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A taxonomic revision of two local endemic *Radix* spp. (Gastropoda: Lymnaeidae) from Khodutka geothermal area, Kamchatka, Russian Far East

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Introduction

Khodutka geothermal area is located near Khodutka and Priemysh volcanoes and is one of the largest geothermal areas of the Kamchatka Peninsula. Vakin (2003) described geological, geochemical and geothermic conditions of this geothermal area in detail. The main thermal water sources have temperatures up to 87°C and a discharge of approximately 150 l×sec.⁻¹ are flows out into the warm lake with dimensions of ca. 250 m length and 80 m width. This warm river is ca. 20 m in width beginning from the lake and flows to the Bolshaya Khodutka River basin. Two local endemic *Radix* species were described from this geothermal area, especially *Lymnaea (Radix) hadutkae* Kruglov & Starobogatov, 1989 and *L. (R.) thermokamtschatica* Kruglov & Starobogatov, 1989 (Kruglov & Starobogatov 1989, 1993; Kruglov 2005). These species were separated using proportions of shell and reproductive system (Kruglov & Starobogatov 1989, 1993; Starobogatov *et al.* 2004). According to the diagnosis, *L. (R.) hadutkae* differs in the ear-shape shell, a form of the provaginal duct with cylindrical distal part and conical proximal part, and larger value of the index of the copulatory apparatus (ICA: proportion of the preputium to phallotheca is 1.27) from other species within the section *Thermoradix* Kruglov & Starobogatov, 1989. The last whorl is large, 0.86–0.89 of the shell height; an excess of the last whorl over upper margin of the aperture is 0.15–0.16 of the aperture height. *L. (R.) thermokamtschatica* has the cylindrical provaginal duct, relatively short bursa duct (1.5X longer than the bursa copulatrix diameter) and very long phallotheca (ICA is 0.77). The last whorl is large, 0.85–0.87 of the shell height; an excess of the last whorl over upper margin of the aperture is 0.2–0.25 of the aperture height. In accordance with an identification key (Starobogatov *et al.* 2004), the main diagnostic feature is an excess of the last whorl over the shell aperture, which has ≤ 0.78 and ≥ 0.80 of the penultimate whorl width in the first and second species, respectively. In the present paper, we revised these taxa using newly collected topotypes and additional *Radix* spp. specimens from other areas of the Russian Far East.

During field expeditions in 2010–2013, lymnaeid snails were collected from eight localities on the Russian Far East, including the Khodutka geothermal area. Sampled specimens were preserved in 96 % ethanol. Materials are deposited in the Biological Museum of the Institute of Ecological Problems of the North (INEP), the Ural Branch of the Russian Academy of Sciences, Arkhangelsk, Russia. Species identification was performed using shell morphology, soft body anatomy and molecular data. Anatomical and morphological details were photographed using a stereomicroscope (Leica M165C, Leica Microsystems, Germany). The type specimens of *Lymnaea (Radix) hadutkae* Kruglov & Starobogatov, 1989 and *L. (R.) thermokamtschatica* Kruglov & Starobogatov, 1989 were studied in the collection of the Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russian Federation (ZIN).

Molecular analysis was performed in the Institute of Ecological Problems of the North of the Ural Branch of Russian Academy of Sciences (purification and PCR) and the Engelhardt Institute of Molecular Biology of Russian Academy of Sciences (sequencing on ABI PRISM 3730). We analyzed *Radix* spp. samples from Khodutka area, as

Kamchatka, Primorye, Sakhalin, and Kuriles (Fig. 7). Zhadin (1952) reported that this species is widespread on the Pacific Basin, including Kamchatka, Amur Basin and Primorye, which is in agreement with our records. However, Kruglov & Starobogatov (1993) noted that *R. auricularia* ranged in Europe, the western part of the Middle East and Siberia, but not mentioned in the species records from the Far East. Thereafter, Starobogatov *et al.* (2004) again reported that species ranged on the Far East, where it was recorded in rivers of the Pacific coast from Kamchatka to Primorye. Meanwhile, Kruglov & Starobogatov (1989, 1993), Starobogatov *et al.* (2004) and Kruglov (2005) listed many local endemic *Radix* species for different areas of the Russian Far East, which belong to the sections *Ussuriradix* Kruglov & Starobogatov, 1989, *Nipponiradix* Kruglov & Starobogatov, 1989 and *Okhotiradix* Kruglov & Starobogatov, 1989. Taxonomic position of these taxa is uncertain and they need in a current revision based on mitochondrial and nuclear molecular markers.

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APPENDIX 1. List of studied *Radix auricularia* specimens from Russian Far East. Materials are deposited in the Biological Museum of Institute of Ecological Problems of the North (INEP), the Ural Branch of Russian Academy of Sciences, Arkhangelsk, Russian Federation.

COI NCBI's GenBank acc. no.	Haplotype Code	Specimen Voucher	Locality	Habitat type	Latitude	Longitude
KM067596	PAR1	INEP-378.1	Russia, Kamchatka, Paratunskie hot springs	Geothermal	52°49'26"	158°09'48"
KM067598	PAR1	INEP-393.1	Russia, Kamchatka, Paratunskie hot springs	Geothermal	52°49'26"	158°09'48"
KM067599	PAR1	INEP-386.2	Russia, Kamchatka, Paratunskie hot springs	Geothermal	52°49'26"	158°09'48"
KM067600	PAR1	INEP-390.2	Russia, Kamchatka, Paratunskie hot springs	Geothermal	52°49'26"	158°09'48"
KM067601	PAR1	INEP-398.2	Russia, Kamchatka, Paratunskie hot springs	Non-geothermal	52°49'26"	158°09'48"
KM067597	PAR1	INEP-379.1	Russia, Kamchatka, Paratunskie hot springs	Geothermal	52°49'26"	158°09'48"
KM067602	KHO1	INEP-375.1	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM067603	KHO1	INEP-385.2	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM067604	KHO1	INEP-385.3	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM067605	KHO1	INEP-491.1	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM067606	KHO1	INEP-392.1	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM111179	KHO2	INEP-491.4	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM111180	KHO2	INEP-491.5	Russia, Kamchatka, Khodutka geothermal area	Geothermal	52°06'27"	157°39'25"
KM067607	MAL1	INEP-117.1	Russia, Kamchatka, Malkinskie hot springs	Geothermal	53°19'19"	157°32'14"
KM067608	MAL1	INEP-117.3	Russia, Kamchatka, Malkinskie hot springs	Geothermal	53°19'19"	157°32'14"
KM067609	MAL1	INEP-119.3	Russia, Kamchatka, Malkinskie hot springs	Geothermal	53°19'19"	157°32'14"
KM067610	MAL1	INEP-119.4	Russia, Kamchatka, Malkinskie hot springs	Geothermal	53°19'19"	157°32'14"
KM067611	MAL1	INEP-119.5	Russia, Kamchatka, Malkinskie hot springs	Geothermal	53°19'19"	157°32'14"

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