Doklady Biological Sciences, Vol. 383, 2002, pp. 147–150. Translated from Doklady Akademii Nauk, Vol. 383, No. 5, 2002, pp. 710–714.

GENERAL BIOLOGY

System of Principles for Conservation of the Biogeocenotic Function and the Biodiversity of Filter-Feeders

S. A. Ostroumov

Presented by Academician V.N. Bol'shakov November 30, 2001

Received December 20, 2001

An ecologically substantiated system of protected terrestrial and water areas is an essential component of biodiversity conservation [1].

Studies by many authors [2–4] and our own works [6, 7] showed that filter-feeders play an important role in elimination of suspended particles from water and its purification. Therefore, filter-feeders provide habitats for other species in aquatic ecosystems. This implies that the problem of conservation of the filtration function in the population of hydrobionts should be properly taken into account when developing the system of conservation of terrestrial and aquatic areas.

The goal of this work was to formulate and substantiate the suggestion that the system of protected terrestrial and aquatic areas should be supplemented by sites intended to conserve the filtration function of filter-feeding hydrobionts (filter-feeders of zoobenthos, in particular). An additional goal of this work was to formulate and substantiate the system of basic principles and conditions of their protection.

Emphasis should be placed on the following aspects of this problem: the state of the population of filter-feeders (bivalve mollusks, in particular); the factors making it necessary to protect populations of filter-feeders; and basic requirements for the conditions of their protection.

The state of the populations of filter-feeders (as exemplified by bivalve mollusks).

Some species of bivalve mollusks are included in the Red Data Books of Russian Federation (34 taxa, in 2000) [8] and some other states of the former Soviet Union. In the North America and Western Europe, many populations of bivalve mollusks are also endangered and included in the IUCN Invertebrate Red Data Book [9].

In many aquatic ecosystems, there is a trend toward a decrease in the populations and biomass of bivalve mollusks at polluted sites. This concerns both freshwater [7] and marine [4] ecosystems.

Moscow State University, Vorob'evy gory, Moscow, 119992 Russia

The state of filter-feeding hydrobionts should be taken into account in the context of the general state of aquatic ecosystems. Even in some reserves, the state of many aquatic ecosystems is far from satisfactory. Using the methods based on the morphometric characteristics of aquatic organisms such as the roach (*Rutilus rutilus*) and the lake frog (*Rana ridibunda*), it has been shown that the state of aquatic ecosystems in the Voronezhskii State Natural Reserve is unsatisfactory [10]. The state of aquatic ecosystems was also found to be unsatisfactory in many places outside state natural reserves: the town of Voronezh, Lake Kostomukshinskoe (Karelia), a lake in the Zheleznogorsk raion of the Kursk oblast, etc. [10].

Factors making it necessary to protect populations of filter-feeders. There are several factors making it necessary to protect populations of filter-feeders (including bivalve mollusks), including:

conservation of the gene pool as a part of biodiversity;

conservation of the gene pool as a resource and a reserve for aquaculture; and

conservation of water self-purification in natural water bodies.

Various aspects of conservation of the gene pool were considered in the preceding works on the general problems of conservation of biodiversity [11, 12] and more specific problems of conservation of invertebrates [9].

Let us consider the third factor in more detail. The role of invertebrates in self-purification of water bodies was studied by many researchers (for review, see [2–7, 13–15]). The whole volume of water in many large aquatic ecosystems can be filtrated by bivalve mollusks within the time interval from 0.7 (South San Francisco Bay) to 25 days (Narragansett Bay) [5]. Within one year, marine bivalve mollusks are capable of eliminating, from water column above 1 m^2 of bottom surface, the amount of carbon ranging from 4.9 to 263 g [5]. The importance of the general filtration activity of mollusk populations is illustrated by the data shown in Table 1.

Filter-feeders contribute to regulation of plankton populations, purification of water, and reduction in the concentration of suspended particles in water. There-

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Table 1. Total filtration activity of populations of filter-feeding mollusks (data of numerous authors cited from [5, 7])

Site of measurement	Test	Numerical value, days (m^3)
Bay of Brest, France	Time of filtration of the entire volume	2.8
Oostershelde estuary, The Netherlands	Time of filtration of the entire volume	3.7
West Wadden Sea	Time of filtration of the entire volume	5.8
East Wadden Sea	Time of filtration of the entire volume	2.1
Rivers of North America	Filtration volume of water column above 1 m^2 of bottom surface per day	(0.3–10)
Various marine ecosystems of Western Europe	Filtration volume of water column above 1 m^2 of bottom surface per day	(1–10)

fore, the processes mediated by filter-feeders are important for the formation and maintenance of the entire ecosystem [13, 14]. Given the importance of the filtration activity of filter-feeders, this can be regarded as an essential function of the population of these invertebrates and an essential component of structural and functional organization of the corresponding aquatic biogeocenoses. A decrease in the overall filtration activity of filter-feeders (e.g., as a result of reduction of the total biomass of mollusk populations or inhibition of the activity of individual mollusks, see Table 2) poses an environmental hazard of suppression of the processes of self-purification of water [15]. Therefore, not only the biodiversity, but also the abundance of bivalve mollusks and other filter-feeders of zoobenthos, should be a subject of conservancy. Special malacological and hydrobiological reserves should be organized to attain this goal.

Principles of nature conservation conditions in malacological and hydrobiological reserves. The current state of knowledge about ecology of aquatic systems and hydrobionts suggests that the principles summarized in Table 3 should be taken as basic principles of nature conservation conditions in malacological and hydrobiological reserves. Although a complete implementation of these principles may be impracticable, it is necessary, from the ecological point of view to set them as a goal to be approached as close as possible.

Table 2. Modification of the efficiency of elimination of suspended particles from water as a result of pollution-induced suppression of filtration activity [7]

Mollusk species	Substance*	EEE**
Unio tumidus	SWM1, 50 mg/l	112.2–186.7
Mytilus galloprovincialis	SWM2, 20 mg/l	127.7–276.4
Crassostrea gigas	SWM3, 30 mg/l	153.2–10800
Crassostrea gigas	SWM4, 20 mg/l	153.4–261.7
Crassostrea gigas	SWM5, 1 mg/l	121.0–200

* SWM1 is the synthetic washing mixture OMO; SWM2 is the synthetic washing mixture IXI; SWM3 is the synthetic washing mixture Deni Automate; SWM4 is the synthetic washing mixture Lanza; SWM5 is the synthetic washing mixture Vesna-delicate.

** EEE is the effect on the efficiency of elimination [7].

Principle 1. Conservation of as complete a set of species of the aquatic ecosystem as possible is the most general rule of long-term conservation of ecosystems. This principle is based on the whole aggregate of knowledge about the interspecies relationships in ecosystems that are important to maintain the ecosystem stability for long time [11, 12].

Principle 2. Conservation of functional activity of organisms in population is an essential factor required to maintain the water self-purification capacity of ecosystem at a sufficiently high level [13–15]. As shown earlier, at least 19 processes are required to conserve the water self-purification capacity of ecosystems. Of these 19 processes, at least 5–6 are biological, and they are provided by the functional activity of major groups of hydrobionts [6, 7, 13, 14], including filter-feeders [2–7]. Imbalance of these processes (inhibition of the filtration activity of hydrobionts, in particular) imposes an environmental hazard of deterioration of water quality and loss of habitats of endangered species.

Principle 3. Conservation of biomass and productivity of aquatic communities and populations of hydrobionts is an absolutely necessary condition for implementation of Principle 2 (see above). In the case of reduction of the biomass of filter-feeders (e.g., bivalve mollusks), there is a corresponding decrease in the overall volume of water filtrated by these organisms per unit time. These organisms, in this case, are unable to provide the a complete elimination of suspended particles from water, thereby posing the environmental hazard of deterioration of water quality in the ecosystem.

Principle 4. Conservation of the populations of other organisms (including populations living outside the conservation area) that determine the survival rate and life cycle of the protected hydrobionts is a necessary condition for conservation of the hydrobionts protected. For example, the life cycles of many freshwater mollusks include the stage of glochidia, which grow on fish gills. Therefore, conservation of fish population is a necessary condition of survival of these mollusks

Table 3. Principles of nature conservation conditions in malacological and hydrobiological reserves

No.	Principle (requirement for hydrobiont conservation conditions)	Brief substantiation
1	Conservation of the whole set or the maximum possible number of species of aquatic ecosystem	Because of interspecies relationships in ecosystems, this is a necessary condition of long-term conservation of the most important groups of hydrobionts
2	Conservation of filtration activity of organisms and populations	Filtration activity of hydrobionts was found to play a significant role in elimination of suspended particles and water purification [2–7, 13–15]
3	Conservation of biomass and productivity of aquatic communities and populations of hydrobionts	This is an absolutely necessary condition of implementation of the principle mentioned above
4	Conservation of populations of other organisms (including populations living outside the conservation area), which determine the survival rate and life cycle of protected hydrobionts	Certain hydrobionts during their life cycle depend on populations of other organisms (including populations living outside the conservation area) (see the text and [15])
5	Observation of nature conservation conditions within the water catchment areas and rivers upstream of the reserve site	Water quality in protected area depends on the degree of pollution and erosion of the water catchment area; water quality in rivers also depends on the state of the river sites located upstream

[15]. However, because of the high mobility, the areas of fish populations may exceed the borders of malacological and hydrobiological reserves. The fish populations should be protected within the entire area occupied by the population (or in the maximum possible part of it), including zones located outside malacological reserves.

Principle 5. Observation of nature conservation conditions within water catchment areas and rivers upstream of the reserve site is also very important, because this determines the water quality in the aquatic ecosystem to be protected. Pesticides, fertilizers, and soil erosion in water catchment areas exert negative effects on water quality.

Although the principles discussed above are not new, their combined and systemic application is related to new approaches to the problem of biodiversity conservation. The following aspects of the problem should be particularly noted in this context. The conventional approach to the problem of biodiversity conservation requires conservation of living organisms as species. The main goal of conservation is believed to be attained if a population of the species of interest is maintained in a viable state, even if the size of the population is reduced. In this work, I propose to supplement this condition with five additional principles. For example, the maximum possible conservation of the functional activity (Principle 2) and biomass (Principle 3) of populations of endangered species of filter-feeders are proposed to be taken into account as goals of environment conservation. In addition, Principles 4 and 5 are suggested to be specific features of conservation of endangered hydrobionts and aquatic ecosystems.

Significant investments are required to implement these principles. In my opinion, organizations interested in large volumes of clean and pure water could be a potential source of funding of nature conservation measures in malacological and hydrobiological reserves. Hydrobionts, including filter-feeders, contribute to maintenance of water quality at a sufficiently high level [15]. Deterioration of water quality certainly increases the cost of water treatment in industrial water supply systems. Deterioration of the quality of natural water entering the water scoop system causes instability of water supply and increases the cost of water treatment. Therefore, consumers of clean and pure water should be interested in the support of malacological and hydrobiological reserves of that type, because, in addition to conservation of endangered species of filter feeders, these reserves maintain the filtration activity of the species at the level providing a sufficiently high quality of water.

Detailed analysis of terminological aspects of this problem is beyond the scope of the present work. In my opinion, such terms as malacological reserve, hydrobiological reserve, refugium, conservation zone, sanctuary, protected zone, etc. can be used in the literature. Other terms can also be suggested to designate the protected areas of the types discussed above in this work.

In summary, I suggest that the existent system of protected terrestrial and water areas should be supplemented with special sites intended to conserve populations of filter-feeding hydrobionts. In addition to biodiversity conservation, these populations should be conserved because they fulfil a very important biogeocenotic function of water filtration and purification.

The system of five principles (five points) is proposed to provide an ecological basis of the environment conservation conditions at these sites (malacological and hydrobiological reserves).

ACKNOWLEDGMENTS

I am grateful to V.D Fedorov, V.L. Kas’yanov, V.V. Malakhov, A.V. Yablokov, and other researchers at

Moscow State University and Russian Academy of Sciences for stimulating discussion and valuable criticism. I am grateful to my colleagues from the Institute of Biology of Southern Seas, National Academy of Sciences of Ukraine, G.E. Shul'man, G.A. Finenko, Z.A. Romanova, A.V. Pirkova, V.I. Kholodov, and A.Ya. Stolbov; members of ASLO, NABS; as well as J. Widdows and N. Walz, and all others who offered critical discussion, help, and advice. I thank A.F. Alimov for stimulating criticism and O.S. Ostroumov for assistance.

This study was partly supported by the Open Society Support Foundation (grant RSS no. 1306/1999).

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