



***Grandidierella bonnieroides* Stephensen, 1948 (Amphipoda, Aoridae)—first record of an established population in the Mediterranean Sea**

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Abstract

The first record in the Mediterranean Sea of the invasive aorid amphipod crustacean *Grandidierella bonnieroides* is presented. A widespread circumtropical species, recorded off the Saudi coast of the Arabian Gulf, the Red Sea and the Suez Canal, it may have been introduced into the Mediterranean through the Suez Canal. This tube-builder species of soft bottoms recently established a population in the polluted Haifa Bay, Israel. Further, this is the first Mediterranean record of the genus.

Key words: *Amphipoda*, *Grandidierella bonnieroides*, *Invasive Alien Species (IAS)*, *Mediterranean Sea*

Introduction

Amphipod crustaceans are commonly introduced in marine and estuarine waters worldwide. They comprise 30% of documented crustacean invasions in North America (32, including 3 cryptogenic species) (Ruiz *et al.* 2011), 18%, 44% in New Zealand and Australia (20, 18, respectively, including 5 cryptogenic species) (Ahyong & Wilkens 2011), 50% in South Africa (17, including 7 cryptogenic species) (Griffiths *et al.* 2011), 24% along the Atlantic coast of Europe (12 species) (Noël 2011), less than 4% (4 species) in the Mediterranean Sea (Galil 2011). Most were considered to have been introduced by shipping, whether with ballast or with fouling communities; however, in the Mediterranean Sea their principal pathway of introduction is the Suez Canal.

The Levantine basin is exceptionally vulnerable to biological invasions of Erythraean species (Galil 2000; Galil *et al.* 2015), and it is likely that little studied taxa, such as amphipods, harbor yet undocumented Erythraean species.

Grandidierella Coutière, 1904 is a circumtropical genus, never before recorded in the Mediterranean Sea; the species generally occurs in polluted brackish waters, where constructs tubes on a variety of hard substrates, in association with the species of *Jassa* sp. Leach, 1814, and various polychaetes (Barnard *et al.* 1991).

Two tubicolous aorid amphipods, *Grandidierella japonica* Stephensen, 1938, and *G. bonnieroides* Stephensen, 1948, proved to be highly successful invasive species, widespread in both the northern and southern hemispheres, where they have established self-sustaining and thriving populations. *Grandidierella japonica*, native of the Japanese archipelago, was first reported outside its native area in 1966 in San Francisco Bay (Chapman & Dorman 1975), but has since spread along the western coast of North America from Mexico to British Columbia, Canada, Hawaii, New South Wales, Australia (Myers 1981), and recently along the Atlantic coast of southern UK and France (Jourde *et al.* 2013 and references therein).

The type material of *G. bonnieroides* was collected in Bonaire, Netherlands Antilles, Caribbean Sea (Stephensen 1933). It is widespread circumtropical species (Myers 1981), though yet no recorded from the tropical eastern Atlantic Ocean (Fig. 1). It should be noticed that several records of *G. bonnieri* Stebbing, 1908 and one of *Unciolella lunata* Chevreux, 1911 have been recognized as mis-identifications of *G. bonnieroides* (Myers 1970; 1972; 1981; 2009). Figure 1 shows all the records of the species.

This paper reports the presence of its population collected off the Mediterranean coast of Israel (Fig. 2), comprising the first record of the species and of the genus in the Mediterranean Sea.

Materials and methods

In the course of surveys of the shallow soft bottoms in Haifa Bay (Figs 1, 2), three replicate sediment samples (R_1 , R_2 , R_3) were taken with a 32×35 cm Van-Veen grab (KAHLSICO, model WA265/SS214), volume 20 L, and penetrating up to 20 cm into the substrate, preserved in 70% alcohol and within days sieved on a 250 μ m mesh; in August 2014. The specimens were identified following Myers (1970; 2009).

Sixty-one specimens were examined under a stereo microscope and dissected.

Their length, from tip of rostrum to apex of telson, was measured using by Image J software after placement on graph paper and photography (FINEPIX S1800, FUJIFILM). The illustrations were produced using a Leica 4000B light microscope with camera lucida. The general terminology of amphipod morphology followed the one found in handbook edited by Ruffo (1982).

Specimens are deposited in the Zoological Museum of the University of Palermo (MZPA), Italy, and in the Steinhardt Museum of Natural History, Tel Aviv University, Israel (SMNH-TAU).

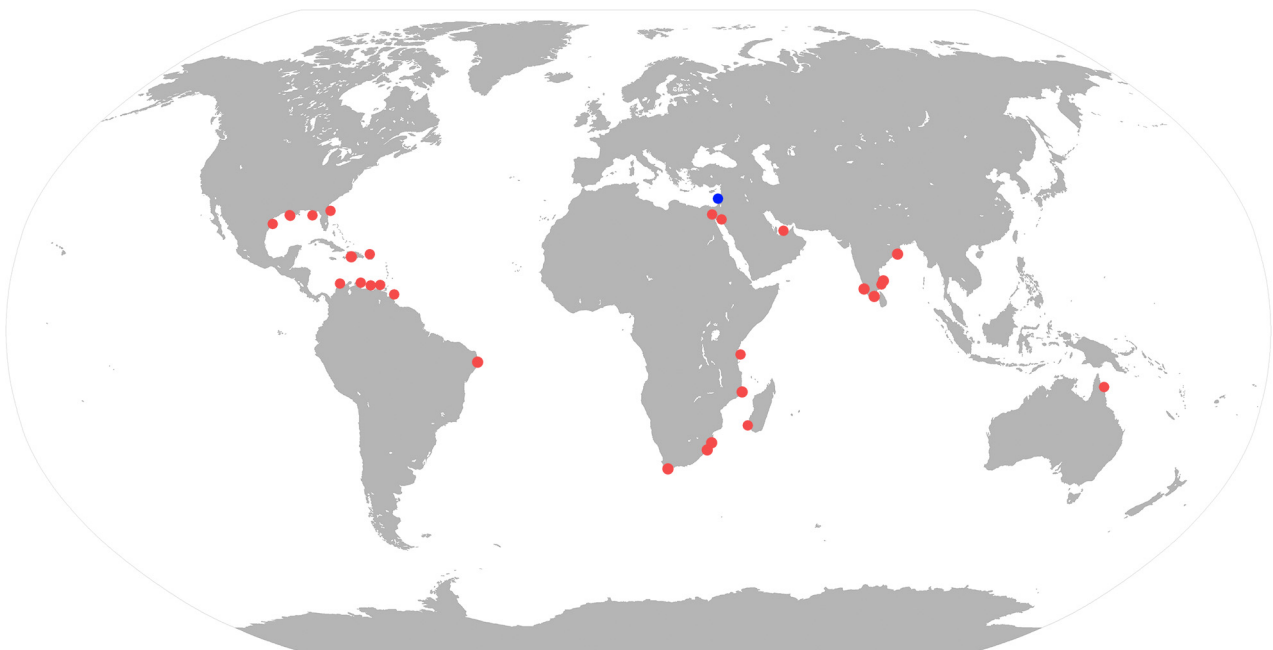


FIGURE 1. Distribution of *Grandidierella bonnieroides*: Chilika Lake, Orissa, India (Chilton 1921); Suez canal (Schellenberg 1928); Etang Saumâtre, Haiti (Shoemaker 1935); Njarackal, Cochin, Kerala, India (K.H. Barnard 1935); Adyar, Chennai, Tamil Nadu, India (Panikkar & Aiyar 1937); Brazilian coast (Schellenberg 1938); Curaçao; Bonaire (Shoemaker 1948; Stephensen 1933; 1948; Lowry & Stoddart, 2003); Durban Bay, Durban, South Africa; Richards Bay, Kwa Zulu-Natal, South Africa (K.H. Barnard 1951; 1952); Soalara, Madagascar (Ruffo 1958); Madras, Tamil Nadu, India (Nayar 1959); Tuticorin, Tamil Nadu, India; Mandapam, Tamil Nadu, India (Nayar 1966); Tulear, Madagascar (Ledoyer 1967; 1968; 1973); Gran Roque, Los Roques Islands, Venezuela; Marguerita Island, Venezuela; Tortola Island, British West Indies, Caroni Swamp, Trinidad; Port St. Joe, Florida; Salt Spring, Marion, Florida; Williams, Lake Pontchartrain, Louisiana; Riviera Beach, Baffin Bay, Texas; Sta. Marta Island, Colombia; Msasani Bay, Tanzania (Myers 1970); Madagascar (Mayers, 1972); Mozambique (Griffiths 1973); Natal, Brazil (Griffiths 1974a); Cape Province east of Cape Agulhas (Griffiths 1974b); Lizard Island, Queensland, Australia (Myers 1981); Lagoons Dawhat as Sayh, Arabian Gulf, Saudi Arabia (Myers 1981); Vellar-Coleroon estuarine, Porto Novo, India (Asari & Myers 1982); Gulf of Aqaba, Red Sea (Lyons & Myers 1990); Bonaire, Netherlands Antilles, Caribbean Sea (Myers 2009); (blue circle) Israel coast, Mediterranean Sea (This paper).

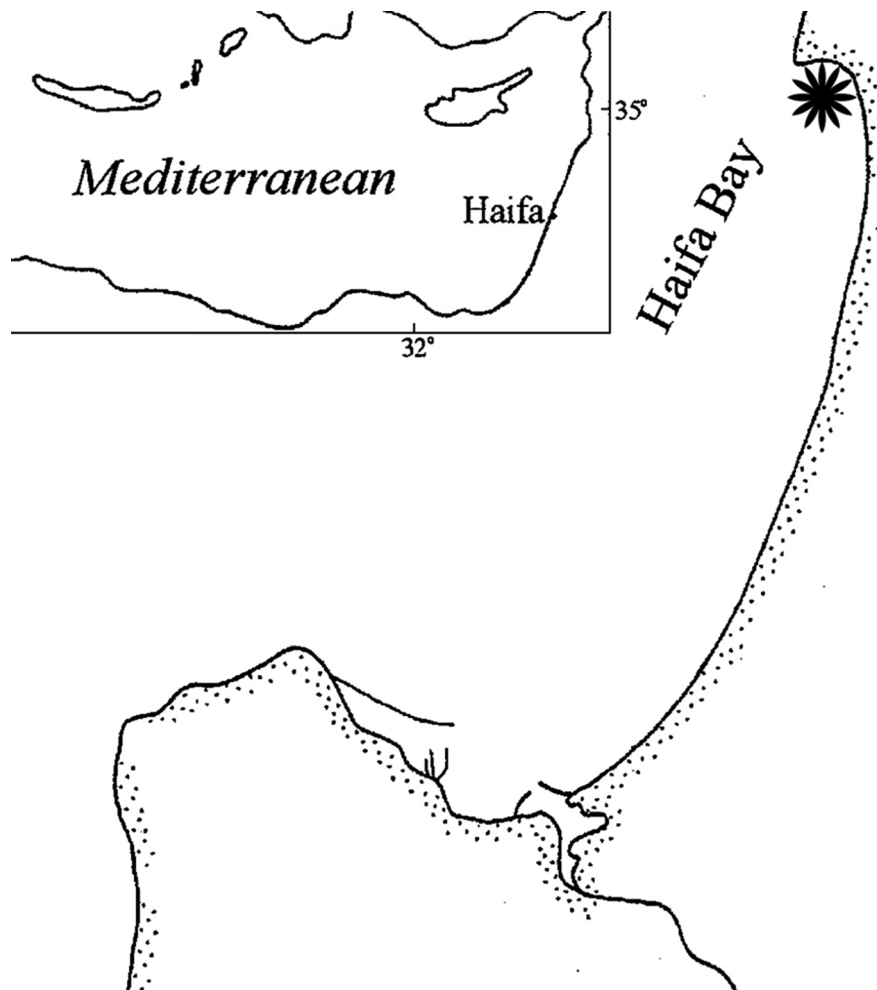


FIGURE 2. Map of the sampling site along the southern coast of Israel, Haifa Bay 32° 55' 07" N, 35° 04' 33" E.

Results

227 specimens of *Grandidierella bonnieroides* were collected in the north Haifa Bay, opposite the mouth of the Na'aman stream, at a depth of 7.85 m. *Grandidierella bonnieroides* lives exclusively in sand or with fine sediments and organic detritus (Barnard *et al.* 1991), and has been found in this own usual habitat. Specimens were collected in association with amphipod *Cheiriphotis mediterranea* Myers, 1983 and *Photis longicaudata* (Bate & Westwood, 1862), with which constituted the dominant peracaridans (Table 1). Almost all specimens were sorted without antennae and pereopods.

The species has not been reported previously from the Mediterranean Sea.

TABLE 1. Species abundance of amphipods detected in the three sampling replicates (R₁, R₂, R₃) recorded in Haifa Bay.

| | R ₁ | R ₂ | R ₃ |
|------------------------------------|----------------|----------------|----------------|
| <i>Grandidierella bonnieroides</i> | 34 | 131 | 62 |
| <i>Cheiriphotis mediterranea</i> | 207 | 493 | 1091 |
| <i>Photis longicaudata</i> | 47 | 158 | 546 |
| <i>Corophium</i> sp. | 5 | 0 | 11 |
| <i>Ampelisca</i> sp. | 1 | 4 | 8 |
| <i>Megaluropus</i> sp. | 7 | 1 | 0 |

Systematics

Subphylum CRUSTACEA Brünnich, 1772

Class MALACOSTRACA Latreille, 1802

Superorder PERACARIDA Calman, 1904

Order AMPHIPODA Latreille, 1816

Suborder SENTICAUDATA Lowry & Myers, 2013

Infraorder COROPHIIDA Leach, 1814 (*sensu* Lowry & Myers 2013)

Parvorder COROPHIIDIRA Leach, 1814 (*sensu* Lowry & Myers 2013)

Superfamily AOROIDEA Stebbing, 1899

Family AORIDAE Stebbing, 1899

Genus *Grandidierella* Coutière, 1904

Grandidierella bonnieroides Stephensen, 1948

(Figs 3, 4, 5, 6)

Synonym section:

Grandidierella bonnieroides Stephensen, 1948: 12, fig. 3.—Myers, 1970: 141, fig. 1–2.—Myers, 1972: 790; 1981: 218.—Ledoyer, 1973: 40.—Griffiths, 1974b: 282.—Asari & Myers, 1982: 252, figs 9–10.—Lowry & Stoddart, 2003: 70 (catalogue).

Grandidierella megnae.—Chilton, 1921: 548, fig. 10.—Stephensen, 1933: 434.—Shoemaker, 1935: 70.

Unciolella lunata.—Schellenberg, 1928: 669, fig. 207.

Grandidierella bonnieri.—K.H. Barnard, 1935: 299.—Panikkar & Aiyar, 1937: 294.—Schellenberg, 1938: 215.—Shoemaker, 1948: 11, fig. 3.—K.H. Barnard, 1951: 708; 1952: 279, fig. 1.—Ruffo, 1958: 58, figs 8, 9.—Nayar, 1959: 38, pl. 14, figs 1–5; 1966: 161, fig. 17f.—Ledoyer, 1967: 137, fig. 28a; 1968: 287, fig. 25b.—Griffiths, 1973: 283; 1974a: 228.

Material examined. Israel. Haifa Bay 32° 55' 07" N, 35° 04' 33" E, depth 7.85 m, 7 August 2014, 8 males, 48 females, 171 immature (1 male, 6 females, 27 immature; 3 males, 29 females, 99 immature; 4 males, 13 females, 45 immature, respectively in the three replicates). 1 male, 2 females, 10 immature (SMNH TAU AR-29389), the balance retained in the Zoological Museum of the University of Palermo (MZPA-AMPH-0008).

(The bold-italic parts are diagnostic descriptions).

Diagnosis: Male, 3.3 mm (MZPA-AMPH-0008m). *Head* lateral cephalic lobes apically truncate. *Antenna 1* flagellum with about 19 articles; accessory flagellum with one long and one distal rudimentary article. *Antenna 2* with few long setae. *Lower lip* with fine setae only. *Maxilla 1* inner plate without setae. *Mandible*, palp article 3 subequal to 2, posterior margin substraight, setae distal. *Pereonites 1–3* with apically acute sternal spines. *Gnathopod 1* enlarged in males only; coxa unproduced anterodistally. ***Gnathopod 1*** coxa ventral margin without small spine, ***basis*** robust, half or more as broad as long, without a spine, ***anterior margin without stridulating ridges***, posterodistal margin with setae sparse, anterodistal margin with flange weak; ischium anterior margin without flange, posterior margin with setae sparse; merus not greatly elongated, fused along its entire length with carpus, posterior margin with sparse setae, without posterodistal spine; ***carpus twice length of propodus, anterior margin without stridulating ridges, with setae sparse, anterior margin with no spine, a row of setae on inner face, posterior margin with submarginal spine*** (lacking in smaller males), ***strong posterodistal spine, and smaller obtuse distal spine***; propodus, anterior margin weakly setiferous, posterior margin straight or evenly convex, palm absent; dactylus more than half length of propodus. *Gnathopod 2* subchelate; basis anterodistal margin without flange, posterodistal margin without robust setae, with few setae along length of basis; merus not enlarged or

produced away from carpus; carpus longer than propodus, anterior margin not lobate, with a few spaced setae; propodus with few setae, palm with pair of robust setae defining palm. *Pereopod 3–7* absent in all the Mediterranean collected specimens. *Uropod 1* rami subequal, peduncle much longer than broad, distoventral spine one fifth length of peduncle. *Uropod 2* biramous; peduncle without distoventral spine. *Uropod 3 uniramous, ramus at least twice length of peduncle*. *Telson* with distal fine setae only.



FIGURE 3. *Grandidierella bonnieroides* Stephensen, 1948, Haifa Bay, Israel: A, male; B, mature female; C, immature. Scale bar = 1 mm.

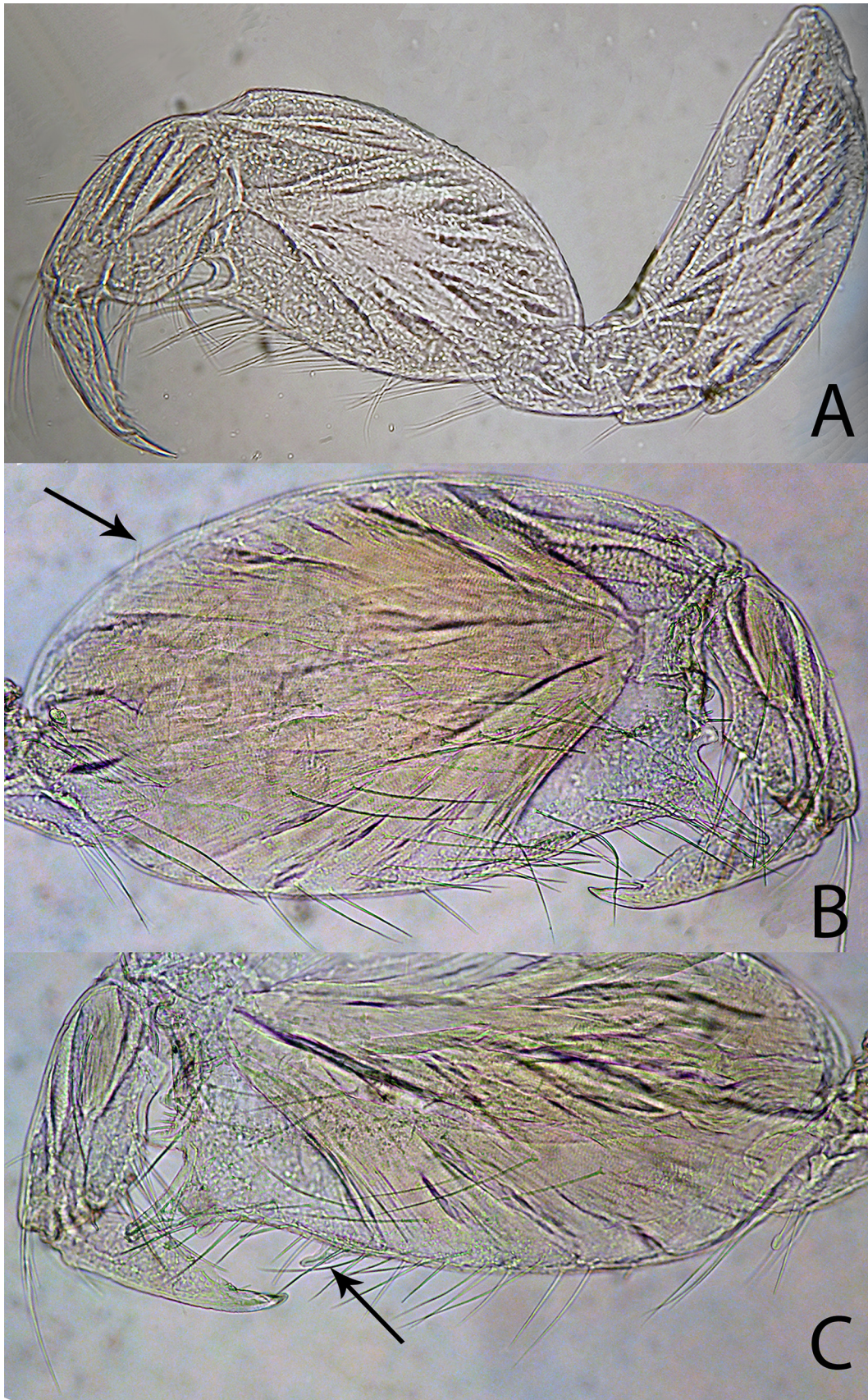


FIGURE 4. *Grandidierella bonnieroides* Stephensen, 1948, Haifa Bay, Israel, male: A, yg male (<math>< 2.5\text{ mm}</math>) gnathopod 1 (inner face); B, mature male (MZPA-AMPH-0008m) (3.3 mm) right gnathopod 1 with detail of anterior margin of carpus without stridulating ridges (inner face); C, same individual, left gnathopod 1 with detail of posterior margin of carpus with submarginal spine (inner face).

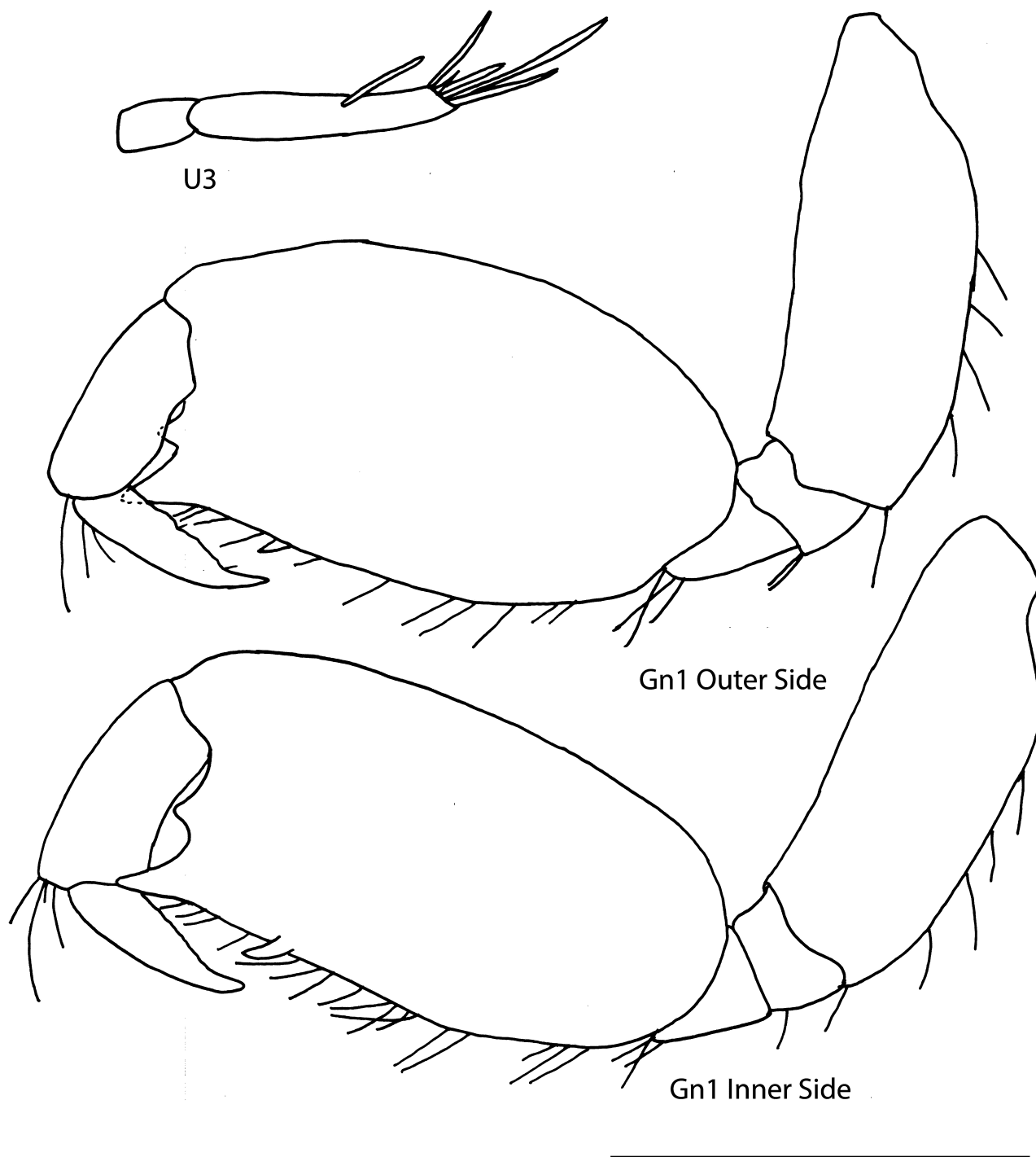


FIGURE 5. *Grandidierella bonnieroides* Stephensen, 1948, Haifa Bay, Israel, male: A, uropod 3; B, gnathopod 1 (outer face); C, gnathopod 1 (inner face). Scale bar = 0.5 mm.

Female, 3.25 mm (MZPA-AMPH-0008f) (sexually dimorphic characters). *Sternal spines* absent. *Gnathopod 1* basis slender, much less than half as broad as long; carpus a little longer than propodus; propodus palm present, evenly continuous with posterior margin, posterior margin with three robust setae; dactylus significantly overlapping palm.

Remarks. Among all the Aoridae known from Mediterranean Sea (Myers 1982; Christodoulou 2013) and Red Sea (Ruffo 1959; Sorbe *et al.* 2002), only *Grandidierella* genus has together uropod 3 uniramous and gnathopod 1 carpochelelate in male. The only *Grandidierella* species, recorded in area adjacent to the Mediterranean Sea, are *G. japonica* from Atlantic coast of France (Jourde *et al.* 2013) and *G. bonnieroides* from the Red Sea side of Suez

Canal (Schellenberg 1928). These two species can be delimited by the presence/absence of the transverse ridges on the anterior margin of carpus of the gnathopods 1 in male, present in *G. japonica* and absent in *G. bonnieroides*.

Further, the presence of a submarginal spine on the posterior margin of the carpus of the male gnathopod 1 is a character that distinguishes *G. bonnieroides* from the other closely related species (Ledoyer 1967; Myers 2009).

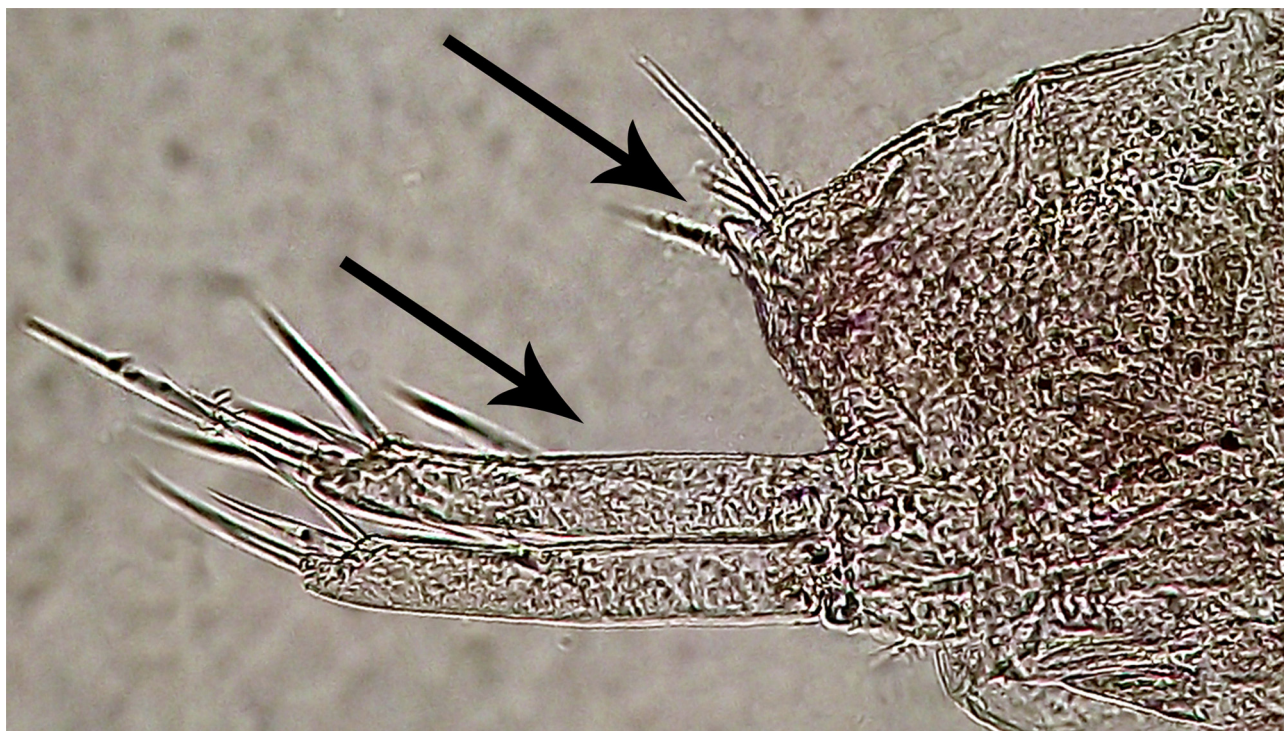


FIGURE 6. *Grandidierella bonnieroides* Stephensen, 1948, Haifa Bay, Israel, male: uropods 3 and telson with detail of distal fine setae.

Discussion

Grandidierella bonnieroides is commonly found on soft bottoms in shallow bays, tide pools, and mangrove marshes (Heard 1982), in muddy bottoms with scarce vegetation (Oliva-Rivera 1998), and also in high salinity (58‰) lagoons (Myers 1981).

Grandidierella bonnieroides is known as an opportunistic pollution indicator species (Grizzle 1984; Barnard *et al.* 1991), colonizing areas which undergo periodic defaunation, establishing on occasion dense populations (96,000 m⁻², *vide* Santos & Simon 1980). It is therefore not surprising that the species occurs off the Israeli coast in the eutrophic and polluted Haifa Bay (Herut *et al.* 2012). The collection site is sampled annually in the framework of the 'National Monitoring programme', therefore we may assume that this is a very recent introduction. The large number of specimens collected in August 2014, including ovigerous females and numerous juveniles, indicates a locally established population.

Such behavior could be the reason of the high abundance detected in this first record, commonly unusual as first case of capture of invasive species. This species has been named 'detritus-blanket tube-builder' (Barnard *et al.* 1991) as the individuals lives into a mass of detritus-debris, pulling it over itself like a blanket and cementing particles together until tube-walls have been formed around the individuals (Barnard *et al.* 1991).

It is unclear whence *G. bonnieroides* has arrived. It is widely believed that transportation of the tubicolous amphipods in ship fouling or ballast sediments is a likely dispersal method (Jourde *et al.* 2013), and the occurrence of *G. bonnieroides* in Haifa Bay, next to a major port, suggests that it is indeed plausible. Yet, the great majority of non indigenous species documented in the Levantine Sea are considered to have been introduced through the Suez Canal (Galil *et al.* 2014). The occurrence of the species in the Red Sea and the Suez Canal itself (see above) lends credence to the possibility of introduction through that corridor.

From a taxonomic perspective, the genus *Grandidierella* represents a problematic taxon, due to a considerable

variation during the growth (Myers 1970). In fact, some co-generic species are recognized overlapping in some juvenile characters (Myers 1970), limiting the monitoring of occurrence of the species.

Further, this genus closely resembles the genus *Unciolella* Chevreux, 1911, with which shares the uniramous uropod 3 within the family Aoridae and from which differs principally in the carpochele shape of the gnathopods 1 in adult males (Myers 1982), that prevents mis-identification between the two genera. However, it cannot be excluded that the only Mediterranean record of *Unciolella* sp. (Chevreux 1911), along the Algerian coast, identified in an immature specimen (3 mm), has been mis-identified with an immature *Grandidierella* sp.

Myers (2009) considered *G. bonnieroides* a 'species complex'. Clearly, there is a need to clarify the identity of the species established in the Mediterranean Sea and to reconstruct its invasion history. Molecular tools, widely relied upon to provide data concerning species' identity and invasion history, may help interpret the historical, ecological and observational data (Lawson Handley *et al.* 2011).

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