

## First record of *Eudiaptomus gracilis* (G.O. Sars, 1863) (Copepoda: Diaptomida) in the inland waters of Turkey

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**Abstract:** The Calanoid copepod *Eudiaptomus gracilis* (G.O. Sars, 1863) is recorded from Turkish inland waters for the first time. Males and females of *Eudiaptomus gracilis* were consistently found during 6 sampling periods in the Yeşilirmak River. The species was collected from the Yeşilirmak River and Suat Uğurlu and Hasan Uğurlu dam lakes in the Black Sea region and detailed descriptions of both sexes are given.

**Key words:** First record, *Eudiaptomus gracilis*, inland waters, Suat Uğurlu, Hasan Uğurlu, Yeşilirmak River

### *Eudiaptomus gracilis* (G.O. Sars, 1863) (Copepoda: Diaptomida)'in Türkiye içsularından ilk kaydı

**Özet:** Kalanoid kopepod *Eudiaptomus gracilis* (G.O. Sars, 1863), Türkiye içsularında ilk kez kaydedilmiştir. Dişi ve erkek *E. gracilis* altı örnekleme döneminde sürekli bulunmuştur. Tür, Karadeniz Bölgesinde bulunan Yeşilirmak, Suat Uğurlu ve Hasan Uğurlu Baraj Gölleri'nden toplanmış ve her iki eşeyin detaylı çizimleri verilmiştir.

**Anahtar sözcükler:** İlk kayıt, *Eudiaptomus gracilis*, iç sular, Suat Uğurlu, Hasan Uğurlu, Yeşilirmak

### Introduction

Copepods are one of the most important components of zooplankton in continental waters and they play an important role in the trophic dynamics of freshwater ecosystems (Jimenez-melero et al., 2005). Because of their peculiar morphology, life cycle, and habitat specialization, especially calanoid copepods could be used in environmental education and as a foremost group for the conservation of temporary water-bodies in a similar way to large branchiopods (Belk, 1998; Eder and Hödl, 2002; Eder, 2008).

Different species of calanoid copepods inhabit certain ecological conditions consisting of environment factors such as mineralization, temperature, gas regime, current, depth, pollution, concentration of suspended matter, and pH, as well as a number of biotic factors. The peculiarities of the water as a surrounding environment of copepods depend on the geographical position of the water body, landscape, bottom type, past geological events, and effects of climate (Samchyshyna, 2008).

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The freshwater calanoid copepod *Eudiaptomus gracilis* is a member of the successfully established permanent populations and they extend their distribution to more water bodies (Rossetti et al., 1996; Riccardi and Giussani, 2007). Indeed, once introduced into a new habitat, an invader has to pass through sequential “filters” in the invasion sequence (Williamson and Fitter, 1996; Muirhead and MacIsaac, 2005) before becoming successfully established.

The success of invasions depends strongly on community characteristics, and environmental tolerance to ambient physical and chemical conditions, including the diversity of the resident species pool (Case, 1990; Tilman, 1997; Levine, 2000; Louette et al., 2006; Riccardi and Rossetti, 2007).

*E. gracilis*, which is a eurythermic and eurytopic species as well as a strong competitor, seems to be more abundant in eutrophic lakes (Hofmann, 1979). Species like this occur in the plankton biomass all year round. These are species with the life cycle adapted to inhabiting a variety of ecological conditions such as permanent and temporary waters, ditch-water and flowing waters, and different ranges of salinity (fresh and salty). Species like this are generalists and have wide ecological plasticity (Samchyshyna, 2008). *E. gracilis* is eurythermic and perennial with egg production throughout the year (Elster, 1954; Ravera, 1954, 1955; Hofmann, 1979; Santer et al., 2000).

*E. gracilis*, which is the most widely distributed calanoid copepod species in Europe, has not been reported in Turkey to date. Their cosmopolitan distribution leads us to suspect that more than one species may be included under the name *E. gracilis*. We made some drawings and descriptions of both sexes in order to provide a basis for future comparisons. In addition, the species can now be added to the known Copepoda fauna of Turkey.

## Materials and methods

This study was performed in the lower basin of the Yeşilirmak River. The study area contained 2 dam lakes, Suat and Hasan Uğurlu, as well as the river sections below and above the dam lakes (Figure 1). Originating at Köse Mountain to the east, the Yeşilirmak River continues to flow through Canik



Figure 1. The study area and sampling sites.

Mountain and passes through the Çarşamba Prairie, spreading out there, and then flows into the Black Sea. The Yeşilirmak River, 519 km in length, consists of the confluence of 3 main tributaries: the Kelkit, Çekerek and Tozanlı streams. There are 5 power plants on the river, namely Kılıçkaya on the Kelkit Streams, Ataköy and Almus on the Tozanlı Stream, and Suat and Hasan Uğurlu on the river near the mouth.

Suat Uğurlu Dam Lake is located at latitude of 41°03'N and longitude of 36°40'E (Figure 1). It is 60 m above sea level. The reservoir has a maximum depth of 25 m, a length of 382 m, and a surface area of 10 km<sup>2</sup>. The maximum inflow ( $5 \times 10^7 \text{ m}^3 \text{ s}^{-1}$ ) to the reservoir occurs in spring and the minimum ( $25 \text{ m}^3 \text{ s}^{-1}$ ) in fall. The reservoir was created in 1982 for irrigation and power generation.

Hasan Uğurlu Dam Lake is located at latitude of 40°55'N and longitude of 36°38'E (Figure 1). The reservoir is 90 m above the sea level. It has a maximum depth of 54 m, a length of 658 m and a surface area of 23 km<sup>2</sup>. The maximum inflow ( $87 \times 10^9 \text{ m}^3 \text{ s}^{-1}$ ) to the reservoir occurs in spring and the minimum ( $13 \times 10^5 \text{ m}^3 \text{ s}^{-1}$ ) in fall. The reservoir was created in 1981 for power generation.

Samples of zooplankton was collected by vertical hauls of a standard net (60 µm mesh size), in April 2008, July 2008, November 2008, February 2008, June 2009, and July 2009, 6 times, during routine survey cruises in the river section above and below the dam lakes and the 2 dam lakes in 9 sites. Sites 1, 2, and 3 were located on the river section below the Suat Uğurlu Dam Lakes; sites 4 and 6 and 7 were in Suat and Hasan Uğurlu Dam Lakes, respectively; site 5 (Terce Creek) and sites 8K and 8T were located on the Kelkit and Tozanlı Streams, respectively, flowing into Hasan Uğurlu Dam Lake (Figure 1).

The net was hauled vertically from the bottom to the surface in the lakes and samples were placed into glass jars. Water samples of 80 L were taken from the river to determine the density of zooplankton and the water samples were filtered in the field using a 60 µm mesh plankton net and were placed into glass jars as well. Water current velocity was determined with a current meter (Global Water brand FP 201 model).

Plankton samples were fixed with 4% buffered formaldehyde and analyzed in the laboratory under a stereomicroscope (Olympus CH40) for taxonomic features. Drawings and measurements were made using an Olympus microscope with drawing-tube attachment and micrometric ocular, respectively. The total body lengths of 60 adults (30 males + 30 females) of *E. gracilis* were measured with an ocular micrometer (100 subdivisions) at 10× magnification.

Density of specimens was estimated by optical inverted microscopy according to Wetzel (1975). Number of organisms in a liter was determined by counting all vertical samples in the lakes and filtered water samples in the river.

The samples are kept at the Plankton Laboratory, Fisheries Faculty, Mustafa Kemal University. The species were identified with the aid of Dussart (1967), Damian-Georgescu (1970), and Kiefer (1978).

Water temperature, dissolved oxygen, salinity, and conductivity were measured with a YSI-85 water quality meter. The other parameter (pH) was measured with a WTW Photoflex Turb Photometer in the field.

## Results

### Water quality parameters

Water temperature ranged from 6.8 to 29.4 °C with a mean of 16.96 °C. The current velocity reached the highest value ( $2.00 \text{ m s}^{-1}$ ) at the station below the Suat Uğurlu Dam Lake and lowest value ( $0 \text{ m s}^{-1}$ ) in the river section opening to the Black Sea. The mean current velocity during the study period was  $0.76 \text{ m s}^{-1}$ . The water depth in the dam lakes ranged from 8 to 100 m with a mean value of 46.35 m, while water depth in the river sites ranged from 0.41 to 4 m with a mean value of 1.63 m. The conductivity value varied from 105.40 to 819.50 µs with a mean value of 407.33 µs. Dissolved oxygen reached the maximum concentration of  $14.80 \text{ mg L}^{-1}$  and minimum concentration of  $0.05 \text{ mg L}^{-1}$ , with a mean value of  $9.71 \text{ mg L}^{-1}$ . pH value did not vary much among the sites. The maximum, minimum, and mean pH values were 8.84, 6.95, and 8.11, respectively. The water during the study exhibited freshwater features, with salinity ranging from 0.00 to 0.50 ppt, with a mean value of 0.21 ppt.

The calanoid *Eudiaptomus gracilis* was found in maximum abundance in February at site 1 (24,327 ind. m<sup>-3</sup>). The second greatest abundance of the species was obtained in July 2009 at Hasan Uğurlu Dam Lake (13,045 ind. m<sup>-3</sup>) and the third highest abundance was recorded in November 2008 at Hasan Uğurlu Dam Lake (7575 ind. m<sup>-3</sup>). While the species was found on 1 sampling date (July 2008) at station Terce, it was not found at station Tozanlı on any sampling date (Table).

P1 to P4 with detailed spine/seta formula as follows (spines in Roman numerals, setae in Arabic numerals):

	Exopodite	Endopodite
P1	I-1;0-1; I,I-2,2	0-1;1,2,3
P2	I-1;I-1; I,I-1,4	0-1;0-2;2,2,3
P3	I-1;I-1; I,I-1,4	0-1;0-2;2,2,3
P4	I-1;I-1; I,I-1,4	0-1;0-2;2,2,3

Table. Abundance of *Eudiaptomus gracilis* in sampling sites (ind.m<sup>-3</sup>).

Stations	Sampling dates					
	Apr. 08	Jul. 2008	Nov. 08	Feb 09	Jun. 2009	Jul. 2009
1	1079	263	135	24327	452	1065
2	1930	45	--	1218	416	128
3	421	83	513	3216		373
SUD (4)	414	129	5119	2132	112	--
Terce (5)	--	985	--	--	--	--
HUD (6)	238	1319	7575	1469	--	13045
HUD (7)	--	--	--	159	--	3866
Tozanlı (8T)	--	--	--	--	--	--
Kelkit (8K)	2763	418	372	889	--	107

HUD: Hasan Uğurlu Dam Lake, SUD: Suat Uğurlu Dam Lake, --:Absent.

### *Eudiaptomus gracilis* (G.O. Sars, 1863)

Material examined: Lower basin of Yeşilirmak River, Hasan Uğurlu Dam Lake, Suat Uğurlu Dam lake. 20 males and 20 females, preserved in glycerol-formalin mixture (9/1), in the author's collection at the Fisheries Faculty of Mustafa Kemal University, İskenderun, Hatay.

### Diagnosis

Body slender, with a typical diaptomid shape. Rostrum has 2 finger-like projections with rounded tips in female, and strongly developed, long and lanceolate in male. Lateral wings of fifth pediger moderately developed, almost symmetrical, partially overlapping proximal and lateral margins of genital somite. Wings almost equal in size. Each wing rounded, postero-laterally directed and armed with 1 postero-lateral and 1 inner spine; spines on postero-lateral of wings bigger than inner ones. Endopodite of female P5 shorter than first exopodite segment, with 2 relatively short spines (1 subterminal and 1 terminal), of different length. P5 Third exopodite-segment with well-defined base, inner spine with fine, serrate margins and almost the same length with terminal claw. Endopodite 2-segmented

### Description

**Female** (Figure 2). Body length (including furcal setae) 1.67-1.98 mm (average of 30 specimens 1.79 mm). Fourth and fifth thoracic somites fused, except on lateral margins. Fifth thoracic somite with developed wings; both sides with about the same development, and so the thoracic somites strongly symmetrical (Figure 2A, B). Thoracic wings relatively pointed and both of them with 2 short hyaline spines. Urosome with 3 somites, the intermediate one short; genital segment twice as long as anal segment, its lateroproximal expansions almost symmetrical and with a moderately long hyaline spine on each side. Furcal rami symmetrical, lined with setules on inner surface.

Antennules (Figure 2C) long, reaching the end of furcal rami; antennular setation is showing typical organization in the genus *Eudiaptomus*.

Swimming legs (Figures 2D-G) typical of the subfamily Diaptominae. P5 (Figure 2H) symmetrical. Rostrum symmetrical, with 2 rostral filaments (Figure 2I). Endopodite 2 of P2 with Schmeil's organ (Figure 2J). Coxopodite with a long, strong, hyaline spine. Basipodite subrectangular. Endopodite bisegmented,



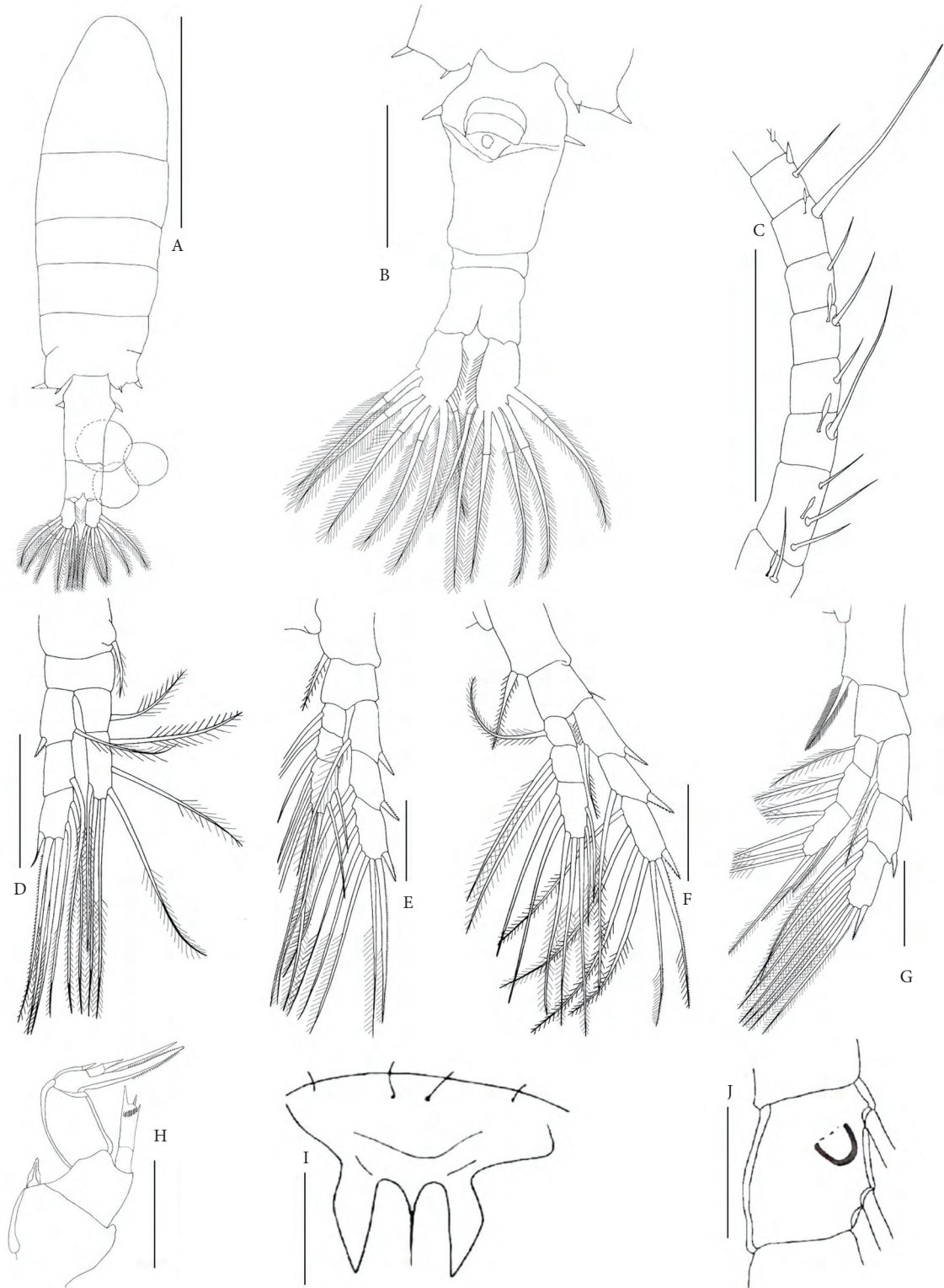


Figure 2. *Eudiaptomus gracilis* (G.O. Sars, 1863), ♀. A, habitus, dorsal; B, pedigers 4, 5 and urosome, ventral; C, Antennule segments; D, P1; E, P2; F, P3; G, P4; H, P5; I, Rostral spines; J, Schmeil's organ of P2. (Scales: A, 717 µm; B, 213 µm; C, 225 µm; D, 113 µm; E, 100 µm; F, 110 µm; G, 113 µm; H, 125 µm; I, 30 µm; J, 50 µm).

reaching almost distal margin of first exopodal segment, partly covered with short hairs, which are inserted subterminally, and 2 short spines, 1 of which is in subterminal and 1 in terminal position.

First exopodal segment about 1.7 times longer than exopod 2, with smooth margins. Outer spine on exopodite 2 shorter than exopodite 3, inner seta on exopodite 3 almost the same size with end claw (Figure 2H).

**Male** (Figure 3). Body length (including furcal setae) 1.44-1.73 mm (average of 30 specimens 1.60 mm). Thoracic wings small, slightly asymmetrical, with delicate lateral spine and a median sensilla on each side (Figure 3A, B). Urosome symmetrical, 5-segmented. First urosomite slightly asymmetrical, posterior half of left lateral margin slightly protuberant (Figure 3B). Furcal rami asymmetrical, right ramus wider than left one, lined with setules on its inner surface. Inner bristle with a sclerotized 'knee' (Figure 3B). The morphology of left antennule is similar to that of female.

Rostral spines more delicate and slender than those of female (Figure 3C). Antepenultimate segment of right antennule with hyaline lamella or sometimes with a small, thumb-shaped, curved process (Figure 3D). Right antennule geniculate and with spines as in Figure 3E. Spermatophore as depicted in Figure 3F. Right P5 (Figures 3G) with endopodite rather small, rounded at its end. Coxopodite ovoidal, with long hyaline spine on a cylindrical basis. Basipodite rectangular, with a chitinous process on proximal posterior surface; distal inner margin of this segment with a small lamella. Distal outer corner of exopodite 1 blunt, distal inner corner of this segment strongly sclerotized in semilunar form.

Exopodite 2 about twice as long as wide, and its inner marginal surface with a long sulcus; an outer marginal spine inserted on its proximal and middle parts, relatively short, and half as long as exopodite 2. Terminal claw relatively slender, curved inner margin with a row of small denticles on middle portion, its slightly dilated base with a chitinous process. Endopodite 1-segmented, reaching proximal third of exopodite 2 or shorter.

Left P5 (Figure 3G). Coxopodite quadrangular, with a long hyaline spine on a cylindrical basis;

inner margin strongly sclerotized. Basipodite subrectangular, somewhat narrow distally and with a small lamella one its terminal 1/3; this hyaline lamella making a small hook on inner distal margin of the same segment. Exopodite 2-segmented, the first exopodite segment trapezoidal, inner side bulgy and distally covered with fine setules; second segment prolonged distally as a finger, a straight spine inserted on its proximal inner part, the proximal inner part of this segment evenly convex and also covered with fine setules. Endopodite long, reaching the middle part of exopodite 2. Spermatophore as depicted in Figure 3F.

## Discussion

The Turkish copepod fauna is rich in Calanoida, particularly in the genus *Arctodiaptomus*. Among the species of the genus *Arctodiaptomus*, *A. belgrati* Mann, 1940, *A. byzantinus* Mann, 1940, *A. osmanus* Kiefer, 1974, *A. pectinicornis* (Wierzejski, 1887), *A. similis* (Baird, 1859), *A. spectabilis* Mann, 1940, *A. stephanidesi bulgaricus* (Kiefer, 1971), *A. wierzejskii* (Richard, 1888), *A. (Rhabdodiaptomus) acutilobatus* (G.O.Sars, 1903), *A. (Rh.) bacillifer* (Koelbel, 1885), *A. (Rh.) bacillifer propior* Kiefer, 1952, *A. (Rh.) burduricus* Kiefer, 1939, *A. (Rh.) centetes* (Brehm, 1938), *A. (Rh.) niethammeri* (Mann, 1940), *A. (Rh.) salinus* (Daday, 1885), *A. (Rh.) spinosus* (Daday, 1891) are widely spread in Turkey. So far, a few species in the genus *Eudiaptomus* known from Turkey were *Eudiaptomus drieschi* (Poppe & Mrázek, 1895), *E. anatolicus* Gündüz, 1998, *E. arnoldi* (Siewerth, 1928), and *E. vulgaris* (Schmeil, 1898) (Ustaoğlu, 2004).

The species inhabit a wide variety of habitat typologies, but *E. gracilis* is found in slow-flowing rivers and in mountain lakes. *E. gracilis* seems to be tolerant to a wide range of trophic conditions, but it seems to tolerate highly eutrophic conditions better.

Invasive *E. gracilis* is broadly consistent with expectations based on life history. Among the traits that characterize a good invader, a high dispersal capacity and a type demographic strategy, along with the physiological capacity to tolerate and reproduce in a wide range of environmental conditions, are considered essential (Ehrlich, 1986; McMahon, 2002).

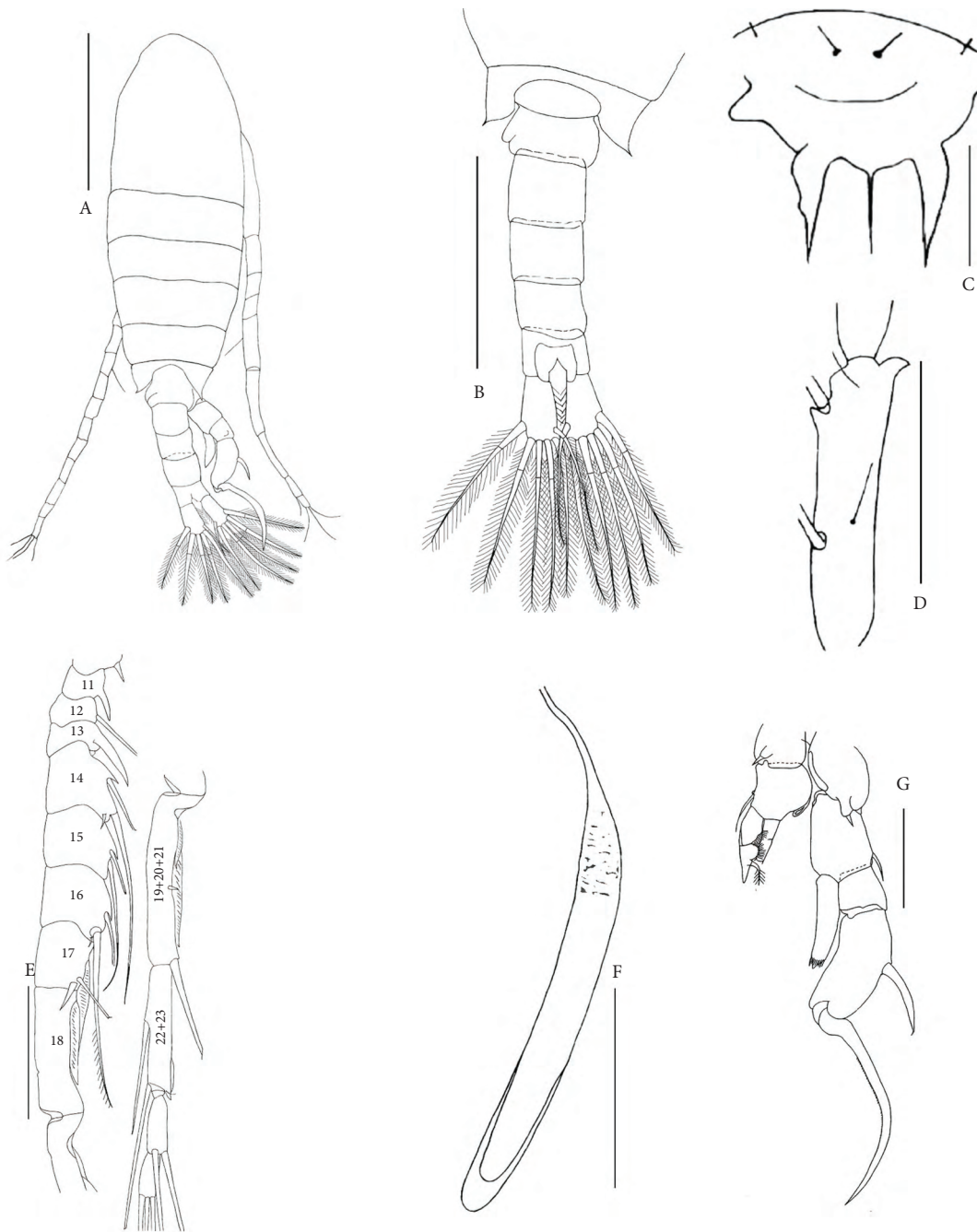


Figure 3. *Eudiaptomus gracilis* (G.O. Sars, 1863), ♂. A, habitus, dorsal; B, pedigers 4, 5 and urosome, dorsal; C, Rostral spines; D, Antepenultimate segment of right antennule; E, Right antennule, segments; F, Spermatophore; G, P5 (Scales: A, 505 µm; B, 253 µm; C, 45 µm; D, 113 µm; E, 158 µm; F, 227 µm; G, 125 µm).

Although *E. gracilis* lacks diapausing eggs (Santer et al., 2000; Bohonak et al., 2006), which are known to enhance dispersal potential (Bilton et al., 2001; Panov et al., 2004), at least for short distances (Zeller et al., 2006), its wide distribution throughout different

continents in water bodies of different typologies (Gaviria, 1998; Dussart and Defaye, 2002) indicates a high dispersal ability as well as an ability to adapt to different local conditions.

The establishment of *E. gracilis* in marginal habitats, including river backwaters and slow-flowing river stretches, provides further support of its ability to tolerate even extremely harsh conditions (Riccardi and Rossetti, 2007).

*E. gracilis* is broadly distributed in Europe (including the United Kingdom, Belgium, Bosnia-Herzegovina, Bulgaria, Finland, France, Lake Lemman, Switzerland, Germany, Czech Republic, Hungary, Norway, Slovenia, Slovakia, Croatia, Austria, Sweden, Greece, Poland, Italy), Estonia, Lithuania, northwestern Russia, Ukraine, Yugoslavia, Israel, Siberia, USA (including Alaska), Hong Kong, China, and Israel (Gaviria, 1998; Dussart and Defaye, 2002; Riccardi and Rossetti, 2007). *E. gracilis* is recorded from Turkey for the first time through this study. Consequently, these results give us some detailed

information on the species in Turkey and their characteristics. They can now be added to the known Copepoda fauna of Turkey.

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