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New Record of the Freshwater Pearl Mussel *Margaritifera togakushiensis* from Northern Sakhalin, the Russian Far East

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Abstract: This paper is the first report of the freshwater mussel *Margaritifera togakushiensis* from northern Sakhalin. Species identification was performed based on shell characteristics. Twenty six dead shells and one live mussel were collected from the Dagi River in northern Sakhalin. One pair of the dead shells was regarded as *M. togakushiensis*, whereas all of the other specimens were *Margaritifera laevis* (Haas, 1910) [= *Kurilinaia zatravkini* (Bogatov, Prozorova & Starobogatov, 2003)]. The white-spotted char, which is the host of *M. togakushiensis*, lives abundantly in the Dagi River. All habitats of *M. togakushiensis* are located within the distribution area of the white-spotted char. Based on this relationship, it is possible that *M. togakushiensis* widely inhabits the northern part of the Russian Far East, as well as Sakhalin and Japan.

Keywords: Margaritiferidae, shell morphology, white-spotted char, Dagi River, potential distribution

Introduction

Freshwater pearl mussels (Margaritiferidae) are widely distributed in the northern hemisphere (Machordom *et al*., 2003). Glochidial larvae in Margaritiferidae are obligate parasites on fish (Akiyama & Iwakuma, 2007). Margaritiferid mussels are only distributed within freshwater environments inhabited by their host fish, due to the parasite-host interaction (Bauer, 1997).

Interpretations of the generic taxonomy of Asian pearl mussel vary, because malacologists have reached no consensus on the problem in recent years (Klishko, 2009). Some genera in the

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Margaritiferidae have been proposed, for example, *Margaritifera*, *Margaritinopsis* and *Pseudunio* by Smith (2001) and *Margaritifera*, *Dahurinaia* and *Kurilinaia* by Bogatov *et al*. (2003) based on comparative methods, *i.e*., using the "frontal contour" of the shell as the primary or sole character (Graf, 2007). However, all genera in the Margaritiferidae are basically unified as *Margaritifera* in the present study, following Huff *et al*. (2004), which showed that the comparative method proposed by Bogatov *et al*. (2003) is insufficient for a complete revision of the margaritiferid genera. Graf & Cummings (2007) reviews the validity of the conclusion and mussel species based on comparative method are considered as a synonym and altered to a valid name (Graf, 2007).

Margaritifera togakushiensis was described as new species in 2005 and has hitherto been cited only from Japan (Kurihara *et al*., 2005; Kondo & Kobayashi, 2005; Kondo, 2008). Shells of the species are similar to another margaritiferid species, *Margaritifera laevis* which is distributed in Japan, Sakhalin and the Kuril Islands (Kondo, 2008). However, both species are clearly distinguished by differences in some characters in shell shape (Kondo & Kobayashi, 2005). The host fish species are different between the two species. Under natural condition, the host fish for *M. togakushiensis* is often *Salvelinus leucomaenis*, whereas that for *M. laevis* is *Oncorhynchus masou masou* and *O. masou ishikawae* (Naito *et al*., 1994; Kondo *et al*., 2000; Kobayashi & Kondo, 2005). Accordingly, *M. togakushiensis* and *M. laevis* can be separated on the basis of shell shape and host fish species.

In Sakhalin, only one margaritiferid species, *Margaritifera laevis,* has been found in previous studies, and *Kurilinaia laevis*, *K. zatravkini* and *K. kurilensis* are synonyms of that species (Graf, 2007; Kantor *et al*., 2010). However, we fortunately collected *M. togakushiensis* in northern Sakhalin for the first time and here report about the mussel in detail.

Materials and Methods

Brief searches for freshwater pearl mussels and host fish were performed within a section established in the main river-bed of the Dagi River, located in northern Sakhalin, between 21st and 24th October 2011 (Fig. 1). Previously, *M. laevis* was found in the river (Nomoto *et al*., 2011). Riparian vegetation of the river mainly consisted of the coniferous tree *Larix gmelinii*. Water in the river was strongly tea-colored due to high concentrations of humic substances. Sandy gravel and sand were the dominant substrates.

For mussel sampling, two persons waded close to the shore along the river and searched for mussels by naked eye during the daytime. Live mussels and dead shells were collected by hand;

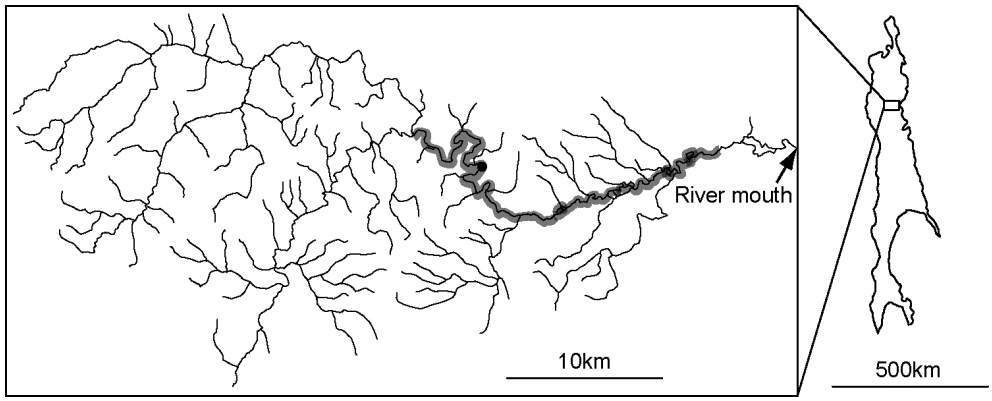
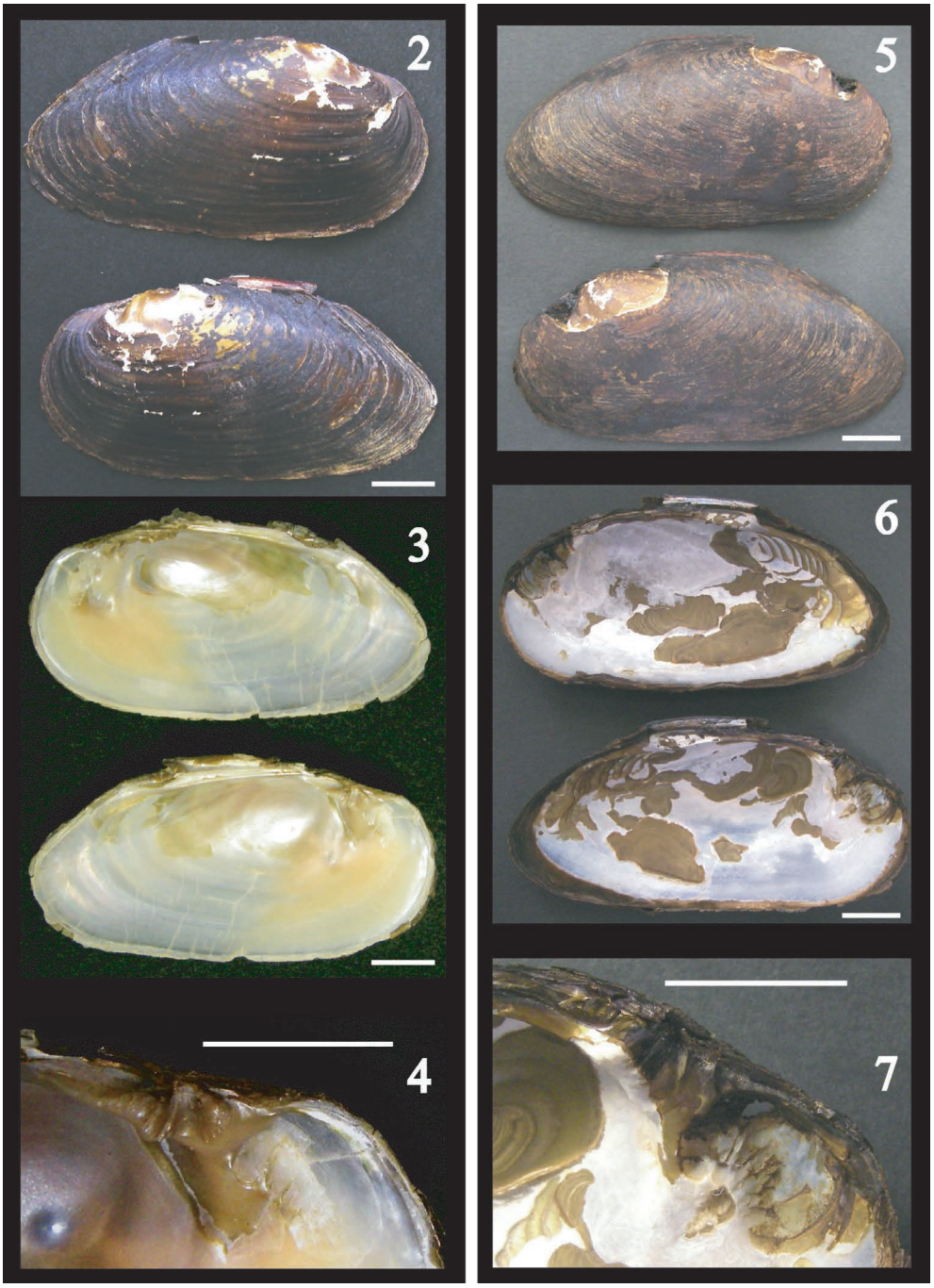


Fig. 1. Map of the Dagi River system located at northern Sakhalin. Shaded line indicates sampling section. A closed circle represents the site for intensive fishing.



Figs. 2–4. Dead shells of *Margaritifera togakushiensis* (ID1) collected in the Dagi River, northern Sakhalin. **2**. External surface. **3**. Internal surface. **4**. Anterior adductor muscle scar of left valve. Scale bar = 10 mm.
Figs. 5–7. Dead shells of *Margaritifera laevis* (= *Kurilinaia zatravkini*) (ID2) collected in the Dagi River, northern Sakhalin. **5**. External surface. **6**. Internal surface. **7**. Anterior adductor muscle scar of left valve. Scale bar = 10 mm.

shell dimensions (shell length, shell height, shell width and distance between apex of wing and anterior margin) were measured with a vernier caliper to within 0.1 mm accuracy. The live mussel was measured as well as the dead shells, but the shell width of the mussel was not measured. The live mussel was immediately released into the collection site after the measurements.

Shell size is helpful for species identification: shell length in *M. togakushiensis* is less than 100 mm but *M. laevis* grows over 100 mm (Kondo & Kobayashi, 2005). Kondo & Kobayashi (2005) also showed that *M. laevis* and *M. togakushiensis* could be distinguished by three shell characters: presence/absence of inclination of dorsal margin, shape of anterior margin and shape of adductor muscle scar. A specimen with no inclination of the dorsal margin, a rounded anterior margin and pointed ear-shaped adductor muscle scar is *M. togakushiensis*, whereas a specimen with inclination of the dorsal margin, a semi-elliptical anterior margin and a rounded ear-shaped adductor muscle scar is *M. laevis*. To ensure accuracy, *M. togakushiensis*-like specimens (Figs. 2–4, 8) were identified for the present study by Takaki Kondo and Osamu Kobayashi, who described *M. togakushiensis* as a new species (Kondo & Kobayashi, 2005), and Teruhiko Awakura, who has studied the ecology of the Margaritiferidae since 1960s (Awakura, 1964) in addition to the authors.

To understand the taxonomic position of *M. togakushiensis* in the Russian classification scheme for freshwater pearl mussels, which is based on comparative methods, specimens were also identified to species according to Bogatov *et al*. (2003). All Russian margaritiferid species can be distinguished by using the identification key in Bogatov *et al*. (2003). *Dahurinaia transbaicalica*, which was described by Klishko (2008), is not listed in the article, but we did not care about the species because it has recently been regarded as a junior synonym of *Dahurinaia ussuriensis*, distributed in the Amur River basin (Bogatov, 2012). We tried to identify the collected specimens to species using only shell shape. To do this based on Bogatov *et al*. (2003), first of all, we discriminated *K. laevis*, *K. zatravkini* and *K. kurilensis* (= *M. laevis*) from the other margaritiferid species by the presence of lateral (posterior) teeth and the ratio of *d* (distance between apex of wing and anterior margin of shell) to shell length. The three species have lateral (posterior) teeth and the ratio for these species is not more than 0.78. Next, to select the correct species from the three candidates, we calculated the ratio of shell width to maximum shell height (SW/SH) (*K. laevis*, <0.54; *K. zatravkini*, 0.55< <0.61; *K. kurilensis*, >0.63). To identify the fish species in the Dagi River, lure fishing was conducted by four persons within the section indicated in Fig. 1 between 21st and 24th October 2011. Variously colored minnows, spoons and spinners were used for the fishing. Intensive fishing was performed within a site at the middle reaches of the Dagi River on October 22nd, 2011. After intensive fishing, individuals of fish caught per

Fig. 8. The live mussel of *Margaritifera laevis* (ID5) collected in the Dagi River, northern Sakhalin. Scale bar = 10 mm.

Table 1. Results of the examination for mussels collected at middle and lower reaches of the Dagi River, northern Sakhalin.

ID	Condition	Shell characteristics							Scientific name referred to Kondo & Kobayashi (2005)	Scientific name referred to Bogatov *et al.* (2003)
		Lateral (posterior) teeth	Distance between apex of wing and anterior margin (*d*) (mm)	SL (mm)	SH (mm)	SW (mm)	SW/SH	*d*/SL		
1	Dead shells	Present	51.8	65.3	33.3	18.3	0.5495	0.79	*Margaritifera togakushiensis*	?
2	Dead shells	Present	69.3	99.1	47.8	29.1	0.61	0.70	*Margaritifera laevis*	*Kurilinaia zatravkini*
3	Dead shells	Present	70.1	106.4	47.9	27.9	0.58	0.66	*M. laevis*	*K. zatravkini*
4	Dead shells	Present	65.8	91.0	44.1	25.4	0.58	0.72	*M. laevis*	*K. zatravkini*
5	Live mussel	Present	65.7	95.6	45.9	–	–	0.69	*M. laevis*	?

Table 2. Results of lure fishing within a site established at middle reaches of the Dagi River, northern Sakhalin.

Scientific name	English name	No. of collected fishes
Hucho perryi	Sakhalin taimen	4
Salvelinus malma malma	Dolly varden	6
Salvelinus leucomaenis leucomaenis	White-spotted char	20
Oncorhynchus kisutch	Coho salmon	2

species were counted and recorded.

Results

Twenty-six dead shells and one live mussel were collected during our search. Of the dead shells, four pairs including the specimens in Figs. 2–7 were almost unbroken, and thus exact species identification was performed for these shells in addition to the live mussel (Fig. 8). A summary of shell dimensions and species identification is shown in Table 1. All dead shells were collected from the river bank and bottom. The live mussel was accidentally collected with a hook of a fishing lure. One of the dead shells (ID1) was identified as *M. togakushiensis* because the shape of the adductor muscle scar was like a pointed ear (Fig. 4), the anterior margin of the shell was rounded and the dorsal margin of the shell was not inclined diagonally forward (Figs. 2, 3). The specimen was similar to *K. zatravkini* but could not be identified distinctly using the Russian classification (Table 1). The other specimens (ID2 to 5) were identified as *M. laevis*, whereas these specimens (except ID5) were *K. zatravkini* under the Russian classification. The live mussel (ID5) could not be identified clearly to species because a check of the lateral (posterior) teeth and measurement of shell width were not carried out.

Four species of Salmonidae, *i.e.,* Sakhalin taimen (*Hucho perryi*), Dolly varden (*Salvelinus malma malma*), white-spotted char (*Salvelinus leucomaenis leucomaenis*) and Coho salmon (*Oncorhynchus kisutch*), and one species of Cyprinidae, *i.e.,* Rosyface dace (*Tribolodon ezoe*) were caught. White-spotted chars were caught throughout the sampling section. A brief summary of intensive fishing within a site is presented in Table 2. The four salmonid species referred to above were caught in the site. White-spotted char was the most abundant.

Discussion

In the Dagi River, a dead shell of *M. togakushiensis* was collected. Though a live individual of

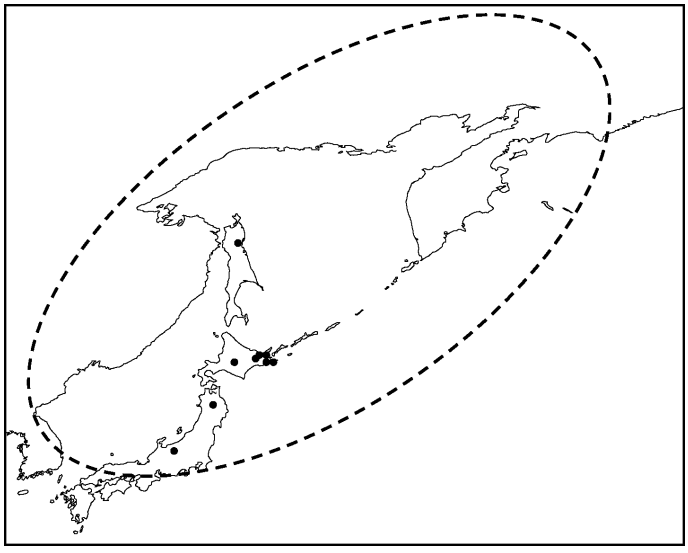


Fig. 9. Worldwide distributions of the freshwater mussel *Margaritifera togakushiensis* and white-spotted char *Salvelinus leucomaenis*. Closed circles indicates the distribution site of *M. togakushiensis* (Kondo, 2008), an area surrounded by dashed line is the distribution region of white-spotted chars (Dunham *et al.*, 2008).

the species could not be found, this finding suggests that *M. togakushiensis* is distributed in Sakhalin. In the Russian Far East, 11 margaritiferid species, *i.e.*, *Dahurinaia dahurica*, *D. komarovi*, *D. prozorovae*, *D. sujfunensis*, *D. tiunovae*, *D. ussuriensis*, *Kurilinaia kamchatica*, *K. kurilensis*, *K. laevis*, *K. middendorffi* and *K. zatravkini* are present according to Kantor *et al*. (2010) and Bogatov (2012). Nowadays, *M. togakushiensis* is considered to be different from these species (Graf, 2007). Our result supports this, because *M. togakushiensis* could not be identified distinctly at least based on shell characteristics using the Russian classification scheme.

Occurrence of *M. togakushiensis* is potentially supported by the white-spotted char, the host for *M. togakushiensis* larvae. Thus potential distribution of *M. togakushiensis* can be extrapolated to the worldwide distribution of the white-spotted char. The white-spotted char is distributed along the northwestern Pacific Rim, and all habitats of *M. togakushiensis* are contained within this area (Fig. 9). The wide distribution of the white-spotted char suggests that *M. togakushiensis* might be widely distributed in northern parts of the Russian Far East such as the Kamchatka Peninsula, Magadan Oblast and Khabarovsk Krai.

Some margaritiferid species, including *M. togakushiensis*, exclusively coevolve with salmonid fishes through migration of the fishes. Thus understanding the exact distributions of *M. togakushiensis* and the white-spotted char is of interest in terms of historical biogeography.

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北サハリンで確認されたコガタカワシンジュガイの新産地記録

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要　約

本報告は，北サハリンに分布するコガタカワシンジュガイの死殻の発見を初めて報告するものである。著者らは 2011 年 10 月 21～24 日にかけて，北サハリンを流れるダギ川にてカワシンジュガイ類及び魚類の採集を行なった。26 個体の死殻と 1 個体の生貝が採集され，これらの標本のうち，ほぼ欠損の無い死殻 4 個体と生貝 1 個体に対して殻形態に基づく種同定を行なった。コガタカワシンジュガイらしき標本に関しては慎重な種同定を行なうため，著者らの他に，コガタカワシンジュガイに詳しい研究者 3 名による種同定も合わせて行なわれた。結果，死殻 1 個体がコガタカワシンジュガイ，その他の標本はカワシンジュガイと同定された。魚類はイトウ，オショロコマ，アメマス，ギンザケ，エゾウグイが採集され，これらのうち，コガタカワシンジュガイの宿主であるアメマスが最も多く釣獲された。コガタカワシンジュガイの分布はアメマスの分布範囲内に限定されており，アメマスの世界的な分布から，コガタカワシンジュガイはサハリンより北部のカムチャッカ半島，マガダン州，ハバロフスク地方にも分布する可能性があると考えられる。