



## Two new species of *Aphelochaeta* (Polychaeta: Cirratulidae) from deep water off northern California

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### Abstract

Two new species belonging to the genus *Aphelochaeta* (Polychaeta: Cirratulidae) are described from continental slope sediments off northern California. Specimens were collected during extensive monitoring of the San Francisco Deep Ocean Disposal Site off the Farallon Islands from 1996 to 2004. The genus *Aphelochaeta* is one of the more speciose genera collected from depths of 2400–3200 m. *A. bullata* sp. nov. is characterized by the presence of four peristomial annulations, a pronounced dorsal crest, and elongated, natatory-like simple capillaries in the noto- and neuropodia of the thoracic region. *A. guttata* sp. nov. has a unique methyl green staining pattern consisting of speckles all over the body, thoracic segments that are swollen ventrally, and weakly inflated posterior segments. Comparison is made with the type species *A. monilaris* (Hartman, 1960) and other continental shelf and slope species from California. Morphological characters important for differentiation of these species are discussed; these include characters related to the peristomium, shape of abdominal segments and methyl green staining patterns. The generic definition is emended to include numbers of asetigerous peristomial annulations.

**Key words:** continental slope, systematics, morphology

### Introduction

One of the dominant infaunal polychaete families in continental slope sediments off the east and west coasts of the United States is the Cirratulidae, the majority of which are new to science and known only by provisional names (Blake & Grassle, 1994; Blake et al. 2009). The cirratulid fauna from California was described by Blake (1996) in a monograph that treated 46 species mostly from intertidal and nearshore subtidal habitats. The deep-water fauna from the continental shelves, however, is largely unknown. An extensive monitoring program from 1996 to 2004 at the San Francisco Deep-Ocean Disposal Site (SF-DODS) off northern California yielded 24 species of cirratulids in five genera: *Aphelochaeta* (11 species), *Chaetozone* (8 species), *Monticellina* (3 species), *Tharyx* (1 species) and *Dodecaceria* (1 species). A total of 20 species were determined to be new to science. Of these, Blake (2006) described three new species of *Chaetozone* and redescribed *Chaetozone spinosa* Moore, 1903.

The present paper, which deals with two new species of *Aphelochaeta*, complements that study by describing species from the same deep-water habitats off northern California. The new *Aphelochaeta* species described here provide new details concerning peristomial annulations, shape

of abdominal segments and methyl green staining patterns that will be important for phylogenetic analyses of the bitentaculate cirratulid polychaetes.

## Materials and methods

Sediment samples were collected using a 0.25-m<sup>2</sup> Hessler-Sandia box core. The samples were sieved using a 300- $\mu$ m- mesh sieve, initially preserved in 10% buffered formalin, and later transferred to 80% ethanol (ETOH). Specimens were submerged in a saturated solution of methyl green (MG) and 80% ETOH for a minimum of 60 seconds to determine MG staining patterns. Stained specimens were photographed using a Nikon D80 SLR camera mounted on a Wild M-5 stereomicroscope. Images were edited using Photoshop CS3 software. Specimens intended for scanning electron microscopy (SEM) were dehydrated by passing the specimens through an ascending series of ethanol, ending in 100% ETOH, followed by critical point drying. Specimens were mounted on stubs and sputter-coated with gold palladium. A Jeol JSL-840 Scanning Electron Microscope (Marine Biological Laboratory, Woods Hole, MA) was used for all SEM observations.

Type specimens were deposited in the Los Angeles County Museum of Natural History in Los Angeles, California (LACM-AHF POLY) and the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (NMNH). The more extensive bulk collections will eventually be distributed among these same museums and the California Academy of Sciences in San Francisco.

## Results

### Genus *Aphelochaeta* Blake, 1991 Emended

Type species: *Tharyx monilaris* Hartman, 1960. Original designation by Blake, 1991.

**Diagnosis.** Prostomium conical; peristomium elongate with 1–4 asetigerous annulations, with pair of grooved dorsal tentacles arising either on or anterior to setiger 1; first pair of branchiae arising either on or anterior to setiger 1; thoracic region frequently expanded, with crowded segments; abdominal segments variable, sometimes moniliform; setae simple capillaries, with distinct serrations or sawtooth edge not visible in light microscopy, but fibril endings sometimes seen with SEM; far posterior segments frequently expanded, tapering to simple pygidial lobe.

**Remarks.** Members of the cirratulid genus *Tharyx* at one time included species with both simple and serrated capillaries. Blake (1991) reinstated *Monticellina* Laubier, 1961 to include species with serrated capillaries and limited *Tharyx* to species with the knob-tipped spines that he had discovered in the type species, *T. acutus* Webster & Benedict, 1887. The genus *Aphelochaeta* was established to include ten species with simple, non-serrated capillaries. However, subsequent investigations using SEM have demonstrated that the blades of “smooth” capillary setae often exhibit fine serrations along the blades that are not seen with light microscopy. The original diagnosis (Blake 1991) and the subsequent description of six new species (Blake 1996) did not include information on the number of peristomial annulations, origin of the first pair of branchiae, and nature of the thoracic segments; the genus diagnosis is therefore emended to include these characters.

### *Aphelochaeta bullata* sp. nov.

Figures 1, 3A–C, 4A–B

*Aphelochaeta* sp. 2: Blake et al. 2009 (in press).

**Material examined.** California, continental slope off San Francisco, west of Farallon Islands, R/V *Point Sur*: Sta. 57, 37°42.99'N, 123°32.99'W, 2650 m, 16 Oct 2000, 3 paratypes (LACM-AHF POLY 2215); Sta. 27, 37°41.00'N, 123°32.00'W, 2929 m, 8 Oct 1999, 1 paratype (LACM-AHF POLY 2214); Sta. 24, 37°36.97'N, 123°27.92'W, 2650 m, 19 Oct 2000, holotype (LACM-AHF POLY 2210); Sta. DR2A, 37°22.92'N, 124°01.00'W, 3775 m, 29 Sep 2006, 4 paratypes (LACM-AHF POLY 2213); Sta. 6, 37°40.02'N, 123°27.00'W, 2697 m, 22 Sep 2002, 2 paratypes (LACM-AHF POLY 2212); Sta. 114, 37°35.07'N, 123°26.90'W, 2505 m, 26 Sep 2003, 1 paratype (LACM-AHF POLY 2216); Sta. 19, 37°38.01'N, 123°30.00'W, 3000 m, 22 Sep 2002, 1 paratype (USNM 1123176); Sta. 114, 37°35.08'N, 123°26.96'W, 2420 m, 27 Sep 2002, 2 paratypes (USNM 1123177); Sta. 20, 37°37.94'N, 123°30.97'W, 3035 m, 24 Sep 2003, 1 paratype (USNM 1123178); Sta. 6, 37°39.93'N, 123°26.92'W, 2750 m, 3 Oct 2004, 4 paratypes (USNM 1123179).

**Additional material for SEM.** Sta. 114, 37°35.00'N, 123°27.00'W, 2420 m, 27 Sep 2002, 1 specimen; Sta. 23, 37°37.00'N, 123°29.00'W, 2970 m, 9 Oct 1997, 1 specimen; Sta. 19, 37°37.98'N, 123°30.03'W, 3123 m, 22 Oct 2001, 1 specimen.

**Description.** A moderate-sized species, holotype incomplete, 15 mm long for 93 setigers, thorax 1.05 mm wide, abdomen 0.6 mm wide; thoracic region broad, greatly swollen dorsally, flattened ventrally, composed of about 20–30 very crowded, narrow segments, lacking dorsal and ventral grooves; smaller individuals with ten crowded segments; abdominal region narrower than thoracic region, with segments less crowded, wider than long, never moniliform, lacking dorsal and ventral grooves. Pygidium not observed. Color in alcohol light tan, with no visible pigmentation.

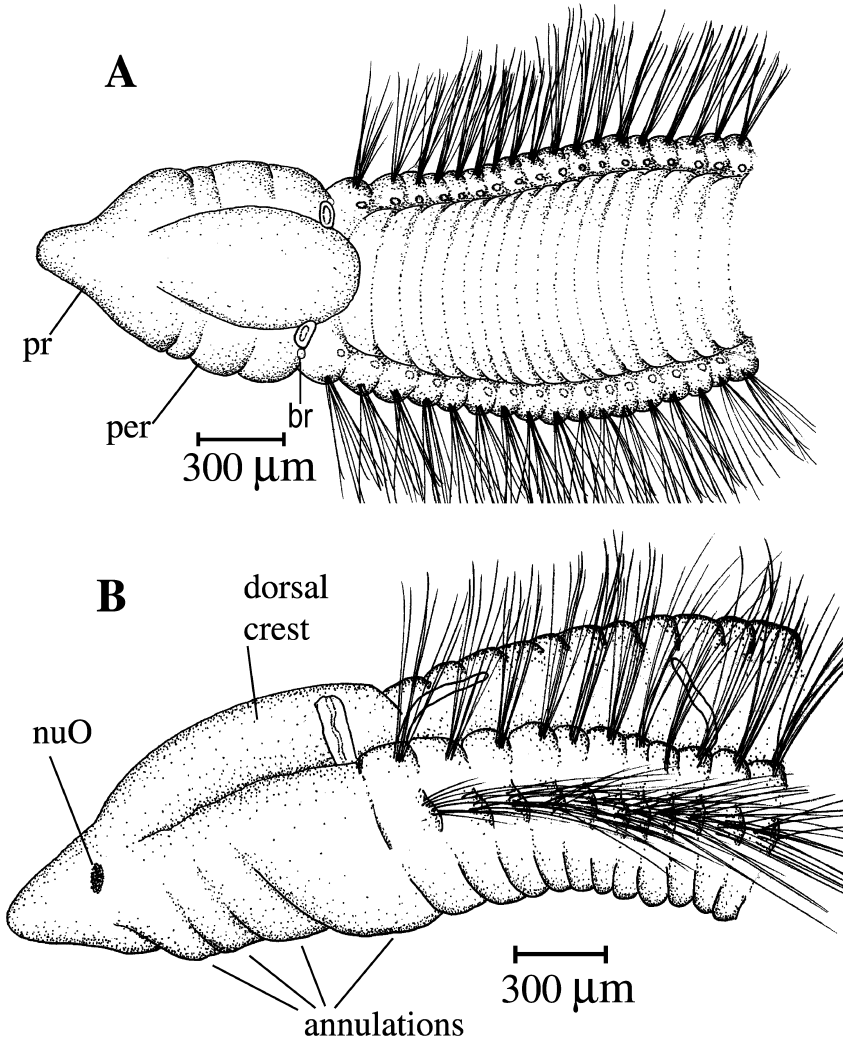
Prostomium conical with rounded tip, as wide as long; peristomium longer than wide, with four annulations, with posteriormost annulation largest (Fig. 1A); prominent dorsal crest present, dome-like, extending to posterior margin of setiger 1 (Figs. 1B, 3B); head region appearing disproportionately large; eyes absent; nuchal organs circular, lacking pigmentation; dorsal tentacles arising at the junction of peristomium and setiger 1, lateral to dorsal crest. First pair of branchiae arising from peristomium, lateral and directly beside dorsal tentacles (Fig. 3A); second pair dorsal to notosetae on setiger 1, continuing on subsequent segments throughout body. Parapodia well developed anteriorly, produced into fleshy lobes, not elevated over dorsum; posterior setigers similar with parapodia less developed. Setae all long, narrow, simple capillaries, up to 16–19 notosetae and 12–15 neurosetae in thoracic setigers; reduced to 5–8 noto- and neurosetae in far abdominal segments; notosetae longer than neurosetae with noto- and neurosetal fascicles arising close to one another. Most specimens with long natatory-like setae present from setiger 1 in thoracic noto- and neuropodia providing “bottle-brush” appearance to anterior end (Fig. 3C). Long natatory setae comprise bulk of thoracic setae, sparse in abdominal region, present in both noto- and neuropodia.

**Methyl green staining pattern.** Body with overall blue-green color; no other staining reactions apparent (Fig. 4A–B).

**Remarks.** *Aphelochaeta bullata* sp. nov. is readily separated from other deep-water California *Aphelochaeta* species by the pronounced inflated dorsal crest on the peristomium, which has four clearly discernible annulations. The expanded nature of the head region has not been reported for other species of this genus. The thorax is domed dorsally, accentuating the podial lobes so that they protrude from the body. *A. bullata* sp. nov. also has extremely long natatory-like setae in both the noto- and neuropodia of thoracic segments, giving the anterior end a bottle-brush appearance. These long natatory-like setae have been observed in other species of *Aphelochaeta* from our collections from deep water but are most prominent in abdominal rather than thoracic segments and occur mainly in the notopodia. *A. bullata* sp. nov. can be separated from other cirratulids in bulk samples due to the lack of a defined methyl green staining pattern. Ovigerous females with eggs measuring 100–120 µm in diameter were collected in October 2004. Even with careful collection and

preservation, no fully intact specimens of this species were collected in nine years of monitoring (1996–2004) or from two extra deep reference samples collected in 2006. Specimens with up to 103 setigers were collected, but these readily fragmented into several smaller pieces.

**Ecology.** A total of 130 specimens of *Aphelochaeta bullata* sp. nov. were collected in the 135 samples obtained over the nine years of monitoring (1996–2004). *A. bullata* sp. nov. occurred over a wide depth range but was never locally abundant. Most specimens were collected from sediments having high silt-clay fractions.



**FIGURE 1.** *Aphelochaeta bullata*, sp. nov. A, anterior end in dorsal view; B, anterior end in lateral view. Abbreviations: br, branchiae; nuO, nuchal organ; per, peristomium; pr, prostomium.

**Etymology.** From the Latin *bullatus* meaning inflated, referring to the inflated nature of the peristomium.

**Distribution.** Middle and lower slope off northern California, 2160–3775 m.

***Aphelochaeta guttata* sp. nov.**

Figures 2, 3D–E, 4C

*Aphelochaeta* sp. 8: Blake et al. 2009 (in press).

**Material examined.** California continental slope off San Francisco, west of Farallon Islands, R/V *Point Sur*: Sta. 57, 37°43.01'N, 123°32.98'W, 2640 m, 1 Oct 2004, holotype (LACM-AHF POLY 2205); Sta. 17, 37°38.05'N, 123°27.94'W, 2750 m, 24 Sep 2003, 7 paratypes (LACM-AHF POLY 2209); Sta. 57, 37°42.97'N, 123°32.95'W, 2750 m, 26 Sep 2003, 9 paratypes (LACM-AHF POLY 2208); Sta. 17, 37°37.98'N, 123°27.99'W, 2776 m, 2 Oct 2004, 16 paratypes (LACM-AHF POLY 2207); Sta. 17, 37°37.94'N, 123°27.91'W, 2780 m, 15 Oct 2000, 23 paratypes (LACM-AHF POLY 2206); Sta. 16, 37°37.97'N, 123°27.04'W, 2690 m, 2 Oct 2004, 8 paratypes (USNM 1123174); Sta. 57, 37°42.99'N, 123°32.99'W, 2650 m, 16 Oct 2000, 11 paratypes (USNM 1123175).

**Additional material for SEM.** Sta. 1, 37°41.10'N, 123°30.98'W, 2665 m, 29 Oct 1997, 2 specimens; Sta. 116, 37°34.998'N, 123°28.995'W, 2928 m, 3 Oct 2004, 1 specimen.

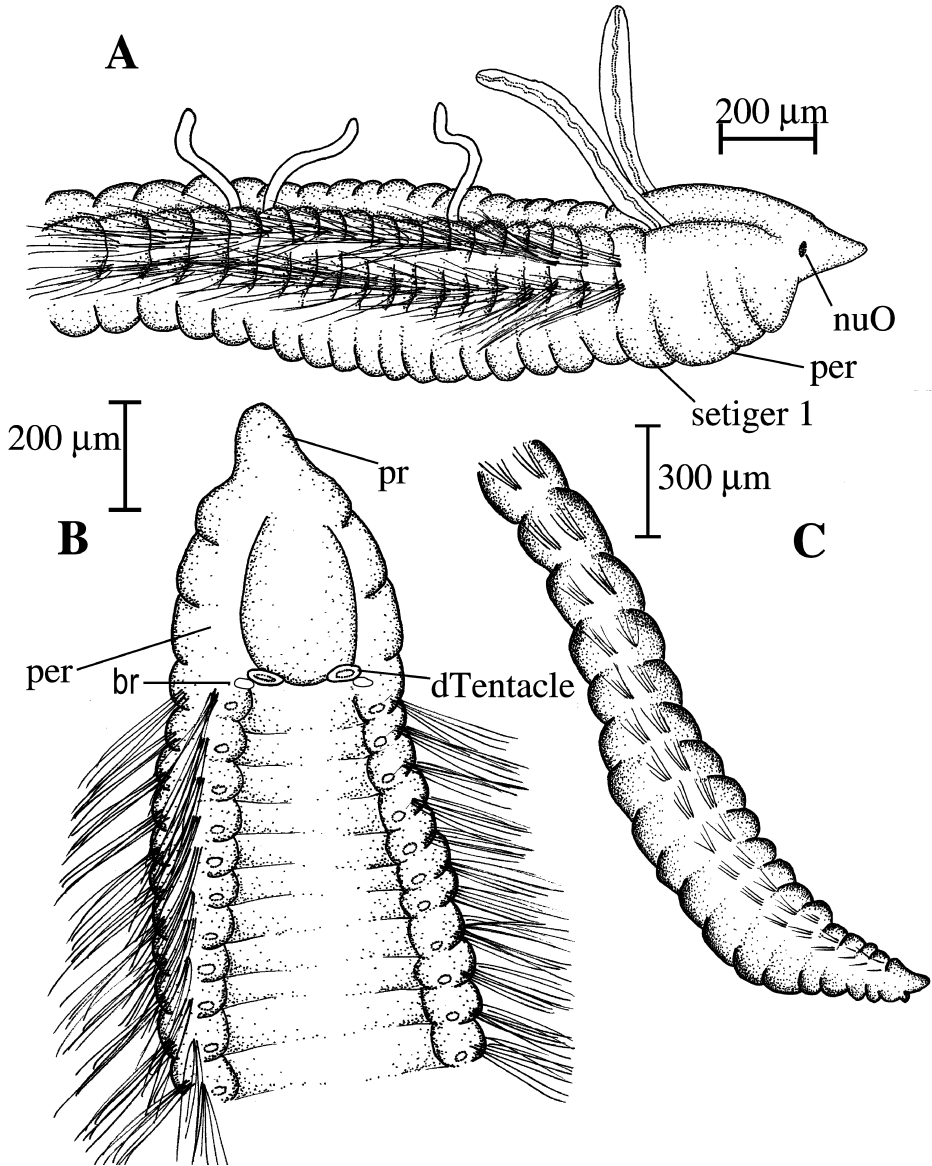
**Description.** A moderate-sized species, holotype complete, 16 mm long for 101 setigers, thorax 0.5 mm wide, abdomen 0.4 mm wide; thoracic region weakly expanded, dorsally rounded, swollen ventrally, composed of 15–20 crowded setigers, lacking dorsal and ventral grooves (Fig. 2A); abdominal segments less crowded, as long as wide, appearing moniliform in smaller individuals, lacking dorsal and ventral grooves; posterior region weakly expanded for last 10–15 setigers, lacking dorsal and ventral grooves, narrowing to pygidium with simple dorsal lobe above anal opening (Fig. 2C). Color in alcohol light tan, with no visible pigmentation.

Prostomium conical, with rounded tip, as wide as long; peristomium as long as wide, with three subequal annulations (Figs. 2B, 3D); minute dorsal crest present, terminating at posterior margin of setiger 1; eyes absent; nuchal organs circular, lacking pigmentation; dorsal tentacles arising at junction of peristomium and setiger 1. First pair of branchiae arising from peristomium, lateral and just posterior to dorsal tentacles (Fig. 3E); second pair dorsal to notosetae on setiger 1, continuing on subsequent segments throughout body. Anterior thoracic parapodia enlarged, elevated above dorsum (Fig. 3E). Posterior setigers similar with parapodia less developed. Setae all long, narrow, simple capillaries, 10–15 notosetae and 6–11 neurosetae in thoracic setigers; reduced to 7–10 noto- and neurosetae in far abdominal segments; notosetae longer than neurosetae; noto- and neurosetal fascicles arising close to one another. Some specimens with long natatory-like notosetae in far thoracic and abdominal segments, up to five per notopodial fascicle.

**Methyl green staining pattern.** Body stains intensely throughout with irregular speckles, concentrated on the peristomium and interparapodial regions (Fig. 4C).

**Remarks.** The methyl green staining pattern is diagnostic for this species and provides a means to readily distinguish *A. guttata* sp. nov. from several other species of *Aphelochaeta* that may have a similar body profile. Weakly expanded posterior segments are also diagnostic, but relatively few specimens retained their posterior ends. The presence of elongate natatory-like setae differs from that observed in *A. bullata* sp. nov. in that they are not prominent in the thoracic setigers and are few in number, therefore the body of *A. guttata* sp. nov. does not take on the bottle-brush appearance of *A. bullata* sp. nov. Ovigerous females with eggs measuring 90–130 µm were collected in October 2004.

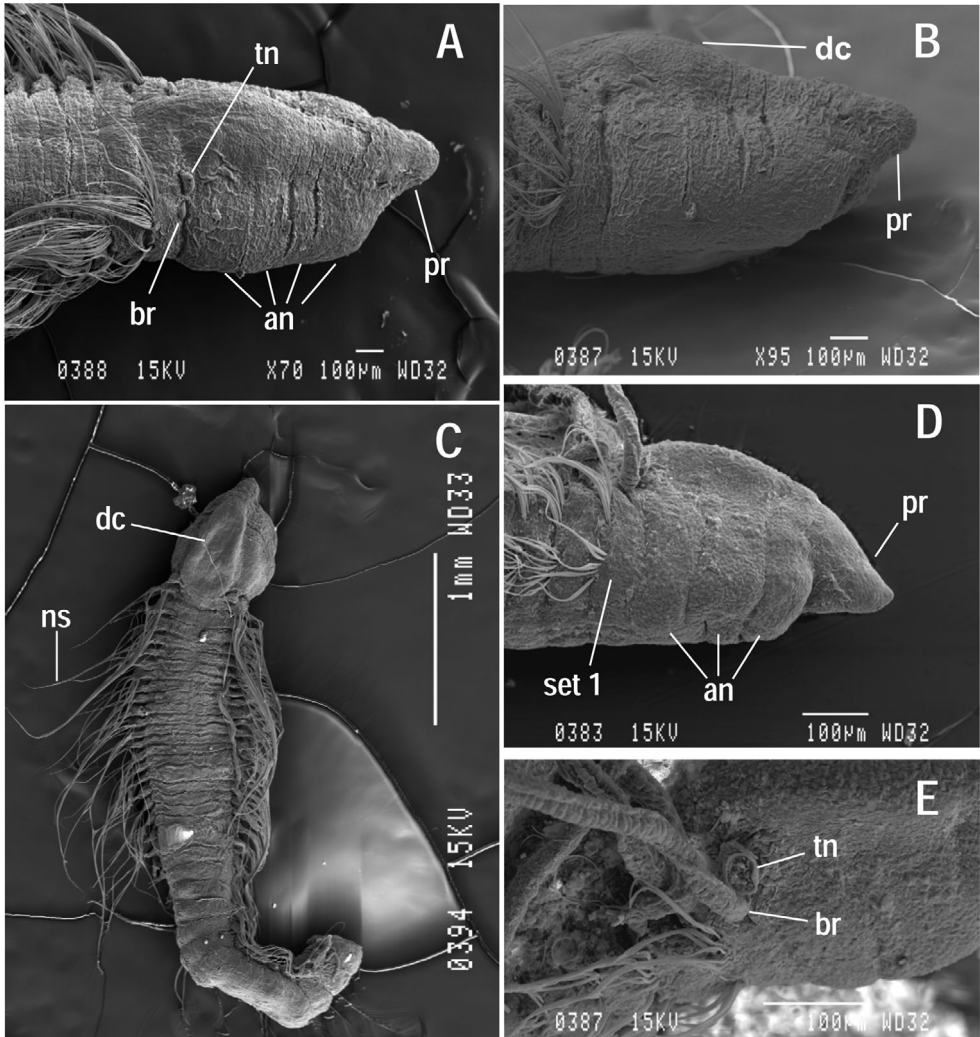
**Ecology.** *Aphelochaeta guttata*, with 388 specimens collected in 135 samples, ranked 39th of approximately 800 species of benthic invertebrates in the collection. Most specimens were collected from sediments having high silt-clay fractions.



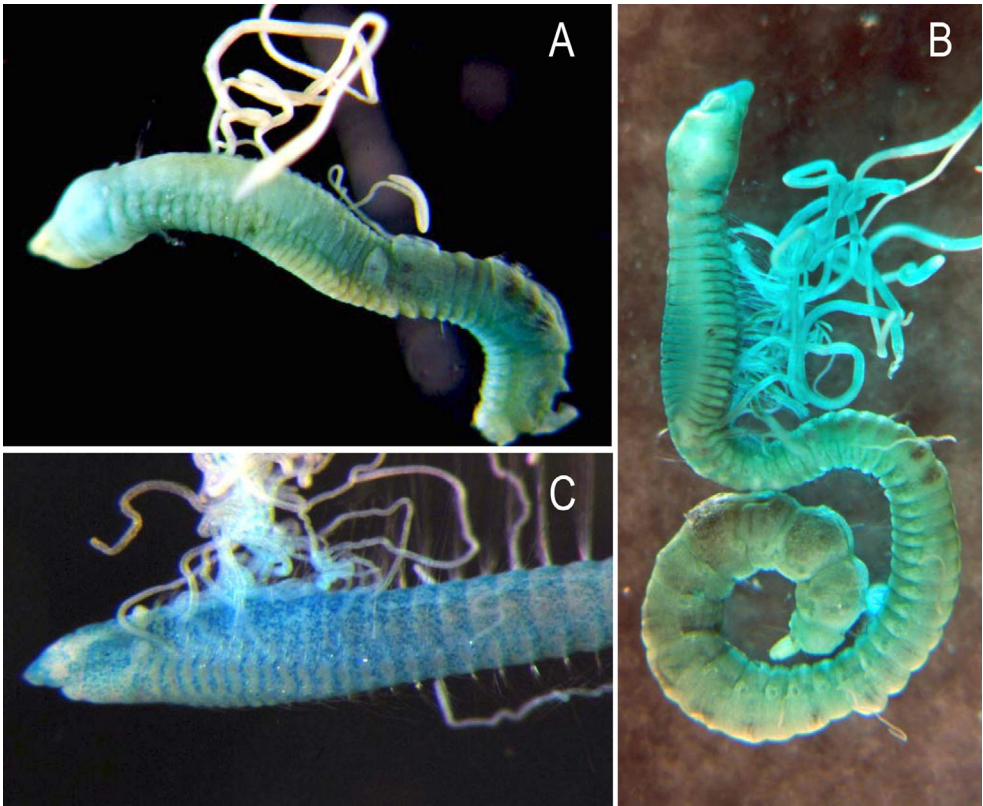
**FIGURE 2.** *Aphelochaeta guttata*, sp. nov. A, anterior end in lateral view; B, anterior end in dorsal view; C, posterior end in lateral view. Abbreviations: br, branchiae; nuO, nuchal organ; per, peristomium; pr, prostomium; set, setiger; dTentacle, dorsal tentacle.

**Etymology.** From the Latin, *guttatus* meaning spotted, speckled and refers to the distinctive methyl green staining pattern of this species.

**Distribution.** Middle and lower slope off northern California, 2420–3666 m.



**FIGURE 3.** A, SEM of *Apheleochaeta bullata* sp. nov. showing peristomial annulations and position of first branchiae; B, SEM of *A. bullata* showing pronounced dorsal crest; C, SEM of *A. bullata* body profile showing elongate, natatory-like setae; D, SEM of *A. guttata* sp. nov. showing peristomial annulations; E, SEM of *A. guttata* showing location of first branchiae in relation to dorsal tentacles. Abbreviations: an, annulations; br, branchiae; dc, dorsal crest; ns, natatory-like setae; pr, prostomium; set, setiger; tn, tentacle.



**FIGURE 4.** A–B, photographs of *Aphelochaeta bullata* sp. nov. showing lack of methyl green (MG) staining pattern (A, lateral view; B, ventrolateral view); C, photograph of *A. guttata* sp. nov. showing MG staining pattern, lateral view.

## Discussion

Species of *Aphelochaeta* are a common component of deep-sea benthic infauna, but relatively few species have actually been described, possibly due to a perceived absence of characters required to distinguish one species from another (Blake 1996). However, as reported here, prostomial and peristomial characters together with overall body shape and methyl green staining patterns have proven important in distinguishing between species. Several other species of *Aphelochaeta* from the eastern Pacific SF-DODS study area and other deep-water sites on the US Atlantic slope have been identified and will be described elsewhere (Doner in preparation).

Table 1 provides comparative data on the two new species of *Aphelochaeta* described herein and five additional shelf species from offshore California, including the type species, *A. monilaris* (Hartman, 1960).



TABLE 1. Taxonomic characters of six species of *Aphelocheata* from offshore California waters compared with the type species, *A. monilaris* (Hartman, 1960).

Species	Number peristomial annulations	Position of first pair branchiae	Thoracic profile	Abdominal segments	Ventral groove	Nature of posterior segments	Methyl green staining pattern	Bathymetric Distribution
<i>monilaris</i> (Hartman, 1960)	2–3	Peristomium	Dorsoventrally round	Moniliform	Absent	Inflated	Ventral bands present on thorax	Shelf & slope depths
<i>bullata</i> sp. nov.	4	Peristomium, lateral to dorsal tentacles	Dorsally round, ventrally flattened	Not moniliform	Absent	Unknown	Absent	Slope depths: 2160–3775 m
<i>guttata</i> sp. nov.	3	Peristomium, posterolateral to dorsal tentacles	Dorsoventrally round	Not moniliform	Absent	Weakly inflated	Speckles throughout body	Slope depths: 2420–3666 m
<i>glanularia</i> Blake, 1996	2–3	Setiger 1, lateral to dorsal tentacles	Dorsally round, ventrally flattened	Narrow segments, never moniliform	Present posterior thorax through remainder of body	Inflated with dorsal and ventral grooves	Light speckles in thoracic region, anterior ventral thorax	Shelf depths: 77–200 m
<i>phillipsi</i> Blake, 1996	1	Peristomium, lateral to dorsal tentacles	Dorsally round, ventrally flattened	Not moniliform	Absent	Weakly inflated	Vague bands on peristomium, bands on ventral thorax	Shelf depths: 60–98 m
<i>tigrina</i> Blake, 1996	3	Peristomium	Dorsally round, ventrally weakly round	Not moniliform	Present in posterior region only	Inflated laterally, dorsoventrally compressed	Irregular speckles dorsum, transverse ventral bands, posterior end with bands	Shelf depths: 90–160 m
<i>williamsae</i> Blake, 1996	2–3	Peristomium	Dorsally round, ventrally flattened	Elongate to submoniliform	Absent	Inflated	Ventral bands posterior thorax	Shelf depths: 90–150 m

Dean & Blake (2007) discussed in detail the difficulty of dealing with peristomial annulations in bitentaculate cirratulids. In some species the annulations are indistinct and are best viewed ventrally or with the aid of SEM. The annulations are not a preservation artifact that results in creases in the peristomium since they occur in a distinct pattern within each species as evident when large numbers of specimens are available for examination. The number and length of these annulations appear to be species-specific characters, with most species having three subequal annulations as in *A. guttata* sp. nov. *Aphelochaeta bullata* sp. nov. is unique in that it has four annulations, with the fourth being the largest. The number and relative size of these annulations has not been accurately depicted in all species and warrants further investigation.

The manner in which the shape of abdominal segments is described is in need of refinement. The available descriptions of a range of abdominal segments are: moniliform, rounded, submoniliform, and narrow. The term moniliform implies that the segments resemble a string of beads, where each segment is rounded with distinct constrictions between segments. Submoniliform segments may appear rounded but lack the constriction between the segments. Narrow segments are wider than long and are often crowded. Only one species has been described with true moniliform segments, the type species *A. monilaris*. Blake (1996) noted that the presence of moniliform segments in this species was best developed in sexually mature specimens. Immature specimens of *A. guttata* can appear moniliform but this is not true of mature specimens. Observations of abdominal segments are therefore best referenced with regard to development of the individual to aid in separation of species.

Species-specific methyl green staining pattern is a useful tool for distinguishing species at the regional or local level. MG staining patterns for the genus have been adequately described for only the eight species of *Aphelochaeta* treated by Blake (1996). Ventral staining of posterior thoracic segments, usually in bands, has been noted for several species. The intensity and exact location of these bands as well as staining patterns on the prostomium/peristomium and posterior segments further separate species. *A. guttata* sp. nov. has this thoracic ventral banding, but is unique in that the entire body is covered in dark speckles when stained. Even when posterior ends are missing, anterior staining patterns may aid in the identification of fragmented specimens.

Despite definition of additional characters, characterization of species in this genus remains difficult. While other bitentaculate cirratulid genera have numerous species-specific setal characters, the lack of apparent setal morphology in the genus *Aphelochaeta* makes it difficult to distinguish between the various species. Differences in length between the noto- and neurosetae as well as the presence of long, natatory-like setae, number of setae per fascicle in both the thoracic and abdominal region, and capillary thickness are useful characters that should be included in species descriptions. Consistent use of characters such as degree of inflation of the dorsal crest, origin of the first pair of branchiae, presence of dorsal and ventral grooves, and body profile in cross section in both the thorax and abdomen would further aid in distinguishing species. Details of fibril endings on the capillary setal blades may also represent useful taxonomic characters but these are observed only with SEM. The presence of a minutely serrated edge on otherwise "smooth" capillaries obscures the distinction between the genera *Aphelochaeta* and *Monticellina*. Based on the diversity of species now known, it is unlikely that either of these genera are monophyletic (see Dean & Blake 2009 for further discussion). Additional study of these two genera using both traditional morphology and molecular methods is in progress (Doner in preparation).

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