Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2021, 11(3), 285-291, doi: 10.15421/2021_173

ORIGINAL ARTICLE

Diversity of aquatic animals in water bodies Opechen' (Dnipro floodplain, Ukraine)

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Received: 03.05.2021. Accepted 01.06.2021

The species composition of vertebrate aquatic animals living in urban lakes of the Opechen' system is considered. These lakes were formed due to the transformation of the Pochayna River and are currently experiencing significant anthropogenic pressure, which affects the diversity of aquatic and primary animals. Lakes with the most unfavorable ecological conditions are characterized by a low species diversity of fish, especially in lake Luhove; 13 species were found. The highest species diversity was found in the lakes of the lower cascade, Kyrylivs'ke, and Yordans'ke, in which there were 27 and 25 species, respectively. Active transformation and fragmentation of biotopes significantly influenced the presence of other classes of aquatic animals, including amphibians, birds, and mammals. So, the reservoir of the Opechen' system is poor in the species composition of amphibians; there are only one species here, a marsh frog. Birds are represented by 28 species, of which 8 are nesting and five wintering; the rest are recorded during seasonal and forage migrations. The population of aquatic animals of the Opechen' system reflects the consequences of a significant anthropogenic transformation of the river with its subsequent irrational use. This is manifested in the destruction of coastal macrophytes adjacent to lakes, deforestation of floodplain forests, water pollution by discharging untreated wastewater. At the same time, ten species of animals are included in the lists of the Berne Convention, 13 species are included in the Bonn Convention, and one species in the IUCN in the Opechen' system, which indicates the importance of the cascade of the Opechen' system for existence of rare species.
Keywords: Opechen' system, aquatic animals, near-aquatic animals, biodiversity, urbanization, anthropogenic load.

Introduction

Anthropogenic transformation of the natural environment is carried out at a significant speed in most countries of the world and increasingly exacerbates the problems of preserving the ecosystem and biodiversity in urbanized and transformed territories (Carpenter et al., 2006). Freshwater ecosystems are essential functional elements of the urban environment and provide the city with several unique ecosystem services. They are important centers of biological diversity but are highly vulnerable to anthropogenic pressure. Inland water bodies of Kyiv (Ukraine) are no exception, and their long-term irrational use leads to some environmental problems for natural complexes (Panasyuk et al., 2016). A striking example of the problems described is the lakes of the Opechen' system. This system consists of 7 lakes and has a large intake area and water surface. The system is located on the right bank of the Dnieper floodplain in the middle reaches of the former Pochayna River. One of the constituent parts is the structure and species composition of the biota, which can record the consequences of anthropogenic impacts on the city's water bodies. Considering this, the study of aquatic and semiaquatic animals, in particular vertebrates, which are the upper link of the food pyramid, acquires particular relevance by integrating the consequences of anthropogenic activity. Therefore, the purpose of the work was to characterize the modern species composition of aquatic and semiaquatic animals living in/on the lakes of the Opechen' system.

Materials and Methods

The collection of material was carried out during 2017–2021. The material collected in 2012–2016 was also used. Ichthyological studies were carried out using standard fishing methods, including fishing net and hook fishing gear. The catches of amateur fishers were investigated. Determination of the species composition of fish was carried out according to (Movchan, 2011).

To count the avifauna, we used 10×40 and 12×5 binoculars and a digital camera with 20x magnification. During the reproductive period, the presence of nests in the studied lakes was checked. Breeding reliability was determined following the criteria recommended by the European Committee of the Ornithological Atlas EOAC (Breeding Bird Atlas of Europe, 1992). The studies were carried out by route counts (Borowiec et al., 1981). Identification of species and assessing their status in water bodies was carried out following Fesenko & Bokotey (2002).

Based on the results of visual observations, materials were collected on amphibians, reptiles, and mammals.

We also consider it necessary to place information on the hydroecological state of the lakes in the Materials and Methods section.

Hydroecological aspects of lakes. The water bodies of the Opechen' system include seven lakes: Mins'ke (Opechen' – 6), Luhove (Opechen' – 5), Ptashyne (Luhove – 2), Bohatyrs'ke (Opechen' – 3; Andriyivs'ke), Kyrylivs'ke (Opechen' – 2; Verkhne), Yordans'ke (Opechen' – 1; Nizhne), Vovkuvate (bay Vovkuvate), which are connected between a system of culverts – collectors and flow into the Kanevs'ke reservoir. The total area of the water mirror of reservoirs in low water is 73 hectares, the volume of water mass is about 4,200,000 M^3 (Goncharova et al., 2020). The Opechen' system is located in the right-bank part of Kyiv (Ukraine) in the Obolon district and is the former riverPochayna, which in the 1980' transformed into a cascade of lakes; the reservoirs have an elongated shape with a total area of 15.5 hectares and depth of 12-15 m. The area of each lake varies within 1.0–20.5 hectares, length 210–1090 m, depth 5.5–16.3 m. (Panasyuk et al., 2016). Because the Opechen» system has a significant area, the lakes differ significantly in the degree of anthropogenic load. The scheme of the lakes of the lake system is shown in Fig. 1.

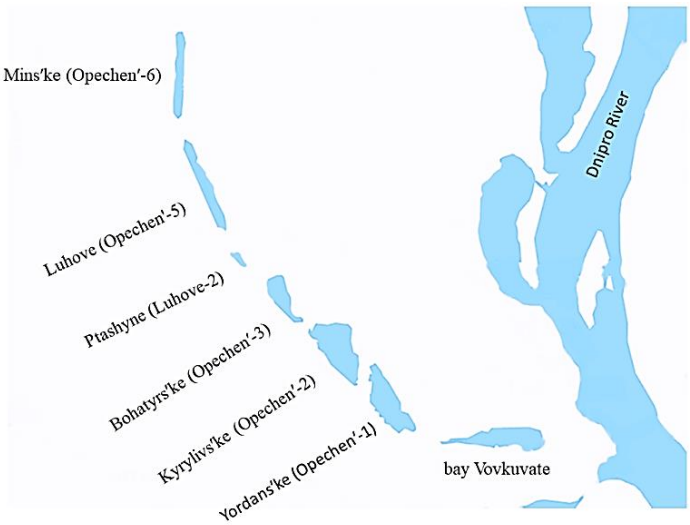

Fig. 1. The layout of the lakes of the Opechen system.

Among all lakes in the system, the most polluted is the lake Luhove. This is due to the development of the adjacent territories of this reservoir with industrial facilities, garage cooperatives, and the laid railway. The indicators reflecting the quality of the aquatic environment indicate a long-term anthropogenic load on these lakes. Therefore, studies of the content of heavy metals in water from 2006 to 2016. Contamination with Al (III), Fe (II), Cu (II), Mn (II), Zn (II), and Pb (II) compounds was revealed (Romanenko et al., 2015; Zhezherya et al., 2016). In addition, reservoirs are characterized by a significant accumulation of heavy metals in bottom sediments, particularly lake Luhove (Cd, Pb content) (Goncharova et al., 2020). In these lakes, the main danger is represented by oil products, but their content can fluctuate in different years, decreasing the cascade. Therefore, the lower lakes Kyrylivs'ke and Yordans'ke are considered the cleanest, the water quality which is "satisfactory, moderately polluted", and the toxicity of water and bottom sediments is "weak moderate (Goncharova et al., 2020). An important aspect of the ecological state of the reservoir is the characteristic of the structure of the biota. Thus, the lakes of the Opechen' system have an insignificant species diversity of macrophytes, which ranges from 5 to 11 species, in particular, in lakes Mins'ke, Luhove – 6, Andriyivs'ke – 8, Kyrylivs'ke – 9 and Yordans'ke – 14. Lakes with the worst water quality (Luhove, Andriyivs'ke, Kyrylivs'ke) have less species diversity (Zub et al., 2019) in particular, over ten years in lake Kyrylivs'ke, the species diversity of algae has been reduced by almost half (Kravtsova & Semenyuk, 2017). In addition, studies of ichthyoparasitic showed the poverty of the parasite fauna of fish in the lakes «Opechen'» (Yuryshynets', 2015).

Results and discussion

Ichthyofauna is one of the most important elements of lake ecosystems; its structure and composition may reflect the state of the reservoir (Brygadyrenko, 2015; Grynevych et al., 2018; Prysiazhniuk et al., 2019; Komlyk & Brygadyrenko, 2019; Rudenko et al., 2019; Kalyn et al., 2020; Hrynevych et al., 2021). Therefore, one of the main directions in conducting complex research is monitoring the state of groups of ichthyofauna as an integral part of the ecosystem and objects of amateur fishing (Sytnyk et al., 2005; Kundyev & Sytnyk, 2011). According to the research results, 28 fish species were identified (Table 1) belonging to cyprinids *Cyprinidae*, *Balitoridae*, *Cobitidae, Perconidae*, *Esocidae*, *Gasterosteidae*, *Odontobutidae,* and *Gobiidae*. The ichthyofauna composition was mainly represented by a complex of indigenous and invasive species characteristic of the Middle Dnieper.

Table 1. Species composition of ichthyofauna in water bodies of the Opechen' system

№	Species name	Name of the lakes				
		Mins'ke (Opechen'-6)	Luhove (Opechen'-5)	Bohatyrs'ke (Opechen'-3)	Kyrylivs'ke (Opechen'-2)	Yordans'ke (Opechen'-1)
1	*Sander lucioperc*a (Linnaeus, 1758)	–	–	+	+	+
2	*Gymnocephalus cernua* (Linnaeus, 1758)	–	–	+	+	+
3	*Perca fluviatilis* (Linnaeus, 1758)	+	+	+	+	+
4	*Esox lucius* (Linnaeus, 1758)	+	–	–	+	+
5	*Gobio gobio* (Linnaeus, 1758)	–	–	–	+	–
6	*Gobitis taenia* (Linnaeus, 1758)*	–	–	–	+	+
7	*Nemachilus barbatulus* (Linnaeus, 1758)	+	–	–	–	–
8	*Leucaspius delineatus* (Heckel, 1843)	+	+	+	+	+
9	*Leuciscus idus* (Linnaeus, 1758), **	–	–	–	+	+
10	*Squalius cephalus* (Linnaeus.1758)	–	–	–	+	+
11	*Abramis brama* (Linnaeus, 1758	+	+	+	+	+
12	*Blicca bjoerkna* (Linnaeus, 1758)	+	+	+	+	+
13	*Rutilus rutilus* (Linnaeus, 1758),	+	+	+	+	+
14	*Alburnus alburnus* (Linnaeus, 1758)	+	+	+	+	+
15	*Scardinius erythrophthalmus* (Linnaeus, 1758)	+	+	+	+	+
16	*Carassius auratus* (Linnaeus, 1758)	+	+	+	+	+
17	*Cyprinus carpio* (Linnaeus, 1758),	+	+	+	+	+
18	*Rhodeus sericeus* (Pallas, 1776) *	+	+	+	+	+
19	*Tinca tinca* (Linnaeus, 1758)	+	–	–	+	+
20	*Gasterosteus aculeatus* (Linnaeus, 1758)	–	–	–	+	–
21	*Pungitius platygaster* (Linnaeus, 1758)	–	–	+	+	+
22	*Misgurnus fossilis* (Linnaeus, 1758)*	+	+	–	+	+
23	*Syngnathus nigrolineatus* (Eichwald, 1831)	+	–	–	+	+
24	*Perccottus glenii* (Dybowski, 1877)	+	+	+	+	+
25	*Neogobius melanostomus* (Pallas, 1814)	–	–	–	+	–
26	*Babka gymnotrachelus* (Kessler, 1857).	–	–	+	+	+
27	*Neogobius fluviatilis* (Pallas, 1814);	+	+	+	+	+
28	*Proterorhinus semilunaris* (Heckel, 1837)	+	–	+	+	+
Total	28	18	13	15	27	25

Note * species included in Resolution 6 of the Berne Convention ** - species included in the Red Book of Ukraine

When the aquatic environment is polluted with toxic compounds, significant changes occur in the structure of the ichthyocenosis, in particular, the number of certain ecological groups of fish, including the complex bottom, decreases (Khudiyash et al., 2020), because of what in the lake. The smallest number of fish species was found in Luhove, which indicates its unsatisfactory condition. Another negative factor is a significant transformation of the territories adjacent to water bodies and the coastal strip, which shows the conditions for reproducing a number of their representatives of the ichthyofauna. Ultimately, this leads to a change in the structure of the ichthyocenosis and a decrease in the ecological compatibility of fish. Considering that many reservoirs interconnect the lake: Andriyivs'ke, Kyrylivs'ke, and Yordans'ke, it is appropriate to assume a free exchange of ichthyofauna (Prychepa & Medovnyk, 2017) therefore, the species composition of fish in these lakes is similar. The routes of entry into the upper and lower lakes of the *Syngnathusabaster* (Risso, 1826), a brackish water representative of the Ponto-Caspian complex, have not been reliably established. It can be assumed that this species could have been transferred to the lake Mins'ke from the lake Redchine by fish-eating waterfowl. Therefore, it is possible that the Italian needlefish could also get into the lake. Andriyivs'ke and lake Redchene, but due to unsatisfactory habitat conditions, the species could not occupy its ecological niche. The intensive pollution of the lake should be noted. The meadow affects the species composition and biomass of zoobenthos organisms, which indirectly affects fish species composition and physiological state.

Lake Luhove turned out to be relatively poor in zoobenthos compared to other studied lakes (Kovalenko et al., 2019). The presence of *N. barbatulus* (L) char in lake Mins'ke should be noted. This species has already been recorded (Sytnyk et al., 2005), and we have confirmed its presence in this lake. It is characteristic that this species was absent in other systems like Mins'ke (Table 1).

It should be noted that under conditions of excessive anthropogenic pollution, fish periodically experience stress, which enhances their metabolic processes. This was vividly illustrated by physiological and biochemical indicators of chronic stress, in particular the activity of alkaline phosphatase and the content of malondialdehyde, which were increased in fish due to the action of unfavorable conditions (Prychepa et al., 2019; Prychepa & Kovalenko, 2020; Prychepa et al., 2021). It should be noted that under conditions of excessive anthropogenic pollution, fish periodically experience stress, which enhances their metabolic processes. This was clearly demonstrated by the physiological and biochemical indicators of chronic stress, in particular the

activity of alkaline phosphatase and the content of malondialdehyde, which were increased in fish due to the action of unfavorable conditions (Prychepa et al., 2019; Prychepa & Kovalenko, 2020; Prychepa et al., 2021). It should be noted that the highest biological diversity is observed in the lower lakes, in particular. Kyrylivs'ke and Yordans'ke (Table 1), in which 27 and 25 species were found, respectively. The invasive species of the studied lakes include *Gasterosteus aculeatus* (L), *Pungitius platygaster* (L), Carassius *auratus* (L), *Perccottus glenii* (D), *Babka gymnotrachelus* Kessler, 1857). (Fig. 2), *Neogobius melanostomus* (P). Among the predatory species, we identified three fish species, in particular *Perca fluviatilis* (L) (Fig. 3), *Esox lucius* (L), *Sander lucioperca* (L) (the latter species is represented only in 3 lower lakes). It should also be noted that there are significant fluctuations in their numbers relative to the season. The most adapted river perch is found even in the most polluted lakes (Luhove). An important aspect to consider when planning recreation areas around water bodies is the presence of 3 species (*Rhodeus sericeus* (P), *Cobitis taenia* (L), *Misgurnus fossilis* (L.)) included in Resolution 6. Bernese conventions and 1 type are included in the Red Book of Ukraine (*Leuciscus idus* (Linnaeus, 1758)).

Fig. 2. *Babka gymnotrachelus* (K) caughton the lake Kyrylivs'ke

Fig. 3. *Perca fluviatilis* (L) caughton the lake Kyrylivs'ke

Furthermore, we examined the species composition of two more vertebrates, including amphibians (Amphibia) and reptiles (Reptilia), which are also an integral part of aquatic and semiaquatic ecosystems. The class of reptiles on the Opechen' system's lakes is represented by two species – the *Natrix natrix* (Linnaeus, 1758) and Emys *orbicularis* (Linnaeus, 1758). The latter species is included in the IUCN lists, which is essential from the point of view of environmental impact assessment and the formation of an eco-network in the conditions of the city of (Vasylyuk et al., 2019). One species represents the amphibian class. (*Rana ridibunda* (Pallas, 1771)). The insignificant species diversity of amphibians compared with other reservoirs and watercourses in Kyiv is associated with excessive transformation of biotopes, making the typical reproduction process of these animals impossible. Therefore, the most plastic species is the marsh frog, which is found in all studied water bodies. This species has high viability in urbanized water bodies, can displace other species, form populations with increased density and piston (relatively natural) age, size, and sex composition (Kustovs'kyy et al., 2018). It is known that tailless amphibians are vulnerable to the harmful effects of several harmful factors of natural and anthropogenic origin. In most world ecosystems, an increase in the proportion of various anomalies, a decrease in the number or complete disappearance of many amphibian species is recorded (Berger, 2008).

Avifauna is an essential component of aquatic ecosystems; therefore, the study of its species composition in urbanized water bodies is of particular importance for characterizing the ecological state of water bodies.

According to the research results, 28 bird species were registered (Table 2), which are combined in 8 rows, particularly *Podicipediformes, Anseriformes, Ciconiformes, Charadriformes, Passeriformes, Gruiformes, Coraciformes*and *Pelecaniformes*. Of these, eight species nest. The rest were recorded during seasonal or forage migrations and wintering. Naturally, the reservoirs with the highest anthropogenic load have a low biological diversity of birds (Luhove and Mins'ke lakes (13 species each)). In contrast, the lake had the most significant species richness of birds. Yordans'ke (25 species) is a reservoir of the lower cascade. It should be noted that the most significant number of bird species was recorded during seasonal and forage migrations. The overwhelming majority of species are found precisely in the lakes of the lower cascade, in particular, Kyrylivs'ke and Yordans'ke (16 and 25 species, respectively). Thus, we can talk about the importance of these lakes as wintering places for individual representatives of the bird fauna. This is due to non-freezing areas on the lakes Kyrylivs'ke and Yordans'ke, which facilitate the wintering of waterfowl. In winter, the weather conditions and the nature of the freeze-up affect the species composition and the number of waterfowl that stop at these lakes. Also, during 2015-2018, on lakes Kyrylivs'ke and Yordans'ke, *Podiceps cristatus* (L) attempted to breed, and its nesting was recorded. However, these reservoirs are subject to intense eutrophication, which worsens the living conditions of grebes, for example, on the lake, on the embankment (located on the left bank of Kyiv), which is also subject to a significant influence of recreation, 3-5 pairs of *P. cristatus* (L) nested (2018-2019) (Prychepa & Kovalenko, 2021).

Table 2. Species composition of the avifauna of the studied lakes

№	Species name	Name of the lakes				
		Mins'ke (Opechen'-6)	Luhove (Opechen'-5)	Andriivske (Opechen'-3)	Kyrylivs'ke (Opechen'-2)	Yordans'ke (Opechen'-1)
1	*Podiceps cristatus* (Linnaeus, 1758)	–	–	–	+	+
2	*Phalacrocorax carbo* (Linnaeus, 1758)	+	+	+	+	+
3	*Ixobrychus minutes* (Linnaeus, 1758)*; **	+	+	+	+	+
4	*Ardea cinerea* (Linnaeus, 1758)	+	+	+	–	+
5	*Cygnus olor* (Gmelin, 1789) **	–	–	–	–	+
6	*Anas platyrhynchos* (Linnaeus, 1758) **	+	+	+	+	+
7	*Anas crecca* (Linnaeus, 1758)	–	–	–	–	+
8	*Anas querquedula*(L) **	–	–	–	–	+
9	*Anas clypeata* (Linnaeus, 1758) **	–	–	–	–	+
10	*Aythya ferina* (Linnaeus, 1758) **	–	–	–	–	+
11	*Aythya fuligula* (Linnaeus, 1758) **	–	–	–	–	+
12	*Bucephala clangula* (Linnaeus, 1758)***; **	–	–	–	–	+
13	*Gallinula chloropus* (Linnaeus, 1758)	+	+	+	+	+
14	*Fulica atra* (Linnaeus, 1758) **	+	+	+	+	+
15	*Tringa ochropus* (Linnaeus, 1758) **	-----	-----	-------	------	+
16	*Tringa nebularia* (Gunnerus, 1767)	------	----	------	------	+
17	*Actitis hypoleucos* (Linnaeus, 1758) **	------	-----	------	---------	+
18	*Xenus cinereus* (Guldenstadt, 1775)*; **	----	-----	------	+	-----
19	*Larus ridibundus*(Linnaeus, 1758)	+	+	+	+	+
20	*Larus cachinnans* (Pallas, 1811)	+	+	+	+	+
21	*Larus canus* (Linnaeus, 1758)	+	+	+	+	+
22	*Sterna hirundo*(Linnaeus, 1758)*; **	+	+	+	+	+
23	*Alcedo atthis* (Linnaeus, 1758)*; **	+	+	+	+	+
24	*Acrocephalus scirpaceus* (Hermann, 1840)	+	+	+	+	+
25	*Acrocephalus arundinaceus* (Linnaeus, 1758)	+	+	+	+	+
26	*Panurus biarmicus* (Linnaeus, 1758)	------	-------	------	+	------
27	*Remiz pendulinus*(Linnaeus, 1758)	------	-------	-------	+	-----
28	*Emberiza schoeniclus* (Linnaeus, 1758)	----	------	-------	-----	+
	Total	13	13	13	16	25

Note: * – species included in Resolution 6 of the Berne Convention ** – species included in the resolution of the Bonn Convention, *** species included in the edition of the Red Book of Ukraine

The most significant number of wintering species was recorded on the lake Yordans'ke (5-9 species). Thus, in the winter period of 2021, the *Bucephala clangula* (L) (Fig. 4) (Red Data Book of Ukraine) was in the ice hole of lake Yordans'ke for several weeks. Moreover, the gulls were constantly found on the lake: *Larus canus* (L) (Fig. 5), *Larus cachinnans* (P), and *Larus ridibundus* (L). Due to the close location of the two lakes, flocks of wintering birds often change their habitat.

Among the species registered on the lake: 4 species are included in the Bern Convention, 13 species in the Bonn Convention, and one species in the Red Book of Ukraine.

Fig. 4. *Bucephala clangula* (L) (like Yordans'ke)

Fig. 5. *Larus canus* (L) (like Yordans'ke)

The Mammalia is represented by two species, in particular *Ondatra zibethicus* (L) and *Castor fiber* (L) (Berne Convention). *C. fiber* (L) was recorded from two lower lakes: Kyrylivs'ke and Yordans'ke, while muskrat was found in all the studied water bodies.

Conclusions

The research results made it possible to assess the species composition of aquatic and semi-aquatic vertebrates in the Opechen' system's city lakes.

In some of the Opechen' system lakes, experiencing less anthropogenic impact (Kyrylivs'ke), a greater variety of fish has been recorded – 27 species. In contrast, 13 fish species were recorded in lakes with the highest anthropogenic load (Lake Luhove).

All the cascade lakes had a low variety of amphibians, and only one species has been found - the marsh frog.

It turned out that during the period of research on the lakes, there were 28 species of birds, of which eight were breeding and five wintering. The rest were recorded during seasonal and forage migrations.

The example of the Opechen' Lakes illustrates the impact of urbanization on the fauna. A negative role in this is played by the destruction of coastal thickets adjacent to lakes, deforestation of floodplain forests, and pollution of the aquatic environment by wastewater discharges.

Despite this, ten species included in the Berne Convention were found, 13 species included in the Bonn Convention, one species (IUCN) indicates the existence of conditions for several species and are important places for wintering.

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Citation:

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