BIOLOGICAL PROPERTIES OF FRESHWATER BODIES

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Keywords: water ecosystems, phytoplankton, macrophytes, zooplankton, zoobenthos, fish, bioproduction, biodiversity.

Contents

Summary

Animals and plants inhabiting rivers, streams, lakes and wetlands create the biological properties of fresh waters. The moving freshwater biotope enables the survival and reproduction of life forms capable of living in a suspended state and others attached to the bottom. Aquatic communities are represented by phyto- and zooplankton, benthos (bottom organisms) and nekton (fishes). Primary production is produced by autotrophs (phytoplankton and macrophytes). Secondary production is the result of transformation of organic matter by heterotrophs (zooplankton, zoobenthos and fishes). Freshwater ecosystems are negatively effected by human activity that leads to eutrophication, acidification, and pollution, by toxic and radioactive materials.

We know the following biological properties of waters that provide life to different organisms: the ability to support ecosystems created by natural evolution, as well as their biodiversity; self-renewable production of organic matter including fish; self-purification of wastes; maintenance of global turnover of matter in biogeochemical cycles in the biosphere.

1. Introduction

The biological properties of freshwater ecosystems are defined by the whole complex of animals and plants inhabiting water bodies, and the evolutionarily comprised structure of interrelations between living organisms and the physico-chemical conditions of water bodies and their catchments. These conditions are heavily influenced by climate, geographic location and type of water body. It is an incontrovertible paradigm that water is essential for maintaining life. It is also an irreplaceable resource for living organisms whose vital functions themselves also influence water properties. By 'biological properties of water bodies' (rivers, lakes, streams, bogs) we imply those properties which are inherent to aquatic ecosystems in general, i.e. the total aggregation of biotic and abiotic elements connected by flows of matter, energy and information. Life in water ecosystems, unlike terrestrial ecosystems, is characterized by the considerable dependence of hydrobionts on their environment, owing to the important role of ecological metabolism taking place in water ecosystems, and to of the rapid distribution of nutritious matter. Water as a biotope is much denser than air. This fact defines the life forms capable of living in a suspended state and being attached to the bottom.

The following functional characteristics are attributed to biological properties:

- maintenance of evolutionarily formed structure of aquatic ecosystems and adjacent habitats and their biodiversity;
- self-renewable production of organic matter, including protein (e.g. fish) that is consumed by humans;
- self-purification, by degradation and sedimentation of wastes;
- maintenance of global turnover of matter in biogeochemical cycles in biosphere.

2. Main Features of Biological Structure of Fresh Waters

Species diversity in freshwater communities is insignificant compared to terrestrial ecosystems. Many freshwater taxons (species, genera, families) are widely distributed within the continents and even on adjacent continents. All biological communities are not isolated in water bodies. They are closely interconnected with the environment. Freshwater biotopes are divided into three groups:

1. Lentic systems (Lat. *lenis*)- lakes and pools.
2. Lotic systems (Lat. *lotus*)- streams and rivers.
3. Wetlands.

2.1. Lakes

The community of fauna and flora, and their inter-relationships, in lakes and pools depend on the geographic zone and on stratification. The latter has a major impact on availability of dissolved nutrients, oxygen and temperature. The following zones are normally distinguished in a lake: the littoral zone, where rooted vegetation (macrophytes) predominate and bottom organisms (benthos) are abundant; the limnic zone (open water zone), where plankton dominates; and the deep-water profundal zone, where heterotrophic organisms live. Such characteristics as species structure and abundance vary significantly between different geographic regions. These characteristics also depend on peculiarities of geology, relief and hydrologic regime.

Autotrophic organisms are represented by macrophytes and phytoplankton. Macrophytes are mainly associated with shallow lakes, because most are attached to the bottom and they require good light levels. In deep lakes phytoplankton is mainly responsible for primary production. If the turbidity is low, phytoplankton can occur throughout the water column. Phytobenthos, comprising both algae and spermatophytes) can be dominant in small lakes, especially in shallow lakes and the fringes of large ones. Trophic chains based on detritus are well developed in lakes.

Lake plankton consists mainly of autochthonous elements. The number of bacteria reaches 1-3 million. specimens per 1 ml of water, and there may be several tens of actinomycete cells per 1 ml. Fungi are represented by the most numerous yeasts and most diverse phycomycetes. Phytoplankton in coldwater lakes is represented by common diatoms (e.g. *Melosira, Asterionella, Cyclotella*). Warm water lakes are inhabited more by green algae (*Closterium, Pediastrium, Scenedesmus*) and blue-green algae (*Microcystis, Aphanizomenon, Anabaena*). Phytoplankton biomass in lakes around the world varies from 0.0003 to 300 mg per m^3.

Zooplankton consists mainly of colorless flagellates, infusoria, rotifers, cladoceran and copepod crustaceans. The most typical infusoria genera are *Tintinnus* and *Tintinnopsis*; rotifers include *Asplanchna* and *Brachionus*; cladocerans ('water fleas') include *Daphnia, Bosmina, Chydorus* and *Diaphanosoma*, and the copepods include *Diaptomus, Heterocope, Cyclops, Mesocyclops*. Rotifers and cladocerans predominate in coldwater lakes. The density of infusoria in various lakes is typically 20 000 to 30 000 specimens per liter, but can be up to 100 000 specimens per liter. The number of colorless flagellates is much higher. The greatest number and biomass of different types of phytoplankton are usually present in the surface layer, particularly in stratified lakes. The clearest stratification coincides with the peak period for photosynthesis.

Unlike mires and flowing water bodies, neuston and pleuston are richly represented in lakes. Bugs (e.g. *Gerris, Hydrometra, Velia), Gyrinus* beetles, and dipterous flies, e.g. *Podura* and *Ephydra* inhabit a surface film of water. The lower surface of a water film on vegetation is inhabited by invertebrates such as beetles (e.g. *Hydrophilidae*), water boatmen (e.g. *Notonecta*), snails (e.g. *Lymnaea*), crustaceans (e.g. *Cyclops* and *Scapholeberis*), mosquito larvae (e.g. *Culex* and *Anopheles*), and larvae of other insects and fishes. Duckweeds (*Lemna*) are common higher plants that float on the water surface.

Benthic organisms reach their greatest biodiversity and number in the littoral zone (i.e. near the shore). They are less well represented in the sublittoral, and are scarce in the profundal. Phytobenthos usually develops at a depth of less then 4-5 meters. In Lake Baikal, however, phytobenthos occurs at depths down to 50 m.

Macrophytes, e.g. *Phragmites*, *Scirpus*, *Ceratophyllum, Sagittaria*, *Typha*, etc. are most vigorous in the zone adjacent to the shore, at depths of 1-2 m. Water lilies such as *Nuphar* and *Nymphaea* and pondweed e.g. *Potamogeton* can form a fringe in deeper water down to 2 to 2.5 m. In Lake Baikal and a few other lakes, algae and mosses can occur at depths down to 50 meters, e.g. *Cladophora*, *Enteromorpha*, *Spirogyra*, *Fontinalis*, etc. Bacteriobenthos can be prolific on silty substrates. Such ground can contain several billions of bacteria per gram of substrate, along with high densities of fungi and actinomycetes.

Like phytobenthos, zoobenthos in lakes is most abundant in the littoral zone and least so in the profundal. Many species of insect larvae, particularly chironomids (e.g. *Cricotopus, Psectocladius, Trichocladius*; *Apatania, Leptocerus*), mayflies (e.g. *Heptagenia),* stoneflies, snails (e.g. *Lymnaea ovata)*, sponges (e.g. *Spongia) and hydrozoans* (e.g. *Hydra*) etc. live in the bottom sediments near the shore, with greater diversity if stones are present to provide some structure. Oligochaete worms (e.g. *Propappus volki),* mosquito larvae (e.g. *Bezzia, Culicoides*), and nematode worms are common on exposed sandy shores, but species diversity of benthic organisms is generally higher on silty ground. Oligochaetes such as *Tubifex* can be abundant, as can the chironomid larvae *Spirosperma*, *Chironomus*, *Glyptotendipes*, and *Cryptochironomus*, and mollusks such as *Pisidium*. From the littoral to the profundal the substrate gradually become more silty. The bottom fauna becomes poorer as light levels decline. Chironomid larvae, mollusks and oligochaetes are most common at depth. Some microbenthic animals, such as cladocera, copepod and ostracoda crustaceans, are abundant in lake sediments.

Numerous periphytic algae live on the surface of macrophytes, stones and other material. Organisms such as *Cricotopus* and other chironomid larvae can inhabit the periphyton.

Nekton is almost completely composed of fishes; they comprise local, lake-river and anadromous species. Northern and high mountain lakes tend to be dominated by salmonid fishes. Carp are most common in southern lowland lakes. Moving southward, the species diversity and biomass of fishes increase.

Lakes are generally divided into oligotrophic, mesotrophic and eutrophic, depending on availability of nutrients and production of organic matter. Ultra-oligotrophic lakes (mostly arctic and high mountain coldwater lakes) can also be recognized as a separate category, with very high transparency of water. At the other end of the spectrum, hyper-eutrophic (mostly tropical) lakes are distinguished as a category of eutrophic lakes. Oligotrophic lakes may become naturally transformed by inflow of nutrients, and may become eutrophic. Today, however, such transformations are more often the result of human activity, particularly run-off of agricultural fertilizers and sewage pollution (anthropogenic eutrophication).

Salinity is another important variable in lakes, and brackish and salt water lakes are distinguished from freshwater lakes. Endorheic lakes, i.e. those with no outlet, are most likely to become brackish or saline, because they are subject to on-going evaporation and concentration of salts.

Lakes often become stratified, particularly in summer in regions with a temperate climate. In summer warm upper layers (epilimnion) become temporarily isolated from cold, denser, deep waters (hypolimnion). Their junction is known as the thermocline zone, and this can act as a barrier for exchange of matter. Oxygen concentration in the hypolimnion, and nutrients in the epilimnion, can become depleted, thus limiting biological production. Intermixing of all water layers occurs in autumn when the surface layer cools, becomes denser and sinks. The consequent 'turnover' of water supplies nutrients to the photic zone and oxygen to the deeper layers, and this can result in sudden growth or even blooming of phytoplankton. In the regions with a warm climate intermixing occurs only in winter; in tropical and arctic regions the mixing is more gradual and irregular.

2.2. Streams and rivers

The fauna and flora of flowing (lentic) systems is characterized by significant species diversity, closely related to biotope diversity. Rivers are divided into zones according their plant and animal communities.

2.2.1. Upper reaches of rivers (streams)

The upper reaches of streams in upland and mountainous areas are characterized by such factors as shallow water, low temperature, fast flow, high saturation with oxygen, exposed rocks and a relatively large splash zone. The fast flow prevents colonization by higher plants but algae (e.g. *Hydrurus*) and mosses (e.g. *Fontinalis*) can become well established, attaching themselves to relatively stable rock and large boulders. The fauna is largely restricted to small-sized animals that can live among the algae or moss, or live in crevices and under stones. Several species of mollusk may be present in upper reaches, as they have efficient means of securing themselves to hard surfaces. Trout and grayling may be present but their biomass is normally very low, because of the general lack of food and the need to constantly swim against the current.

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Biographical Sketch

Tatyana I. Moiseenko is Professor of Ecology, and a corresponding member of Russian Academy of Sciences. She work in the Water Problems Institute of the Russian Academy of Sciences as Deputy Director and Head of the Department of Water Quality and Ecology. Her main sphere of scientific interests is aquatic ecology. Of special interest is**:** water ecosystems under pollution impact (toxic pollution by metals, eutrophication, acidification, and structural-functional changes in water ecosystems; diagnostics' criteria of early warning in water ecosystems and critical levels and pollution loads for surface water. She is author and co-author of more than 250 publications, including 7 books. She works as an expert in a number of international projects, and is leader of a Scientific Project entitled**: "**Regularities of Water Ecosystems Changes under Anthropogenic Impact in Global and Local Scales" under the Russian Foundation of Fundamental Research.