Трансформация экосистем
Ecosystem Transformation

ISSN 2619-094X Print
ISSN 2619-0931 Online
www.ecosysttrans.com

Article

Revisiting the morphofunctional state of the organs of wels catfish (*Silurus glanis* L.)

Nadezhda Yu. Terpugova[1*], Maria P. Grushko[2], Nadezhda N. Fedorova[2], Viktoria V. Volodina[3]

[1] *Federal Research Institute of Fisheries and Oceanography (VNIRO), Okruzhnoy proezd 19, Moscow, 105187 Russia*

[2] *Astrakhan State Technical University, ul. Tatishcheva 16, Astrakhan, 414056 Russia*

[3] *St. Petersburg Marine Fisheries College, Kaliningrad State Technical University, Bolshaya alleya 22, St. Petersburg, 197022 Russia*

**n.terpugova@bk.ru*

Received: 21.03.2022
Revised: 12.04.2022
Accepted: 13.05.2022
Published online: 19.08.2022

DOI: 10.23859/estr-220321
UDC 574.24

Translated by D.M. Martynova

Annotation. The state of the organs of wels catfish (*Silurus glanis*) caught in the Volga-Caspian fishery region have been analyzed. Destructive processes in the gill apparatus manifested in the changes of the epithelium of filaments and lamellae. Signs of hemosiderosis were found in the spleen. Necrotic areas and signs of fatty degeneration were found in the liver. Pathologies were observed in the stomach and intestines, manifested by edema and desquamation of the epithelium. All examined organs were characterized by signs of impaired blood microcirculation. The pathomorphological studies indicated the response of the fish organism to the environmental conditions. The revealed pathological signs served as red flags of nonspecific adaptation taking place at the cellular and tissue levels. Such responses allowed the fish to adapt and survive in the prevailing environmental conditions.

Keywords: inflammatory process, hyperplasia, hypertrophy, histological structure, histopathology, Volga River Delta, gill apparatus, parenchymal organs

To cite this article. Terpugova, N.Yu. et al., 2022. Revisiting the morphofunctional state of the organs of wels catfish (*Silurus glanis* L.). *Ecosystem Transformation* **5** (3), 21–28. https://doi.org/10.23859/estr-220321

Introduction

Nowadays, conservation of biological diversity is one of the main issues worldwide. However, sustainable functioning of populations and communities is impossible without healthy breeders that predetermine the quality of other levels of biological organization (Lukin and Lukina, 2015). It is known that hydrobionts are capable of accumulating various substances, including pollutants that enter water bodies as a result of discharges and leaks, harming much the habitats. For example, anthropogenic intoxication of fish contributes to the development of various morphofunctional disorders (Lukin and Lukina, 2019).

Wels catfish (*Silurus glanis* L.) is one of the main fishery objects in the Volga-Caspian region; it accounts for up to 20 % of the total catches (Kolosyuk and Nikiforov, 2018). However, a decrease in fish stocks has recently been noted, true for wels catfish as well (Barabanov and Izherskaya, 2020). It is obvious that a whole complex of abiotic and biotic factors may affect the population size; anthropogenic impact is involved in this process in many cases. Morphological and functional changes in the fish tissues and organs may serve as the criteria for assessing the well-being of the environment. In this regard, histopathological processes in wels catfish, characterized by a sedentary lifestyle, undoubtedly arouse scientific interest. Our study aims to assess the morphofunctional state of the internal organs of wels catfish.

Materials and methods

The biological material was collected in the western part of the Volga River Delta (Main Bank) in spring 2019–2020. A total of 20 individuals aged 2–4 years were caught, their average weight was 2.407 ± 0.13 kg, body length, 71.4 ± 0.9 cm. The material was processed by standard methods of histology: organ tissues of the common catfish (gills, liver, spleen, stomach, intestines, and gonads) were fixed in a 10 % formaldehyde solution and embedded in paraffin; 5-μm-thick sections were stained with hematoxylin-eosin (Volkova and Eletsky, 1989). Slides were analyzed under a light microscope "Micromed-2" (Russia). In total, 120 histological preparations and over 400 slides were analyzed. Microphotographs were taken by a mounted Sony DSC-W7 photo camera.

Results

According to histopathological analysis of the gill apparatus of wels catfish, 1/3 of the filaments were covered with respiratory lamellae, the rest, with epithelial layers formed as a result of hyperplasia of the stratified non-keratinized epithelium (Fig. 1). Hyperplasia is one of the typical compensatory-adaptive reactions of the body, i.e., the changes aimed at replacing the functions of a damaged organ (Lukin and Lukina, 2015).

Numerous mucous cells of the gill apparatus of the catfish were uncharacteristically enlarged and filled with secretion in 55% of the examined individuals. The parts of the filaments, which were characterized by the presence of lamellae, also had pathological abnormalities. Abnormal morphology of the gill apparatus included curvature of the lamellae, their thickening at the ends (due to the growth of the respiratory epithelium), and the presence of areas of desquamation of the respiratory epithelium of the lamellae. Blood capillaries were dilated and filled with blood cells. Malfunctioning of blood circulation caused stagnation in the circulatory system of the organ and inhibited gas exchange (Rosety-Rodríguez et al., 2002).

Malfunctioning of the hematopoietic system of the examined catfish was also evidenced by the histological analysis of the spleen. From the outside, it was covered with a capsule of dense connective tissue, rather powerful trabeculae departed from it. A clear division of the spleen into white and red pulp was noted (Fig. 2). The large vessels of the organ were overflowing with blood cells; areas of the red pulp were characterized by a large number of mature erythrocytes, decaying erythrocytes, macrophages, and areas of accumulation of hemosiderin granules. The white pulp was represented by white and red blood cells at different stages of differentiation. In 37 % of the examined individuals, numerous macrophages were localized around the sinusoidal vessels of the organ, their cytoplasm was filled with hemosiderin granules, indicating intensive erythrocyte destruction and protein metabolism disorders. Hemosiderosis of the spleen is observed during the diseases of the hematopoietic system (anemia) and intoxication with hemolytic poisons (Yarygin and Serov, 1977).

The liver, which performs the function of detoxification and accumulation of pollutants penetrating the body, is one of the target organs for pollutants and xenobiotics. Therefore, the histological structure of the liver is most indicative when examining the fish affected by anthropogenic load. In most of the studied individuals, the entire liver structure was not disturbed, and the beam structure was preserved. Hepatocytes were characterized by the presence of large nuclei with a clear contour. At the same time, signs of impaired blood circulation of the organ were obvious. Vessel lumens were unevenly dilated, stasis and aggregation of blood cells were observed (Fig. 3).

Necrotic areas surrounded by lymphoid elements (infiltration) were registered in the stroma of the liver in 10 % of the studied fish. Predominantly, these areas were localized along the vessels. It should be noted that liver necrosis occurs with various lesions, often chronic. The presence of necrosis always indicates a severe, usually progressive course of the pathological process (Kryuchkov et al., 2004).

Fatty degeneration was detected in the liver of 15 % of the examined fish, affecting about 5 % of hepatocytes on the field of view. At the same time, the cytoplasm of the liver cells was completely filled

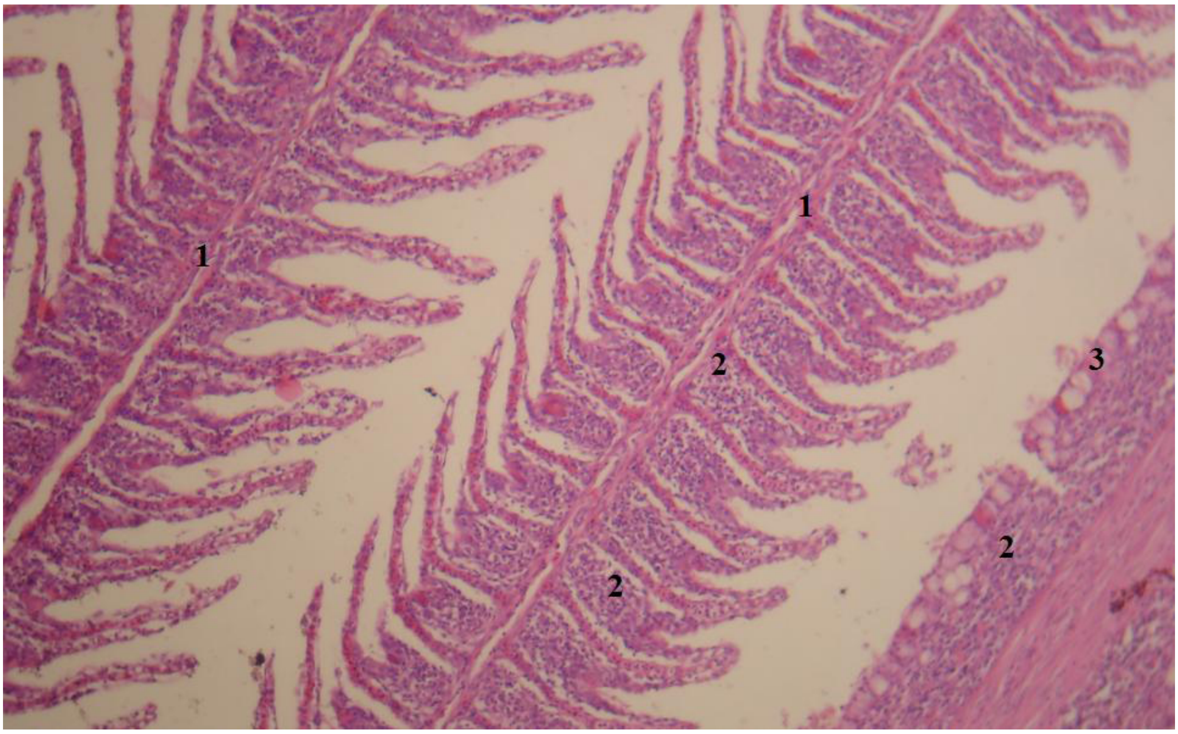

Fig. 1. A fragment of the gills of wels catfish *Silurus glanis*: 1 – filaments with deformed lamellae; 2 – proliferation of stratified non-keratinized epithelium; 3 – hypertrophy of mucous cells. Hematoxylin-eosin. Magnification ×100.

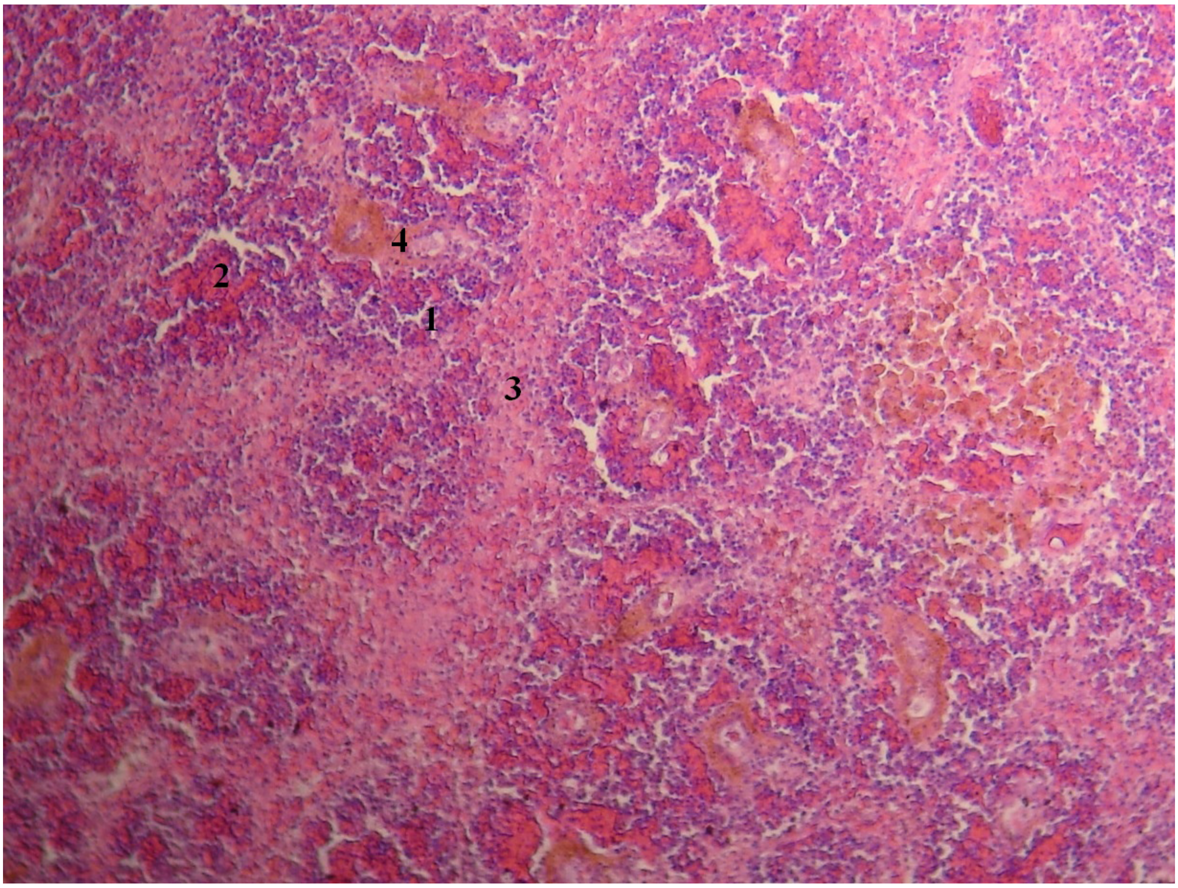

Fig. 2. A fragment of the spleen of wels catfish *Silurus glanis*: 1 – areas of white pulp; 2 – areas of red pulp; 3 – trabeculae; 4 – accumulation of hemosiderin. Hematoxylin-eosin. Magnification ×150.

with large fat drops, and the nucleus was shifted to the periphery of the cell. Fatty cysts replacing 5–6 hepatocytes have also been noted. Diagnosed disorders may reduce metabolic activity of liver, namely, may decrease its antitoxic functions.

When analyzing the organs of the gastrointestinal tract, it was found that the stomach was covered on the outside with a thin connective tissue membrane. A very powerful muscle layer consisting of longitudinal and circular muscle fibers underlaid this membrane. The mucous membrane of the stomach of fish formed the folds represented by a single-layer prismatic epithelium. A large number of tubular branching glands opened at the fold base. The walls of these glands were lined with cuboidal epithelium containing secretory granules in the cytoplasm.

In more than 25 % of the examined individuals, the single-layer prismatic epithelium lining the surface of the stomach was edematous, accompanied by an increase in the intercellular space. At the same time, epithelial cells of the mucous membrane had a well-defined polarity: the oval nucleus was located in the basal section, and the apical part of the cell was light-colored. Desquamation of the epithelium lining the tubular glands was noted (Fig. 4). The vessels of the lamina propria were dilated and filled with blood cells. Areas of tissue infiltration by lymphocytes were also detected here, this indirectly indicated inflammatory processes.

Histological structure of the intestine was characterized by different sizes of the intestinal villi. Approximately half of the studied individuals had swelling of the single-layer prismatic epithelium lining the villi. In the epithelial cells, light goblet cells attracted much attention, they were expanded and filled with a secret; this was characteristic of the lateral surfaces of the intestinal villi even to a greater extent (Fig. 5). The loose connective tissue of the stroma of the villi was distinguished by the presence of dilated and overflowing vessels with blood cells.

It is known that venous plethora develops when the blood outflow malfunctions. At the same time, the veins are dilated and “clogged” with uniform elements. Considering the fact that the state of the digestive organs in hydrobionts primarily depends on the food quality, the violations listed above appear because of negative environmental conditions. Many xenobiotics enter the intestine from the liver through the bile ducts and then return to the liver through the portal system (Park, 1968). Such circulation of toxicants is considered as one of the bases for the accumulation of xenobiotics (Sidorov, 1983). Long-term intake of toxicants in small doses with food and water weakens the protective functions of the body and thus the ability to resist foreign agents (helminths, viruses, bacteria, etc.) (Volodina et al., 2015).

Histological examination of the gonads of wels catfish female evidenced that the bulk of the oocytes were at the stage of trophoplasmic growth; thus, the gonads corresponded to maturity stage IV (Fig. 6). The cell nuclei were irregular in shape and had jagged edges. The oocyte nucleus contained from 12 to 20 nucleoli on the central section. The cytoplasm was filled with yolk granules, fat drops were recorded as well, and cortical granules were noted along the cell periphery. The shell of oocytes consisted of the internal (own) gelatinous membrane and the outer (follicular), characteristic of mature cells.

The reserve oocytes were represented by the cells at the stage of protoplasmic growth. These oocytes were significantly smaller than mature cells, they had rather large light nuclei, containing from 5 to 10 nucleoli located along its periphery. The cytoplasm had a homogeneous structure. The oocytes were covered with a thin membrane.

The testicles of wels catfish are of the cyprinoid (acinous) type, where the seminiferous tubules coil in various planes without a specific orientation (Fig. 7). On the histological sections, individual acini of irregular shape were visible. Primary spermatogonia (large cells) were visible along the periphery of the acini, along the walls of the tubules. The bulk of the acini contained spermatids, however, acini were also recorded, where mature spermatozoa were noted along with spermatids. In other words, uneven development of the testicles (asynchrony) was observed. According to the maturity scale, the gonads of males were at maturity stage IV. The testis was covered from the outside with a connective tissue sheath. In the walls of the acinus, consisting by the follicular epithelium, numerous unevenly dilated blood vessels were recorded, their lumens were filled with blood cells.

Discussion

The revealed histopathological disorders in the organs of wels catfish indicate the presence of an inflammatory process and can be considered as a test reaction to prolonged intoxication. It should be noted that no deviations in behavior were found in all examined fish, as well as no ulcers, tumors, and other damage to the skin. Consequently, the compensatory-protective potential was preserved in the body, providing its adaptive capabilities to negative environmental factors. At the same time, the absence of external manifestations brings to a false idea of the well-being of the population, which can only be refuted with the use of histomorphological methods.

Most of the registered changes in the body of fish are the consequences of exposure to toxic substances in the environment (water and bottom

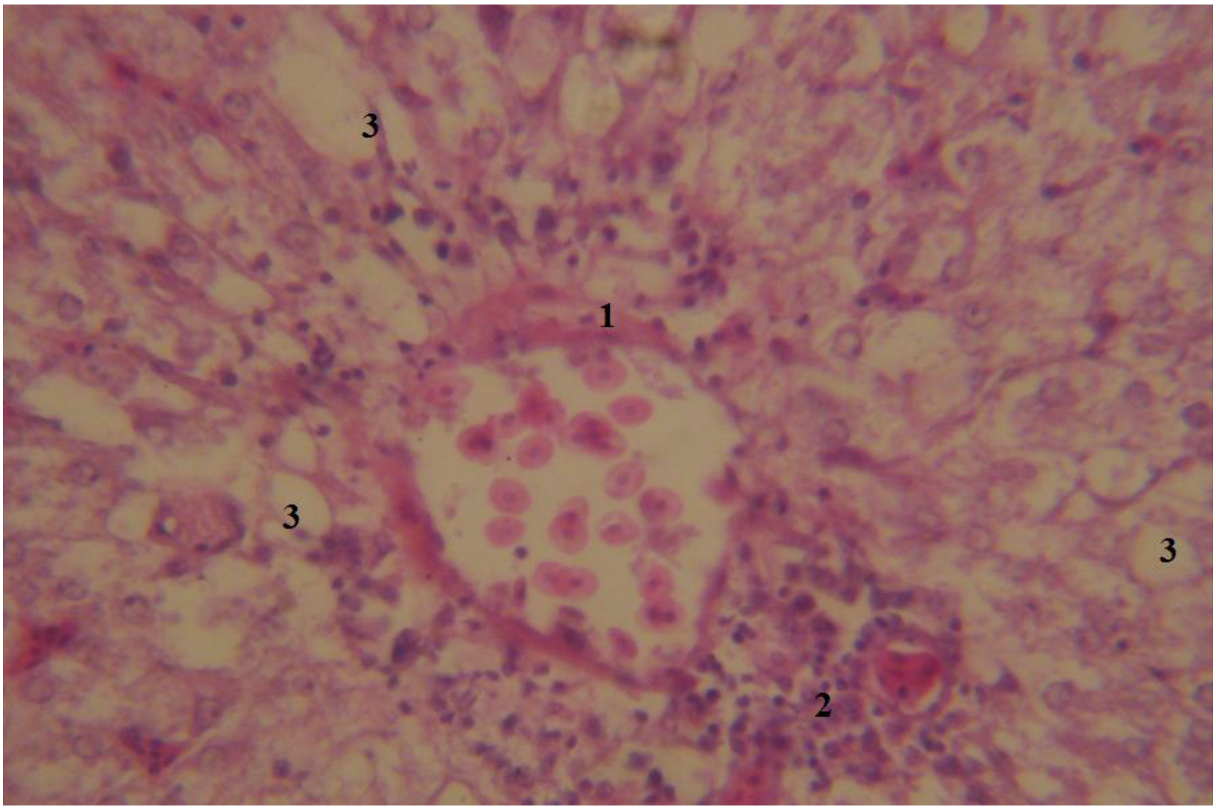

Fig. 3. A fragment of the liver of wels catfish *Silurus glanis*: 1 – vessel with blood cells; 2 – necrotic area, infiltration with lymphocytes; 3 – fatty degeneration of hepatocytes. Hematoxylin-eosin. Magnification ×1200.

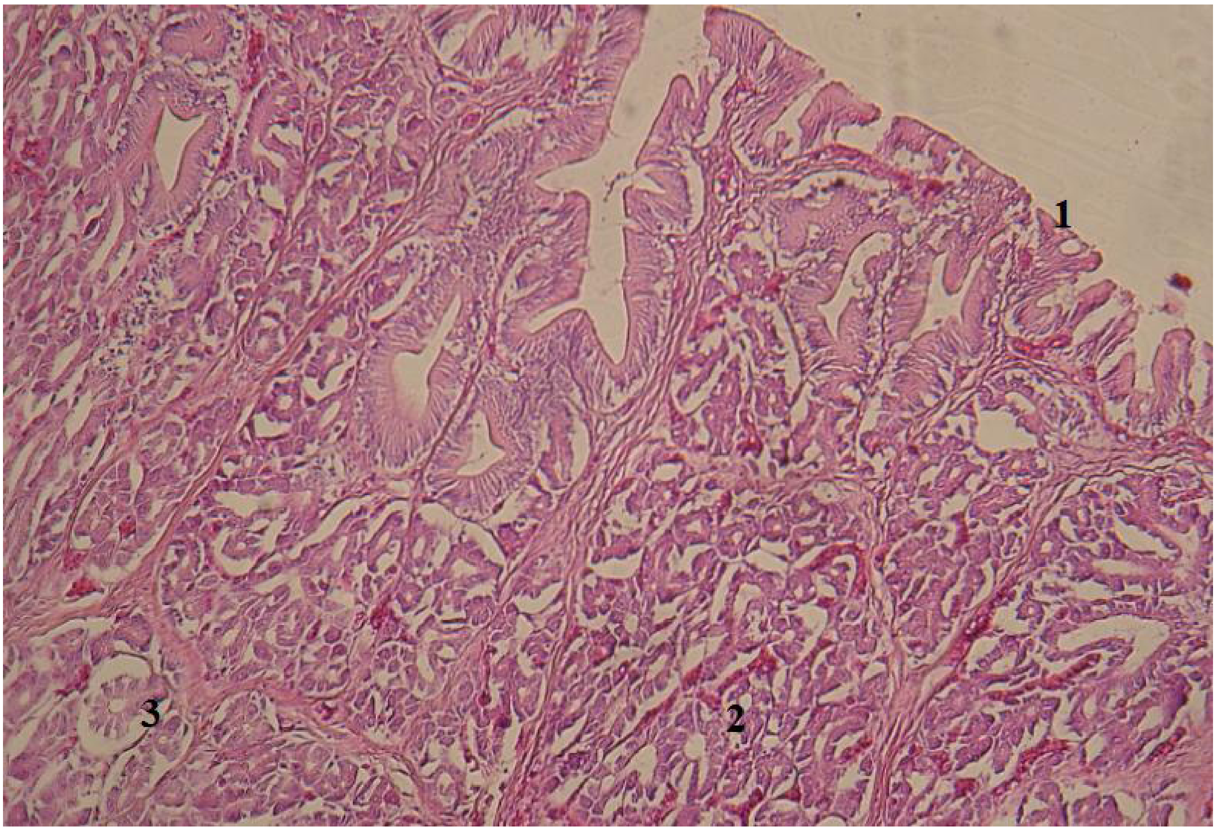

Fig. 4. A fragment of the stomach of wels catfish *Silurus glanis*: 1 – single-layer prismatic epithelium; 2 – gastric glands; 3 – desquamation of the epithelium. Hematoxylin-eosin. Magnification ×100.

Fig. 5. A fragment of the intestine of wels catfish *Silurus glanis*: 1 – serous membrane; 2 – muscular membrane; 3 – swelling of the intestinal mucosa. Hematoxylin-eosin. Magnification ×100.

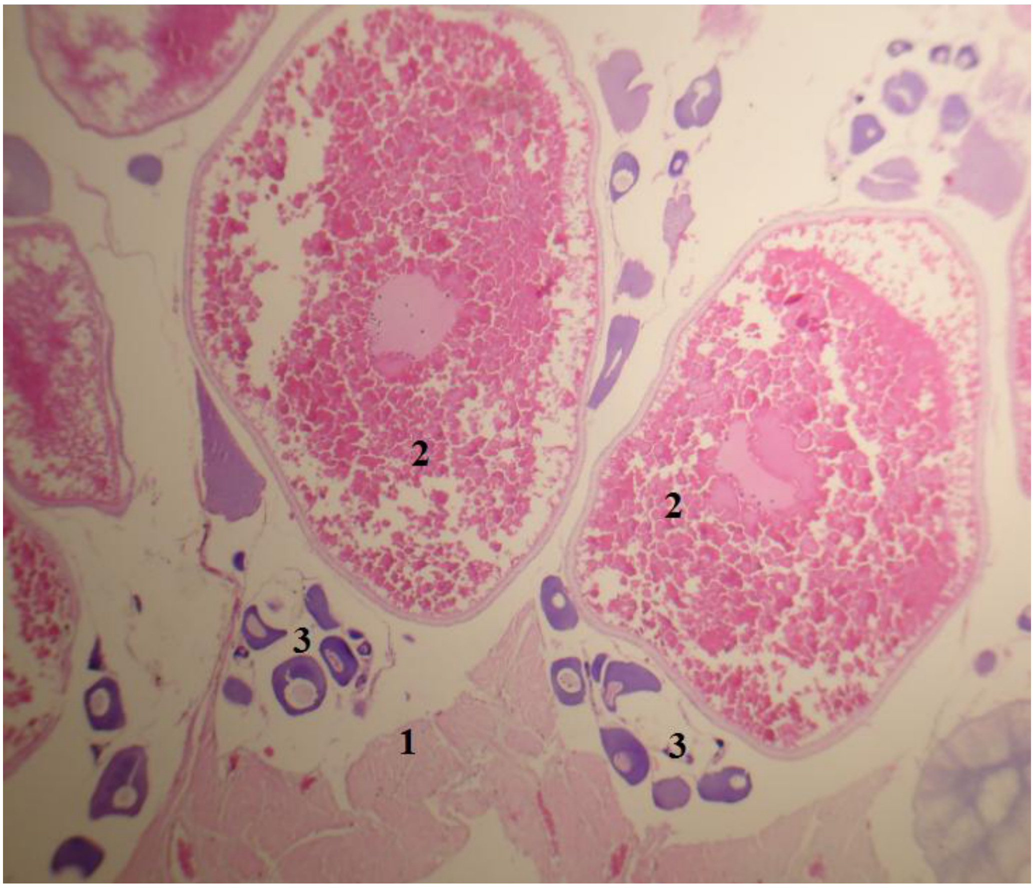

Fig. 6. A fragment of the ovary of a female of wels catfish *Silurus glanis*: 1 – gonad wall; 2 – oocytes, stage IV of trophoplasmic growth; 3 – reserve oocytes. Hematoxylin-eosin. Magnification ×200.

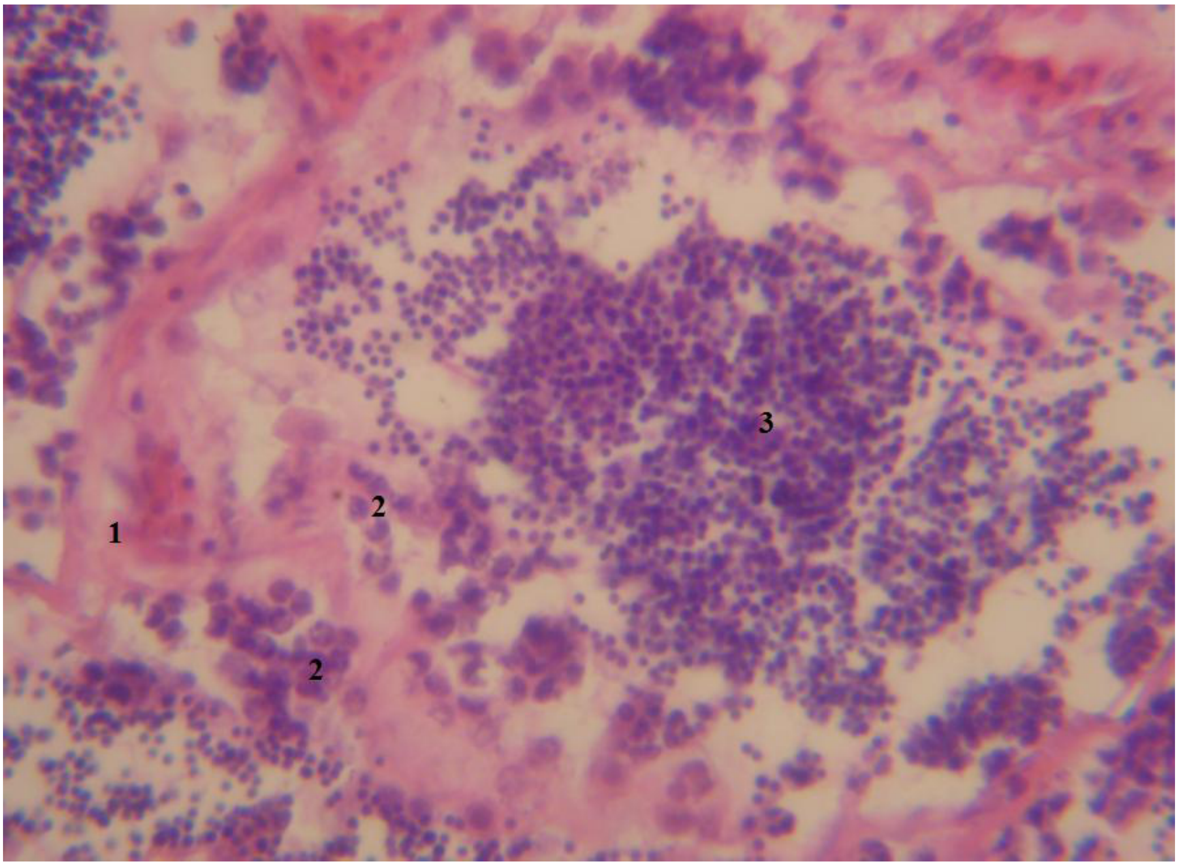

Fig. 7. A fragment of the testis of a male of wels catfish *Silurus glanis*: 1 – acinus wall with blood vessels; 2 – primary spermatogonia; 3 – spermatids. Hematoxylin-eosin. Magnification ×1000.

sediments of the Volga-Caspian canal). Chronic toxicosis, like any chronic disease, may take a long time. The sluggish nature of toxicosis creates the conditions for natural selection by the death of some and the adaptation of other individuals. In addition, under conditions of prolonged exposure to toxic substances, the body may possibly adapt to them. Thus, one of the consequences of anthropogenic impact is fish intoxication, which contributes to the development of morphological and functional disorders that are integrated at higher levels of organization (populations, communities) and are the basis for their subsequent transformations (Lukin and Lukina, 2019).

Conclusions

Catfish are sedentary species, so they may serve as an indicator of the water quality of the Volga River. The fish selected for analysis was part of the commercial population and had no external lesions. The organs of *S. glanis* had several pathologies: destructive processes in the gill apparatus due to degradation of filaments and respiratory lamellae; signs of hemosiderosis in the spleen; necrosis and fatty degeneration in the liver; edema and desquamation of the epithelium in the stomach and intestines. In addition, in all organs, including the gonads, there were the signs of impaired blood microcirculation. In general, progressive changes (hypertrophy, hyperplasia, and inflammation) were observed, manifesting a typical compensatory-adaptive reaction of the damaged organ. In addition, there were typical pathological reactions (regressive changes), their consequences include the restriction of the organ function or the death of the body (impaired blood circulation, necrosis). The revealed pathological manifestations indicate non-specific adaptation taking place at the cellular and tissue levels under the influence of adverse environmental factors. This reaction allows the body to adapt and to survive in chronic intoxication.

ORCID

N.Yu. Terpugova 0000-0003-3403-0075
M.P. Grushko 0000-0001-7529-5382
N.N. Fedorova 0000-0001-9411-6642
V.V. Volodina 0000-0002-2743-1615

References

Barabanov, V.V., Izherskaya, V.A., 2020. Otsenka sostoyaniya presnovodnoj ihtiofauny Volgo-Ahtubinskoj pojmy na modern nom etape (v 2018–2019 gg.) [Assessment of the state of the freshwater ichthyofauna of the Volga-Akhtuba floodplain at the present stage (in 2018–2019)]. *Vestnik Astrakhanskogo gosudarstvennogo tekhnologicheskogo universiteta. Seriya: Rybnoe khozyaystvo [Bulletin of the Astrakhan State Technical University. Series: Fisheries]* **2,** 52–58. (In Russian).

Kolosyuk, G.G., Nikiforov, S.Yu., 2018. Vliyanie factorov sredy na promysel soma v Volgo-Kaspiiskom i Severo-Kaspiiskom rybohozyaj-stvennykh podrajonakh [The influence of environmental factors on the catfish fishery in the Volga-Caspian and North-Caspian fishery sub-areas]. *Vestnik Astrakhanskogo gosudarstvennogo tekhnologicheskogo universiteta. Seriya: Rybnoe khozyaystvo [Bulletin of the Astrakhan State Technical University. Series: Fisheries]* **1,** 49–58. (In Russian).

Kryuchkov, V.N., Abdurakhmanov, G.M., Fedorova, N.N., 2004. Morphologiya organov i tkanei vodnykh zhivotnykh [Morphology of organs and tissues of aquatic animals]. Nauka, Moscow, Russia, 144 p. (In Russian).

Lukin, A.A., Lukina, Yu.N., 2015. Problemy zdorov'ya ryb vo vnutrennikh vodoemakh Rossii [Issues of fish health in the inland waters of Russia]. *Trudy VNIRO [Proceedings of Russian Federal Research Institute of Fisheries and Oceanography]* **157,** 32–44. (In Russian).

Lukin, A.A., Lukina, Yu.N., 2019. Arkticheskii golets kak indicator kachestva gornykh ozer Khibinskogo massiva v usloviyah chronicheskogo zagryazneniya [Arctic char as an indicator of the quality of mountain lakes in the Khibiny mountains under conditions of chronic pollution]. *Trudy VNIRO [Proceedings of Russian Federal Research Institute of Fisheries and Oceanography]* **178,** 104–111. (In Russian).

Park, D.V., 1973. Biokhimiya chuzherodnykh soedineniy [The biochemistry of foreign compounds]. Meditsina, Moscow, USSR, 286 p. (In Russian).

Rosety-Rodríguez M., Ordoez F.J., Rosety M. 2002. Morpho-histochemical changes in the gills of turbot, *Scophhalmus maximus* L., induced by sodium dodecyl sulfate. *Ecotoxicology and Environmental Safety* **51** (3), 223–228.

Sidorov, V.S., 1983. Ekologicheskaya biokhimiya ryb [Ecological biochemistry of fish]. Nauka, Leningrad, USSR, 238 p. (In Russian).

Volkova, O.V., Eletsky, Yu.K., 1989. Osnovy gistologii s gistologicheskoi tekhnikoi [Fundamentals of histology with histological technique]. Meditsina, Moscow, USSR, 234 p. (In Russian).

Volodina, V.V., Grushko, M.P., Fedorova, N.N., 2015. Morfofunktsional'noe sostoyanie organov i tkanei kaspiiskogo tyulenya (*Phoca caspica* Gmelin, 1788) na fone parasiticheskikh invazii [Morphofunctional state of organs and tissues of the Caspian seal (*Phoca caspica* Gmelin, 1788) against the background of parasitic invasions]. Astrakhan State Technological University, Astrakhan, Russia, 144 p. (In Russian).

Yarygin, N.E., Serov, V.V. 1977. Atlas patologicheskoi gistologii [Atlas of pathological histology]. Meditsina, Moscow, USSR, 200 p. (In Russian).