8-31-2015

Taxonomy of the Bitentaculate Cirratulidae (Polychaeta)

Stacy A. Tewari
University of Massachusetts Boston

TAXONOMY OF THE BITENTACULATE CIRRATULIDAE (POLYCHAETA)

A Thesis Presented

by

STACY A. TEWARI

Submitted to the Office of Graduate Studies,
University of Massachusetts Boston,
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2015

Environmental Biology Graduate Program

TAXONOMY OF THE BITENTACULATE CIRRATULIDAE (POLYCHAETA)

A Thesis Presented

by

STACY A. TEWARI

Approved as to style and content by:

_____
Michael Rex, Professor
Chairperson of Committee

_____
Richard Kesseli, Professor
Member

_____
John Ebersole, Associate Professor
Member

_____
Alan Christian, Program Director
Environmental Biology Graduate Program

_____
Richard Kesseli, Chairperson
Biology Department

ABSTRACT

TAXONOMY OF THE BITENTACULATE CIRRATULIDAE (POLYCHAETA)

August 2015

Stacy A. Tewari, B.S., University of Rhode Island
M.S., University of Massachusetts Boston

Directed by Professor Michael Rex

The bitentaculate cirratulid polychaetes are an important faunal element of both near shore and deep-sea benthic faunal communities. The true diversity of the family is currently unknown due to a large number of undescribed species and erroneously applied "cospmopolitan" names being applied to local species. Cirratulids have been misidentified even in the local waters near the University of Massachusetts Boston. The current study presents six new species from North America. *Caulleriella venefica, Chaetozone anasimus, Chaetozone diodonta,* and *Chaetozone hystricosus* are described from Boston Harbor and Massachusetts Bay where only two species had previously been reported. *Aphelochaeta bullata* and *A. guttata* are described from continental slope sediments off northern California. Morphological characters important for differentiation of these genera and species are discussed. Setal morphology as well as arrangement is clarified for both *Caulleriella* and *Chaetozone*.

For the more simplistic genus *Aphelochaeta,* characters related to the peristomium and shape of the abdominal segments in both juveniles and adults is presented. The importance of methyl green staining patterns as a tool to discerning even incomplete specimens is also presented. These formal descriptions of new taxa will contribute to a larger understanding of the systematics and interrelationships of the bitentaculate Cirratulidae.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

The segmented worms comprising the Phylum Annelida have historically been split into three classes: Polychaeta (marine bristleworms), Oligochaeta (earthworms), and Hirudinea (leeches). Recent morphological and molecular work has shown that the Hirudinea are actually nested within the Oligochaeta (Martin, 2001; Siddal et al., 2001). The relationship between the Polychaeta and a combined Hirudinea/Oligochaeta clade remains unresolved at this time, even as additional genes and taxa are added to the analyses. Relationships within the Polychaeta also remain unresolved. Several recent studies have attempted to construct large-scale molecular phylogenies of the Polychaeta but have failed to elucidate a consistent relationship among the various polychaete families (Rousset et al, 2006). Molecular studies also have failed to identify a basal polychaete form (McHugh, 2005). Recent work has shown more promise in finding intra-family relationships where both molecular and morphological characters are used in a total evidence approach (Aguado et al, 2012; Osborn & Rouse, 2010).

The Cirratulidae are one of approximately 80 polychaete families currently recognized but the phylogeny of the family remains unresolved. Other families may be nested within the Cirratulidae. For example, molecular data suggests that the currently recognized Ctenodirilidae may be nested within the Cirratulidae (Rousset et al, 2006).

There is currently no known apomorphy for the family, which makes it unclear which groups it is appropriate to include in the family. A study including taxa from the majority of the currently recognized cirratulid genera has yet to be conducted. Such a study has the potential for clarifying this issue.

Our current understanding of the Cirratulidae is based strictly on morphology; with the family consisting of 11 genera subdivide into three arbitrary groups.

1. The mulitentaculate soft-bottom genera
2. The bitentaculate soft-bottom genera
3. The bitentaculate hard-bottom genera

These three subgroups are separated visually based on differences in the number of dorsal tentacles (filaments) and setal structure. The multitentaculate genera have more than one pair of dorsal tentacles and include *Cirratulus, Cirriformia, Protocirrineris, Fauvelicirratulus,* and *Timarete.* These genera are separated primarily based on the kind(s) of setae present, the segment (s) from which the tentacles arise, and origin of the first branchiae. The bitentaculate soft-substrate genera are characterized by the presence of a single pair of dorsal tentacles and are defined based on the type and arrangement of setae. The five bitentaculate soft-bottom genera are *Aphelochaeta, Caulleriella, Chaetozone, Monticellina,* and *Tharyx.* The only hard-bottom bitentaculate genus is *Dodecaceria,* characterized by a single pair of dorsal tentacles, spoon-shaped hooks, and the habit of either boring into calcareous substrate or producing a calcareous rocklike structure.

Recent taxonomic work has demonstrated that the true diversity of the Cirratulidae is greatly underestimated. For example, Dean and Blake (2007, 2009)

described 18 species from Costa Rica, 14 of which were new to science. Historically, many species have been reported over erroneously broad geographical ranges because the finer distinctions between species were overlooked. Poor species descriptions and illustrations furthered the problem by leading to misidentifications. European names were applied globally due to the short list of published species descriptions. A good example is *Chaetozone setosa* Malmgren, 1867 that was originally described from Spitzbergen, Norway but has since been "identified" globally. Blake (2015) has shown that the range of *C. setosa* is limited to the Arctic and that other reports represent misidentifications. This calls into question the use of several other "cosmopolitan" cirratulid species names in use today, including *Aphelochaeta marioni*, *Aphelochaeta monilaris*, and *Monticellina dorsobranchialis*, each of which may represent species groups of similar looking cirratulids.

A related issue is the broad generic diagnoses currently in use. Over the years, the systematic accounts have been modified to include a wider interpretation of what the characteristics of a species included in a particular genus are so that a place could be found for those species that did not seem to fit anywhere. These vague definitions result in species having been placed in a genus more for convenience than to reflect evolutionary relationships. For example, there is a group of *Chaetozone* that are closely related to each other but depart from all other described *Chaetozone*. This group has a grub-like body shape, lack cinctures, have reduced noto- and neuropodia, and have a broad, flattened prostomium. *Chaetozone pinguis* Hartman, 1978, *Chaetozone gayheadia* Hartman, 1965, and *Tharyx fusiformis* Monro, 1939 all more closely resemble a multitentaculate than a bitentaculate and may warrant the errection of a new genus.

As a first step towards resolving the numerous taxonomic issues within the Cirratulidae, three genera of the bitentaculate soft-bottom taxa will be examined since they include species that are often the dominant contributors to benthic faunal assemblages. New characters are presented that are diagnostic for these genera that aid in clarifying what species should be included in each genus as well as those that should be excluded upon further review.

Systematic Account

Cirratulidae Ryckholdt, 1851

Genus *Aphelochaeta* Blake, 1991 Emended

Type species: *Tharyx monilaris* Hartman, 1961. 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.

Genus *Caulleriella* Chamberlin, 1919

Type species: *Cirratulus viridis* Langerhans, 1880.

Diagnosis: Prostomium elongate; peristomium elongate to short, pair of grooved dorsal tentacles usually originating anterior to setiger 1; middle body segments not beaded; parapodia with noto- and neuropodia widely seprated laterally; modified setae include bidentate crotchetlike hooks, not arranged in modified cinctures; pair of anal cirri frequently present.

Genus *Chaetozone* Malmgren, 1867

Type species: *Chaetozone setosa* Malmgren 1867, by monotypy.

Diagnosis: Prostomium blunt to conical, peristomium elongate to short, usually lacking eye spots, with a pair of small nuchal slits or depressions at posterior edge; with a single pair of grooved dorsal tentacles arising from posterior edge of peristomium, or sometimes more posterior on an achaetous anterior segment, or rarely an anterior setiger. First pair of branchiae arising from an achaetous segment or first setiger; or sometimes with first two pairs of branchiae on a single anterior segment. Body basically thick and fusiform over many segments, rarely with middle or posterior body segments beaded or moniliform. Setae include capillaries on most setigers and acicular spines in neuropodia and/or notopodia, spines typically concentrated in posterior segments, forming distinct cinctures with spines emerging from elevated membranes; cinctures with few to many spines and with none to many alternating capillaries; some species with posterior noto- and neuropodial sigmoid acicular spines numerous, encircling entire posterior parapodia; bidentate spines sometimes present in juveniles or occasionally in ventral most position of far posterior setigers of adults accompanying unidentate spines in cinctures; some

species with long, natatory-like capillaries, sometimes limited to gravid individuals. Pygidium a simple lobe, disk like, or with long, terminal cirrus.

In this thesis I will describe six new species of bitentaculate Cirratulidae from North America, emphasizing key characters that can be used to separate the species beyond the commonly used absence/presence of various types of modified setae. This suite of clearly defined character states can then be applied to other Cirratulidae for more consistent generic placement and as a first step towards a larger revision of the family. The genus *Chaetozone* remains the most diverse genus in regards to type of spines.

CHAPTER 2

DISCUSSION

As new species of bitentactulate Cirratulidae are described, it is evident that new informative characters states and combinations of characters exist than previously recognized. A full revision of the five bitentaculate soft bottom genera is still needed as the characters used to define the genera still lead to confusion and the generic placement of numerous species is still in question. The erection of new genera may still be warranted based on and expanded dataset. By further clarifying character states, the generic placements should show stronger morphological support and less potential overlap.

The presence of bidentate hooks previously placed a species in the genus *Caulleriella*. After examining species such as *Chaetozone diodonta* (Doner & Blake 2006) and *Chaetozone lunula* Blake, 1996 where inner unidentate spines and outer bidentate spines are present, a revision of the generic designation for both *Caulleriella* and *Chaetozone* was in order. Bidentate hooks may also be present in juveniles of some species but absent in adults, so examination of a wide variety of size classes is important for accurate characterization (Blake, 2015). It is also the separation of these spines that is a generic level character.

The arrangement of modified setae is another character that can be used for species level characterizations. The term cincture refers to the arrangement of spines

and companion capillary setae in posterior setigers. A full cincture occurs when the noto- and neuropodial spines and companion setae are arranged in such a manner that they appear to encircle the entire side of the body, leaving little discernable space between the noto- and neuropodial fascicles as is observed in *Chaetozone hystricosus* Doner & Blake, 2006. Partial cinctures occur in species where there is a discernable gap between the noto- and neuropodial fascicles as occurs in *Chaetozone* anasimus Doner & Blake, 2006. For species of *Chaetozone,* this character should be referred to in descriptions as a range from partial to full cinctures. In *Caulleriella,* the spines are widely separated, emerging from the four quadrants of the body, never forming cinctures, so the presence of cinctures is said to be lacking.

The nature of the unidentate spines in *Chaetozone* also shows great variability in structure. In *Chaetozone setosa*, the spines are rounded with a thick border, brassy in color, and bluntly pointed (Blake, 2015). In *Chaetozone anasimus* the spines are thinner with the elongated tip bent back to touch the shaft of the spine whereas in *C. hystricosus* the spines are short, in comparison to *C. setosa*, rounded with a blunt tip. The variation in spines types may not be apparent unless viewed under 400X magnification (oil immersion). *Chaetozone* is the largest of the bitentaculate genera and there appear to be subgroups within the genus that require further investigation. Other species with flip-tip spines as observed in *C. anasimus* include *Chaetozone nicoyana* Dean & Blake, 2007 and *Chaetozone commonalis* Blake, 1996.

The truly bidentate spines of *Caulleriella* and knob-tipped spines of the genus *Tharyx* have lead to some confusion in the literature (Blake, 1996). Certain species have been shifted back and forth between the two genera due to confusion over the

true nature of the spines as in *Tharyx killariensis* (Southern, 1914). At one time *T. killariensis* was classified as a *Caulleriella* due to the presence of bidentate spines and originally as a *Chaetozone* due to the presence of spines but was transferred to *Tharyx* due to the presence of knob-tipped spines. When viewed under 100X magnification, the two teeth on true *Caulleriella* spines are easily discernable. For the spines of species of *Tharyx*, even under 400X magnification (oil emersion), defined teeth may not be observed. The tips are more blunted and the spines themselves are not angled vis-à-vis towards each other. In addition, the noto- and neuropodial fascicles of *Tharyx* arise closer together, with only a slight separation, whereas the fascicles in *Caulleriella* are widely separated.

The genus *Aphelochaeta* is characterized by its lack of characters and is the most difficult of the genera for taxonomists to identify. There are no modified setal structures to separate the species. Incomplete specimens must be treated with caution, since anterior fragments can resemble other genera. Setal arrangement may be similar to some species of *Monticellina*, which have distinctive sawtoothed capillary setae that originate in the midbody. Even when complete specimens are present, setae should be examined closely. *Monticellina* setae can be similar in thickness to the simple capillary setae of *Aphelochaeta* and the sawtooth edge may only be visible when the setae are lying at a certain angle. Several segments should be examined from different regions of the body for these modified setae. Counting the number of setae per fascicle may be useful for some species, but in species such as *Aphelochaeta bullata* Doner & Blake, 2009 the fascicle is too dense to warrant counting for every specimen encountered.

A more reliable character is overall body shape. There are subgroups within the *Aphelochaeta* such as robust body with crowded segments throughout (*Aphelochaeta marioni* (Saint-Joseph, 1894)), moniliform abdominal segments with inflated anterior and posterior ends (*Aphelochaeta monilaris* (Hartman, 1960)), and weakly expanded thorax (*Aphelochaeta guttata* Doner & Blake, 2009). It is this later group of *Aphelochaeta* with a weakly expanded thoracic region, crowded anterior segments and weakly expanded posterior region that are the most difficult to identify. Juveniles may appear to have moniliform, or beadlike abdominal segments that are not present in full-grown individuals and may be misidentified as *Aphelochaeta monilaris*. The overall body shape of the adults can resemble *Chaetozone* or *Tharyx*, especially if only incomplete specimens are present. For accurate identification, alternative tools must be utilized.

The most reliable tool for identifying various size classes and incomplete specimens of *Aphelochaeta* is methyl green staining. Allowing a specimen to rest in a concentrated solution of methyl green for 30 to 60 seconds followed by a 70% ethanol wash allows for staining of glandular patterns not otherwise apparent. Certain species retain no stain, as in *Aphelochaeta bullata* Doner and Blake, 2009. Other species stain with dark ventral banding as in *Aphelochaeta marioni* (Saint-Joseph, 1894). Still other species have distinct speckling patterns as observed in *Aphelochaeta guttata* Doner & Blake, 2009. Where species complexes exist, the methyl green pattern could be used to further exam the relationship since slight variations in patterns could be used as species level characters. Methyl green patterns have been reported for other cirratulid genera, including ventral thoracic banding as in *Monticellina acunai* Dean &

Blake, 2009, and an anterior "mask" as observed in *Tharyx kirkegaardi* Blake, 1991. Including descriptions and photographs as part of standard cirratulid species description would greatly facilitate the identification of species.

This body of work is a small step towards addressing the global issue of cirratulid taxonomy. The character states identified and expanded use of methyl green as a tool to identify known species and incomplete specimens are affordable tools that can be used in the laboratory setting to continue this work and others like it. Recognizing that new species exist in even well studied habitats such as Boston Harbor and Massachusetts Bay demonstrate that species records for "cosmopolitan" cirratulids such as *Chaetozone setosa* should be viewed with caution. There are still a vast number of bitentaculate Cirratulidae across the globe waiting to be described. By expanding the number of described species and accurately redescribing known species, the validity of the bitentaculate genera as presently defined can more accurately be assessed.

APPENDIX A

NEW SPECIES OF CIRRATULIDAE (POLYCHAETA) FROM THE NORTHEASTERN UNITED STATES

SCIENTIFIC ADVANCES IN POLYCHAETE RESEARCH
R. Sardá, G. San Martín, E. López, D. Martin and D. George (eds.)

SCIENTIA MARINA 70S3
December 2006, 65-73, Barcelona (Spain)
ISSN: 0214-8358

New species of Cirratulidae (Polychaeta) from the northeastern United States

STACY A. DONER and JAMES A. BLAKE

ENSR Marine & Coastal Center, 89 Water Street, Woods Hole, Massachusetts 02543, USA.
E-mail: sdoner@ensr.aecom.com

SUMMARY: Polychaetes of the family Cirratulidae are common components of the benthic fauna of the northeastern United States. Although several species have been treated by Blake (1991), the true diversity of northeastern Atlantic cirratulids is underestimated since species remain largely undescribed or are erroneously assigned european names. The present paper provides descriptions of three new species of *Chaetozone* and one new species of *Caulleriella*. All four of these taxa were collected as part of environmental monitoring programmes in Long Island Sound, Boston Harbor, Massachusetts Bay, and/or Georges Bank from depths ranging from 10 to 200 m. In addition to traditional observations, details provided by the Scanning Electron Microscope (SEM) and staining patterns revealed by Methyl Green are used to further define these taxa and to distinguish them from congeners. Formal descriptions of these new taxa will contribute to a larger understanding of the systematics and interrelationships of the bitentaculate Cirratulidae.

Keywords: Polychaeta, Cirratulidae. new species, New England.

RESUMEN: NUEVAS ESPECIES DE CIRRATULIDAE (POLYCHAETA) DEL NORDESTE DE LOS ESTADOS UNIDOS. – Los poliquetos de la familia Cirratulidae son componentes comunes de la fauna bentónica del nordeste de los Estados Unidos. Aunque algunas especies han sido tratadas por Blake (1991), la diversidad real de especies de cirratúlidos en ell atlántico nororiental está subestimada pues muchas especies permanecen hoy en día por describir o están erróneamente referidas a nombres de especies europeas. En este trabajo se presenta la descripcíon de tres nuevas especies de *Chaetozone* y una nueva especie de *Caulleriella*. Los cuatro taxones fueron recolectados como parte de programas de control ambiental en el estrecho de Long Island, el puerto de Boston, la bahía de Massachusetts, y/o en el Banco Georges en profundidades entre 10 y 200 metros. Para la descripción de los taxones y su caracterización frente a especies próximas, junto a las observaciones tradicionales, se aportan observaciones realizadas al Miscroscopio Electrónico de Barrido así como sobre los patrones de teñido revelados por el Verde de Metilo. Las descripciones formales de estos taxones contribuirán a mejorar el conocimiento sobre la sistemática y las interrelaciones de los Cirratulidae bitentaculados.

Palabras clave: Poliquetos, Cirratulidae, nuevas especies, Nueva Inglaterra.

INTRODUCTION

The cirratulid fauna of the nearshore and shelf habitats of the northeastern United States is rich with species with many being entirely new to science. Traditional treatment of the cirratulid fauna has resulted in the assignment of european names to local species. Several species were treated by Blake (1991), but the majority of taxa continue to be assigned either provisional or inappropriate names. Species of the genera *Caulleriella* and *Chaetozone* are collected in large numbers in water depths of less than 200 m in Massachusetts waters. Local specimens of *Chaetozone* have been identified as *C. setosa*, Malmgren 1867, the type-species, originally described from Spitsbergen in the Arctic. Recent examination of benthic infaunal samples from Boston Harbor, Massachusetts Bay, and Georges

Bank has revealed that specimens provisionally identified as *C. setosa* in monitoring programmes, actually represent three undescribed species.

Two of the three new species of *Chaetozone* are common in Boston Harbor and Massachusetts Bay, while the third is known only from shelf locations on Georges Bank. The new species of *Caulleriella* is found in nearshore habitats in Long Island Sound and Massachusetts Bay, but is more common in deeper waters on Georges Bank. Formal descriptions of these four new taxa will contribute to a larger understanding of the systematics and interrelationships of the bitentaculate Cirratulidae of the northeastern United States and the western Atlantic Ocean.

Type specimens of the four new species described in this paper are deposited in the Museum of Comparative Zoology in Cambridge, MA (MCZ) and the National Museum of Natural History, Smithsonian Institution in Washington D.C. (NMNH).

SYSTEMATIC ACCOUNT

Caulleriella venefica, n. sp.
(Figs. 1, 5B, E)

Material examined. Georges Bank, Cr. M-4 Sta. 5-9, 40°39.9'N, 67°46.7'W, 84 m, coll. 10 May, 1982, holotype (USNM 1076557); Cr. M-4 sta.5-12, 40°39.0'N, 67°46.1'W, 86 m, coll. 10 May 1982, 3 paratypes (USNM 1076558); Cr. M-5 Sta. 5-16, 40°40.6'N, 67°46.1'W, 78 m, coll. 21 Jul 1982, 2 paratypes (USNM 1076559); Cr. M-5 sta.5-22, 40°39.5'N, 67°43.3'W, 84 m, coll. 21 Jul 1982, 3 paratypes (USNM 1076560); Cr. M-6 sta.5-16, 40°40.6'N, 67°46.1'W, 78 m, coll. 19 Nov 1982, 5 paratypes (USNM 1076561); Cr. M-1 sta. 5-1, 40°39.5'N, 67°46.2'W, 84 m, coll. 6 Jul 1981, 7 paratypes (USNM 1076562)

Description. A moderately-sized species, 11-15 mm long, 0.39-0.47 mm wide for 95-105 chaetigers. Body long, thickened throughout with narrow, crowded segments. Body dorsoventrally flattened with narrow ventral groove. Colour in alcohol light tan to brown. No obvious pigmentation except dark internal area in prostomium and sometimes at its tip. Longitudinal muscles apparent along medial dorsal surface.

Prostomium elongate, narrow, apically pointed (Figs. 1A,B, 5B); eyes absent; nuchal organ, elongate lateral slit, posterior to oral opening (Fig. 5E), carried posteriorly into peristomium (Fig. 5B). Peristomium enlarged, achaetous; surmounted by prominent dorsal crest extending from posterior margin of prostomium to chaetiger 1 (Fig. 5B). Dorsal tentacles arising from posterior margin of peristomium; first pair of branchiae located on chaetiger 1, dorsal to notochaetae, continuing throughout. Dorsal tentacles thick with ciliated groove; branchiae long, thin.

Parapodia of anterior chaetigers reduced to low rounded lobes; becoming simple tori on segments with hooks. Notochaetae of anterior chaetigers arranged in spreading fascicle of 4-6 capillaries (Fig. 1E); bidentate hooks first present from chaetiger 13-14, completely replacing capillaries; two hooks per notopodium. Neuropodia with bidentate hooks from chaetiger 9–10; two hooks per fascicle in posterior segments with single capillary. Hooks of noto- and neuropodia directed toward each other *vis á vis*, occurring in pairs, with innermost hook more robust than outer one (Fig. 1C); hooks with apical end curved; apical tooth about one third as long as main fang; hood lacking (Fig. 1F). Interramal notch present on chaetigers bearing hooks. Posterior end narrow, tapering. Pygidium with two short anal cirri ventrally (Fig. 1D).

Etymology. The species name *venefica* comes from Latin, meaning "Witch" and refers to the resemblance of the anterior end to a witch's hat.

Methyl green staining pattern. Body staining more or less uniform throughout, with no distinct pattern; anterior half of prostomium staining most intensely.

Remarks. *Caulleriella venefica* has an unusually elongated prostomium and a distinct chaetal armature consisting of pairs of curved, bidentate spines that are directed medially from each ramus, (vis-à-vis). In this respect, the species resembles *Chaetozone armata* Hartman from California and another new species from off Costa Rica (Harlan Dean, personal communication). The nuchal organ of *Caulleriella venefica* differs in shape and position from *Chaetozone* species (see below). In *Caulleriella* the nuchal organ is a longitudinal slit whereas in *Chaetozone* species that have been examined, the nuchal organ is circular and has been misinterpreted as an eye by some investigators. Thus the location of the nuchal organ and its shape may be an important generic-level character in some cirratulids.

Distribution. Eastern North America: Long Island Sound, Georges Bank, Massachusetts Bay, 30-85 m.

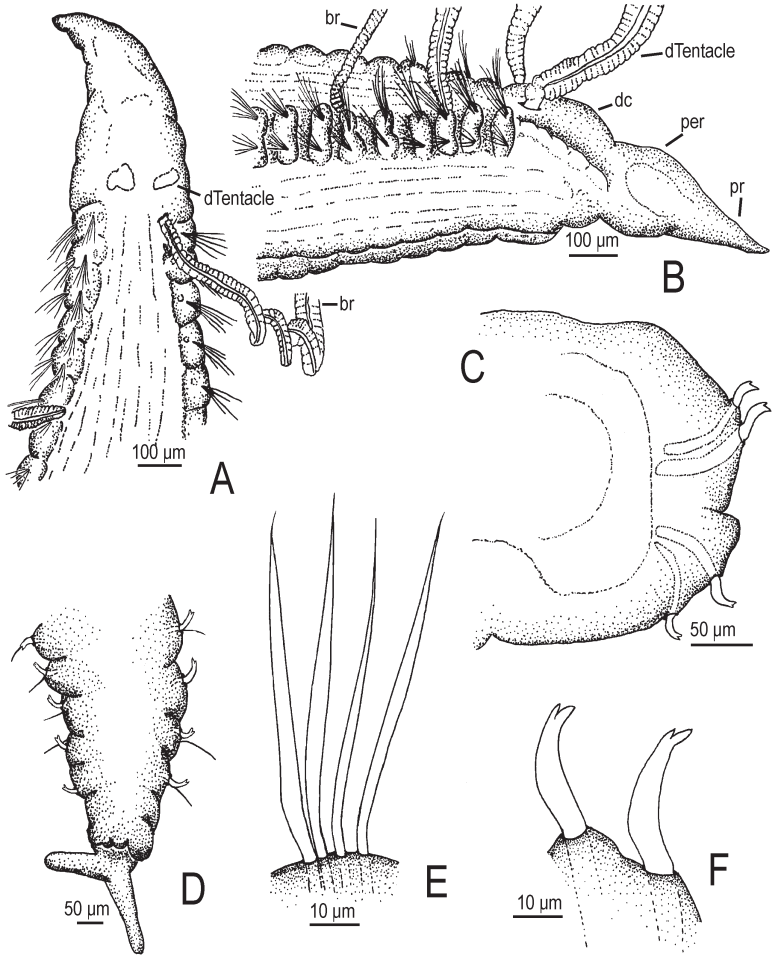

FIG. 1. – *Caulleriella venefica* (Sta. NF23-1): A, anterior end in dorsal view; B, anterior end in lateral view; C, posterior chaetiger in cross section; D, posterior end in dorsal view; E, notochaetae of anterior chaetigers; F, notopodial hooked chaetae from posterior chaetiger.

Chaetozone anasimus n. sp.
(Figs. 2, 5C, G)

*Material examined***.** Massachusetts Bay, collected August 2002; sta. FF11-1, 42°65.9'N, 70°50.0'W, 89 m, Holotype (MCZ 65293); sta. FF14-2, 42°41.7'N, 70°65.5'W, 74 m, 6 paratypes (MCZ 65294); sta. FF11-2, 42°65.9'N, 70°50.0'W, 89 m, 10 paratypes (MCZ 65295);; sta. FF04-2, 42°17.3'N, 70°25.5'W, 90 m, 6 paratypes (MCZ 65296).

Description. A moderately- sized species, 9-12 mm long, 0.5-1 mm wide for 65-75 chaetigers. Body thick, robust in anterior two-thirds, then tapering posteriorly; body segments narrow, crowded anteriorly; dorsoventrally flattened; shallow midventral groove present. Colour in alcohol light tan, lacking any distinctive body pigments.

Prostomium short, conical, pointed, usually with tip directed dorsally (Figs. 2A,B, 5C); eyes absent; nuchal organ present on lateral surface of peristomium just anterior to oral opening, appearing as longitudinal groove (Fig. 5C, G); supraoesophageal ganglion visible; peristomium with pair of dorsal tentacles; first pair of branchiae positioned laterally to tentacles. Subsequent chaetigers with branchiae dorsal to notochaetae.

Noto- and neurochaetae from chaetiger 1 all capillaries, numbering about 6–8 per fascicle; acicular spines first present from about chaetiger 50–55 in neuropodia and chaetiger 55–60 in notopodia. In the most posterior chaetigers neuropodial spines numbering 6–10, notopodial spines numbering 10-14;

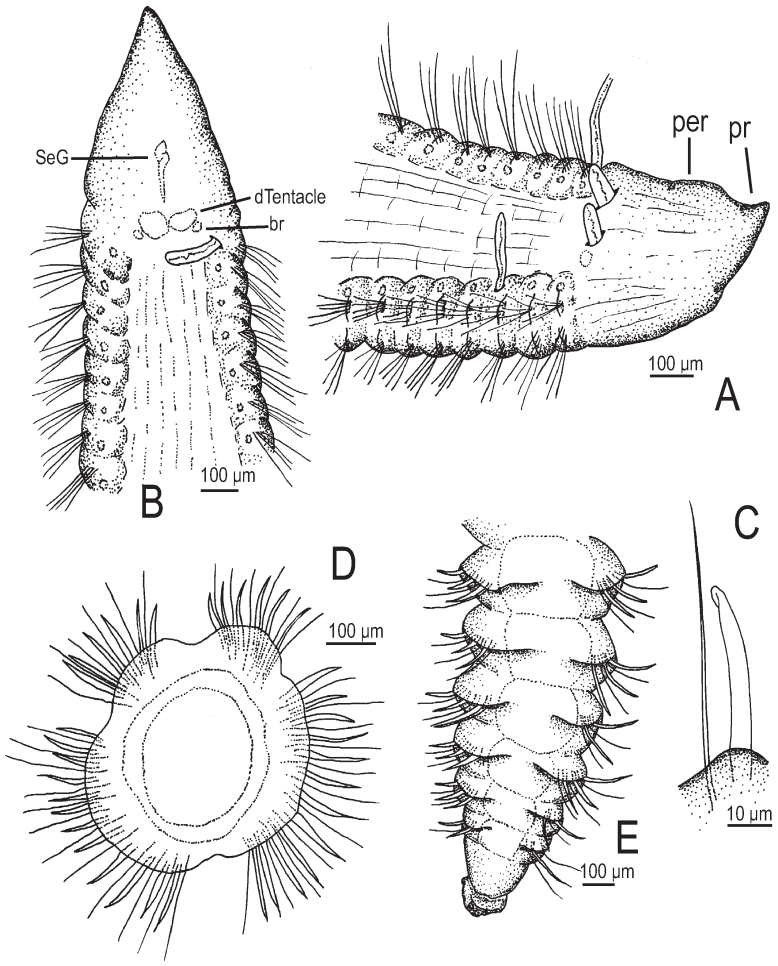

FIG. 2. – *Chaetozone anasimus* (Paratype Sta. FF14-2, MCZ 65294): A, anterior end in lateral view; B, anterior end in dorsal view; C, spine and capillary from chaetiger 60; D, cross section from near chaetiger 60; E, posterior end in dorsal view.

spines forming only a partial cincture, accompanied by alternating, thin, smooth capillaries (Fig. 2D); spines with pointed tips that bend back to touch shaft of spine (Fig. 2C), sheath apparent. Parapodia reduced to low tori from which chaetal fascicles emerge; these formed into low membranes in far posterior chaetigers bearing cinctures. Pygidium bearing ventral, cuplike lobe (Fig. 2E).

Methyl green staining pattern. Base of prostomium stains most intensely. Remainder of body staining uniformly, with no distinct pattern. Tip of prostomium not staining.

Etymology. The species name *anasimus* comes from the Latin, meaning with upturned nose and refers to the upturned prostomium.

Remarks. *Chaetozone anasimus* is found in the sediments of Boston Harbor and Massachusetts Bay along with *C. hystricosus*. Both species have in past ecological surveys been considered as one species. The presence of modified spines with tips that bend back along the shaft in *C. anasimus* distinguish it from the blunt, acicular spines of *C. hystricosus*. The bent tip on the spines of *C. anasimus* is similar to that of *C. commonalis* Blake from California.

Distribution. Eastern North America: Massachusetts Bay, Boston Harbor, 75-84 m.

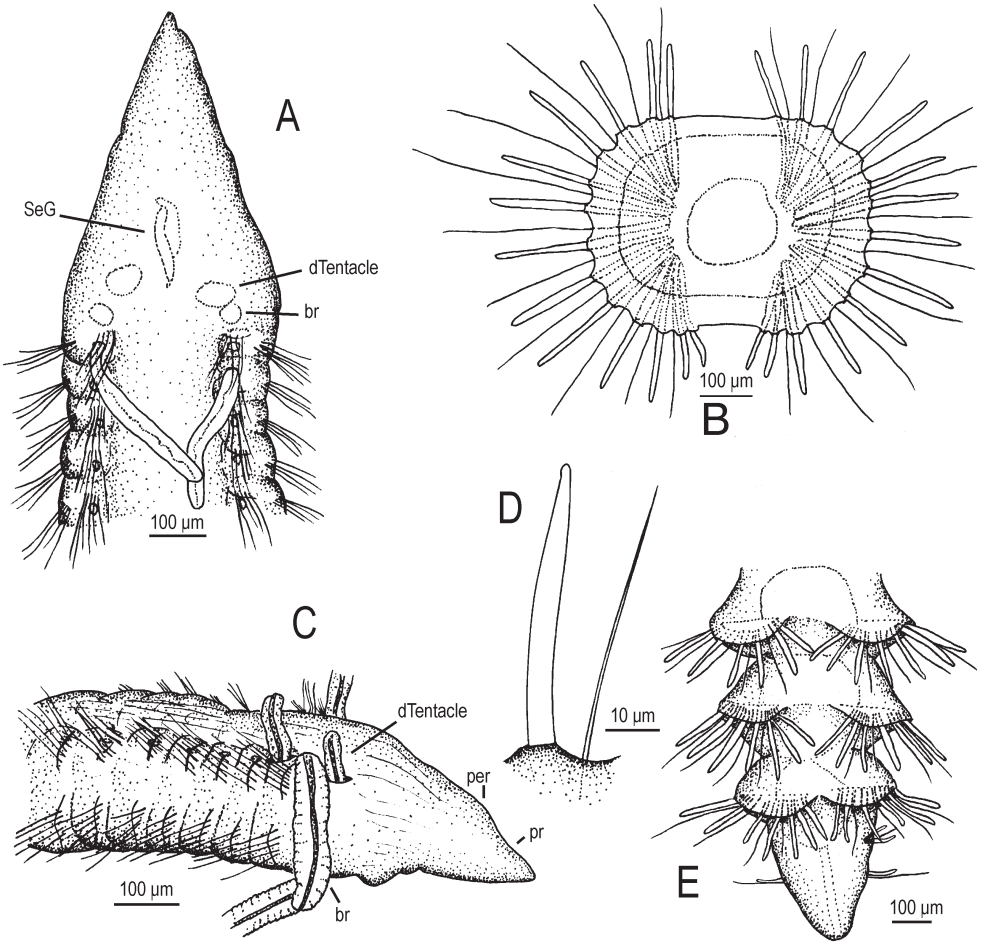

FIG. 3. – *Chaetozone hystricosus* (Paratype Sta. FF04-2, MCZ 65298): A, anterior end in dorsal view; B, cross section showing full cincture from chaetiger 69; C, anterior end in lateral view; D, spine and capillary from chaetiger 70; E, posterior end in dorsal view.

Chaetozone hystricosus n. sp.
(Figs. 3, 5A, F)

Material examined. Massachusetts Bay, sta. FF14-3, 42°17.3' N 70°25.50'W, 90 m, coll. August 2003, holotype (MCZ 65297); sta. FF04-2, 42°17.3' N 70°25.50'W, 90 m, coll. August 2002, 10 paratypes (MCZ 65298); sta. FF04-3, 42°17.3' N 70°25.50'W, 90 m, coll. August 2003, 10 paratypes (MCZ 65299).

Description. A moderately-sized species, adults 9-15 mm long 0.38-0.45mm wide for 70-80 chaetigers. Colour in alcohol light tan, lacking distinctive body pigment. Body long, somewhat dorsoventrally flattened with midventral groove; body segments crowded anteriorly, less so in posterior chaetigers.

Prostomium long, pointed at anterior end; eyes absent; ciliated, oval nuchal organs present on lateral surface of peristomium just anterior to oral opening (Fig. 5A, F); supraoesophageal ganglion visible with light microscopy (Fig. 3A); peristomium with pair of dorsal tentacles at posterior margin, with first pair of branchiae lateral to tentacles. Subsequent branchiae arising dorsal to notochaetae (Figs. 3A, C).

Noto- and neurochaetae from chaetiger 1 all capillaries, 7-9 in notopodia and 5-7 in neuropodia per fascicle; acicular spines from chaetiger 40-45 in neuropodia and 45-50 in notopodia. Anterior parapodia reduced to low tori; posterior segments separated by deeply cut intersegmental furrows with highly elevated membranous podial lobes from

which spines and capillaries emerge. In the most posterior chaetigers, acicular spines 6-7 per fascicle, forming full cincture (Fig. 3B); spines accompanied by alternating, thin, smooth capillaries; acicular spines short, thickened with blunt tips (Fig. 3D). Pygidium simple rounded lobe (Fig. 3E).

Methyl Green Staining Pattern. Body staining more or less uniformly throughout, with no pattern.

Etymology. The species name *hystricosus* comes from the Latin, meaning prickly or thorny, referring to the appearance of the spiny cinctures in posterior segments.

Remarks. *Chaetozone hystricosus* is easily confused with *C. anasimus* since they occur together in the same habitat. Examination of the anterior end reveals a circular depression identified on SEM as a nuchal organ. The nuchal organ may be misidentified as an unpigmented eye due to its presence and location on the peristomium. However, it is in fact ciliated, confirming that it is not an eye but a sensory organ. The nuchal organ is also present in *C. anasimus* but is not as readily observed. Of the *Chaetozone* species examined, *C. hystricosus* most closely resembles *C. setosa* with its full cinctures and form of the acicular spines. The main difference between these two species is the greater number of

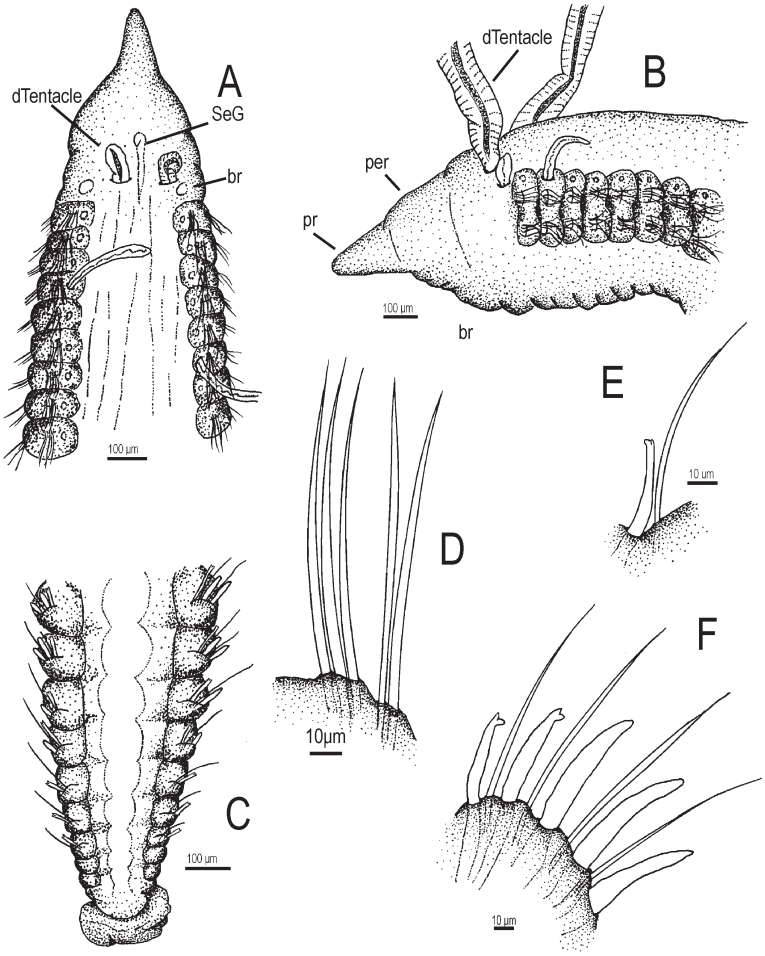

FIG. 4. – *Chaetozone diodonta* (Paratype Sta.16, USNM 1076552): A, anterior end in dorsal view; B, anterior end in lateral view; C, posterior end in dorsal view; D, notochaetae of anterior chaetiger; E, posterior spine with companion capillary chaeta; F, posterior neuropodium showing spines and hooks.

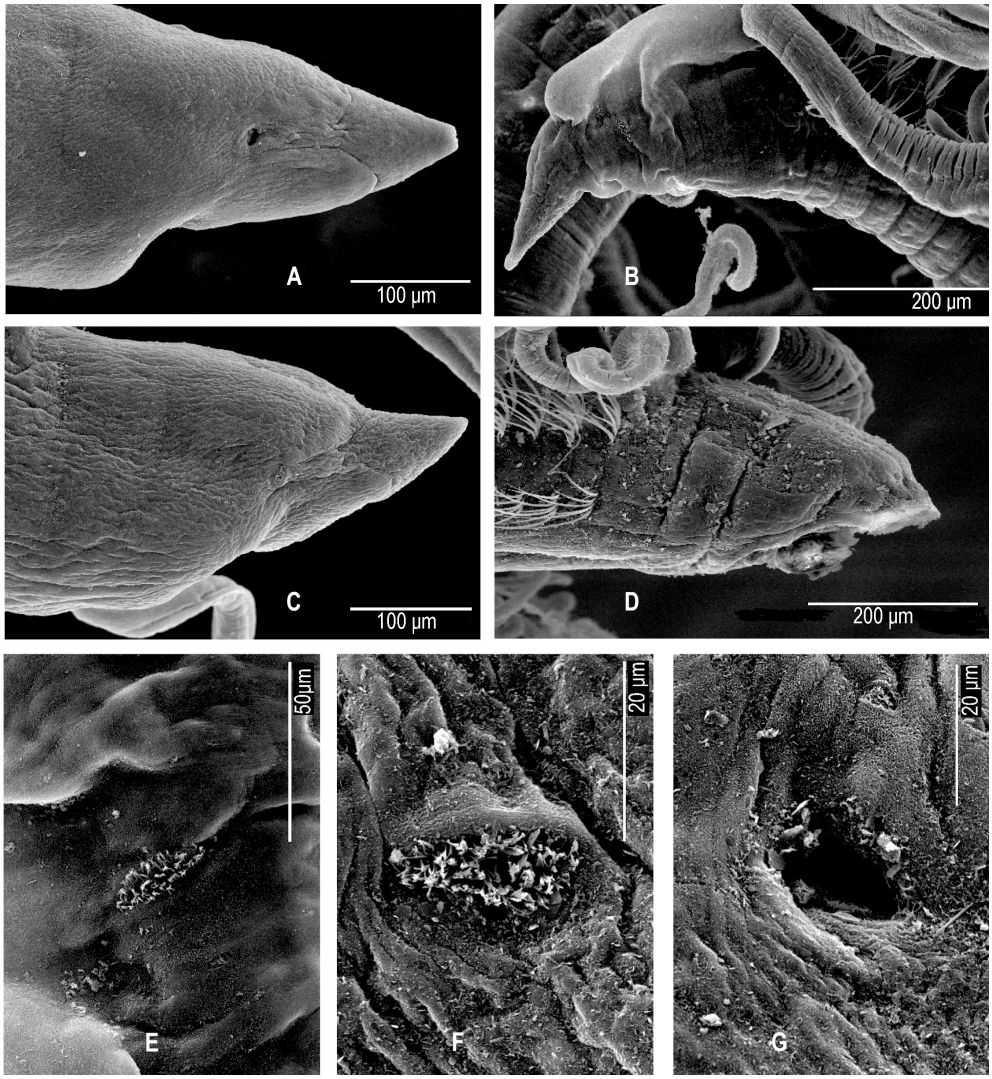

FIG. 5. – A, SEM of *Chaetozone hystricosus* showing nuchal organ location; B, SEM of *Caulleriella venefica*; C, SEM of *Chaetozone anasimus*; D, SEM of *Chaetozone diodonta*; E, close-up of *C. venefica* nuchal organ; F, close-up of *C. hystricosus* nuchal organ; G, close-up of *C. anasimus* nuchal organ.

spines, up to fifteen, that occur in the cinctures of *C. setosa*.

Distribution. Eastern North America: Massachusetts Bay, Boston Harbor, 70-100m.

Chaetozone diodonta, n. sp.
(Figs. 4, 5D)

Material examined. Georges Bank, Cr. M-6 sta.17 rep4, 40°35.0'N, 67°11.7'W, 141m, coll. 19 Nov 1982, holotype (USNM 1076549); Cr. M-3 sta.17, 40°35.0'N, 67°11.7'W, 141 m, coll. 10 Feb 1982, 5 paratypes (USNM 1076550); Cr. M-4 sta. 16, 40°34.2'N, 67°12.3'W, 142 m, coll. 10 May 1982, 4 paratypes (USNM 1076552); Cr. M-2 sta. 2, 40°59.0'N, 66°55.8'W, 79 m, coll. 09 Nov 1981, 4 paratypes (USNM 1076553); Cr. M-4 sta. 16, 40°34.2'N, 67°12.3'W, 142 m, coll. 10 May 1982, 3 paratypes (USNM 1076554); Cr. M-8 sta. 8, 40°27.1'N, 67°37.4'W, 152m, coll. 13 May 1983, 3 paratypes (USNM 1076555).

Description. A moderate-sized species, 5.8-9.0 mm long, 0.6-0.8 mm wide for 100 chaetigers. Body of uniform thickness throughout with midventral groove, dorsoventrally flattened posteriorly. Colour in alcohol light tan, lacking distinctive body pigment.

TABLE 1. – Comparative morphology for species of *Chaetozone*.

	Prostomium shape	Origin of first branchiae	Chaetal type	Origin of modified chaetae	Cinctures	No. of spines in posterior chaetigers	Pygidium
Chaetozone setosa[1]	short, conical, pointed	posterior to tentacles on peristomium	acicular spines	chaetiger 40 in neuropodia, chaetiger 50 in notopodia	full	6 to 8 in both noto and neuropodia	small, flat, rounded ventral lobe
Chaetozone anasimus	short, conical, pointed	positioned laterally to tentacles	spines w/ tips pointed, bending back to touch shaft of spine	chaetiger 50-55 in neuropodia, chaetiger 55-60 in notopodia	partial	6 in neuropodia, 12 in notopodia	cup-like ventral lobe
Chaetozone hystricosus	long, pointed	positioned laterally to tentacles	acicular spines, thickened	chaetiger 40-45 in neuropodia, chaetiger 45-50 in notopodia	full	6 to 7 in both noto and neuropodia	simple rounded lobe
Chaetozone diodonta	long, conical	positioned laterally to tentacles	bidentate hooks and robust spines	neurohooks chaetiger 11-15, notohooks chaetiger 90, neurospines chaetiger 61, notospines chaetiger 67	partial	3 spines, 3 hooks, single hook only in last 10 chaetigers	flattened, saucer-like lobe

[1.] Based on lectotype: Stockholm Museum of Natural History, No. 1493-03. (Designated by M.E. Petersen, 1999).

Prostomium conical, one-third longer than wide (Fig. 4A, B); eyes absent; nuchal organ oval, elongate (Fig. 5D). Peristomium as long as wide. Dorsal tentacles arising from posterior part of peristomium, first branchiae anterior to chaetiger 1, lateral to dorsal tentacles (Fig. 4A, B). Subsequent pairs of branchiae on following segments positioned dorsal to and slightly posterior to notochaetae (Fig. 4B).

Noto- and neuropodia reduced to low tori bearing chaetal fascicles. Notochaetae of anterior chaetigers simple, smooth capillaries, 7-8 per fascicle (Fig. 4D); robust spines from chaetiger 65-70 with addition of bidentate hooks at chaetiger 90; posterior spines not forming well-developed cinctures (Fig. 4D). Neurochaetae of first chaetigers simple capillaries, 5-6 per fascicle with transition to bidentate hooks by chaetiger 15 and addition of robust spines by chaetiger 60 (Fig. 4E, F); chaetae of last ten fascicles of body reduced to single capillary and hook. Pygidium a flattened, saucer-like, lobe (Fig. 4C).

Methyl green staining pattern. Body staining more or less uniform throughout, with no pattern; prostomium and pygidium retain no stain.

Etymology. The species name *diodonta* comes from the Greek, meaning two-toothed, referring to the presence of the bidentate hooks that accompany acicular spines.

Remarks. *Chaetozone diodonta* differs from other species found in the northeastern Atlantic in that it has both bidentate hooks and spines in its chaetigers. Typically, hooks are found in *Caulleriella* species whereas spines are found in *Chaetozone* species. The transition of the chaetae from hooks to spines and back to hooks poses some question as to the generic classification of this species. The location and shape of the nuchal organ resembles that of a *Chaetozone*. The noto- and neuropodia are also not widely separated as seen in *Caulleriella*, suggesting that it is in fact a *Chaetozone*. *C. diodonta* resembles *C. lunula,* Blake from California, with both species having spines and hooks.

Distribution. Eastern North America: Georges Bank, 100-160 m.

DISCUSSION

The bitentaculate cirratulid fauna of the northeastern United States is rich with species, yet the majority of taxa are known by inappropriate european names or provisional names assigned in local monitoring programmes. In addition, several distinct species are believed to be lumped under single names. The first effort to deal with this problem was by Blake (1991) who redefined the genus *Tharyx* and redescribed its type-species *T. acutus* Webster and

Benedict. Blake (1991) also established the genus *Aphelochaeta* and resurrected the genus *Monticellina* Laubier, both of which were assigned species formerly included in *Tharyx*. Numerous additional species of *Aphelochaeta* are known from the area and species of *Monticellina* are now believed to be more complex than reported by Blake (1991). The genera *Caulleriella* and *Chaetozone*, not included in Blake (1991), are nevertheless well represented in the nearshore and shelf sediments off New England. The four species described in this paper contribute to a larger assessment of the cirratulid fauna of the offshore regions of the western North Atlantic.

The three *Chaetozone* species reported in this paper suggest that new characters associated with segmentation patterns and branchial distribution, details of posterior spines, and placement and form of the nuchal organs may be important in developing a phylogenetic analysis of the family in general. Some of these issues, especially those dealing with anterior segmentation and branchial distribution, are considered by Blake (2006) in a companion paper in this volume. Chaetal distribution patterns and the nature of the nuchal organs are considered in more detail for the New England species (Table 1).

Chaetozone setosa Malmgren, the type species of *Chaetozone,* is well-known for the cinctured nature of its posterior acicular spines (Chambers, 2000). In this species, the spines are so numerous that there are only small gaps dorsally, ventrally, and laterally in the fascicles to indicate where the noto- and neurochaetal fascicles begin and end. For the three *Chaetozone* species described in the present paper, the cinctures are not as extreme as in *C. setosa* and there are differences in the nature of the spines and sometimes with the companion chaetae. *C. hystricosus* has well-developed cinctures, whereas *C. anasimus* and *C. diodonta* have fewer chaetae with the noto- and neurochaetal fascicles clearly distinct from one another. *C. diodonta* is the most distinctive of the group with both bidentate hooks and robust spines included among the posterior chaetae. Most species of the genus *Chaetozone* typically have only unidentate acicular posterior spines, bidentate hooks being reserved for species of the genus *Caulleriella*. A similar situation was found in *C. bansei* Blake from California (Blake, 1996). In *C. anasimus*, the tips of the posterior spines bend back and are fused with the shaft. This arrangement is known for *C. curvata* Hartmann-Schröder from Chile, *C. commonalis* Blake from shelf and upper slope depths from California, and a new deep-water species, also from California (Hartmann-Schröder, 1965; Blake, 1996; 2006). These four taxa thus appear to represent a closely-related species group within the genus *Chaetozone*.

Nuchal organs appear to vary more between genera than species. For example, nuchal organs of species of *Chaetozone* observed in this paper are small, circular or oval structures, whereas those of *Caulleriella venefica* are elongated slits. The four species of Chaetozone treated by Blake (2006) in this volume provide similar observations on nuchal organ structure. Although these observations are too few to draw larger conclusions, the structure and placement of the nuchal organs may prove useful in a phylogenetic analysis of cirratulids. In some bitentaculate cirratulids what are described as eyes are most likely nuchal organs.

ACKNOWLEDGMENTS

We are indebted to Jason Williams, Hofstra University, for preparing the SEMs. Samples from Boston Harbor and Massachusetts Bay were collected as part of the Harbor and Outfall Monitoring Program funded by the Massachusetts Water Resources Authority (MWRA). This work was supported by NSF Grant No. DEB-0118693 (PEET) to James A. Blake, University of Massachusetts.

REFERENCES

Blake, J.A. – 1991. Revision of some genera and species of Cirratulidae from the Western North Atlantic. *Ophelia*, Suppl. 5: 17-30.

Blake, J.A. – 1996. Family Cirratulidae. In: J.A. Blake, B. Hilbig and P.H. Scott (eds.), *Taxonomic Atlas of the Santa Maria Basin and Western Santa Barbara Channel. Vol. 6. Annelida Part 3. Polychaeta: Orbiniidae to Cossuridae*. pp, 263-384. Santa Barbara Museum of Natural History, California.

Blake, J.A. – 2006. New Species and Records of Deep-Water Cirratulidae (Polychaeta) from off Northern California. *Sci. Mar.,* 70S3: 45-57.

Chambers, S.J. – 2000. A redescription of *Chaetozone setosa* Malmgren, 1867 including a definition of the genus, and a description of a new species of *Chaetozone* (Polychaeta: Cirratulidae) from the northeast Atlantic. *Bull. Mar. Sci.* 67: 587-596.

Hartmann-Schröder, G. – 1965. Die Polychaeten des Eulitorals. In: Hartmann-Schröder, G. und G Hartmann, Zur Kenntnis des Eulitorals der chilenischen Pazifkküste und der argentinischen Küste Südpatagoniens uner besonderer Berücksichtigung der Polychaeten und Ostracoden. *Mitt. Hamb. Zool. Mus. Inst., Suppl.* 60: 57-167.

Petersen, M.E. – 1999. Reproduction and development of Cirratulidae (Annelida: Polychaeta). *Hydrobiologia,* 402: 107-128.

Received September 15, 2004. Accepted May 11, 2005.

APPENDIX B

TWO NEW SPECIES OF APHELOCHAETA (POLYCHAETA: CIRRATULIDAE) FROM DEEP WATER OFF NORTHERN CALIFORNIA

Zoosymposia 2: 127–137 (2009)
www.mapress.com/zoosymposia/

ISSN 1178-9905 (print edition)
ZOOSYMPOSIA
ISSN 1178-9913 (online edition)

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

STACY A DONER[1,2,3] & JAMES A BLAKE[1]

[1]*Marine and Coastal Center, AECOM Environment, Woods Hole, Massachusetts 02543, USA.*
E-mail: Stacy.Doner@aecom.com; James.Blake@aecom.com
[2]*Department of Biology, University of Massachusetts, Boston, Massachusetts 02125, USA.*
[3]*Corresponding author*

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

Accepted by N. Maciolek: 20 Apr. 2009; published: 31 Aug. 2009

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^2 Hessler-Sandia box core. The samples were sieved using a 300-µm- 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 discernable 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.

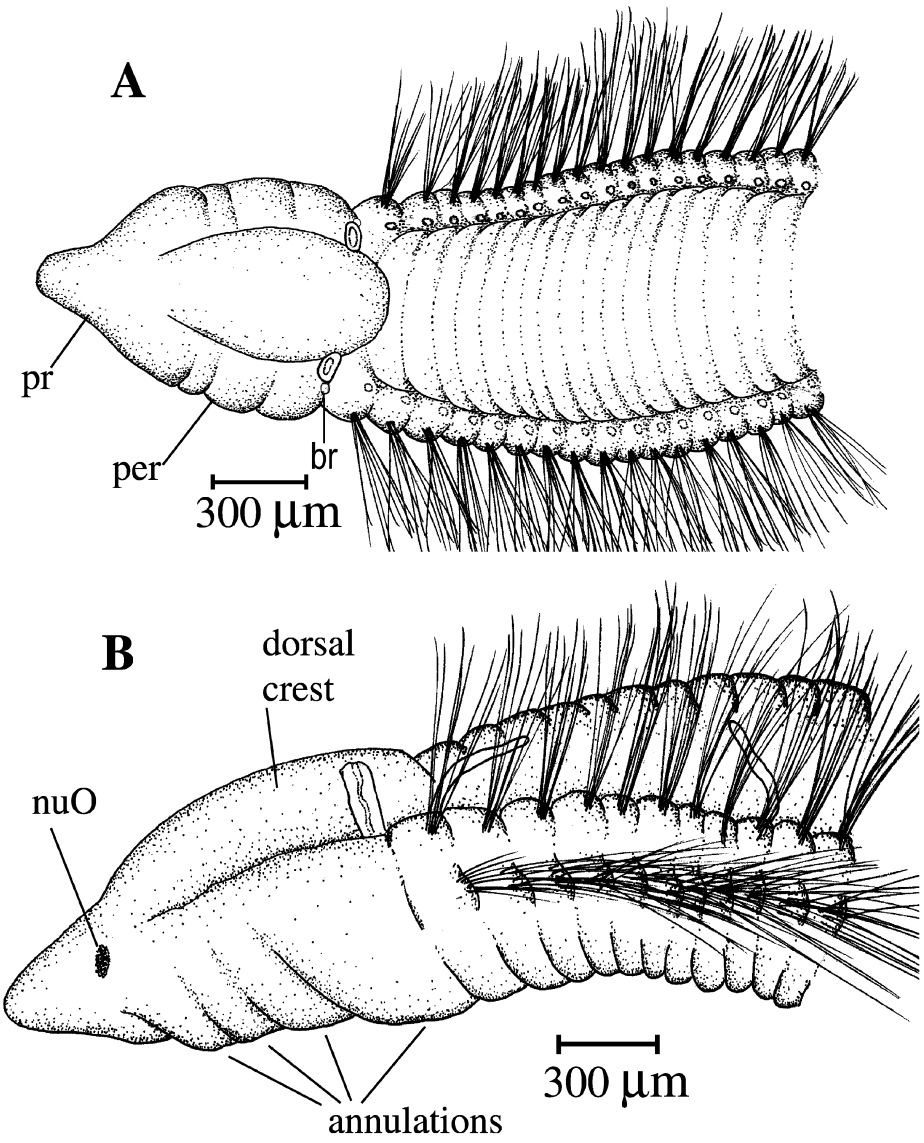

FIGURE 1. *Aphelochaeta bullata*, sp. nov. A, anterior end in dorsal view; B, anterior end in lateral view. Abbreviations: br, branchiae; nuO, nuchal organ; per, peristomium; pr, prostomium.

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.

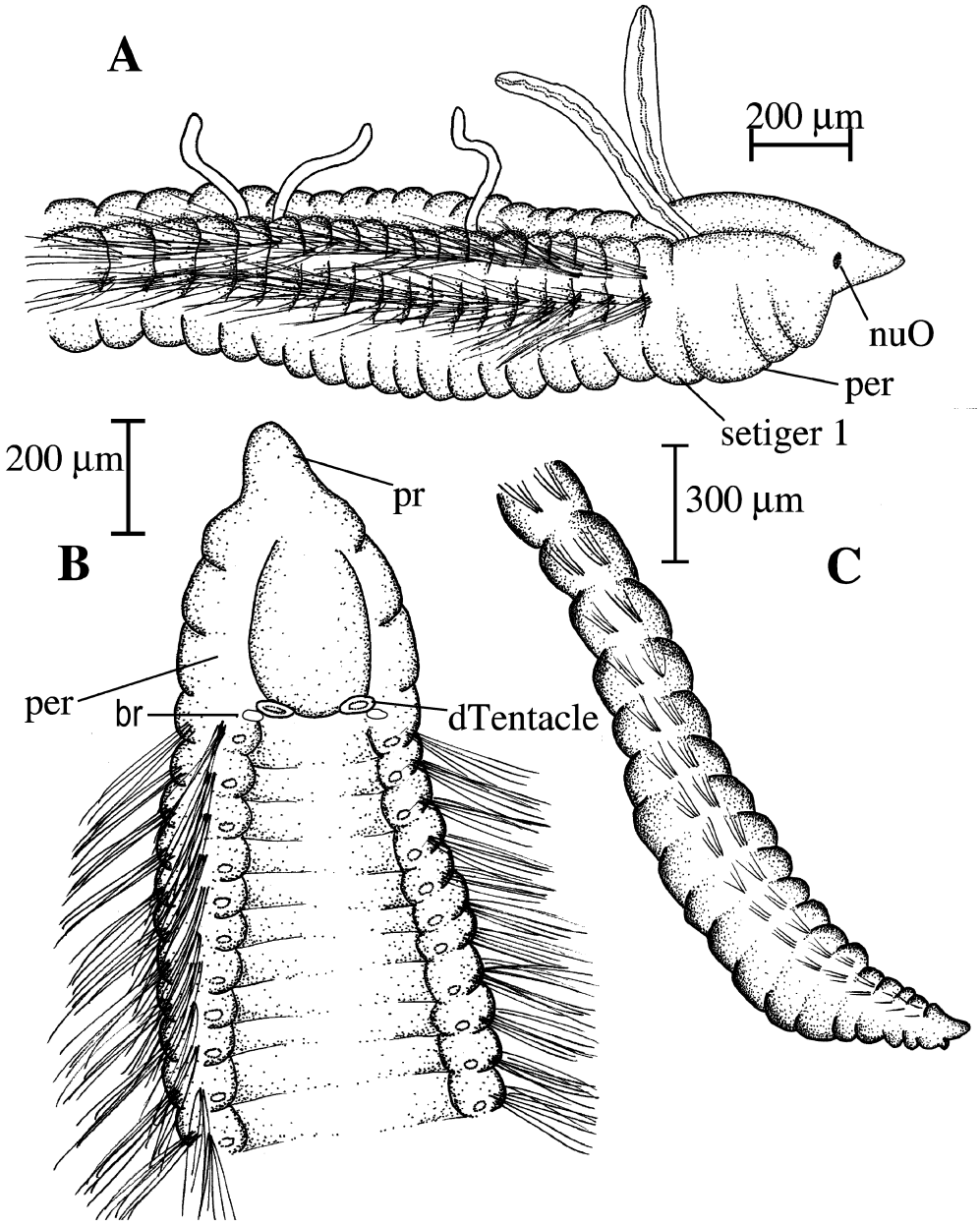

FIGURE 2. *Aphelochaeta guttata*, sp. nov. A, anterior end in lateral view; B, anterior end in dorsal view; C, posterior end in lateral view. Abbreviations: br, branchiae; nuO, nuchal organ; per, peristomium; pr, prostomium; set, setiger; dTentacle, dorsal tentacle.

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.

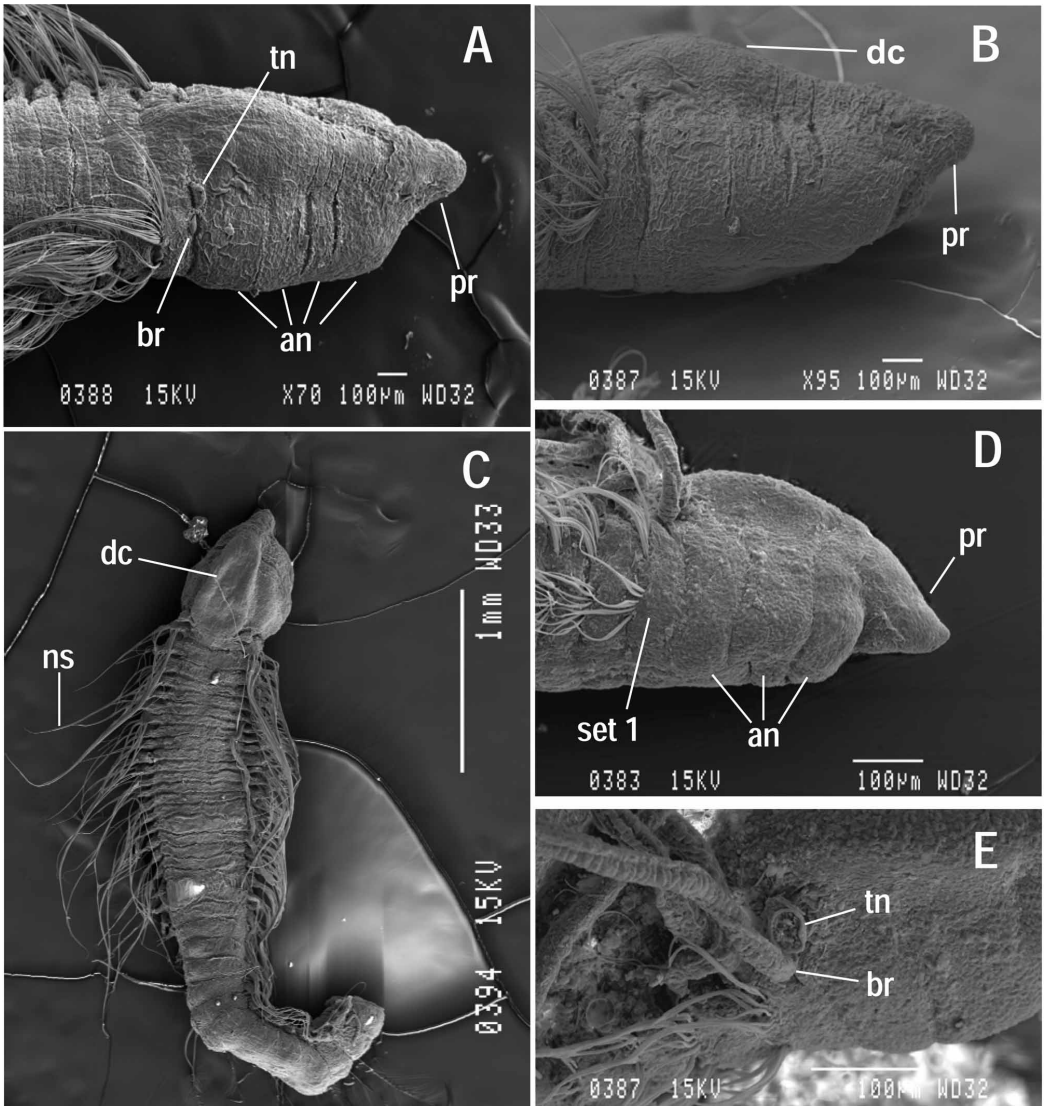

FIGURE 3. A, SEM of *Aphelochaeta bullata* sp. nov. showing peristomial annulations and position of first branchiae; B, SEM of *A. bullata* showing pronounced dorsal crest; C, SEM of *A. bullata* body profile showing elongate, natatory-like setae; D, SEM of *A. guttata* sp. nov. showing peristomial annulations; 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.

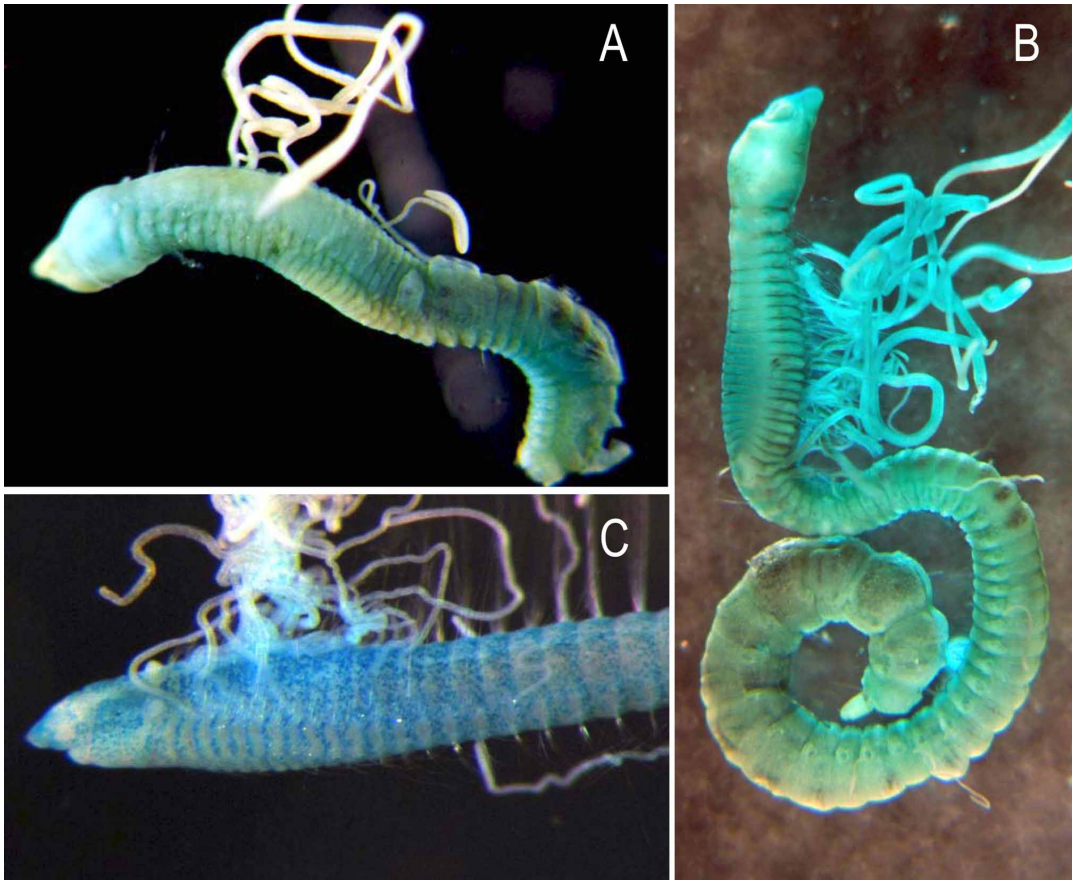

FIGURE 4. A–B, photographs of *Aphelochaeta bullata* sp. nov. showing lack of methyl green (MG) staining pattern (A, lateral view; B, ventrolateral view); C, photograph of *A. guttata* sp. nov. showing MG staining pattern, lateral view.

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 *Aphelochaeta* 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
***monilaris* (Hartman, 1960)**	2–3	Peristomium	Dorsoventrally round	Moniliform	Absent	Inflated	Ventral bands present on thorax	Shelf & slope depths
***bullata* sp. nov.**	4	Peristomium, lateral to dorsal tentacles	Dorsally round, ventrally flattened	Not moniliform	Absent	Unknown	Absent	Slope depths: 2160–3775 m
***guttata* sp. nov.**	3	Peristomium, posterolateral to dorsal tentacles	Dorsoventrally round	Not moniliform	Absent	Weakly inflated	Speckles throughout body	Slope depths: 2420–3666 m
***glandaria* 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
***phillipsi* 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
***tigrina* 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
***williamsae* 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).

Acknowledgements

The US EPA and US Army Corps of Engineers (USACE) in San Francisco provided support for

collection and analysis of samples during the SF-DODS monitoring program. We thank Mr. Allan Ota of the US EPA, Mr. Mike Donnelly of the USACE, and the crew of the *R/V Point Sur* of Moss Landing, California, for their support. We thank Lara Orensky for her assistance with the SEM. This study was supported by the National Science Foundation under Grant No. DEB-0118693 (PEET) to James A. Blake, University of Massachusetts, Boston.

References

Blake, J.A. (1991) Revision of some genera and species of Cirratulidae (Polychaeta) from the western North Atlantic. *In*: Petersen, M.E. *Systematics, Biology, and Morphology of World Polychaeta: Proceedings of the 2nd International Polychaete Conference, Copenhagen, 1986*. *Ophelia Supplement*, 5, 17–30.

Blake, J. A. (1996) Family Cirratulidae Ryckholdt, 1851. Including a revision of the genera and species from the Eastern North Pacific. *In*: Blake, J.A., Hilbig, B. & Scott, P.H. (Eds.), *Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel, Volume 6. The Annelida Part* 3. *Polychaeta: Orbiniidae to Cossuridae*. Santa Barbara Museum of Natural History, Santa Barbara, California, pp. 263–384.

Blake, J.A. (2006) New species and records of deep-water Cirratulidae (Polychaeta) from off Northern California. *In*: Sardà, R., San Martin, G., López, E., Martin, D., & George, D. (Eds.), *Scientific Advances in Polychaete Research*. *Scientia Marina*, 70S3 (Suppl. 3), 45–57.

Blake, J.A., Maciolek, N.J., Ota, A.Y. & Williams, I.P. (2009) Long-term benthic infaunal monitoring at a deep-ocean dredged material disposal site off Northern California. *Deep Sea Research II* doi:10.1016/j.dsr2.2009.05.021

Blake, J.A. & Grassle, J.F. (1994) Benthic community structure on the U.S. South Atlantic slope off the Carolinas: Spatial heterogeneity in a current-dominated system. *Deep-Sea Research II*, 41, 835–874.

Dean, H.K. & Blake, J.A. (2007) *Chaetozone* and *Caulleriella* (Polychaeta: Cirratulidae) from the Pacific Coast of Costa Rica, with descriptions of eight new species. *Zootaxa*, 1451, 41–68.

Dean, H.K. & Blake, J.A. (2009) *Monticellina* (Polychaeta: Cirratulidae) from the Pacific coast of Costa Rica with description of six new species. *Zoosymposia,* 2, 105–126.

Hartman, O. (1960) Systematic account of some marine invertebrate animals from the deep basins of Southern California. *Allan Hancock Pacific Expeditions*, 22, 69–215.

Laubier, L. (1961) *Monticellina heterochaeta* n.g., sp. nov., Cténodrilide (Polychètes sédentaires) des vases côtières de Banyuls-sur-Mer. *Vie et Milieu,* 11, 601–604.

Moore, J.P. (1903) Polychaeta from the coastal slope of Japan and from Kamchatka and Bering Sea. *Proceedings of the Philadelphia Academy of Natural Sciences*, 55, 401–490.

Moore, J.P. (1909) Polychaetous annelids from Monterey Bay and San Diego, California. *Proceedings of the Philadelphia Academy of Natural Sciences,* 61, 235–295.

Webster, H.E. & J.E Benedict, (1887) The Annelida Polychaeta from Eastport, Maine. *Reports of the United States Fish Commission for 1885*, 707–755, 8 plates.

REFERENCE LIST

Aguado, M.T., San Martin, G., & Siddall, M.E. (2012) Systematics and evolution of syllids (Annelida, Syllidae). *Cladistics* 28: 234–250.

Blake, J.A. (1991) Revision of some genera and species of Cirratulidae (Polychaeta) from the western North Atlantic. *Ophelia Supplement* 5, 17–30.

Blake, J. A. (1996) Family Cirratulidae Ryckholdt, 1851. Including a revision of the genera and species from the Eastern North Pacific. *In:* J.A. Blake, B. Hilbig, & P.H. Scott (eds). *Taxonomic atlas of the benthic fauna of the Santa Maria Basin and western Santa Barbara Channel, Volume 6. The Annelida Part 3.* Santa Barbara Museum of Natural Hisotry, Santa Barbara, California, pp. 263-–384.

Blake, J.A. (2006) New species and records of deep-water Cirratulidae (Polychaeta) from off Northern California. *Scientia Marina* 70S3 (Suppl3), 45–57.

Blake, J.A. (2015) New species of *Chaetozone* and *Tharyx* (Polychaeta: Cirratulidae) from the Alaskan and Canadian Arctic and Northeastern Pacific, including a description of the lectotype of *Chaetozone setosa* Malmgren from Spitsbergen in the Norwegian Arctic. *Zootaxa* 3919(3): 501–552.

Dean, H.K. & Blake, J.A (2007). *Chaetozone* and *Caulleriella* (Polychaeta: Cirratulidae) from the Pacific Coast of Costa Rica, with description of eight new species. *Zootaxa* 1451: 41–68.

Dean, H.K. & Blake, J.A. (2009). *Monticellina* (Polychaeta: Cirratulidae) from the Pacific coast of Costa Rica with description of six new species. *Zoosymposia* 2: 105–126.

Martin, P. (2001) On the origin of the Hirudinea and the demise of the Oligochaeta. *Proceedings of the Royal Society, London* 268: 1089–1098.

McHugh, D. (2005) Molecular systematics of polychaetes (Annelida). *Hydrobiologia* 535/536: 309–318.

Osborn, K.J. & Rouse, G.W. (2010) Phylogenetics of Acrocirridae and Flabelligeridae (Cirratuliformia, Annelida) *Zoologica Scripta* 40, 204–219.

Rousset, V., Pleijel, F., Rouse, G.W., Erseus, C., & Siddall, M.E. (2006) A molecular phylogeny of annelids. *Cladistics* 22: 1–23.

Siddal, M.E., Apakupakul, K., Burreson, E.M., Coates, K.A., Erseus, C., Gelder, S.R., Kallersjo, M., & Trapido-Tosenthal, H. (2001) Validating livanow: molecular data agree that leeches, branchiobellidans, and *Acanthobdella peledina* form a monophyletic group of oligochaetes. *Molecular Phylogenetics and Evolution* 21: 346–351.