New findings of the *Plicifusus* species in the Russian Arctic (Neogastropoda: Buccinidae)

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**ABSTRACT.** Three species, attributed to buccinid genus *Plicifusus*, had been previously known from the Arctic: *Plicifusus kroeyeri* (Møller, 1842), *P. johanseni* Dall, 1919, and *P. rodersi* (Gould, 1860). Study of museum collections and recently obtained material from the Laptev and East Siberian seas resulted in discovery of *Plicifusus maehirai* Tiba, 1980, previously known from the Northern Pacific, and *Plicifusus* sp., which probably belongs to an undescribed species. *P. johanseni* has been found in the Russian waters for the first time. Lectotype of *P. johanseni* has been designated.

**Introduction**

Only three buccinid species, attributed to *Plicifusus* Dall, 1902, have been known from the Arctic: *Plicifusus kroeyeri* (Møller, 1842), *P. johanseni* Dall, 1919, and *P. rodersi* (Gould, 1860) [MacGiniyte, 1959; Kantor, Sysoev, 2006; Sirenko, 2009; Kosyan, Kantor, 2012; Merkuljev, 2015].

The morphological description and synonymy of the type species of the genus *P. kroeyeri* were provided in a revision by Kosyan and Kantor [2012]. The radula of *P. rodersi* was published by Sirenko [2009] under the name *P. mcleani*, which was reduced to a junior synonym of *P. rodersi* by Merkuljev [2015]. *P. johanseni* was one of the last species of the genus, described by W.H. Dall. The type material was represented by two dead specimens with strongly eroded, partly broken shells, hardly allowing species identification. Few later findings of *P. johanseni* were identified erroneously, as it was shown by Kantor and Sysoev [2006]. A number of authors listed the species as valid [Abbott, 1974; Baxter, 1987; Kantor, Sysoev, 2006]. Kosyan and Kantor [2012] also considered it valid but due to poor condition of the syntypes and lack of better material expressed uncertainty in whether the species was recent or fossil. Clark [2016], based on fresh material from the Chuckchi Sea, finally established the species as valid and Recent.

In this paper, we recorded one more species of *Plicifusus* inhabiting the Arctic – *P. maehirai* Tiba, 1980, and provide morphological description for *P. johanseni* and *Plicifusus* sp., which is probably a new species.

**Material and methods**

The material on *Plicifusus johanseni* and *P. maehirai* was collected during the recent cruise of R/V Dalnie Zelentsy in summer of 2015. The material on *Plicifusus* sp. was obtained from the Zoological Institute of RAS. Also lectotype of *Fusus kroeyeri* stored in Zoological Museum of the University of Copenhagen was studied.

The gross anatomy was investigated using light microscope, radulae were separated from buccal mass, transferred into diluted bleach and kept for several minutes until soft tissues were dissolved, washed in distilled water, air dried and examined in TESCAN scanning electron microscope.

**Abbreviations of the depositories:** CMNML, Canadian Museum of Nature, Ottawa, Canada; UKM, Sea and Shell Museum [Umi-to-kai-no-myujiamu: UKM] in Rikuzentakata City, Iwate Prefecture, Japan; after the Tsunami in 2011, the collections were removed to the temporary facility of the Rikuzentakata City Museum; USNM, National Museum of Natural History, Smithsonian Institution, Washington DC, USA; ZIN, Zoological Institute of Russian Academy of Sciences; ZMUC, Zoological Museum of the University of Copenhagen, Denmark.

**Abbreviations on the figures:** adg, opening of anterior duct of digestive gland; AL, aperture length, an, anus; ao, anterior aorta; aoe, anterior oesophagus; bm, buccal mass; cg, capsule gland; cm, columnellar muscle; ct, eutennidium; dg, digestive gland; eye, eye; fo, female orifice; ft, foot; gl, gland of Leiblein; H, height of the shell, h, height of the last whorl; hd, head; int, intestine; kd, kidney; lf, longitudinal fold on inner stomach wall; mo, mouth opening; nr, nerve ring; oeo, oesophageal opening; odn, odontophore nerves; op, operculum; os, osphradium; p, penis; pma, posterior mixing area; poe, posterior oesophagus; pr, proboscis; prp, propodium; prr, proboscis retractors; rd, rhynchodaemae; re, rectum; rs, rhyn-
Plicifusus johanseni

(Dall, 1902: 40.)

Plicifusus johanseni Dall, 1919

(Figs 1 B-E, 2, 3 A-B, 4)

Material examined. Laptev Sea, 76°18.2’N, 142°21.9’E, 17-23 m (Fig. 4). Distribution: Alaska, between WNW of Cape Kruzenstern (67°30.54’N, 165°52.28’W) and North of Barrow (71°31.42’N, 157°23.25’W), and as far north as 72°30.63’N, 166°50.26’W, NW of Icy Cape, at depths of 38-91 m [Clark, 2016]; Laptev Sea, 17-23 m (Fig. 4).

Remarks. In the original description, Dall [1919] did not select holotype among two specimens collected from two close but different localities in Alaska, and thus both of them must be considered syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have syntypes. He noted, that “The expedition collected a dilapidated specimen at Point Barrow, but I have
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FIG. 1. Shells of *Plicifusus*. A. Lectotype of *Fusus kroeyeri*, ZMUC-GAS-61, 68 mm, Western Greenland. B. Lectotype of *P. johanseni*, USNM 27475a, H 54.2 mm (photo taken from USNM website), Icy Cape, Alaska. C. Paralectotype of *P. johanseni*, CMNML 004117, Point Barrow, Alaska. D. *P. johanseni*, spm. no. 1, st. A-26, 76°18.2'N, 142°21.9'E, 17 m, H 45.5 mm (radula on Fig. 3A). E. *P. johanseni*, spm no. 2, st. O-29, 74°55.6'N, 119°15.5'E, 23 m, H 34.7 mm (anatomy on Fig. 2, radula on Fig. 3B). Scale bar 10 mm.

FIG. 2. Anatomy of *Plicifusus johanseni* no. 2 (shell on Fig. 1E, radula on Fig. 3B). A. Cephalopodium, front view. B. Operculum. C. Mantle. D. Upper section of penis. E. Foregut, right lateral view. F. Stomach, opened dorsally. G. Stomach, general view.

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**FIG. 3. Radulae of *Plicifusus*.** A. *P. johanseni* no. 1 (shell on Fig. 1D). B. *P. johanseni* no. 2 (shell on Fig. 1E, anatomy on Fig. 2). C. *P. maehirai* no. 1 (shell on Fig. 5B). D. *P. maehirai* no. 2 (shell on Fig. 5C).

27475a, on which the Dall’s description was based, is obviously erroneously referred to as holotype and moreover, its locality is given erroneously: Point Barrow instead of Icy Cape. To avoid further misconception, we designate this specimen, USNM 27475a (Fig. 1B) with shell length 52 mm, as lectotype, and specify the type locality of the species as Icy Cape. Consequently, we designate the second specimen, collected at Point Barrow and kept at the Canadian Museum of Nature (CMNML 004117), as paralectotype (Fig. 1C).

Though general shell shape, sculpture and radula morphology of the whelks, found in the Laptev Sea, are typical for *Plicifusus* [Kosyan, Kantor, 2012], they are rather difficult to be attributed to any of known *Plicifusus* species. The shells possess peculiar shell shape with flattened periphery of the whorls as well as strongly S-curved axial ribs, and are close to North Pacific *P. scissuratus* Dall, 1918. But *P. scissuratus* is known from relatively warm waters of Hokkaido and Southern Kurile Islands, and hardly may be found in the Arctic Ocean. From circumpolar *P. kroeyeri* (Møller, 1842) (Fig. 1A) our shells differ in the pattern of spiral sculpture, consisting of less frequent and more prominent spiral cords. From *P. rodgersi* (Gould, 1860) – another species of *Plicifusus*, which is found in the Arctic Ocean (the Chuckchi Sea) – it differs in shell shape and sculpture. *P. johanseni* was described from Alaska, which is rather close to the locality of our shells and much closer in hydrological conditions than the locality of *P. scissuratus*. Shell shape, spiral sculpture of medium frequent, prominent ribs, alternately bifurcated in median sec-
tion of the whorl, and shape of axial ribs (when visible) of the type of *P. johanseni* are also similar to specimens from the Laptev Sea.

Dall [1919] considered *Plicifusus johanseni* as conchologically the most similar to *Aulacofusus esychus* (Dall, 1907). But, besides absence of axial ribs, *A. esychus* significantly differs in foregut and stomach anatomy [Kosyan, Kantor, 2013]. Clark [2016] described fresh shells of *P. johanseni*, collected near the type locality (Alaska) and noted [p. 76-77], that it may be distinguished from *P. kroyerii* by: (1) smaller, more slender shell; (2) very fine, uniform spiral lirae, compared to *P. kroyerii* which has fine incised lines, becoming spaced further apart on the base; (3) fewer, more consistent number of axial ribs, 12-14 compared with typically 18-28 (very rarely fewer) in *P. kroyerii* of the same size; and (4) the axial ribs of *P. johanseni* are less prominent than those of *P. kroyerii*, typically (but not always) becoming faint or absent on the penultimate whorl.” This description does not completely coincide with ours: the number of spiral ribs in our specimens is about 30 (30 – in type specimen of *P. johanseni*, 40 – in Clark’s shells and 60 (Fig. 1A) – in type specimen of *P. kroyerii*); the axial ribs are as prominent as in *P. kroyerii* and do not become faint or absent on the last whorl. Nevertheless, we prefer to attribute our specimens to *P. johanseni*, considering variation of spiral and axial sculpture as intraspecific.

**Plicifusus maehirai** Tiba, 1980
(Figs 3C-D, 4, 5)


*Plicifusus obtusatus* Golikov in Golikov, Scarlato, 1985: 404, fig. 5. – Alexeev, 2003: 91, pl. XXXI-5. – Kantor, Sysoev, 2006: 197, pl. 100 L.

**Types:** Holotype of *Plicifusus maehirai* – UKM 33233 (R13263) (Fig. 5A), holotype of *Plicifusus obtusatus* – ZIN 33732/1.

**Type localities:** *Plicifusus maehirai* – off Kushiro, eastern Hokkaido; *P. obtusatus* – Terpeniya Bay, Sakhalin Island, 53 m.

**Material examined.** Laptev Sea, 76°18.2’N, 142°21.9’E, 17 m, R/V Dalnie Zelentsy, st. A-26, 21.08.2014 (spm. no. 1, female). Laptev Sea, 75°17.4’N, 151°10.4’E, 15 m, R/V Dalnie Zelentsy, st. A-8, 22.08.2014 (spm. no. 2, male dissected).

**Shell** broad-fusiform, with medium-thick, with rather fragile walls, covered with adhering beige periostracum, with rather long straight siphonal canal (Fig. 5). Aperture broad oval, its height comprises about 0.5 shell height. Upper whorls eroded, axial sculpture on other whorls of closely spaced, slightly S-curved orthocline axial ribs, 16-18 in number on last whorl. Spiral sculpture of well pronounced flattened cords, separated by alternating deep and shallow grooves, about 25 in total on penultimate whorl. Measurements: no. 1. H 41.8
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**mm, h 31.7 mm, AL 24 mm; no. 2. H 44.7 mm, h 33.4 mm, AL 26.3 mm.**

**Soft body** morphology the same as described by Kosyan and Kantor [2012].

**Radulae** of spms no. 1 and 2 about 300 µm wide (1.25% and 1.14% of AL respectively). Rachidian teeth tricuspid, intermediate cusps in spm. no. 1 significantly longer (Fig. 3C) or equal (Fig. 3D) to marginal ones; lateral teeth tricuspid with narrower and shorter intermediate cusp.

**Distribution:** Northern part of the Sea of Japan, Southern Kurile Islands, the Sea of Okhotsk, Eastern Kamchatka, 25-200 m; Laptev Sea, 15-17 m (Fig. 4).

**Remarks.** The above described specimens have been found in the same samples with *P. johanseni*, comparing to which they have definitely more inflated whorls and less attenuated shells. From another similar arctic species – *P. kroeyeri*, they differ in significantly lesser spiral cords, from *P. rodgersi* – in shell shape with well defined siphonal canal and more pronounced axial sculpture. Conchologically our specimens are much closer to the boreal *P. maehirai*, which has been previously known only from the North Pacific, in northern part of the Sea of Japan, Sea of Okhotsk and eastern Kamchatka [Kosyan, Kantor, 2012]. The radulae of our specimens differ from illustrated radulae of *P. maehirai* from southern Sakhalin and northern part of the Sea of Okhotsk [Kosyan, Kantor, 2012; fig. 11A-D] in significantly longer intermediate cusps of central teeth. The reason may be geographic variability. Assuming that *P. maehirai* is found in the Arctic, its distribution appears to be very wide, probably circumpolar. Such wide distribution is known for a number of Colinae [Colus islandicus (Mohr, 1786), Anomalosipho altus (S.Wood, 1842), Aulacofusus

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**FIG. 5. Shells of *Plicifusus maehirai*. A. Holotype, UKM 33233 (R13263), off Kushiro, eastern Hokkaido, H 36.8 mm. B. Spm. no. 1, Laptev Sea, 76°18.2’N, 142°21.9’E, 17 m, H 41.8 mm (radula on Fig. 3C). C. Spm. no. 2, Laptev Sea, 75°17.4’N, 151°10.4’E, 15 m, H 44.7 mm (radula on Fig. 3D). Scale bar 10 mm.**
brevicauda (Deshayes, 1832)] and congeneric P. kroeyeri.

**Plicifusus sp.**
(Figs 4, 6-7)

**Material examined.** East-Siberian Sea, 70°10’N, 170°37’E – 70°11’N, 166°52’E, 24 m, icebreaker Severny Polyus, st. 39(44), 30.09.1946 (2 spms, no. 1 dissected).

**Shell** wide-fusiform, rather thick-walled, covered with adhering beige to brown periostracum, with rather short, slightly left-recurred siphonal canal (Fig. 6 A-B). Aperture oval, its height comprises about 0.5 shell height. Upper whorls eroded, axial sculpture on other whorls represented by widely spaced, slightly or moderately opisthocline axial ribs, generally S-curved with characteristic sharp bend in upper part of shell whorl, up to 12 on last whorl. Spiral sculpture of well pronounced flattened cords, separated by deep and wide grooves (half of rib’s width) in younger specimen, becoming shallow and narrow in older specimens, about 25 in number on penultimate whorl. Measurements: no. 1. H 36.8 mm, h 25.8 mm, AL 20.6 mm (female); no. 2. H 33.7 mm, h 22 mm, AL 16.5 mm (female); no. 3. H 20.9 mm, h 15.8 mm, AL 12.6 mm (female).

**Soft body.** Head (Fig. 7B, hd) with medium long tentacles. Small black eyes situated on lobes at base of tentacles. Operculum oval (Fig. 7A), with terminal nucleus. Mantle with rather long muscular siphon (Fig. 7D, s). Ctenidium spans 0.8, osphradium – 0.5 of mantle length. Ctenidium twice broader than osphradium. Rectum situated dorsally of capsule gland and opens in middle of mantle length. Hypobranchial gland not developed. Capsule gland medium large, 0.5 mantle length, with vagina situated ventrally on its top (Fig. 7D, cg). Female orifice (fo) narrow and elongated.

**Digestive system.** Proboscis partly retracted. Multiple proboscis retractor muscles follow laterally along rynchodaem and attach to lateral walls of body haemocoel at basal part of proboscis (Fig. 7C, prr). Buccal mass occupies 2/5 of proboscis length and attached to its walls by multiple muscular bands of odontophore reractors. Radula equals to odontophore in length. Radula of spm. no. 1 (Fig. 6C) about 300 µm wide (1.46% of AL). Rachidian with 3 cusps of equal length. Lateral teeth normally with three cusps, median shortest. Intermediate cusps on lateral teeth in right longitudinal row absent.

Valve of Leiblein large, inflated (Fig. 7C, vl). Salivary glands of medium size, separate, rounded, situated on both sides of nerve ring (Fig. 7E, sg). Salivary ducts medium thick, running along anterior oesophagus (Fig. 7C, sd). Posterior oesophagus convoluted (Fig. 7C, poe). Large and thick gland of Leiblein situated parallel to posterior oesophagus (Fig. 7C, gl).
FIG. 7. Anatomy of *Plicifusus* sp. no. 1 (shell on Fig. 6A, radula on Fig. 6C). A. Cephalopodium, ventral view with operculum. 

Stomach occupies approximately 1/3 of whorl (Fig. 7E). Posterior mixing area well developed, comprising 1/4 of entire stomach length (Fig. 7F, pma); it lined by tall transverse folds. Posterior oesophagus opens into stomach ventrally. Opening of anterior duct of digestive gland (adg) very large, situated near to intestine opening. Longitudinal fold on inner stomach wall (flf) present, lined by low frequent transverse folds. Rest of inner and outer stomach wall lined by tall transverse folds. Opening of posterior duct hidden deep in oesophageal opening.

Remarks. General shell shape and sculpture as well as morphology of the soft body and radula of the examined molluscs are typical for *Plicifusus*, but identification of the species is difficult. From the most similar species *P. rodgersi* and *P. johanseni*, *Plicifusus* sp. differs in its peculiar axial sculpture of rare S-curved axial ribs with characteristic sharp bend in upper part of shell whorl, as well as a wider shell shape and less attenuated spire. *Plicifusus* sp. differs from *P. kroeyeri* in less frequent spiral and axial sculpture and lower axial ribs. We have only two hardly damaged specimens in our disposal and prefer not to describe a new species until more material is available.

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