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GENERAL BIOLOGY

Biodiversity Protection and Quality of Water: The Role of Feedbacks in Ecosystems

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V.I. Vernadsky pointed out that "the living matter in the biosphere plays a fundamental and active role, and in exercising its power it is in no way comparable with anything else, with any other geological factor." [1]. Finding concrete evidence that support this statement still remains an important aspect in the study of ecosystems, including aquatic systems. To reach a sustainable use of water resources, we have to maintain a proper self-purifying potential of water bodies, which sustains the water quality that is necessary for the consumption of water as a useful resource [2]. To maintain the self-purification potential under the conditions of anthropogenic stress, analysis of the factors that are the main prerequisites for the maintenance of water quality in water bodies is necessary; the analysis must include consideration of connections between these factors.

The goal of this work is to contribute to better understanding of the connections between biodiversity maintenance, water quality, and sustainable use of water resources, taking into account new results of my own studies, as well as the concept referred to as "the inhibitory analysis of interactions between organisms" [3].

Using the approach based on the inhibitory analysis of interactions among organisms [3], we carried out some new experiments to study the influence of several chemical substances on the ability of bivalves to filter water and to remove unicellular organisms from it. The method was described in [2]. The conditions of the experiments are given in Tables 1 and 2. The bivalves were grown at the aquaculture farm of INBUM NANU. The experiments allowed us to obtain new information on the ability of chemical substances that can pollute the aquatic environment to inhibit the efficiency of removal of the suspension of unicellular organisms from the water (Tables 1, 2). The quantitative estimation of the effect on the efficiency of removal of the suspension from water (EER) was calculated as the ratio of the optical density in the experimental beaker to the optical density in the control beaker (the variant with bivalves, without adding the tested substance to the water).

The data obtained agree with the results of the studies where the ability of some other chemical substances and mixed chemical preparations to exert the same influence on benthic [4–8] and planktonic [9] organisms was demonstrated. The new results, together with the previous data [4–9], are useful for analysis of the feedback between the self-purification potential of water bodies and the maintenance of their biodiversity [2].

One of the key prerequisites for protecting biodiversity is habitat maintenance (see, e.g., [10–12]). The main part of the aquatic organism's habitat is water of a sufficiently high quality, i.e., water with a certain set of parameters that characterize its purity and ability to be a proper environment for organisms. Many parameters of natural water (for example, the abundance/number of suspended particles etc.), in their turn, depend on the number of aquatic organisms and their functioning, including their filtering activity. The filtering activity reaches 1–10 m^3/day above 1 m^2 of the bottom of freshwater and marine water bodies (data by different authors, see [13]) and takes part in the formation of water quality and habitats for many species. Thus, the filtering activity is one of the prerequisites for the maintenance of biodiversity of aquatic organisms in actual ecosystems. For the purposes of our analysis, it is important that the total filtering activity in actual ecosystems depends on at least three factors.

First, the total filtering activity depends on the total quantity of filtering organisms. The latter is made up of the quantity of populations of various species of filter-feeders. In ecosystems, the set of species of filter-feeders may include various species of the pelagic and benthic zones, including some representatives of the groups mentioned in Table 3.

Second, the filtering activity of invertebrates depends on the concentrations of suspended matter in the water. With an increase in the suspension concentration, the rate of filtration may decrease [14, 15].

Third, the filtering activity depends on the degree of pollution of water by chemical pollutants, as was

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Table 1. Effects of the detergent IXI (20 mg/l) on the optical density (OD_{550}) of the suspension of *S. cerevisiae* during its filtration by marine mussels *Mytilus galloprovincialis*

Period of measurements (ordinal number)	Period of time from the beginning of incubation, min	Experiment (+detergent) A	Control 1 (with mussels, without detergent) B	Control 2 (without mussels, without detergent) C	A/B, %
1	3	0.30	0.24	0.31	125
2	8	0.24	0.18	0.30	133
3	25	0.15	0.06	0.27	250

Table 2. Effects of the detergent Deni-Automat (DA, 30 mg/l) on the change of the optical density (OD_{550}) of the suspension of *S. cerevisiae* during its filtration by oysters *Crassostrea gigas*

Period of measurements (ordinal number)	Period of time from the beginning of incubation, min	Experiment (+detergent) A	Control 1 (with oysters, without detergent) B	Control 2 (without oysters, without detergent) C	A/B, %
1	2	0.26	0.17	0.33	153
2	10	0.15	0.01	0.31	1500
3	40	0.11	0.001	0.32	11000

shown, for example, in our studies on bivalves ([2–7] and new results obtained in this work) and rotifers [9].

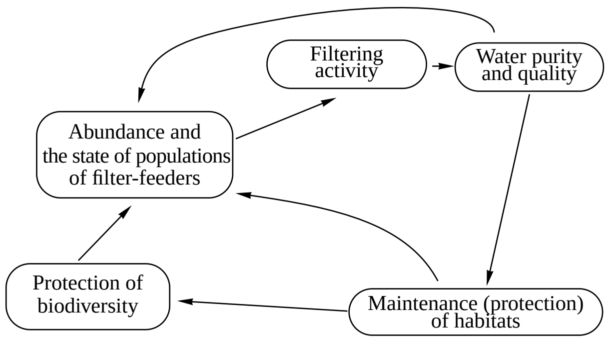
The links between biodiversity maintenance and some parameters of aquatic ecosystem are shown in a simplified way in the figure; arrows indicate the influence of some parameters (factors) on other factors.

As can be seen from this schematic diagram, the links can be divided into two classes: the links marked by the arrows going from the left to the right (for convenience, they can be called links of the first type) and the links marked by arrows going from the right to the left (feedbacks, which a reverse relative to the links of the first type). It is important that the links of the first type and feedbacks form cycles that can facilitate destabilization of the system when the filtering activity decreases.

Table 3. Biodiversity of organisms that are involved in water filtration sensu lato

Blocks of the ecosystem	Organisms of freshwater ecosystems	Organisms of marine ecosystems
Pelagial (plankton, nekton)	Protista (infusoria, heterotrophic Mastigophora); Rotatoria; Cladocera; Copepoda; larvae of some Insecta; Pisces (some representatives)	Protista; Rotatoria; among Coelenterata–Rhizistomida; larvae of Nemertini, Polychaeta, Sipunculoidea, Phoronoidea, Brachiopoda, Bryozoa; larvae of molluscs, larvae of copepods (Copepoda); larvae of Cirripedia, larvae of Echinodermata; larvae of Hemichorda; Euphausiida; Mysida; some representatives of Decapoda (Macrura); Tunicata (Class Appendiculariae; Class Salpae; Pyrosomida); Pisces (some representatives)
Benthal (benthos)	Protista (infusoria; heterotrophic Mastigophora); Spongia (Porifera); Bryozoa; Mollusca (Bivalvia); larvae of some Diptera; larvae of Trichoptera; larvae of some mayflies	Protista; among Ctenophora—attached ctenophors Tjalfiella; Spongia (Porifera); Hydrozoa; some of Actinozoa (Gorgonaria), some representatives of Pennatularia, rare Actinaria (for instance, Metridium); some of Polychaeta; Bryozoa; Brachiopoda; Kamptozoa (synonym Entoprocta); Phoronida; Sipunculida; Pterobranchia; Acrania; Mollusca (Bivalvia, and some representatives of Gastropoda); some representatives of Amphipoda (for instance, Corophiidae); Cirripedia; Echinodermata: Crinoidea, some of Ophiuroidea, some of Asteroidea (family Brisingidae), some of Holothuroidea (such as Psolus; Tunicata (Class Ascidiae)

Note: In the table the examples of large taxons are indicated, of which some representatives participate in water filtration and in the removing of seston from it. The table is not intended to be all-embracing and comprehensive. I thank Prof. V.V. Malakhov for advice.



Connection and mutual cross-influence of some parameters of aquatic ecosystems and processes that are important in protecting their self-purification potential.

The figure shows clearly that biodiversity protection is both a prerequisite and a consequence in the system of interconnections of the factors. On the one hand, biodiversity protection is a prerequisite for the maintenance of the proper filtering activity, purity and quality of water, and the conservation of the habitats. On the other hand, water purity and habitat maintenance are indispensable for biodiversity protection. Therefore, biodiversity protection and water quality conservation is a single dual task with two-way feedbacks. At the same time, when speaking about biodiversity, it is necessary to stress the importance of not only filter-feeders, but other groups of organisms as well.

The latter is proved by the following example. On the one hand, to protect the populations of freshwater fish, it is necessary to maintain the quality and purity of water in the habitats of fish. On the other hand, the following feedback loop is known: to maintain the quality of water, the filtering activity of Bivalvia is necessary, including the filtering activity of the organisms of the superfamily Unionoidea (Unionacea, Najadacea); the quantity of the latter depends on the successful completion of the life cycle of the larvae of the bivalves. The larvae (glochidiae) of the bivalves of the superfamily Unionoidea need fish, e.g., Percidae (*Perca* sp. and *Acerina cernua*); Cyprinidae (*Leuciscus idus* and *Pelecus cultratus*), to the gills of which they stick when growing (for one or two months). Therefore, water quality maintenance in many freshwater bodies depends on conservation of fish populations and their quantity. This fact is not at all the only example of the dependence of the quality and purity of water on the quantity and functioning of aquatic organisms that are not connected (at first sight) with water purification. Further arguments for the importance of practically all aquatic organisms to water self-purification are given in [5, 6].

The above arguments emphasize the primary role of biodiversity protection in the maintenance of the self-purification potential of water bodies and sustainable use of water resources. The feedback between water quality and biodiversity is not limited by the fact that, for protection of biodiversity, it is necessary to maintain the quality of water. As was demonstrated above, the opposite is also true: to maintain the water quality, it is necessary to protect the functionally active biodiversity of water ecosystems. In other words, protection of the functionally active biodiversity of aquatic organisms in a water body is a method (and an indispensable one) of purity maintenance in this ecosystem. This strengthens the arguments which give priority to the protection of biodiversity and its functional activity: this is not only an ethical imperative, but also an economic necessity.

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