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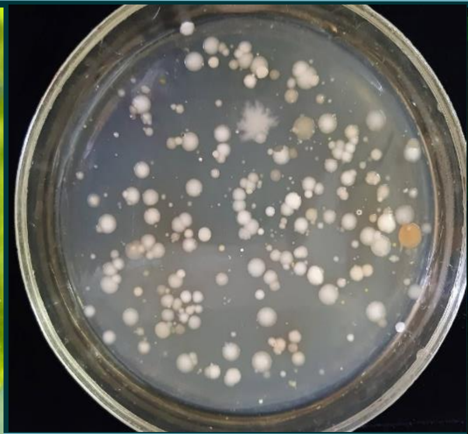
BIOINDICATOR SPECIES AS A TOOL FOR WATER QUALITY DETERMINATION






Contents

1. THE IMPORTANCE OF WATER FOR LIVING ORGANISMS

In terms of free water, the Earth is the most "water-rich" planet in the Solar System. The total volume of the hydrosphere exceeds 1454 million km^3 , of which almost 94% is occupied by the World Ocean, 4.12% by groundwater, 1.64% by glaciers and 0.0001% by river water. The volume of fresh water in the hydrosphere is generally 2% of its total volume, and taking into account the inaccessibility of the part of it that is preserved in glaciers, it is only 0.3% of the hydrosphere volume.

For a large number of living organisms, especially in the early stages of the biosphere's development, water is the environment for the origin and development of all living things. Water in the biosphere is in constant motion, originating in the geological and biological cycles of substances. Water is life, it is the basis for the existence of life on the planet.

Human civilisation cannot exist without water, as people use water not only for drinking but also for sanitation and industrial and domestic needs. Water is used in many technological processes and is an integral part of many industrial and processing facilities.

As for living beings, all metabolic processes in their bodies involve water. The more energetic these processes are, the greater the need for water is. A young growing organism has a higher water content than an adult. In a newborn, the amount of water reaches 75% of body weight.

Every living cell in the human body contains a healing aqueous solution of various nutrients. Water takes an active part in chemical reactions in the body, transports nutrients to each cell, removes toxins, slaggings and excess salts, and helps to lower blood pressure.

Thanks to the properties of water as a solvent, blood and lymph provide an ideal medium for the most complex biochemical processes in the body. The body's ability to maintain a constant body temperature is largely due to the following three physical properties of water:

* water has a high capacity to store heat. Even cold-blooded animals are able to maintain a relatively constant body temperature in the face of short-term fluctuations in ambient temperature due to the physical properties of the fluid contained in their bodies;

* water has a high degree of thermal conductivity. This makes it easy to remove heat from deep parts of the body;

* water is constantly evaporating from the surface of the lungs and skin. This evaporation loses a considerable amount of heat, which is important for the processes of physical heat regulation.

Adequate intake of water is one of the basic conditions for health. Drinking enough water is one of the best ways to prevent the formation of kidney stones. Water "lubricates" the joints, thereby acting as a cushion for the spinal cord, and also regulates body temperature and ensures skin elasticity. Water is essential for normal digestion. Taking part in the metabolism, this unique liquid helps to reduce fat accumulation and reduce weight.

Insufficient water intake disrupts the normal functioning of the body: fatigue and decreased performance, impaired digestion and assimilation of food, slowed biochemical reactions, increased blood viscosity, which creates conditions for blood clots, and disrupts the process of blood formation. Without water, it is impossible to regulate the body's heat exchange with the environment and maintain a constant body temperature.

Since the brain is 75% water, relative dehydration causes the brain cells to experience severe stress. Dehydration negatively affects the most important functions of the body, weakening it and making it vulnerable to disease.

2. WATER IN THE REGION OF TRANSCARPATHIA

The Zakarpattia region is one of the regions of Ukraine best endowed with water resources. Water resources here are formed by surface runoff from the rivers of the Tisza River basin: local river runoff generated within the region, transit river runoff generated in the Romanian, Hungarian and Slovak Republics, and operational groundwater reserves (Mishhenko, 2009). The rivers of Transcarpathia are geographically located and belong to the basin of one of the largest tributaries of the Danube, the Tisza, which is the main waterway in the region. All rivers originate in the highlands of the Carpathians (Semal, 2014).

The territory of the region is cut by a dense network of rivers. The average density of the river network is 1.7 km/km2 . In total, there are 9,429 rivers in the region, with a total length of 19,866 km. The total length of 155 rivers, each of which is longer than 10 km, is 3.43 thousand km. Of these, the Tisa, Borzhava, Latorytsia and Uzh rivers are over 100 km long each. The number of small rivers (up to 10 km long) is 9,277, which corresponds to 79% of all watercourses. Their total length is 16,248 km.

The total length of the Tisza River is 967 km, 262 km of which are within Ukraine. On the territory of the region, it receives right tributaries: the Kosovska (41 km), Teresva (56 km), Tereblya (91 km), Rika (92 km) and Borzhava (106 km) rivers. The length of the Latorytsia River is 191 km (144 km within the region), the length of the Uzh River is 133 km (107 km within the region).

There are 9 reservoirs and 59 ponds in the region. The total volume of all artificial reservoirs is 60.5 million m3 , the water surface area is 1.56 thousand hectares. The largest is Synevyr Lake, with an area of about 7 hectares and an average depth of 15-16 m. It is located at an altitude of 989 m above sea level.

According to the Zakarpattia Geological Exploration Expedition, the forecasted resources of drinking groundwater in the region are 1.109 million m3 /day. In general, these resources are sufficient to meet the population's drinking water needs, but they are very unevenly distributed. In the plain part of the region, groundwater resources far exceed the amount of their possible use. In the mountainous part of Zakarpattia, especially in areas with waterproof flysch rocks, drinking groundwater resources are insignificant, up to 50-100 m3 /day. In this regard, mountain streams in forested areas outside of settlements are perspective for centralised supply of quality water to the population.

Centralised groundwater intakes provide drinking water to 25 cities and urban-type settlements in the region. In rural settlements, centralised water supply is practically absent. Their water supply is mainly provided by domestic wells. For local water supply of certain administrative, social, industrial, agricultural and other facilities, single wells are used. According to official information, about 1,300 production (drinking water) wells have been drilled in the region over the years. The average long-term runoff generated within the region is about 7,040 million m3 /year. Together with the transit runoff coming from neighbouring territories, the surface runoff of the region's rivers is 13,440 million m3 /year (Semal, 2015).

3. WATER POLLUTION

Throughout its existence, mankind has been using water from rivers, lakes and underground sources not only for water supply, but also for discharging polluted water into them. Until the beginning of the twentieth century, this was not a major concern. Solar radiation, oxygen, physical and chemical processes, and living organisms ensured self-purification of water bodies. Only 50-70 years ago, polluted water from urban settlements was often discharged into rivers without cleansing (Fig. 1). In 15-20 km, they were self-purified to the point where they were again used to supply water to other cities.

Fig. 3.1. Dumping of polluted water into rivers.

Significant urbanisation, concentration of industrial enterprises and transport in cities, increased mining, expansion of drainage and irrigation reclamation, ploughing of land to river channels, and the creation of a large number of landfills have led to significant, and in some regions critical, depletion and pollution of surface and groundwater. Not only small rivers and lakes, but also large river systems and underground aquifers have become contaminated. In the developed regions of the world, there are no more large river and lake systems with close to natural hydrological regimes and chemical composition of water. Due to river carnage, accidents on water transport and drilling platforms, and waste dumping on the seabed, the waters of some seas and the entire world ocean are now significantly polluted.

Pollution of natural waters is defined as the process of changing the composition and properties of water in a water body as a result of the intake of pollutants caused by human activity, which leads to a deterioration in water quality.

A clear distinction must be made between the concepts of pollutant and polluter. A water pollutant is a substance that, when released into water, causes a deterioration in its quality. A pollutant (source of pollution) is an object that introduces pollutants, microorganisms or heat into surface or groundwater.

About 2,000 pollutants have been detected in water bodies, including 750 in drinking water, more than 600 of which are organic substances. Moreover, the anthropogenic input of many elements into the water environment exceeds the natural amount.

Human economic activity is not limited to water pollution. Water resources are often depleted in different parts of the world (Fig. 2).

Water depletion is a decrease in the minimum allowable flow of surface water or a reduction in groundwater reserves. The minimum permissible flow is considered to be the flow that ensures an ecologically satisfactory state of the water body and conditions of water use.

Fig. 3.2. Depletion of water bodies.

The causes of water depletion in reservoirs and watercourses are most often uncontrolled and mismanaged use of surface and groundwater; deforestation and shrubbery, particularly in the upper reaches of the basin and near river banks; draining of marshes; ploughing of coastal slopes; water and wind erosion of soil; and abandonment of ponds.

Human intervention in the development of natural complexes disrupts the balance that has developed over many millennia. Deforestation, draining of swamps, destruction of ponds, straightening of riverbeds lead to unimpeded discharge of meltwater into rivers and reservoirs. Rapid spring flows erode slopes and banks, silt up streams and springs. Deforestation of coastal forests and shrubs, and ploughing of floodplains to river channels, causes widespread soil erosion. The drainage of marshes makes it impossible to maintain normal river flows and deprives marsh plants and animals of moisture. Often, the damage caused by the drainage of marshes is greater than the benefits gained from them. All this causes pollution and destruction of a large number of rivers and lakes. As a result, they lose their natural, social and economic value.

Relief features and the diversity of natural complexes in the river basins of Transcarpathia have determined the degree of anthropogenic pressure and the nature of the use of the basin areas, while forested areas and mountainous terrain have limited their agricultural use. The uneven settlement of river valleys in different parts of the river basin also causes uneven anthropogenic impact in different areas. Among the rivers that are most affected by anthropogenic impact is the transboundary Uzh river, which discharges 14% of the total volume of polluted water in the Zakarpattia region.

Fig. 3.3. The Uzh River within the city of Uzhhorod (V. Pliashechnyk)

Water quality, as in focus, reflects the complexity of aquatic ecosystems and their abiotic and biotic components. It is the result of the functioning of aquatic ecosystems, primarily biota. At the same time, the water of watercourses and reservoirs is the only possible habitat for aquatic plants and animals. In view of this, as well as the availability of the modern Methodology for Environmental Assessment of Surface Water Quality by Relevant Criteria developed in Ukraine, which contains a system of environmental classifications of surface waters of land and estuaries, it is most appropriate to determine the environmental status of surface waters using this methodology. This methodology has been adopted as a valid interagency regulatory document and is mandatory for all agencies in organising and carrying out state monitoring.

The main role in water self-purification processes belongs to aquatic life - hydrobionts. The intensity and effectiveness of these processes depend on the state of aquatic communities and the state of hydrobiocenoses.

4. BIOINDICATION AS A METHOD OF ENVIRONMENTAL RESEARCH

Due to the profound transformation of the natural environment under the influence of anthropogenic impact, which has reached the global level in terms of its scale and is outpacing the impact of natural factors in terms of strength and speed, the problems of preserving the ecosystem and the biosphere as a whole are becoming more acute and urgent.

Determination of biologically significant anthropogenic loads based on the reactions of living organisms and their communities to them is associated with bioindication. The importance of vegetation cover as an indicator of ecosystem health lies in the fact that it is very sensitive to changes in environmental factors. Urban ecosystems are most affected by human activity. Therefore, it is important to monitor the state of the environment and timely analyse the pollution of the city's territory. To some extent, bioindicative assessment can solve these issues.

Monitoring systems based on the study of plant and animal behaviour make it possible to assess the biological effects of air pollution, their spatial distribution, and possible accumulation over large areas.

Some species of plants and animals change their developmental characteristics (growth rate, flowering process, fruit formation, colour intensity, etc.) in response to various stimuli. These properties have long been noticed by mankind and used for practical purposes. Due to the general environmentalisation of various scientific fields and human thinking in general, bioindication methods are increasingly used by modern scientists, including in environmental quality monitoring.

Bioindication (Greek: bios - life, Latin: indiso - indicate) is an operational monitoring of the environment based on observations of the state and behaviour of biological objects (plants, animals, etc.).

This method is becoming more and more common because indicator organisms have such advantages as :

* summarise biologically relevant environmental data;

* are capable of responding to short-term and volley releases of toxicants;

* respond to the speed of changes in the environment;

* indicate the places of accumulation of pollutants and their migration routes;

* allow us to develop early assessments of the harmful effects of toxicants on humans and wildlife and to set permissible loads on ecosystems.

Bioindication is used in environmental studies as a method of detecting anthropogenic pressure on biocenosis. The bioindicator method is based on the study of the impact of changing environmental factors on various characteristics of biological objects and systems. Biological systems or organisms that are most sensitive to the factors that are studied are chosen as bioindicators. Changes in the behaviour of the test object are assessed in comparison with control situations taken as a standard. For example, when assessing the ecological state of surface waters, observations of the behaviour of daphnia, molluscs, and some fish species are used as bioindicators.

A number of indicator plants respond to increased or decreased concentrations of micro- and macroelements in the soil. This phenomenon is used for preliminary soil assessment and identification of possible mineral prospects.

One of the specific methods of environmental pollution monitoring is bioindication, the determination of the degree of pollution of geophysical environments using living organisms which are bioindicators. Living indicators should not be too sensitive and too resistant to pollution. They should have a sufficiently long life cycle. It is important that such organisms are widespread across the planet, and each species should be specific to a particular habitat. Lichens fully meet all these requirements. They react differently to pollution than higher plants.Long-term exposure to low concentrations of pollutants causes damage to lichens that does not disappear until their slates die. This is probably due to the fact that lichens regenerate their cells very slowly, while damaged tissues in higher plants regenerate quite quickly. Due to a number of biological features, lichens are good indicators of changes in the state of the environment in terms of its pollution with sulphur dioxide, fluorides, alkaline dust, and heavy metals.

Fig. 4.1 Bioindicator lichens.

Bioindication has a number of advantages over instrumental methods. It is highly efficient, does not require large expenditures and makes it possible to characterise the state of the environment over a long period of time.

Environmental factors strictly determine which organisms can live in a certain place and which cannot. Taking it into consideration , it is possible to use the inverse pattern and draw conclusions about the physical environment based on the state of the organism living in it. This is how the method of bioindication of the environment emerged, which is especially widely used in forest typology, phytocoenology, and to determine the level of air pollution using lichens (lichen indication), mosses (bioindication) or fungi (mycoindication).

Thus, bioindicators are a group of individuals of the same species or grouping, the presence, quantity or intensity of development of which in a particular environment is an indicator of certain natural processes or environmental conditions.

Biological indication is widely used today to assess environmental pollution, which "removes" species of lower and higher plants and fauna that are unstable to pollution factors from their natural ecological niches.

Bioindication has certain advantages as a method of obtaining direct information about changes in the state of biota under specific pollution conditions, but it should be combined with chemical and geophysical experiments to obtain not only qualitative but also quantitative data.

Thus, due to the need for global monitoring, the use of indicator capabilities of biological objects is becoming increasingly important. Indicator plants are used both to detect individual pollutants and to monitor the general state of the environment.

Basic principles of bioindication

All biological systems - organisms, populations and biocenoses - have adapted to the complex of factors in a particular area in the course of their development. They have occupied a certain area within the biosphere, an ecological niche, in which they find optimal living conditions and can feed and reproduce normally. Each organism has a genetically determined, phylogenetically acquired, unique physiological tolerance range for each factor that affect it, within which this factor is suitable. If the factor is too low or too high, but not yet lethal, the organism is in physiological pessimism. In the examined area of the factor's intensity, which is particularly favourable for a given person, the body exists in physiological optimum conditions.

There are different forms of bioindication. If two identical reactions are caused by different anthropogenic factors, then we speak of nonspecific bioindication. If certain changes can be attributed to only one factor, we are talking about specific bioindication.

If a bioindicator reacts with a significant deviation of vital index from the norm, it is a sensitive bioindicator.

Accumulative bioindicators accumulate anthropogenic impact without rapid manifestations of deviation. Such significant accumulation of pollution, is gradually exceeding the normal level, and most often occurs at the level of ecophysiological or biocenotic processes.

In nature, all types of bioindication are included in a chain of sequential reactions and processes. If an anthropogenic factor acts directly on a biological element, then we are talking about direct bioindication. But often bioindication becomes possible only after a change in state under the influence of other directly involved elements. In this case, we are dealing with indirect bioindication and a bioindicator. It is often preferably to detect the biological effect of an anthropogenic factor in advance in order to be able to influence this effect under certain conditions The presence of very bioindicators leads to early indication, when the reaction occurs at minimal doses in a short period of time and finishes in a short period of time and takes place at the site of the factors effect on elementary molecular and biochemical processes.

Six different types of sensitivity can be distinguished depending on development time of bioindication reactions:

Type I: the bioindicator gives a single strong reaction after a certain time, during which it did not respond to the action (no effective level) and loses sensitivity (above the upper effective level).

Type II: as in the first case, the reaction is immediate and strong, but lasts for some time after which it abruptly disappears.

Type III: the bioindicator reacts from the moment of detection of the deviated action with the same intensity over a long period of time.

Type IV: after an instant strong reaction, its cessation is observed, first rapidly, then more slowly.

Type V: when a disturbed action occurs, a reaction begins, which is becoming more and more intense until it reaches a maximum, and then gradually stops.

Type VI: the type V reaction is repeated many times; oscillation of bioindicator parameters occurs.

Bioindication can be used at different levels of living organisation (macromolecule, cell, organ, organism, population, biocenosis). As the level of organisation of biological systems increases, so does their complexity, as their interrelationships with location factors become increasingly complex. At the same time, bioindication at lower levels is dialectically included in bioindication at higher levels, acting in a new way. While direct and more often specific types of bioindication prevail at the lower levels of organisation of biological systems, indirect bioindication dominates at the higher levels.

Due to the complexity of biological systems, only nonspecific bioindication is often possible. However, this is where the pathways to detecting complex stressors and thus to assessing the permissible loads on a complex ecosystem open up. Sometimes bioindication methods that are easily used at lower organisational levels become so complex in more complex systems that it becomes impossible to distinguish the impact of a factor. On the other hand, bioindicators that are detected at a higher organisational level are linked to corresponding changes at the previous levels. This pattern should be taken into account when looking for opportunities of early bioindication. Compared to individual organisms, ecosystems often respond to stressful impacts with a delay and in a highly altered form.

According to the organisational levels of biological systems, different levels of bioindication can be identified:

Level 1: biochemical and physiological reactions;

Level 2: anatomical, morphological, biorhythmic and behavioural abnormalities;

Level 3: floristic and faunal changes;

Level 4: cenotic changes;

Level 5: biogeocenotic changes;

Level 6: changing landscapes.

There are two proper methods of bioindication: passive and active monitoring. In the first case, visible or invisible damage or abnormalities are studied in free-living organisms, which are signs of stress. In active monitoring, the same impacts are detected on test organisms that are under standard conditions in the researched area.

There are four main requirements to consider when conducting bioindication:

1. the relative speed of the transaction.
2. obtaining sufficiently accurate and reproducible results.
3. the presence of objects used in bioindication, if possible in large quantities and with homogeneous properties.
4. error range compared to other testing methods is no more than 20%.

5. ASSESSMENT OF THE ECOLOGICAL STATUS OF WATER BODIES/WATERCOURSES AND WATER QUALITY BY AQUATIC PLANTS

The state of the ecosystem of a water body/watercourse is assessed in a variety of ways using a number of indicator indicators. In recent decades, the practice of determining the ecological status of water bodies and watercourses has been expanded to include biological methods, including bioindication methods, along with traditional chemical, physical or bacteriological methods. The latter are based on the understanding that the abiotic properties of water determine the spectrum of species, each of which is adapted only to certain natural conditions and cannot exist outside them (Bioindication..., 1994; Weinert, Walter, Wetzel, 1988; Vinogradov, 1976; Vyshyvkin, 1969; Glukhov, Mashtaler, 2007; Jorgensen, Costanza, Xu, 2005; Stцker, 1981). Knowing the conditions when certain species of aquatic and near-water plants and animals develop, the quantitative and qualitative composition of organisms living in water or their communities can determine the ecological status of a water body, including its pollution or deterioration of water quality.

One of the most important areas of bioindication is phytoindication, which uses plant traits and properties or their specific set (populations, species, communities) as indicators. The foundations of phytoindication were laid in the middle of the 20th century (Balashov, 1969; Korchagin and Vinogradov, 1967; Vinogradov, 1976; Vyshivkin, 1969). Subsequently, the theoretical foundations and methodological aspects of phytoindication were developed, and the main directions were formed based on both the object of research or practical needs and the specifics of indicators (Bulokhov, 1996; Viktorov and Chikishev, 1990; Macrophytes..., 1993).

Phytoindication studies of various directions and their practical application have been significantly developed in Ukraine (Balashov, 1969; Glukhov, Mashtaler, 2007; Karpova et al., 2010; Kondratiuk, 2008; Korzhenevskyi, 2002; Macrophytes..., 1993; Movchan, Kanevskyi, Semichaevskyi, 1993; Polishchuk, Havryshova, Garasevych, 1984; Romanenko, Zhukinskyi, Oksiuk, 1998; Turmanina, 1988). These works, along with theoretical foundations and methodology, are summarised in the works of Y.P. Didukh (Didukh and Pluta, 1994; Didukh, 2012), who also developed phytoindicative ecological scales adapted to the Ukrainian territory for species of the flora of Ukraine (Didukh, 2011).

Aquatic plants - the so-called macrophytes - are effective bioindicators that can be used to determine water quality. These are plants of relatively large size, visible to the naked eye, belong to different taxonomic groups, but whose existence is closely related to water. This group includes vascular plants, mosses, and multicellular algae that grow directly in water or in the coastal zone with highlevel of humidity. Aquatic plants are an essential component of the ecosystems of most reservoirs and watercourses, they influence hydrochemical and hydrobiological processes, playing an important and multifaceted role in the life of the reservoir.

The use of aquatic plants, as well as their communities and habitats with their participation as indicators of the ecological status of water bodies, is convenient, fast and sufficiently informative in terms of bioindication, taking into account a small number of species, ease of observation and the ability to identify species composition directly in the field. At the same time, aquatic plants and their communities are quite flexible and sensitive to environmental changes, well reflecting the hydrological regime of a reservoir or watercourse, the peculiarities of the chemical composition of water, etc. It is important that aquatic plants can reflect a wide range of environmental conditions - some species cannot tolerate the slightest pollution and live only in very clean water, but most species are quite tolerant to various types of pollution and can even accumulate pollutants in their tissues, and some of them are able not only exist and successfully reproduce in polluted waters, but even withstand high concentrations of toxicants. Due to this, aquatic plants and their communities can be successfully used as indicators of the ecological status of water bodies/watercourses and water quality in them. Therefore, even a preliminary survey of the vegetation cover of a water body allows to rapidly assess its ecological condition.

Indication by aquatic plants has certain limitations and is possible when the conditions in the water body/watercourse are favourable for the development of aquatic plants, namely: moderate flow velocity, shallow waters protected from wind and waves, bottom sediments suitable for plant growth and anchoring, etc.

Ecological groups of aquatic plants

Depending on the nature of their adaptation to the aquatic environment, macrophytes are divided into two main ecological groups: helophytes (air-water plants) and hydrophytes (plants with leaves floating on the water surface and submerged in the water column). Coastal and shallow areas of water bodies are occupied by thickets of air-water plants (reeds, cattails, arrowroot, spurge, etc.), with their rhizomes and lower parts of the stem in the water and the majority of the plant in the air. These are large perennial grasses with a powerful root system. Dense thickets of these species usually border a water body.

Plants with leaves floating on the surface of the water are mainly inhabitants of quiet lakes or river bays with moderate currents. Some of them are attached to the bottom by rhizomes (pitcher plants, water lilies, water walnuts), while others are free-floating, moving on the water surface affected by wind or current (salvinia, duckweed, toadflax).

Submerged plants are almost entirely underwater and are the best adapted of all aquatic plants to live in the aquatic environment (eelgrass, waterweed, elodea, pondweed, kelp, etc.). Thus, due to their close connection with the aquatic environment, hydrophytes are the most dependent on the ecological state of a water body and are therefore the most sensitive indicators of water quality (Karpova, Zub, Melnychuk, and Protsiv, 2011).

Aquatic plant species as indicators of environmental conditions

Despite the fact that only a part of the total diversity of aquatic macrophytes is suitable for use as indicators, since most aquatic plants are tolerant to environmental conditions, groups of species can be distinguished among them that are indicators of certain environmental conditions (Karpova, Zub, Melnychuk, and Protsiv, 2011; Maltsev, Karpova, and Zub, 2011).

Indicators of flowing water (rheophilic conditions). An important condition for the natural functioning of river ecosystems is the presence of a current, which is adapted to the existence of a group of aquatic plants living in the riverbed. This group includes species that can withstand certain flow speeds and water level fluctuations and require a high concentration of oxygen dissolved in water for their development. These are, first of all, various species of duckweed (pierced-leaved, long, curly duckweed), straight and drooping hedgehogsheads, umbrella sucker, arrowhead, yellow pitcher, and lake kuga.

Indicators of standing water (limnophilic conditions). When a river is regulated, its natural hydrological regime changes, and conditions close to lake conditions are created in the area upstream of the dam: the flow rate decreases to almost standing water, siltation processes are activated, and the level of water trophicity increases. In such areas, communities of aquatic plants adapted to flowing water (rheophilic conditions) give way to aquatic plants of stagnant water that can withstand siltation, deterioration of oxygen conditions and excess organic matter in the water. They are represented by thickets of common reed, narrow-leaved cattail, white water lily, floating, knotted, comb, hair and shiny pondweed, and spiked water lily.

Indicators of waterlogging. In dying old-growth floodplains, shallow rivers and ponds, waterlogging processes are usually observed. In this case, there is an excessive content of organic matter, a significant accumulation of dead plant remains and the resulting decrease in the level of oxygen dissolved in water, an increase in the concentration of hydrogen sulphide and methane, and the water in the reservoir becomes brown. Under such conditions, a specific complex of aquatic plants develops and dominates. These include broad-leaved cattail, common bladderwort, submerged duckweed, small and triboric duckweed, multirooted spirodelia, and aloe vera. The degree of development of these species can be used to determine the intensity of waterlogging processes in a water body.

Determining water quality by aquatic plants

According to the developed methods (Karpova, Zub, Melnychuk, and Protsiv, 2011; Maltsev, Karpova, and Zub, 2011), bioindication of the ecological status of a water body or watercourse by aquatic plants is carried out by assessment of:

- species composition of aquatic plants in the reservoir/watercourse;
- the number (abundance) of individuals of certain species;
- the degree of development of individual species or aquatic plant communities/habitats (projected coverage - PC*);
- the presence of individual indicator species and indicator groups;
- the spatial distribution of the thickets on the water body.

When surveying a water body, it is advisable to pay special attention to the most abundant (dominant) plant species and their communities, as they reflect the overall picture of the ecological status of the water body/watercourse. However, it is also necessary to take into account species that are not numerous or even rare, which, in the case of periodic observations, i.e. monitoring, may indicate the direction of processes occurring in the water body.

An indicator of the ecological status of a water body can be not only the species composition of aquatic plants, but also the abundance of species and the specifics of the spatial distribution of aquatic vegetation, etc. The easiest way to do this is to study the species composition of aquatic plant communities in a particular section of a watercourse or reservoir. Determining the species composition involves compiling a complete list of plant species, which includes all species that occur in the area under study.

Several recommendations are offered for the practical implementation of the description of aquatic vegetation and the compilation of a general list of aquatic plant species.

* To determine the water quality of a water body/watercourse in general, it is necessary to select the most typical sites. For a comprehensive assessment of water quality, one should try to cover a variety of habitats in the water body, e.g., for a river - riffles, rifts, bays.

* If the goal is to study the impact of a single source of pollution on water quality, then sites should be selected upstream and downstream of the source of pollution.

* The length of the surveyed areas depends on the size of the water body. For example, for a small river or pond, it is necessary to survey 50 m of the coastline in 2-3 sections and make 3-4 descriptions. For a medium-sized river and a small pond (lake), 100 m of coastline (5-8 descriptions).

* The survey should be carried out both from the shore and from the pond (knee-deep or from a boat), always looking inside the thickets for interesting findings.

* Be sure to examine all possible belts and layers of aquatic vegetation: the upper surface, the water surface itself, and its thickness.

It is important to note that during the surveys and collection of material, it is not allowed to collect or disturb communities of protected species - those included in the Red Data Book of Ukraine, international and regional red lists. After compiling a general list of plants, indicator species and indicator groups are identified among them, which will be used in further work.

Assessment of the ecological status of a water body/watercourse and determination of water quality by indicator species of higher aquatic plants (Macrophyte Index (MI))

Based on the patterns of change in the species composition of aquatic plants in a water body/watercourse, their abundance and spatial distribution, which occurs due to changes in the hydrological regime, trophic state, increased pollution and deterioration of water quality (mainly due to an increase in the concentration of nutrients and trophic level), the state of the water body and water quality can be determined. The hydrological regime and trophic state of a water body/watercourse is determined by the specific species composition, primarily by sensitive indicator species, taking into account the phytoindicative ecological scales established for most macrophyte species (Didukh, 2011).

A preliminary assessment of the ecological status of a water body/watercourse or a separate site/area and determination of water quality can be made by the presence of indicator species through the establishment of an aquatic plant index or Macrophytic (biotic) index (MI), the methodology for determining which was developed by domestic hydrobiologists and botanists (Karpova, Zub, Melnychuk, and Protsiv, 2011; Maltsev, Karpova, and Zub, 2011). The methodology is based on the natural change in indicator groups of aquatic plant species that occurs in a water body in response to increasing pollution and deteriorating water quality. By determining the presence of species of a certain indicator group in a water body/watercourse and calculating the total number of aquatic plant species growing in it, it is possible to obtain the Macrophyte Index (MI), which will be an indicator of the ecological status of the water body/watercourse and water quality. The Macrophyte Index is determined using a special table (Table 1). After examining the water body/watercourse section, we identify aquatic plants and compile a general list of them. Then, to assess the condition of the water body, the table should be used to calculate the approximate number of all aquatic plants found in the water body under assessment, taking into account all species found in the water body, not just those listed in the table. We use the table to determine which indicator species occur in the study area. First, we look for species sensitive to pollution in our list, which are listed in the first (second) rows of the table. If there are such species from the first (second) indicator group, the other rows below are not considered, and the assessment is carried out within this group. If these species are not in our description, we move on to the next line and look for species from the next indicator group, ignoring the rest, etc. Next, within this line, we set the total number of species of this group in the study water body and at the intersection with the column with the corresponding number of species, we find the value of the Macrophyte Index in the table.

Table 5.1. Determination of water quality by aquatic plants through the establishment of the Macrophyte Index

<table>
<tr><th colspan="2" rowspan="2">Indicator species</th><th colspan="3">Total number of presented species</th></tr>
<tr><th><5</th><th>6-10</th><th>>11</th></tr>
<tr><td colspan="2">Isoëtes lacustris, water moss (Fontinalis) (Fig. 5.1), algae Chara sp. (Fig. 5.2), Myriophyllum alterniflorum</td><td>10</td><td>9</td><td>-</td></tr>
<tr><td colspan="2">Potamogeton complex (except Stuckenia pectinata), Persicaria amphibia (Fig. 5.3), Ranunculus aquatilis</td><td>9</td><td>8</td><td>7</td></tr>
<tr><td colspan="2">Potamogeton complex (Potamogeton perfoliatus (Fig. 5.4), P. lucens, P.crispus (Fig. 5.8)), and Potamogeton with floating leaves (Fig. 5.7), Nuphar lutea (Fig. 5.10), Elodea canadensis, Sagittaria sagittifolia (Fig. 5.9), Myriophyllum verticillatum (Fig. 5.5, 5.6), Ceratophyllum submersum</td><td>-</td><td>7</td><td>8</td></tr>
<tr><td colspan="2">Nymphaea alba (Fig. 5.12), Myriophyllum spicatum, Batrachium circinatum (Fig. 5.11), Stuckenia pectinata</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td colspan="2">Stratiotes aloides, Utricularia vulgaris (Fig. 5.13), Hydrocharis morsus-ranae (Fig. 14).</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td rowspan="2">Ceratophyllum demersum, Lemna sp.</td><td>ПП*<50%</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>ПП*>50%</td><td>1</td><td>2</td><td>-</td></tr>
<tr><td colspan="2">Filamentous algae</td><td>1</td><td>2</td><td>-</td></tr>
</table>

*Projected plant coverage on the water surface in percentage

After surveying the area of the water body/stream section, we identify macrophyte species and compile their general list. To assess the condition of the water body using the table, it is necessary to estimate the approximate number of all aquatic plants encountered in the water body being evaluated. All species found in the water body are considered, not just those listed in the table. According to the table, we determine which indicator species are present in the surveyed area. Initially, in our list, we look for species sensitive to pollution, indicated in the first (second) rows of the table. If these species are present in our description, the subsequent rows, including indicator groups, are not considered, and the assessment is carried out within this group. If these specified species are not present in our description, we move on to the next row and look for species from the next indicator group, disregarding the rest, and so on. Then, within this row, we determine the total number of species in this group in the surveyed water body. At the intersection with the column containing the corresponding number of species, we find the value of the Macrophyte (Biotic) Index (MI) in the table.

The Macrophyte (Biotic) Index (MI) has values that coincide with the water quality classes commonly used in Ukraine: 9-10 points (blue color) - Class I water quality, very clean; 7-8 points (green color) - Class II, clean; 5-6 (yellow color) - Class III, polluted; 3-4 (orange) - Class IV, dirty; 1-2 (red color) - Class V, very dirty.

The higher the Macrophyte Index value, the better the water quality and ecological conditions in the water body/stream.

Fig. 5.1. Water moss *Fontinalis*

Fig. 5.2. *Chara sp.*

Fig. 5.3. Persicaria amphibia

Fig. 5.4. Potamogeton perfoliatus

Fig. 5.5. *Myriophyllum verticillatum*

Fig. 5.6. *Myriophyllum verticillatum*

Fig. 5.7. Potamogeton natans

Fig. 5.8. Potamogeton crispus

Fig. 5.9. Sagittaria sagittifolia

Fig. 5.10. Nuphar lutea

Fig. 5.11. Batrachium circinatum

Fig. 5.12. Nymphaea alba

Fig. 5.13. *Utricularia vulgaris*

Fig. 5.14. *Hydrocharis morsus-ranae*

6. HYDROBIONTS OF PROTOZOA AS BIOINDICATOR SPECIES

Ciliated protozoa are an essential component of various types of water bodies and are represented by three morphological (behavioural) groups. Depending on the environmental conditions, these protozoa form specific combinations of species, the composition of which is determined by their ecological preferences and tolerance to various factors.

Due to their short life cycle, they react quickly to external factors, such as organic or toxic pollution, changing the species composition and population density. These protozoa are widely used as indicator organisms, in particular, in the saprobility system. In order to rapidly assess the impact of wastewater on the quality of the aquatic environment, there is a problem associated with the need for species identification, which is a complex task and requires significant time and effort.

Ciliate protozoa are an extremely diverse group of hydrobionts and are an important component of biocenoses of various types of water bodies. Due to their species diversity, these organisms are widely used as indicators of water quality (Table 1). Depending on the conditions, protozoa form specific communities, the composition of which is determined by the environmental tolerance of different species to environmental factors. At the same time, due to their short life cycle and the ability to survive adverse conditions in the form of cysts, infusoria respond quickly to external factors, including organic or toxic pollution. This is usually reflected in changes in the species composition of their communities and the density of individual populations. Protozoa are particularly widely used as indicators of saprobility.

Usually, regardless of the type of habitat (bottom sediments, water column, surfaces of objects or plants submerged in water), ciliate communities contain representatives of three behavioural groups - swimming, crawling and sessile (attached). The number of representatives of these groups also depends on environmental quality parameters.

Sediment samples are taken from the river using a 100 ml syringe. Samples can be taken without reference to dates, but in accordance with changes in air and water temperature.

Once samples have been collected, they should be immediately delivered to the laboratory and processed. In order to preserve unprocessed samples and prevent changes in the composition and quantitative ratio of protozoa, samples can be kept in a refrigerator at +5°C for several days.

Quantitative counts of activated sludge and sediment organisms are carried out in a 25 µl drop taken with a pipette. The drop is applied to a slide and covered with a cover slip. The number of ciliated protozoa is counted in the entire volume of the drop under a microscope at low magnification (Ч100). The species composition and counting of infusoria is also carried out with a microscope using a digital camera.

Before quantitative accounting, the species composition of organisms is determined. Species identification is carried out in vivo, using oxypropyl cellulose to slow down the movement of infusoria. To identify species, specialised identifiers, i.e. identification tables, should be used.

The following indicators are used for the environmental classification of surface water quality according to tropho-saprobiological (ecological and sanitary) criteria:

hydrophysical: transparency m, suspended solids, mg/dm3 ;

hydrochemical: ammonium nitrogen N/dm3 , nitrite nitrogen N/dm3 , nitrate nitrogen N/dm3 , phosphorus phosphate P/dm3 , dissolved oxygen, mg O2 / dm3 , oxygen saturation %, permanganate oxidation mg O/dm3 , bichromate oxidation mg O/dm3 , BOD mg O2 / dm3 ;

hydrobiological: phytoplankton biomass mg/dm3 , self-purification-self-pollution index (A/R);

Bacteriological: bacterioplankton count, million cells/cm3 , saprophytic bacteria count, thousand cells/cm3 .

Saprobility bioindicators (saprobility indices) are determined by Pantle-Book and Goodnight-Whitley. Saprobility (the ability of aquatic organisms to live in water containing different amounts of organic matter), in turn, includes (from lower to higher organic matter content, respectively): oligosaprobic, mesosaprobic and polysaprobic zones. According to trophicity (a characteristic of an organism's habitat that is determined by the content/amount of nutrients), organisms are divided into oligotrophic, mesotrophic, eutrophic, polytrophic, and hypertrophic organisms.

Table 6.1. Species of infusoria as indicators of saprobility of the Uzh River.

№	Назва виду	Рівень сапробності
1	*Acineria uncinata*	a-p
2	*Aspidisca cicada*	a-b
3	*Aspidisca lynceus*	b-a
4	*Euplotes affinis*	b-a
5	*Frontonia angusta*	b-a
6	*Cinetochilum margaritaceum*	e
7	*Colpidium colpoda*	p
8	*Halteria chorelligera*	o
9	*Holophria discolor*	a-b
10	*Tachysoma pellionellum*	b-a
11	*Trithigmostoma cucullulus*	a-p
12	*Trithigmostoma srameki*	b-a
13	*Trachelius ovum*	a-b
14	*Carchesium polypinum*	a
15	*Chilodonella uncinata*	a
16	*Epistylis coronata*	a
17	*Lepharisma lateritum*	b
18	*Litonotus lamella*	a
19	*Paramecium caudatum*	p-a
20	*Plagiocampa rouxi*	a-b
21	*Tokophrya quadripartita*	a-b
22	*Urostyla grandis*	a
23	*Vorticella aquadulcis*	b-a

24	*Holosticha pulaster*	b-a
25	*Paramecium bursaria*	b-a
26	*Leptopharynx costatus*	o-a
27	*Metopus es*	p
28	*Dexiostoma campylum*	p
29	*Tokophrya lemnarum*	b
30	*Mesodinium acarus*	b
31	*Opercularia articulata*	a-b
32	*Amphileptus pleurosigma*	b-a
33	*Oxytricha setigera*	a-b
34	*Paramecium putrinum*	p
35	*Strobilidium humile*	b
36	*Stylonychia mytilus*	a
37	*Oxytricha chloreligera*	a
38	*Paramecium aurelia-complex*	a-b
39	*Frontonia leucas*	b-a
40	*Uroleptus piscis*	a

Note: o - oligosampled, b - betamesosampled, a - alphamesosampled, p - polysampled, e - eurisampled.

Below are the author's photos of some species of infusoria found in the Uzh River.

Fig. 6.1. *Acineta fluviatilis*

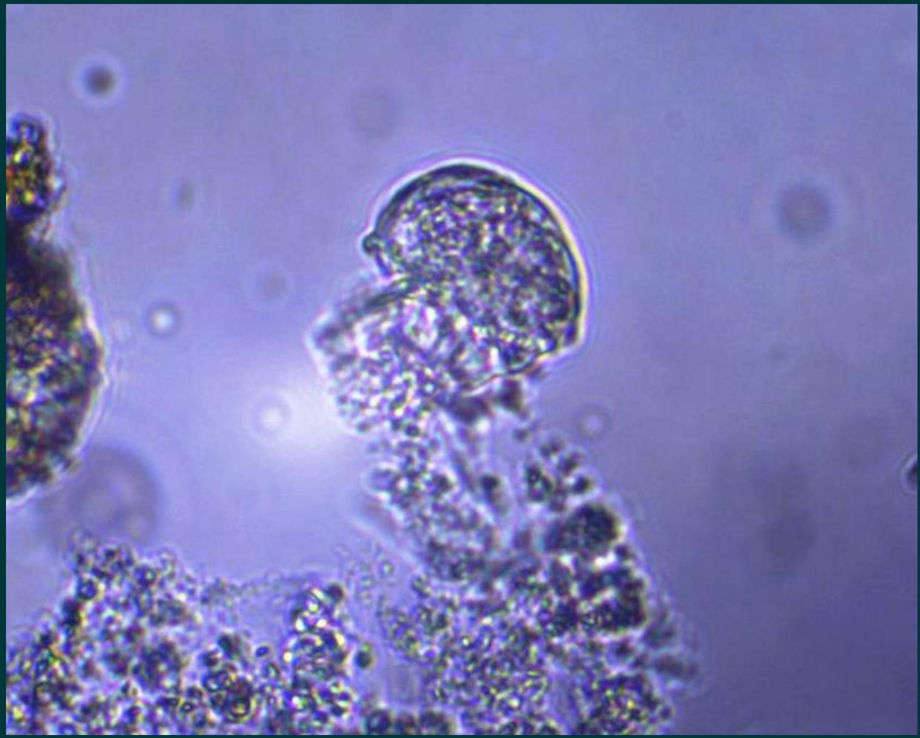


Fig. 6.2. *Aspidisca cicada*

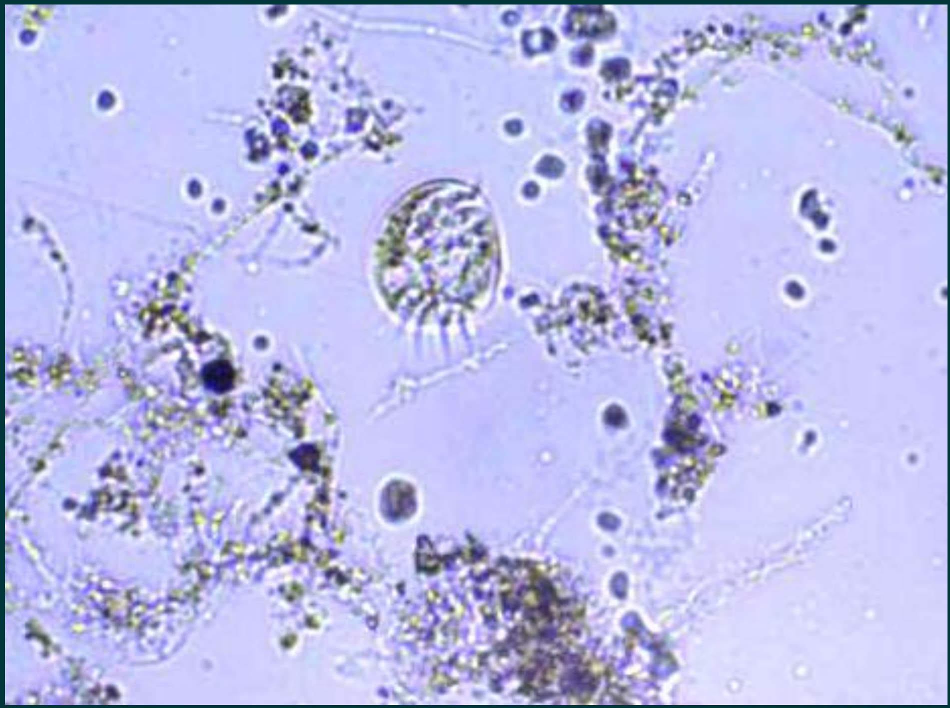


Fig. 6.3. *Aspidisca lynceus*

Fig. 6.4. *Euplotes affinis*

Fig. 6.5. *Frontonia angusta*

Fig. 6.6. *Colpidium colpoda*

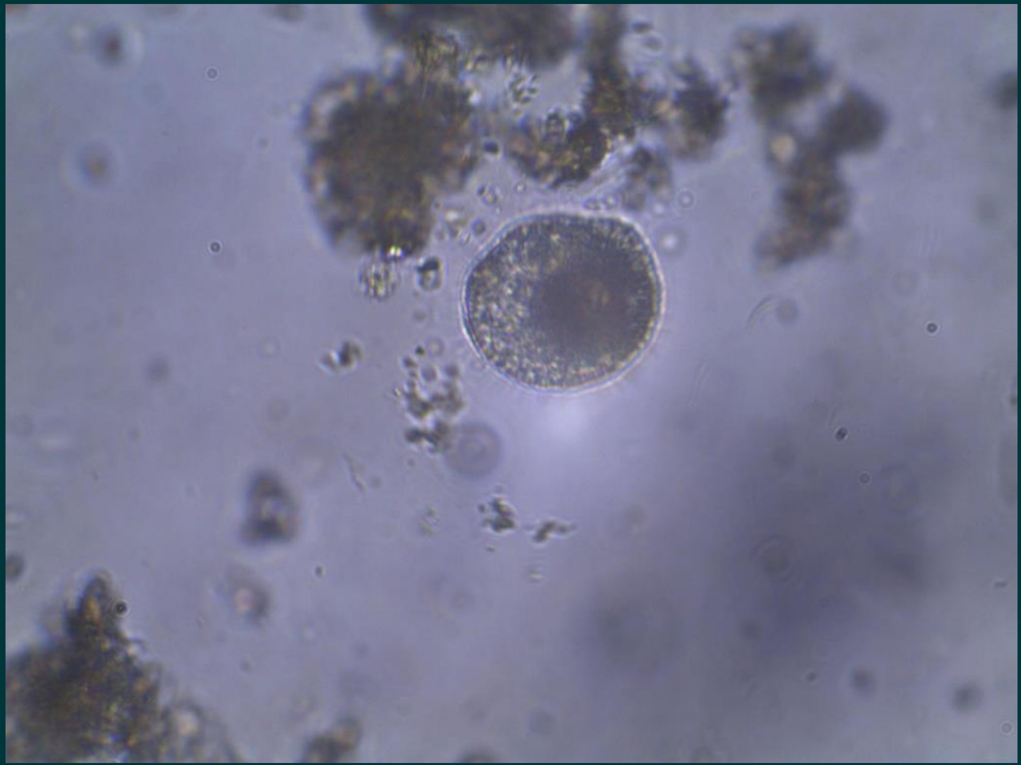


Fig. 6.7. Halteria chorelligera

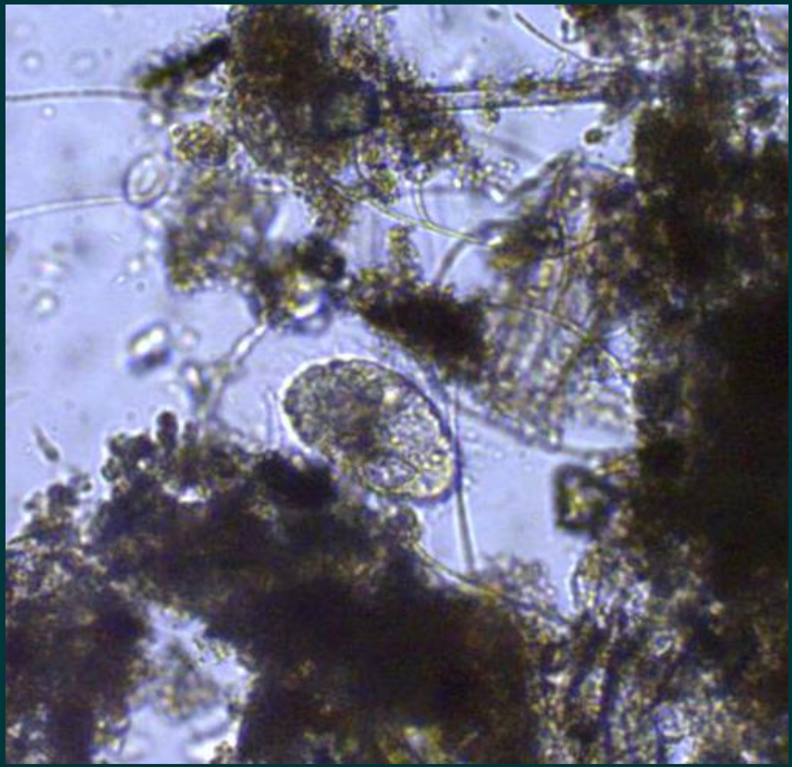


Fig. 6.8. *Histobalantium natans*

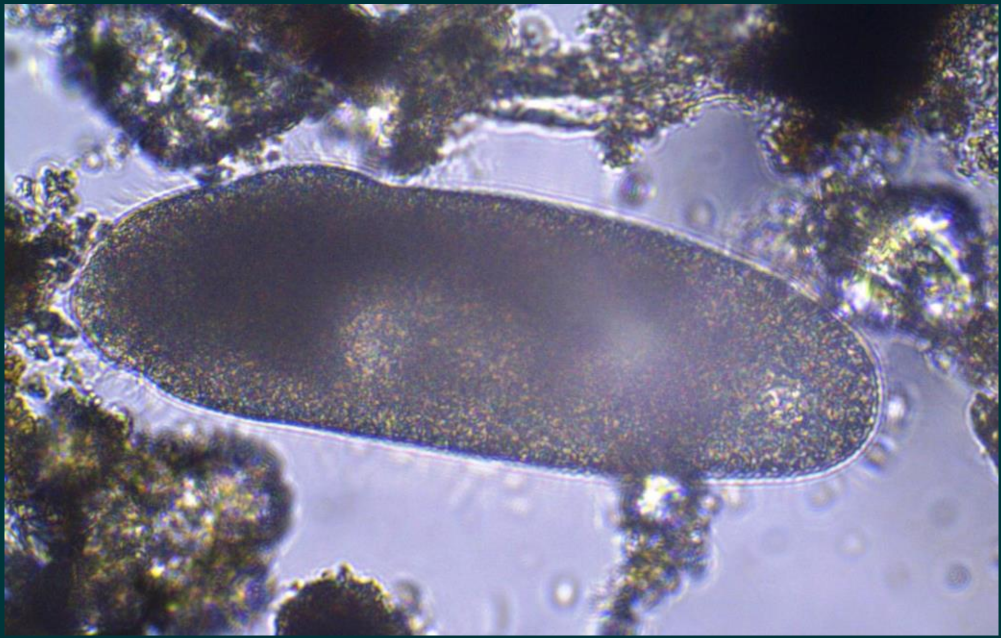


Fig. 6.9. *Ophryoglena flava*

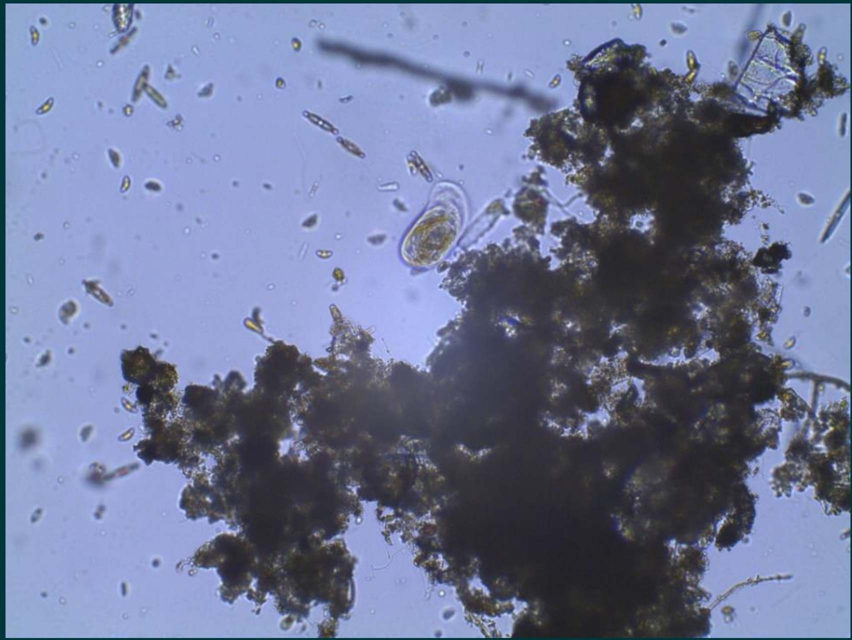


Fig. 6.10. *Trithigmostoma cucullulus*

Fig. 6.11. *Chilodonella uncinata*

Fig. 6.12. Epistylis coronata

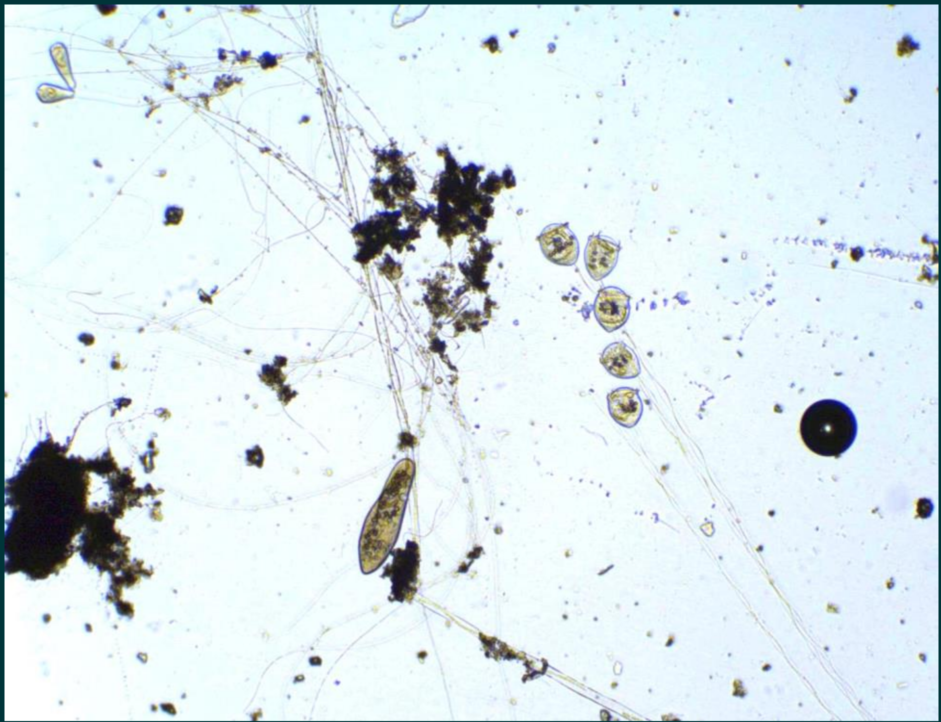


Fig. 6.13. *Paramecium caudatum, Carchesium polypinum*

Fig. 6.14. *Tokophrya quadripartite*

Fig. 6.15. *Urostyla grandis*

Fig. 6.16. *Vorticella aquadulcis*

Fig. 6.17. *Paramecium bursaria*

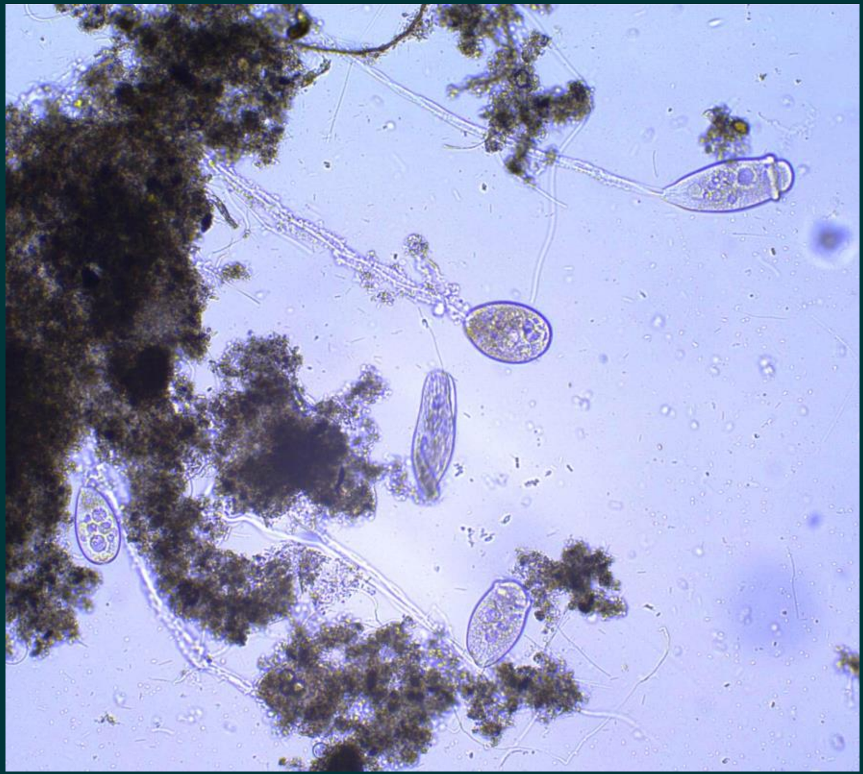


Fig. 6.18. *Metopus es*

Fig. 6.19. *Tokophrya lemnarum*

Fig. 6.20. *Opercularia articulate*

Fig. 6.21. *Oxytricha chloreligera*

Fig. 6.22. *Paramecium caudatum*

7. INSECTS - BIOINDICATORS OF WATER BODIES

Many species of insects are associated with fresh water. Some of them (water beetles, bedbugs) live in water bodies permanently, while others, amphibians (mayflies, dragonflies, springtails, damselflies, damselflies, damselflies) live in water bodies only in the pre-immature stages of life. Insects play an important role in aquatic biocenoses and human activity. They are part of various trophic links and play a sanitary role in water bodies. Some species kill mosquito larvae and pupae, while others are pests of fisheries. Insects also provide abundant food for fish and other aquatic organisms. Inhabiting almost all types of water bodies, insects are able to live in wet places outside of them and fly from one body of water to another, which indicates their high ecological plasticity and wide distribution. At the same time, they often react sharply to changes in environmental factors, which is why the entomofauna of each particular water body accurately reflects its type and the processes taking place in this water body. Hence, insects play an important role as environmental indicators, which is essential for a comprehensive assessment of continental water bodies.

Insects are a very promising group of animals for bioindication research. They are distinguished by a large species and ecological diversity, different resistance to anthropogenic impacts and different characteristic reactions to them.

When determining the ecological status of a particular area/location, the following population characteristics of insects are of bioindicator value:

* The relative abundance of insect populations. In ecosystems that have experienced or are experiencing anthropogenic impact, the number of some insect species decreases, others increase, others do not change significantly, and others undergo abrupt changes (first decreases, then increases, or vice versa).

* Phenotypic structure of insects. The variability of phenotypic structure (the ratio of phenotypic forms of adults) may correlate with the level of air pollution, for example, an increase in the proportion of melanistic (black) individuals in populations.

* Sex structure of populations. The sex ratio in insects can be influenced by various factors. It is very difficult to determine which factor is decisive here, but a detailed study of the model species' populations in ecosystems can determine the degree of their anthropogenic transformation by the sex ratio index.

* Spatial distribution of insects in biocenoses. The spatial distribution of insects in biocenoses is influenced by microclimatic conditions, landscape structure and anthropogenic factors, including the impact of pesticides, heavy metal salts, agricultural and forestry activities.

* Seasonal dynamics. Climatic factors that cause photoperiodic and temperature reactions of insects determine their annual cycles. They differ from species to species. The ratio of groups distinguished by the type of adult activity in different biotopes and their number can be used to determine the degree of anthropogenic impact on their communities.

* Intraspecific body size of insects. The tendency of increasing insect body size for populations in habitats with increased anthropogenic pressure has been proved.

* The number of ecological groups in the insect community by biotopic preference. An objective indicator of anthropogenic transformation of biotopes is the number of ecological groups by relictity categories in the community, especially the number of eurybiont species (living in environments with different levels of factors), which increase in biotopes with increasing anthropogenic impact. The number of stenobiont species in such habitats is decreasing.

The degree of anthropogenic load on the environment can also be determined by such indicators as species composition and stationary distribution of insects; dynamics, structure and spectra of species dominance; nature of vertical distribution of soil insect populations in the soil profile; the nature of anatomical, morphological, biochemical, physiological, immunological, cytogenetic, biorhythmic and behavioural deviations under the influence of anthropogenic stressors; determination of the concentration of chemical pollutants and radionuclides in the body of insects, etc.

The number of insect species living in water bodies is significant, and methods for using them as bioindicators have been developed in some detail. Most methods are based on the use of indicator properties of individual species, as different species have different ranges of demanding environmental conditions. These methods require mandatory identification of animals to species.

Other methods are based on information about the characteristics of communities rather than individual species. They take into account the ratio of the number of certain organisms and their groups (taxa) in the community. These methods also require species identification, as well as counting the number of species, calculating the ratio of numbers, etc.

Several methods have been developed based on the use of both indicator properties of individual species, genera, families, and structural characteristics of communities. In this case, the advantages of both approaches are combined, there is no need to identify organisms to the species level, and the approach is accessible to non-specialists. The simplest, most versatile and at the same time suitable for widespread use are the Mayer method and the Woodiwiss method.

The species used are large, mostly visible to the naked eye, insect species that inhabit both bottom sediments and aquatic plant communities. Among them are representatives of taxa with a high sensitivity to pollution: aquatic larvae of a number of insects that spend most of their life cycle in water (larvae of mayflies, mayflies, water bugs, and hard-winged insects). Other groups of insects are able to withstand significant organic water pollution: larvae of chironomids (ringing mosquitoes).

These methods provide only a rough estimate of the ecological status of a water body and water quality, but they are more convenient and easier to use. They are available for use not only by zoologists, but also by technical staff of sanitary and epidemiological stations, biology teachers, members of school and student nature clubs, environmental activists, etc. This greatly expands public opportunities to implement a large-scale system of environmental monitoring of water bodies.

Collection and processing of entomological hydrobiological samples

Observations of aquatic insect biology are carried out both in the field and in the laboratory; for the latter, glass cylinders of 3-5 litres, half-filled with water and set at an angle of 45°, were used.

When planning work, research sites should be selected in advance, and schemes of sampling points should be drawn up. When choosing a survey season, it should be borne in mind that aquatic insect communities are best studied from spring to autumn.

Water bodies are surveyed in different areas: in the coastal zone, among aquatic vegetation and at the bottom. In addition, water traps are used to catch insects, which are 1.5-2.5-litre plastic bottles cut in half and stacked in a "top" pattern. The shores and bottom of dried-up water bodies are also subjected to research. In winter, samples are taken under the ice. At the same time, the lower surface of stones and other objects immersed in water is examined.

Sample collection, recording and labelling:

1. Select a habitat typical of the river section under study;
2. Enter the water and catch organisms within the selected habitat with a water net;
3. Turning the net out, rinse off its contents into a plastic bucket half-filled with river water;
4. Thoroughly rinse off by hand any organisms attached to plant shoots, stones or other solid objects that have appeared in the sample;
5. Remove plant shoots and their fragments, hard substrates, debris, etc. from the bucket;
6. Pour the contents of the bucket into the rinsing sieve;
7. Thoroughly rinse the contents of the rinsing sieve from the sludge;
8. Pour a small amount of water into the bottom of the jar and transfer the contents of the rinsing sieve into it;
9. Fix the sample by pouring it with a fixing solution (formalin, ethylene glycol, etc.);
10. Seal the sample jar and put an appropriate label on it (date, name of the water body, type and number of the habitat under study);
11. Make a detailed description of the sampling point in your diary. You may need this for further interpretation of the processing results.

The collected material is processed in the laboratory. The systematic affiliation of the collected insect species is determined. After that, the results of determining the taxonomic affiliation of organisms and counting "groups" should be recorded in a work diary (separately for each sample). These records can be used to calculate the Mayer index, which is based on the determination, using a special table, of a biotic index that characterises the degree of pollution of a particular area of a water body or watercourse.

Definition of the Mayer index. Groups of animals are divided into 3 groups according to their demanding environmental conditions - the columns in Table 7.1.

Table 7.1. Definition of the Mayer index

Inhabitants of clean water	**Organisms of medium sensitivity**	**Inhabitants of polluted water**
Mayflies larvae (Ephemeroptera) (Fig. 7.1)	dragonflies larvae (Odonata) (Fig. 7.2)	Water scorpion (Nepacinerea) (Fig. 7.4)
Springtails larvae (Plecoptera) (Fig. 7.3)	Twilight spinneret (Gyrinidae) (Fig. 7.5)	Water beetles (Hydrophilidae) (Fig. 7.7)
Caddisflies larvae (Trichoptera) (Fig. 7.9)	Diving beetles (Dryopidae) (Fig. 7.8)	Mosquito larvae (Chironomidae) (Fig. 7.10)
Floating beetle (*Platambus*) (Fig. 7.6)		

To determine the Mayer's index, count the number of groups found in the sample from the first, second, and third columns of the table. Multiply the number of groups from the first column by 3, the second by 2, and the third by 1. Find the sum of all three numbers. The sum characterises the degree of pollution of the water body: more than 22 – the water belongs to the 1st class of quality (very clean); from 17 to 21 – to the 2nd class (clean); from 11 to 16 – to the 3rd class (moderately polluted); less than 11 – to the 4th - 6th class (polluted, very polluted).

Among insects, the best indicators of the state of water bodies are representatives of mayflies, dragonflies, springtails, water bugs, beetles, damselflies, and some dipterans.

Fig. 7.1. The larva of the *Baetis daylily*
(https://www.researchgate.net/profile/J-Brittain/publication/234149978/figure/fig5)

Fig. 7.2. *Calopteryx* dragonfly larva (http://lifeinfreshwater.net/wp-content/gallery/broad-winged-damselfly)

Fig. 7.3. *Nemoura* springtails larva (https://www.imago-images.com/bild/st/0081495984/w.jpg)

Fig. 7.5. Twilight spinneret *Orectochilus* (https://www.mindat.org/gbif_t

Fig. 7.4. *Nepa* water scorpion (https://ukrbin.com/files/09/CRW_9471_01.jpg) Fig. 7.4. *Nepa*

Fig. 7.6. The *Platambus* floating beetle (http://vilkenart.se/Photos/911/Platambus_maculatus_590998_1.jpg)

Fig. 7.7. The water beetle *Hydrobius* (https://i0.wp.com/insektarium.net/wp-content/uploads/2020/03/hy-fuscipes.jpg)

Fig. 7.8. *Dryops* diving beetle (http://www.naturefg.com/images/c-animals/dryops-auriculatus.jpg)

Fig. 7.9. The larva of the *Rhyacophila* caddisfly (http://www.biopix.eu/photos/rhyacophila-fasciata-00043.jpg)

Fig. 7.10. *Chironomus* mosquito larva
(https://www.commanster.eu/Commanster/Insects/Flies/SuFlies/Chironomus.cingulatus5.jpg)

When selecting insects as model bioindication objects, we are guided by the generally accepted requirements for bioindicator organisms such as sufficiently well-studied species and intraspecific taxa, wide range, low migration activity, high indicative plasticity of the species, ease of collection in nature, and sufficient numbers for sampling.

8. FISH AS BIOINDICATORS OF FRESH WATERS

The transformation of aquatic ecosystems caused by anthropogenic changes at the basin level has led to a significant deterioration of fish populations in most reservoirs of Ukraine. The goal of any reservoir reconstruction is to increase productivity or expand the spectrum of its use, but the structural complexity of ecosystems does not allow predicting all the negative changes and processes that will develop as a result of human activity. In this context, the problem of identifying environmental risks and indicators at the biocoenotic and population levels that will allow for negative changes in ecosystems is acute. At the moment, the level of ichthyological research does not always allow us to clearly determine what processes in reservoirs are associated with changes in the species composition or structure of fish populations. That is why there is a need to develop theoretical approaches to the use of fish as indicators of the state of hydroecosystems.

The use of structural features of fish populations and communities as bioindicators has both advantages and disadvantages compared to aquatic invertebrates, algae, and higher aquatic plants. The advantages of this technique include the relatively large size of objects, the relative simplicity of determining the species belonging to fish, the possibility of conducting research with minimal use of laboratory equipment, as well as the fairly simple determination of the structural characteristics of fish populations.

The most significant defects are: the difficulty of determining reliable indicators of the number of populations of various fish species; mobility of representatives of the ichthyofauna, which allows them to avoid adverse conditions; the factor of removing fish for fishery purposes, which disrupts the structure of populations and groups.

Most Western European countries use biotic indices for standard water quality control for bioindication. In the last decade of the 20th century in Europe and the USA, there was a tendency to develop biological assessment methods within the ecosystem integrated approach. In Ukraine, researchers are currently showing interest in studying different approaches to using fish as indicators of the state of hydroecosystems. At the same time, it should be noted that there is a certain difficulty in using fish as indicators, which is primarily connected with the following disadvantages:

1) empirical data have some ambiguity;

2) lack of reliable criteria for choosing absolutely adequate biological indicators for the purpose of assessing the impact on ecosystems;

3) the problem of choosing a "benchmark" for comparing assessment results;

4) about 2/3 of biotic indices are based on benthic macroinvertebrates;

5) fish are considered very rarely as bioindicators;

6) the possibility of bioindication based on the structural features of fish populations in the reservoirs of Ukraine has not been sufficiently investigated;

7) the vast majority of research on the problem of bioindication in Ukraine is carried out on large rivers and reservoirs, small rivers have not been studied in this aspect;

8) problems of assessing the quality of the environment from anthropocentric and ecosystemic positions, and problems of determining the optimal level of anthropogenic transformation of hydroecosystems;

9) new threats to the stability of ecosystems are constantly arising - this requires expanding the possibilities of bioindication.

The detection of ichthyological indicators at the biocenotic and population levels, that characterize the state of hydroecosystems, may in the future be the basis for research aimed at predicting changes and preventing ecological risks in the reservoirs of Ukraine. The detailing of the dependencies between quantitative indicators characterizing the structure and dynamics of ichthyocenoses and fish populations and the influence of the main factors on ichthyofauna, on the other hand, allows us to reveal the peculiarities of the structure of ichthyocenoses and the quantitative characteristics of the size-mass, sex structure of fish populations, which correspond to a certain level of negative changes in hydroecosystems. Analyzing the existing approaches and methods, in our opinion, there are 5 indicators of population and coenotic levels that will allow us to judge transformations in the reservoir:

Divercity of the population . As you know, each age group is represented by individuals of different sizes, which depends on the quality of the environment, so their size distribution will differ. To assess the current state of environmental quality, analyzes performed on juveniles and short-lived fish will be most informative, as the size diversity of older age-groups of long-lived fish may be the result of actions that took place in past periods. The coefficient of variation can also be an indicator . Thus, if the ecological conditions of the environment are favorable for the development of fish, then individuals of the same species with a wide range of biological characteristics survive and coexist, for example, fish with different body lengths and weights. If the ecological conditions of the environment are unfavorable and negative factors influence them, then the action of stabilizing selection is observed, which cuts off extreme variants and supports a certain phenotype with a narrow range of indicator variations. Accordingly, the coefficient of variation of each indicator will be low in its value.

Size and mass structure of the population. Indicators of the population structure of a species can be an indirect reflection of the influence of negative factors. Thus, significant dynamics of indicators in the size-mass structure of individuals makes it possible to talk about the facts of overfishing and undermining the population size. The use of this indicator is possible for species with sexual dimorphism in size .

Ratio of sexes is a particularly important indicator for fish with sexual dimorphism. Under certain conditions, there may be sharp deviations from the "normal" sex ratio as a result of various natural and/or anthropogenic factors. The sex structure of individual fish species varies considerably, but mostly the ratio is about 1:1. Taking this dependence into account, it can be stated that the preference of females over males can be an indicator of the level of extraction and the state of the fish population in the studied reservoirs.

Individual morphological variability of individuals and the presence of phenodeviations. To determine the level of variability when studying a natural population as a complete genetic-evolutionary system, accounting is perspective for the stability of individual development by such features as the level of fluctuating asymmetry and the number of phenodeviations. The latter, as a peculiar group of changes that occupy an intermediate position between qualitative and quantitative signs and indicate hereditary deviations from the norm, are very changable and occur with different frequency. As a rule, in natural populations there are different levels of deviations, the frequency of which is small, but in some cases their frequency increases significantly. In addition, there is another approach to assessing the stability of individual fish development in the conditions of anthropogenic pressure on ecosystems - the analysis of morphological bilateral signs, in which the variability of these signs on the left and right sides of the body is clarified.

Among the clearly expressed signs, that is, those that do not require a very close inspection of fish, there are various violations in the structure and topography of the organs of the lateral line.

The main types of fish anomalies in the studied region were: curvature of the spine, underdevelopment of one gill cover, bent fins. Their share was 1%, and the main reason for such changes is inbreeding. Summing up, it should be noted that the frequency of appearance of any phenodeviant depends significantly on the living conditions of the fish. The most important environmental factors that affect the frequency and degree of manifestation of these anomalies are temperature, excessive or deficient supply of food for fish, the gas regime of the reservoir, water pH, and the level of pollution. The presence of phenodeviants in the population can be considered as an indirect indicator of a decrease in genetic diversity and developmental homeostasis. Genes or a combination of genes that are not detected in a well-balanced genotype and optimal living conditions are determined when the genetic imbalance occurs and when environment is unfavorable.

A large number of asymmetric manifestations in fish indicates a decrease in the viability of their natural populations being influenced by powerful anthropogenic pressure, pollution in particular, and can be used as indicators of the state of the environment.

Anomalies of the skeleton. The connection between the frequency of skeletal anomalies of aquatic vertebrates and pollution was confirmed experimentally. The organochlorine pesticide Kepon, for example, caused scoliosis in lampreys, and when exposed to heavy metals, spinal curvatures and fractures were observed in fish. Therefore, monitoring involves a careful examination of the fish for obvious abnormalities, with possible follow-up fluoroscopy to detect hidden deformities, such as vertebral adhesions. It is difficult to examine the gill stamens and dorsal fins. Plankton and plankton samples can be of great benefit in order to detect pathologies in larvae and anomalies in young fish.

The number of cases of skeletal anomalies in fish is increasing every year. Examples of anomalies: spinal fusions and curvatures, spinal compression (flattening), head and fin anomalies. Such violations occur in most natural populations, but they are most often observed in polluted water areas.

Ulcers on the skin are observed in many types of fish. The frequent appearance of ulcers was called "ulcer syndrome". The main reason for the appearance of ulcers in fish is a high level of contamination of water bodies with hydrocarbons and an increase in water populations of microorganisms potentially pathogenic for fish. In the spring, the percentage of sick fish is higher. Therefore, when catching fish for the purpose of monitoring, the season of the year should be taken into account. In addition, microbiological tests of samples taken from bottom sediments and the water column should be carried out.

Fin erosion is one of the most common fish diseases, clearly linked to pollution.

The causes of erosion are complex and may include chemical agents (which affect the epithelium), lack of dissolved oxygen in the water, and secondary bacterial contamination. Systematic bacterial infection is not necessarily associated with the appearance of fin erosion, although many types of bacteria can be identified in a sample taken from an ulcer. Monitoring of this indicator is recommended taking into account the season, size of fish, sensitivity of the species, living conditions and migration.

Tumors are found in almost all types of fish. Tumors are often infectious. Tumors can be caused by extreme water pollution and viral infections. There is also evidence that aflatoxin contamination can cause liver tumors in lampreys. Fish tumors are potentially useful indicators for monitoring the aquatic environment.

Species and taxonomic diversity. Information on the taxonomic diversity of functional groups of hydrobionts is an indicator of environmental conditions. Thus, species and taxonomic diversity will have maximum values for some average water quality parameters and decrease towards very clean, oligotrophic, oligosaprobic and very dirty hypertrophic and polysaprobic water bodies. It should also be noted that the variety of fish species depends on many hydrological, hydrobiological, hydrochemical and other factors. The most important should include current strength, depth, transparency, salinity, gas regime, feed base, etc. All of the above factors have an impact both directly and indirectly on specific species and on the structure of the ichthyocenosis as a whole.

It is known that the relationship between indicators of diversity and sustainability (stability) of ecosystems is sometimes contradictory. The stability of biosystems increases with increasing diversity, but at the same time it is noted that the diversity itself is formed due to the stability of ecosystems.

Thus, as a result of the analysis of various approaches in the field of bioindication of water quality and the state of hydroecosystems, it should be noted the perspective of using ichthyological indicators. It is advisable to use them as bioindicators at the population and coenotic levels. At the population level, the following indicators are promising for bioindication: - dimensional diversity of individuals of the population using the variation indicator; size-mass structure of the population with indicators of average long-term data on body length or weight; sexual structure with indicators of increase or decrease in the share of individuals of the same sex; individual morphological variable number of individuals and number of phenodeviations. At the coenotic level, it is advisable to use the following indicators as indicators: the number of fish species, diversity indices, and the diversity of fish with different degrees of wall- and eurybiontity.

9. AMPHIBIANS AS BIOINDICATORS OF FRESH WATERS

One of the modern and most promising methods of ecological assessment of the quality of the environment is bioindication, which allows you to detect the degree and intensity of the impact of pollutants, as well as trace the dynamics of ecosystem degradation in time and space and present the data in an integrated form. The natural reactions of the animal organism to the quality of the environment can often be extrapolated to humans.

The advantages of using bioindicators for the integral assessment of biosystems of various levels of complexity is that they react not only to individual pollutants, but also to the entire complex of substances that affect certain reactions of the organism as a whole.

Amphibians meet all the requirements for animals used for bioindication. Amphibian species that occur in the study area have clear and convenient signs for research, their eggs and larvae are sensitive to pollution. The morphophysiological parameters of the amphibian organism reflect the state of the local biotope of existence. Amphibians do not have a tendency to migrate, they are characterized by a high level of polymorphism. All these factors make it possible to successfully use amphibians as bioindicators.

In order to identify adaptations of amphibians that arise under the influence of water pollution, we propose to conduct research at three levels: at the population level (to assess the number, sexual and phenetic composition), at the level of individuals (to assess the morphology, physiology and stability of development) and at the cell level (the stability of nuclear structures).

Determination of the species and quantitative composition of amphibians must be carried out during life according to the standard method on every 100 m of the coastline. The gender and phenetic structure of populations should be analyzed in the spring without removing animals from the habitat.

Study of the structure of amphibian populations

The structure of the population makes it possible to assess the degree of ecological plasticity of the population and the species as a whole. One of the most important assessment criteria of the state of the population and biological progress or regression is *the size of the population* is an integrating indicator reflecting the state and dynamics of the population.

The sex composition of the population of most tailless amphibians is easily determined by the presence of resonators and nuptial calluses in males. The ratio of males to females in the population should theoretically be close to 1:1. It is with an equal share of females and males in the reproductive part of the population that a higher reproductive potential is formed.

Fig. 9.1. Male lake frog with resonators

A decrease in the number of females brings only harm to the population, as it leads to a decrease in its reproductive potential and an reduction of its genetic structure. Regarding the shortage of males, there is an interesting point of view in the literature, according to which the loss of males under the influence of adverse factors is to some extent beneficial, because in this case the reproductive capabilities of the population do not suffer or suffer to a much lesser extent than with the loss of females. At the same time, genotypes resistant to adverse factors are selected. Thus, a microevolutionary process is ensured.

The sex structure of amphibian populations can be used as a pollution marker, which allows for quick, reliable water bioindication without removing animals from the population.

Phenetic structure of amphibian populations . Genetic heterogeneity of natural populations is manifested in intrapopulation polymorphism. In a number of species of frogs, there is the so-called "striata" morph, which phenotypically manifests itself in the form of a light dorsomedial stripe (Fig. 9.2) , and the "maculata" morph - a spotted individual (Fig. 9.3) . It is known that in many species of amphibians, the proportion of the striata morph is increasing in populations most prone to anthropogenic influence. Analysis of the genetic nature of the trait indicates that it is a monogenic mutant. The dominant allele of the diallelic autosomal gene - striata determines the presence of a stripe (complete dominance) . Thus, striata is a good phenetic marker that can be used to study phenotypic manifestations of changes in the genetic structure of a population.

Fig. 9.2. Morph "striata" of the lake frog

Fig. 9.3. Morph "maculata" of the lake frog

Taking into account the effect of non-selective elimination on the genetic structure of the population, as well as a number of features of the striata morph, we can conclude that the high occurrence of this phenotype in polluted water is due to a number of advantages it receives in these conditions. The striata morph is characterized by a higher level of oxidation-reduction processes, hemoglobin content, reduced sodium permeability and the content of a number of metals at a higher body weight. A change in the phenetic structure of amphibian populations in a polluted water body is associated with different adaptive value of phenotypes, which is manifested in their selective mortality.

Thus, the ratio of striata and maculata phenotypes in amphibian populations can be a convenient feature for bioindication of pollution.

Morphological indicators of amphibians against the background of anthropopressing

The sizes of morphological features are formed largely under the influence of the environment, and the average values of many features can be reliable markers of negative changes occurring in the habitat of amphibians. Living in polluted water bodies is usually associated with changes in the exterior parameters of amphibians (body length and weight). It is known that amphibians are smaller in size in a polluted water body. This may be due to the accumulation of toxic substances in their body, metabolic disorders.

For bioindication, it is advisable to use both the entire complex of signs (males and females) and individual most informative ones, since with the increase in the concentration of heavy metals in water, a reliable change of all morphological signs occurs.

Standard morphological parameters must be measured using a caliper with an accuracy of 0.1 mm.

Teratogenesis of amphibian populations . Under conditions of environmental stress, the variety of types of anomalies and the general frequency of aberrations changes, so the variety and frequency of anomalies can be an indicator of the degree of transformation of the natural environment.

The high frequency and variety of types of anomalies , in our opinion, may be an indicator of chronic stress due to the increased content of heavy metals in the water. According to the literature, anomalies are the result of a critical disturbance in the stability of development (Kurtyak F.F., 2010)

The frequency and diversity of congenital morphological abnormalities can be highly effectively used in environmental monitoring systems.

The *stability of development* is evaluated using the indicator of fluctuating asymmetry. The degree of pollution of the water environment relative to the norm is determined by a violation of the stability of development based on fluctuating asymmetry. The indicator of fluctuating asymmetry reflects morphogenetic homeostasis.

For operational primary bioindication of the ecological state of reservoirs and watercourses, it is advisable to use the population characteristics of tailless amphibians, the ratio of males to females, the proportion of the striata morph, and the assessment of fluctuating asymmetry.

For an extended, in-depth assessment of the ecological state of reservoirs and watercourses, the entire complex of tested population, organismal and cytological characteristics sensitive to environmental pollutants can be recommended. This complex also includes (in addition to the characteristics for primary bioindication) variations of morphometric parameters, indexes of internal organs and fatness, detection of the spectrum of phenodeviants, assessment of ontogenetic homeostasis by the level of stability of nuclear structures .

A high birth rate and a wide variety of phenodeviants can be recommended as indicators of heavy metal pollution of water bodies and watercourses.

10. WHAT DO YOU NEED TO KNOW ABOUT WATER AND ITS MICROBIAL COMPOSITION TO PROTECT YOURSELF FROM INFECTIONS THAT ARE SPREAD BY WATER?

At different times of the development of human civilization, water was one of the crucial conditions for human existence and, at the same time, a factor in the spread of infections. With the invention of sewerage and treatment facilities, the situation has changed drastically, at the same time due to the intense deterioration of the ecological situation, the water of open reservoirs and other objects of the environment can be a factor in the transmission of pathogenic microorganisms.

Microorganisms are mandatory inhabitants of water bodies, which play a key role in their vital activity, providing closed cycles of the main biogenic elements. Water is a natural habitat for various microorganisms. The totality of all aquatic microorganisms is designated by the term microbial plankton. Its qualitative composition depends on the season, meteorological factors, the degree of remoteness of the reservoir from populated areas, the chemical composition of the source, the nature of the soil of the banks, the presence and composition of hydrobionts, sources of pollution.

The quantitative composition of microorganisms in water is affected by its bio- and physico-chemical composition (content of organic and inorganic substances, temperature, pH value, irradiation, saturation of CO_2 and O_2, etc.), depth of reservoirs, flow rate, flora and fauna, inflow of sewage water and other factors. On the surface of the water, microorganisms are adversely affected by the rays of the sun, and at depth - high pressure, low temperature, lack of oxygen.

Water has its permanent inhabitants, at the same time, many microorganisms fall from the soil, especially after rains. So, if 1 ml of lake water contains about 10 microbial cells, then after rain their number increases to 1,200. These are representatives of microorganisms that participate in the cycle of nitrogen, sulfur, and fiber decomposition. Photosynthesizing bacteria develop in water bodies rich in hydrogen sulfide. When a large amount of organic substances enters, bacteria appear that can be the causative agents of intestinal infections and other diseases.

The number of microorganisms in water is also affected by the proximity of settlements - towns and villages. There are significantly fewer microorganisms in the water upstream of settlements than near the settlement and downstream.

The number of microorganisms also changes depending on the depth. Thus, 70-100 microbial cells are determined on the surface of the reservoir in 1 ml of water; at a depth of 5 m - 140-150; 10 m –~200; 20 m –~150; 40 m –~50; 50 m - only 5-10 cells.

Microorganisms that enter the water from the soil can survive there for different periods of time. It depends on the type of microorganism and the nature of the water. Cholera vibrios, typhoid and dysentery bacteria, causative agents of tularemia, anthrax bacilli (anthrax) and many other microorganisms dangerous for humans and animals are detected in the water.

It is believed that about 25% of infectious diseases are transmitted through water. For example, in clean well water, salmonella can be stored from 2 days to 3 months, shigella - 5-9 days, leptospira - 7-150 days. The quality of water is determined, first of all, by the total number of microorganisms found in it.

Since water is used during the production of any type of product, as well as directly for food, the compliance of its quality with sanitary and microbiological indicators is extremely important. Intestinal infections such as cholera, typhoid and paratyphoid, salmonellosis, dysentery, hepatitis A, poliomyelitis, as well as leptospirosis, anthrax, tularemia, tuberculosis, thrush, Ku fever, and various fungal diseases can be transmitted by water.

In order to prevent the spread of infections by water, there is a system of sanitary and microbiological research . The purpose of sanitary and microbiological research is:

- detection of pathogenic microorganisms and products of their metabolism (toxins) in environmental objects;
- assessment of the sanitary and hygienic quality of these objects;
- creating recommendations for the "remediation" of environmental objects by influencing the pathogenic microbiota.

Fig. 10.1. Determination of ZMCH of a water sample from a natural reservoir

All and sanitary indicator microorganisms (SPM) are considered as indicators of biological water pollution .
Sanitary indicator microorganisms:
are constantly and in large quantities contained in human and animal secretions;
do not reproduce intensively in the environment;
are easily detected by modern research methods.

Sanitary indicators of the state of the environment. Total microbial count (TQM) is the presence of mesophilic aerobic and facultatively anaerobic microorganisms in environmental objects, regardless of the species composition in a certain volume or mass of the product.

The species composition of the main sanitary-indicative microorganisms:

- Escherichia coli bacteria (E. coli)
- enterococci,
- proteins,
- clostridium botulism and tetanus,
- thermophilic bacteria,
- salmonella,
- bacteriophages of enterobacteria (coliphages).

Indicators of fecal pollution, which means, possibly contamination of water with pathogenic microorganisms, are bacteria of the Escherichia coli group (BGKP).

Bacteria of the genera Echerihia, Enterobacter, Klebsiella, Citrobacter and other representatives of the Enerobacterium family , which are Gram-negative rods that do not form spores and capsules, belong to BGKP. They ferment glucose and lactose with the formation of acid and gas at a temperature of 37 °C for 24–48 hours.

Water quality is also assessed by the presence of E. coli in it. Determine coli-titer and coli-index. The coli index is the number of individuals of Escherichia coli found in 1 liter of water. Coli titer is the smallest amount of water in which at least one Escherichia coli is found. The presence of the latter in the water indicates its contamination with the contents of the gastrointestinal tract.

Tap water is considered to be of good quality if the coli index is 2-3 and the coli titer is 300. Well water should have a coli index of no more than 10 and a coli titer of at least 100.

The total microbial count indicates contamination of the object with substances of organic origin. The greater the value of ZMCH, the greater the probability of the presence of pathogenic microorganisms in the object. But this number is not always a correct indicator of object pollution, since its value may be high due to saprophytic microorganisms, while pathogenic ones may be absent. In this regard, ZMCH is used as an indicator of the intensity of environmental pollution by organic substances.

Fig. 10.2. Exceeding the indicators of sanitary norms of water quality according to the microbiological indicator: ZMCH and the number of bacteria of the *Enterobacteriaceae family*

General rules for water sampling

Water samples for analysis are taken from open water bodies with the help of special devices - bathometers, which are lowered to a certain depth, where the device opens and water is collected in it, which is then brought to the surface. Certain rules must be followed when taking samples.

1. If there is a source of pollution, then three water samples are taken from such a reservoir : above the source of pollution, opposite it and downstream.

2. Water samples from wells are taken 2 times: in the morning before water analysis and in the evening after analysis.

3. From ponds, lakes and rivers, water samples are taken from a depth of 0.5 - 1 metres and at a distance of 1 - 2 metres from the shore.

Water samples must be taken in sterile containers . For microbiological analysis 2 liters of water are needed. An accompanying note is attached to each sample, in which the following is noted: the name of the source and its location; year, month and date of sampling; the exact place of sampling; air temperature, data on precipitation on the day of sampling and for the last 10 days; water temperature; a brief description of the reservoir; for which purpose it is directed. Samples are delivered to the laboratory immediately.The content of mesophilic aerobes and facultative anaerobes is determined in 1 liter of water . Two volumes are inoculated from each sample, so that the number of colonies that will grow varies between 30 and 300. When analyzing tap water, 1 ml of contaminated water - 0.01 and 0.001 ml is added to each of the two cups . When determining the microbial count of heavily polluted and wastewater, the studied samples are diluted with sterile water, making serial dilutions.

Sanitary and microbiological examination of water is carried out during :

- selection of the source of centralized economic and drinking water supply and periodic control of this source;
- control of the effectiveness of disinfection of drinking water of centralized water supply;
- during monitoring of underground sources of centralized water supply (artesian wells, groundwater, etc.);
- determination of the state and degree of suitability of water sources of individual water use (wells, springs, etc.);
- monitoring the sanitary-epidemiological state of water in open bodies of water: reservoirs, ponds, lakes, rivers.

11. SIGNIFICANCE OF ENVIRONMENTAL UPBRINGING AND EDUCATION

The ecological situation on the planet encourages rapid re-development of thinking of the world society, formation of ecological awareness and ecological culture. In this regard, education and eco-education are becoming new priority areas of education. The experience of the countries of the European Union shows that based on the principles of environmental policy of the country, the high level of ecological culture and the active position of society in nature conservation activities, it is possible to improve the state of the environment . However, the high level is ecological culture is not possible without an appropriate level of environmental education, which must be carried out on the basis complexity and continuity. Increasing the level of education in society based on the integration of knowledge and modernization of the entire educational space with sustainable elements development of societ is urgent . Systematic environmental education in the countries of Western Europe and Japan starts already from early childhood .

Environmental education today is a continuous complex process of forming an ecological outlook, ecological consciousness and culture of the entire society as a whole. Its foundation lies in the acquisition of a system of knowledge about the laws of functioning, vital activity and interaction of all living things, the role of man in preserving the environment; the process of environmental education and training, development of professional knowledge, skills necessary for environmental protection activities.

The level of development of modern education in general and eco-education in particular depends on the implementation of new original and innovative methods and methods of teaching and upbringing. This includes the widespread and continuous computerization of environmental education from the youngest students to the graduates. It is also necessary to continue the introduction of extracurricular activities of the teacher, for example, "summer ecological camp", or starting from the younger grades, project lessons such as "The forest is my friend", "Nature and art", etc.

Environmental education is an organic and priority part of the entire education system, which gives it a new quality, which forms a different attitude not only to nature, but also to society, to human being. Environmentalization of education means the formation of a new outlook and a new approach to activity based on the formation of noospheric humanitarian and ecological values.

Appropriate school education and upbringing, their modernity and progressiveness depend primarily on the direction and quality of the professional training of the teacher. But, at the same time, the formation of a proper attitude to the surrounding world , connected primarily with the imitation of those models and the attitude that is characteristic of people from the closest environment of the child. Parents, as well as teachers, give the child the first example of morality.