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External Morphology of the Posterior End, the "Opisthosoma", of the Beard Worm *Oligobrachia mashikoi* (Pogonophora)

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ABSTRACT—The entire length of the beard worm, *Oligobrachia mashikoi* (Pogonophora), including the posterior end, the "opisthosoma" was collected successfully. This species is exclusive to Tsukumo Bay in Ishikawa Prefecture, Japan. Although the portion preceding the opisthosoma was similar to a fine filament, it abruptly assumed a shape similar to a shovel and appeared to be composed of many segmental structures. The number of segments exceeded 50. The dorsal side of the opisthosoma differed from that of the ventral side in morphology. The opisthosoma was equipped with 4 lines of setae arranged longitudinally and a sucker on the tip. When considering the fact that the Family Oligobrachiidae is the most primitive group of pogonophores, the external morphology of the opisthosoma is interesting as it may be reminiscent of the ancestral condition. This is the first report of the opisthosoma in Oligobrachiidae.

Key words: Pogonophora, beard worms, opisthosoma, external morphology

INTRODUCTION

In general, pogonophores live in self-made tube that is about 1 mm in diameter. Pogonophores inhabit cold and abyssal ocean habitats. They lack a mouth, digestive tract, and anus. When out of the tube, their body length is between 2, 3 and 10 cm, and the body width is 0.6–0.8 mm. Therefore, they are very slender worms. The anterior end of the body is equipped with tentacles referred to as a "beard". The number of tentacles varies from species to species. Knowledge of pogonophores is summarized in a monograph by Ivanov (1963) and reviews by Southward (1971, 1993). Southward (1993) states that pogonophores live on symbiotic bacteria. More than 100 species of pogonophores have been identified from the seas of the world. It is surmised, however, that there are still more than 50 unidentified species (Southward, 1971). Usually, specimens of pogonophores are collected using dredges or trawling gear. As a result of the use of these devices, however, most of the specimens lose the posterior end of the body because their bodies are so slender and fragile. Therefore, it is very difficult to collect specimens including the posterior end, "opisthosoma". The opisthosoma is known in only 11 species: *Siboglinum fiordicum* (Webb, 1964a, 1965), *S. ekmani* (Webb, 1964b), *S. caulleryi* (Ivanov, 1964), *S. longicollum* (Southward and Brategard, 1968), *S. poseidoni* (Flügel and Langhof, 1983), *Choanophorus indicus* (Bubko, 1965), *Polybrachia canadensis* (Southward, 1969), *Sclerolinum minor*, *S. major*, *S. magdalenae*, and *S. brattstromi* (Southward, 1972). Although all opisthosoma of these species have a segmental structure with a regular arrangement of setae, there are some differences from species to species. Therefore, the opisthosoma is an important characteristic for the identification of species in pogonophores.

In the Tsukumo Bay of the Noto Peninsula in Ishikawa Prefecture, the shallow sea bottom is bathed by warm current flows. One species of beard worms, *Oligobrachia mashikoi*, inhabits the area (Imajima, 1973). Water temperature ranges from 9°C in winter to 23°C in summer. This environment differs in the water temperature of Scandinavia (8–18°C), where Nordic pogonophores are often collected (Southward, 1971). The entire body of the Tsukumo Bay species, including the opisthosoma, was collected for the

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first time using a newly designed dredger. Although the fundamental features of the opisthosoma of this species are similar to those of others described so far, some characteristics are clearly different. The results are reported here.

MATERIALS AND METHODS

We collected beard worms on Oct. 23, 2002. In Tsukumo Bay, the present species is found at 24.5 m depth and not in the deepest area, 26.5 m. The mud in this area has the characteristic odor of hydrogen sulfide.

A dredger was devised specifically for this work. It was a box-type (40×40×70 cm), and made of 7 mm-thick iron (Fig. 1). At the bottom, iron gratings of 1cm in diameter were mounted, as shown in the picture, and a plastic net lined the gratings. On 4 faces near the top of the dredger, lead plates (each 5 kg) were attached as a sinker. In total, the weight of the dredger was about 80 kg on land. To take a sample, the dredger was suspended upside down in the sea at 5 m above the sea bottom. After swinging of the dredger stopped, the dredger was dropped toward the sea bottom where it stuck in the mud. The rope was then pulled with a winch, which was fixed previously to the top of the dredger. By this action, the dredge was rotated in the mud and turned upright while retaining inside the mud containing the beard worms. One entire specimen, including the opisthosoma, was collected.

The worm was pushed out from its tube into the seawater using a syringe, and was observed to be alive under a binocular dissecting microscope. After anesthetizing with menthol, the worm was fixed and kept in 4% seawater formalin. During observation of the external morphology under the microscope, the specimen was displaced into 70% alcohol solution. We also observed the opisthosoma fixed with 4% seawater formalin using a scanning electron microscope (Hitachi S3000N), under the conditions of 25 K voltage and 50 Pa vacuum rate. However, the specimen was immersed in absolute alcohol for 10 min just before taking pictures to remove salts precipitated from seawater.

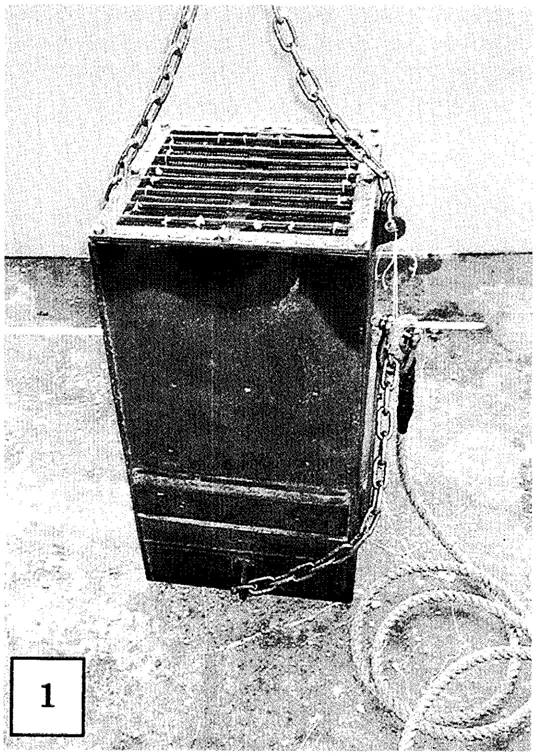

Fig. 1. Photograph of the dredger used in this study. In this photograph, the dredger is upside down. The dredger was suspended in this position temporarily at 5 m above the sea bottom. When the dredger stopped swinging, it was dropped down to the sea bottom in this upside-down position. The dredger stuck in the mud at the bottom. Then, the rope attached to the side of the dredger was pulled by a winch in order to rotate the dredger in the mud. The dredger with specimens was lifted from the mud in the upright position onto the research ship.

RESULTS

Observation of the living specimen

The whole length of the specimen from head to tail and an enlarged view of the opisthosoma are shown in Figs. 2 and 3, respectively. Since beard worms have a large quantity of hemoglobin in their blood, the opisthosoma was vividly red. The tip of the opisthosoma was equipped with a sucker (Fig. 4). This sucker could be drawn deeply into the opisthosoma. During this motion, the opithosoma appeared bifid. Under low magnifications, the opisthosoma had the form of an elongated shovel. Under higher magnifications, however, it could be seen to have many crinkles (Fig. 3), and the space between the crinkles could be stretched and shrunk freely.

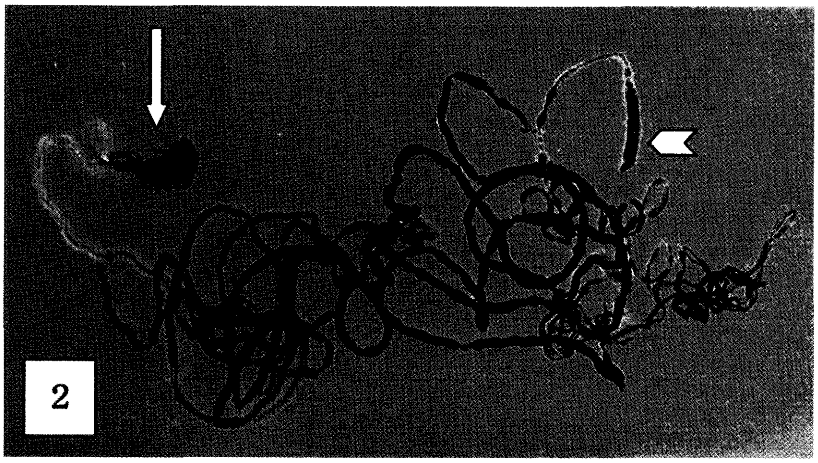

Fig. 2. Whole length of the specimen from head to tail. The arrow indicates the head, in which the “beard” grows, and the arrowhead shows the body end, “opisthosoma”. Although the body is curled in a complicated shape, this is only one individual. The body length is about 13cm (depending on the conditions of anesthesia). The body width is about 0.6–0.8 mm.

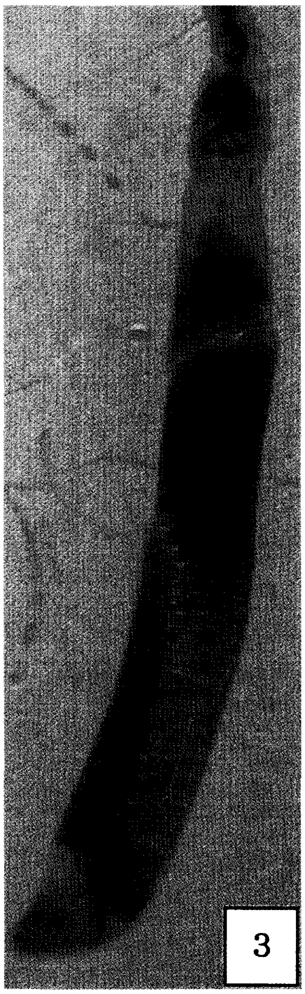

Fig. 3. Live opisthosoma before fixation. Note that it has many crinkles (segmental structures).

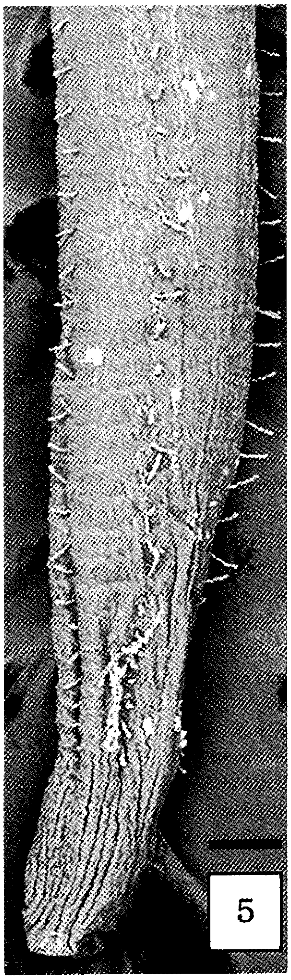

Fig. 5. Scanning electron micrograph of the opisthosoma. Bar, 100 μm.

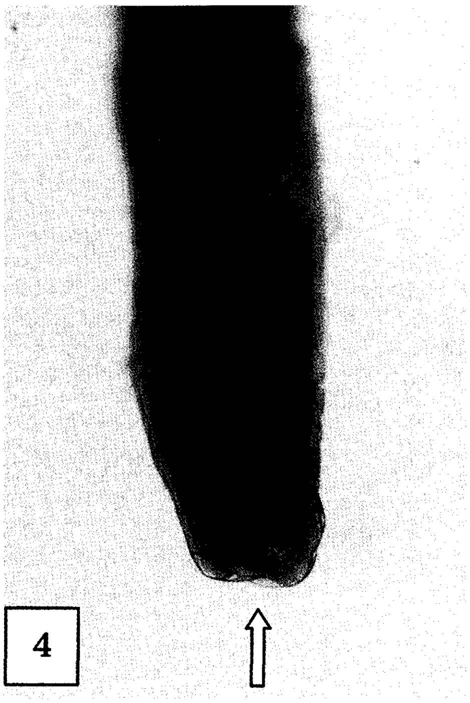

Fig. 4. Tip of a live opisthosoma. Note that it has an open identified as a "sucker" (arrow).

Fig. 6. Scanning electron micrograph showing a seta. Bar, 10 μm.

Observation by the scanning microscope

A picture of the opisthosoma is shown in Fig. 5. The opisthosoma was clearly composed of segmental structures. The boundaries among segmental structures looked black lines. On the surface throughout the opisthosoma, fine longitudinal crinkle pattern was recognized, which may reflect the presence of chitin. Setae were arranged longitudinally in 4 lines. The surface of setae was smooth, and the top was round and somewhat swollen (Fig. 6).

Observation using a dissecting microscope

The fixed opisthosoma was observed at 80 × magnifi-

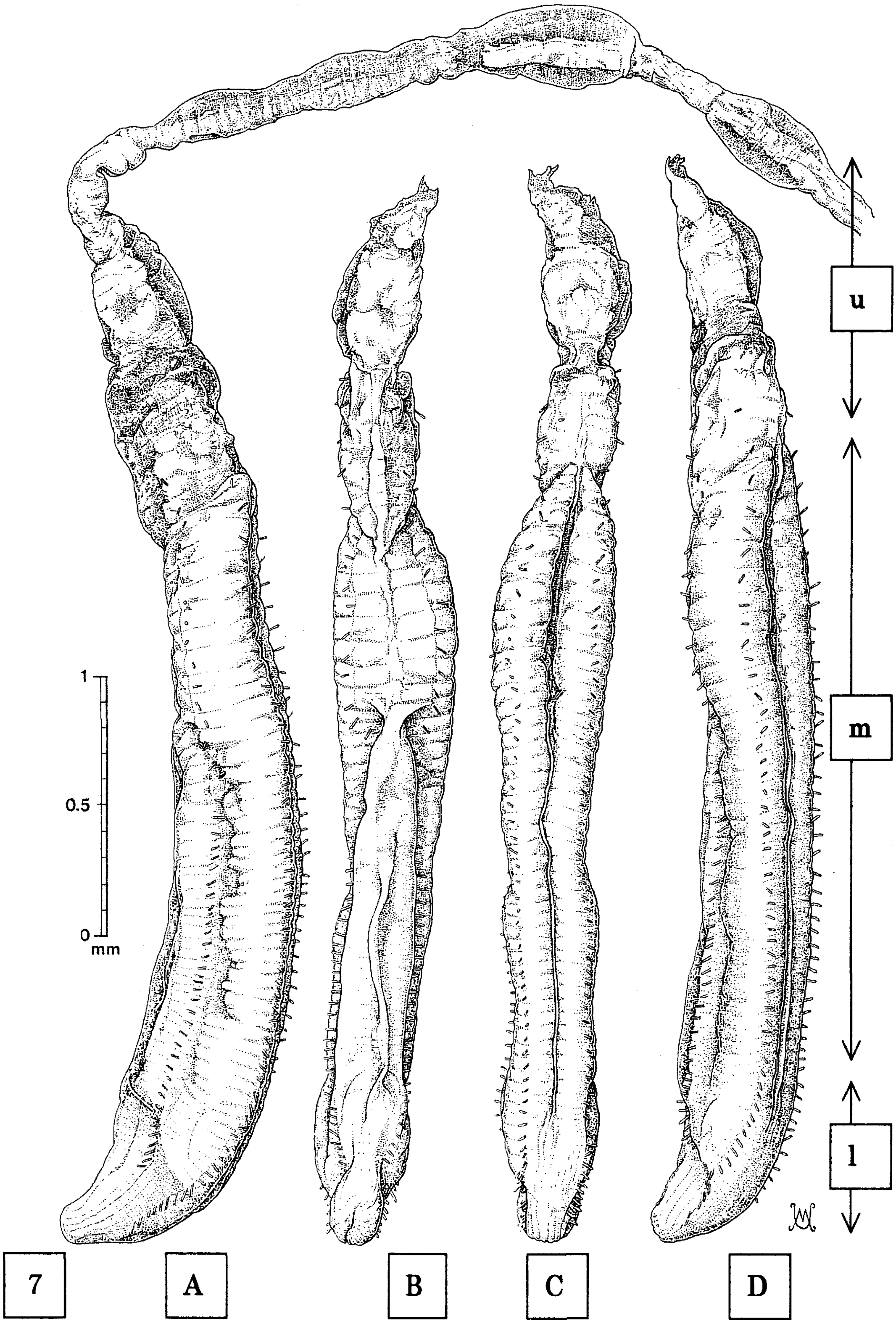

Fig. 7. Illustrations of the opisthosoma. A. Ventral side viewed laterally. B. Ventral side viewed frontally. C. Dorsal side viewed frontally. D. Dorsal side viewed laterally. u: upper region; m: middle region; l: lower region.

cation (Fig. 7). The body just preceding the opisthosoma was like a fine filament with a diameter of 0.2–0.3 mm. However, the opisthosoma abruptly thickened and elongated into the shape of a shovel that was somewhat bent. Although setae line on one side was succeeded by the end of opisthosoma, on the other side the line ran out before the end. Therefore, the side with the setae near the end was determined to be dorsal, and the opposite side as ventral, as according to examples of annelids. The opisthosoma has three characteristic regions, as described below.

The upper region appeared to be segmental structure. However, the metamerism was not clear (Fig. 7C, D). The length and width of this region were about 1 and 0.5 mm, respectively. In the upper region, the setae were arranged irregularly. It is not clear whether this irregularity is due to an artifact introduced during sampling.

The middle region of the opisthosoma showed clear metamerism. The length of this region was about 2.7 mm, and the width 0.35–0.5 mm. Forty segments were counted in this structure (Fig. 7C, D). Each segment had four setae at four specific points, two on the dorsal and two on the ventral sides. Each seta seemed to be aligned longitudinally. There was a definite groove in the central part of the dorsal side (Fig. 7C). On the other hand, on the ventral side, there was a bulge-like structure running longitudinally from the eleventh segment to the end of the opisthosoma (Fig. 7B). In this bulge, segmental structure was not clearly observed.

In the lower region, metamerism became unclear again. The length and width of this region were 0.7 and 0.35 mm, respectively. The end had a sucker (Fig. 7B), which looked like a longitudinal sinus. Many longitudinal crinkles were observed near the sucker (Fig. 7A). The dorsal line of setae was longer than the ventral line.

DISCUSSION

Before the development of pogonophores was understood, beard worms were assumed to be members of deuterostomes, since the side in which the nervous system runs longitudinally was regarded as the dorsal side (Ivanov, 1963). When the opisthosoma was found in some species, it was discovered that the morphology of the opisthosoma resembled that of annelids (Webb, 1964a, b, 1965; Flügel and Langhof, 1983). In addition, the development of beard worms was also reported (Bakke, 1977). In the larvae of *Siboglinum poseidoni*, it was shown that a transient mouth and digestive tract were formed (Callsen-Cencic and Flügel, 1995), and these temporary organs were examined under the electron microscope (Callsen-Cencic and Flügel, 1995). Furthermore, it was reported that the amino acid sequence of subunits of the hemoglobin of tube worms, which are another group of Pogonophora, resembles that in annelids (Suzuki *et al.*, 1989). Therefore, pogonophores are now considered to be phylogenetically close to annelids and related phyla (Southward, 1993).

In general, external characteristics of the present species are not different from those of other beard worms, as described by Imajima (1973). In all species in which the opisthosoma has been identified so far, the number of segments has been counted. In six species: *Siboglinum caulleryi* (Ivanov, 1964), *S. longicollum* (Southward and Brattegard, 1968), *S. poseidoni* (Flügel and Langhof, 1983), *Sclerolinum brattstromi* (Southward, 1972), *S. minor* (Southward, 1972), and *S. major* (Southward, 1972), the opisthosoma is composed of 6–8 segments. *Siboglinum fiordicum* and *Choanophorus indicus* has 13–18 segments (Webb, 1964a; Bubko, 1965). In addition, in *Siboglinum ekmani* (Webb, 1964b) and *Scleroninum magdalenae* (Southward, 1972), the number is similar, 17 and 18–20, respectively. In *Polybrachia canadensis*, the opisthosoma is composed of the greatest number of segments described so far, 25 (Southward, 1969). In the present species, *Oligobrachia mashikoi*, however, the number of segments exceeded 40, even in the middle region of the opisthosoma, and was surmised to be over 50 in total in the upper, middle and lower regions. The Family Oligobrachidae is the most primitive group of Pogonophora (Ivanov, 1963). Therefore, the large number of segments of the opisthosoma in this species may reveal a primitive condition, inherited from an ancestor such as annelids.

It is known that in one species (*Riftia pachyptila*) of tube worms, the part corresponding to the opisthosoma is composed of 30 segments (Jones, 1985). In addition, only this part has setae regularly. Therefore, this morphology in tube worms to be rather similar to that in beard worms, in spite of the facts that the "beard" part is regarded as homologue to "obturaculum" with branchiae, and that external appearance of tube worms is quite different from beard worms. Therefore, in both groups, the part of opisthosoma may leave common ancestral morphology.

The opisthosoma has been regarded as a kind of anchor to fix the body to the sea bottom (Webb, 1964a, b). The motions of the opisthosoma under the dissecting microscope, however, match the suggestion that this organ is a tool to actively dig the sea bottom (Southward, 1971). In the opisthosoma obtained in this study, there were some morphological differences between the dorsal side and the ventral one. On the ventral side, there was a bulge-like ridge. It is not certain whether this structure is characteristic of this single specimen alone, pahaps an artifact resulting from the time when the opisthosoma was fixed, since this was the only one individual obtained.

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