Трансформация экосистем
Ecosystem Transformation
www.ecosysttrans.com

Dynamics of the fish population of the high floodplain lake of the Oka River basin by the example of the Lake Erus, Ryazan Oblast, Russia

Elena Yu. Ivancheva*, Victor P. Ivanchev, Irina Yu. Lychkovskaya

Oka State Natural Biosphere Reserve, Brykin Bor 51, Spassky District, Ryazan Region, 391072 Russia

**eivancheva@mail.ru*

Received: 09.04.2020
Accepted: 20.05.2020
Published online: 05.11.2020

DOI: 10.23859/estr-200409
UDC 597.08.574.5

ISSN 2619-094X Print
ISSN 2619-0931 Online

Translated by D.M. Martynova

The long-term dynamics of the fish population was studied in the forest lake of the high floodplain of the Oka River, located in the southeastern Meshchera Lowlands. The maximum ecological capacity of the lake is fifteen fish species and the minimum, three fish species. The dynamics of the composition and species structure of the fish community depends on a number of factors. The most significant factors are the physico-chemical characteristics of the lake, the level of spring floods, and the interactions between aboriginal and invasive species.

Keywords: forest lake, high floodplain, fish population dynamics, native species, invasive species, species relationships.

Ivancheva, E.Yu. et al., 2020. Dynamics of the fish population of the high floodplain lake of the Oka River basin by the example of the Lake Erus, Ryazan Oblast, Russia. *Ecosystem Transformation* **3** (4), 65–73.

Introduction

The central lake-river system of the Meshchera Lowlands comprises several structural elements, including the lakes of the high floodplain of the Oka River (Ivancheva et al., 2018). There are several lakes, namely, Erus, Leshchennik, Lipatovo, and Pilki, on the territory of the Oka State Natural Biosphere Reserve, located in the southeastern part of the Meshchera Lowlands (Pankova, 2014). Conditional isolation from the parent watercourse is their characteristic feature; however, they join the flood in the years with high floods, so their fish communities exchange with that of the Oka River. In the last two decades, the flood level in the Oka River has significantly decreased, and the floods have become extremely irregular, which was reflected in the structure of the fish population of these lakes. Taking into account the low water content of these lakes and the arid summer-autumn regime of the last few years, affecting significantly all components of the lake biota, it is extremely important to assess the current state of these water bodies.

The study aims to trace the dynamics of the fish population of the model lake of the high floodplain of the Oka River and to search for the affecting factors.

Materials and methods

The Lake Erus, located in the eastern section of the Oka State Nature Biosphere Reserve has been one of the model lakes for many years. This is the most typical high floodplain lake of glacial origin, with an area of 25.5 hectares, flooded only during high floods. The depth of the lake basin is not known exactly, since there is a layer of liquid silt 4.0-m deep under a small layer of water (50–100 cm). Most of the lake water surface (more than 50%) is covered with thickets of water soldiers *Stratiótes aloídes*; less extensive thickets are also formed by Manchurian wild rice *Zizania latifolia*, bulrush *Typha latifolia*, and common reed *Phragmites australis*. Also, the thickets of white water lily *Nymphaea candida* are widely spread here (Pankova, 2014).

Since 1948, the Lake Erus periodically attracts the attention of ichthyologists (Ivanchev and Ivancheva, 2012; Letopis prirody, 1948, 1954, 1987; Panchenko, 1990; Seleznev, 1963); annual monitoring has been started in 2014 and is continued nowadays. Test fishing in 2006 and annually since 2014 is carried out with fixed nets with a mesh size of 12, 18, 30, 45, and 60 mm; small-size fish species and the weatherfish were sampled with a pot hauler (capture area of 1 m^2) and a trap net.

We analyzed quantitative data for 1954, 1987, 2006, and 2014–2019. The study did not include data from 1948, since the lists of fish for all lakes in the Reserve archives are given without quantitative characteristics for this year. The species share was characterized using the following scale: rare species (share in the population < 0.1%); low-abundance (0.1–1.0%); common (1.1–5.0%); numerous (5.1–10.0%); dominant (> 10%); super-dominant (> 50%) (Ivanchev and Ivancheva, 2010; Tereshchenko and Nadirov, 1996).

The fish species are given in accordance to the «Atlas of the Freshwater Fish of Russia» (2002) taking into account the most recent data (Ryby..., 2010). Quantitative samples of macrozoobenthos were collected in the Lake Erus on August 18, 2014 and August 27, 2019 with an Ekman-Berge bottom grab with a capture area of 1/100 m^2. In total, four combined samples were taken, 4–6 replicates per sample. The collected material was processed according to the standard technique used at the Institute for Papanin Institute for Inland Water Biology, Russian Academy of Sciences (Metodika..., 1975). The invertebrate species were identified by the series of taxonomic keys (Opredelitel..., 1994, 1995, 1997, 2001, 2004).

The fishery assessment of the fodder base was carried out according to the scale developed by the GosNIORKh (former branch of Russian Federal Research Institute of Fisheries and Oceanography, VNIRO) (Pidgayko et al., 1968). All groups of invertebrates, except mollusks, were classified as "soft-bodied benthos" (B_{soft}). All the representatives of the soft-bodied benthos, as well as the mollusks with a shell size of less than 14 mm (Zhivoglyadova and Frolenko, 2017), were referred to the forage benthos (B_{forage}). The classification suggested by S.P. Kitaev (2007) and the Pantle – Buck saprobity index (*I*) modified by M.V. Chertoprud (2002) were applied to determine the trophic type of the lake via the zoobenthos biomass. Major physico-chemical indicators of water were determined using the analyzer "Expert-001".

Results and Discussion

Living environment for fish in the Lake Erus

Water in the Lake Erus is characterized by a very low content of dissolved oxygen; pH is neutral in the littoral and profundal zones (Table 1).

Macrozoobenthos inhabits mainly the coastal zone of the lake. The invertebrate aquatic fauna comprises 20 species and supra-specific taxa, the macrozoobenthos, 13 species and genera, most of them are found in the littoral zone (Table 2).

Average quantitative data on the state of macrozoobenthos community in the littoral of the Lake Erus are presented in Table 3. According to the scale for assessing the food capacity of the water body by the benthos characteristics (Pidgayko et al., 1968), the Lake Erus is classified as of medium degree of the food capacity. By the trophic status, the lake is β-mesotrophic. By the end of summer, the water quality corresponds to the β-mesosaprobic according to the Pantle – Buck saprobity index (*I* = 2.7) (Table 3).

Dynamics of fish population

In total, fifteen fish species were recorded in the Lake Erus during the entire observation period, since 1948. The list of species and the frequency of their occurrence in the catches are presented in the Table 4. The dynamics of the fish population structure in the Lake Erus is presented in Table 5. Such species as belica and weatherfish may have lived in the lake for many years, but have not been identified due to the use of the fishing gear with large mesh size.

According to the Wunder's classification (Wunder, 1936, cited after Nikolsky, 1974), which characterizes

Table 1. Main physico-chemical parameters of water of the Lake Erus on August 27, 2019.

Ecological zone	Parameters		
	pH	O_2, mg/L	T, °C
Littoral	6.8	0.58	19.2
Profundal	6.6	1.97	16.7

Table 2. Taxonomic composition of macrozoobenthos of the Lake Erus in 2014 and 2019. * – epineuston, ** – nekton.

Taxa	Ecological zone	
	Littoral	Profundal
Oligochaeta		
Lumbriculus variegatus (Müller, 1773)	+	–
Stylodrilus heringianus Claparede, 1862	+	–
Oligochaeta gen. sp.	–	+
Mollusca		
Anisus vortex (Linnaeus, 1758)	+	–
Anisus contortus (Linnaeus, 1758)	+	–
Segmentina montgazoniana Bourguignat in Servain,1881	+	–
Segmentina sp.	+	–
Musculum sp.	+	–
Pisidium amnicum (Müller, 1774)	+	–
Crustacea		
Asellus aquaticus (Linnaeus, 1758)	+	–
Gammarus lacustris Sars, 1863	+	–
Collembola:		
Podura aquatica Linnaeus, 1758*	+	–
Ephemeroptera		
Caenis horaria (Linnaeus, 1758)	+	–
Odonata		
Coenagrion armatum (Charpentier, 1840)	+	–
Enallaghma cyathigerum Charpentier, 1840	+	–
Heteroptera		
Hydrometra gracilenta Horváth, 1899*	+	–
Plea minutissima Leach, 1817**	+	–
Microvelia buenoi Drake, 1920*	+	–
Coleoptera		
Hydroporus sp.**	+	–
Hyphydrus sp.**	+	–

Table 3. Quantitative characteristics of the macrozoobenthos of the Lake Erus in 2014 and 2015.

Parameters	Ecological zone	
	Littoral	Profundal
Average abundance (N, ind./m^2)	391	16
Average total biomass (B_{total}, g/m^2)	3.5	0.2
Average biomass of the forage benthos (B_{forage}, g/m^2)	3.4	0.2
Average biomass of the soft-bodied benthos (B_{soft}, g/m^2)	0.8	0.2
Type of water body trophicity	β-mesotrophic	ultra-oligotrophic
Pantle – Buck saprobity index	2.7	

Table 4. Fish species recorded in the Lake Erus and their frequency of occurrence according to the data of catches in 1954, 1987, 2006, and 2014–2019.

Species	Frequency of occurrence, %
Zope *Abramis ballerus* (Linnaeus, 1758)	22.2
Common bream *Abramis brama* (Linnaeus, 1758)	33.3
White bream *Blicca bjoerkna* (Linnaeus, 1758)	11.1
Prussian carp *Carassius auratus* (Linnaeus, 1758)	100
Crucian carp *Carassius carassius* (Linnaeus, 1758)	44.4
Belica *Leucaspius delineatus* (Heckel, 1843)	?
Ide *Leuciscus idus* (Linnaeus, 1758)	33.3
Lake minnow *Phoxinus percnurus* Berg, 1949	66.6
Roach *Rutilus rutilus* (Linnaeus, 1758)	44.4
Rudd *Scardinius erythrophthalmus* (Linnaeus, 1758)	55.5
Tench *Tinca tinca* (Linnaeus, 1758)	33.3
Weatherfish *Misgurnus fossilis* (Linnaeus, 1758)	?
Northern pike *Esox lucius* Linnaeus, 1758	44.4
European perch *Perca fluviatilis* Linnaeus, 1758	44.4
Chinese sleeper *Perccottus glenii* Dybowski, 1877	77.7

the fish species in regard to their optimal oxygen regime, the frequently encountered fish species (frequency of occurrence exceeding 33.3%) belong to group 3, i.e. they require a relatively small amount of oxygen and so may live at a concentration of 4 mg O_2/L (European perch, roach, pike, and rudd), and to group 4, tolerating very low oxygen saturation, as low as 0.5 mg O_2/L (Prussian carp, crucian carp, and tench). The rest of the species, apparently, do not tolerate oxygen deficiency, so they die subsequently after appearing in the lake during a spring flood.

The data obtained in 1954 indicate a fairly high species diversity of the fish population, which is the highest for the entire period of observations of the lake. In particular, there were 11 species observed, and the Shannon index that time was 2.1. The fish population was represented by aboriginal species. Crucian carp, roach, and European perch dominated.

In the 1987, there were two carp species, but the crucian carp dominated, and the Prussian carp was represented only by females. This allows us to suppose the presence of the gynogenetic form of the latter. Regard must be paid to the fact that the Prussian carp was represented only by females in many floodplain water bodies in the late 1980s – early 1990s, according to unpublished data of I.M. Panchenko.

According to some authors (Gerasimov et al., 2018), the larger body height in the Prussian carp correlates with unisexuality and, accordingly, with the gynogenetic reproduction. According to the catch data in 1987, the Prussian carp of the Lake Erus were not characterized by larger body height. In particular, the ratio of body height to body length was 0.40 ± 0.011, and the ratio of the head length to body length was 0.26 ± 0.017. During the period of 2014–2019, the proportions of the body of this carp species remain the same, i.e. the ratio of body height to body length is 0.40 ± 0.017, and the ratio of head length to body length is 0.26 ± 0.09.

In the catch of 2006, when the invasive species, the Chinese sleeper, entered the lake, we recorded five species only, and the Chinese sleeper was the super-dominant. The relative abundance of Prussian carp exceeded that of the crucian carp twofold, the sex ratio in the Prussian carp population was close to 1:1.

Since the late 1980s – early 1990s, the share of the Prussian carp began to increase in the water bodies of the Ponto-Caspian Region. The exact reasons for this phenomenon are not known yet (Gerasimov et al., 2018; Podushka, 2004; Vekhov, 2007, 2013; etc.). Since the increase in the number of the Prussian carp is large-scale and affects many water bodies of the Ponto-Caspian Region, the reason for this phenomenon should also be global. Yu.V. Gerasimov and co-authors (Gerasimov et al., 2018) believe that climate warming is one of the reasons, due to which the thermophilic and

Table 5. The share of the fish species (%) in the catches in the Lake Erus in 1954–2019. * – incomplete catch is presented (the sample of only crucian and prussian carps); + – information on species abundance was obtained using special fishing gear; ? – no data.

Species	Year								
	1954	1987*	2006	2014	2015	2016	2017	2018	2019
Zope	6.9	?	0	2.9	0	0	0	0	0
Common bream	8.86	?	0	0.6	0	2.4	0	0	0
White bream	0.12	?	0	0	0	0	0	0	0
Prussian carp	0.57	18.37	4.54	71.3	17.3	12.1	6.7	9.7	1
Crucian carp	25.32	81.63	0.52	0	0	1.2	0	0.1	0
Belica	?	+	+	0	0	0	0	0	0
Ide	3.34	?	0	1.3	0	0.6	0	0	0
Lake minnow	0	?	0	0.1	70.4	77.1	41.3	60.2	85.4
Roach	26.58	?	0	4.9	0	1.8	0	0.1	0
Rudd	5.98	?	7.58	0.1	0	1.2	0	0.8	0
Tench	0.12	?	0	0.4	0	0.6	0	0	0
Weatherfish	0	0	+	0	0	0	0	0	0
Northern pike	1.15	?	9.09	0.2	0	0	0	0.1	0
European perch	21.06	?	0	1.2	0	0.6	0	0.4	0
Chinese sleeper	0	?	77.27	17	12.3	2.4	52	28.6	13.6
Total number of specimens	**869**	**49**	**66**	**902**	**629**	**162**	**870**	**1259**	**2154**

heat-resistant Prussian carp changed its life strategy from gynogenetic to bisexual reproduction. In addition, at the end of the XX century, there was a deliberate and unintentional introduction of the bisexual Amur carp into a large number water bodies. This species is rheophilic, so it was actively dissipating along the watercourses and thus spread widely.

In any case, only the bisexual Prussian carp is currently found in the Lake Erus. Meantime, the crucian carp is found as single specimens. Both species easily tolerate a lack of oxygen, but the Prussian carp is characterized by a wider food spectrum; the crucian carp feeds mainly on benthos, but the Pruccian carp, if necessary, easily switches to feeding on plankton due to the greater number of stamens on the gill arches (Panchenko, 1990). Perhaps, the hybridization of these two species may be the reason for the displacement of the crucian carp by the Prussian carp. The volume of ejaculate in males of the Prussian carp is almost twice that of the crucian carp, the fertility of the first species is also much higher than that of the latter (Plieva et al., 2012). In addition, these hybrids are more viable than the juveniles of non-hybrid species.

In 2014, the number of observed species was high (11 species), but the Shannon index was lower than that in 1954 (1.42). The decrease in species diversity was associated with the pronounced dominance of the Prussian carp. Regard must be paid to the fact that the thickets of the water soldiers *Stratiotes aloides* disappeared in many floodplain lakes, including the Lake Erus, during the winter of 2012/2013. This plant species serves as the main refuge of the Chinese sleeper from predators (pike and the European perch), so the Chinese sleeper abundance decreased sharply (Ivancheva and Ivanchev, 2014). However, the water soldiers' population began to recover gradually already in 2014, so the abundance of the Chinese sleeper became comparable to that of the Prussian carp the next year already.

Also in 2014, we recorded a single case of the lake minnow, which had not previously been observed in the reserve (Ivanchev and Ivancheva, 2015). In the Ryazan Oblast, we noted this species previously only in the Moksha River basin (Ivanchev and Ivancheva, 2010). The lake minnow has a fragmented range (Berg, 1949a, b; Ryby..., 2010), which margins have changed obviously; therefore, the present range can be considered as secondary (Alimov et al., 2004). The lake minnow is probably characterized by invasive features, thanks to which it penetrated and naturalized in the studied reservoir. In 2013, the highest flood level was observed since 2000, which probably contributed to the penetration of this species into the lake.

In 2015, the lake minnow sharply increased its abundance, when its share in the catches exceeded 70%. This phenomenon is typical for the naturalization of a species in a new habitat (Alimov et al., 2004). Similar outbreaks of the lake minnow abundance were noted in the lakes of Mordovia Republic, Russia (Artaev and Ruchin, 2015).

In 2016, some species, such as the Prussian carp, the Chinese sleeper, and zope, were affected by motile aeromonas septicemia (MAS, or bacterial hemorrhagic septicemia, caused by bacteria *Aeromonas hydrophila*); as a result, the relative fish abundance decreased by 4 times. Meantime, no infected specimens of the lake minnow were observed, and its share in the catches increased to 77%. The lake minnow may have been a carrier of MAS, and the fish disease epizootic was preconditioned by a general increase in the carrier fish abundance.

In 2017 and 2018, MAS infection gradually subsided, and the fish abundance increased up to average values, with two invasive species dominating, the Chinese sleeper and the lake minnow.

In 2019, only three species remained in the lake (the Chinese sleeper, lake minnow, and the Prussian carp); they are all invasive. The Chinese sleeper and lake minnow represent the dominant complex, and the lake minnow is the super-dominant. The most probable reasons for such a poor composition of the ichthyofauna are:

1) low level of floods, preventing various fish species from penetrating into the lake, including predators that are capable to regulate the abundance of invasive species;

2) the loss of fish species hat need higher oxygen content in water (zope, common bream, ide, roach, etc.);

3) high ecological plasticity of the species remaining in the lake, their ability to exist at low concentrations of dissolved oxygen;

4) predatory of the Chinese sleeper and lake minnow; these species eat the eggs of various fish species (Ryby..., 2010; Zaloznykh, 1982; Zhuravlev et al., 2006);

5) possible hybridization of carp species; as a result, the crucian carp was replaced by the Prussian carp;

6) development of thickets of macrophytes, which are the shelters for the Chinese sleeper and which serve as a substrate for phytophilous fish species for laying their eggs.

Conclusions

Therefore, the dynamics of the fish population of the high floodplain lake is primarily preconditioned by its physicochemical characteristics (size and water volume, concentration of dissolved oxygen, etc.). The food capacity of the lake, i.e. the possibility of habitation of a certain number of the forage aquatic organisms, is the consequence of these characteristics. In the Lake Erus, the coastal zone, characterized by dense bottom sediments, is the most favorable place for inhabiting of the most benthic organisms; the rest of the lake basin is filled with liquid silt, where the environment is unfavorable for most benthic species. Both aquatic invertebrates and fish living in such lake must be adapted to low oxygen saturation of water.

Other important factors influencing the dynamics of the fish population include the presence and the area of the projected cover of macrophytes that serve as the shelters, and the level of spring floods, which affect the penetration of various fish species into the lake. Such penetration results in newly formed relationships between the species (predation, hybridization) as well as in the introduced infections.

References

Alimov, A.F., Bogutskaya, N.G., Orlova, M.I., Paevskiy, V.A., Reznik, S.Ya., Kravchenko, O.E., Gel'tman, D.V., 2004. Antropogennoe rasprostranenie vidov zhivotnykh i rastenii za predely istoricheskogo areala: protsess i rezul'tat [Anthropogenic distribution of animal and plant species beyond the historical area: process and result]. In: Alimov, A.F., Bogutskaya, N.G. (eds.), *Biologicheskiye invazii v vodnykh i nazemnykh ekosistemakh [Biological invasions in aquatic and terrestrial ecosystems].KMK*, Moscow – Saint Petersburg, Russia, 16–43. (In Russian).

Artaev, O.N., Ruchin, A.B., 2015. Redkie ryby i ryboobraznye Mordovii: analiz fakticheskikh dannykh o rasprostranenii i chislennosti [Rare fish and fish-like vertebrates of Mordovia: analysis of the factual data on distribution and abundance]. *Tomsk State University Journal* **20** (2), 425–429. (In Russian).

Atlas presnovodnykh ryb Rossii [Atlas of the Freshwater Fish of Russia], 2002a. Vol. 1. Reshetnikov, Yu.S. (ed.). Nauka, Moscow, Russia, 379 p. (In Russian).

Atlas presnovodnykh ryb Rossii [Atlas of the Freshwater Fish of Russia], 2002b. Vol. 2. Reshetnikov, Yu.S. (ed.). Nauka, Moscow, Russia, 251 p. (In Russian).

Berg, L.S., 1949a. Ryby presnykh vod SSSR i sopredel'nykh stran. Ch. 2 [Fish of the fresh waters of the USSR and neighboring countries. Part 2]. Academy of Sciences of the USSR, Moscow – Leningrad, 447–925. (In Russian).

Berg, L.S., 1949b. Ryby presnykh vod SSSR i sopredel'nykh stran. Ch. 3 [Fish of the fresh waters of the USSR and neighboring countries. Part 3]. Academy of Sciences of the USSR, Moscow – Leningrad, 926–1382. (In Russian).

Chertoprud, M.V., 2002. Modifikatsiya metoda Pantle – Bukka dlya otsenki zagryazneniya vodotokov po kachestvennym pokazatelyam makrobentosa [Modification of the Pantle – Buck method for assessing the pollution of watercourses by qualitative indicators of macrobenthos]. *Vodnye Resursy [Water Resources]* **29** (3), 337–342. (In Russian).

Gerasimov, Yu.V., Smirnov, A.K., Kodukhova, Yu.V., 2018. Assessment of the possible causes of changes in abundance and sexual structure in the populations of Prussian carp (*Carassius auratus gibelio* Bloch., 1783). *Inland Water Biology* **1**, 72–80.

Ivanchev, V.P., Ivancheva, E.Yu., 2010. Kruglorotyye i ryby Ryazanskoy oblasti i prilezhashchikh territoriy [Cyclostomes and fish of the Ryazan Oblast and adjacent territories]. Golos gubernii, Ryazan, Russia, 292 p. (In Russian).

Ivanchev, V.P., Ivancheva, E.Yu., 2012. Vidovaya struktura rybnogo naseleniya i yeye dinamika vnepoymennykh ozer Okskogo zapovednika i ego okrestnostey [The species structure of the fish population and its dynamics of the out-of-floodplain lakes of the Oka State Biosphere Nature Reserve and its environs]. *Trudy Okskogo zapovednika [Proceedings of the Oka State Biosphere Nature Reserve]* **27**, 315–329. (In Russian).

Ivanchev, V.P., Ivancheva, E.Yu., 2015. Ozernyy gol'yan *Phoxinus percnurus* – novyi vid ikhtiofauny Okskogo zapovednika [Lake minnow *Phoxinus percnurus*, a new species of the ichthyofauna of the Oka State Biosphere Nature Reserve]. *Trudy Okskogo zapovednika [Proceedings of the Oka State Biosphere Nature Reserve]* **33**, 144–146. (In Russian).

Ivancheva, E.Yu., Ivanchev, V.P., 2014. Vzaimootnosheniya invazionnogo i aborigennykh vidov ryb v razlichnykh tipakh poymennykh ozer [The relationship of invasive and aboriginal fish species in different types of floodplain lakes]. *Materialy lektsiy II Vserossiyskoy shkoly-konferentsii "Ekosistemy malykh rek: bioraznoobraziye, ekologiya, okhrana", 18–22 noyabrya 2014 g. T. 2 [Materials of lectures of the II All-Russian Scientific School and Conference "Ecosystems of Small Rivers: Biodiversity, Ecology, Conservation", November 18-22, 2014. Vol. 2.* Filigran, Yaroslavl, Russia, 157–161. (In Russian).

Ivancheva, E.Yu., Ivanchev, V.P., Lychkovskaya, I. Yu., 2018. Results and perspectives of fish population studies in the central lake-river system of the Meschera lowland. *Ecosystem Transformation* **1** (2), 30–45.

Letopis' prirody Okskogo gosudarstvennogo zapovednika za 1946–1950 gg. [Chronicle of the nature of the Oka State Biosphere Nature Reserve for 1946–1950]. Arkhiv Okskogo gosudarstvennogo zapovednika [Archive of the Oka state reserve]. F.5363.0.1. D.62. 154 p. (In Russian).

Letopis' prirody Okskogo gosudarstvennogo zapovednika za 1954 g. [Chronicle of the nature of the Oka State Biosphere Nature Reserve for 1954]. Arkhiv Okskogo gosudarstvennogo zapovednika [Archive of the Oka state reserve]. F.5363.0.1. D.107. 69 p. (In Russian).

Letopis' prirody Okskogo gosudarstvennogo zapovednika za 1987 g. [Chronicle of the nature of the Oka State Biosphere Nature Reserve for 1987]. Arkhiv Okskogo gosudarstvennogo zapovednika [Archive of the Oka state reserve]. F.5363.0.1-T. D.109. 204 p. (In Russian).

Opredelitel' presnovodnykh bespozvonochnykh Rossii i sopredel'nykh territoriy. T. 1, 1994 [Keys to freshwater invertebrates in Russia and adjacent lands. Vol. 1, 1994]. Tsalolikhin, S.Ya. (ed.). Nauka, Saint Petersburg, Russia, 395 p. (In Russian).

Opredelitel' presnovodnykh bespozvonochnykh Rossii i sopredel'nykh territoriy. T. 2, 1995 [Keys to freshwater invertebrates in Russia and adjacent lands. Vol. 2, 1995]. Tsalolikhin, S.Ya. (ed.). Nauka, Saint Petersburg, Russia, 627 p. (In Russian).

Opredelitel' presnovodnykh bespozvonochnykh Rossii i sopredel'nykh territoriy. T. 3, 1997 [Keys to freshwater invertebrates in Russia and adjacent lands. Vol. 3, 1997]. Tsalolikhin, S.Ya. (ed.). Nauka, Saint Petersburg, Russia, 439 p. (In Russian).

Opredelitel' presnovodnykh bespozvonochnykh Rossii i sopredel'nykh territoriy. T. 5, 2001 [Keys to freshwater invertebrates in Russia and adjacent lands. Vol. 5, 2001]. Tsalolikhin, S.Ya. (ed.). Nauka, Saint Petersburg, Russia, 836 p. (In Russian).

Opredelitel' presnovodnykh bespozvonochnykh Rossii i sopredel'nykh territoriy. T. 6, 2004 [Keys to freshwater invertebrates in Russia and adjacent lands. Vol. 6, 2004]. Tsalolikhin, S.Ya. (ed.). Nauka, Saint Petersburg, Russia, 528 p. (In Russian).

Kitaev, S.P., 2007. Osnovy limnologii dlya gidrobiologov i ikhtiologov [Fundamentals of limnology for hydrobiologists and ichthyologists]. Karelian Research Centre, Russian Academy of Sciences, Petrozavodsk, Russia, 395 p. (In Russian).

Metodika izucheniya biogeotsenozov vnutrennikh vodoyemov [Methods of studying biogeocoenoses of inland water bodies], 1975. Mordukhay-Boltovskoy, F.A. (ed.). Nauka, Moscow, USSR, 240 p. (In Russian).

Nikol'sky, G.V., 1974. Ekologiya ryb [Fish ecology]. Vysshaya shkola, Moscow, USSR, 366 p. (In Russian).

Pankova, N.L., 2014. Struktura i dinamika rastitel'nogo pokrova vodoyemov Okskogo zapovednika [The structure and dynamics of the vegetation cover of the reservoirs of the Oka State Biosphere Nature Reserve]. Golos gubernii, Ryazan, Russia, 166 p. (In Russian).

Panchenko, I.M., 1990. Ikhtiofauna vodoyemov Okskogo zapovednika i yeye osobennosti [Ichthyofauna of reservoirs of the Oka State Biosphere Nature Reserve and its features]. In: Priklonsky, S.G. (ed.), *Mnogoletnyaya dinamika prirodnykh ob"yektov Okskogo zapovednika. Trudy Okskogo zapovednika. T. 16 [Long-term dynamics of natural objects of the Oka State Biosphere Nature Reserve. Proceedings of the Oka State Biosphere Nature Reserve. Vol. 16]*. TsNIL Glavokhoty, Moscow, Russia, 154–182. (In Russian).

Pidgayko, M.P., Aleksandrov, B.M., Ioffe, Ts.I., Maksimova, L.P., Petrov, V.V., Savateeva, Ye.B., Salazkin, A.A., 1968. Kratkaya biologo-produktsionnaya kharakteristika vodoyemov Severo-Zapada SSSR [Brief biological and production characteristics of water bodies of the North-West of the USSR]. *Izvestiya GosNIORKh [Bulletin of the State Research Institute of Lake and River Fisheries]* **67**, 205–228. (In Russian).

Pliyeva, T.Kh., Tetdoyev, V.V., Mikhaleva, T.A., Lavrent'yeva, N.M., 2012. Rybovodno-biologicheskaya i produktsionnaya kharakteristika proizvoditeley zolotogo i serebryanogo karasey i ikh gibrida [Fish-breeding and biological and production characteristics of producers of the Prussian and crucian carps and their hybrid]. *Vestnik RUDN. Seriya Agronomiya i Zhivotnovodstvo [RUDN Journal of Agronomy and Animal Industries]* **3**, 67–72. (In Russian).

Podushka, S.B., 2004. O prichinakh vspyshki chislennosti serebryanogo karasya [On the causes of the outbreak of the Prussian carp population]. *Nauchno-tekhnicheskiy byulleten' laboratorii ikhtiologii INENKO [Scientific and Technical Bulletin of INENKO Ichthyology laboratory]* **19**, 5–15. (In Russian).

Ryby v zapovednikakh Rossii, 2010. Presnovodnyye ryby. T. 1 [Fish in the nature reserves of Russia.

Freshwater fish. Vol. 1]. Reshetnikov, Yu.S. (ed.). KMK, Moscow, Russia, 627 p. (In Russian).

Seleznev, V.V., 1963. Ryby vodoyemov Okskogo zapovednika [Fish of the water bodies of the Oka State Biosphere Nature Reserve]. *Trudy Okskogo zapovednika [Proceedings of the Oka State Biosphere Nature Reserve]* **5**, 5–26. (In Russian).

Tereshchenko, V.G., Nadirov, S.N., 1996. Formirovaniye struktury rybnogo naseleniya predgornogo vodokhranilishcha [Formation of the structure of fish population in the foothill water reservoir]. *Voprosy Ikhtiologii [Journal of Ichthyology]* **36** (2), 169–178. (In Russian).

Vekhov, D.A., 2013. Nekotoryye problemnyye voprosy biologii serebryanogo karasya *Carassius auratus* s. lato [Some problematic issues in the biology of the Prussian carp *Carassius auratus* s. lato]. *Nauchno-tekhnicheskiy byulleten' laboratorii ikhtiologii INENKO [Scientific and Technical Bulletin of INENKO Ichthyology laboratory]* **19**, 5–38. (In Russian).

Zaloznykh, D.V., 1982. Nekotoryye aspekty biologii rotana v vodoyemakh Gor'kovskoy oblasti [Some aspects of the Chinese sleeper biology in water bodies of the Nizhny Novgorod Oblast]. In: Zaloznykh, D.V. (ed.), *Nazemnyye i vodnyye ekosistemy. Mezhvuzovskiy sbornik. Vyp. 5 [Terrestrial and aquatic ecosystems. Inter-university collection. Issue 5].* N.I. Lobachevsky Gorky State University, USSR, 44–47. (In Russian).

Zhivoglyadova, L.A., Frolenko, L.N., 2017. Kharakteristika kormovoy bazy ryb-bentofagov nizhnego Dona [Characteristics of the food supply for benthos-feeding fish in the lower reaches of the Don River]. *Izvestiya TINRO [TINRO Bulletin]* **189**, 139–146. (In Russian).

Zhuravlev, V.B., Lomodurov, Ye.I., Lukoyanov, D.P., 2006. Vseleniye rotana-goloveshki v poymennyye vodoyemy basseyna Verkhney Obi [The introduction of Chinese sleeper into the floodplain water bodies of the upper Ob' River basin]. *Tezisy dokladov IX s'ezda gidrobiologicheskogo obshchestva RAN. T. 1 [Abstracts of the IX Congress of the Hydrobiological Society of the Russian Academy of Sciences. Vol. 1]*. Togliatti, Russia, 163. (In Russian).