Peculiarities of the Distribution of Heavy Metals in the Organs of the Pacific Redfin

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Abstract. This article presents data on the levels of Zn, Mn, Cu, Fe, Pb and Cd in the organs and tissues of the Pacific Redfin. For each metal, rows of its distribution within the organs of Pacific Redfin were built. An attempt was made to determine the nature of the accumulation of metals in the organs and tissues of fish, driven by the ecology and biology of the species.

1. Relevance, scientific significance of the issue
Interest in the study of metal content in fish is dictated by two main reasons: using them as food objects, and also as indicators of the state of the environment.

The issue of the content and distribution of metals in the organs and tissues of fish in the scientific literature is covered quite widely [6, 8, 10, 15, 16, 18, 19, 26, 28, 29, 30, etc.].

However, data on the metal content in fish of Primorye are few [9, 12, 25]. At the same time, the northern part of the region is a well-known metallogenic province [20], while the southern part is experiencing anthropogenic pollution, coming both from its own large cities (Vladivostok, Nakhodka, Ussuriysk) and due to transboundary transport with water and air flows [11, 21]. In this regard, it was of interest to determine the levels of heavy metals in the specimens of commercial fish species using the example of the large-scaled Redfin Tribolodon hakonensis (Günther) and the small-scaled Redfin Tribolodon brandti (Dybowski).

2. Formulation of the problem
The purpose of this work is to identify patterns of distribution of metals in the organs and tissues of the large-scaled Redfin Tribolodon hakonensis (Günther) and the small-scaled Redfin Tribolodon brandti (Dybowski).

To achieve the goal it was necessary to perform the following tasks:

1. Determine the levels of metal content in organs and tissues of large-scaled Redfin Tribolodon hakonensis (Günther) and small-scaled Redfin Tribolodon brandti (Dybowski).

2. Determine the nature of the accumulation of metals in the organs and tissues of fish, driven by the ecology and biology of the species.

3. Compare the distribution of metals in the organs and tissues of the Pacific Redfin and the silver Prussian carp Carassius auratus gibelio.
3. Theoretical part

In the Primorsky Territory, two types of Redfins of the genus Tribolodon are known: small-scaled T. brandti (Dybowski) and large-scaled T. hakonensis (Günter) [21].

Pacific Redfin is widespread along the Asian coast of the Pacific Ocean from Korea to the Shantar Islands; in the Amur, it inhabits the lower reaches and the rivers flowing into the estuary; it is found near the South Kuril Islands, Sakhalin and Japan [4, 22, 17].

Small-scaled Redfin is found along the coast of the Sea of Japan from the Foggy river in the south to 47°19’ N. The population of these species is especially high in the rivers of the southern Primorye, which flow into the Peter the Great Gulf [4]. The abundance and biomass of the small-scaled Redfin decrease from south to north, and those of the large-scaled Redfin increase in that direction [3].

Pacific Redfins are the only representatives of the carp family that adapted to feeding under oceanic salinity [7, 5, 17].

Pacific Redfins are semi-migrating fish [2, 17].

In the summertime, small-scaled Redfin is widespread in coastal waters, it can be found up to a depth of 40 m; large-scaled Redfin is confined to a narrow coastal strip (to a depth of 20 m) and the lower course of rivers [1].

Pacific Redfins are medium-sized fish. They reach a length of 50 cm and a mass of 1.5 kg [17].

In the southern Primorye (the Peter the Great Gulf) Pacific Redfin is an important object of local fishing.

For the study, 5 specimens of fish of the same size were taken from each station and were dissected by organs and a part of the spinal muscle was isolated. Scales, skin, gills, gonads, liver, kidneys, and spleen were taken for analysis. Dried at a temperature of 85°C weights of organs weighing 0.5 g from each specimen were subjected to the acid decomposition of concentrated HNO₃ of high purity. The content of metals (Zn, Fe, Cu, Mn, Cd, Ni, Pb) in the samples was determined by atomic absorption spectrophotometry (AAS) on a Shimadzu AA-6800 instrument using flamed and flameless options. Analytical control was performed using blank samples and standard NIST 2976 material. To determine the significance of differences in the mean values of metal concentrations, the Mann-Whitney test was used. Statistical processing was performed using the standard EXCEL and STATGRAPHICS Plus 5.1 packages.

The choice of metals was determined by the following considerations: Fe and Mn, as well as Cu and Zn, are true bio-elements, but at high concentrations have a negative effect on living organisms. In addition, Cu and Zn are tracers of human impact, if they are not associated with ore-bearing, mining and use in production. Compounds Cd, Ni and Pb indicate an industrial pressure on the environment.

The Redfins were selected from the following places in Primorsky Krai: the Krolevetsky Lake, the Kiparisovka, Lebedinaya, Artyomovka, Razdolnaya rivers, Vostok and Amursky gulfs. 50 specimens were studied. The average fish size was 320 ± 10 mm.

4. The results of experimental studies

Earlier, in a number of papers, we provided information concerning the features of the distribution of heavy metals in the crucian carp bodies of the silver Prussian carp Carassius auratus gibelio from water bodies of the south of Primorsky Krai [14, 23, 24].

In the organs of the Pacific Redfins, in contrast to the silver Prussian carp, a slightly different distribution of metals was observed.

The following is a comparative description of the characteristics of the distribution of heavy metals in the organs and tissues of the Pacific Redfins and the silver Prussian carp.

4.1. Zinc

Unlike the silver Prussian carp, which had a maximum of the element in the gills and kidneys, in the Pacific Redfins the highest zinc content was found in scales (194.6 ± 37.4 µg/g) and gonads (179.6 ± 147.4 µg/g). The content of this metal in the skin was rather high (150.4 ± 68.6 µg/g). In the muscles, the amount of zinc is minimal (19.5 ± 4.1 µg/g).
In a number of literary sources, it is noted that many metals are localized in organs and formations that are in direct contact with the aquatic environment (gills, fins, skin, scales). The external organs of fish perform not only protective (barrier) functions, but also constitute an additional reserve fund of trace elements [18, 8].

The levels of zinc in the skin of Redfins and silver Prussian carp are virtually the same (for the silver Prussian carp it is 147.2 ± 70.9 µg/g), but in the ranks of the distribution of metal through the organs, the skin of these fish takes different places. For the silver Prussian carp, the skin is preceded by gills, kidneys, spleen, liver and gonads, and for Redfins only scales and gonads precede, that is, for the carp practically all organs, except for scales and muscles, are characterized by a high content of this metal. The identified feature, in our opinion, is related to the ecology of these species of fish: the silver Prussian carp is an inhabitant of fresh standing water bodies, where the concentration of zinc is always elevated compared to sea and estuarine waters, where Redfins spend most of the time [18].

An increased zinc content, like that of the silver Prussian carp, was found in the liver (104.1 ± 41.5 µg/g), gills (93.0 ± 15.7) and kidneys (76.0 ± 19.7 µg/g).

Distribution series for organs of the Redfin is as follows: scales>gonads>skin>liver>gills>spleen>kidneys>muscles.

Significant differences between the zinc content in the organs of fish were found for scales, in which Zn is greater in Redfins, and for muscles, kidneys, and gills, in which the carp has more metal.

4.2. Iron
The maximum iron concentrations for the Redfins, like that of the Prussian carp, were observed in the spleen (900.8 ± 360.3 µg/g) and liver (545.4 ± 414.0 µg/g). And in absolute terms, they were also close.

Distribution series for organs of the Redfin is as follows: spleen>liver>kidneys>gills>gonads>muscles>scales>skin.

The distribution of iron in the organs of both species of fish is almost the same.

4.3. Manganese
For manganese, the distribution series for organs and tissues of Redfins is as follows: scales>gills>kidneys>liver>spleen>gonads>skin>muscles.

It basically repeats the distribution series of manganese in the bodies of the Prussian carp. For the Prussian carp, the series begins with the gills, followed by scales. Redfins have almost the same Mn content in these organs (scales - 18.2 ± 7.1 µg/g, gills - 17.5 ± 9.6 µg/g). In contrast to the Prussian carp, in the Redfin, the kidney, liver and spleen follow in the opposite direction, which indicates, obviously, the prevalence of manganese elimination from the body.

The main difference is that the Redfin is characterized by lower levels of manganese in all organs, which is undoubtedly associated with living in the marine environment, where, on the one hand, the metal concentration in water is lower and on the other hand, the dissolved oxygen content is higher, especially in shallow water dynamic zone (ensuring the progress of oxidative processes).

4.4. Copper
For copper, the distribution series for organs of the Redfin is as follows: liver>spleen>kidneys>gonads>gills>scales> muscles>skin.

Like with the Prussian carp, the series begins with the liver, the concentration of the metal in which was 28.0 ± 20.7 µg/g, which is almost equal to the copper concentration in the liver of the Prussian carp (26.5 ± 19.0 µg/g). However, the sequence: spleen, kidneys and gonad in the Prussian carp goes in the opposite direction. The muscles and skin of the Prussian carp are also swapped in this series. The predominance of copper in the Prussian carp gonads indicates an active course of generative processes.

Significant differences in the levels of copper content in the same organs in Prussian carp and Redfins were not found.
4.5. Nickel

For nickel, the distribution series in the organs of the Redfin is as follows: scales > gills > spleen > kidneys > muscles > liver > gonad > skin.

As can be seen, in the beginning of the series there are the organs that are in direct contact with the aquatic environment and carry out the deposition and excretion of excess element - the scales and the gills.

The predominant part of nickel in water is in suspended form, the amount of which decreases with moving from fresh to saline waters [13, 31]. Consequently, once could expect lower levels of nickel content in the scales and gills of the Redfins dwelling in seawater, as compared with the Prussian carp - inhabitant of fresh water. However, Redfins differ (at the trend level) by a higher nickel content than Prussian carps.

4.6. Lead

Lead concentrations in the organs of the Redfins were highly different between different sampling places.

The distribution series of Pb content in the organs of the Redfin is as follows: scales > gills > spleen > liver > kidney > skin > muscles > gonad.

The series begins with scales and gills - organs of contact with the external environment and deposition, followed by organs that perform excretion (kidneys) and detoxification (liver). The series ends with muscles and gonads. Identified features of the distribution of metal in the organs indicates a normal functional state of the body.

In the literature, it is noted that in warm-blooded animals, along with the spleen, bones and fatty tissue of the kidneys, the organs depositing Pb are nails and hair [27]. One can assume that fish scales have a similar function, which explains the significant metal content in this organ.

4.7. Cadmium

The distribution series of cadmium content in the organs is as follows: kidney > liver > skin > scales > muscles > gonads > gills.

As can be seen, in the Redfins the Cd excretion from the body prevails, as evidenced by the predominant accumulation in the organs of deposition (kidney, liver) and excretion (scales, skin). One can assume that gonads being near the end of the series indicates the effect of the regulatory mechanisms of the body aimed at protecting the reproductive health of fish and ensuring stable offspring.

5. Conclusion

Thus, in the Redfins, as in the Prussian carp, zinc (scales, skin, gonads) and iron (muscles, kidneys, gills, liver, spleen) are most abundant. Then, copper (muscles, kidneys, gonads, liver and spleen) and manganese (scales, gills) follow in decreasing concentrations. Thus, biophilic elements are contained in larger quantities than Ni, Pb and Cd. As in the Prussian carp, in the Redfins the same features are observed in the distribution of metals throughout the organs, the difference is in the concentration values for each species of fish.

As noted by a number of researchers and confirmed by us in this work, first of all, the body accumulates chemical elements necessary for its normal functioning and actively participating in physiological and biochemical processes of respiration, deposition, excretion, blood formation, etc., i.e. processes in which metals perform biocatalytic functions.

References
[1] Vdovin A N, Gavrenkov Yu I 1995 Estimation and state of reserves of the Pacific Redfins of Peter the Great Gulf Ichthyology Studies T 35 vol 5 pp 714 - 717
[2] Vdovin A N, Zuenko Yu I 1997 Vertical zonality and ecological groups of fish in the Peter the Great Gulf News of TINRO T 122 pp 152-176
[3] Gavrenkov Yu I 1989 Biology of the Pacific Redfins of the genus Tribolodon as a promising aquaculture facility in southern Primorye (M.: VNIIPRH) 25 p
[4] Gavrenkov Yu I, Ivankov V N 1979 Taxonomic status and biology of Pacific Redfins of the genus Tribolodon of the southern Primorye Ichthyology Studies T 19 vol 6(119) pp 1014-1023
[5] Gavrenkov Yu I 1982 Ecology of small-scaled Tribolodon brandti (Dybowski) and large-scaled Tribolodon hakonensis (Günther) of Pacific Redfin during the breeding season Ichthyology Studies 22 Vol 1 pp 49-53
[6] Glazunova I A 2005 Content and distribution of heavy metals in the upper reaches of the Ob fish: Abstract of thesis (Barnaul: AltSU) 19 p
[7] Gritsenko O F 1974 Systematics of Pacific Redfins of the genus Tribolodon Sauvage 1883 (-Leuciscus brandti (Dybowski) Ichthyology Studies 14 vol 5(88) pp 782-795
[8] Evtushenko N Yu, Danilko O V 1996 Features of the accumulation of heavy metals in the fish tissues of the Kremnechug reservoir Gidrobiol T 32 4 pp 58-66
[9] Zorina L G, Gordienko P S, Dobrzhansky V G 1999 Assessment of water pollution by the content of trace elements in fish Tr. Of the Far East state tech. uni. Vladivostok 124 pp 112 - 114
[10] Ivashov P V, Sirotsky S E 2005 Heavy metals in the fish fauna of the Amur lake ecosystems Biogeochemical and geoeological processes in ecosystems (Vladivostok: Dal'nauka) vol 15 pp 130-139
[11] Kachur A N, Kondratiev I I, Perepelyatnikov L V 2001 Ecological and geochemical problems of land and coastal-marine landscapes of the coastal zone of the Russian part of the Sea of Japan Vestnik DVO RAN 5 pp 53 - 71
[12] Kovekovdova L T, Simokon M V 2002 Heavy metals in the tissues of commercial fish from the Amur Bay of the Sea of Japan Biol. seas T 28 2 pp 125-130
[13] Lundin P N, Nabivanets B I 1986 Forms of metal migration in fresh surface waters (L.: Hydrometeoizdat) 270 p
[14] Marchenko A L, Chernova E N, Khristoforova N K 2006 The content of heavy metals in the muscles of the silver Prussian carp Carassius auratus gibelio from reservoirs in the south of Primorsky Krai Electronic Journal "Research in Russia" 78 pp 759 - 768 http://zhurnal.ape.relarn.ru/articles/2006/078.pdf
[15] Moiseenko T I 2010 Bioaccumulation of metals in the body of fish as an indicator of hydrogeochemical background and anthropogenic load Development of ideas of continental biogeochemistry and geochemical ecology (M.: GEOKHI RAS) pp 288–301
[16] Morozov N P, Petukhov S A 1986 Trace elements in the commercial ichthyofauna of the oceans (M.: Agropromizdat) 160 p
[17] Novikov N P, Sokolovsky A S, Sokolovskaya T G, Yakovlev Yu M 2002 Fish of Primorye Vladivostok: Dalrybytvut) 552 p
[18] Patin S A, Morozov N P 1981 Trace elements in marine organisms and ecosystems (M.: Light and food industry) 152 p
[19] Popov P A, Vizer A M, Androsova N V 2012 Metal content in the muscle tissue of commercial fish species from the Siberian reservoir and the Ob River in the dam area Siberian Journal of Ecology 4 pp 479–483
[20] Radkevich E A, Bersenev I I, Bourda A I 1968 The main features of the geology and metallogeny of Primorye (Vladivostok: Far East Prince. Publishing House) 103 p
[21] Svinukhov V G 1997 Ecology of the atmosphere of the cities of Primorsky Krai (Vladivostok: Publishing House of the Far Eastern University) 140 p
[22] Sokolov A V 2001 Some features of the biology of the redfin (Tribolodon) of the Tumnin River (Tatar Strait, Sea of Japan) Readings in memory of Vladimir Yakovlevich Levanidov (Vladivostok: Dal'nauka) vol 1 pp 305-309
[23] Chernova E N, Marchenko A L, Khristoforova N K, Kovalev M Yu, Kavun V Ya 2006 The levels of heavy metals in the silver Prussian carp (Carassius auratus gibelio) from the waters of
the southern Primorye Proceedings of the International Conference "Environmental problems of the use of marine areas" (Vladivostok) pp 203-206

[24] Chernova E N, Marchenko A L, Khristoforova N K 2006 Metal concentrations in the Prussian carp bodies (Carassius auratus gibelio) from lakes and rivers of the Primorsky Territory Proceedings of the IV International Scientific and Practical Conference “Heavy metals and radionuclides in the environment” (Kazakhstan, Semipalatinsk) T 2 pp 104 - 107

[25] Chernova E N, Kavun V Ya 2000 Concentrations of heavy metals in bodies of silver Prussian carp Carassius auratus gibelio (Cypriniformes, Cyprinidae) from the Lebedinoye lake of the basin of the Tumannaya Ecological state and biota of the southwestern part of the Peter the Great Gulf and the mouth of the Tumannaya river (Vladivostok: Dal'nauka) T 1 pp 186-194

[26] Dallinger R, Kautzky H 1985 The passage of Cu, Zn, Cd and Pb along foot chain into the fish Salmo gairdneri Heavy metals Environ. Int. Conf. At. Sept. vol 1 pp 694 – 696

[27] Grandjean P 1978 Lead concentration in single hairs as a monitor of occupational lead exposure International Archives of Occupational Environmental Health vol 42 2 pp 69 – 81

[28] Karen V C, Lieven B, Ronny B 2003 Determination of concentration of heavy metals in fish Environ. Toxicol. and Chem 7 pp 1548-1555

[29] Portmann J 1972 The levels of certain metals in fish from costal waters around England and Wales Aquaculture vol 1 1 pp 91-96

[30] Sorensen E M 1992 Metal poisoning in fish U.S.A. Texas: CRC Press. 362 p

[31] Gimaltdinov I K, Levina T M, Stolpovskii M V, Solovev D B 2018 Dynamics of the Localized Pulse in Bubbly Liquid IOP Conference Series: Materials Science and Engineering 463 paper № 022002. [Online]. Available: https://doi.org/10.1088/1757-899X/463/2/022002