Bathocyroe longigula spec. nov., an undescribed ctenophore (Lobata: Bathocyroidae) from the epipelagic fauna of Japanese coastal waters

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This paper presents the description of a new lobate ctenophore, *Bathocyroe longigula* (order Lobata, family Bathocyroidae) based on two intact specimens. One was collected in April 2001 at the surface in coastal waters of Ise Bay near Toba on the Pacific coast of central Japan, and the other in March 2010 at the surface in Tabira port near Hirado in Kyushu, the main southern island of Japan. The new species can be distinguished from its congeners, *Bathocyroe fosteri* Madin & Harbison, 1978 and *B. paragaster* (Ralph & Kaberry, 1950), by its long stomodaeum with a narrow dark-orange band, which extends to about mid-length of the oral lobes, and the numerous tiny, dark-orange spots of irregular shape found along its meridional canals. The differences between the three species attributed to the genus *Bathocyroe* are shown in Table 1.

Introduction

Ctenophores (Phylum Ctenophora) are carnivorous marine organisms with fragile gelatinous bodies. They are wide-spread in all waters from polar to tropical regions, but they are still very poorly known because of the difficulty in collecting them whole and preserving them intact. The phylum is divided into two classes, Nuda (or Atentaculata) and Tentaculata, depending on the presence or absence of tentacles. Nuda contains the single order Beroida whereas Tentaculata consists of six orders: Cydippida, Platyctenida, Ganeshida, Thalassocalycida, Lobata and Cestida (Harbison & Madin, 1982; Harbison, 1985), though recent research suggests that the Cydippida is polyphyletic (Podar et al., 2001).

Among the families of the order Lobata, Bathocyroidae is a monogeneric family represented by *Bathocyroe* that includes just two described species, *Bathocyroe fosteri*, originally collected from the mesopelagic zone below 200 m depth in the North Atlantic, and *B. paragaster* reported from the surface waters of the Cook Strait of New Zealand in the South Pacific Ocean. These two species of *Bathocyroe*, both possess the following features: (1) interradial canals issuing from an infundibular canal, (2) branches of paragastric canals extending to lowest edge of oral lobes, (3) subtentacular meridional canals connecting with branches of paragastric canals at lowest edge of oral lobes,

(4) substomodaeal meridional canals uniting with subtentacular canals at lower margin of oral lobes, and (5) flapping movement of the oral lobes as seen in *Ocyropsis*. Several bathocyroids, presumably undescribed species, have been observed *in situ* by zoologists using research submersibles in the North Pacific, North Atlantic and Mediterranean (e.g., Youngbluth et al., 1988; Lindsay, 2005; Lindsay & Hunt, 2005; Burton & Lundsten, 2008; Mills et al., 1996; Kitamura et al., 2008; Lindsay & Miyake, 2009), but no detailed descriptions of these taxa have been made.

In this paper, we describe a new species in the genus *Bathocyroe*, based on two intact specimens collected from the epipelagic fauna of Japanese coastal waters.

Materials and methods

Two intact specimens were examined. The first was collected on 27 April 2001 at the surface in the coastal waters of Ise Bay near Toba, Mie Prefecture, on the Pacific coast of central Japan, and photographed under a binocular dissecting microscope by the first author. This specimen was ca 26 mm in total length. Unfortunately, it disintegrated in a rearing tank two days after collection and could not be preserved. Instead, 24 photographs of it were kept for study.

The second specimen was obtained on 2 March 2010 at the surface in Tabira port near Hirado, Nagasaki Prefecture in Kyushu, southern Japan, by a staff member of the Saikai National Park Kujukushima Aquarium. This second specimen was measured and photographed (88 photos) by the second author and then shipped to the first author for examination, as recommended by the third author. This specimen was examined and photographed again by the first author (34 photos) five days after collection, and it was preserved in a solution of 2.5% buffered formalin-sea water. However, by that time most of the muscular tissue had disintegrated, and all that remained recognizable were some comb plates and the aboral portion, including the sensory organ and the stomodaeum.

All physical remains of the second specimen and all the photographs of both specimens are deposited in the type specimen collection of the National Museum of Nature and Science, Tokyo, under the registration number NSMT-Co 1544. The drawing and the description of the present species are based mainly on observations and photographs of the holotype, with supplementary information obtained from the photographs of the paratype.

Descriptive part

Bathocyroe longigula spec. nov.
(figs 1-3)

Material.— Holotype, (NSMT-Co 1544), Japan, Nagasaki Pref., Tabira port in Hirado City (NW coast of Kyushu, 33°21'N, 129°34'E), 2.iii.2010, at surface, water temperature 14.5°C, leg. Shiori Horinouchi. Paratype (cf. Materials and methods), no longer extant, Japan, Mie Pref., Toba, Ise Bay (Pacific coast of central Honshu), 27.iv.2001, at surface, leg. Takushi Horita.

Etymology.— The species name, a noun in apposition, is derived from Latin *longus*, "long", and *gula*, "throat", referring to the exceptionally long stomodaeum of this species compared with those of other species of *Bathocyroe*.

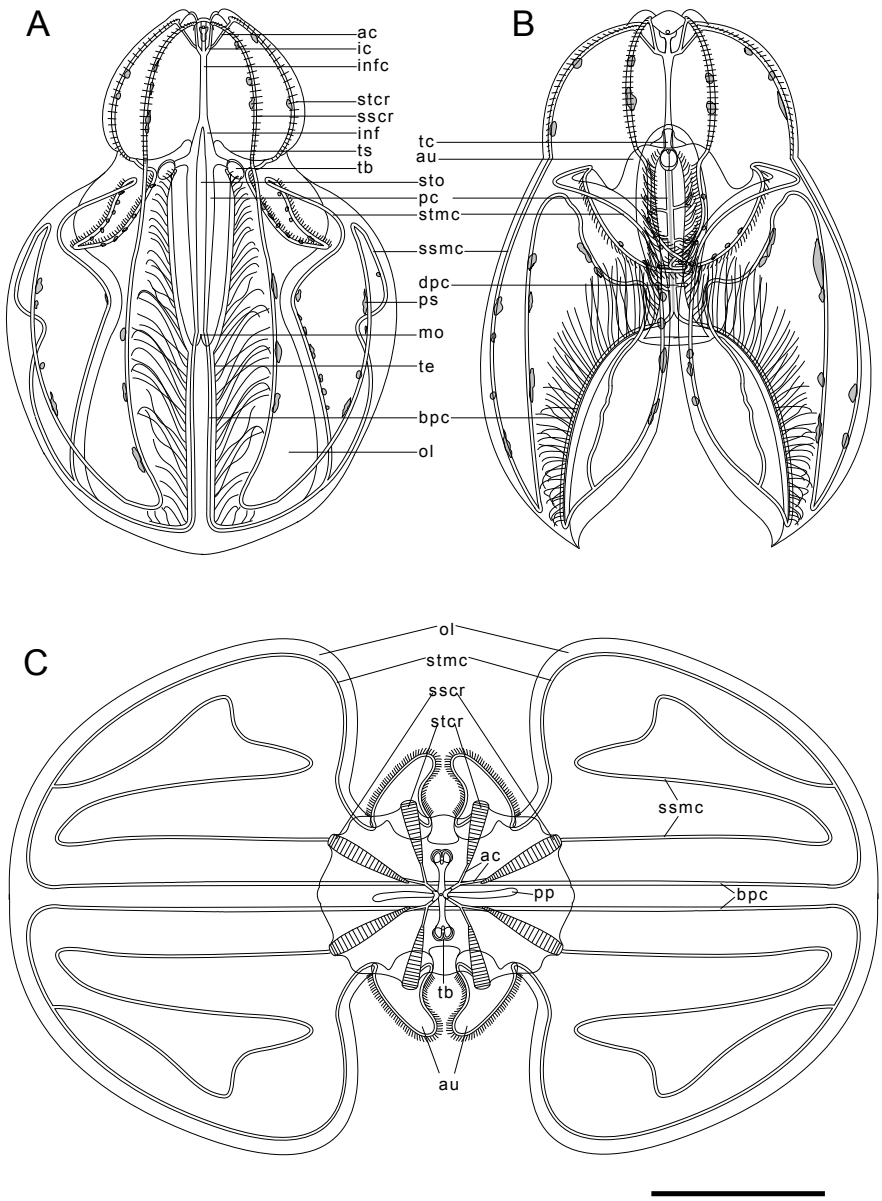

Fig. 1. Drawing of the holotype of *Bathocyroe longigula* spec. nov., viewed (A) in the tentacular plane, (B) in the stomodaeal plane, and (C) from the aboral pole. The tentacles and pigment spots are omitted in (C) to clarify the pattern of the canals in the oral lobes. Abbreviations: ac, adradial canal; au, auricle; bpc, branch of paragastric canal; dpc, diverticulum of paragastric canal; ic, interradial canal; inf, infundibulum; infc, infundibular canal; mo, mouth opening; ol, oral lobe; pc, paragastric canal; ps, pigment spot; pp, pole plate; sscr, substomodaeal comb row; ssmc, substomodaeal meridional canal; stcr, subtentacular comb row; stmc, subtentacular meridional canal; sto, stomodaeum; tb, tentacle bulb; tc, tentacular canal; te, tentacle; ts, tentacle sheath. Scale bar: 10 mm.

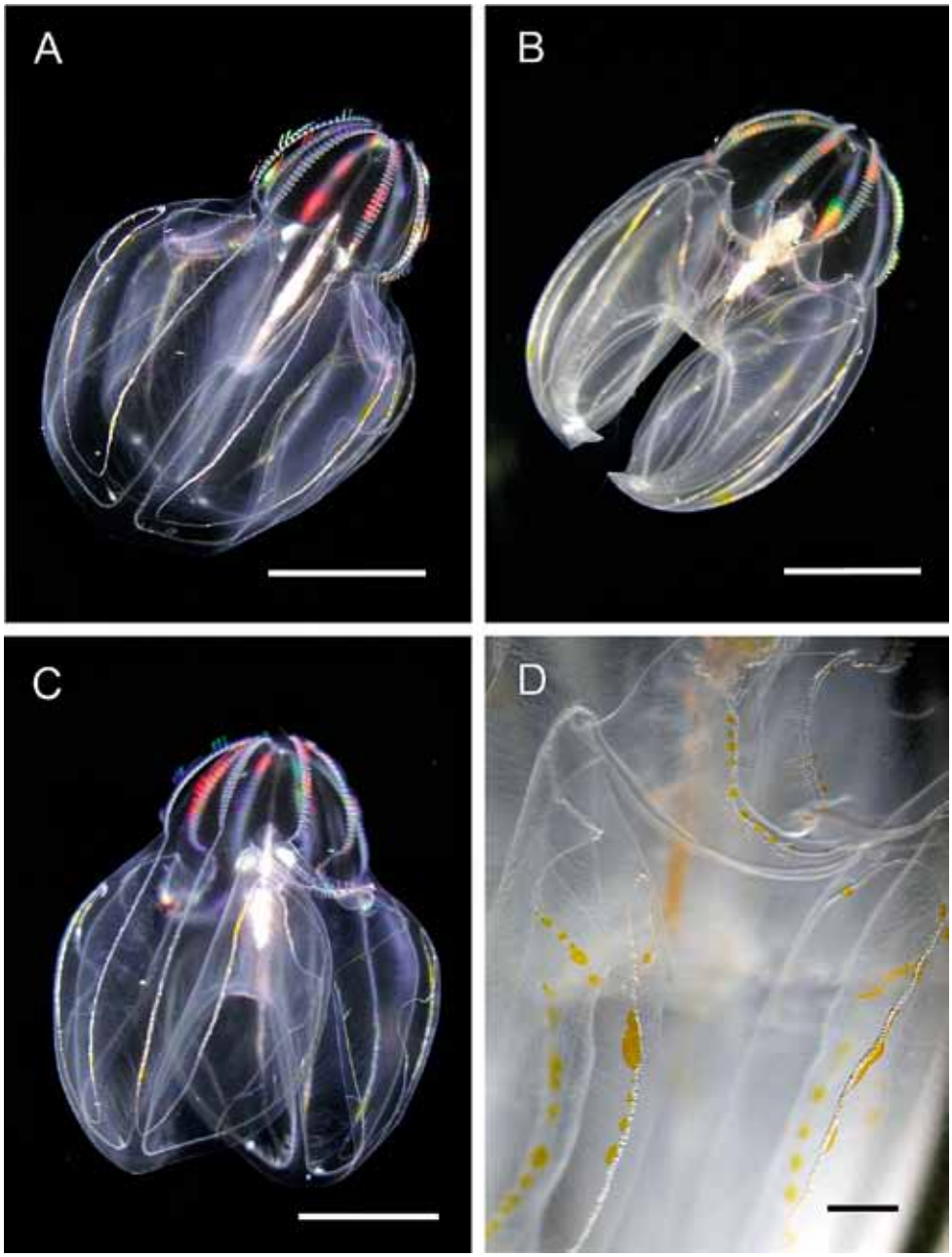

Fig. 2. Laboratory photographs of the holotype (31.5 mm in TL) of *Bathocyroe longigula* spec. nov. in life, (A) tentacular plane, (B) stomodaeal plane, (C) intersectional view between the tentacular and stomodaeal planes, (D) close-up showing the size, the shape and the distribution of the pigment spots. Scale bars: 10 mm in (A-C), 2 mm in (D).

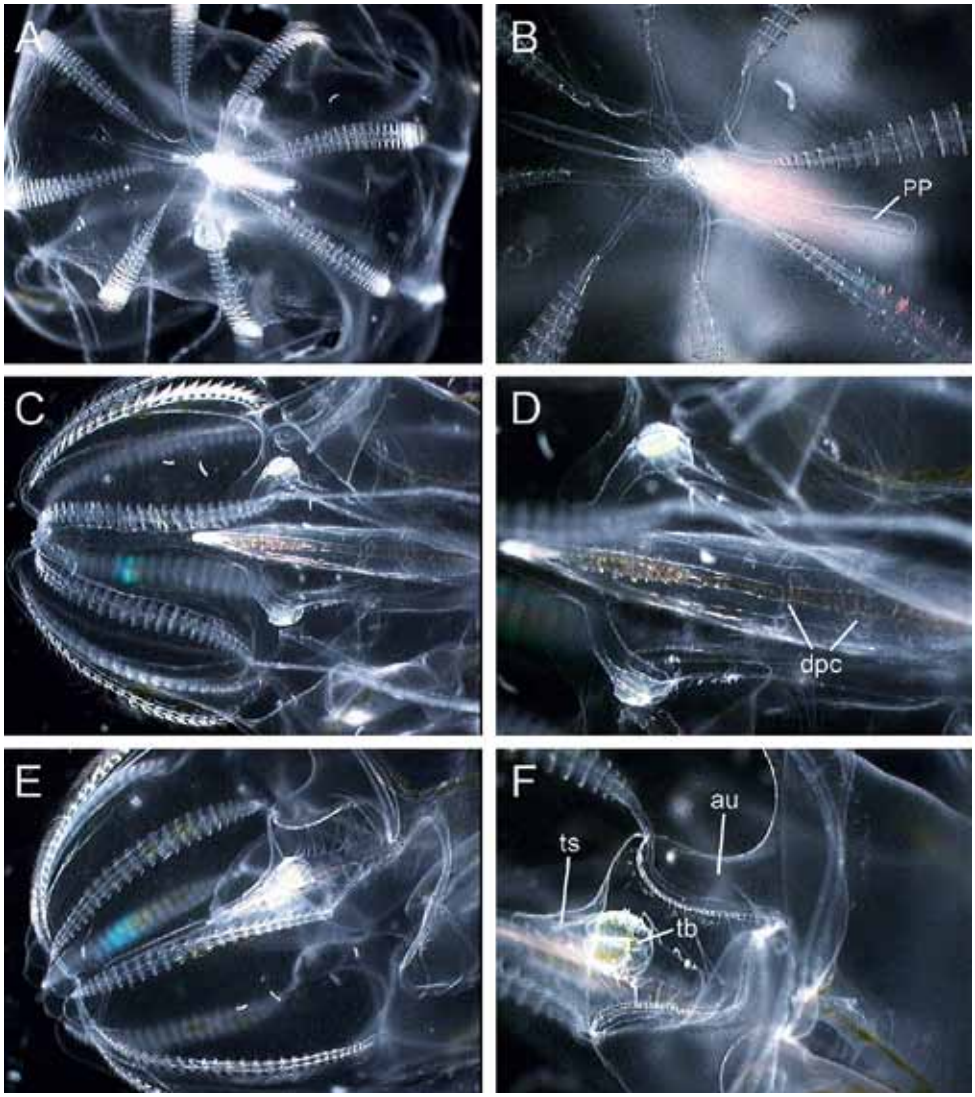

Fig. 3. Laboratory photographs of the paratype (ca 26 mm in TL) of *Bathocyroe longigula* spec. nov. in life, (A) aboral view, (B) ditto, close-up showing the pole plates (pp), (C) tentacular plane of the body, (D) ditto, close-up showing some diverticulae of the paragastric canal (dpc), (E) upper body portion viewed in the stomodaeal plane, (F) ditto, close-up showing a tentacle bulb (tb) enclosed in presumptive remnants of a tentacle sheath (ts) and an auricle (au).

Diagnosis.— Lobate ctenophore with large oral lobes and auricles. Interradial canals arising from infundibular canal. All adradial canals connected to aboral ends of meridional canals. Substomodaeal meridional canals connected orally to adjacent subtentacular meridional canals at lower margin of oral lobes. Subtentacular meridional canals united orally to branches of paragastric canals at lowest edge of oral lobes. Paragastric canals bearing blindly-ending diverticulae on each side of stomodaeum. Stomodaeum

long, extending to mid-length of oral lobes, and coloured with a narrow dark-orange band. Tentacles with simple lateral filaments and conspicuous tentacle bulbs with large double bases. Numerous tiny, dark-orange spots of irregular shape arranged along meridional canals.

Description.— Body, Oral lobes, and Auricles. The holotype is the larger specimen, 31.5 mm in total length. The body (tip of mouth to aboral pole) is slightly compressed in the tentacular axis, with the stomodaeal axis ca 1.3 times as long as the tentacular axis. The body outline is roughly circular in the tentacular plane and semi-elliptical in the stomodaeal plane (fig. 1A-B). There are 16 body ridges when viewed from the aboral pole, and the comb rows lie along eight of these (fig. 1C). The ridges are least pronounced between adjacent subtentacular comb rows.

The two oral lobes are large, comprising about two-thirds of the total length of the animal, and their bases arise at the level of the aboral one-fourth of the stomodaeum. The long stomodaeum, approximately 2.3 times as long as the infundibular canal, extends to mid-length of the oral lobes, and the mouth opens at that point (fig. 1A). Thus, the oral lobes are almost equal to the body in length.

The four auricles with ciliary combs are extremely wide with a deep bend in the base, appearing heart-shaped with a blunt tip (figs 1B, 3F). They do not reach to the mouth.

Comb Rows.— The comb rows are short and almost all the same length, reaching only to the level of the tentacle bulbs. The subtentacular comb rows end slightly above the auricles. The substomodaeal comb rows have about 32 comb plates, and the subtentacular comb rows about 30 comb plates in the holotype. The auricles possess numerous ciliary combs arranged along their edges.

Statocyst and Pole Plates.— The statocyst is slightly sunken in a small pit flanked by six ridges developed between the comb rows when viewed in the tentacular plane (fig. 1A). The pole plates are long, extending to the level of the aboral thirteenth substomodaeal comb plate in the holotype (the tenth substomodaeal comb plate in the paratype).

Tentacular Apparatus.— A pair of large and conspicuous tentacle bulbs lies to either side of the stomodaeum close to the infundibulum at the level of the oral ends of the comb rows (figs 1A-B, 2A,). Each tentacle bulb consists of an obvious double base, i.e. two enlarged swellings are present in the distal portion of each tentacular canal. The bulbs are whitish in colour, but include bright-orange-pigmented granules arranged diagonally. Each tentacle bulb is enclosed in the presumptive remnants of a tentacle sheath, which form a small pit elongated towards the infundibulum between the oral ends of the adjacent subtentacular comb rows (fig. 1A-B). The pit looks like the blind sac of *Leucothea* (cf. Chun, 1880; Mayer, 1912) or the notch noted in *Lampocteis cruentiventer* Harbison, Matsumoto & Robison, 2001 "(Deep notch present at level of infundibulum between adjacent subtentacular comb rows.)", but these latter structures do not enclose the tentacle bulbs (Harbison, Matsumoto & Robison, 2001). A pair of tentacles with numerous contractile lateral filaments arises from the tentacle bulbs. Each tentacle descends to the margin of the mouth, and then follows the branch of the paragastric canal to the lowest edge of the oral lobe where the branches of the paragastric canal meet the subtentacular meridional canal (fig. 1A).

Gastrovascular System.— The mouth opening is located in the mid-space between the oral lobes, below the tips of the auricles. The mouth has insignificant lips and does

not protrude. The stomodaeum is long and reaches to about the aboral two-thirds of the body. It appears flat when viewed in the tentacular plane and flask-shaped with the narrowest part slightly above the mouth when viewed in the stomodaeal plane, as in most other ctenophores (fig. 1A-B).

The stomodaeum leads into the infundibulum, which is laterally compressed in the stomodaeal axis, funnel-form in the tentacular plane (fig. 1A). The infundibular canal, the tentacular canals and the paragastric canals arise from the infundibulum. The infundibular canal is short, measuring about 30% of the body length, and opens aborally in the same manner as seen in the most other species of ctenophores. The tentacular canals divide bifidly in their distal portion, and dilate to form the conspicuous tentacle bulbs (fig. 1A, C). The paragastric canals with simple or branched, blind-ending diverticulae descend to near the mouth along the stomodaeum, and then each gives rise to two branches extending into the lowest edge of the respective oral lobe (fig. 1B).

Four interradial canals arise from the aboral portion of the infundibular canal, slightly below the sense organ (fig. 1A-B). Each interradial canal divides into two adradial canals, which connect to the aboral end of the meridional canals. The subtentacular meridional canals pass into the periphery of the auricles and extend along the margins of the oral lobes (fig. 1B, C). They join the branches of the paragastric canals at the lowest edge of the oral lobe. The substomodaeal meridional canals wind within the oral lobe, each forming a modified S-shape with a lower acute angle and two upper acute angles, finally connecting to the subtentacular meridional canal at the lower margin of the oral lobe (fig. 1C). This is the almost the same course as seen in *Bathocyroe paragaster* (cf. Ralph & Kaberry, 1950).

Gonads.— No trace of gonads was observed in either the holotype or the paratype.

Coloration.— The stomodaeum bears a narrow, dark-orange band extending along the oral-aboral axis. The tentacle bulbs are whitish but include bright-orange-coloured granules. In addition to these, there are numerous tiny spots, coloured dark orange (figs 1A-B, 2D), which are irregular in both size and shape and are arranged along all of the meridional canals. The distribution of these spots did not alter over the course of the five days the organism was kept in captivity. Other parts of the body are transparent and colourless.

Behaviour.— The ctenophore usually swam in the oral direction using its comb plates while also being able to swim very actively by flapping the oral lobes, as is seen in species of *Ocyropsis* (cf. Mayer, 1912; Harbison & Madin, 1982) and *Bathocyroe fosteri* (Madin & Harbison, 1978). Up to eight consecutive flapping movements of the holotype were observed in a rearing tank. This specimen fed on *Artemia* nauplii.

Parasites.— Several individuals of trematoda larva infected the gelatinous body parts in both the holotype and the paratype.

Discussion

Bathocyroidae is a monogeneric family currently represented only by two species of *Bathocyroe*, *B. fosteri* and *B. paragaster*. The latter species was originally described as *Bolina paragaster*, but was transferred to *Bathocyroe* by Madin & Harbison (1978) on account of the common possession of a unique canal pattern not seen in any other lobate genus. The common features are as follow: the interradial canals issue from the infun-

dibular canal; the branches of the paragastric canals extend into the oral lobes and connect with the subtentacular meridional canals at the lowest edge of the oral lobes; and the substomodaeal meridional canals wind simply in the oral lobes and then join the subtentacular canals at the lower edge of the oral lobes. Our specimens also share these features and thus clearly belong to this family and genus.

Bathocyroe longigula can be distinguished from *B. fosteri* by its longer stomodaeum, the more complex windings of the substomodaeal meridional canals in the oral lobes, and the course of the subtentacular meridional canals in the oral lobes. In *B. fosteri* the stomodaeum is very short, 'Stomach flask-shape, extending half-way to statocyst' (Madin & Harbison, 1978: 560), the substomodaeal meridional canal makes a simple S-shape in the oral lobes, and the two subtentacular meridional canals in each oral lobe are connected to each other at the lowest margin of the oral lobes. In addition, *B. fosteri* bears no pigment spots along the meridional canals, as seen in *B. longigula*.

Bathocyroe longigula is similar to *B. paragaster* in some respects, notably the canal pattern in the oral lobes and the conspicuous tentacule bulbs with large double bases. However, *B. longigula* can be distinguished from *B. paragaster* by the long stomodaeum, the paragastric canals with diverticulae (Ralph & Kabbery, 1950 show simple paragastric canals in Fig. II, although not mention in the text), and the numerous pigment spots arranged along all of the meridional canals.

As for the pigment spots arranged along the meridional canals in *B. longigula* they are not formed inside the canals, although they are never formed apart from the canals. *B. paragaster* is described to have mostly light-red globules inside the canals, "All the canals, but especially the paragastric canals and the tentacular canals contain

Table 1. Comparative table of the species attributed to the genus *Bathocyroe*.

Characteristics	*Bathocyroe longigula* spec. nov.	*Bathocyroe paragaster* (Ralph & Kaberry, 1950)	*Bathocyroe fosteri* Madin & Harbison 1978
Lenght of infundibular canal vs stomodaeum	1 : 2.3 (very long stomodaeum)	1 : <1 (described as "stomodaeum short, the funnel tube is long")	1 : ≤1 (described as "stomach extending half-way to statocyst")
Canal pattern at oral lobe tip			
Diverticulae of paragastric canal	Present	Absent (the authors show simple canals in Fig. II, but not mention in the text)	? (the authors make no mention at all on the basal part of the canal)
Coloration in stomodaeum	A narrow dark-orange band	Deep red-brown pigmentation	Intense red pigmentation
Coloration in other part	Numerous colored spots along meridional canals (outside canals)	Light red globules in all canals (especially paragastric & tentacular canals)	None

many tiny globules, more so than in other ctenophores. Many of those globules are coloured light red." (Ralph & Kaberry, 1950: 5). These globules, however, are probably "lipids or particles from prey", they are clearly different from the spots as seen in *B. longigula*. Those spots were found in both the holotype reared 5 days after collecting and the paratype just after collecting, but the globules were not found in the paratype. Thus, we consider the spots seen in *B. longigula* to be a specific feature. Moreover, the two known species have deep red-brown or intense red pigmentation of the stomodaeum (Ralph & Kaberry, 1950; Madin & Harbison, 1978). *B. longigula* only bears a narrow dark-orange band in the stomodaeum, as a striking difference. Table 1 shows the differences between the three species attributed to the genus *Bathocyroe*.

Bathocyroe fosteri was described from the mesopelagic zone of the North Atlantic Ocean, below a depth of 200 m and at water temperatures below 11°C, whereas *B. paragaster* was from surface waters of the Cook Strait near New Zealand in the South Pacific Ocean. Several bathocyroids, presumably undescribed species, have been observed from research submersibles in the North Pacific, North Atlantic and Mediterranean (e.g., Youngbluth et al., 1988; Lindsay, 2005; Lindsay & Hunt, 2005; Burton & Lundsten, 2008; Mills et al., 1996; Kitamura et al., 2008; Lindsay & Miyake, 2009). One of them (Kitamura et al., 2008: 325, fig. 25.13) remarkably resembles *B. longigula* in the outline of its body and its long stomodaeum. Nevertheless, no detailed description of a similar animal based on captured live specimens has been made.

Our specimens seem to be sexually immature since no trace of gonads was found. Nonetheless, they are not larval forms but evidently adults, inasmuch as Ralph and Kaberry (1950) described a cydippid larval stage of *B. paragaster*. Thus we consider *B. longigula* to be the adult form of a new species in the genus *Bathocyroe*.

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