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The occurrence of two morphologically similar *Chaetozone* (Annelida: Polychaeta: Cirratulidae) species from the Italian seas: *Chaetozone corona* Berkeley & Berkeley, 1941 and *C. carpenteri* McIntosh, 1911

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Abstract

The present study reports the spread of the cirratulids *Chaetozone corona* Berkeley & Berkeley, 1941 and *Chaetozone carpenteri* McIntosh, 1911 in the Western Central Adriatic Sea, off the coasts of Pescara (Italy). The two species were collected between 2014 and 2016 from soft bottom stations (at depths from 16.5 to 130 m) where the environment was more or less disturbed due to fishing activities. One specimen of *C. corona* was found also off the coast of Calafuria (Livorno, Italy), representing the first record of this species in the Tyrrhenian Sea. *Chaetozone carpenteri* could be a native species present in the Mediterranean for a long time but rarely recorded because of taxonomic confusion. *Chaetozone corona* was already known from the eastern Mediterranean Sea (except from the Adriatic Sea), where it is considered an established alien species. Our results extend the geographic range of these two cirratulid species, providing some information on their ecology and habitat preference. We also suggest a likely vector of spread of *C. corona* from the easternmost part of the Mediterranean towards the study area. The finding of reproducing specimens of *C. corona* and *C. carpenteri* supports the hypothesis that these two species have found a suitable habitat in the Western Central Adriatic Sea, and there will become well established. Although nothing suggests that *C. corona* would be invasive, it may, however, compete with native species. These findings also seem particularly relevant in order to improve the knowledge of Mediterranean biodiversity.

Keywords: Cirratulidae, *Chaetozone carpenteri*, *Chaetozone corona*, Adriatic Sea, Tyrrhenian Sea

Introduction

Historically, bitentaculate specimens of *Chaetozone* having posterior spines arranged into cinctures on posterior segments were referred globally to *Chaetozone setosa* Malmgren, the type species originally described from Spitsbergen, in the Arctic north of Norway. Recently, the elucidation of new characters among species of *Chaetozone* from North America and elsewhere, and the redescription of *C. setosa* provided by Chambers (2000), led to descriptions of numerous new species and the identification of distinct species groups (Blake 1996, 2006; Chambers & Woodham 2003; Doner & Blake 2006; Chambers et al. 2007). With the realisation that the genus *Chaetozone* contains numerous

species, many of which have gone unrecognised, the greater majority of the older records of *C. setosa* from worldwide locations are now believed to refer to other taxa (Blake 2015). Blake (2015) provided an updated overview, as well as a review of characters important in the taxonomy of the genus *Chaetozone*. This author also suggested that *C. setosa* is limited to Arctic and subarctic areas around Spitsbergen and other areas of northern Europe.

To date, in the Italian inventories of polychaetes the genus *Chaetozone* is still represented by only three species (Castelli et al. 2008) – *Chaetozone caput-sociis* Saint-Joseph, 1894, *Chaetozone gibber* Woodham & Chambers, 1994 and the type species *C. setosa*, Malmgren, 1867 – together with the closely

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related *Caulleriella zetlandica* McIntosh, 1911. Subsequent to the recent redescription provided by Woodham and Chambers (1994a), this species should be referred to the genus *Chaetozone*, as it was in the original description provided by McIntosh (1911) (Blake 1996). Chambers et al. (2011) described a similar state of art in the *Chaetozone* species inventory for the Mediterranean Sea, at least until recently. Yet other bitentaculate cirratulids had already been recorded from the Mediterranean coasts over the years (McIntosh 1911; Simboura 1996; Arvanitidis 2000; Simboura & Nicolaidou 2001; Simboura & Zenetos 2002; Çinar et al. 2004, 2006; Zaâbi et al. 2009), which had often been identified as *Chaetozone* sp., and which in turn may encompass more than one species. Most records of the new *Chaetozone* species from the Mediterranean were previously referred to the type species, *C. setosa* Malmgren, 1867, or to *C. gibber*, in technical reports and published papers (Çinar & Ergen 2007; Simboura et al. 2010; Chambers et al. 2011). The problem of confusion among *Chaetozone* was exacerbated by the lack of original generic diagnoses for this genus (Woodham & Chambers 1994b). *Chaetozone setosa* is currently recognised to be a species complex (Chambers & Woodham 2003), and according to Blake (2015) *C. setosa*, *Chaetozone carpenteri* McIntosh, 1911 and *Chaetozone corona* Berkeley & Berkeley, 1941 belong to the same species group (i.e. the *C. setosa* group), characterised by species with an enlarged lobe or crest overlying the peristomium.

Recently, during sampling programmes off the coasts of Italy (Procida Island and Sardinia, Punta Tramontana; Tyrrhenian Sea) and Croatia (Rovinj, Adriatic Sea), bitentaculate cirratulids were found in most samples and, after a painstaking examination, Chambers et al. (2011) identified several specimens of *Chaetozone* as *C. carpenteri*. These authors (Chambers et al. 2011) also suggested that many specimens previously detected from the Mediterranean might have been misidentified. Similarly, some specimens reported as *C. setosa* or *Chaetozone* sp. from the east (Izmir Bay, Aegean Sea) and central Mediterranean Sea (Zakynthos Island, Ionian Sea) were re-examined and identified as *C. corona* (Çinar & Ergen 2007; Simboura et al. 2010).

Chaetozone carpenteri has been rarely reported from the Mediterranean Sea; its first description dates back to a few specimens collected from the Atlantic coasts of Spain and the coast of Algiers (Algeria, western Mediterranean Sea), in 1870 (McIntosh 1911). The specimen from Algiers was the only one reported from the Mediterranean until the recent record of specimens from the eastern Adriatic and

the Tyrrhenian Sea reported by Chambers et al. (2011) and then by Mikac (2015). Recently, further specimens have also been reported from the Sea of Marmara (eastern Mediterranean Sea), by Çinar et al. (2014). *Chaetozone corona* was originally reported from the Pacific Ocean (Berkeley & Berkeley 1941; Hartman 1961; Blake 1996) and is currently recorded in the eastern Mediterranean, specifically only in the Levantine Sea, the Greek Ionian Sea, the Aegean Sea and the Sea of Marmara (Çinar & Ergen 2007; Simboura et al. 2010; Çinar et al. 2011, 2012, 2014; Çinar & Dagli 2013; Çinar & Bakir 2014). Both the species *C. corona* and *C. carpenteri* have been recently re-described, by Çinar and Ergen (2007) and Chambers et al. (2011), respectively; their presence in the Mediterranean Sea has been recognised only in the last decade.

In this study, we report the first occurrence of *C. corona* in the Adriatic Sea, as well as in the Tyrrhenian Sea, and point out the presence of *C. carpenteri* off the Adriatic coasts of Italy, thus extending the geographic range of these two species within the Mediterranean Sea. We also give some morphological details as well as ecological notes about these two species, in order to improve the knowledge of their ecology. We discuss the hypothesis of an introduction of *C. corona* to the Italian coasts as well as the potential vectors of its introduction and spread through the Mediterranean Sea.

Materials and methods

Specimens of *Chaetozone corona* and *Chaetozone carpenteri* were collected in the Central Adriatic Sea, during several monitoring surveys of benthic macro-invertebrates, carried out at 32 stations located along a 140-km-long, east–west transect in Italian territorial waters from the town of Pescara to the island of Pianosa (Figure 1). Sampling campaigns were carried out in two different seasons (i.e. winter and summer), from 2014 to 2016. Thirty-two soft-bottom stations were sampled, in duplicate from St. 1 to St. 22 and in triplicate from St. 23 to St. 32. Sediment samples were collected with a Van Veen grab (area: 0.1 m²) and sieved onboard through a 1-mm mesh; material retained on the sieve was fixed in 8% buffered formaldehyde solution. In the laboratory, samples were sieved through a 0.5-mm mesh, and macroinvertebrates were stained with Rose Bengal to facilitate sorting and identification to the species level.

Only one individual of *C. corona* was collected from a hard-bottom sampling station, offshore from the Calafuria resort (closed to the town of Livorno)



Figure 1. Map of the study area and location of sampling stations (St.).

in the Tyrrhenian Sea (Figure 1). In this study area, three stations (5, 10 and 20 m) were sampled in triplicate along a depth transect. At each station, fouling organisms on hard surfaces were scraped by divers within 25 × 25 cm quadrats.

Specimens pertaining to the genus *Chaetozone* were examined using a stereomicroscope and a Nikon Eclipse (E200) compound microscope equipped with a digital camera to achieve images. Measurements of length and width were detected by the photo analysis program Nis-Elements D (v. 2.30).

Several specimens were dehydrated and gold-coated for scanning electron microscope (SEM) study following the standard procedure described in Munari (2014).

The material examined was deposited at the Laboratory of Marine Benthos Ecology collection of the University of Ferrara.

Sediment characteristics, depth, total organic carbon (TOC) concentrations in sediment and water

parameters are summarised for Adriatic and Tyrrhenian stations from which specimens of *C. corona* and *C. carpenteri* were collected (Table I).

Measurements of TOC concentrations in sediment were carried out only in summer 2015. TOC analyses were performed following Cicero and Di Girolamo (2001).

Results

Sampling stations in the Adriatic Sea were characterised by muddy (silty clay–silty sand) sediments. In the present study, TOC concentrations varied from 0.10% (St. 21) to 0.93% (St. 19) at stations off Pescara coasts (Central Adriatic Sea).

Taxonomic accounts

Class POLYCHAETA Grube, 1850
 Order TERESELLIDA *sensu* Rouse & Fauchald, 1997
 Family CIRRATULIDAE Carus, 1863

Table 1. Details, water parameters at the bottom, TOC (total organic carbon) concentrations in sediment and sediment granulometric composition of the stations where specimens of *Chaetozone corona* Berkeley & Berkeley, 1941 and *C. carpenteri* McIntosh, 1911 were recorded in the Central Adriatic Sea and Tyrrhenian Sea. n.e. = not examined.

Station	Bottom	Latitude	Longitude	Depth (m)	Sediment	Temp (°C, min–max)	Salinity (PSU, min–max)	TOC (%)	<i>C. corona</i>	<i>C. carpenteri</i>
St. 5	Soft	42°28'20.781"N	14°17'11.164"E	16.5	Silty sand	16.2–18.4	36.2–17.1	0.11		*
St. 7	Soft	42°28'44.146"N	14°17'56.393"E	19.5	Silty sand–sandy silt	16.3–18.1	36.4–37.2	0.55	*	
St. 8	Soft	42°28'41.728"N	14°17'59.365"E	19.5	Sandy silt	16.3–18.1	36.4–37.2	n.e.	*	
St. 11	Soft	42°29'14.577"N	14°20'07.535"E	27.5	Silt–clayey silt	16.4–17.2	36.5–37.4	0.46	*	*
St. 12	Soft	42°29'11.468"N	14°20'09.131"E	27.5	Silt–clayey silt	16.4–17.2	36.5–37.4	n.e.	*	*
St. 13	Soft	42°29'05.938"N	14°22'37.297"E	47.5	Silt–clayey silt	13.1–16.8	37.8–38.1	n.e.	*	*
St. 14	Soft	42°29'02.623"N	14°22'37.978"E	46	Silt–clayey silt	13.1–16.8	37.8–38.1	0.76	*	*
St. 15	Soft	42°28'48.445"N	14°26'13.989"E	70	Silt–silty clay	13.1–17	38.4–38.5	0.51	*	*
St. 16	Soft	42°28'45.206"N	14°26'13.719"E	70	Clayey silt–silty clay	13.1–17	38.4–38.5	n.e.	*	*
St. 17	Soft	42°28'30.81"N	14°29'50.979"E	83	Silty clay	13.1–16.8	38.5	n.e.	*	*
St. 18	Soft	42°28'27.571"N	14°29'50.706"E	83	Silt–silty clay	13.1–16.8	38.5	0.87	*	*
St. 19	Soft	42°28'13.045"N	14°33'28.13"E	92	Silt–clayey silt	12.9–16.9	38.4–38.5	0.93	*	*
St. 20	Soft	42°28'09.807"N	14°33'27.853"E	92	Silt–clayey silt	12.9–16.9	38.4–38.5	n.e.	*	*
St. 21	Soft	42°27'55.097"N	14°37'06.082"E	100.5	Silt–clayey silt	12.9–16.8	38.4–38.5	0.1	*	*
St. 22	Soft	42°27'51.858"N	14°37'05.802"E	100.5	Silt–clayey silt–silty clay	13.1–16.8	38.4–38.5	n.e.	*	*
St. 30	Soft	42°20'58.645"N	15°46'05.681"N	130	Clayey silt	13.1–14.6	38.4–38.7	0.33	*	*
St. CA20	Hard	43°28'10.37"N	10°19'50.06"E	20	Rock	21	38	n.e.	*	

*Indication of the presence of *C. corona* and *C. carpenteri* in the sampling stations.Genus *Chaetozone* Malmgren, 1867***Chaetozone corona*** Berkeley & Berkeley, 1941*Chaetozone spinosa corona* Berkeley & Berkeley 1941: 45–46.*Chaetozone corona*: Hartman 1960: 125, 1961: 109–110, 1969: 235, figs 1–3; Blake 1996: 285–287, fig. 8.6; Çinar & Ergen 2007: 342–344, figs 2–4; Le Garrec et al. 2016: 2, fig. 2.

Material examined. Central Adriatic Sea, off the coast of the town of Pescara. Winter 2014: St. 7, one specimen, St. 8, two specimens; winter 2015: St. 22, one specimen; winter 2016: St. 7, one specimen. Central Tyrrhenian Sea, off the shoreline of Calafuria resort, close to Livorno town, summer 2016: St. CA20, one specimen.

Description. Maximum body length (complete specimen) 14.2 mm for 52 chaetigers, width 1.16 mm. Other specimens were incomplete (19–43 chaetigers) ranging from 0.9 to 1.5 mm wide across the widest part of the body (and from 4.8 to 14.8 mm in length).

Body thickened, becoming slightly compressed posteriorly. Prostomium directed anteriorly, triangular in shape, with blunt tip; with a pair of black eyes laterally. Peristomium dorsally inflated with one large anterior and two shorter posterior rings, extending posteriorly as a median ridge or crest to the anterior side of chaetiger 1. Dorsal tentacles attached between peristomium and chaetiger 1. Branchiae arising immediately posterior and slightly medial to dorsal tentacles (Figure 2(a)). Subsequent branchiae emerging from the posterior edge of parapodia. Most of the branchiae along the body length were lost. Parapodia dorsally elevated, with parapodial lamellae bearing fascicles of noto- and neurochaetae. Notopodia on chaetiger 1 bearing 7–10 capillary chaetae (330 µm long). Neuropodia on chaetiger 1 with 3–4 (up to seven) capillary chaetae and 2–3 pale yellow, slightly curved spines; up to four spines at chaetiger 1 in larger specimens (e.g. specimen not complete from St. 7 of winter 2016: 4.81 mm long, 0.95 mm wide, for 19 chaetigers). Capillary chaetae increasing in length up to chaetiger 13, reaching up to 1480 µm long, then gradually shortening towards the posterior end. Capillary chaetae of posterior parapodia thinner and smooth, without fibrils. Spine on notopodia first present from chaetiger 6, in only some specimens from chaetiger 5 (eg. specimen from St. 7); in the specimen from the Tyrrhenian Sea notopodial spines from chaetiger 8. Spines increasing in size and darkening towards the posterior end. Notopodia and neuropodia of

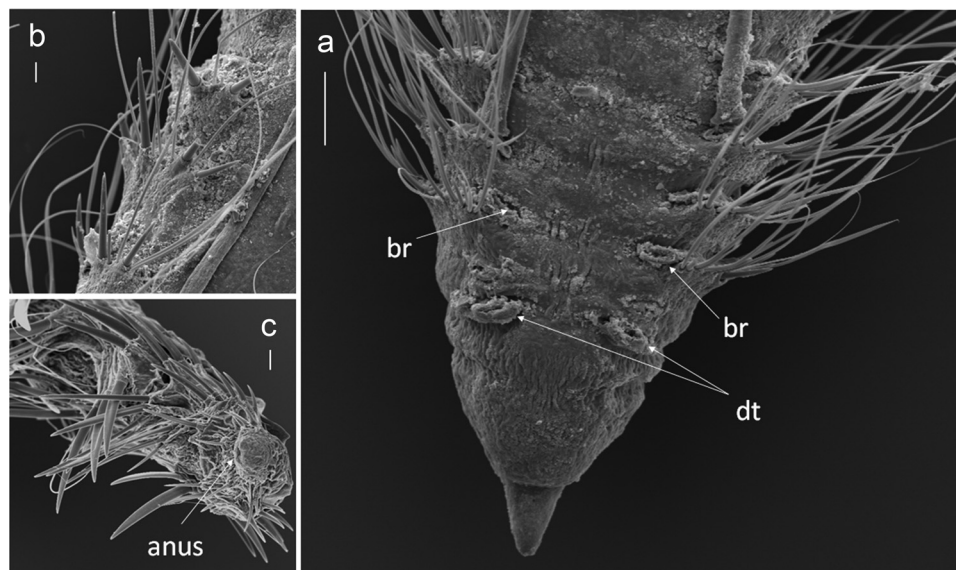


Figure 2. *Chaetozone corona*. (a) Dorsal view, anterior end, with dorsal tentacle (dt) and branchiae (br). (b) Dorsal view of the notopodia showing spines and capillary chaetae, middle part of the body. (c) Posterior part of the body and pygidium, dorso-lateral view. Scale bars: a = 100 μ m; b = 30 μ m; c = 20 μ m.

chaetiger 10 with 4–7 capillaries and 2–3 spines (up to four neuropodial spines in the Tyrrhenian specimen). In the middle part of the body (chaetiger 30), 4–6 notopodial and 4–5 neuropodial capillary chaetae; around four notopodial and five neuropodial spines (Figure 2(b)). In the posterior part of the body (chaetiger 41), notopodia and neuropodia with 4–6 spines (up to eight neuropodial spines in some larger specimens). The number of capillary chaetae was reduced to 3–4 in the middle and the end part of the body. Noto- and neuropodial spines together form partial cinctures in posterior segments, accompanied by thin capillaries (Figure 2(c)).

Chaetal arrangements vary among specimens and among body regions: for example, one capillary alternating with one spine in the middle parapodia, but one capillary between two or three spines in posterior parapodia (Figure 2(c)). Pygidium (Figure 2(c)) with blunt tip; anus in dorsal position.

Larger specimens with body pinkish-coloured due to dense eggs in coelomatic cavity; diameter \pm standard error (SE) = 109.8 \pm 0.6 mm, range: 87.1–133.8 mm (n = 20). Other specimens without gametes cream to pale brownish in colour.

Remarks. Morphological characters of the Adriatic and Tyrrhenian specimens of *C. corona* were similar to those of the original (Berkeley & Berkeley 1941) and subsequent descriptions (Hartman 1969; Blake 1996; Çinar & Ergen 2007). Çinar and Ergen (2007) suggested that the presence of fibrils on one edge of

anterior capillary chaetae could be an artefact resulting from damage of capillaries. Similarly, in our specimens fibrils were evident in most of the anterior chaetae; thus, probably resulting from damage of capillaries.

Çinar and Ergen (2007), as well as Le Garrec et al. (2016), detected black irregular speckles on dorsal, lateral and ventral sides of the peristomium, and on the ventral side (or laterally) of chaetiger 1 (rarely chaetiger 2). Conversely, black spots were very difficult for us to detect, as they had almost disappeared in all our specimens. However, the examined specimens have been preserved in formalin for years, and we believe that the characteristic colour may rapidly disappear if the conservation status of individuals is not optimal. On the contrary, we clearly detected the presence of black speckles in specimens of *C. carpenteri* (see below).

Also, our specimens differed from those described by Çinar and Ergen (2007) in the number of capillary chaetae and spines throughout the body: e.g. 14 capillary notochoetae and 12 in neurochaete on chaetiger 1 according to Çinar and Ergen (2007), and 7–10 capillary notochoetae and 4–7 capillary neurochaetae in the anterior region of specimens from the Italian coasts. Notwithstanding, the number of capillary chaetae and spines observed on anterior parapodia in our specimens was comparable to that found in specimens described by Le Garrec et al. (2016), and to that of specimens from the Pacific as reported by Hartman (1961) and Blake

(1996). In any case, these differences may be mainly due to the natural variability among specimens. In fact, Çinar and Ergen (2007), stated that numbers of capillary chaetae and spines vary among specimens, as also do chaetal arrangements. Moreover, as suggested for *C. carpenteri* by Chambers et al. (2011), the exact number of spines may depend on how one measures and interprets a spine, as many chaetae are damaged.

The body size of individuals among different populations of *C. corona* are similar around the world: 13–14 mm long, in complete specimens with 60 chaetigers in southern California (Blake 1996); 18–25 mm long with 50–60 chaetigers in southern California (Hartman 1969); 19.5 mm with 62 chaetigers in Aegean Sea (Çinar & Ergen 2007); 11–16 mm with 50–55 chaetigers in the Loire estuary (Le Garrec et al. 2016); and 14.2 mm long, in a complete specimen with 52 chaetigers, of the Adriatic population (this study).

Although for a long time *C. corona* was confused with *C. setosa* it differs from the latter and other species belonging to the genus *Chaetozone* in having the neuropodial acicular spines from chaetiger 1 and a pair of black eyes, besides the distinctive shape and inflation of the dorsum of the peristomium. In fact, the most common Mediterranean *Chaetozone*, i.e. the *C. setosa* complex, is characterised by the absence of eyes and the first appearance of neuropodial spines on chaetiger 40. *Chaetozone corona* is also readily distinguished from the other *Chaetozone* species with eyes reported from the Mediterranean, such as *Chaetozone gibber* and *Chaetozone caputesocis*, in that the former shows neuropodial spines from chaetiger 90 and the latter show them from chaetiger 10. *Chaetozone corona* is also distinguished from *Chaetozone zetlandica* (recently redescribed by Woodham & Chambers 1994a) since the latter has heavy spines occurring only in posterior neuropodia, and chaetae of five types with awl-like spinous setae in the notopodia. It also differs from the recently redescribed *C. carpenteri*, which holds noto- and neuropodial spines from chaetiger 6.

Ecology and distribution. *Chaetozone corona* was first reported from the eastern Pacific (off southern California, western Mexico and the Gulf of California) to 119 m depth from mixed sediments (Blake 1996), and from the western Atlantic Ocean (off Brazil) (Omena & Creed 2004) in a community associated with *Halodule wrightii* Ascherson, 1868 in intertidal water (1–3 m). Çinar and Ergen (2007) reported some specimens from the Aegean Sea (Izmir Bay) on sandy mud and *Posidonia oceanica* (Linnaeus) Delile, 1813, between 2.5 and 50 m

depth. Simboura et al. (2010) reported *C. corona* specimens, dated back to the 1980s, from the Ionian Sea (Zakynthos Island) on sand at 5 m depth. This species was also reported from other areas of the Greek coasts and islands (e.g. Elefsis Bay, Saronikos Gulf, the Kyklades and Crete) on sandy, muddy or mixed sediments, as well as biogenic detritus down to 90 m depth (Simboura 1996; Simboura et al. 2010). More recently *C. corona* was reported from the Turkish coasts to 100 m in depth (Çinar et al. 2011, 2012, 2014; Çinar & Dagli 2013; Zenetos et al. 2017). In particular, this species was found from samples collected between 2006 and 2010 at depths from 26 to 66 m in the Sea of Marmara (Çinar et al. 2011); Çinar et al. (2012) recorded *C. corona* in samples collected in 2009 in Mersin Bay (Levantine Sea), at 21 and 72 m. Çinar and Dagli (2013) in 2011 recorded some individuals from bare soft-bottom stations and from a *Posidonia oceanica* meadow, between 5 and 68 m, in the northern Aegean Sea. Finally, Le Garrec et al. (2016) extended its distribution to the Atlantic coasts of France in infra-littoral muddy to sandy sediments, and occasionally in maerl beds. In this study, we found individuals mainly in silt and clayey silt (Table I), in sediments with sand contents varying from 0.9 to 67.8%, silt contents from 39.3 to 99.2% and, finally, clay contents from 0.5 to 59.7%.

Because of taxonomic confusion, knowledge about the density of *C. corona* is still very poor. Data from Izmir Bay indicated a variation of density from 10 ind. m⁻² in winter to 70 ind. m⁻² in spring (Çinar & Ergen 2007). The density of *C. corona* in the central Adriatic Sea (off Pescara coasts) varied from 5 ind. m⁻² (at St. 7, St. 14 and St. 18 in winter 2016; at St. 22 in summer 2016; at St. 12, St. 16 and St. 22 in winter 2015; at St. 7 in winter 2014) to 10 ind. m⁻² (at St. 11 in winter 2016; at St. 14 in summer 2016; and at St. 8 in winter 2014), between 19.5 and 100.5 m depth (Figure 3). *Chaetozone corona* accounted for 0.5% (at St. 12, 27.5 m depth, in winter 2015) and 3.7% (at St. 22, 100.5 m depth, in winter 2016), respectively, of the total abundance of the benthic community.

In the Aegean Sea, *C. corona* was found in semi-polluted to polluted environments, but it was absent from highly polluted stations (Çinar & Ergen 2007; Simboura et al. 2010). In the western Central Adriatic Sea, *C. corona* was recorded from slightly disturbed sediments, whose ecological classification was based on the community composition and structure, through AZTI Marine Biotix Index (AMBI) (Borja et al. 2000) and Multivariate - AZTI Marine Biotic Index (M-AMBI) (Muxika et al. 2007) indices. Indeed, the benthic community of the

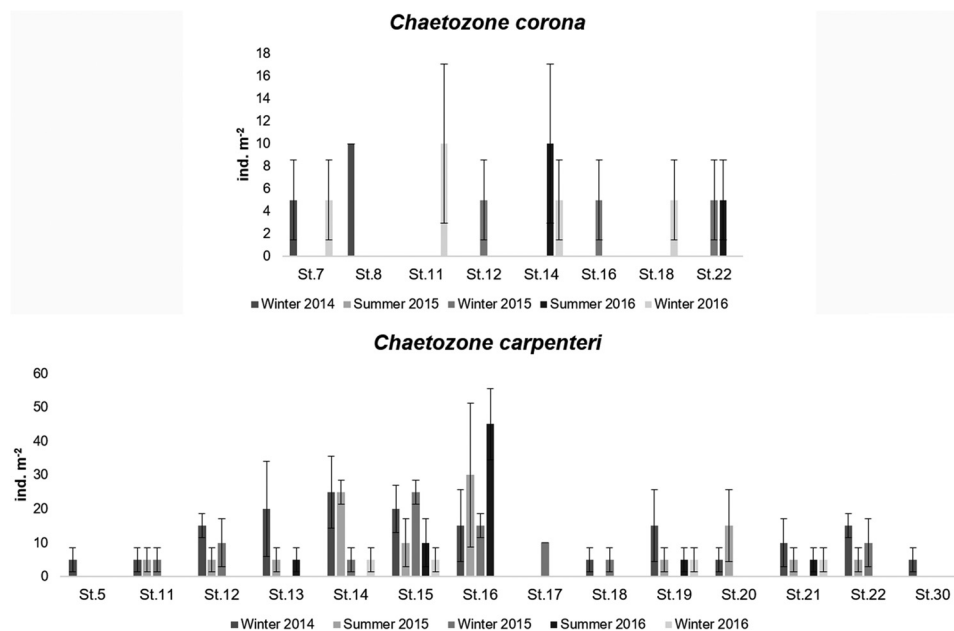


Figure 3. Occurrence of *Chaetozone corona* Berkeley & Berkeley, 1941 and *C. carpenteri* McIntosh, 1911 in the Central Adriatic Sea: densities (average individuals m^{-2}) \pm standard error.

sampling stations showed the presence of opportunistic species (e.g. *Prionospio fallax* Söderström, 1920 and *Chaetozone* sp.) together with pollution-sensitive ones (e.g. *Oestergrenia digitata* (Montagu, 1815), *Nucula sulcata* Bronn, 1831, *Aricidea (Acmira) assimilis* Tebble, 1959 and *Brissopsis lyrifera* (Forbes, 1841)). Similarly, in the Tyrrhenian Sea, we found *C. corona* in a slightly disturbed station, numerically dominated by sensitive organisms.

The species seems to exhibit a tolerant but not opportunistic feature, in accordance with the AMBI (Borja et al. 2000) and TURKISH Benthic Index (TUBI) (Çinar et al. 2015) classification indices, both of which assign this species to the pollution-tolerant group. However, further studies are needed to confirm this judgement.

On hard bottom, *C. corona* was recorded among encrusting algae, and biogenic constructions consisting of calcareous animals and plants mixed with debris and cemented by algae and other limestone-producing organisms. The community at the sampling station was characterised by syllid polychaetes and bivalves typical of hard bottoms, such as *Striarca lactea* (Linnaeus, 1758), *Gregariella* Monterosato, 1883 spp. and the endolithic *Lithophaga lithophaga* (Linnaeus, 1758).

Pathways of dispersal and status. Çinar and Ergen (2007) hypothesised that *C. corona* may have been introduced from southern California into the East

Mediterranean basin through ballast waters. Similarly, Le Garrec et al. (2016) suggested that *C. corona* may have been introduced by way of commercial shipping to the Atlantic coasts of Europe (Loire Estuary) and then would have been transported by currents towards the north-west along the coast of Brittany. These authors also tend to rule out aquaculture as a mode of introduction of this species to French Atlantic coasts. Apart from the opening of the Suez Canal, the two main vectors of introduction of marine alien species in the Mediterranean are shipping, combining ballast water and hull fouling, and aquaculture (Galil 2000; Gollasch 2006). The Adriatic Sea is the site of intense shellfish farming along the Italian coast, and finfish farming along the Croatian coast. To our knowledge, *C. corona* has not been recorded in any shellfish farming areas, such as those of the northern Adriatic that have experienced several introductions of alien species (Bertasi 2016; Munari et al. 2016). Accordingly, we tend to exclude that aquaculture activities may have played a role in the spreading dynamics of *C. corona* to the Adriatic and Tyrrhenian seas. The Adriatic Sea is also subjected to heavy marine traffic from merchant ships, supplier vessels for offshore activities (e.g. gas platforms), ferry boats, trawl-fishing vessels and recreational boats (<http://www.marinetraffic.com>). Therefore, *C. corona* may have been introduced from the East Mediterranean basin to the central Adriatic Sea through commercial shipping, and

then in the same way to the Tyrrhenian. Also, marine currents may have had a role in the current distribution and spread of *C. corona*. Indeed, two main currents dominate the Adriatic circulation: the West Adriatic Current flowing towards the south-east along the western coast, and the East Adriatic Current flowing north-east along the eastern coast. In addition, two main cyclonic gyres occur, one in the northern part and the other in the south. Le Garrec et al. (2016) also hypothesised that the presence of thermic barriers, residual currents and nocturnal migration of adults in the water column could explain the distribution pattern of *C. corona*. Therefore, we believe that all these pathways might together have contributed to the dispersal of *C. corona* in the Mediterranean, and might have limited the progression of the species into the northern Adriatic Sea. A molecular analysis including specimens from different parts of the Mediterranean and the world would be needed to confirm such speculations.

The species was initially reported as cryptogenic in the Mediterranean Sea (Çinar & Ergen 2007), and also hypothesised to be a “rare” cryptogenic species along the Atlantic coasts of France (Le Garrec et al. 2016). More recently, the species has been considered an established alien in the eastern Mediterranean Sea (i.e. Sea of Marmara, Aegean Se, and Levantine Sea; Çinar & Bakir 2014; Zenetos et al. 2017).

***Chaetozone carpenteri* McIntosh, 1911**

Chaetozone carpenteri McIntosh 1911: 166, pl. 6, fig. 5c–e; Chambers et al. 2011: 45, fig. 2.

Material examined. Central Adriatic Sea, off the coast of Pescara, winter 2014: St. 5, one specimen, St. 12, three specimens; summer 2015: St. 14, four specimens, St. 16, four specimens; winter 2015: St. 15, five specimens, St. 17, two specimens, St. 22, two specimens; summer 2016: St. 22, one specimen; winter 2016: St. 14, one specimen.

Description. Maximum body length (complete specimen) 25.6 mm for 64 chaetigers and 2.3 mm width (from St. 5, 16.5 m depth, winter 2014). Other specimens were incomplete (29–53 chaetigers) ranging from 0.7 to 1.9 mm wide across the widest part of the body. Body surface smooth, iridescent and a little wider between chaetigers 12 and 22 in some specimens. The anterior dorsal surface is slightly rounded, and the ventral surface flattened with a longitudinal groove. Posterior segments are concertina-like, typical of the genus *Chaetozone*. The prostomium is conical with a pair of eyes not well defined; without nuchal grooves. Peristomium achaetous, with a dorsal raised area posterior to the eyes; a ventral mouth and a pair of grooved palps (only palp bases present) originating from the dorsal surface posterior to the raised area. In some specimens we detected black irregular speckles on lateral and ventral sides of the peristomium and chaetiger 1 (Figure 4(a)).

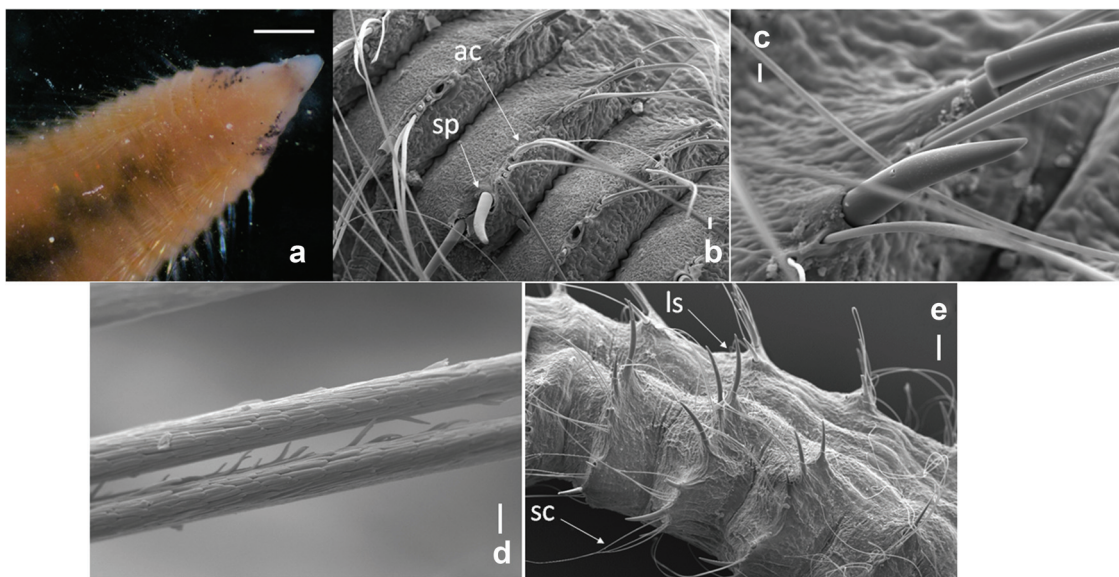


Figure 4. *Chaetozone carpenteri*. (a) Dorsal view of prostomium showing eyes and black speckles, anterior end. (b) Lateral view of awl-shaped capillary (ac) chaetae and large spines (sp), anterior end. (c) Detail of large spine. (d) Detail of damaged chaetae of first chaetigers. (e) Lateral view of long spines (ls) and short capillaries (sc), posterior end. Scale bars: a = 0.5 mm; b = 20 µm; c = 10 µm; d = 2 µm; ee = 100 µm.

Branchiae present from chaetiger 1 on the dorsal surface of the outer edge of the chaetae, between the parapodial folds (most of the branchiae are lost). Parapodia all biramous. Chaetae arranged in fan-shaped rows. There are four types of chaetae: awl-shaped capillaries (Figure 4(b)), large spines (Figure 4(b,c)), long spines and short capillaries (Figure 4(e)). The awl-shaped capillary chaetae are longer in the middle body region and present in numbers of 5–8 in anterior neuropodia, up to 11 in larger specimens (e.g. complete specimen from St. 14 of summer 2015: 23.4 mm long and 1.9 mm wide for 58 chaetigers) and 9–16 in anterior notopodia. They are constricted about the level of the skin and yellow coloured. The tip flattens out more in the shorter and less in the long forms, and tapers to a long, hair-like, curved extremity. Chaetae of anterior chaetigers with fine fibrils in some specimens (Figure 4(d)). Very large spines appear from chaetigers 7–9 in numbers of 2–3, both in neuro- and notopodia. Spines become longer from approximately chaetiger 20, increasing in noto- and neuropodia from 2–3 to 5–6 in posterior segments (beyond chaetiger 40). In posterior chaetigers capillary setae become shorter, thinner and fewer than in the anterior part of the body. Pygidium is a small, flat, rounded lobe.

Larger specimens had mature oocytes in the coelomatic cavity; diameter \pm SE = 99.7 ± 0.6 μ m, range = 79.6–135.2 mm (n = 31).

Remarks. Our specimens from the Central Adriatic Sea agreed closely with the original (McIntosh 1911) and subsequent descriptions (Chambers et al. 2011), but there were some differences worth mentioning.

Chambers et al. (2011) found spines arising from chaetiger 7–8 in specimens from Cape Finisterre Atlantic coast of Spain), and from around chaetiger 6–9 in specimens from the Northern Adriatic and the Tyrrhenian Sea. This is in agreement with the characteristic of specimens from the Central Adriatic, in most of which spines were clearly visible from chaetiger 9. Conversely, according to McIntosh (1911) spines arose from chaetiger 10. Also, the number of spines (i.e. 2–3 notopodial and neuropodial spines) in the anterior chaetigers was similar to that reported by Chambers et al. (2011). In the original description, McIntosh (1911) did not mention the number of spines in anterior chaetigers, but in the figure chaetiger 10 is illustrated with four spines in noto- and neuropodia; however, in this specimen the bristles were all broken, making their number unreliable. The number of spines from approximately chaetiger 20 to the posterior part of the body was similar in our specimens and those described by Chambers et al.

(2011) and by McIntosh (1911): up to 4–6 long spines in posterior chaetigers of specimens from the Central Adriatic, up to 5–6 in those from Croatia and the Tyrrhenian Sea, and up to four (in chaetiger 40) in those from stations of the Porcupine Expedition of 1870. Number of capillaries differed from the description provided by Chambers et al. (2011). On chaetiger 1 we found 10–16 notopodial capillaries in complete specimens of 18.2–23.4 mm long and 1.7–1.9 mm wide, with 58–60 chaetigers (from St. 14, at 46 m depth) and 9–10 notopodial capillaries in less wide specimens (e.g. incomplete specimen 6.9 mm long, 1.5 mm wide with 30 chaetigers, from St. 22, at 100.5 m depth). Numbers of notopodial and neuropodial capillary chaetae might vary in order of individual size, as reported for specimens of *C. corona* (Çinar & Ergen 2007). Differently from us, Chambers et al. (2011) found 8–10 notopodial and 4–6 neuropodial capillary chaetae in anterior parapodia (maximum length of specimens 23 mm with 60 chaetigers; 2 mm wide).

We found a slight enlargement of the body between chaetigers 10 and 20, while Chambers et al. (2011) found a constant width along the body. In some specimens we detected black, irregular speckles on lateral and ventral sides of the prostomium, peristomium and chaetiger 1, according to the original description by McIntosh (1911) (Figure 4(a)).

The arrangements of spines and capillaries, together with the presence/absence of eyes, and number of segments, are useful characters for identification of *Chaetozone* species (Chambers et al. 2011). *Chaetozone carpenteri* can be quickly distinguished from the other *Chaetozone* species from the Mediterranean (*C. setosa*, *C. gibber*, *C. zetlandica* and *C. corona*) by the first appearance of neuropodial and notopodial spines from chaetiger 7–9, the presence of two or three types of spines, respectively, and two types of capillary chaetae, in addition to the black speckles on the prostomium, peristomium and chaetiger 1, according to McIntosh (1911) and Chambers et al. (2011).

Chambers et al. (2011) and McIntosh (1911) did not mention the presence of serration or minute fibrils that we found in our specimens; however, these fibrils may have resulted from damage of capillaries, as Çinar and Ergen (2007) suggested for specimens of *C. corona*.

Ecology and distribution. *Chaetozone carpenteri* was first reported by McIntosh (1911) from three Porcupine Expedition stations: on the coast of Algiers (Bono Bay, 45 m depth), and the Atlantic coast of Spain (off Cape Guardia and Cape

Finisterre). Recently, it was recorded by Chambers et al. (2011) off Italian and Croatian coasts. In the Northern Adriatic Sea it was found off the coast of Rovinj between 31 and 37 m depth, in detritic bottoms (silty sand); in the Tyrrhenian Sea it was found in a sandy bottom (silty sand, north-west Sardinia at 42 m depth); and in the Gulf of Naples it was found in sandy mud as well in mud, between 80 and 98 m depth (Chambers et al. 2011). Afterwards (between 2012 and 2013) it was reported from the Croatian coasts of the Central Adriatic Sea, both in the sandy mud of the Split Harbour at 20 m depth, and in the gravelly mud of the River Krka estuary (Mikac 2015). The species has also been found on the coasts of Turkey in the Sea of Marmara in soft bottom (including phanerogams), between 11 and 100 m depth (Çinar et al. 2014).

In the western Central Adriatic Sea we found this species mainly in silt and clayey silt (Table I), in sediments with sand contents varying from 0.3 to 17.7%, silt contents from 36.2 to 99.8% and clay contents from 4 to 61.7%. It was absent in sediments with high sand contents.

In previous works, information about the density of *C. carpenteri* was not given. Off the coast of Pescara (central Adriatic Sea) the density of *C. carpenteri* varied from 5 ind. m⁻² (at St. 14, St. 15, St. 20 and St. 21 in winter 2016; at St. 13, St. 19 and St. 21 in summer 2016; at St. 11, St. 14, and St. 18 in winter 2015; at St. 5, St. 11, St. 18, St. 20, and St. 30 in winter 2014) to 60 ind. m⁻² (at St. 16 in summer 2015), between 16.5 and 130 m depth. *Chaetozone carpenteri* accounted for 0.2% (at St. 5, 16.5 m, in winter 2014) and 13% (at St. 16, 70 m, in summer 2015, and at St. 22, 100.5 m, in winter 2014) of the total abundance of the benthic community (Figure 3).

In this study, *C. carpenteri* inhabits muddy sediments as does *C. corona*, with which it coexists in some of them (Table I). In the sampling stations we recorded very low TOC concentrations, but these sediments (and thus the benthic communities) are subjected to high physical disturbance due to fishing activities. Considering the high density at which *C. carpenteri* was recorded with respect to *C. corona*, it seems to exhibit an opportunistic feature, in accordance with the AMBI classification index (Borja et al. 2000). However, although *C. setosa* and *C. gibber* have been found from semi-polluted sediments and thus reported as pollution indicators (Ergen 1992; Zenetos et al. 1994; Simboursa et al. 1995; Borja et al. 2000; Simboursa & Zenetos 2002; Solis-Weiss et al. 2004), knowledge about *C. carpenteri* populations is still too poor to affirm that it has the same role.

This is the first study to report the presence of reproductive specimens of *C. carpenteri* in the Mediterranean.

Conclusive remarks

Detailed morphological investigations of bitentaculate cirratulids suggest that numerous local, endemic species with defined habitat preferences, depth ranges and geographic distributions are present among materials previously assigned to a single species (Blake 1996, 2006). Thanks to the enhanced level of taxonomic awareness, which led to the re-examination of specimens previously considered unidentified or assigned to a higher level of taxonomic classification, and of those incorrectly identified as *Chaetozone setosa*, the number of fully identified species of the genus *Chaetozone* is currently rising in the Mediterranean Sea. The species with greatest morphological similarity to *Chaetozone corona* is *Chaetozone carpenteri*, known from the Mediterranean. A detailed comparison of the main morphological characters of the eight valid species of *Chaetozone* recorded in European waters was provided by Le Garrec et al. (2016).

This study reports the first record of *C. corona* from the Italian coast of the Adriatic and Tyrrhenian seas. Taking into account the relatively poor information available on the benthic biocoenosis of the Central Adriatic Sea, it is not possible to state precisely how many years *C. corona* has been present in the Western Adriatic, as well as in the Tyrrhenian Sea, as it has never been recorded before from Italian coasts.

We found *C. corona* and *C. carpenteri* coexisting in soft bottom habitats of the Central Adriatic Sea. These two species showed wide distribution in sandy, muddy or mixed sediments at a wide depth range in sites disturbed and undisturbed (Table I and Figure 3) by fishing activities. From the coast to offshore, benthic assemblages are exposed to a heavy and prolonged history of exploitation, and are subjected to chronic and intensive effects of bottom trawling and fishing, with habitat degradation which in turn homogenised and simplified the benthic assemblages themselves (Bastari et al. 2017). In the five sampling periods of this study (from winter 2014 to winter 2016), *C. corona* was present at low density (5–10 ind. m⁻²), between 19.5 and 100.5 m depth, whereas *C. carpenteri* showed a wide distribution, as it was present at a large number of stations, between 27.5 and 130 m depth, at a density between 5 and 60 ind. m⁻².

In accordance with the observations of Le Garrec et al. (2016) for the Atlantic coasts, our findings support the hypothesis that *C. corona* is a non-invasive species, at least in the study area (Central

Adriatic Sea). Nevertheless, on the basis of our knowledge, we may hypothesise a possible competition with the native surface detritivores. Indeed, *Chaetozone* species are surficial modifiers (Queirós et al. 2013), and competition among deposit-feeding species living at the sediment/water interface has been observed for a long time (Eagle & Hardiman 1977).

Findings of this study extend the range of distribution within the Mediterranean Sea of two *Chaetozone* species, also providing information on the ecological preferences of these species in terms of habitat.

The repeated observations of the two species from 2014, and the finding of reproducing specimens of both, suggest that *C. corona* and *C. carpenteri* have found a suitable habitat in the western (Central) Adriatic Sea, although at a low density as recorded in this study. Also, our results suggest that their populations may already be, or may become in the immediate future, self-sustaining and well established in the Adriatic Sea, as already happened at least in part of the Eastern Mediterranean (Çinar & Bakir 2014; Zenetos et al. 2017).

Considering its distribution in close proximity to intense ship routes, we would also venture the hypothesis that *C. corona* was introduced and then spread in the Adriatic Sea through ballast waters, and that its current distribution is limited by water currents and the availability of muddy to sandy sediments. Of particular relevance is our record of a specimen of *C. corona* from a hard bottom of the Tyrrhenian Sea. This finding represents an advancement of the knowledge of potential suitable habitats for this species.

As also recommended by other authors (Chambers & Woodham 2003; Çinar & Ergen 2007; Simboura et al. 2010; Chambers et al. 2011; Le Garrec et al. 2016), we believe that re-examination of *Chaetozone* specimens from laboratories or museum collections could determine whether the established alien *C. corona* and the native *C. carpenteri* occur elsewhere in the Mediterranean, beyond the spatial and temporal distribution given in this study. We also emphasise the need to collect new specimens in order to conduct genetic investigations that could allow us to define the history of introduction and spread of *C. corona*, as well as its relationship with the Mediterranean, and morphologically similar, *C. carpenteri*. To date, much remains unknown on the ecology and distribution of these two species in the Western Mediterranean Sea, as well as on their role in the benthic communities. Further efforts are needed to assess the geographic range of rare native species, and the geographic spread and potential invasiveness of alien ones.

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Competing interests

The authors declare that they have neither competing interests nor potential conflict of interest.

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