STYGOCYCLOPIA BALEARICA, A NEW GENUS AND SPECIES OF CALANOID COPEPOD (PSEUDOCYCLOPIIDAE) FROM ANCHIHALINE CAVES IN THE BALEARIC ISLANDS (MEDITERRANEAN)

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Stygocyclopia balearica, a new genus and species of stygobiont pseudocyclopiid calanoid copepod is described from the Balearic Islands (Mediterranean). It was restricted to anchihaline cave waters with salinities of 18 ‰ or more. Its close relationship with *Paracyclopia* FOSSHAGEN, from anchihaline caves on Bermuda suggests a possible tethyan relict distribution. This is the first record of the family Pseudocyclopiidae SARS in Mediterranean waters.

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INTRODUCTION

Calanoids belonging to the hyperbenthic family Pseudocyclopiidae SARS were among the anchihaline crustaceans gathered by the senior author during a recent faunistic survey of the flooded coastal karst of the Balearic Archipelago (Mediterranean). Collections were made in caves with subaerial entrances, scattered over three islands separated by shallow water, *viz.* Mallorca, Cabrera and Illa dels Conills. These caves were mainly formed in Tortonian (10 M.y. BP), coral reef-derived, porous calcarenites (Fig. 1, Stns A-E), but also in older (Jurassic) fissured limestones (Fig. 1; Stns F and G). All contained stratified lakes with salinities above 18 ‰ at least in some part of the water column. Pseudocyclopiids seem to be absent from the lower salinity waters. Most of the caves were located in the vicinity of the sea (< 20 m), but Cova des Serral (Fig. 1, Stn D) is 200 m inland.

The pseudocyclopiids from the Balearic anchihaline caves represent a new genus which is described below. They constitute the first record of the family in Mediterranean waters.

METHODS

Samples were taken using meat-baited traps placed at different depths in the cave lakes and left for several days, and also using a hand-held plankton net with an extensible (to 3 m) handle. Salinity profiles were determined with a salinometer AANDERAA-3017. The terminology used in the descriptions follows HUYS & BOXSHALL (1991). Material is deposited both in the Museu de la Naturalesa de les Illes Balears, Palma de Mallorca (MNCM) and in The Natural History Museum, London (BM (NH)).

TAXONOMIC PART

Family Pseudocyclopiidae SARS, 1902 emend. FOSSHAGEN & ILIFFE, 1985

Stygocyclopia n. gen.

Diagnosis. Rostrum present, with pair of long apical filaments. Antennules short, symmetrical, similar in segmentation in both sexes, with characteristic fusion of ancestral segments I-IV and XXII-XXIII. Antennal endopod completely separated from basis. Caudal rami bearing 7 setae. Swimming legs with segmentation and spine and seta formula as described below for the type species. Inner coxal spines of legs 2 and 3 stout; that of leg 4 reduced. Male fifth legs slender, uniramous, asymmetrical, each ending in 2 points; left longer than right, 5-segmented, not swollen proximally; right 4-segmented. Female fifth legs symmetrical, 3-segmented, uniramous, each ending in 3 points; proximal segments (coxae) of fifth legs of both sexes fused to intercoxal sclerite.

Type species. *Stygocyclopia balearica* n. sp., by monotypy.

Etymology. Generic name composed from the prefix 'Stygo-', refers to its groundwater habits, and the termination '-cyclopia', shared by the other genera in the family.

Stygocyclopia balearica n.sp.
(Figs 2-6)

Material examined. This species was collected at seven localities: Mallorca (Balearic Islands): Cova 'C' de Cala Varques (Manacor). UTM coordinates: x = 525,27; y = 4372,19.

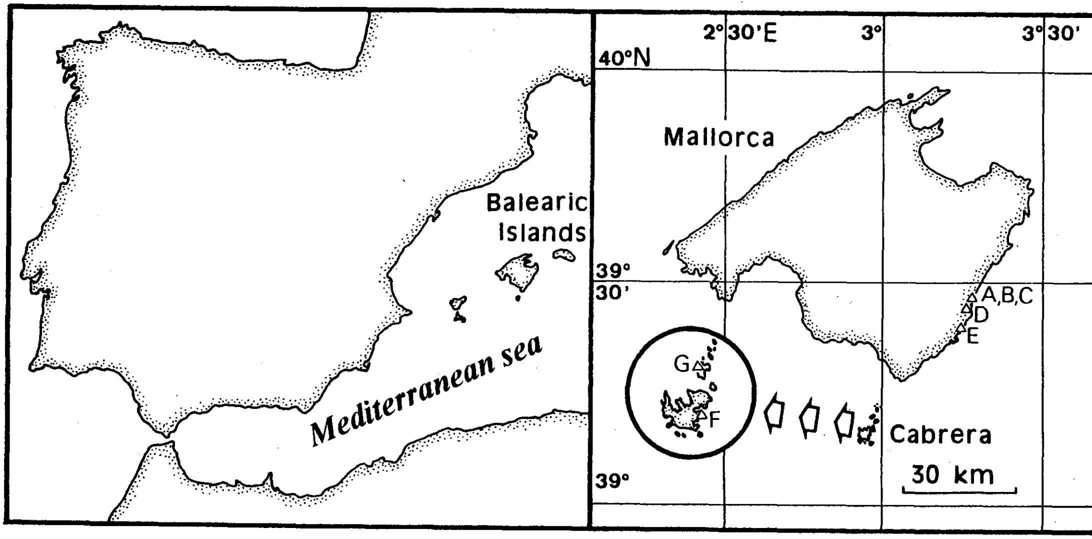

Fig. 1. Map of the Balearic Islands showing distribution of *Stygocyclopia balearica* n. gen., n. sp. A. Cova de Cala Falcó. B. Cova 'A' de Cala Varques. C. Cova 'C' de Cala Varques. D. Cova des Serral. E. Es Secret des Moix. F. Cova des Burrí. G. Cova de sa Llumeta.

Topographic profile of the cave published by TRIAS & MIR (1977).

Holotype: male 0.62 mm (MNCM-253); Allotype: female 0.69 mm (MNCM-254).

Paratypes: 1 male and 8 females (MNCM-255). Collected by D. Jaume, February 1994. Cova de Cala Falcó (Manacor). Coordinates: x = 525,63; y = 4372,78. Topography in TRIAS & MIR (1977). 4 females and 2 copepodids (MNCM-256). Collected by D. Jaume, 26 February 1994. Cova 'A' de Cala Varques (Manacor). Coordinates: x = 525,34; y = 4372,13. Topography in TRIAS & MIR (1977). 1 male and 2 females (BM(NH) Reg. no. 1995.18-20), and 1 copepodid (MNCM-257). Collected by D. Jaume, 10 February 1994 and 19 August 1992, respectively. Cova des Serral (Manacor). Coordinates: x = 524,87; y = 4371,49. 1 male and 6 copepodids (MNCM-258). Collected by D. Jaume, 26 February 1994. Es Secret des Moix (Manacor). Coordinates: x = 523,69; y = 4365,53. Topography published by GINES & al. (1975). 2 females and 3 copepodids (MNCM-259). Collected by D. Jaume, 27 May 1994. Cabrera Archipelago (Balearic Islands): Cova des Burrí (Cabrera). Coordinates: x = 496,60; y = 4337,35. Topography in TRIAS (1993). 1 copepodid (MNCM-260). Collected by D. Jaume, 11 March 1994. Cova de sa Llumeta (Illa dels Conills). Coordinates: x = 496,60; y = 4337,35. Topography in TRIAS (1993). 3 copepodids (MNCM-261). Collected by D. Jaume, 17 June 1994.

Comparative material examined. *Paracyclopia naessi* FOSSHAGEN (in FOSSHAGEN & ILIFFE 1985), Devonshire Cave, Bermuda. 5 adult females and 1 male copepodid (BM (NH) Reg. no. 1995.21-26).

Female. - Eyes absent. Body (Figs 2A, B) colourless, robust, 0.68 to 0.69 mm long, laterally compressed. Prosome about 2.7 times longer than urosome. Rostrum pointed, directed ventrally, bearing pair of long and slender distal filaments. First pedigerous somite integrated into cephalosome. Dorsal fold of cuticular membrane, resembling posterior projection of cephalosome, covering anterior dorsal half of pedigerous somite 2. Pedigerous somites 2 and 3 free, each with pair of dorsal, and 4 and 2 pairs of lateral sensillae, respectively, distributed as in figures; lateral margins rounded, bearing row of submarginal setules along anterior half; those of somite 3 with long and robust sensilla implanted submarginally on posterior half. Pedigerous somites 4 and 5 fused, symmetrical, with 2 pairs of lateral sensillae and pair of patches of short setules as in figures; lateral margins evenly rounded, fringed with row of submarginal setules. Urosome 4-segmented. Genital double-somite symmetrical, with some sparse setules implanted dorsolaterally, and faint, lobate hyaline frill on posterior margin; left seminal receptacle developed, forming dorsal lobe; right not visible (if developed), but corresponding copulatory ducts clearly discerned; single gonopore

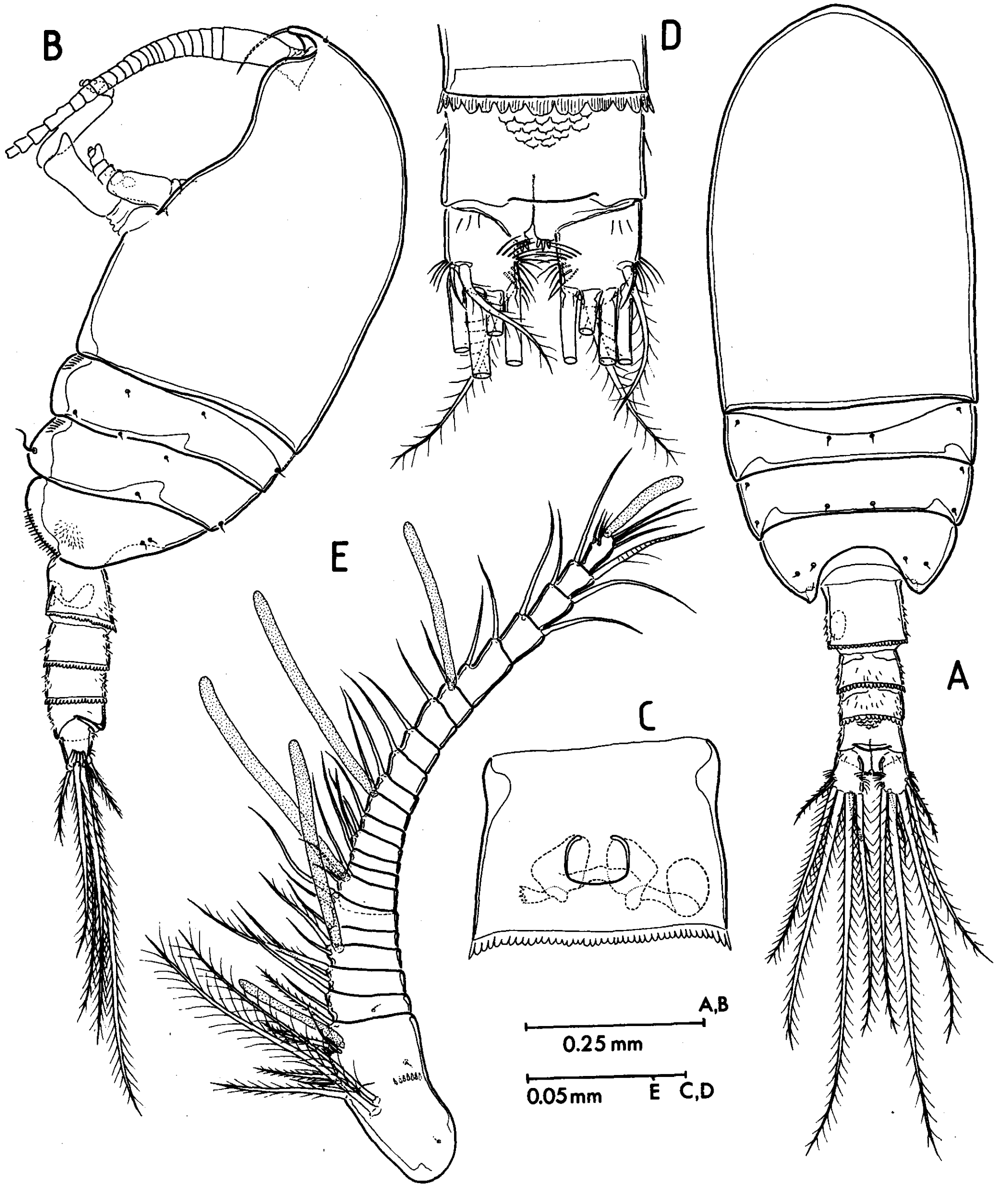

Fig. 2. *Stygocyclopia balearica* n. gen., n. sp., female. A. Dorsal view. B. Lateral. C. Genital double-somite, ventral. D. Anal somite and caudal rami, dorsal. E. Left antennule, ventral.

opening ventrally (Fig. 2C); operculum quadrangular. Urosomal somites 2 and 3 similar, wider than long, ornamented with sparse setules implanted on dorsal and ventral sides, and lobate hyaline frill on posterior margin. Anal somite (Fig. 2D) of same size as preceding somites, strongly incised, with wide dorsal operculum and sparse setules on dorsolateral and ventral surfaces; several rows of faint, hyaline scales implanted dorsally between anterior margin of somite and operculum; anal opening bearing group of 3 rounded denticles on each side. Caudal rami (Fig. 2D) symmetrical, short, about as long as wide, armed with 7 setae and with transverse

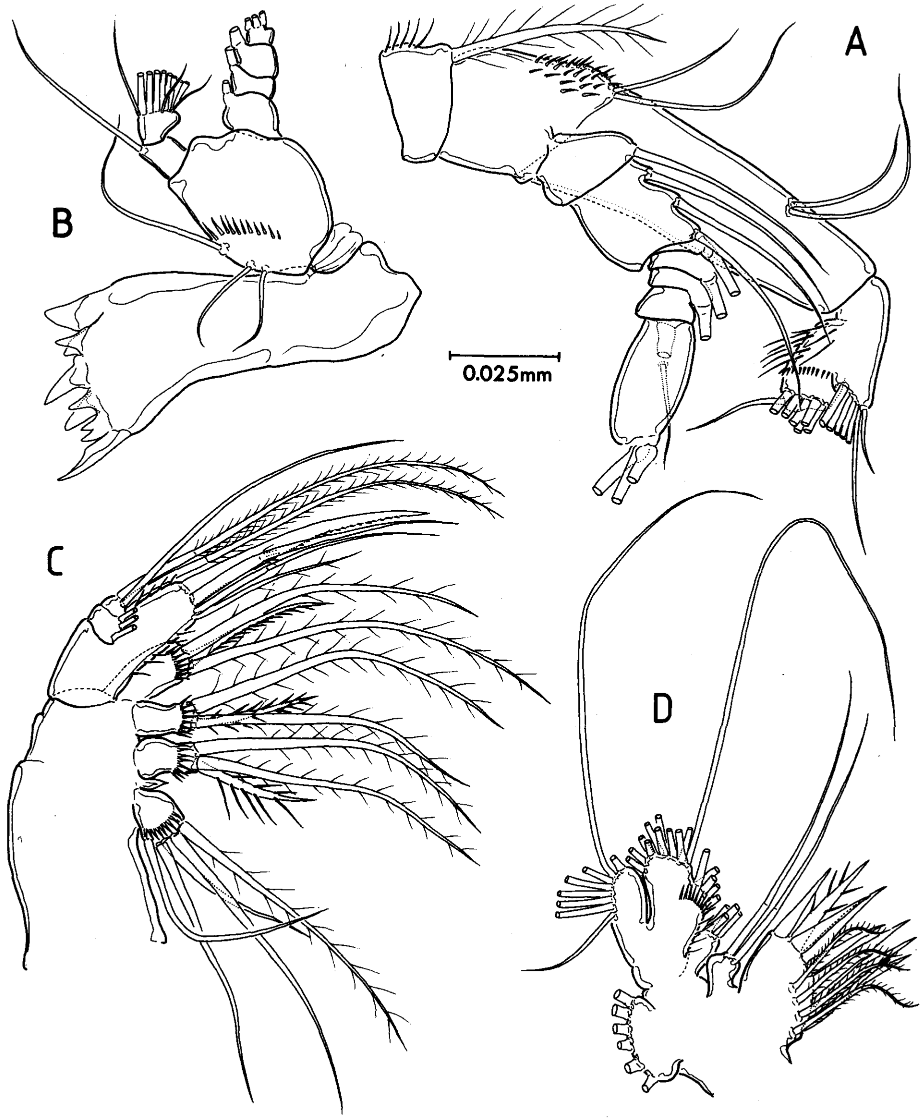

Fig. 3. *Stygocyclopia balearica* n. gen., n. sp., female. A. Antenna. B. Mandible. C. Maxilla. D. Maxillule.

row of long setules midway along medial margin; setae III to VI of HUYS & BOXSHALL (1991) implanted distally, I, II and VII subdistally; setae III to VI thick, with internal tissue finely granulated; transverse row of setules on lateral margin, running close to insertion of setae I and II; sometimes few, thin setules implanted dorsally on basal part of rami.

Antennules (Fig. 2E) short, symmetrical, 22-segmented, directed ventrally and shorter than prosome. First segment the largest, representing fused ancestral segments I to IV; fusion between segments I and II incomplete. Other fusions involving ancestral segments X-XI, XXII-XXIII and XXVII-XXVIII. Segment 6 narrower on ventral side than on dorsal. Segment 8 reduced. Ar-

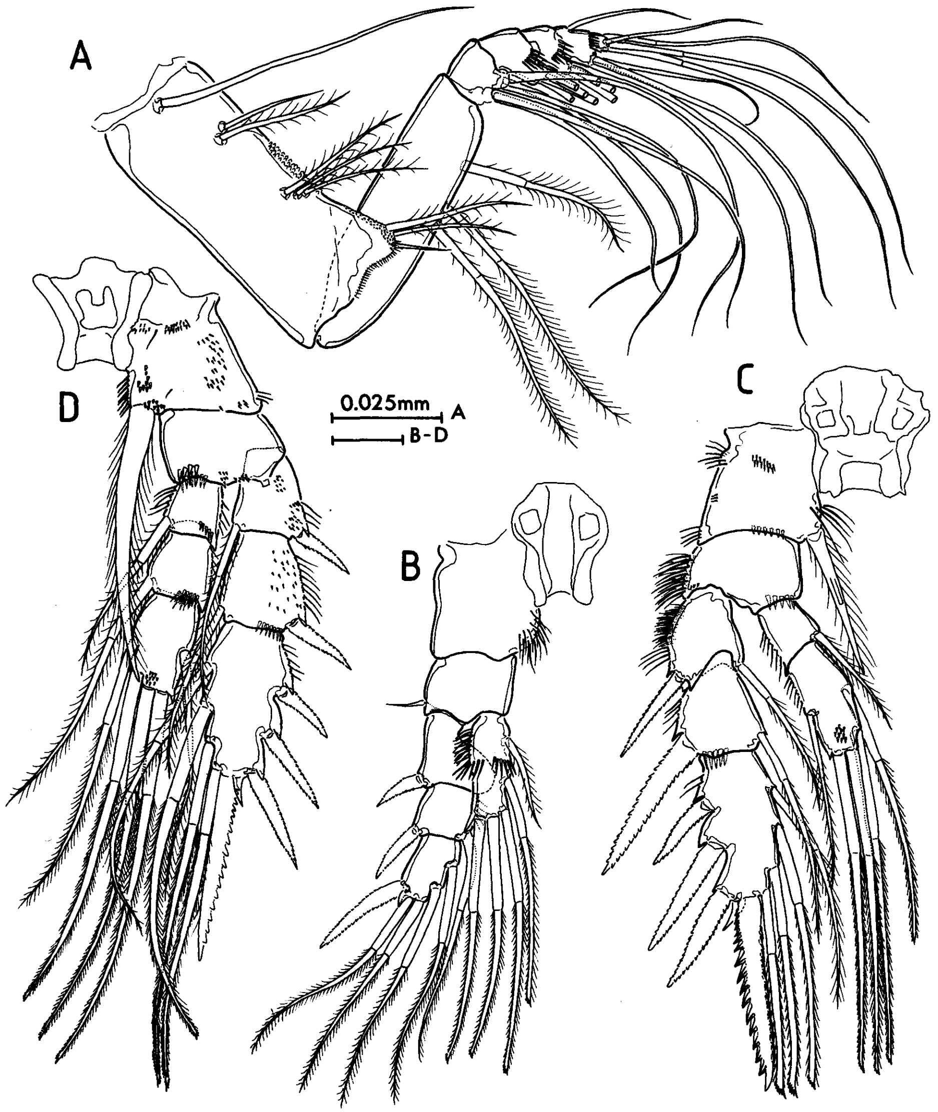

Fig. 4. *Stygocyclopia balearica* n. gen., n. sp., female. A. Maxilliped. B. Leg 1, posterior. C. Leg 2, anterior. D. Leg 3, posterior.

mature elements as follows: I, 3 setae, plus row of short denticles and 1 sensilla on ventral side; II, 2 setae, plus sensilla on ventral side; III, 2 setae + aesthetasc, plus transverse row of short setules on dorsal side; IV, 1 seta; V, 1 seta plus ventral sensilla; VI, 2 setae; VII, 2 setae + aesthetasc; VIII, 1 seta; IX, 2 setae; X-XI, 3 setae + aesthetasc; XII, naked; XIII, 1 seta; XIV, 2 setae; XV, 1 seta; XVI, 1 seta + aesthetasc; XVII to XX, 1 seta; XXI, 1 seta + aesthetasc; XXII-XXIII, 2 setae; XXIV to XXVI, 2 setae; XXVII-XXVIII, 6 setae + aesthetasc.

Antenna (Fig. 3A) biramous. Coxa armed with 1 distal seta and row of setules along inner margin. Basis with 2 distal setae and cluster of short spinules on inner margin. Endopod longer than exopod, 2-segmented, with

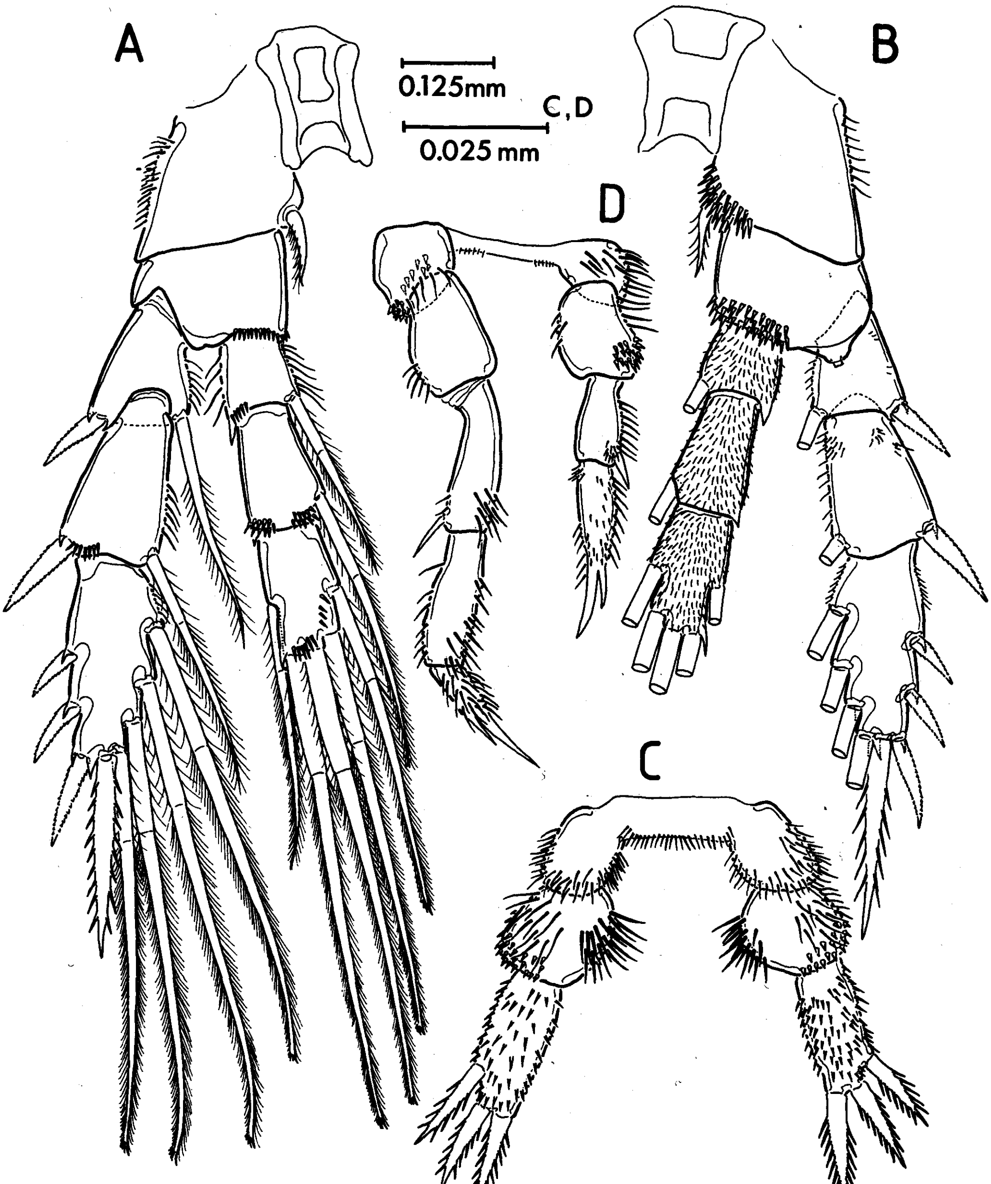

Fig. 5. *Stygocyclopia balearica* n. gen., n. sp.; A-C, female; D, male. A. Leg 4, anterior. B. Leg 4, posterior; C. Fifth legs, posterior. D. Fifth legs, posterior.

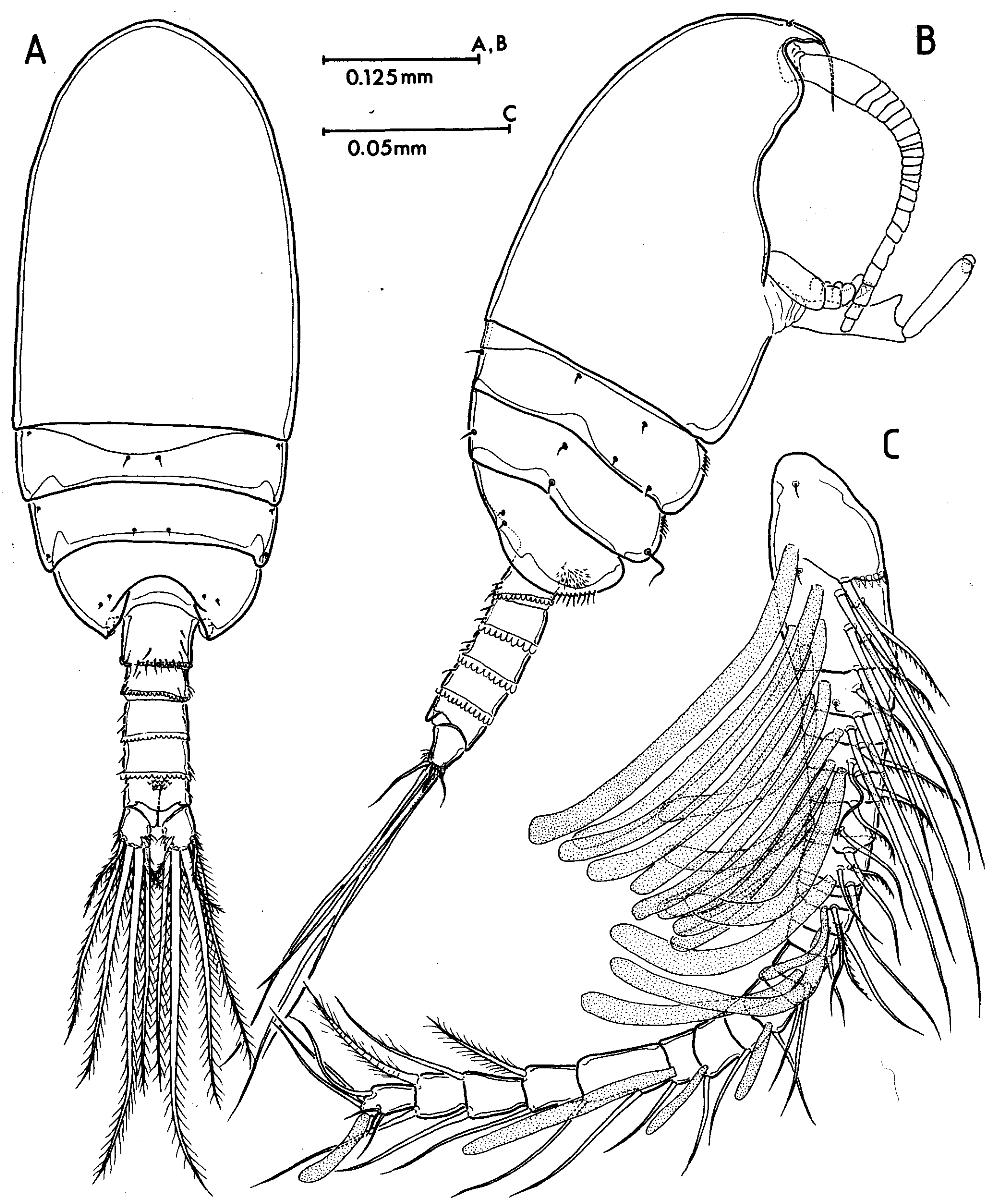

Fig. 6. *Stygocyclopia balearica* n. gen., n. sp., male. A. Dorsal view. B. Lateral. C. Left antennule.

proximal segment not fused at all to basis, very elongate, bearing 2 setae at two thirds distance along inner margin; distal segment short, bilobed, both lobes bearing 7 distal setae; outer margin of distal lobe covered by long setules and with transverse row of short spinules. Exopod 7-segmented; segment 2 representing ancestral segments II, III and IV; segment 7, representing ancestral segments IX and X; setal formula: 1, 3, 1, 1, 1, 1, 4.

Mandible (Fig. 3B) with stout coxal gnathobase; cutting blade sharp, bearing 2 rows of hyaline denticles. Mandibular palp with basis expanded, bearing 3 long setae and transverse row of spinules; endopod shorter than exopod, 2-segmented, first segment bearing 1 seta, second bearing 11 distal setae, 3 reduced; exopod 4-segmented, with setal formula 1, 1, 1, 3; distal segment derived from ancestral segments IV and V.

Maxillule (Fig. 3D) with segmentation not clearly defined; praecoxal arthrite bearing 10 stout spines and 4 setae; coxal epipodite armed with 6 long setae; coxal endite with 2; proximal basal endite discrete, armed with 4 distal setae; distal endite incorporated into segment, bearing 5 marginal setae and row of submarginal spinules; endopod fully incorporated into basis, forming lobe armed with 11 long, distal setae; exopod discrete, with row of 8 long, marginal setae.

Maxilla (Fig. 3C) comprising completely fused praecoxa and coxa, basis, and 2-segmented endopod. Proximal praecoxal endite with 5 long marginal setae and submarginal row of thin denticles; distal armed with 3 setae, 1 of them shorter, thick, and also submarginal row of denticles; pointed process of uncertain homology, located between both endites. Both coxal endites armed as distal praecoxal endite. Basal endite with row of setules on both lateral margins, and bearing 4 setae distally, 1 very thick and denticulated. Endopod short, about half length of basal endite, with setal formula: 3, 3.

Maxilliped (Fig. 4A) powerfully developed, 8-segmented, reflexed distally. Syncoxa armed with 9 setae distributed in 4 groups along medial margin: 1, 2, 3, 3; distal portion of medial margin produced into powerful lobe; ornamentation consisting of 2 patches of tiny denticles and row of short setules, as in Fig. 4A. Basis about as long as syncoxa, slender, armed with 3 long setae along lateral margin. Endopod 6-segmented; small first endopodal segment free, but with sutures faintly delimited; setal formula: 2, 3, 4, 3, 3+1, 4; transverse row of thin denticles on distal margins of segments 3, 4 and 5.

Swimming legs (Figs 4B-D; 5A, B) increasing in size from 1 to 4; each with 3-segmented exopod; endopod of leg 1 unisegmented, that of leg 2 bisegmented; those of legs 3 and 4 3-segmented. Spine and seta formula as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-0	1-0	I-0; I-1; I,1,3	0,2,3
Leg 2	0-1	0-0	I-1; I-1; III,I,4	0-1; 1,2,2
Leg 3	0-1	0-0	I-1; I-1; III,I,4	0-1; 0-1; 1,2,2
Leg 4	0-1	0-0	I-1; I-1; III,I,4	0-1; 0-1; 1,2,2

Distal setae on both rami of all 4 legs (except those on exopod of leg 1) with brush-like tip. Endopod of leg 1 with straight lateral margin, bearing transverse row of spinules; medial margin of first exopod segment swollen. Inner spine on coxae of legs 2 and 3 stout and straight; that of leg 3 especially developed, but not extending beyond tip of endopod; that of leg 4 curved, weakly developed. All 4 legs richly ornamented with denticles, spinules and setules, distributed as figured; posterior surface of endopod of leg 4 completely covered by short setules.

Fifth legs (Fig. 5C) symmetrical, uniramous, reduced, 3-segmented, with proximal segment completely fused to intercoxal sclerite; distal segment elongated, bearing 2 stout spines distally and 1 subdistally. All segments, plus intercoxal sclerite, richly ornamented with setules, as in Fig. 5C.

Male. - Body (Figs 6A, B) 0.59 to 0.62 mm long, with prosome about 3 times longer than urosome. Prosome as in female. Urosome 5-segmented. Genital somite asymmetrical, slightly produced and extended posteriorly on left side; single gonopore opening ventrolaterally on left side close to posterior margin of segment; operculum not clearly defined, forming narrow lappet on gonopore. Anal somite and caudal rami as in female. Antennules (Fig. 6C) symmetrical, 22-segmented; fusion pattern of segments as in female, but differing in armature, especially in numbers of aesthetascs: I, 1 seta + aesthetasc, plus row of short denticles and 1 ventral sensilla; II, 2 + aesthetasc, plus ventral sensilla; III, 2 + 2 aesthetascs; IV, 1 + aesthetasc; V, 2 + 2 aesthetascs, plus ventral sensilla; VI, 2 + 1 aesthetasc; VII, 2 + 2 aesthetascs; VIII, 1 + aesthetasc; IX, 2 + 2 aesthetascs; X-XI, 3 + aesthetasc; XII, naked; XIII, 1 + aesthetasc; XIV, 2 + aesthetasc; XV, 1 seta; XVI, 1 + aesthetasc; XVII, 1 seta; XVIII, 1 + aesthetasc; XIX, 1 seta; XX and XXI, 1 + aesthetasc; XXII-XXIII, 2 setae; XXIV, XXV and XXVI, 2 setae; XXVII-XXVIII, 6 + aesthetasc. Other mouthparts and swimming legs 1 to 4 as in female in segmentation and setation.

Fifth legs (Fig. 5D) asymmetrical, uniramous, slender. Left longer than right, 5-segmented, with proximal segment completely fused to intercoxal sclerite; segment 3 armed with thin, distal spine on outer margin; segment 5 with 2 thin, distal spinous processes, inner more than twice length of outer. Right leg 4-segmented, with proximal segment completely fused with intercoxal sclerite; segment 3 with stout, distal short spine on outer margin; segment 4 produced into 2 distal spinous processes, thicker than those on distal segment of left leg, inner less than twice length of outer. Both legs and intercoxal sclerite richly ornamented with setules, spinules and denticles, as in figures.

Etymology. - The specific name refers to the distribution of the species, in the Balearic Islands (Mediterranean).

Remarks. The family Pseudocyclopiidae Sars comprised to date two genera. The seven species of *Pseudocyclopia* T. Scott are found on muddy substrates in shallow seas (50-120 m depth) around the coasts of Britain and Norway (SCOTT 1892, 1894; SARS 1901-1903, 1919-1921), and also in near-bottom shallow waters of the tropical Atlantic (ANDRONOV 1986) and the NW Pacific (OHTSUKA 1992). The other genus, *Paracyclopia* FOSSHAGEN, is monotypic, with *P. naessi* occurring in anchihaline caves on the island of Bermuda (FOSSHAGEN & ILIFFE 1985).

The family was established by SARS (1901-1903) to accommodate *Pseudocyclopia*, and he used the fusion of the basis and endopod of the antenna, and the proximal fusion of the antennulary segments as diagnostic characters. *Paracyclopia* shares the former character with *Pseudocyclopia*, but displays a relatively unmodified antennule. Major differences between the genera relate to the morphology of fifth legs of both sexes. In *Pseudocyclopia* the left leg of male is swollen proximally, whereas in *Paracyclopia* it is slender. In *Pseudocyclopia* the female fifth legs possess 3 elements on the distal segment, either 1 spinous process and 2 spines, 2 spinous processes and 1 spine, or 3 distinct spines, according to species. In *Paracyclopia* this segment bears only a spinous process and a short spine.

The new taxon from the Balearic Islands lacks the fused basis and endopod of the antenna, but its body and remaining appendages closely resemble those of the other known members of the family. Especially noteworthy in this respect is the large inner spine on the coxae of legs 2 and 3. It is here included in the family Pseudocyclopiidae on the basis of this character.

The new taxon resembles *Paracyclopia naessi* in the morphology of the male fifth legs. In both, the left leg is not swollen proximally, a feature which distinguishes them from *Pseudocyclopia* species. However, close analysis reveals important differences between them. In *Paracyclopia* the male right leg is the longer, in the new taxon the left is longer. Also the number of segments in the right leg differs; including the first segment (coxa) which is completely fused to the intercoxal sclerite, that of *Paracyclopia* is 5-segmented whereas that of the new taxon is only 4-segmented. The difference lies in the distal part of the leg. The 3 proximal segments (coxa, basis and first exopodal segment) are homologous as indicated by the location of a spine on outer margin of the first exopodal segment. The remaining distal part comprises 2 segments plus a distal spine in *Paracyclopia* compared to only 1 in the new taxon. The distal spine of *Paracyclopia* (which was interpreted as a segment by FOSSHAGEN & ILIFFE 1985) may be homologous with the distal inner spinous process on the apical segment of the new taxon, and the distal spine on outer margin of segment 5 of *Paracyclopia* may be homologous with the outer spinous process of the apical segment of the new taxon. The second and third exopodal segments (= segments 4 and 5) of *Paracyclopia* appear to be homologous with the double apical segment of the new taxon.

Other important differences between both taxa include the setation of the endopod of leg 1 and the exopods of legs 2 and 3, and the morphology of female fifth legs. Those of the new taxon display 3 large, stout spines on the distal segment, with clearly defined sutures at their insertion points. In *Paracyclopia* the distal segment bears only one spinous process and a short spine.

These features are considered here as significant enough to justify the erection of a new genus for the Balearic taxon. The differential diagnosis is as follows: *Stygocyclopia* n. gen. bears 2 filaments on tip of rostrum; it displays symmetrical, 22-segmented antennules in both sexes, with ancestral segments I-IV and XXII-XXIII fused; the endopod of the antenna is completely separate from the basis; there are 7 caudal setae; leg 1 bears an outer seta on the basis and 3 medial setae on endopod; legs 2 and 3 bear a medial seta on exopod segment 1; the inner seta on coxa of leg 4 is short and slender. In comparison, *Paracyclopia* lacks rostral filaments; it has symmetrical, 24-segmented antennules in female, with only ancestral segments II-IV fused, and slightly asymmetrical antennules in male, with the right one 23-segmented due to fusion of ancestral segments XXII-XXIII; the endopod of the antenna is imperfectly separated from basis; there are only 6 caudal setae; leg 1 lacks an outer seta on basis, and bears only 2 medial setae on the endopod; legs 2 and 3 lack a medial seta on exopod segment 1; the inner seta on coxa of leg 4 is long, thick and spiniform.

Stygocyclopia balearica n. gen., n. sp. is a thalassostygobiont taxon restricted to water layers with salinities in excess of 18 ‰ in anchihaline cave environments. The absence of other representatives of the family in Mediterranean waters (although this may merely reflect lack of search effort), and its close relationship to the monotypic, stygobiont *Paracyclopia* from Bermuda suggest a tethyan origin and a relict condition. This implies an origin prior to the opening of the Atlantic Ocean for the common ancestor of both genera, and also the survival of *Stygocyclopia* (or its ancestor) through the postulated desiccation of the Mediterranean during the Upper Tertiary (6 M.y. BP)(HSÜ 1973).

This new taxon belongs to a shallow water, hyperbenthic family, in accordance with the hypothesis of STOCK (1986), who regarded the ancestors of the anchihaline cave fauna as shallow water preadapted lineages rather than deep-sea lineages. It is interesting to note here that, within the family Arietellidae, two genera have colonised anchihaline caves, *Paramisophria* SCOTT and *Metacalanus* CLEVE. Both these genera are primarily distributed in shallow water hyperbenthic habitats and have probably colonised anchihaline caves from such original habitats even though the origins of the Arietellidae as a whole appear to be in the deep-water hyperbenthic environment (OHTSUKA & al. 1994).

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