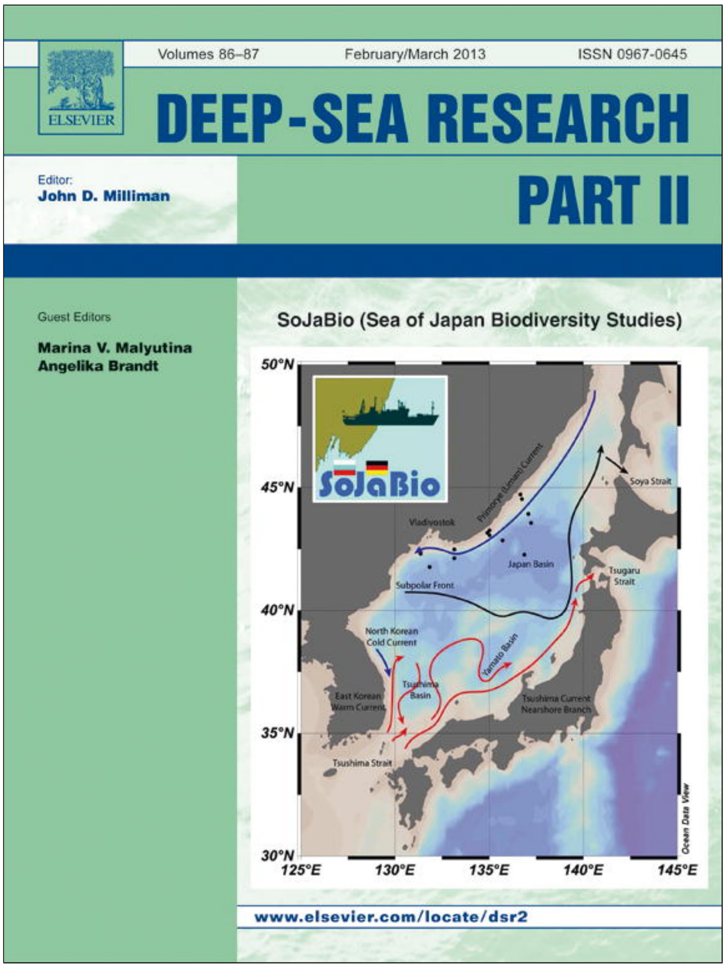
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Edwardsia sojabio sp. n. (Cnidaria: Anthozoa: Actiniaria: Edwardsiidae), a new abyssal sea anemone from the Sea of Japan

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ABSTRACT

The paper describes new deep-water edwardsiid sea anemone *Edwardsia sojabio* sp. n. which is very common on soft muddy bottoms at lower bathyal and upper abyssal depths in the Sea of Japan. It was recorded in high quantity in depths between 2545 and 3550 m and is the second abyssal species of the genus *Edwardsia*.

1. Introduction

The deep-sea basin of the Sea of Japan is well isolated from adjacent deep-sea areas by rather shallow straits; its deep-water fauna is poorly studied but the species diversity was described to be low (Zenkevich, 1963).

The present study is based on material collected by the joint Russian–German expedition *SoJaBio* (Sea of Japan Biodiversity Studies) on board of RV Akademik M.A. Lavrentyev in August of 2010. The vast majority of the sea anemones collected by the expedition were numerous specimens of the small edwardsiid sea anemone described here as *Edwardsia sojabio* n. sp. Edwardsiid sea anemones from the North Pacific and, in particular, from the Far East seas of Russia are poorly known. Only two *Edwardsia* species were known previously from the Sea of Japan: *E. japonica* Carlgren, 1931 from shallow water (0–12 m) and *E. octoradiata* Carlgren, 1931 from unspecified depth. An unidentified *Edwardsia* sp. is reported from East Sakhalin (Kostina, 2008).

Although *Edwardsia* species are numerous and widespread, occurring from polar to tropical waters, surprisingly few species are known from deep water. Actually, only one true abyssal species has been described till now, *E. mcmurrichi* Daly et Ljubenkov, 2008 from off San Francisco, California, at 2650–3136 m depth (according to a list of examined specimens) or 2100–3100 m depth (as listed in "Distribution and habitat", see Daly and Ljubenkov, 2008:11).

2. Material and methods

The specimens were fixed with formaldehyde and then transferred to 70% ethanol for long term storage or placed directly in 96% ethanol. For histological examinations several specimens were embedded in paraffin using the isopropanol-mineral oil technique (Buessa and Peshkov, 2009) and cut into series of 3.5 μm sections. The sections were stained in Masson's trichrome (Romeis, 1953). Cnidae were studied using small pieces of macerated tissue and on histological sections. Cnidae were measured according the method of Hand (1954). This method is more suitable to establish accurate size ranges than the method described by Williams (1996). The obtained measurements are not random and therefore are not suitable for statistical analysis. However, accurate size ranges of cnidae are much more important for taxonomic purposes than the statistical data (e.g. mean and standard deviation). Actually this is confirmed by Williams (1996:350) who stated: "Statistically significant differences occurred between mean lengths of cnidae in replicate samples from the same specimen ..., and between samples from different specimens of the same species". This fact nullifies practical value of the protocol described by Williams (1996) for taxonomy. In fact, we do not know any papers in which these data (the mean and the standard deviation) were used for species' comparisons.

The material examined is summarized in Table 1. Type material is stored in the Museum of the Institute of Marine Biology (MIMB), Vladivostok, Zoological Institute (ZIN), St.Petersburg, Russia, and in the Zoological Museum of Hamburg (ZMH), Germany.

3. Taxonomy

Order Actiniaria Rafinesque, 1815

Family Edwardsiidae Andres, 1881

***Edwardsia* de Quatrefages, 1841**

Edwardsia sojabio sp. n.

(Figs. 1–3)

Edwardsia arctica: Carlgren, 1940:21.

Not *Edwardsia arctica* Carlgren, 1921:39.

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Table 1
List of stations where *E. sojabio* sp. n. was recorded, S=supranet; E=epinet.

No.	Station	Gear C-EBS	Date	Depth (m)	Coordinates	Number of specimens (catalog numbers)
1	B4-8	S	21–22.8.2010	3312–3334	43°01.3440N 135°28.0092E 43°01.2126N 135°28.1308E	154 (MIMB 27388)
2	D2-8	E	01.09.2010	2653–2683	42°06.6051N 131°21.0149E 42°06.4555N 131°20.9308E	18
3	B4-8	E	21–22.8.2010	3312–3334	43°01.3440N 135°28.0092E 43°01.2126N 135°28.1308E	18
4	B5-8	S	23.8.2010	2609–2655	43°01.3064N 135°05.9562E 43°00.9363N 135°06.5366E	32
5	A7-9	E	18.08.2010	3340–3347	44°00.8871N 137°29.7822E 44°00.1668N 137°31.3496E	5 (ZMH-C12153)
6	D2-8	S	01.09.2010	2653–2683	42°06.6051N 131°21.0149E 42°06.4555N 131°20.9308E	137
7	A6-8	E	16.08.2010	2545–2555	44°18.6270N 137°24.4079E 44°18.4712N 137°24.3985E	39
8	A6-8	S	16.08.2010	2545–2555	44°18.6270N 137°24.4079E 44°18.4712N 137°24.3985E	26
9	C1-9	E	27.08.2010	2693–2725	42°26.4275N 133°08.6525E 42°26.4636N 133°08.8737E	17
10	B5-8	E	23.8.2010	2609–2655	43°01.3064N 135°05.9562E 43°00.9363N 135°06.5366E	1
11	D1-4	E	30.08.2010	3356	41°28.7198N 131°46.7702E 41°28.6028N 131°46.6796E	2
13	D1-4	S	30.08.2010	3356	41°28.7198N 131°46.7702E 41°28.6028N 131°46.6796E	1
14	A7-9	S	18.08.2010	3340–3347	44°00.8871N 137°29.7822E 44°00.1668N 137°31.3496E	1 (MIMB 27387) 35 (ZIN 11284)
15	C1-9	S	27.08.2010	2693–2725	42°26.4275N 133°08.6525E 42°26.4636N 133°08.8737E	53
16	C3-4	E	28.08.2010	3427–3431	42°01.5613N 133°09.5741E 42°01.4637N 133°09.7381E	13 (ZIN 11285)
17	B4-7	S	21.08.2010	3298–3353	43°01.5063N 135°26.4484E 43°01.3831N 135°26.3669E	62
18	C1-8	E	27.08.2010	2670–2681	42°26.5832N 133°09.1471E 42°26.6230N 133°09.3740E	5
19	B7-6	S	25.08.2010	517–521	43°13.4229N 135°04.2286E 43°13.5581N 135°04.3569E	1
21	B4-5 #18	MUC	21.08.2010	3340	43°01.1496N 135°26.1901E	1
22	D2-6 #47	MUC	31.08.2010	2654	42°06.3910N 131°21.8463E	4
23	D2-6 #47	MUC	31.08.2010	2654	42°06.3910N 131°21.8463E	7
24	C3-7 #18	MUC	29.08.2010	3428	42°02.1420N 133°10.8608E	1
25	C3-7 #18	MUC	29.08.2010	3428	42°02.1420N 133°10.8608E	2
26	C3-7 #18	MUC	29.08.2010	3428	42°02.1420N 133°10.8608E	2
27	C3-7 #18	MUC	29.08.2010	3428	42°02.1420N 133°10.8608E	1
28	C3-7 #18	MUC	29.08.2010	3428	42°02.1420N 133°10.8608E	1
33	C3-4	S	28.08.2010	3427–3431	42°01.5613N 133°09.5741E 42°01.4637N 133°09.7381E	6 (ZIN 11286)
34 34′	A7-8	S	17.08.2010	3345–3357	44°00.8877N 137°29.7822E 44°00.7933N 137°30.2780E	160
36	C3-3	S	28.08.2010	3431–3435	42°01.3458N 133°09.7454E 42°01.2359N 133°09.8746E	12
37	A6-7	S	16.08.2010	2511–2534	44°00.2607N 137°31.1584E 44°19.2650N 137°24.1206E	60
38	D1-9	AGT-20	31.08.2010	~3550	41°28.7198N 131°46.7702E 41°28.6028N 131°46.6796E	37
39	D2-9	AGT-22	01.09.2010	2629	42°05.9640N 131°19.4615E 42°06.0733N 131°19.4347E	84
40	D2-10	AGT-23	01.09.2010	2641	42°06.7346N 131°20.4442E 42°06.9080N 131°20.5326E	88

3.1. Material examined

See Table 1 for full list of specimens and localities.

Holotype:
MIMB 27387 (length 15 mm, width 3 mm. St. A7-9, 18.08.2010, 3340–3347, 44°00.8871N, 137°29.7822E–44°00.1668N, 137°31. 3496E, RV Akademik M.A. Lavrentyev).
Paratypes:
MIMB 27388 (St. B4-8, 21–22.8.2010, 3312–3334 m, 43°01. 3440N, 135°28.0092E–43°01.2126N, 135°28.1308E, RV Akademik M.A. Lavrentyev, 154 specimens).
ZMH-C12153 (St. A7-9, 18.08.2010 3340–3347 m, 44°00. 8871N, 137°29.7822E–44°00.1668N 137°31.3496E, RV Akademik M.A. Lavrentyev, 5 specimens).
ZIN 11284 (St. A7-9, 18.08.2010, 3340–3347, 44°00.8871N, 137°29.7822E–44°00.1668N, 137°31.3496E, RV Akademik M.A. Lavrentyev, 35 specimens).
ZIN 11285 (St. C3-4, 28.08.2010, 3427–3431 m, 42°01.5613N, 133°09.5741E–42°01.4637N, 133°09.7381E, RV Akademik M.A. Lavrentyev, 13 specimens).
ZIN 11286 (St. C3-4, 28.08.2010, 3427–3431 m, 42°01.5613N, 133°09.5741E–42°01.4637N, 133°09.7381E, RV Akademik M.A. Lavrentyev, 6 specimens).

3.2. Description

3.2.1. External anatomy

Most specimens are in a good condition although strongly contracted with the distal part of the body deeply invaginated and the tentacles visible in only a few specimens. The body, as in most *Edwardsia* species, is elongated and vermiform (Fig. 1). Preserved specimens range 2–30 mm in length and 1–5 mm in diameter, but usually 8–10 mm in length and 1.5–2 mm in diameter.

Column is divisible into physa, scapus, scapulus and indistinct capitulum. The small, not ampullaceos physa has no nemathybomes or periderm and is imperforate. The scapus is covered by a thin periderm. Its appearance varies depending on the degree of contraction, it is smooth and almost translucent in extended specimens but corrugated and dark brown to almost black in strongly contracted specimens. The color and texture of the periderm may vary even within a single specimen. Many of the specimens have a somewhat inflated translucent proximal half of the body and a stronger contracted and therefore darker and more corrugated distal half. The surface of the periderm is free from any sand grains or other solid particles but, as revealed in histological sections, it is covered by a layer of fine mud particles probably glued by a mucous substance. Small nemathybomes, about 60–80 μm in diameter, scattered between the insertions of macrocnemes are barely visible as whitish almost nonprotruding spots on the less contracted areas of the scapus. They do not form any kind of ridges and are not aggregated into groups.

The scapulus of preserved specimens is visible only in a few cases. It lacks nemathybomes, periderm coating and is translucent; the mesenterial insertions are clearly visible here. The border between the scapus and scapulus is a well-marked plain line. The short indistinct capitulum is located at the bases of the tentacles.

The length of the tentacles varies significantly depending on the degree of contraction, the longest measured tentacles of less contracted specimens were up to 8 mm long. On the strongly contracted specimens with the invaginated distal part of the body the tentacles, as revealed in histological sections, are also contracted and in most cases are much shorter, sometimes no more than 0.1–0.2 mm long. The number of the tentacles is probably always 16, in two cycles of 8, although it was not always easy to demonstrate and in most cases the exact number could be assessed only by analyzing several serial transverse sections through the region of the distal end of the actinopharynx and oral disk.

3.2.2. Internal anatomy and histology

The ectoderm of the scapus is very thin, sometimes barely discernible between mesogloea and periderm. In histological sections the border between the scapus and physa is sharply defined (Fig. 2F) and there is almost no transition zone. The ectoderm of the physa is much higher, 30–40 μm and, unlike the ectoderm of the scapus, not covered by periderm and fine mud particles. It consists of high cylindrical epithelial cells among which many vacuolized cells are present. It also contains a significant quantity of nematocysts (basitrichs), which are not present in the ectoderm of the scapus (apart from the basitrichs in the nemathybomes). The mesogloea is about 20–30 μm thick, depending on the degree of contraction. Its inner (endodermal) surface is usually more or less even, while the outer (ectodermal) surface may be very corrugated with rather high irregular ridges and folds on the scapus, but not on the physa (Fig. 2A, C, E, and F). On the scapus the mesogloea may form fine strands running through the ectoderm to the periderm forming tenaculi-like structures, especially noticeable on the tops of ridges or folds (Fig. 2E). The mesogloea and the ectoderm of the scapulus are significantly thicker than those of the scapus. Transition between scapulus and capitulum is rather gradual: the body wall becomes much thinner toward the bases of the tentacles. The ectoderm of both scapulus and capitulum contains basitrichs.

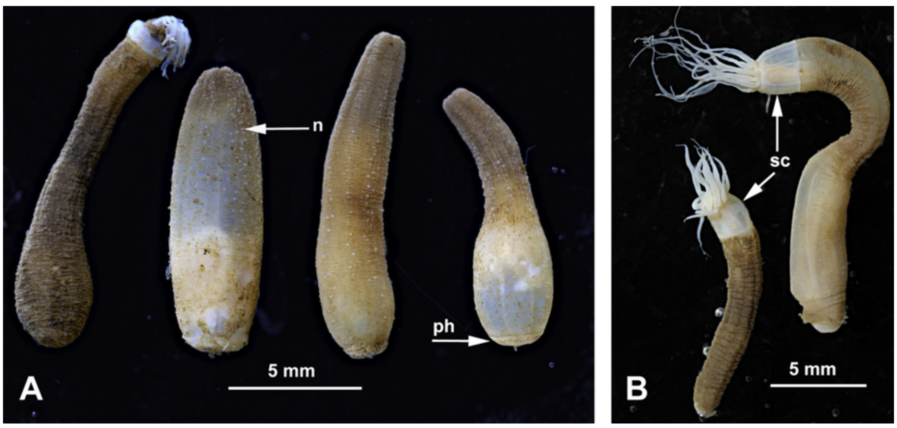

Fig. 1. *E. sojabio* sp. n. (A) Typical appearance of preserved specimens, note scattered nemathybomes (**n**) and physa (**ph**); (B) less contracted specimens with tentacles not retracted, note periderm-free scapulus (**sc**).

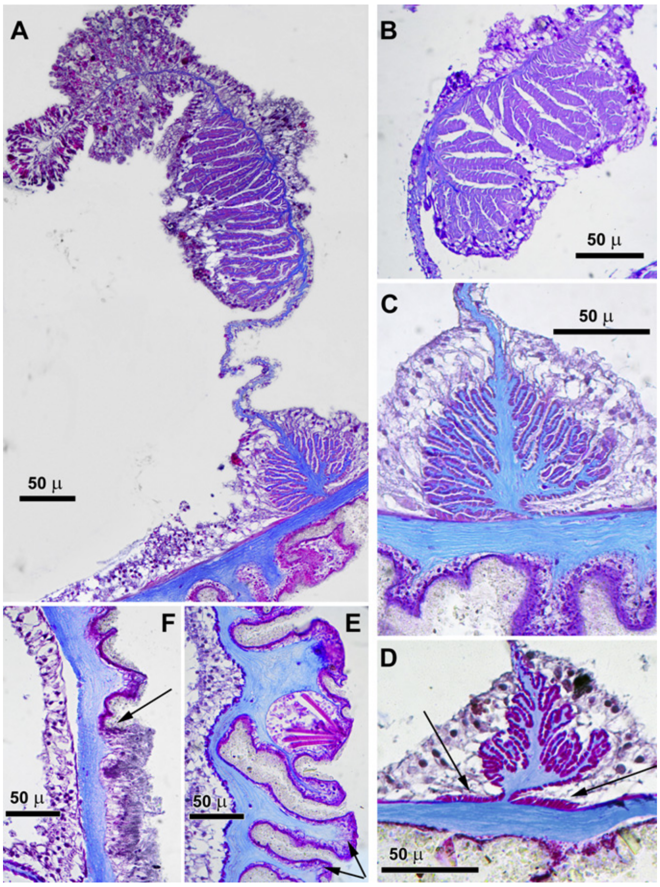

Fig. 2. *E. sojabio* sp. n., histological sections. (A) General appearance of macrocneme showing parietal and retractor muscles and filament; (B) retractor muscles with the folds more or less distinctly arranged onto two groups: the outer pinnate and inner diffuse portions; (C, D), variations in the shape of the parietal muscle, note significant expansion of the longitudinal muscle fibers to the column wall (arrows); (E) nemathybome with basitrichs, note the appearance of mesogloea: more or less even on inner (endodermal) side and highly folded on outer (ectodermal) side, with fine mesogloeal strands running through ectoderm to periderm on the tops of the ridges (arrows); (F) longitudinal section through the proximal part of column showing a border between the scapus and physa (arrow), note the absence of periderm on the physa and much higher ectoderm in comparison with that of scapus.

The endodermal circular muscles of the scapulus are stronger than those of the scapus. Radial muscles of the oral disk and longitudinal muscles of the tentacles are ectodermal. The actinopharynx is rather short, with thin mesogloea. We failed to detect siphonoglyphs. The organization of the mesenteries is typical for *Edwardsia* species having 16 tentacles: eight macrocnemes are present along the whole length of the body and eight microcnemes in the capitulum only, at the bases of the tentacles. Four of these microcnemes are paired with the lateral macrocnemes and other four microcnemes form two pairs in dorsolateral exocoels.

Retractor muscles, as revealed in transverse sections, are moderately developed, with about 12–15 muscle processes, most of which, except several shorter processes in the middle of the retractor, are branched (Fig. 2A). The outer (located closer to column wall) process is most branched, and sometimes might be interpreted as a pennon (Fig. 2B). In some cases the muscle processes are more or less distinctly grouped into two portions, forming outer pennons and an inner diffuse portion of the retractor. The parietal muscles are well developed, hemispherical or trianguloid on transverse sections, usually with many branched lamellae (Fig. 2C and D). The mesogloea of the central lamella of the parietal muscle is rather thick, especially closer to the body wall, but narrows sharply at the connection with the body wall. Parietal muscle fibers are expanded on the body wall (Fig. 2D).

None of the sectioned specimen had gametes. Large inclusions, sometimes containing discernible cells of diatoms, occur in the digestive region (the zone of phagocytosis) of mesenterial filaments of some specimens. The mesenterial filaments are mostly unilobated, of two kinds: the smaller filaments (diameter of the cnidoglandular tract on cross sections about 70 µm) are located distally and contain only basitrichs in the cnidoglandular tracts; the larger filaments (about 100 µm on cross section) are located in the middle and proximal parts of the macrocnemes and contain basitrichs and p-mastigophores A in the cnidoglandular tracts. The trilobate filaments are represented by fragments which may occur sporadically anywhere from the actinopharynx almost to the proximal end of the filament as several widely separated very short, 0.2–0.4 mm, insertions on the unilobate filaments.

3.2.3. Cnidom

Robust and gracile spirocysts, basitrichs, p-mastigophores A (see Fig. 3 and Table 2 for size ranges and distribution). Nemathybomes

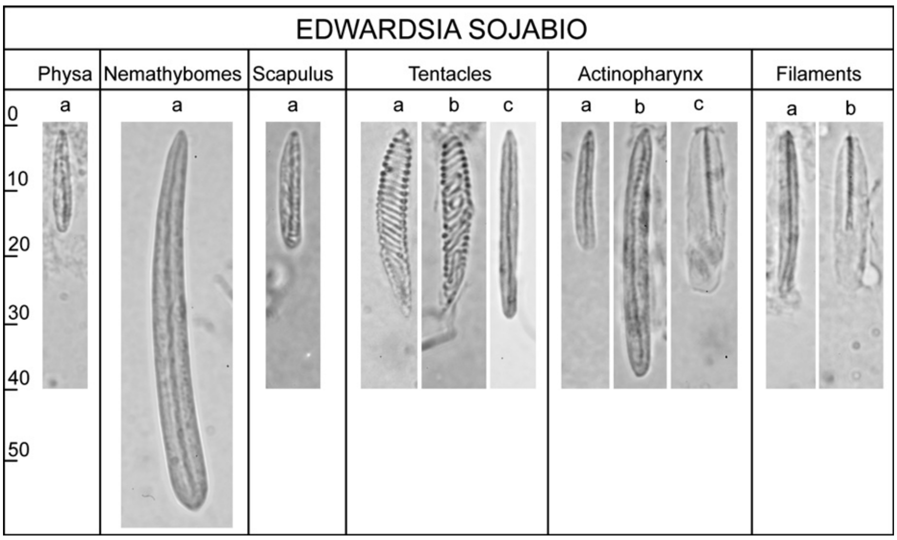

Fig. 3. *E. sojabio* sp. n., cnidom (see Table 2 for size ranges).

Table 2
Size ranges (in microns) and distribution of cnidae of *E. sojabio* sp. n. Letters in brackets correspond to letters in Fig. 3.

Body region	Cnidae	Size ranges (length × width, μm)
Physa	(a) Basitrichs (few)	11–15 × 2–2.5
Nemathybomes	(a) Basitrichs	49–60 × 4–5.5
Scapulus	(a) Basitrichs (few)	14–20 × 2.5–3
Tentacles	(a) Gracile spirocysts (numerous)	17–36 × 2–5
	(b) Robust spirocysts (numerous)	15–36 × 2.5–5.5
	(c) Basitrichs (common)	20–28 × 2–3
Actinopharynx	(a) Basitrichs (common)	16–28 × 2–3
	(b) Basitrichs (common)	31–39 × 3–4
	(c) p-Mastigophores A (common)	21–29 × 5–6.5
Filaments	(a) Basitrichs (common)	18–30 × 2–3
	(b) p-Mastigophores A (common)	22–27 × 5–6

contain one type of nemathocyst, basitrichs, 25–45 cnidae were counted in each nemathybome. The size ranges of nematocysts of smaller and larger specimens are similar and they have the same set of the cnidae.

3.3. Distribution

E. sojabio n. sp. is recorded and appears to be very common at abyssal depths between 2545 and 3550 m in the Sea of Japan and is not known from other regions. The examined material also contained one specimen collected between 517 and 521 m depth (Station B7-7) but it may have been mislabeled.

3.4. Etymology

The species is named after the expedition SoJaBio during which it was collected.

4. Discussion

The genus *Edwardsia* de Quatrefages, 1842 is the most species rich genus of Actiniaria. Most species were described at the end of 19th and in the first half of 20th centuries with several new species added since that time. The most valuable and useful overview of all described *Edwardsia* species is the work of Williams (1981). He recognized 40 valid and 55 invalid nominal species names of *Edwardsia* including *nomina nuda*, *nomina dubia*, homonyms, synonyms and taxons transferred to other genera. Currently the number of valid species of the genus is 48 (our data). England (1987:216) proposed to split the genus into several smaller genera mainly for practical purposes, to reduce the task of "much literature searching… before a single species can be confidently identified", rather than better reflect the phylogeny of the group. He reinstated the genus *Edwardsioides* Danielssen, 1890 for the species possessing only one type of nematocyst, the basitrich, in the nemathybomes and only left in *Edwardsia* those species with two types of nematocysts (pterotrichs and t-mastigophores). Further, based on the absence of microcnemes in the first cycle of the mesenteries, he created the genus *Edwardsianthus* for two species, formerly assigned to *Edwardsia* and now referred to as *Edwardsianthus pudica* (Klunzinger, 1877) and *Edwardsianthus gilbertiensis* (Carlgren, 1931). Daly (2002) and Daly and Ljubenkov (2008) agreed with the creation of the genus *Edwardsianthus*, but argued against reinstating *Edwardsioides*. They referred the species assigned to this genus by England (1987) to *Edwardsia*. In the present paper we follow these authors and although the species described in this paper has only one type of nematocyst in nemathybomes we place it in *Edwardsia* rather than in *Edwardsioides*.

Edwardsia mcmurrichi (the only abyssal species of *Edwardsia* known till now) and *E. sojabio* sp. n. belong to the most diverse species group of *Edwardsia* possessing 16 tentacles and one type of nematocysts in the nemathybomes. The original description of *E. mcmurrichi* is not detailed (consisting of two short paragraphs only), but from the provided figures it can be inferred that it has much weaker retractors and parietal muscles. The retractors of *E. sojabio* sp. n. have more ramified and two times more numerous folds than those of *E. mcmurrichi*. Further, in contrast to the present species, nemathybomes in *E. mcmurrichi* form rather high and distinct longitudinal ridges between the insertions of the macrocnemes. In *E. sojabio* sp. n. the nemathybomes are low, scattered and do not form any visible ridges. Basitrichs in nemathybomes of *E. mcmurrichi* are thinner and shorter (36–49 × 2.2–3.2 μm) than those of *E. sojabio* sp. n. (49–60 × 4–5.5 μm).

Carlgren (1940) identified two specimens, collected by K. Derjugin in 1932 at 2300 m in the Sea of Japan, as *Edwardsia arctica*. These specimens, according to Carlgren (1940), were small and very badly preserved with the tentacles squeezed out through the aboral end of the body. He only tentatively assigned them to *E. arctica* based on a similarity of retractors and parietal muscles. In his figure the retractor indeed appears to be weak, with only a few short branches, but this could be explained by the small size of the specimens. The locality, given by Carlgren (1940) (41°38.5′N, 132°08′E), is very close to SoJaBio station D1-4. Since *E. sojabio* sp. n. appears to be very abundant and widespread in abyssal depths in the Sea of Japan we have no doubt that the specimens examined by Carlgren (1940) are conspecific with the present material. The original description of *E. arctica* is based on several specimens from Arctic locations (East-Greenland, Novaya Zemlya and Kara Sea), most are from shallow waters, 5–35 m and 80 fathoms (146 m; from Kara Sea). Carlgren (1921) also lists a single specimen from Jan Mayen from much deeper water, 1275 m, remarking that it was badly preserved and that identification is dubious. According to Fautin (2012) no specimen from this station is found in Carlgren's type series. Taking into account Carlgren's remark and absence of the specimen in the type series this deep-water record cannot be used to extend bathymetric range of this species. Thus for now *E. arctica* should be considered to be a shallow-water Arctic species. Anyway, it differs from the abyssal *E. sojabio* sp. n. by the appearance of its retractors, which are weaker, have less numerous, widely spaced and only slightly ramified branches and by the form of its parietal muscles.

Thirty two other *Edwardsia* species with 16 tentacles are described. However, after removing all tropical shallow-water species (which obviously cannot be conspecific with the present species) and all species having two types of nematocysts in the nemathybomes (leaving the species with one type of nematocysts in the nemathybomes and the species for which this character is not known), the list can be reduced to the following 6 species:

Edwardsia meridionalis Williams, 1981 is an Antarctic species (from 6 to 500 m), with very different (weak) retractors obviously distinct from *E. sojabio* sp. n.;
Edwardsia norvegica Carlgren, 1942—the original description is based on one specimen from Norway, 125–150 m depth. It has no distinct physa and probably should be assigned to *Scolanthus* rather than to *Edwardsia* (see Carlgren, 1942);
Edwardsia vitrea (Danielssen, 1890)—an Arctic species known from East Greenland, Spitzbergen and north off Iceland at 9–836 m.

It has very thin periderm on the scapus, perforated physa, stronger retractors and smaller nematocysts in the nemathybomes (34–42 × 3–3.5 μm);

Edwardsia islandica Carlgren, 1921 is described from one specimen from south off Iceland, 216–326 m. The retractors appear to be similar to the present species while the parietal muscles differ (having several short parallel, almost not branched mesogloeal processes) and nematocysts in the nemathybomes are smaller (36–48 × 2–2.5 μm);

Edwardsia vegae Carlgren, 1921—the original description is based on one specimen from "Arctic Sea of Siberia", 16–18 m. It has a physa with one central perforation surrounded by a ring of 8 apertures and much larger nematocysts (84–101 × 3 μm) in the nemathybomes in comparison with those of the present species;

Edwardsia japonica Carlgren, 1931 is described from the Sea of Japan. This shallow water species differs clearly from *E. sojabio* sp. n. by its extremely large retractors and its large nematocysts in the nemathybomes attaining 74–100 μm.

Another species described from the Sea of Japan, *E. octoradiata* Carlgren, 1931, has two types of nematocysts in the nemathybomes.

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