Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2018, 8(2), 140-148 doi: 10.15421/2018_321

ORIGINAL ARTICLE

Ichthyofauna of the Zaporizhia Nuclear Power Plant cooling pond (Enerhodar, Ukraine) and its biomeliorative significance

O.M. Marenkov

Oles Honchar Dnipro National University, Dnipro, Ukraine
E-mail: gidrobions@gmail.com
Received: 26.02.2018. Accepted: 04.04.2018

The article presents the results of comprehensive research of the fish fauna of the cooling pond of the Zaporizhia Nuclear Power Plant. The species composition of the fish fauna and the main limiting factors affecting the structure of the ichthyocenosis of the reservoir have been studied. It is noted that the fish fauna is dominated by invasive species (57%), most of which are introduced for the biological melioration in a cooling pond. The decrease in the number of native fish species is caused both by the spread of invasive species and by the factor of high water temperature. The latter factor limits the number of fish species that do not tolerate a rise in water temperature (roach *Rutilus rutilus* (Linnaeus, 1758), bream *Abramis brama (*Linnaeus, 1758), rudd *Scardinius erythrophthalmus* (Linnaeus, 1758)). The paper also presents the results of studies on the nutrition spectrum of fish living in the Zaporizhia NPP cooling pond. The dynamics of catches of the main ameliorative species over the last 10 years has been analyzed. Practical recommendations on the stocking the heat sink with ameliorative fish for the period of 2018–2022 are given.
Key words: Zaporizhia Nuclear Power Plant; cooling pond; fish amelioration; silver carp; black carp; tilapia; fish feeding

Introduction

Using fish for the melioration of technical reservoirs is widespread in Ukraine and in the world; the massive stocking cooling pond with phytoplankton-eaters reduces biomass of algae. Significant ameliorative effect can only be achieved if volumes of stocking are sufficient (Fowler & Robson, 1978). The priority direction in the formation of the ichthyofauna of the Zaporizhia Nuclear Power Plant cooling pond is stocking with silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844) to control the massive growth of phytoplankton ("blooming") and decrease suspended organic substances in water, a black carp *Mylopharyngodon piceus* (Richardson, 1846) helps to control mollusks, a grass carp *Ctenopharyngodon idella* (Valenciennes, 1844) controls the overgrowth of the reservoir, which helps to manage with the biological overgrowth of the drainage and drainage plates (reduction of the number of green algae *Cladophora* and *Ulotrix*), carp *Cyprinus carpio* (Linnaeus, 1758) is used for the accumulation of organic matter, which is made of biomass of benthos organisms, stocking with predators such as channel catfish is used for biomelioration (Smith, 1985; Lieberman, 1996; Rahman et al. 2004; Zhang et al., 2006; Welker et al., 2011; He et al., 2013; Ip et al., 2014).

Hydroshop of Zaporizhia Nuclear Power Plant has a specialized section of biomelioration, which operates in its own fisheries and can provide the fish stocking with stocking material of grass carp and black carp, silver carp, carp, tilapia *Oreochromis mossambicus* (Peters, 1852) and catfish *Ictalurus punctatus* (Rafinesque, 1818). Measures for biological melioration are carried out due to the following basic principles and points. Reclamation at the by fish with a certain food orientation allows selective suppression of certain species of hydrobionts. For this purpose aboriginal species of fish, as well as introduced ones can be used. At the same time, it is important to take into account the nutritional needs of fish. Thus, it is known that when the content of phytoplankton is low silver carp consumes detritus, so, it acts as a seston-feeder, competing with filterers invertebrates, for example, with bivalve mollusks. Bighead consumes large forms of zooplankton, which take part in the filtration of phytoplankton and clear the water (Wurts, 2000). Grass carp basically consume soft water vegetation (filamentous algae, pondweed, hornweed, etc.), its biological function is reducing the level of overgrowing of the reservoir with air and water vegetation. The most productive biomelioration of the cooling pond by the introduction of a grass carp is observed only when the population is dominated by large individuals of four years and more. This should be taken into account in the development of measures for capture and stocking of the Zaporizhia Nuclear Power Plant cooling pond.

In the cooling pond of the Zaporizhia Nuclear Power Plant (ZNPP) there is an aboriginal ichthyofauna, which representatives are more or less adapted to the specific conditions of the technological reservoir, and introduced species, which are introduced for biomelioration purposes. In addition to the deliberate introduction of fish in the cooling pond, self-resettlement processes also occur, for example, stone moroko *Pseudorasbora parva* (Temminck et Schlegel, 1846) and pumpkinseed *Lepomis gibbosus* (Linnaeus, 1758) appeared there and they can significantly increase their size under conditions of unstable ecological balance in the studied reservoir.

The available data of the hydrochemical analysis in the period of selection of hydrobiological samples showed that the quality of water in the cooling pond corresponded to the conditions of fishery ponds. The shallow water of the cooling pond is satisfactory space for spawning and natural reproduction of certain species of fish. The presence of higher water vegetation and the remnants of flooded woody plants created conditions for the natural spawning of some phytophilous species of fish (carp, Prussian carp *Carassius gibelio* (Bloch, 1782)) (Marenkov, 2018b). The presence of places with a sandy bottom creates conditions for spawning of lithophilous species of fish and fish that build nests (zander *Sander lucioperca* (Linnaeus, 1758), channel catfish) (Marenkov & Fedonenko, 2016; Marenkov, 2018c). Also, the morphological and hydrological parameters of the cooling pond have positive indicators for fish farming.

Analysis of indicators of the forage base showed that: 1) the composition and production characteristics of phytoplankton can provide the development of zooplankton and zoobenthos, which serve as a forage base for fish; 2) the species composition and biomass of zooplankton meet the requirements for the management of pasture fish farming; 3) by the amount of benthos, the ZNPP cooling pond can be potentially satisfactory reservoir for benthophagus fish.

The purpose of the work was to study the current state of the ichthyofauna of the ZNPP cooling pond and its role in the biological melioration of the reservoir.

Materials and methods

The research was carried out in the water area of the cooling pond of the Zaporizhia Nuclear Power Plant. The type of cooling pond of the Zaporizhia NPP is the lake-pond (Protasov et al., 2013). The type of regulation of the level regime is seasonal. The cooling pond was built by cutting off part of the Kakhovka Reservoir with alluvial sandy dam and has the following parameters: the area of the mirror is 8.2 km², the volume is 47.05 million m³, the average depth is 5.87 m, the maximum depth is 13.5 m, the length of the coastline is 11.2 km. The water supply and cooling system of the Zaporizhia NPP is quite complicated (Fig. 1).

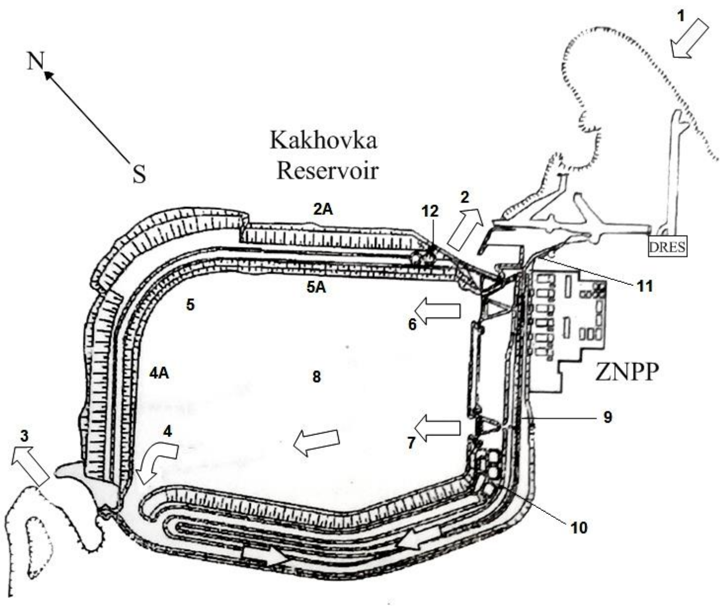

Figure 1. Scheme of water supply and cooling system of Zaporizhia NPP. Arrows indicate directions of water movement in the system, the letters A are coastal shallow water; figures show points of hydrobiological observations. Areas of Kakhovka Reservoir: 1 – water intake; 2 – a water drain of heated water; 3 – exit from cooling pond. Areas of cooling pond: 4 – western; 5 – northern; 6 – eastern; 7 – southern; 8 – central. Channels: 9 – input; 10 – output; 11 – feeding from the exit channel; 12 – output from cooling towers.

The water comes from the Kakhovka Reservoir, which pre-passes through the water supply systems of Zaporizhia NPP. Then water enters the cooling pond, through the supply channel to the power units, then into the outlet, spray devices, two cooling towers, and as the system operates almost continuously, the water returns to the Kakhovka Reservoir again. The average temperature of the cooled water in the pond during the hottest month of the year is 28.7 ºC. In the winter months, the water temperature is 17–18ºC. Ice cover on the pond appears if the cooler is absent.

Ichthyological material was collected from control fishing gear, which was conducted in the autumn of 2017, with a set of stacked nets with a mesh size a=30–110 mm (Chugunova, 1959; Ozinkovska et al, 1998; Arsan et al., 2006). In addition, the reporting materials of the ZNPP (official statistics data) were used. Collection and processing of ichthyological material were carried out in accordance with generally accepted methods. Calculations of the number and ichthyomass were carried out on the basis of the empirical dependencies of "number – catch on effort", for similar reservoirs. The processing of food boluses and intestines of fish was carried out in the research laboratory of hydrobiology, ichthyology and radiobiology of the Oles Honchar Dnipro National University, for each fish separately according to generally accepted methods. Indices for filling the intestines were determined by the actual mass (Marenkov, 2018a).

The intensity of accumulation of ichthyomas in age groups was determined by constructing a specific mass curve using calculated mortality rates (in the absence of fishing) and actual weights, according to the methodology of L.O. Kudersky (1984). The coefficients of natural mortality by age groups were determined using the parabolic equation (Zykov, 1986), with the definition of its parameters, taking into account the actual data of control catches. Limit length (L) was calculated by Ford-Wallford method (Ford, 1933; Protasov et al., 2011). Species names of fish are provided according to the current version of fishbase.org (Froese & Pauly, 2018).
Statistical processing of the material was carried out using software packages for personal computers Microsoft Excel 2010 and STATISTICA 6.0.

Results and Discussion

Structure of ichthyofauna and fishing activities. During the period of the existence of the ZNPP cooling pond, 18 species of fish were registered in the ihtiofauna. According to the results of ichthyological studies in 2017, the composition of the ichtyofauna of the ZNPP cooling pond included 14 species of fish (Table 1).

Table 1. Species composition of the ichtyofauna of the ZNPP cooling pond, autumn 2017

№	Fish species	Observed species	Introduced species	Invasive species	Current ichtyofauna
	Cyprinidae Fleming, 1822				
1.	Bream *Abramis brama (*Linnaeus, 1758)	+	–	–	–
2.	Common bleak *Alburnus alburnus* (Linnaeus, 1758)	+	–	–	+
3.	White bream *Blicca bjoerkna* (Linnaeus, 1758)	+	–	–	+
4.	Prussian carp *Carassius gibelio* (Bloch, 1782)	–	–	+	+
5.	Carp *Cyprinus carpio* (Linnaeus, 1758)	+	+	–	+
6.	Common roach *Rutilus rutilus* (Linnaeus, 1758)	+	+	–	–
7.	Common rudd *Scardinius erythrophthalmus* (Linnaeus, 1758)	+	–	–	–
8..	Grass carp *Ctenopharyngodon idella* (Valenciennes, 1844)	–	+	–	+
9.	Silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844)	–	+	–	+
10.	Stone moroko *Pseudorasbora parva* (Temminck et Schlegel, 1846)	–	–	+	+
	Siluridae Cuvier, 1816				
11.	Wels catfish *Silurus glanis* (Linnaeus, 1758)	+	–	–	+
	Ictaluridae Gill, 1861				
12.	Brown bullhead *Ameiurus nebulosus* (Lesueur, 1819)	–	+	–	+
13.	Channel catfish *Ictalurus punctatus* (Rafinesque, 1818)	–	+	–	+
	Centrarchidae Bleeker, 1759				
14.	Pumpkinseed *Lepomis gibbosus* (Linnaeus, 1758)	–	–	+	+
	Cichlidae Heckel, 1840				
15.	Mozambique tilapia *Oreochromis mossambicus* (Peters, 1852)	–	+	–	+
	Percidae Cuvier, 1816				
16.	Zander *Sander lucioperca* (Linnaeus, 1758)	+	–	–	+
	Mugilidae Cuvier, 1829				
17.	So-iuy mullet *Planiliza haematocheila* (Temminck & Schlegel, 1845)	–	+	–	–
	Gobiidae Fleming, 1822				
18.	Monkey goby *Neogobius fluviatilis* (Pallas, 1814)	+	–	–	+

Note: «+»– presence of species , «–» – absence of species.

The composition of families of the ichthyofauna was following: Cyprinidae – 7 species, Ictaluridae – 2, Centrarchidae, Cichlidae, Siluridae, Gobiidae and Percidae – 1 species.
Thus, the ichthyofauna of the ZNPP cooling pond is rather poor. In the reservoir there are both aboriginal and introduced species. In biomelioration, an important role is played both by native and introduced fishes. Due to the specific conditions of the existence in a cooling pond (high water temperature), as well as due to introduction the species composition of the ichthyofauna of the reservoir has a specific organization that is not typical of the reservoirs of the region (Cravens, 1982; Bernotas, 2002). The structure of the ichthyofauna of the ZNPP cooling pond includes 43% of aboriginal species and 57% of foreign species of fish (Fig. 2).

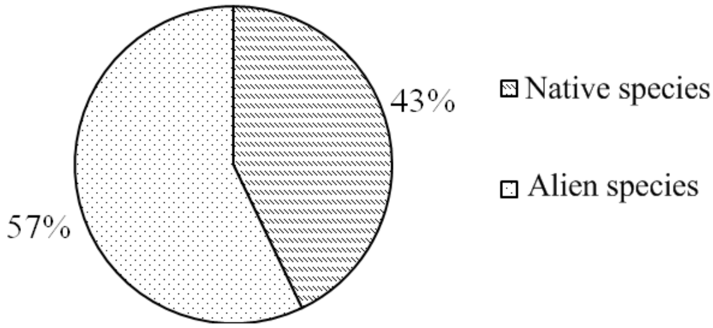

Figure 2. Percentage of native and alien species of ichthyofauna of the ZNPP cooling pond, 2017.

Capture in large-mesh nets (with a mesh size over a=70 mm) by 69.1–72.0% consisted of carp, Prussian carp, tilapia, silver carp. Thus, in the research period, the species with an important biomeliorative value dominated in ichthyofauna. Representatives of the ichthyofauna were phytoplanktophagus, zooplanktophagus, phytophagous, benthophagus and predator species (Fig. 3). The largest percentage (by species composition – 66.2%) fell on the phytophagous species, which were primarily represented by the tilapia, and its biomass was 22.6%. The species – planktophagus (white carp) was 8.8% by number and 68% by biomass.

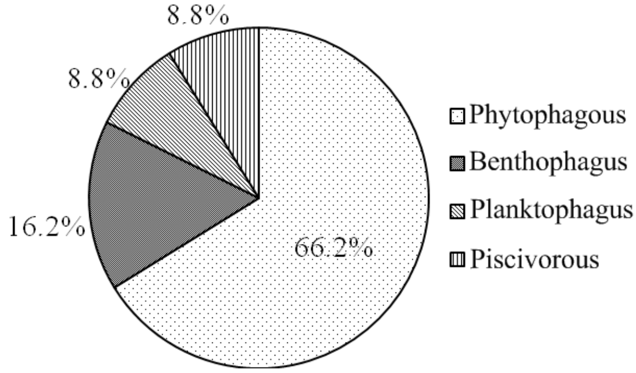

Figure 3. Percentage of the trophic groups of fish of the ZNPP cooling pond according to the control catches, October 2017.

For the biological melioration, ZNPP cooling pond was stocked by: channel catfish, brown bullhead, tilapia, grass carp, silver carp, carp. Stocking with the silver carp was carried out to control the "blooming" of water. In total, for the period of 2007–2016, 1.5 million individuals were stocked (Table 2).

Table 2. The amount of fish stocking in the cooling pond of the ZNPP for the last 10 years, ths. ind.

Fish species and their age	**Years**									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Silver carp (0+)	320.0	95.0	20.0	50.0	122.0	61.0	52.0	73.0	215.1	251.1
Silver carp (1+)	0	11.0	24.0	11.8	16.10	11.8	15.0	8.45	5.7	0
Silver carp (2+)	0	0	0	0.9	0.39	0.9	0	0	0	0
Silver carp (1)	129.3	0	0	0	0	7.0	12.0	0	0	0
Silver carp (2)	0	0	0	0	0	2.0	0.48	0.05	0	0
Total phytoplanktophagus:	449.3	106.0	44.0	62.7	138.49	82.7	79.48	81.5	220.8	251.1
Grass carp (0+)	8.0	17.0	3.5	7.0	15.0	14.0	4.0	8.0	36.7	55.2
Grass carp (1+)	0	0	2.0	0.82	2.2	2.15	0	0.75	0	0
Grass carp (1)	0	0	0	0	0	2.5	0	0.8	0	0
Grass carp (3)	0	0	0	0	0	0	0	0.05	0	0
Total phytophagous:	8.0	17.0	5.5	7.82	17.2	18.65	4.0	9.6	36.7	55.2
Carp (0+)	210.0	210.0	0	22,0	23,0	51,0	0	0	0	0
Carp (1+)	0	0.4	6.0	8.8	1.81	2,0	0	0	0	0
Carp (2+)	0	0.2	2.0	0.38	0	0	0	0	0	0
Carp (1)	0	21.0	0	0	0	4.5	8.5	0	0	0
Total benthophagus:	210.0	231.6	8.0	31.18	24.81	57.5	8.5	0	0	0
Total:	667.3	354.6	57.5	101.7	180.5	158.85	91.98	91.1	257.5	306.3

Note: 0+ – one-summer-old fish, 1+ – two-summer-old fish, 2+ – three-summer-old fish, 1 – one year old, 2 – two years old, 3 – three years old.

In addition, during this period, cooling pond was stocked with grass carp (179.7 thousand individuals) and the carp (571.6 thousand individuals). Studies have shown that active regulation of the number of fish-ameliorators is required to achieve maximum effect. Adjustment of the number of fish must be in accordance with the requirements of annual stocking and periodic reclamation capture of water bioresources.

Analysis of ameliorative fisheries. Reclamation capture of fish during 2007–2016 was based on the following species: silver carp, tilapia and channel catfish (Table 3).

Table 3. Amounts of reclamation capture of water bioresources during the last 10 years

Fish species	Years									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Silver carp, kg	1915	1851	2346	2830	2600	2730	2805	770	733	1565
Channel catfish, kg	446	315	367	250	340	0	601	641	298	372
Tilapia, kg	228	154	523	706	646	1063	1143	1078	573	560
Total:	2589	2320	3236	3786	3586	3793	4549	2489	1604	2497

Ameliorative capture of silver carp is based on individuals of 7–9 kg of mass. The analysis of the ameliorative capture of silver carp over the past 10 years shows a significant decrease in its catch in 2014–2016, which is in the range of 770–1565 kg, which is significantly below the average annual figure of 2014 kg (Fig. 4).

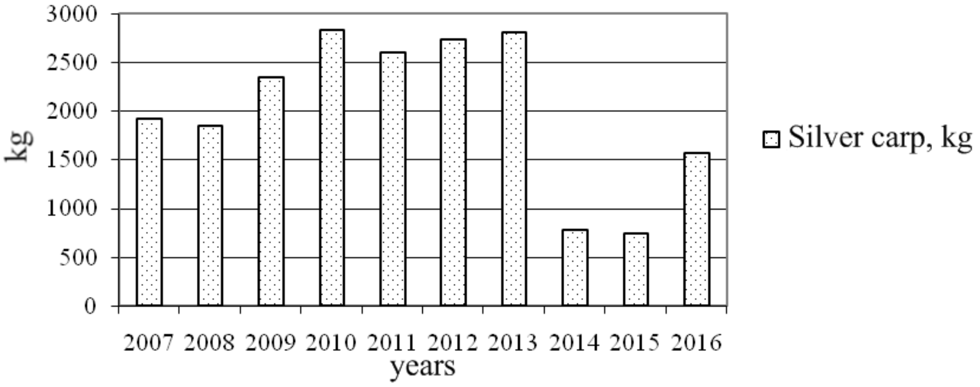

Figure 4. Dynamics of ameliorative capture of silver carp, 2007–2016.

Reduction of silver carp catches in 2014 and 2015 is also explained by the minimum amount of number of this species in 2009 and 2010, as peaks and declines in stocking and catch curves are correlated with a 4-year increment. At the age of 4 years that silver carp reaches an industrial size and a mass of 2.4–2.6 kg. It should be noted that the capture of elderly individuals of the silver carp is one of the main conditions for the successful utilization of organic matter, created by phytoplankton. If elderly individuals of the silver carp are not removed, they will perish and release accumulated biogenic elements again into the reservoir, which in turn will promote the development of algae.

Tilapia acts as a consumer of filamentous algae biomass and prevents them from massive cultivation on hydraulic structures. In the conditions of the cooling pond of ZNPP, it acclimated and formed a self-replicating population and its specimens multiply throughout the year in warm water of the reservoir. The average annual long-term rate of tilapia catches in the cooling pond cooling pond of ZNPP is 667 kg/year. The lowest rates were also observed in 2015 and 2016 and reached 560–570 kg/year (Fig. 5).

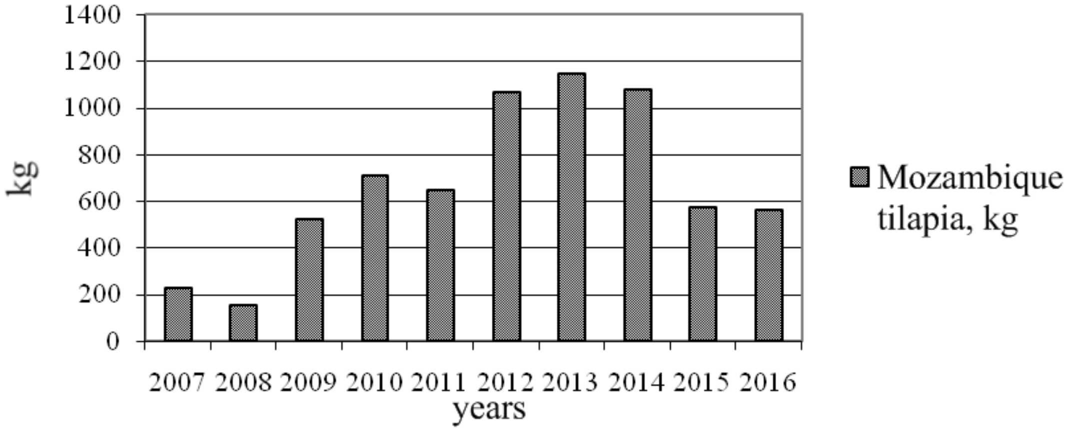

Figure 5. Dynamics of ameliorative capture of tilapia.

Since tilapia grows fast in warm water of the ZNPP cooling pond, it is recommended to carry out its ameliorative capture for reaching the mass of the individual higher than 300–350 g. Basing on the diet of the tilapia, it can be regarded as an effective biomeliorator, but it is a competitor to the grass carp. Biomelioration of a cooling pond by fish with a certain food orientation allows selective suppression of populations of undesirable species of hydrobionts.
Native fish and introduced fish can be used for this purpose. It is necessary to take into account the features of the nutritional needs of fish. The meaning of biological melioration is not only the removal of excess bioproduction of algae, higher plants or shellfish by fish-meliorators, but also to exclude fish from the population, which effectiveness as biomeliorators begins to decrease. Basing on the actual data of linear and weight growth of the silver carps, we calculated the minimum annual natural mortality rate F_m. Using the obtained values of F_m, we can determine the dependence of "length-mortality", which is following (Protasov et al., 2011):

$$F_m = d_0 + d_1 + d_2 \times L^2 \quad (1)$$

where: d_0, d_1, d_2 are coefficients of the parabolic equation. On the basis of the "age–age" empirical dependence from the equation, we obtain the value of F_m for each age group (Protasov et al., 2011). The results are shown in Table. 4

Table 4. The theoretical annual mortality of the silver carps of the ZNPP cooling pond by age groups

Age groups	0+	1	2	3	4	5	6	7	8	9
F_m	0.60	0.37	0.27	0.23	0.22	0.25	0.25	0.33	0.41	0.49
Survival, S	0.40	0.,63	0.73	0.77	0.78	0.75	0.75	0.67	0.59	0.51

Note: F_m **–** natural mortality coefficient, S – survival.

The high rates of natural mortality silver carp fingerlings are caused by the negative influence of fish-eating birds, which significantly consume the youth of silver carp during the winter period. Also, winter conditions are influenced by the weight indexes of the adult silver carp, which are quite low for this species in the conditions of the ZNPP cooling pond and reach 12–20 g, at the norms of 25–30 g. Thus, the output from winter ponds is only 40%, at normative output of 70%.
The maximum ichthyomass of silver carp consists of five-year-old individuals, in the maximum consumption of feed resources will be observed in four or six years-olds. In the future, the ichthyomass of this generation will be gradually reduced, due to natural mortality, that is, the accumulated organic matter will return to the reservoir. Accordingly, these age groups of silver carp should be first captured.
The analysis of theoretical and actual coefficients of natural mortality also shows the necessity of stocking herbivorous fish. On the basis of the data on the stocking and the estimated number of the corresponding generation, after several years of stay in the reservoir, we can determine the average coefficients of total mortality (which, due to the absence of fishing, will correspond to indicators of natural mortality). Calculations were carried out according to the Baranov equation (Protasov et al., 2011):

$$N_t = N_o \times e^{zt}, \quad (2)$$

where: N_t – is number of generation in this year, N_o – is the number of stocking material that formed this generation; Z – is instantaneous total mortality; t – is the number of years since the moment of stocking (Protasov et al., 2011).

Theoretically expected natural mortality of the four-six-years old silver carps should be 0.23–0.25, whereas in the real population it is 0.31–0.42, it means that in the reservoir, there is an increased elimination of these species of fish. One of the reasons for this may be overpopulation, the growth of intra specific competition, therefore, when reducing the ameliorative effect as a result of reduction ichthyomass of generation, it is necessary to regulate the number of ineffective age groups.
Potential consumer of benthos is carp. According to the control catches in 2017, the limit age of the carp was 8 years, that is, the age range was quite wide, and was provided with the indicators of 2008–2009, which were the highest in the last 10 years. In large-mesh grids (with a step a=75 mm and above) individuals aged 5 to 7 years old (43.2%) were mostly found with a length of 42–60 cm, the remainder of generations of 2010–2012. In 2017, the Fulton fattening coefficients ranged from 1.88 to 2.48 (averaging 2.13), which also indicates quite satisfactory conditions for feeding this species.
Characteristics of fish feeding. Studies on fish nutrition have shown that algae and detritus dominated in the qualitative composition of the fish food bolus. In the study of nutrition of carp with the length of 36–44 cm and a weight of 0.9–1.2 kg, the indices of filling of the gastrointestinal tract (GIT) amounted to 42.1–81.2 $^0/_{000}$. The composition of the food bolus of the carp was represented by detritus, soft zoobenthos and crushed shells of zebra mussel.
Studying the nutrition of herbivorous fish was carried out on two species of fish (silver carp and tilapia). In the silver carp with a length of 85–102 cm and a weight of 11.3–12.8 kg, the indices of filling of the gastrointestinal tract were 142.1–281.2 $^0/_{000}$. The composition of the diet was represented by blue-green algae, green algae and diatoms. In the tilapia of 19–41 cm in length and 0.1–1.1 kg in weight, the indices of gastrointestinal tract filling were 191.2–254.4 $^0/_{000}$. A bleak, which food spectrum is 85% coincides with the food spectrum of the silver carp, acts as its food competitor. In the food bolus of tilapia there were: filamentous algae (*Cladophora* and *Ulotrix*) – 85%; pondweed – 10%; detritus, scales of small fish, sand, seeds – 5%.

A food bolus of Prussian carp of 29–40 cm in length and 270–650 g in weight was presented by benthic and zooplanktonic organisms, mainly representatives of the genus Cyclops – 12%, *Bosmina sp.* – 6%, larvae of *Shironomidae* – 5%, macrophytes – 40%, detritus – 30%, sand 4%. The index of filling of the gastrointestinal tract in this case reached 78–80 $^0/_{000}$.
Feeding of predatory species of fish was researched on the example of zander (length of 40–50 cm, weight of 600–750 g) and channel catfish (length of 30–50 cm, weight of 150–1200 g). The spectrum of nutrition of experimental species was based exclusively on fish – 100% (youth of tilapia, Prussian carp, stone moroko, bleack). Gastrointestinal filling index was 25.1–72.2 $^0/_{000}$. Benthic organisms such as crustacean *Amphipoda*, *Insecta* insect larvae and *Cironomidae* larvae were found in the spectrum of pumpkinseed nutrition. Up to 50% of the GIT consisted of detritus and filamentous algae.
Recommended practices regarding stocking the cooling pond of the Zaporizhia NPP with ameliorative fish. The focus area of the formation of the fish fauna of the ZNPP cooling pond is the ameliorative stocking with certain species of fish. Stocking with a silver carp will control the massive growth of phytoplankton and decrease suspended organic matter in water. The black carp helps to control the population of mollusks of the Dreissena genus (*Dreissena bugensis, Dr. polymorpha*) and Thiaridae genus (*Melania tuberculata*, *Tarebia granifer*). The grass carp helps to reduce the overgrowth of the reservoir and tilapia combats the biological overgrowth on the plates of take-out channels and intake channels (reducing the number of green algae of the *Cladophora* and *Ulotrix* genus). Carp is used for the accumulation of organic matter, which is created by the biomass of benthos organisms. Ichthyomelioration is implemented by stocking with predators, such as channel catfish. Taking into account indicators of the development of the natural forage base of the cooling pond, the following volumes of stocking with biomeliorative fish are recommended (Table 5):

Table 5. Recommended amounts of ZNPP stocking for 2018–2022

Species, age of fish	Sample, g	Amount, ths. ind.				
		2018	2019	2020	2021	2022
Carp, 1+	100–130	9.3	10.23	11.25	12.38	13.62
Silver carp, 1+	100–130	62.7	68.97	75.87	83.45	91.80
Bighead, 1+	100–130	38.0	41.80	45.98	50.58	55.64
Grass carp, 1+	100–130	14.8	16.28	17.91	19.70	21.67
Black carp, 1+	100–130	37.5	37.5	30.0	24.0	24.0
Carp, 0 +	25–30	14.9	16.4	18.0	19.8	21.8
Silver carp, 0 +	25–30	180.0	198 , 0	217.8	239.6	263.6
Bighead, 0 +	25–30	60.8	66.88	73,568	80,928	89,024
Grass carp, 0 +	30–50	23.68	26.0	28.7	31.5	34.7
Black carp, 0 +	30–50	60.0	66.0	72.6	79.9	87.8

Note: 0+ – one-summer-old fish, 1+ – two-summer-old fish

Taking into account the high percentage of natural mortality in these years and consumption by fish eating birds, it is recommended to stock the pond with two-summer-old fish.
Under conditions of stocking ZNPP, it is necessary to take measures to minimize the negative impact of fish eating birds, as well as prevent the release (escape) of young fish from the cooling pond to the Kakhovka Reservoir. In this regard, it is necessary to upgrade the fish protection facilities and to comply with the requirements for their exploitation. The effectiveness of fish-protective structures must be at least 70% for fish of industrial species larger than 12 mm. Diameters of holes in the screens of the enclosing fish-protective building should be as in the table 6.

Table 6. Technical characteristics of fish-protective screens for fish protection structures of the ZNPP

Fish body length, mm	12	15	20	30	40	50	60	70	90
Diameter of holes in screens, mm	1.5	2	3	4	6	7	8	9	10

The ameliorative capture is one of the measures for the removal of excess organic matter from a cooling pond. Due to the accumulation of excessive ichthyomass it is necessary to capture older age groups annually using stake nets with a mesh size a = 70–120 mm and a stake seine with a mesh size a = 100 mm in the recommended volumes (Table 7):

Table 7. Recommended volumes of annual ameliorative capture of fish

Species of fish	Number of individuals, ind.	Average age, years	Average weight, kg	Total, kg
Silver carp	300–350	8–12	9.5–14	2850–4900
Carp	200–300	8–12	7.5–12	1500–3600
Grass carp	100–150	5–10	5.5–10	550–1500
Tilapia	500–1000	5–8	0.3–1.1	150–1100
Catfish	50–100	5–9	3–7	150–700

Thus, observance of the proposed recommendations will allow balancing the structure of hydrobiocenoses of the ZNPP cooling pond and improving the effectiveness of biological ameliorative measures in order to improve the quality of the water environment of the technical reservoir.

Conclusions

During the period of the existence of the ZNPP cooling pond, 18 species of fish were registered in the ichthyofauna, and only 14 species have adapted to the specific conditions of the reservoir. The composition of the ichthyofauna of the ZNPP cooling pond includes 43% of native species and 57% of alien species of fish. The process of forming the ichthyofauna currently continues, as there is a process of self-resettlement of new species, such as stone moroko and pumpkinseed. There is also a deliberate introduction of some other species for the purpose of biological melioration (tilapia, grass carp, silver carp, channel catfish, brown bullhead). Since the structure of the ichthyofauna of the investigated reservoir is controlled artificially by means of ameliorative stocking and capture species that have an important biomeliorative value in dominate in the ichthyofauna.

References

Arsan, O. M., Davydov, O. A., Dyachenko, T. A. et al. (2006). Methods of hydroecological investigation of surface waters, Kiev. (in Ukrainian).

Bernotas, E. (2002). Changes in fish biomass under impact of a thermal effluent and eutrophication in lake drūkšiai. *Acta Zoologica Lituanica*, 12(3), 242–253.

Chugunova, I. I. (1959). Guide for studying age and growth of fish (Methodical manual on ichthyology), Moscow. (in Russian).

Cravens, J. B. (1982). Thermal effects. Journal (Water Pollution Control Federation), 54(6), 812–829.

Ford, E. J. (1933). An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933. *Journal of the Marine Biological Association of the United Kingdom*, 19(1), 305–384.

Fowler, M. C., & Robson, T. O. (1978). The effects of the food preferences and stocking rates of grass carp (Ctenopharyngodon idella Val.) on mixed plant communities. Aquatic Botany, 5, 261–276.

Froese R., & Pauly D. (eds.) FishBase. *World Wide Web electronic publication*. Mode of access: WWW. URL: http://www.fishbase.org, version (02/2018).

He, C., Zhou, W., Wang, H., Shi, S. Q. & Yao, H. (2013). Mechanics of pharyngeal teeth of black carp (Mylopharyngodon piceus) crushing mollusk shells. *Advanced engineering materials*, 15(8), 684–690.

Ip, K. K., Liang, Y., Lin, L., Wu, H., Xue, J. & Qiu, J. W. (2014). Biological control of invasive apple snails by two species of carp: Effects on non-target species matter. *Biological control*, 71, 16–22.

Kudersky, L.A. (1984). Types of the structure of populations of commercial fish and the strategy of using their reserves. Issues of the development of fisheries in the basin of Lake Baikal. Collection of scientific papers GosNIORH, 211, 109–117. (in Russian).

Lieberman, D. M. (1996). Use of silver carp (Hypophthalmichthys molotrix) and bighead carp (Aristichthys nobilis) for algae control in a small pond: changes in water quality. *Journal of Freshwater Ecology*, 11(4), 391–397.

Marenkov, O. (2018a). Laboratory Manual on General and Special Ichthyology. *World News of Natural Sciences*, 18(1), 1–51.

Marenkov, O. N. (2018b). Abundance and biomass estimation of this summer individuals of alien fish species in Zaporizke reservoir. *Ukrainian Journal of Ecology*, 8(1), 92–96.

Marenkov, O. N. (2018c). Ecological and biological aspects of zander and Volga zander reproduction under conditions of the Zaporizhzhia reservoir (Ukraine). *Ukrainian Journal of Ecology*, 8(1), 441–450.

Marenkov, O., Fedonenko, O. (2016). Ways of optimization of breeding conditions of fish by using artificial spawning grounds. *World Scientific News*, 49(1), 4–6.

Ozinkovska, S. P., Yerko, V. M., Kokhanova, G. D. et al. (1998). Technique of collecting and processing of ichthyological and hydrobiological materials with the aim to determine the limits of commercial fishing regarding large reservoirs and limans of Ukraine, Kiev. (in Ukrainian).

Protasov, A. A., Sylayeva, A. A., Yarmoshenko, L. P., Novoselova, T. N., Primak, A. B. & Savitskiy, A. I. (2013). Hydrobiological studies on the techno-ecosystem of the Zaporozhye nuclear power station. Hydrobiological Journal, 49(4), 75–92.

Protasov, A.A., Semenchenko, V.P., Sylaieva, A.A., Timchenko, V.M, Buzevich, I.U., Guleykova, L.V., Dyachenko, T.N., Morozova, A.A., Yurishinets, V.I.,Yarmoshenko, L.P., Morozovskaya, I.A., Primak, A.B., Masko, A.N. & Golod, A.V. (2011). Techno-ecosystem

of the nuclear power plant. Hydrobiology, abiotc factors, ecological estmatons, Kyiv, Insttute of hydrobiology NAS of Ukraine (in Russian).
Rahman, M. M., Yakupitiyage, A. & Ranamukhaarachchi, S. L. (2004). Agricultural use of fishpond sediment for environmental amelioration. *Science & Technology Asia*, 9(4), 1–10.
Smith, D. W. (1985). Biological control of excessive phytoplankton growth and the enhancement of aquacultural production. *Canadian Journal of Fisheries and Aquatic Sciences*, 42(12), 1940–1945.
Welker, T. L., Lim, C., Yildirim-Aksoy, M. & Klesius, P. H. (2011). Effects of dietary supplementation of a purified nucleotide mixture on immune function and disease and stress resistance in channel catfish, Ictalurus punctatus. *Aquaculture Research*, 42(12), 1878–1889.
Wurts, W. A. (2000). Sustainable aquaculture in the twenty-first century. *Reviews in Fisheries Science*, 8(2), 141–150.
Zhang, X., Xie, P., Hao, L., Guo, N., Gong, Y., Hu, X. & Liang, G. (2006). Effects of the phytoplanktivorous silver carp (Hypophthalmichthys molitrixon) on plankton and the hepatotoxic microcystins in an enclosure experiment in a eutrophic lake, Lake Shichahai in Beijing. Aquaculture, 257(1–4), 173–186.
Zykov, L.A. (1986). The method of estimating the coefficients of natural mortality, differentiated by age of fish. Collection of scientific papers GosNIORH, 243, 14–12. (in Russian).

Citation:
Marenkov, O.M. (2018). Ichthyofauna of the Zaporizhia Nuclear Power Plant cooling pond (Enerhodar, Ukraine) and its biomeliorative significance. Ukrainian Journal of Ecology, 8(2), 140–148.