Chapter 18
Characteristics of the Ichthyocenosis in the Wintering Pits in the Context of the Zoogeographic Origin on the Example of Shallow Waters of the Volgograd Reservoir Basin

Irina A. Kiyashko and Vladimir V. Kiyashko

Abstract The Volgograd reservoir is a complex hydrological system, in which locations of the wintering pits have long been determined in its the deep-water channel part. Wintering pits can also be found in the floodplain areas, yet their relatively small size does not always allow determination their characteristics by the hydrometric and the bathymetric indicators. The aim of this article is to investigate the species composition of the ichthyocenosis in shallow waters of the Volgograd Reservoir basin, to determine the behavior pattern of fish populations and their involvement in the formation of winter fish aggregations in the context of the zoogeographic origin in order to use the obtained findings in fisheries. Studies were conducted in the channel wintering pits in shallow waters of the Volgograd Reservoir on the example of the Krasnoyarsk floodplain in winter 2019–2020. The floodplain is composed of not only large and small bays deeply protruding into the land, but also of flooded creeks, backwaters, lakes, small rivers and «eriks» (small channels) with preserved flow paths and a wide variety of bio-topes, which provide conditions for feeding, reproduction and wintering of a significant number of fish species. In the wintering pits of the Krasnoyarsk floodplain, were identified 18 fish species from 5 orders and 7 families, which can be divided into 6 faunistic complexes with regard to their morphological and ecological characters. Two of these, the Ponto-Caspian freshwater and Boreal plain, formed the basis of ichthyofauna (77%) of the winter aggregations. At the same time, fish aggregations from the Ponto-Caspian freshwater and the Tertiary plain freshwater faunal complexes, which include such valuable fish species as carp, bream, catfish, silver bream, and asp, in the autumn–winter period can be considered as an indicator of wintering pits.

I. A. Kiyashko (✉)
Saratov State Technical University Yu.A. Gagarina, Saratov, Russia
e-mail: coba80@mail.ru

V. V. Kiyashko
Saratov Branch of FGBNU VNIRO, Saratov, Russia
e-mail: kiyashko_81@list.ru

A. G. Arkhipov (ed.), *Sustainable Fisheries and Aquaculture: Challenges and Prospects for the Blue Bioeconomy*, Environmental Science and Engineering, https://doi.org/10.1007/978-3-031-08284-9_18

Keywords Wintering pits · Volgograd Reservoir · Species behavior · Faunistic complexes

18.1 Introduction

Rational use of natural resources of inland water bodies, increase in its productivity, and increased qualitative and quantitative characteristics of fisheries yields are one of the main tasks posed by the Blue Economy.

The commercial fishery resources in water bodies of the temperate zone of the Europe are formed during a warm period which is characterized by high water temperatures, the availability of a sufficient amount of food and favorable conditions for reproduction and feeding for most commercial fish species (Shashulovsky and Mosiyash 2010).

Winter is a special period for aquatic life. The ice cover hinders water saturation with atmospheric oxygen. The snow cover reduces the access of sunlight to the under-ice space. Feeding capacity of the water body sharply decreases. Water temperature decreases, and most of the cold-blooded animals (especially fish) become inactive. Most fish survive the winter due to the nutrients stored in summer, but the nutrient expenditure causes a decrease in its individual weight.

Previous studies conducted in inland water bodies of various types showed that wintering pits used by fish can help them to survive during unfavorable wintering conditions. Wintering pits are natural places of mass wintering of fish in rivers, lakes and reservoirs. Winter aggregations include fishes of one or several species. In flowing water bodies, wintering pits are located in the deepest places with a slow current. In lakes and reservoirs, they are typically located in the mouth part of inflowing rivers and streams, and at the outlet of underwater sources (Shashulovsky and Ermolin 2005a).

Such places are similar not so much in depth but in comfortable conditions—oxygen content, slow water velocity, high temperature, hard bottom sediments, and the lack of vegetation.

In addition, wintering pits can be located at the outlet of an underwater source in the form of a spring or an underwater river with a weak water flow. Wintering pits can be also located in a deep channel near the riverbed.

Large aggregations in wintering pits are typical to Acipenseridae (sturgeon, sterlet, etc.) and many of Cyprinidae fish (carp, crucian carp, tench, bream, etc.). The main wintering pits in large rivers were identified during the period from the beginning to the middle of the last century.

It should be noted that not all river «pits» become wintering ones, it should have a bottom area with a slow circular current. In such areas, oxygen supply for fish is sufficient, and it does not expend much of energy to resist the current.

Initially, it was believed that fish accumulate in such areas only in winter, when their activity is decreasing; they completely stop feeding or significantly reduce food consumption, and the biological role of channel pits is reduced to the wintering area of the river. However, at present, modern hydroacoustic systems detect aggregation of fish of various age groups in such areas all year around. For example, in spring, significant aggregations of fish are formed in the Kondinskaya wintering pit, and their number varies over days. When the water temperature in the Konda River exceeds 4 °C, the fish migratory activity significantly increases both upstream and downstream in the system "channel pit–tributary of the main river", yet a significant part of fish stays in the Konda River (Chemagin 2016).

One of the main reasons for fish aggregation in such channel areas of the river is a "hydrodynamic shadow" caused by sharp changes in its bottom relief and, accordingly, nonuniform currents. Individual fish species and their aggregations are least susceptible to current effects, which helps them to stay in the occupied spatial areas of the riverbed with minimal energy consumption (Chemagin 2016).

The location of the wintering pits is determined empirically by the presence of mass fish aggregations. Over the years, the location of the pits can change, which is associated with a change in the relief. That is why it is difficult to identify the exact location of the wintering pit, and only the area of its location is therefore indicated.

In the rivers of the basin of the Volgograd reservoir, wintering pits play a special role due to long fish migration routes and the seasonal fish suffocation. In such biotopes, valuable fish species (like pike perch) survive the winter. In addition, in some pits, the commercial valuable species of fish (catfish, bream, pike, etc.) and burbot accumulate for wintering. Therefore, wintering grounds for fish should be considered as an important condition for preservation of the potential of the biological resources of water bodies in the Saratov region.

Numerous studies investigated the ichthyofauna composition in shallow water bodies of different types. Zakora (1974), Nebolsina (1974), and Cherepanov (1995) performed detail studies of shallow waters of the Volgograd Reservoir. Results of their investigations consider role and significance of the shallow waters for the reproduction of fish stocks. In addition, Zakora (1974) profoundly investigated their hydrology, bottom grounds, food resources, and ichthyofauna; and also the measures are proposed to preserve and increase fish productivity in shallow water areas. The studies of these authors has a strictly practical nature and apparently important; however, they did not sufficiently cover the issues of the state of wintering pits.

Previously, it was believed that fish lay on the pit bottom and fall into suspended anabiosis; however, subsequent observations showed that, despite of crowded, fish keep slowly moving, and the movement usually proceeds from the center of the aggregation to its edge (and vice versa). Apparently, this behavior pattern provides equal conditions for all individuals in the shoal. At the same time, some species keep feeding quite actively, for example, bream and ide. In this case, the entire shoal can change its location when feeding grounds are depleted.

In winter, fish obey natural instincts and show specific behavior patterns. To understand the process (behavior patterns), characteristics of ichthyocenosis in shallow waters of the Volgograd Reservoir should be considered in the context of the zoogeographic (faunal) origin.

18.2 Materials and Methods

The aim of the study was to investigate the species composition of ichthyocenosis in shallow waters of the Volgograd Reservoir basin, to determine the behavior pattern of fish species and their role in formation of winter aggregations in the context of the zoogeographic origin in order to use the obtained information by fisheries.

Ichthyofauna of the wintering pits was investigated in channel pits in the Krasnoyarsk floodplain of the Volgograd Reservoir in winter in 2019–2020.

The species composition of ichthyocenosis was determined on the basis of control catches and catches by anglers. In total, 12 nettings were carried out, and 78 anglers were interviewed.

The relative number of fish in catches was determined according to the scale proposed by Ermolin (2010).

The ichthyological material was processed according to the common methods (Pravdin 1966).

The study employed materials obtained by the authors and literature data on characteristics of the floodplain as a fish habitat (Nebolsina 1974).

The fish belonging to faunal complexes is provided in accordance with the studies by Nikolsky (1951), and with clarification by Nebolsina (1980).

18.3 Results

The Krasnoyarsk floodplain stretches along the left bank of the Volga River from the city of Marx to the city of Engels. It includes not only large and small bays deeply protruding into the land, but also flooded river creeks, backwaters, lakes, small rivers and «eriks» with a preserved flow and a wide variety of biotopes.

The floodplain area is about 20 thousand hectares. Along the longitudinal transect of the reservoir, it is 26 km long and 4–10 km wide. Its depths range from 0.1 to 10 m. Large and small islands separating water areas are covered with meadow vegetation, which is a substrate for fish spawning. The biotope diversity provides conditions for feeding and reproduction of a significant number of fish species.

The water level regime and the flow rate depend on the operating mode of the hydroelectric power stations (Saratov and Volgograd).

The content of dissolved oxygen and carbon dioxide, and water pH vary significantly throughout the year with the pronounced seasonal pattern. The greatest oxygen deficiency (49% saturation) can be observed in January–March.

Since aquatic life normally develops in water with a neutral or slightly alkaline pH, the study area provides a favorable habitat for aquatic organisms in terms of pH values.

In the wintering pits of the Krasnoyarsk floodplain, according the control catches and anglers catches form this study, identified 18 fish species from 5 orders and 7 families. The most numerous family is Cyprinidae (12 species). The other 6 families include only 1 species in each (see Table 18.1).

Table 18.1 Species composition of fish in the wintering pits

Species and its taxonomic position	RN
Order I. Salmoniformes	
Family 1. Esocidae Cuvier, 1816	
1. *Esox lucius* Linnaeus, 1758	+++++
Order II. Cypriniformes	
Family 2. Cyprinidae Bonaparte, 1832	
2. *Abramis ballerus* (Linnaeus, 1758)	+++
3. *A. brama* (Linnaeus, 1758)	+++++
4. *Aspius aspius* (Linnaeus, 1758)	+++
5. *Blicca bjoerkna* (Linnaeus, 1758)	+++++
6. *Carassius auratus gibelio* (Bloch, 1782)	+++++
7. *Cyprinus carpio* Linnaeus, 1759	+++
8. *Leucaspius delineatus* (Heckel, 1843)	++
9. *Leuciscus cephalus* (Linnaeus, 1758)	++++
10. *L. idus* (Linnaeus, 1758)	+++
11. *Rutilus rutilus* (Linnaeus, 1758)	+++++
12. *Scardinius erythrophthalmus* (Linnaeus, 1758)	+++++
13. *Tinca tinca* (Linnaeus, 1758)	++
Order II. Siluriformes	
Family 3. Siluridae Cuvier, 1816	
14. *Silurus glanis* Linnaeus, 1758	+++
Order III. Gadiformes	
Family 4. Lotidae Jordan et Evermann, 1898	
15. *Lota lota* (Linnaeus, 1758)	+++
Order IV. Syngnathiformes	
Family 5. Syngnathidae Rafinesque, 1810	
16. *Syngnathus nigrolineatus* Eichwald, 1831	++++
Order V. Perciformes	
Family 6. Percidae Cuvier, 1816	
17. *Perca fluviatilis* Linnaeus, 1758	+++++
Family 7. Eleotrididae Regan, 1911	
18. *Perccottus glenii* Dubowski, 1877	+++++

Note RN—relative numbers; +—the species is represented by single individuals; ++—very low abundance (0.01–0.10%); +++—low abundance (0.11–1.00%); ++++—medium abundance (1.1–4.0%); +++++—high abundance (1.1–4.0%)

Table 18.2 Number of species belonging to different faunal complexes in the Krasnoyarsk floodplain

Name	P.-C.F	B.P	P.-C.S	T.R.F	A.F	Ch.P
Number of species	8	5	1	2	1	1

Note Faunal complexes: P.-C.F.—the Ponto-Caspian freshwater, B.P.—the Boreal plain, P.-C.S.—the Ponto-Caspian Sea, T.P.F.—the tertiary plain freshwater, A.F.—the Arctic freshwater, Ch.P.—the Chinese plain

According to Nikolsky (1951), new species are formed through adaptation to the abotic and biotic conditions of the zone of their formation, and their formation is typically of a group nature. As a result, the so-called faunal complex is formed, which is a group of species of common geographical origin. During the time of their separate existence, faunal complexes diverged in different directions and acquired not only species but also ecological specificity.

In the historical past, faunal complexes that compose the current ichthyofauna of the Volga basin were formed over large areas and in different landscape and geographical zones. Changed climatic conditions, tectonic activity, and human activity have led to and are currently leading to species dispersion. As a result, virtually all water bodies of the Volga River basin include representatives of different faunal complexes, and their ichthyofauna is based on species complexes which were formed at the location of the present water bodies, as well as those formed in the nearby territories (Shashulovsky and Ermolin 2005b).

In its historical development, the Lower Volga is closely connected to the water bodies of the Ponto-Caspian Sea. On the other hand, the middle and upper parts of the Volga River flow through the Boreal Plain Zone. Accordingly, the representatives of these complexes are the basis of the ichthyofauna of the Lower Volga water bodies.

Based on the studies by Nikolsky (1951), Nebolsina (1980) and others, the ichthyofauna of the wintering pits in the Krasnoyarsk floodplain can be divided into six faunal complexes in accordance with their morphological and ecological features (see Table 18.2).

Two of the complexes, the Ponto-Caspian freshwater and the Boreal plain, form the basis of ichthyofauna (77%).

The most diverse is the Ponto-Caspian freshwater complex and it is represented by 8 species (Table 18.2). The Ponto-Caspian fauna has an ancient history, and its components were formed at the end of the Tertiary period. According to Nikolsky (1951), representatives of the genera Rutilus, Scardinius, and Pelecus can be found in the sediments of the Pontic Sea. Modern representatives of the fauna of the Ponto-Caspian are widespread in the rivers of the Ponto-Caspian, Baltic Sea region, and Central Europe, and in the basins of the Northern Dvina and Pechora rivers. Acclimatization works increased number of representatives of this faunal complex in water bodies of Siberia.

The Boreal Plain faunal complex in the Krasnoyarsk floodplain is represented by 5 species (see Table 18.2). The Boreal Plain complex was formed in water bodies located in far-northern latitudes, which led to the development of specific features and, above all, high adaptability and resistance to adverse environmental conditions.

All of them are characterized by high euryoxicity and eurythermality. The faunal complex includes fish adapted to conditions of low oxygen content that breed at high temperatures (crucian carp), and those that breed at relatively low temperatures (pike, roach, ide). Obviously, the species of the studied complex were formed in slow-flowing water bodies with trophicity fluctuations from a high level to dystrophic one.

The species of the Boreal plain and the Ponto-Caspian freshwater complexes are widespread. Broad adaptive capabilities of the above complexes allow fish species to live in most biotopes, which ensures their dominance in ichthyocenosis.

The Tertiary freshwater complex is represented by two species: carp and catfish. This ancient group formed in the Upper Tertiary and in the past was widely distributed in water bodies throughout southern Siberia, as well as in Europe and America. Carp and catfish, similar to the previous species, can be called historically local fish. The species of the Tertiary freshwater complex are characterized by small-sized eyes and using their sense organs for food orientation. These features developed as an adaptation to high turbidity of rivers in which the complex was formed.

The Ponto-Caspian Sea complex includes the Black Sea needlefish. This species originated from marine forms but sufficiently adapted to life in fresh water, and this adaptability was developed in the geological past. At present, it is widespread in all water bodies of the Volga cascade.

The Arctic freshwater complex is represented by only one species, burbot, which is widespread in the Northern Hemisphere and leads an active lifestyle at low temperatures. In northern water bodies, this species is active throughout a year. In the water bodies of the Lower Volga, it is active in the autumn–winter–early spring period at water temperatures below 14 °C. At higher temperatures, burbot hides in the outlet of cold waters or pits with weakly heated water.

The Chinese plain complex includes one species, the Chinese sleeper. Earlier, this species did not occur in the reservoir. The first specimen was caught nearby the village of Usovka at the confluence of the Tereshka River and the Volga River in 1988, the second specimen was taken in the Krasnoyarsk floodplain in 1994, and the third one was found near the left bank opposite the city of Volsk in 1996. Since 1997, the data on the occurrence of Chinese sleeper have been reported from various parts of the reservoir (Shashulovsky 2001).

At present, the abundance of Chinese sleeper in the Krasnoyarsk floodplain is sufficiently high.

18.4 Discussion

Winter is a favorable season only for burbot among the above species since the species was formed in low temperature water bodies. It does not form winter accumulations. The behavior pattern of the species implies an active lifestyle, and its basic vital functions are realized in the late autumn, winter and early spring, when the water temperature does not exceed 10–14 °C. At higher temperature, it stops feeding and hides in shelters (in depressions of the bottom) with low water temperature.

For other fish species, winter is a difficult (unfavorable) period of the year, especially for fish from the Ponto-Caspian freshwater and the Tertiary plain freshwater complexes, since these species are formed in water bodies with a predominant water temperature of about 15–30 °C. When the water temperature drops below 10–7 °C, the fish from these faunal complexes stop feeding and form wintering aggregations. The general behavior pattern of species of the Boreal plain complex occupies, to some extent, a middle position between the behavior pattern of species from the Arctic freshwater complex on the one hand and that of the Ponto-Caspian freshwater and the Tertiary plain freshwater complexes on the other one. These species continue to be active and feed in winter, although they become less active as compared to summer. They can form winter aggregations separately or as part of wintering pits with fish species from the Ponto-Caspian freshwater and the Tertiary plain freshwater complexes.

The Volgograd Reservoir is a complex hydrological system with wintering pits in the deep-water channel part. They can be found in floodplain areas, yet their location is difficult to determine by hydrometric and bathymetric parameters due to their relatively small size. Understanding the behavior patterns of fish in winter in the context of the zoogeographic origin helps to determine the location of wintering pits ~~to~~ and preserve the biological resource potential of the water body.

18.5 Conclusion

Thus, all commercial fish in the Volgograd Reservoir, except burbot, can form wintering pits in floodplain areas. However, this behavior pattern is vital for species from the Ponto-Caspian freshwater and the Tertiary plain freshwater complexes; it is determined by the strategy developed during species formation and aimed at survival in unfavorable winter conditions.

The accumulation of fish from the Ponto-Caspian freshwater and the Tertiary plain freshwater complexes, including such valuable species as crucian carp, bream, catfish, silver bream, and asp, in the autumn–winter period confirms suitability of the study areas for their large aggregations. Therefore, this can be used as an indicator of compliance of the pits with the status of wintering pits.

References

Chemagin AA (2016) Current issues of science and education. https://www.science-education.ru/ru/article/view?Id=25254 (in Russian)

Cherepanov KM (1995) Features of the reproduction of fish stocks in the Volgograd Reservoir. Works GosNIORKh 315:47–60 (in Russian)
Ermolin VP (2010) Composition of the ichthyofauna of the Saratov Reservoir. Iss Ichthyol 50(2):280–284 (in Russian)
Nebolsina TK (1974) General characteristics of the shallow-water zone of the Volgograd Reservoir. Izv Gosniorkh 89:151–158 (in Russian)
Nebolsina TK (1980) Ecosystem of the Volgograd Reservoir and the ways of creating a rational fisheries: Dis. ... Doctor of Biol. Sciences, Saratov, RSFSR (in Russian)
Nikolsky GV (1951) On the method of research zoogeography. Iss Geogr 24:263–275 (in Russian)
Pravdin IF (1966) Guide to the study of fish. USSR, Food Industry, Moscow (in Russian)
Shashulovsky VA (2001) On the appearance of the self-climatizant Chinese sleeper in the Volgograd Reservoir. In: Shlyakhtin (ed) Fundamental and applied aspects of functioning of aquatic ecosystems (187−189). Saratov University Publishing House, Saratov, RF (in Russian)
Shashulovsky VA, Ermolin VP (2005a) Ichthyofauna composition of the Volgograd Reservoir. Iss Ichthyol 45(3):324–330 (in Russian)
Shashulovsky VA, Ermolin VP (2005b) Transformation of the structure of the ichthyocenosis of the Volga River in the ecosystem of the Volgograd Reservoir. Povolzhsky Ecol J 2:185–190 (in Russian)
Shashulovsky VA, Mosiyash SS (2010) Formation of biological resources of the Volgograd Reservoir during the succession of its ecosystem. RF, KMK, Moscow (in Russian)
Zakora LP (1974) Feeding of juvenile fish in shallow waters of the Volgograd Reservoir. Bull GosNIORKh 89:206–211 (in Russian)