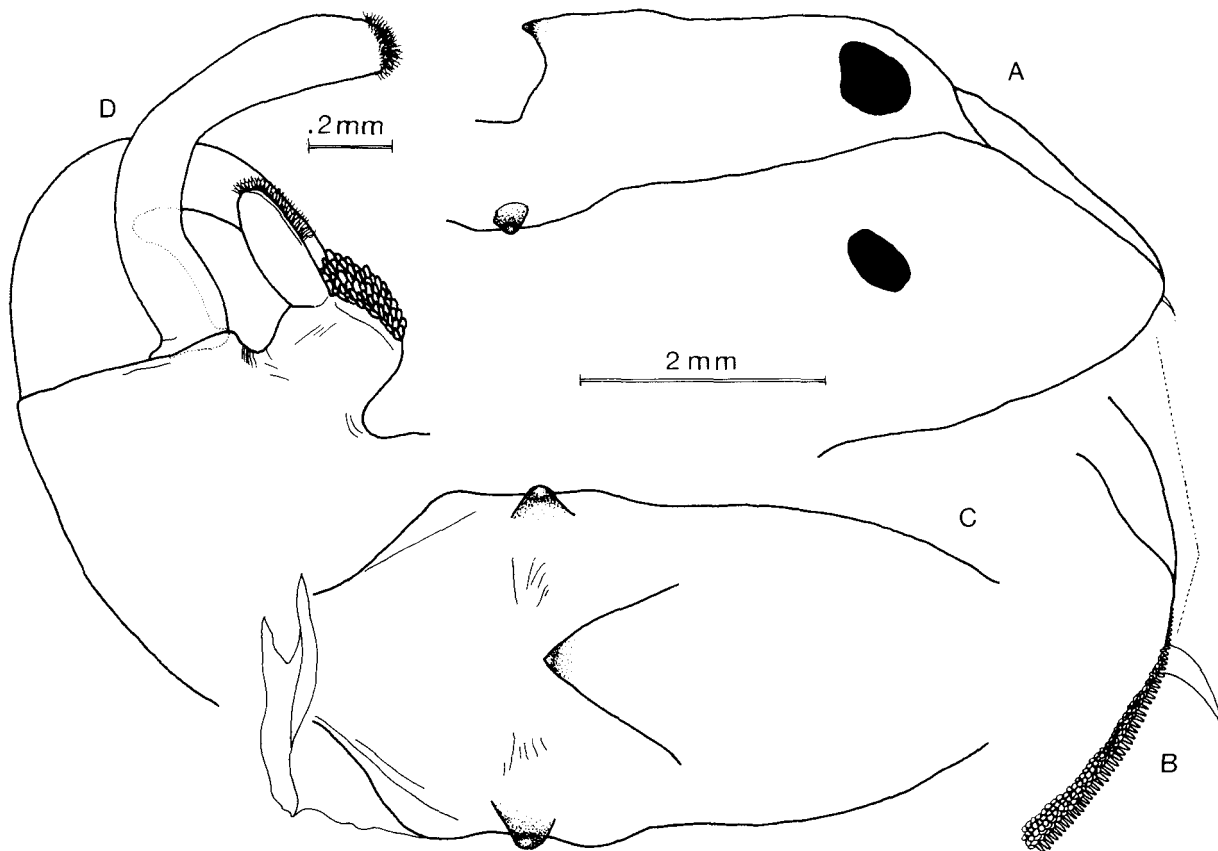


Figure 3.- *Leptestheria mayeti* Simon 1885. Male from Lluçmajor, Majorca. A, cephalon, lateral view; B, anterior region of the cephalon, detail; C, dorsal view of the middle zone of the cephalon, with two lateral prominences (based on a moult); D, clasper of the first right leg.

Leptestheria mayeti Simon 1885. Macho procedente de Lluçmajor, Mallorca. A, cefalon en visión lateral; B, detalle de la región anterior del cefalon; C, visión dorsal de la región media del cefalon, mostrando dos prominencias laterales (basado en una muda); D, pinza de la primera pata derecha.

pond to the Kiefer's description (KIEFER, 1978) (figs. 4,5).

In Majorca, *Metadiaptomus chevreuxi* is the most abundant diaptomid in temporary pools. Adult individuals appear 14 days after first flooding and populations are maintained until the pools dry (May). Maximum length recorded were: 2.59 mm for males, and 4.27 mm for females (furcal setae not included). Individuals are red coloured, except a population from a pool covered by a small building, made in order to reduce evaporation. Inside the building there is a complete darkness, and the *M. chevreuxi* population is completely uncoloured, probably as a result of

the lack of algae in the pool, which are the source of beta-carotene for copepods (RINGELBERG, 1980). Habitat conditions for *M. chevreuxi* are the same as *L. mayeti*.

DISCUSSION

The temporary pools of the arid zone of Majorca are the habitat for a well characterized biota (tables 3, 4) with the majority of the species characteristic of steppic water bodies (GAUTHIER, 1928; ALONSO, 1985a). Some of these taxa (i.e.

Table 2.- Mean values of length (L) and height (H) (cm) for both males and females of a population of *Leptestheria mayeti* studied during the last 1986-87. Standard error of mean with confidence intervals $p < 0.01$ is presented for every sample $N > 3$. Valores medios de la longitud (L) y altura (H) de las valvas, expresadas en cm, para una población de *Leptestheria mayeti* estudiada durante el ciclo 1986-87. El error estándar de la media para $p < 0.01$ se presenta para muestras de tamaño $N > 3$.

Date	Males			Females		
	N	\bar{X}_L	\bar{X}_H	N	\bar{X}_L	\bar{X}_H
7/10/86	—	—	—	1	4.29	2.39
12/10/86	1	6.96	3.29	—	—	—
13/10/86	2	7.33	3.66	1	6.20	3.01
15/10/86	6	7.75 ± 0.40	3.76 ± 0.20	21	6.97 ± 0.11	3.49 ± 0.08
18/10/86	1	7.99	3.85	4	7.07 ± 0.47	3.64 ± 0.23
19/10/86	3	7.61	3.70	7	7.11 ± 0.30	3.41 ± 0.30
22/10/86	—	—	—	1	7.14	3.57
7/11/86	—	—	—	1	7.61	3.76
13/11/86	—	—	—	1	7.80	3.95
15/11/86	—	—	—	1	7.52	3.76
23/01/87	2	9.21	3.85	2	7.71	4.56
3/02/87	9	9.60 ± 0.57	4.57 ± 0.30	—	—	—
24/02/87	8	9.80 ± 0.42	4.64 ± 0.25	1	8.77	4.39
6/03/87	8	10.11 ± 0.42	4.72 ± 0.35	2	8.70	4.32
10/04/87	3	10.36	4.77	—	—	—

Pleuroxus letourneuxi) are widely distributed over the Mediterranean region. Others even have a more reduced distribution, and they appear restricted to certain geographic zones (i.e. *Metadiaptomus chevreuxi*, *Ephemeroporus phintonicus*) (GAUTHIER, 1928; ALONSO, 1985a). If this pattern is a result of an historic process (implying restricted potential for dispersal) (ALONSO, 1985a,b; 1987) or, on the other hand, is a consequence of the unavailability of suitable «niche» in the areas where these species are absent (DUMONT, 1980), is a theme of discussion.

Metadiaptomus chevreuxi and *Leptestheria mayeti* appear as the most characteristic and differentiating elements of the steppic crustacean community in Majorcan temporary pools. They link this community with that of north African arid and semi-arid regions (GAUTHIER, 1928; THIERY, 1986; RAMDANI, 1986). On the other hand both two species differentiate the Majorcan fauna from that of equivalent environments in the Iberic Peninsula (ALONSO, 1985a,b).

On the question about what is the origin of the colonization of Majorca by these two species, some hypothesis can be proposed. First of all, we can consider these species as relics of a period with more generalized steppic conditions. Geographic and climatological changes during the Upper Tertiary and Quaternary would have frag-

mented the steppic regions of the Mediterranean, isolating populations of some species once widely distributed (MARGALEF, 1947). In fact, DUMONT (1980) has proposed that *Metadiaptomus* species of North Africa have moved following the displacements of climatic belts during the Pleistocene, and could have left relic populations after retrogression (he has found such populations in Mali). Nevertheless, there is no proof that the displacement of climatic belts of north Africa has affected the Balearic Islands, and it is difficult to explain why these two species are absent in the Iberic Peninsula, where suitable habitats have always been present (Alonso, pers. com.).

Another hypothesis we propose to explain the dispersion of these two African taxa as far as the Balearics concerns dust rains. They consist on the precipitation of dust, coming from the Atlas valleys, on the shores of the western Mediterranean, specially the Balearic Islands (COLOM, 1948; JANSÁ, 1948; PRODI et al., 1979; FIOL, 1985). FIOL (1985) has analyzed the granulometry of this dust and concludes that it is formed 61 % by particles less than 20 μm , and the remainder 39 % by particles greater than 20 μm (exceptionally they can attain 80 μm). The identified biogenic elements of this dust were spicules of sponges, diatoms, etc, all of marine origin. In order to test if this dust can be a potential vector of dispersal for the two

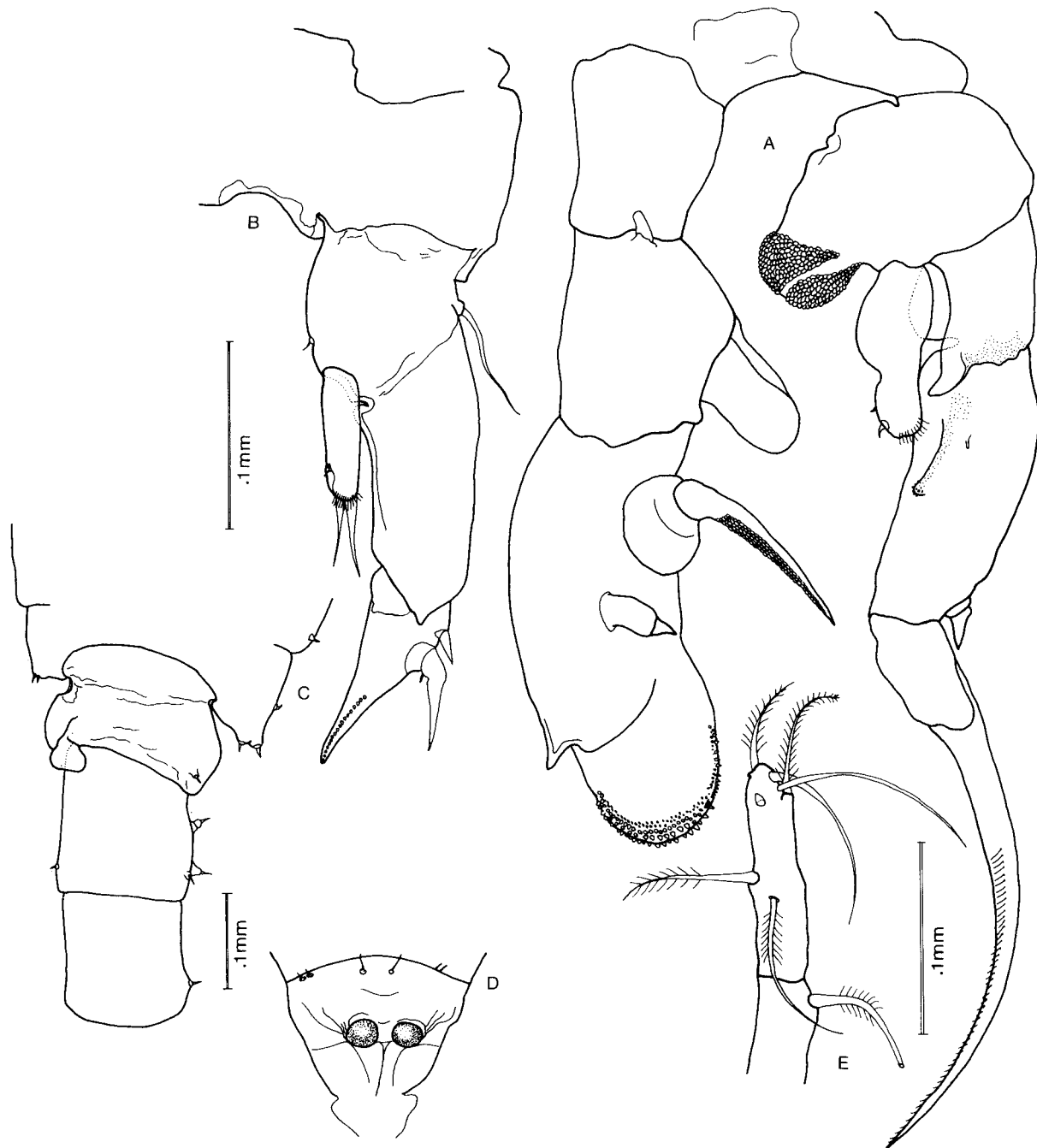


Figure 4.- *Metadiptomus chevreuxi* (Guerne & Richard 1894) from Lluçmajor, Majorca. A, fifth pair of legs of the male; B, fifth leg of the female; C, abdominal region of male, dorsal view; D, labrum of male; E, tip of the geniculate antenna of male. *Metadiptomus chevreuxi* (Guerne & Richard 1894) de Lluçmajor, Mallorca. A, quinto par de patas del macho; B, quinta pata de la hembra; C, visión dorsal de la región abdominal del macho; D, labro masculino; E, segmento apical de la antena geniculada del macho.

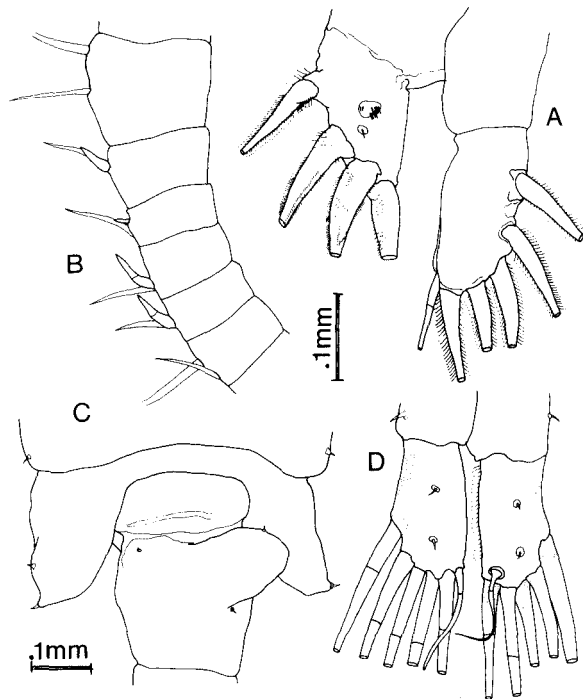


Figure 5.- *Metadiaptomus chevreuxi* (Guerne & Richard 1894) from Lluçmajor, Majorca. A, furcal branches of male; B, segments 9 to 14 of the male geniculated antenna; C, anterior abdominal region of female, dorsal view; D, furcal branches of female.

Metadiaptomus chevreuxi (Guerne & Richard 1894) de Lluçmajor, Mallorca. A, ramas furcales del macho; B, segmentos 9 a 14 de la antena geniculada del macho; C, visión dorsal de la región abdominal anterior de la hembra; D, ramas furcales femeninas.

Table 3.- Aquatic macrophytes recorded in the temporary pools of the semi-arid region of Majorca. Macrófitos citados en las balsas temporales de la región semi-árida de Mallorca.

PTERZDOPHYTA	SPERMATOPHYTA
F. Marsileaceae <i>Marsilea strigosa</i> Willd.	F. Ranunculaceae <i>Ranunculus baudoti</i> Godr.
	F. Crassulaceae <i>Crassula vaillantii</i> (Willd.) Roth
	F. Alismataceae <i>Damasonium alisma</i> Mill.
	F. Zannichelliaceae <i>Zannichellia peltata</i> Bertol.
	F. Callitrichaceae <i>Callitriche brutia</i> Petagna
	F. Elatinaceae <i>Elatine macropotoda</i> Guss.
	F. Lythraceae <i>Lythrum hyssopifolia</i> L.

Table 4.- List of the most characteristic crustaceans of the temporary pools of the semi-arid region of Majorca. Lista de las especies de crustáceos más características de las balsas temporales de la región semi-árida de Mallorca.

CL. BRANCHIOPODA

- O. Anostraca
 - Branchipus schaefferi* Fischer 1834
- O. Notostraca
 - Triops cancriformis* (Bosc 1801)
- O. Conchostraca
 - Leptestheria mayeti* Simon 1885
- O. Cladocera
 - F. Daphniidae
 - Daphnia magna* Kurz 1874
 - Daphnia bolivari* Richard 1888
 - Daphnia obtusa* Straus 1820
 - Ceriodaphnia laticaudata* P.E. Muller 1867
 - F. Chydoridae
 - Pleuroxus aduncus* (Jurine 1820)
 - Pleuroxus letourneuxi* Richard 1888
 - Ephemeroporus phintonicus* (Margaritora 1969)
 - Dunhevedia crassa* King 1853
 - Tretocephala ambigua* (Lilljeborg 1900)
 - Leydigia acanthocercoides* (Fischer 1854)
 - Alona elegans* Kurz 1875

SCL. COPEPODA

- O. Calanoida
 - F. Diaptomidae
 - Metadiaptomus chevreuxi* Guerne & Richard 1894
 - Neolovenula alluaudi* (Guerne & Richard 1890)
 - Mixodiaptomus incrassatus* (G.O. Sars 1903)
 - Arctodiaptomus wierzejskii* (Richard 1888)

species we deal with, we have measured the size of their disseminules (eggs). Thus, *M. chevreuxi*: 101.5 μm (mean) ($n = 25$; range: 88.4-119.6 μm); *L. mayeti*: 180 μm ($n = 5$). Our data fall far from the size range of dust particles in *L. mayeti*, but in the case of the calanoid is more difficult to be sure that they are too big to be dispersed by this vector. Nevertheless, if dust was the vector of dispersal, it continues being difficult to explain why they are not present in the Iberic Peninsula, where dust rains are not unknown phenomena.

A third hypothesis can be conceived attending the known migratory routes of birds over the western Mediterranean (Luis et al., 1980, and references therein). It is fully accepted that birds are a very important vector for passive dispersal of aquatic organisms (MARGALEF, 1983). PROCTOR (1964) and PROCTOR et al. (1967) have demons-

trated the suitability of the digestive tract of waterfowl, especially waders, for the dispersal of disseminules of many freshwater crustacean species. THIERY & PONT (1987) considers that the distribution of *Eoleptestheria ticinensis* (Balsamo-Crivelli 1859) in western Europe is a result of dispersal mediated by tran-Saharan migrating birds coming from central Europe. In our case, dispersal by birds could not be accepted if, as it seems to be (LUIS *et al.*, 1980), the prenuptial tran-Saharan migration of non-gliding birds discurred over all the western Mediterranean basin, and did not concentrate on the straits (Cap Bon, Gibraltar). Nevertheless, our knowledge of these migratory routes is not so solid as to generalize. We should accept more restricted routes (i.e. over the straits and the Balearics) of non-gliding birds (i.e. waders, ducks, etc.) to explain why *L. mayeti* and *M. chevreuxi* are not present in suitable habitats of western Europe (i.e. Sardinia, Iberia, south of France, etc.). The importance of the Balearic islands as a migration pathway, referred elsewhere (ARAUJO *et al.*, 1977), and the possible occurrence of *Leptestheria mayeti* in Sicily (COTTARELLI & MURA, 1979; THIERY, 1986) point to this last hypothesis. It would be necessary to have a more accurate knowledge of the lifespan of disseminules in the digestive tract of the birds involved, and a better knowledge of the western Mediterranean migration routes, to test if birds have been the vectors of dispersal of the species we deal with.

So, the presence of *Metadiaptomus chevreuxi* and *Leptestheria mayeti* in Majorca accepts some explanatory hypothesis, alternatively in concordance with one of the two theories accepted to explain the non-cosmopolitanism of zooplankton. If

we consider the two taxa we deal with as relics of a period with more generalized steppic conditions, we will be in agreement with ALONSO (1985a, b; 1987), who sustains that the tendency to relictism or endemism in the zooplankton is a result of limitations in dispersal potentialities. On the other hand, if we explain their presence as a result of a suitable habitat («niche») availability, we will be in agreement with DUMONT (1980), who sustains that the pattern of distribution of a zooplankton is given by the availability of suitable habitats for colonization, no matter that the dispersal potentials were. Nevertheless, we think that these two hypotheses are not mutually exclusive. The colonization of the Balearic islands by these two taxa can be explained as the result of habitat availability and coincidence with that occupied in north Africa (THIERY, 1986), combined with the possibility of dispersal over a restricted zone (islands along the main routes of bird migration from north Africa to Europe).

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RESUMEN

METADIAPTOMUS CHEVREUXI (COPEPODA: CALANOIDA: DIAPTOMIDAE) Y *LEPTESTHERIA MAYETI* (BRANCHIOPODA: CONCHOSTRACA: LEPTESTHERIIDAE), DOS CRUSTÁCEOS ESTEPARIOS AFRICANOS HALLADOS EN MALLORCA

Se presenta el hallazgo en aguas esteparias de la isla de Mallorca del diaptómido *Metadiaptomus chevreuxi* Guerne & Richard 1894 y del conchostráceo *Leptestheria mayeti* Simon 1885, hasta ahora considerados especies características de las aguas esteparias de la región norteafricana. Se presenta la autoecología y se discute el carácter diferenciador que ambas especies confieren a las comunidades de crustáceos de las aguas temporales mallorquinas en contraposición a comunidades semejantes de la Península Ibérica. Se plantean tres hipótesis (relictismo, dispersión mediante lluvias de barro, ornitocoria) para explicar el poblamiento de la isla de Mallorca por ambas especies, de las que la última parece la más plausible.

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