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SHORT COMMUNICATION

Mercury Status of the Primorsky Minnow, *Phoxinus oxyrhynchus* (Mori, 1930) and the Manchurian Lake Minnow, *Rhynchocypris mantschurica* (Berg, 1907)

NADEZHDA YA. PODDUBNAYA[1,*], MARINA D. MOLEVA[1], DASHA S. SOROKINA[1], GALINA P. SALKINA[2]

[1]Department of Biology, Cherepovets State University, Cherepovets 162600, Russian Federation
[2]Joint Directorate of the Lazovsky State Nature Reserve and the National Park "Zov Tigra", Lazo 692980, Russian Federation

*E-mail: poddoubnaia@mail.ru |Received: 03/07/2024; Accepted: 28/05/2025

Abstract

The total mercury (THg) content was evaluated in muscles (mg.kg^{-1} wet weight) of the Primorsky minnow, *Phoxinus oxyrhynchus* (Mori, 1930) and the Manchurian Lake minnow, *Rhynchocypris mantschurica* (Berg, 1907) from the unique ecoregion of Ussuri broadleaf and mixed forests in the Russian Far East in 2023. The results showed that the THg concentration in the muscles of the Primorsky minnow from the Kievka River basin ranged from 0.052 to 0.350 mg.kg^{-1}; with a mean of 0.106 ± 0.015, and a median of 0.078 mg.kg^{-1}. The THg concentration in the muscles of the Manchurian Lake minnow from the Melgunovka River basin were lower than those for *R. mantschurica* with a range of 0.025–0.097 mg.kg^{-1}; and a mean of 0.047 ± 0.004, and median of 0.046 mg.kg^{-1}. The THg concentrations in minnows of the same size group (<115 mm in body length i.e. immature) from the Kievka River and Melgunovka River basins differed significantly (P = 0.001) and were about 2 times higher in the Kievka than the Melgunovka. The THg levels in the minnows (0.047–0.106 mg.kg^{-1}) and the frequency of consumption by people (once per week) indicate a low risk to human health. These data are close to the range of Hg concentrations in freshwater fish (0.038–0.02 mg.kg^{-1} WW) in the Songhua and Liaohe River basins in China bordering the study region.

Keywords: ecotoxicology, environmental risk, fish, ichthyophages, total mercury

Introduction

Mercury is a highly toxic substance capable of accumulating in tissues and organs of living organisms (UNEP, 2013; Kalisińska et al., 2019). Fish play an important role in the accumulation of mercury and provide an indication of bioavailable mercury in the environment. The level of accumulated mercury may depend on the age, size and trophic status of the fish (Backstrom et al., 2020; Smalling et al., 2021; Ivanova et al., 2023). Minnows are eaten by more than 100 species of vertebrates in the Ussuri broadleaf and mixed forests ecoregion above the lower Amur River and Ussuri River in the Russian Far East. They are one of the main food objects for about 40 species of vertebrates: fish – lenoks (*Brachymystax lenok* (Pallas, 1773), *B. savinovi* Mitrofanov, 1959) (Reshetnikov et al., 2003), 26 species of birds: e.g., common kingfisher *Alcedo atthis* (Linnaeus, 1758), red-breasted merganser (*Mergus serrator* Linnaeus, 1758), scaly-sided Merganser (*M. squamatus* Gould, 1864), goosander (*M. merganser* Linnaeus, 1758) (Butyev et al., 2005; our data), striated heron (*Butorides striata* (Linnaeus, 1758) (Andronov et al., 2011); mammals: e.g., the American mink (*Neogale (Neovison) vison* (Schreber, 1777)), the Eurasian otter (*Lutra lutra* (Linnaeus, 1758)), and the Eurasian water shrew (*Neomys fodiens* Pennant, 1771) (Poddubnaya and Kolomiytsev, 2016). Minnows are of lesser feeding importance for more than 60 other species of vertebrates: e.g., Siberian taimen (*Hucho taimen* (Pallas, 1773), the Sakhalin taimen (*Parahucho perryi* (Brevoort, 1856), the whitespotted char (*Salvelinus leucomaenis* (Pallas, 1814)), the redfin *Pseudaspius leptocephalus* (Pallas, 1776) (Reshetnikov et al., 2002, 2003), the northern snakehead (*Channa argus* (Cantor, 1842)), and Dione's rat snake (*Elaphe* *dione* (Pallas, 1773), red-backed snake (*Oocatochus rufodorsatus* (Cantor, 1842), the tiger keelback (*Rhabdophis tigrinus* (Boie, 1826) (Bannikov et al., 1971), for about 50 species of birds (Butyev et al., 2005; Andronov et al., 2011), the leopard cat (*Prionailurus bengalensis euptilurus* Elliot, 1871), kolonok (*Mustela sibirica* Pallas, 1773), the brown rat (*Rattus norvegicus* (Berkenhout, 1769), the Ussuri white-toothed shrew (*Crocidura lasiura* Dobson, 1890) (Poddubnaya, unpubl. data). Among consumers of minnows, 29 species are rare or endangered (The Red Data Book of Primorsky Krai, 2005). The local human population also consumes minnows (Reshetnikov et al., 2002).

The study of mercury content in animal tissues and organs in the south of the Russian Far East is of great interest, since this territory borders China, having localities where there are deposits of mercury-containing minerals (Shcheka et al., 1991). Freshwater fish from the Songhua and Liaohe River basins bordering the study area contain some of the highest concentrations of mercury in China (Ai et al., 2022). This may be influenced by cross-border transport of mercury compounds from places with the highest levels of anthropogenic mercury pollution in Asian countries (Li et al., 2009).

The concentration of mercury in the tissues and organs of animals from higher trophic levels depends on the content of mercury in the organism of minnows. Therefore, a pilot study on mercury concentration in two species of minnows (*Phoxinus oxyrhynchus* and *Rhynchocypris mantschurica*) in the south of the Russian Far East was carried out.

Materials and Methods

Ethical approval

This study was approved by the Bioethics Commission of Cherepovets State University (protocol no. 1-2023 dated December 25, 2023). Fish were caught in accordance with the Fishing Rules of the Russian Federation. The questionnaires were performed in accordance with the World Medical Association (WMA) Declaration of Helsinki: ethical principles for medical research involving human subjects (WMA, 2008).

Experimental design

The physico-chemical parameters of the water body of the Kievka River have been summarised by Vaskovsky (1972) and these are briefly summarised here. This river is located on the eastern macroslope of the Sikhote-Alin and flows into the Sea of Japan, it has a mountainous character. The length of the river is 105 km, the catchment area is 3120 km^2, and the total fall of the river is 500 m. The water layer reaches 1–1.5 m, the average flow speed in the river is 1.0–1.2 m.s^{-1}. The river's supply is dominated by rain floods, the share of underground supply accounts for about 15 %, and snow about 5 %. The water is colder than the air during the entire ice-free period, and only in October in the lower reaches of the river water is the air warmer. Water mineralisation is low, with a reduced concentration of macro-ions and biogenic elements. The water is ultra-fresh, with a deficiency of calcium and magnesium. Bottom sediments and wetlands contributing to mercury methylation are practically absent.

The middle part of the Melgunovka River is located on an elevated terrace with hilly terrain (150–200 m) of the Prikhankai plain. The length of the river is 165 km, the catchment area is 3510 km^2, and the total fall of the river is 547 m. The flow speed on the rifts is 0.5–0.7 m.s^{-1}. The water of the Melgunovka River belongs to the bicarbonate class of the calcium group with a low degree of mineralisation. The water is very soft.

Both rivers have clean, cool water and a fast current with areas with rocky and pebbly sandy bottoms, which provides favourable habitat conditions for minnows. The minnows were caught in shallow lake areas of rivers with rocky-sandy soil, without swampy banks, which remain connected to the main riverbed during the low-water period of the year.

Fish were caught with a single-hook fishing rod at the end of September 2023 in accordance with the Fishing Rules of the Russian Federation. Captured individuals included 25 specimens of the Primorsky (coastal) minnow *Phoxinus oxyrhynchus* (Mori 1930) from the Lazovsky district (43°15′0″N, 134°0′0″E), in the Kievka River basin and 18 specimens of the Manchurian Lake minnow *Rhynchocypris mantschurica* (Berg, 1907) from the Khorolsky district (44°25′30″N, 132°04′30″E), in the Melgunovka River basin. They were euthanised by cervical dislocation and kept frozen at -20 °C until processed. Prior to dissection, the mass (± 0.1 g) of each sample was determined with electronic scales and body length was measured (± 1.0 mm). Fish were frozen and transported to the Ecological and Analytical Laboratory of Cherepovets State University, for morphometric processing, preparation and analysis.

Measurements of total mercury in muscles were performed in wet weight (WW) on the mercury analyser (RA-915M, Lumix, Russia). The measurement accuracy of the device is 0.001 mg.kg^{-1}. The accuracy of the analyser was monitored using DORM-4 (Canada) reference samples with a known mercury concentration (mg.kg^{-1}). All captured individuals were divided into groups depending on the maturity of the gonads and total length: <115 mm and ≥115 mm. In the Kievka River basin, eight individuals had mature gonads and a body length exceeding 115 mm, and 17 had immature gonads and a body length less than 115 mm. In the Melgunovka River basin, only one individual was mature i.e. ≥115 mm and 17 were <115 mm and had immature gonads.

In May and September 2018, 118 residents of the Lazovsky district (the Kievka River basin) were interviewed on their consumption of fish from local waters. The study involved 97 men and 21 women aged from 18 to 78 years, which represents 0.99 % of the population of the study area. Each participant completed a questionnaire to indicate their gender, age, place of residence, frequency of minnows consumption followed WHO recommendations (WHO, 1963).

Statistical analysis was carried out using StatSoft Statistica 12.0 and Microsoft Excel 2016 programmes. The significance level was set at $P < 0.05$.

Results and Discussion

The THg concentration in the muscles of the Primorsky minnow from the Kievka River basin ranged from 0.052 $mg.kg^{-1}$ RW to 0.350 $mg.kg^{-1}$ RW; the mean was 0.106 ± 0.015 $mg.kg^{-1}$ RW, and the median was 0.078 $mg.kg^{-1}$. In fish <115 mm total length i.e. immature individuals, the mean was 0.078 ± 0.005 $mg.kg^{-1}$, compared with a mean value for fish ≥115 mm i.e. mature individuals of 0.167 ± 0.050 $mg.kg^{-1}$ RW.

The THg concentration in the muscles of the Manchurian Lake minnow from the Melgunovka River basin ranged from 0.025 $mg.kg^{-1}$ RW to 0.097 $mg.kg^{-1}$ RW; the mean was 0.047 ± 0.004 $mg.kg^{-1}$, and the median was 0.046 $mg.kg^{-1}$ RW.

Our data for concentrations of THg in the muscles of fish exceed the data obtained earlier in the mouth of the Artemovka River, which flows into the Sea of Japan, where the mercury content in sediments is 0.053 $mg.kg^{-1}$ dry weight (DW) and in minnow muscles ranged from only 0.020-0.025 $mg.kg^{-1}$ DW (Kovekovdova and Simokon, 2010). The range of Hg concentrations in freshwater fish in the Songhua and Liaohe River basins bordering the study region is 0.038–0.102 $mg.kg^{-1}$ RW (Ai et al., 2022), which is close to our data. The THg content in the muscles of the Manchurian Lake minnow was higher than in the Siberian wood frog (*Rana amurensis*) and the Sakhalin toad (*Bufo sachalinensis*) from the Melgunovka River basin (Poddubnaya et al., 2024). Mean THg concentrations were 0.055 ± 0.018 $mg.kg^{-1}$ dry weight (DW) in muscles in the immature and 0.035 ± 0.005 $mg.kg^{-1}$ DW in adults Siberian wood frogs, and 0.058 ± 0.007 $mg.kg^{-1}$ DW in muscles in the immature Sakhalin toad (Poddubnaya et al., 2024).

A comparison of THg concentration in minnows of the same size group (<115 mm in length) from the Kievka River and Melgunovka River basins showed a statistically significant difference ($P = 0.001$): the mean concentration in the Primorsky minnow from the Kievka River (0.106 $mg.kg^{-1}$) was significantly greater than in the Manchurian Lake minnow from the Melgunovka River (0.047 $mg.kg^{-1}$). The mean THg concentration for larger, mature Primorksy minnows in the Kievka River (0.167 $mg.kg^{-1}$) was about 2 times greater than for smaller, immature fish (0.078 $mg.kg^{-1}$). This increase in THg in the muscles of fish with age is natural (Backstrom et al., 2020; Smalling et al., 2021; Ivanova et al., 2023), then the differences in the muscles of minnows from the two areas may be related to the location of the areas. A possible interspecific difference in fish nutrition is also possible. The detected THg concentrations in the muscles of minnows of both species are much lower than the maximum permissible concentrations of mercury compounds for non-predatory freshwater fish (0.3 $mg.kg^{-1}$ of raw weight; SanPiN 2.3.2.1078-01, 2001).

The survey of 118 local residents showed that 59.3 % of them consume minnows regularly (once per week) in different seasons of the year. The THg levels in the minnows (0.047–0.106 $mg.kg^{-1}$) and the frequency of consumption by people indicate a low risk to human health.

Conclusion

The low mercury status of minnows allows us to expect low levels of environmental hazards for humans and wild animals preying on these fish species. Additional studies are needed on the mercury content of ichthyophages such as, the scaly-sided merganser which is listed as an endangered species on the IUCN Red List. Our pilot studies should be continued throughout the south of the Russian Far East with larger numbers of samples.

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Author contributions: Nadezhda Ya. Poddubnaya: Conceptualisation, methodology, writing. Marina D. Moleva: Collected data and review. Dasha S. Sorokina: Collected data and review. Galina P. Salkina: Writing-original draft.

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