The genus *Pseudectinosoma* KUNZ, 1935: an update, and description of *Pseudectinosoma kunzi* sp. n. from Italy (Crustacea: Copepoda: Ectinosomatidae)

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With 4 figures and 1 table in the text

Abstract: *Pseudectinosoma kunzi* sp. n. from cave waters of southern Italy is described. Confocal Laser Scanning Microscopy (CLSM) supported the morphological analysis. An emended diagnosis of the genus is provided. A plausible paleogeographical landscape is briefly depicted to explain the present-day distribution and ecology of the *Pseudectinosoma* species.

Introduction

Living together with *Acanthocyclops agamus* KIEFER, 1938, in Castelcivita Cave, southern Italy, a new harpacticoid copepod was discovered and is described herein. It is to be adscribed to a new species of *Pseudectinosoma* KUNZ, 1935, a little known and poorly diversified genus, with marine origin.

Habitat

Castelcivita Cave is located on the south-western part of the Alburni Massif at 94 m a.s.l., near Castelcivita town (Salerno), about 30 km inland from the Thyrrhenian coast. The cave system of Castelcivita developed on 3 levels, into the Alburnian carbonatic platform, since Plio-Pleistocene times. The intermediate level is still active, with some pools and lakes, of different extension and depth.

The fauna inhabiting these waters of phreatic origin appears to be greatly diversified, showing marked differences in the species composition and in the relative taxa abundance, depending on different sampling times.

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Methods

Samples were taken using a 100 μm mesh net, through which water was filtered at depths of 0.3–1.5 m. A Bou-Rouch pump was used as well, on silted sand banks, along the shore-lines of the lakes.

Specimens were preserved in 7 % formalin solution. Whole and dissected specimens were mounted in polyvinyl lactophenol. Drawings and measurements were made using a Leitz Laborlux phase contrast microscope, with camera lucida. Confocal laser scanning microscopy with Sarastro 2000 (Molecular Dinamics) corroborates tegumental analyses.

Species description

Order Harpacticoida Sars, 1903
Family Ectinosomatidae Sars, 1903
Genus *Pseudectinosoma* Kunz, 1935
Pseudectinosoma kunzi sp. n.

Material examined: 1 ♀ holotype and 3 ♀ ♀ paratypes completely dissected and mounted in polyvinyl lactophenol; 1 ♀ mounted in the same medium, without dissection; Castelcivita Cave (Salerno, southern Italy); coordinates: 15° 12′ 32″ E, 40° 29′ 42″ N (I.G.M., Fg. 198 II NO); altitude: 94 m a.s.l.; little pool with siphon connection to a subterminal lake, about 3.5 km from the entrance; little amount of sediment on calcareous bottom; depth: 0.3–1.5 m; 30 September 1995; coll. D. Galassi, G. Maj & G. Costantino. 1 ♀ paratype dissected and mounted as above; subterminal lake; depth: about 14 m; abundant sediment composed of a superficial layer of silt and a deeper layer of sand on calcareous bottom; 26 June 1995; coll. D. Galassi, G. Maj & G. Costantino. Holotype in the Natural History Museum, London (Reg.no. 1996.1050). Other material in the author's collections at the Dipartimento di Scienze Ambientali, University of L'Aquila (Italy).

Morphology: Female length, excluding caudal setae, 280–360 μm (n = 6) (288 μm, holotype). Body fusiform (Fig. 1 a), unpigmented. Rostrum hyaline (Fig. 1 b), reaching the distal third of second segment of antennule on frontal side. Cephalotorax smooth, tegumental structures reduced; only one pair of setules on dorsal surface of cephalic shield. Posterior dorsal margins of abdominal somites, excluding anal somite, with denticulate hyaline frill; anal somite with 2 sensillae distally on dorsal surface (Fig. 1 f). Ventral margins of all abdominal somites armed with semi-incised subulate hyaline frill (Fig. 1 a, f). Genital double-somite completely fused, without cuticular ornamentation.

Caudal rami (Figs. 1 c–d; 3c-d) wider than long, hyaline frill of anal somite fully-incised subulate. Armature as follows: anterolateral accessory seta
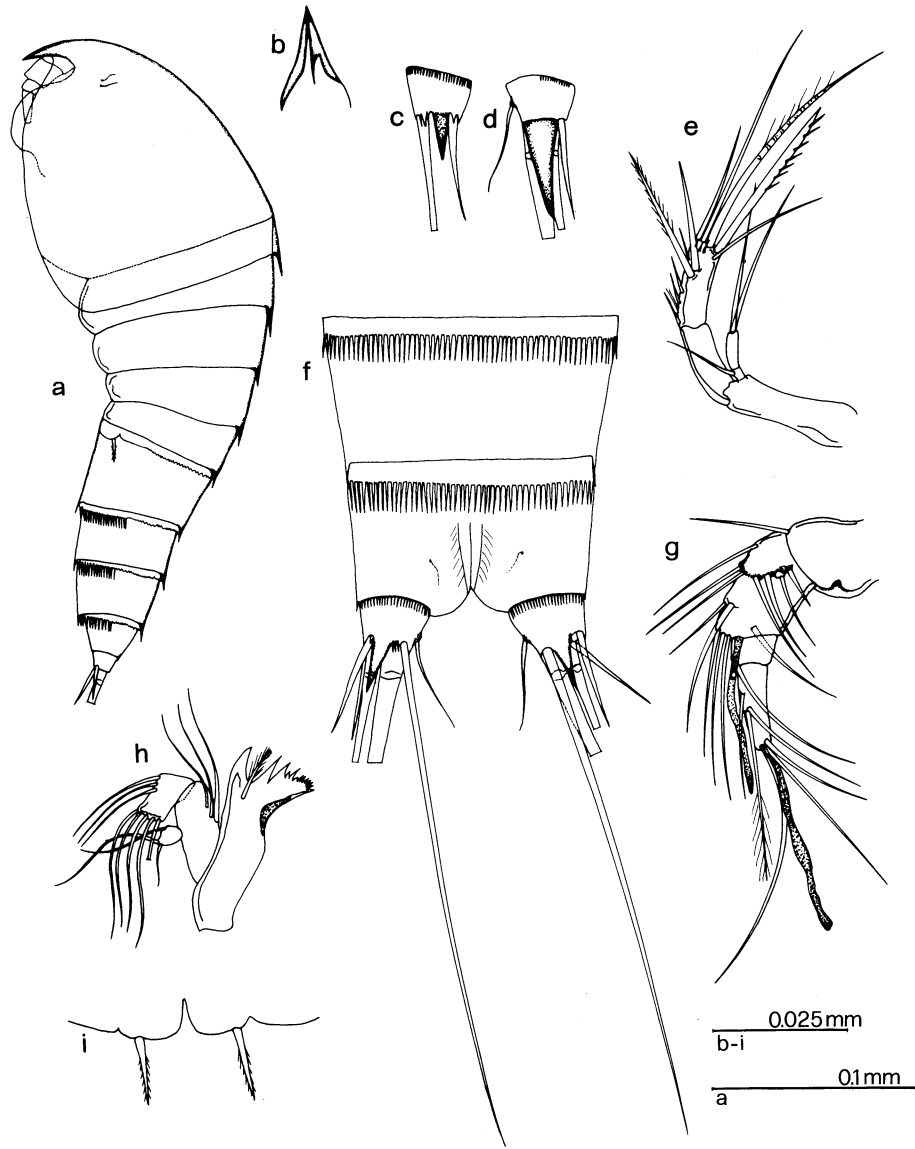
Fig. 1. *Pseudectinosoma kunzi* sp. n. a. Habitus, lateral view (♀ , paratype), b. rostrum, ventral view (♀ , paratype), c. caudal ramus, ventral view, d. caudal ramus, dorsal view (♀ , paratype), e. antenna (♀ , holotype), f. anal somite and caudal rami, ventral view (♀ , paratype), g. antennule (♀ , holotype), h. mandible (♀ , holotype), i. leg 5 (♀ , holotype).

lacking, 1 anterolateral seta inserted somewhat ventrally, 1 posterolateral seta dorsally inserted, 2 terminal setae of different lengths, 1 long terminal accessory seta, 1 dorsal seta on inner knob. Dorsal and ventral ends of each caudal ramus prolonged into triangular lappets; dorsal lappet strong, ventral lappet spiniform, short spinules are inserted near the ventral lappet.

Antennule (Figs. 1 g, 3 b): short, 4-segmented; first segment with 1 outer distal seta, second segment bearing 1 proximal outer seta, 6 setae on frontal ridge, 2 lateral outer setae, 1 inner seta on caudal surface, 3 distal outer setae and 1 aesthetasc; third segment short, with 1 outer seta, fourth segment with 1 outer seta, 2 lateral setae inserted along the fusion line of the same segment; 3 setae and a long aesthetasc inserted on the tip.

Antenna (Fig. 1 e): basis unarmed; exopod 2-segmented, first segment bearing 1 lateral seta, second segment with 2 long apical setae; endopod 2-segmented, first segment naked, second segment with numerous cuticular spinules and 2 setae on the inner margin, 1 strong seta, 1 geniculate seta and 3 plain setae distally.

Labrum subrounded, apparently smooth (Fig. 3 a).

Mandible (Fig. 1 h): cutting edge of coxa with 6 teeth and a crenulate chitinous lamella; 1 seta at basis of teeth. Basis with 3 medial setae; exopod bearing 1 subapical seta and 2 apical setae of different lengths; endopod bearing 8 setae, 3 of which along medial margin.

Maxillule (Fig. 2 g): praecoxal arthrite bearing 5 setae and 1 strong spine. Basis apparently fused with endopod into a laminar plate bearing 7 setae; exopod 1-segmented, with 2 apical plumose setae.

Maxilla (Fig. 2 f): praecoxa and coxa fused; the segment originated by fusion with 4 endites; first and second one as a single dichotomous protuberance, bearing 2 setae, third endite represented by 2 long setae, fourth endite well developed, inserted near articulation of basis, bearing 3 setae. Basis and proximal segments of endopod more or less fused; free endopod apparently 3-segmented but only distal segment well recognizable and it bears 3 long and thin setae. Endopod with 2 strong setae and 1 thin seta inserted along fusion lines of basal segments of endopod; 4 thin setae on free distal margin of basis.

Maxilliped (Fig. 2 h) not prehensile, 3-segmented; basis lacking armature, first segment of endopod about two times longer than second one, with numerous tiny spinules along inner and outer margins and 1 distal spinule, second segment of endopod with 2 subapical setae and 2 apical setae of different lengths.

Leg 1 (Fig. 2 a): basis with inner medial spine and a short outer seta; exopod 3-segmented, segment 1 with 1 setate outer spine and a row of spinules; segment 2 with 1 setate outer spine and a long inner seta, segment 3 with 1 outer spine, 2 apical setae and 1 long subapical seta. Endopod 2-segmented, seg-
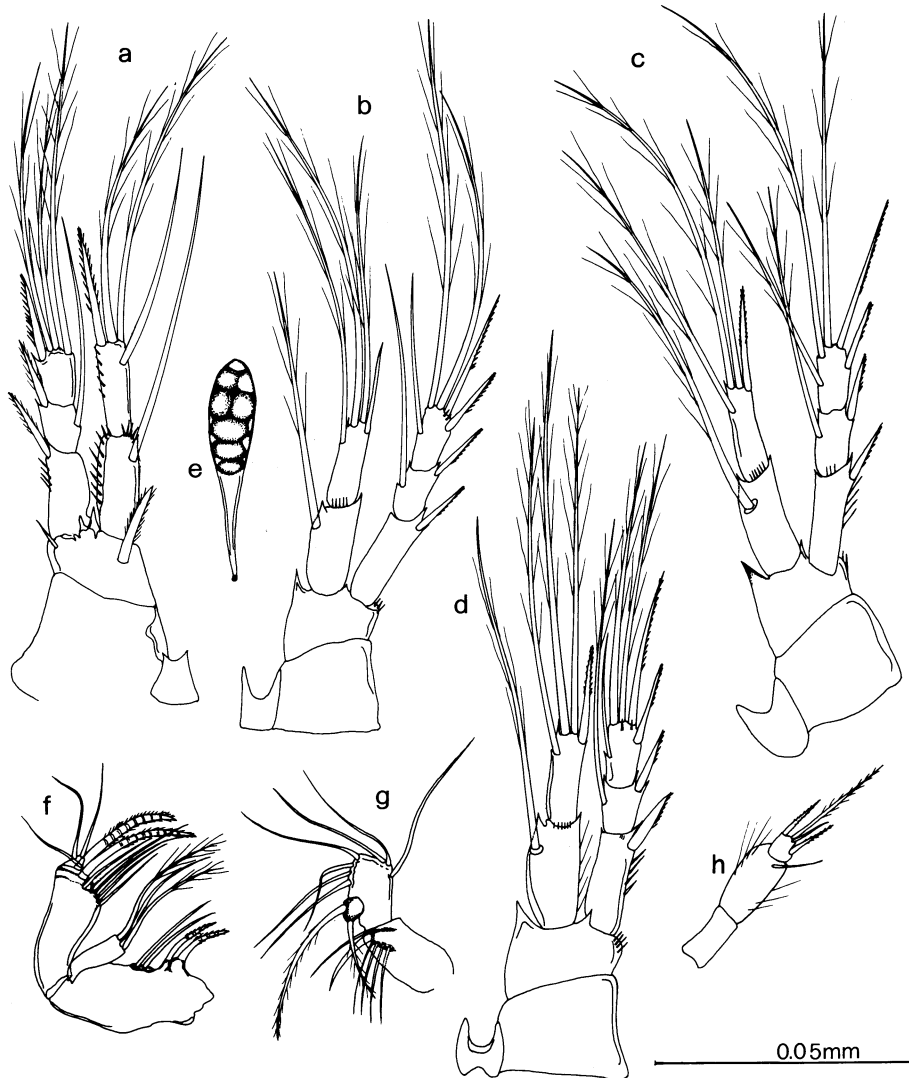
Fig. 2. *Pseudectinosoma kunzi* sp. n. (♀ , holotype). a. Leg. 1, b. leg. 2, c. leg 3, d. leg 4, e. spermatophore, f. maxilla, g. maxillule, h. maxilliped.

ment 1 with a long inner seta and an outer row of spinules; segment 2 with 1 inner seta, 2 apical setae and 1 outer spine.

Leg 2 (Fig. 2 b): basis unarmed, with an outer row of tiny spinules; exopod 3-segmented, segment 1 with 1 setate outer spine, segment 2 with 1 setate outer spine and a long inner seta, segment 3 with 2 inner and 1 apical setae, 1
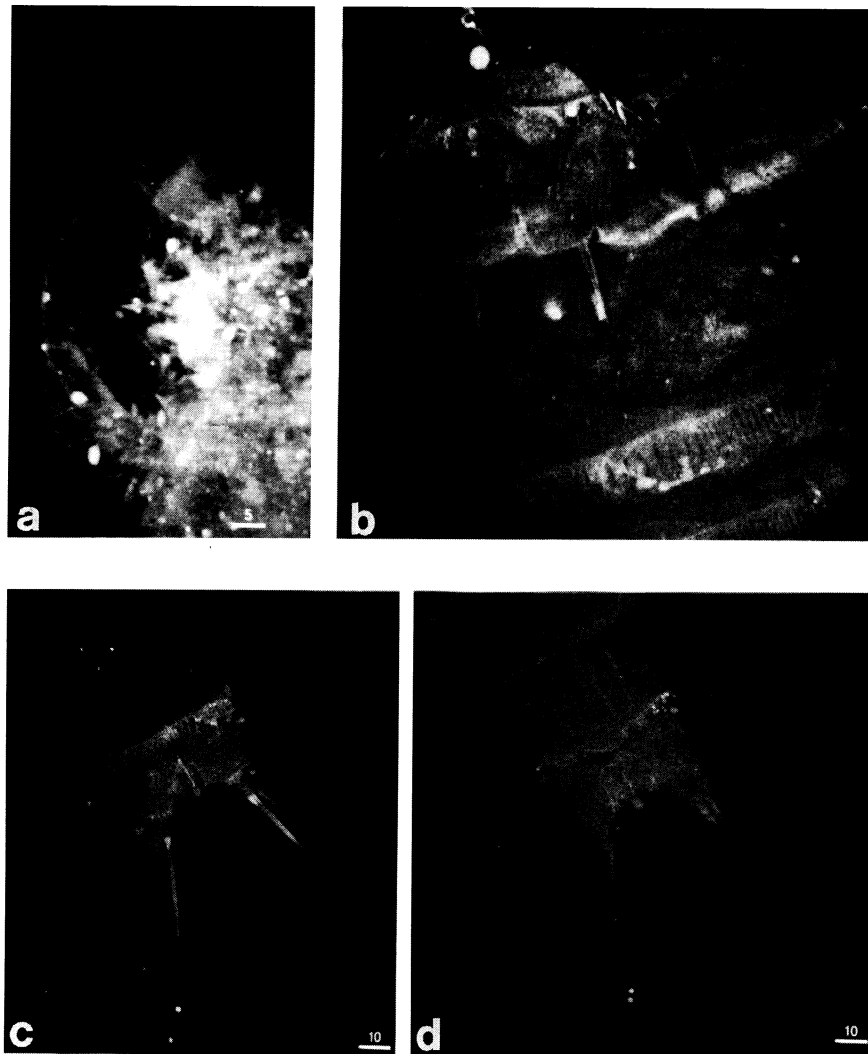
Fig. 3. CLSM analyses of *Pseudectinosoma kunzi* sp. n. a. antennule, b. leg 5, c. caudal rami, ventral view, d. caudal rami, dorsal view (scale bar in μm).

apical and 1 outer spines. Endopod 2-segmented, segment 1 with a long inner seta, segment 2 with 1 inner seta, 2 apical setae and 1 short outer spine.

Leg 3 (Fig. 2c): basis unarmed, bearing an outer row of tiny spinules; exopod 3-segmented, segment 1 with 1 outer spine and a row of spinules; segment 2 with 1 outer spine and a long inner seta, segment 3 with 2 inner and 1 apical setae, 1 apical and 1 outer spines. Endopod 2-segmented, segment 1 with a long inner seta, segment 2 with 1 inner and 2 apical setae, and 1 outer spine.

Leg 4 (Fig. 2 d): basis unarmed, with an outer row of tiny spinules; exopod 3-segmented, segment 1 with 1 outer spine and 1 row of spinules, segment 2 with 1 outer spine and 1 inner seta, segment 3 with 2 inner and 1 apical setae, 1 apical and 1 outer spines. Endopod 2-segmented, segment 1 with a inner long seta, segment 2 with 1 inner and 2 apical setae, and 1 outer spine.

Intercoxal sclerites of all legs without armament.

Leg 5 (Fig. 1 i): baseoendopod and exopod completely fused and reduced to a subrounded chitinous lamellar plate, bearing 1 seta, implanted in a somewhat external position.

Male unknown. Spermatophore as in Fig. 2 e.

Variability: No variation was observed among the specimens; the only difference being the larger body size (360 µm) of the single specimen from the subterminal lake in comparison with the population from the pool (280–320 µm).

Etymology: Specific epithet after Dr. HELMUT KUNZ, a leading scientist in the systematics of marine and brackish water copepods.

Discussion

The genus *Pseudectinosoma* includes 3 species; besides *P. kunzi* sp. n., the others are: *P. minor* KUNZ, 1935, from salt marshes of Kiel Bay (Belt Sea), from the Baltic proper (SCHÄFER 1936, DRZYCIMSKI 1985, 1993), from salt marshes of New Jersey, U.S.A. (COULL 1977), and *P. vandeli* (ROUCH 1969) from the karstic system Cent-Fons, Department of Herault, near Montpellier (France).

KUNZ (1935) established the genus *Pseudectinosoma,* with the species *P. minor,* to accomodate harpacticoids from benthic biotopes of Kiel Bay (Germany), close to *Sigmatidium* GIESBRECHT, 1881. Nevertheless, SCHÄFER (1936), examining new material of *P. minor* from Baltic proper, after comparison of the types, revealed some mistakes in the original description of the species, which, in his opinion, invalidated the genus, as later on reported also by LANG (1948). Subsequently, KUNZ (1974), after a revision of the "*Sigmatidium*-related genera" provided an emended diagnosis of *Pseudectinosoma* in respect to *Sigmatidium, Noodtiella* WELLS, 1965, and *Lineosoma* WELLS, 1965. On this occasion, the genus *Pseudectinosoma* was re-established, based on the characters: antennule 5-segmented, large mandibular palp and maxillule, both bearing numerous setae, 5–7 setae or spines on third segment of exopod P3–P4, 2-segmented endopod P2–P4.

The diagnosis of the genus is herein enlarged to include a 4-segmented condition of the antennule, as the result of a fusion of the fourth and fifth antennular segments. At present, no further morphological details are provided,

due to the loss of the type material of *P. minor* (KUNZ, pers. comm.) and of *P. vandeli* (ROUCH, pers. comm.). Nevertheless, the genus will need in the near future a revision, because of important morphological differences between species, such as the armature of the first segment of antenna exopod (naked in *P. vandeli*, vs. armed with 1 seta in *P. minor* and *P. kunzi* sp. n.), the number of maxillar endites (3 endites in *P. minor* and *P. vandeli* vs. 4 in *P. kunzi* sp. n.), the armature of the basal maxillipedal segment (bearing 1 seta in *P. minor* vs. naked in *P. vandeli* and *P. kunzi* sp. n.) and particularly the structure of the female P5 (baseoendopod and exopod incompletely fused in SCHÄFER's (1936) Fig. 11 of *P. minor*, vs. the same fused into a laminar plate in the remaining species). This kind of difference as well as a similar condition in *Sigmatidium* and *Noodtiella* species (MIELKE 1974, 1979) suggest a wider systematic revision of the "*Sigmatidium*-related genera". To date, the new species is assigned to the genus *Pseudectinosoma*. Within this genus, *Pseudectinosoma kunzi* sp. n. is easily distinguishable by a 4-segmented antennule, derived by complete fusion of the 4th and 5th segments, clearly distinct in the other *Pseudectinosoma* species; by a reduced armature of the third segment of leg 1 exopod (Table 1), bearing only 2 spines and 2 setae and by a leg 5 with only 1 subapical outer seta.

Regarding the chetotaxy of leg 5, the unique seta on the laminar plate could represent the vestigial exopodal armature as well as the basipodal outer seta shared by the great majority of copepods (HUYS & BOXSHALL 1991). The new species closely resembles *P. vandeli* in the same armature of legs 2–4 and in the general tendency towards a simplification of the mouthparts structural plan and female leg 5, as compared with *P. minor*. Without any doubt, *P. vandeli* and especially *P. kunzi* sp. n. show many regressive traits; these character states could be regarded as apomorphic within the genus or as troglomorphic features, as a result of selection in groundwaters. As a matter of fact, stygobiont taxa belonging to different phylogenetic lineages often show reductions and/or character losses (STOCK 1980, HOLSINGER 1988, 1992, NOTENBOOM 1991, GIERE 1993, BOUTIN 1994, CULVER et al. 1995), the evolutionary history of which is still debated (NOTENBOOM 1991, BOTOSANEANU & HOLSINGER 1991, DANIELOPOL & ROUCH 1991). Therefore, the subterranean, often convergent, evolution of characters might obscure the phylogenetic relationships between marine epigean and stygobiont taxa.

Table 1. Setation formula of legs 1–4 in *Pseudectinosoma* species.

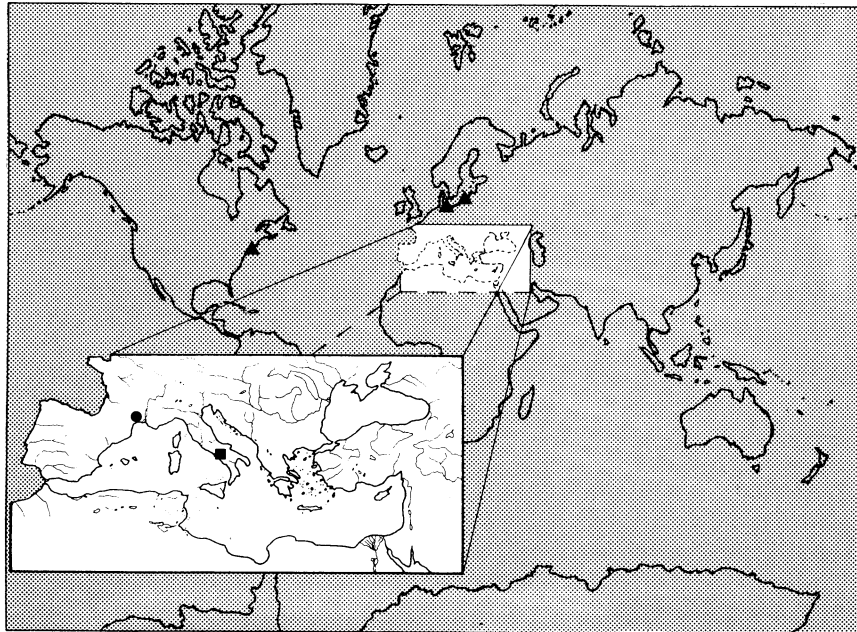| *Pseudectinosoma* species	LEG 1		LEG 2		LEG 3		LEG 4	
	Exp	Enp	Exp	Enp	Exp	Enp	Exp	Enp
P. minor KUNZ	0.1.221	1.221	0.1.222	1.221	0.1.322	1.221	0.1.223	1.221
P. vandeli (ROUCH)	0.1.221	1.121	0.1.221	1.121	0.1.221	1.121	0.1.221	1.121
P. kunzi sp. n.	0.1.121	1.121	0.1.221	1.121	0.1.221	1.121	0.1.221	1.121

Fig. 4. Distribution of the genus *Pseudectinosoma* KUNZ, 1935 (▲ = *P. minor* KUNZ, 1935; ● = *P. vandeli* (ROUCH, 1969); ■ = *P. kunzi* sp. n.).

The geographical distribution of the *Pseudectinosoma* (Fig. 4) species suggests an ancient origin of this genus. The only "marine" species, *P. minor,* inhabits the detrital environment of brackish waters of the shore lines of the Baltic Sea and salt marshes of New Jersey (U.S.A.), showing an amphiatlantic distribution, with marked preference for the inbenthic biotope (frequently epipsammic, rarely collected in algae, e.g. *Vaucheria,* never in interstitial habitat). This species, linked to oligohaline littoral biotopes, could represent an intermediate level in the evolutionary history of the subterranean freshwater species of *Pseudectinosoma* from a more ancient marine ancestor. On the other hand, *P. vandeli* and *P. kunzi* sp. n. are true stygobiont species, endemic to isolated cave systems, very close to the Mediterranean Sea; although they are not directly associated with the interstitial biotope. Only recently, a small population of *Pseudectinosoma* sp. was collected from a porous aquifer in the alluvial plain of the Rhône River, north of Lyon, France (DOLE, pers. comm.).

Probably, the marine littoral ancestor, preadapted to lower salinity, according to the oligohaline preferences of the extant *P. minor,* lived along the shore lines of the premessinian Mediterranean Sea and colonized the cave environments through the karstic discontinuities of the carbonatic platform as ROUCH (1986) hypothesized for a few other harpacticoids such as *Esola spelaea* (CHAPPUIS, 1938), *Psyllocamptus monachus* CHAPPUIS, 1938, *Typhlamphias-*

cus latifurcata POR, 1968, *Schizoperoides expeditionis* POR, 1968 and *Cleto-camptus xenuus* POR, 1968. The stygobiont perimediterranean species of *Pseu-dectinosoma* may represent distributional relicts of a Proto-Mediterranean fauna, which, during the Messinian salinity crisis (HSÜ 1978, HSÜ et al. 1973, CITA & CORSELLI 1993), disappeared from the marine environment due to drastical changes in salinity, as a consequence of the partial or total dessication of the Mediterranean Sea. A passive isolation of preadapted populations, according to the "Modéle biphase" (BOUTIN & COINEAU 1990) or the "Two-step model" evolution of interstitial and crevicular stygobionts (NOTENBOOM 1991), appears to be more congruent with the "spot distribution" of these stygobiont species than an active dispersion mechanism.

Acknowledgements

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