

THE ROLE OF HERBIVOROUS FISHES AT RECONSTRUCTION OF ICHTHYOFAUNA  
UNDER THE CONDITIONS OF ANTHROPOGENIC EVOLUTION OF WATERBODIES

B.V. Verigin

Laboratory of Ichthyology

Faculty of Biology, Moscow State University

INTRODUCTION

Man's economic activities cause great changes in the appearance of our planet. Inland waterbodies (freshwater) comprise a small portion of the land mass; however, large volumes of this water are used by many industries. Therefore, management of these waterbodies by man has influenced them greatly. Inland freshwater fisheries must be developed which will maintain waterbodies in their present condition and also take into account future anthropogenic effects.

Hydrotechnical construction causes hydrological changes which result in two opposite processes. The natural hydrological regime of rivers is changed as they are turned into reservoir systems, which cause lakes with slow flow. These reservoirs are created for energy, transportation and irrigation purposes and are rather different in their area, depth and other characteristics. Peculiar to our country is the presence of considerable numbers of large, rather shallow, reservoirs. They were created on the lowland rivers of the south slope (the Dnieper, the Don, the Volga) and occupy large areas in the most populated regions.

On the other hand, the number of artificial channels is increasing. They are created for irrigation, water supply, soil drying, transportation and other purposes. Among these channels there are some as large as the Karakum Channel, North-Crimea Channel, Channel Dnieper-Donbass, Dnieper-Krivoi Rog, Irtysch-Karaganda and others. There are also small channels such as these used for irrigation and collection of irrigation water from fields and drainage ditches are important and compose many hundreds of kilometers.

Water chemistry is changed in some degree by changing the hydrological regime. But in most cases, the change in water quality is caused by man's activity on the land that surrounds the waterbody. These changes in water chemistry are rather well known as water pollution results because of different poisons that have been washed from the fields by effluents from chemical and other plants. However, there are more complicated water chemistry changes that we cannot call "pollution". As a result of economic activity, a large amount of biogenes are also added to waterbodies. These are mainly compounds of nitrogen and phosphorus. These are sources of nutrients for aquatic plants which assimilate the sun's energy and become the base for all other links to the aquatic ecosystem.

Enrichment by nutrients, as a result of man's activity, is called anthropogenic eutrophication. This process may be a positive one, within definite limits, as it increases biological and economic productivity of waterbodies,

but when hypereutrophication results, this process becomes negative. The decomposition of huge masses of higher plants and algae causes the oxygen levels to sharply decline. Water becomes unusable for fish life and for drinking. This is termed secondary pollution.

The types of anthropogenic effects on waterbodies are variable in historical aspect. Originally the most salient factor was hydrotechnical construction. This developed from primitive irrigation systems and waterflows, in ancient times, to the present day constructions such as the Kara-Kum Channel and cascades on large rivers.

## DISCUSSION

### Thermal Effluents

During the last decade, simultaneously with population growth, industry growth and intensification of agriculture, excessive eutrophication has increased sharply. Together with hydrotechnical and chemical factors there is added a new strong anthropogenic factor - a thermal one. It results from the development of thermal and atomic energy. Only 30 - 35% of the energy contained in fuel converts into electroenergy. About 15% is lost in the air and 50 - 55% in the water. This results from vapor condensation as the water in condensers is warmed by 8 - 10 C. The warm water of atomic stations is 1.7 - 2.0 times greater than from thermal ones. Thus, the amount of warm water has increased greatly. It is known that in the near future, in the United States, 30% of the annual river flow will pass through condensers or 100% during the low-water period. The amount of water that presently flows to waterbodies will be enough to boil the cascade of waterbodies on one of our large rivers. The amount of heated water in both countries which waterbodies receive will increase several times.

### Aquatic Vegetation

These anthropogenic factors cause ecosystems and the biological equilibrium to change. The principle effect of ecosystem disbalance is an excessive development of aquatic vegetation, submerged and partly submerged higher plants (macrophytes), and algae (microscopical unicellular and colonial algae). There is another after effect, but it is less important. Algae creates biological obstruction to water use in different branches of the economy. These obstructions often reach such proportions that water cannot be used normally and cause factories to shut down.

Overgrowth of shallow water by vegetation reduces water quality and also causes additional evaporation of valuable moisture, especially in southern irrigation channels. Overgrowth of channels at thermal stations reduces their ability to cool water, which provokes unnecessary use of fuel. The most serious damage results, however, from the overgrowth of artificial irrigation channels and collector-drainage system channels.

Excessive development of algae ("flowering") presents a serious problem for water supply and other water use. This is especially true as concerns waterbodies that are subjected to anthropogenic eutrophication. For the struggle against aquatic plants different mechanical and chemical methods are

utilized, but these methods do not solve the problem because mechanical removal of vegetation is very unprofitable, and chemical methods lead to water pollution.

### Herbivorous Fish

Recently, because of the development of methods for the artificial reproduction of the Far-East herbivorous fishes [grass carp, Ctenopharyngodon idella (Val.), silver carp, Hypophthalmichthys molitrix (Val.), and bighead, Aristichthys nobilis (Rich.)], we use biological methods for aquatic plant control. Great success has been obtained against aquatic macrophytes. Stocking of commercial, irrigation and technical waterbodies with grass carp allows us, in a short time, to get rid of soft submerged vegetation and rigid partly submerged ones. It is not my purpose to speak in detail of the use of the fish, but some ecological effects of these introductions will be mentioned. The primary effect of the removal of macrophytes in lakes and reservoirs is the improvement of conditions for zooplankton and fishes; zooplanktophage survival is increased.

Apprehensions have been expressed in the literature about the possibility of zoogenous succession and phytocenosis of high plants in waterbodies. However, we do not have exact observations of this phenomenon. One publication indicated that buttercup increased after introduction of grass carp. This is a littoral plant found in shallow areas inaccessible to grass carp. Charophyta also develop in ponds where grass carp are introduced. Young grass carp do not control Charophyta, but large fishes do not allow it to develop. When it became evident that grass carp did not eat water ladies thumb (Polygonum amphibium), we feared that waterbodies would be overgrown with it. But we soon realized that water ladies thumb did not appear in ponds inhabited by grass carp because the latter destroyed its sprouts.

The destruction of vegetation also effect animal populations inhabiting a waterbody. The quantity of blood-sucking mosquitoes is reduced as the larvae are deprived of shelter. The number of small trash fishes inhabiting vegetation is also decreased. There is apprehension that destruction of plants damaged the reproduction of fishes spawning there, but for the present these apprehensions are not confirmed. Introduction of grass carp into the Khauzhan waterbody, in Turkmenia, did not reduce catches of native fishes. The reason being that some balance was maintained. Although spawning places were reduced, coarse fishes did not eat eggs and larvae in as great amounts. There may be other reasons, but the above mentioned one does not mean that the reduction of vegetation does not effect the ichthyocenosis. The use of grass carp must take place under those conditions where we can regulate its abundance and in such waterbodies where the full reconstruction and cultivation of ichthyofauna can be provided.

### Anthropogenic Eutrophication

The struggle against microscopical algae that causes the "flowering" of water is more complicated. This problem is closely connected with anthropogenic eutrophication. I have mentioned this phenomenon before but I will examine it in more detail.

In the recent literature I have not succeeded in finding a strict definition of this concept. However, as to the cause of this phenomenon, its effect, and the role of different factors, the definitions of numerous scientists are practically the same. Summing them, the modern definition of "anthropogenic eutrophication" must be formulated as the increased trophic conditions in the waterbody which are under the effect of enrichment by chemical biogens resulting from man's economic activity on the surrounding area which changes water quality for the process of economic water use.

Examining this phenomenon, it becomes clear that additional application of biogens intensifies biological processes in waterbodies, which leads to the growth of masses of living matter in the ecosystem. Increasing production which increases the ecosystem mass is characterized by the rate of anthropogenic eutrophication.

We know that the rate of biological productivity is determined not only by the mass of the ecosystem but also by the turnover rate. The same as a percentage of the capital, the productivity is determined by the size of "capital" and the rate of turnover. The rate of biological cycles in aquatic ecosystems depends initially on the temperature regime. Until recently this rate has been determined by the peculiarities of climate and is a natural factor, therefore, it has not been necessary to take temperature into account when considering the phenomenon of anthropogenic eutrophication (Figure 1).

As mentioned before, in the near future and especially in perspective, with the development of thermal and atomic energy, the amount of additional heat will grow and hence the rate of biological cycles in ecosystems will increase. Therefore, the anthropogenic effect on the productivity of waterbodies will consist of two processes: 1) increase in productivity at the expense of an increase in ecosystem mass, and 2) an increase in productivity at the expense of the acceleration of biological turnover of this mass. Under these new conditions, it is logical to modify the concept of "anthropogenic eutrophication". It can be considered as two processes, namely, the entrance of additional heat to the system which I term thermal eutrophication, which increases biological turnover in ecosystems. The derivative of these processes will be the phenomenon of anthropogenic eutrophication.

Anthropogenic eutrophication can more strictly be defined as the biological productivity of aquatic ecosystems are increased by the effect of man's economic activities on the surrounding watershed and results in degradation of water quality and makes the water uneconomical for use.

The reverse of this is the phenomenon of anthropogenic pollution which is defined as deterioration of water quality at the place of habitation and the object of economical use. It can be primarily chemical and primarily thermal as well as secondary or eutrophicated. Secondary pollution appears as a result of anthropogenic eutrophication, (chemical or thermal) which leads to unnecessary production of organic matter by autotrophic plants. Unbalanced ecosystems arise in which the primary link is hypertrophicated and the productivity of the next link falls behind.

## Ichthyofauna Reconstruction

The task of creating a balanced ecosystem can be solved by reconstruction of its ichthyofauna. The native ichthyofauna of our eutrophicated waterbodies consists primarily of relatively cold resistant non-productive fish species that are the producers of the third and fourth order, i.e., the zoophages or predators. These species must be replenished or replaced by highly productive warm-water fish species that are the producers of the second order, i.e., phytophages. The most important second order species are those which use phytoplankton and detritus as food.

Eutrophication resulting from chemical and thermal introductions into aquatic ecosystems are currently considered to be a negative anthropogenic effect which decreases the productivity and water quality of these systems. Ichthyofauna reconstruction can turn these negative effects into positive ones that increase not only economic productivity, but also water quality.

The negative effect of chemical eutrophication is evident in our large waterbodies or the south slope rivers: the Dnieper, the Don, the Volga. Therefore, a mass introduction of silver carp was planned and a rather small introduction has been made. These herbivorous fishes can take the lead role in the fisheries of these waterbodies. They grow rapidly, adding a kilogram or more a year, which is much more than any of the native fishes. Only in relatively small waterbodies, where on a unit of area a rather large sample was introduced, has there been large fishery effect. The fish productivity of these waterbodies has increased from some kg/hectare to 2-3 centners/ha. But it is not quite clear how silver and bighead carp can restrain the production of algae and improve water quality. The problem arises as a result of eutrophication. Blue-green algae develop which comprises 30% of the phytoplankton production. They are considered as toxic and inedible plants. Thus, some question arises as to whether these fishes can effect the development of blue-greens. Food habit studies indicate that both species avoid blue-green algae.

Only precisely conducted observations can determine the capability of the silver and bighead carp in controlling different taxons of algae. Their food preference is affected by the size of the algae, as they prefer large cells and colonies. These data are interesting and indicate that they do not simply remove a definite biomass but they repress algae reproduction.

It was shown experimentally that silver and bighead carp assimilate blue-green algae as they do all other groups, however, the theoretical and experimental principles of the quantitative estimation of the ecological role of phytoplanktophagous fishes has not been studied sufficiently. These investigations will be continued.

I would like to reiterate that the use of herbivorous fishes does not suppress eutrophication, but the direction of the productive processes and the form of biological production are changed. Instead of useless algae, we obtain important fish production, and rationally utilize anthropogenic eutrophication.

The same argument can be presented for thermal eutrophication. In the future, warm water from electropower stations will be used for fisheries purposes. Fish for stocking purposes will be reared in heated ponds using artificial food. Research indicates that introduction of Far-East herbivorous fishes to these waterbodies gave good results.

Heated water leads to a sharp increase in growth rate, and rapid maturity. Mass introduction of these fishes to cooling pools increases their productivity to 2-4 centner/hectare. There is also a positive result after introduction of African herbivorous tilapia to cooling pools. Undoubtedly the Indian giant carps and some other phytophagous fishes of the south-eastern part of Asia might also grow well in these conditions.

The introduction of herbivorous fishes is only the first step toward ichthyofauna reconstruction. A third trophic link which includes warm water zoophages (buffalo, catfishes and some other fishes of the United States) could also be added.

Polyculture is intensively developed in pond fisheries. In the future we can consider reconstructing entire cooling pool ecosystems by utilizing more thermophilous organisms. By experimentation and study of these relatively small cooling pools we can obtain information that will allow for ichthyofauna reconstruction in larger waterbodies where electropower plants will be constructed.

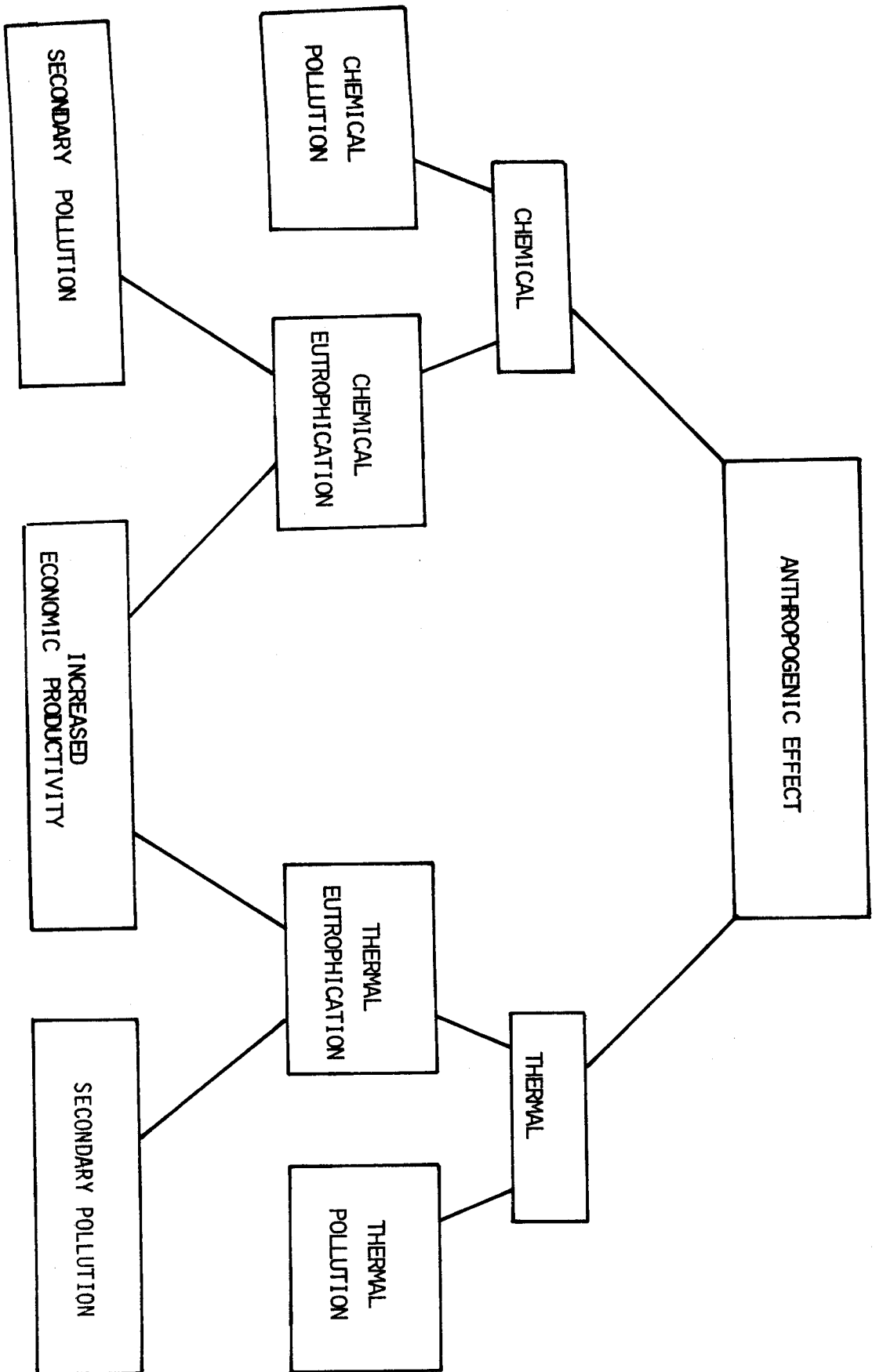


Figure 1. Anthropogenic effects and how they relate to water quality.