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# THE EFFECTS OF FISH CAGE AQUACULTURE ON THE PROFOUND MACROZOOBENTHOS IN THE OLIGO-MESOTROPHIC RESERVOIR IZVORU MUNTELUI BICAZ (ROMANIA)

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**Abstract:** The influence of the trout aquaculture in floating cages upon the chemical characteristics of the actual sediments in the farms neighboring area is reduced by a series of factors which cause that just a part of the organic and mineral matter introduced in the ecosystem to arrive on the bottom, under the cages. The trout aquaculture in floating cages influences the structure of the benthic macroinvertebrates’ communities by simplifying it, increasing the abundance and the weight of the detritivorous oligochets. These effects appear on limited areas in the farms neighboring area and may be explained as forms of a limited eutrophication.

**Key words:** aquaculture, Carpathians, macrozoobenthos, Oligochaeta, reservoir

## 1. INTRODUCTION

Despite of all economical advantages, cage farmed fish production represents an environmental risk (Hakanson, 2005) by development of the organic waste emission consisting mainly by uneaten food pellets and faeces (Winsby et al., 1996). Analyses of benthofaunistical characteristics like composition, diversity and abundance are sensitive approaches to evaluate impacts on sediment and surrounding environment (Black, 2001). In the present study, we analyzed the macroinvertebrate community composition and sediment geochemistry in relation with the impact of increased cage culture of rainbow trout (*Rhabdofario mykiss*) from 70 t in 2004 to 200 t in 2006 in the oligo-to mesotrophic reservoir Izvoru Muntelui – Bicaz.

This study aimed at determination of benthic communities and abiotic factors in aquaculture area characteristics, and to compare these parameters with the reference values obtained in the areas free from aquaculture farms.

## 2. STUDY SITE

Izvorul Muntelui–Bicaz reservoir is located north–east of the Carpathian Mountains, being a relative young (1961) dimictic, oligotrophic, and large man made lake: 26.5 km long, 0.7 km mean width, 88.6 m maximum depth, a surface area of 3109 ha and a volume of 1230 mil. $m^3$. Rainbow trout aquaculture in the lake is practiced in Potoci area located in the lower part, in two floating farms (~0.9 ha total area) producing together >70 t commercial fish per year.

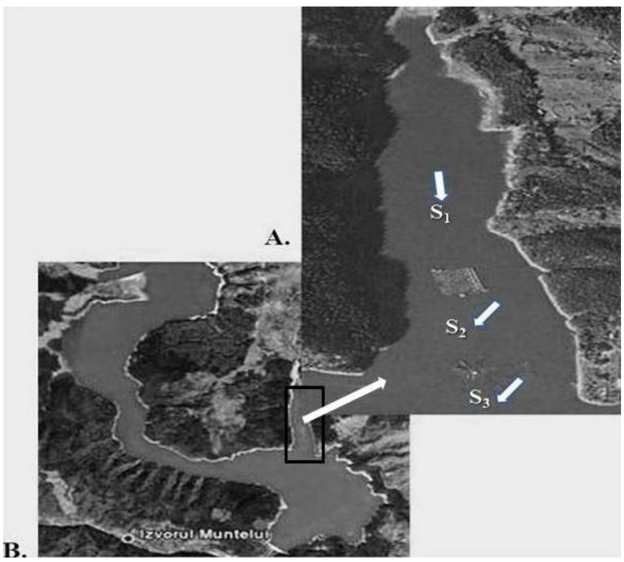


Figure 1. Location map of the study area. A) Sampling sites B) Izvoru Muntelui – Bicaz reservoir

The study was undertaken in three selected sampling sites: $S_1$ – located 150 m upstream of a first trout farm (24 m water depth); $S_2$ – between the two farms (46 m water depth) and $S_3$ downstream of the second farm (60 m water depth).

## 3. METHODS

The macrozoobenthos from those profound habitats was sampled monthly from May 2006 to July 2007. Three randomly distributed samples were taken at each sampling site using a modified Petersen grab (170.5 $cm^2$ covering area) and washed through a 0.25 mm sieve.

Invertebrates were weighed by a Mettler AK160 electronic microbalance (0.001 mg precision) to estimate the main groups biomass. Standard statistical methods were used to analyze the obtained data.

For the chemistry analysis, we sampled sediments using the same grab, determining the following chemical parameters: organic matter, organic nitrogen, total phosphorus, but also the concentrations of mineral forms of nitrogen and phosphorus ($NH_4^+$, $NO_3^-$, $PO_4^{3-}$) from the interstitial water of sediments.

## 4. RESULTS AND DISCUSSION

At the sampling site $S_1$ (Table 1) were found: *Tubifex tubifex* (77.57%), *Limnodrilus hoffmeisteri* (10.52%), *Procladius choreus* (9.92%) and other taxa (1.99%). At the sampling site $S_2$ were found: *Tubifex tubifex* (96.66%), *Limnodrilus hoffmeisteri* (2.69%), *Procladius choreus* (0.54%) and other taxa (0.65%). At the sampling site $S_3$ were found: *Tubifex tubifex* (98.37%), *Limnodrilus hoffmeisteri* (1.48%) and other taxa (0.15%).

Table 1. The macrozoobenthic species density (individuals.$m^{-2}$) at each sampling site

| Site | Oligochaeta | Chironomidae | Other taxa | Total |
|---|---|---|---|---|
| $S_1$ | 80.817 | 2.68007 | 0.20328 | 83.7008 |
| $S_2$ | 175.455 | 0.46510 | 0 | 175.920 |
| $S_3$ | 297.585 | 0.07618 | 0 | 297.662 |

An intensification of the biochemical processes in sediments, environmental reducing character, and releasing of an important quantity of P-$PO_4^{3-}$ from the sediments interstitial water in the free water above occurred (Table 4).

We can observe that at the control site ($S_1$) the numerical (Table 1) and the biomass (Table 2) density have had the lowest values, different from the profound areas from the deep oligotrophic lakes comparatively to the values from the sites being under the aquaculture influence (Plavan, 2005).

Table 2. The macrozoobenthic biomass (grams.$m^{-2}$) in Izvoru Muntelui – Bicaz dam lake

| Taxa | $S_1$ | $S_2$ | $S_3$ |
|---|---|---|---|
| *Chaetogaster limnaei* | 19.35 | 0 | 0 |
| *Limnodrilus hoffmeisteri* | 4768.8 | 1641.6 | 1642.2 |
| *Tubifex tubifex* | 35,130.15 | 58,882.8 | 108,539.4 |
| *Pisidium casertanum* | 214.65 | 0 | 0 |
| *Asellus aquaticus* | 0 | 19.35 | 0 |
| *Chironomus plumosus* | 194.1 | 0 | 19.35 |
| *Cricotopus sylvestris* | 19.35 | 0 | 19.35 |
| *Cryptochironomus defectus* | 38.7 | 0 | 6.38 |
| *Dicrotendipes nervosus* | 19.35 | 0 | 0 |
| *Harnischia fuscimana* | 78 | 0 | 0 |
| *Polypedilum nubeculosum* | 272.1 | 0 | 0 |
| *Polypedilum* sp. | 38.7 | 38.7 | 0 |
| *Procladius choreus* | 4494.9 | 330.15 | 103.13 |
| TOTAL | 45,288.15 | 60,912.6 | 110,329.8 |

Table 3. Comparative data concerning some chemical parameters of the reservoir sediments in 2007

| Parameter | Site | | |
|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ |
| Organic matter (%) | 3.79 | 5.11 | 5.53 |
| Organic nitrogen (%) | 0.21 | 0.33 | 0.33 |
| Total phosphorus (%) | 0.14 | 0.24 | 0.24 |

Table 4. Comparative data concerning the biogenic elements concentration in the interstitial water of the reservoir sediments in 2007

| Parameter | Site | | |
|---|---|---|---|
| | $S_1$ | $S_2$ | $S_3$ |
| N–$NH_4^+$ (mg/100 g sediment) | 2.79 | 6.48 | 7.77 |
| N–$NO_3^-$ (mg/100 g sediment) | 0.24 | 0.26 | 0.22 |
| N-$NH_4^+$/N-$NO_3^-$ | 11.62 | 24.92 | 35.31 |
| N-$NH_4^+$ + N-$NO_3^-$ (mg $100^{-1}$ g sediment) | 3.03 | 6.74 | 7.99 |
| P – $PO_4^{3-}$ (µg $100^{-1}$ g sediment) | 25.76 | 42.93 | 66.97 |
| mineral N/mineral P | 117.62 | 157.62 | 119.30 |

The decreasing of the biodiversity (i.e., taxa numbers) at the sampling sites $S_2$ and $S_3$ can be associated to increased depth and also to influence of the floating farms, some of the missing species being indicators of clean waters: *Pisidium casertanum*, *Harnischia fuscimana* and *Polypedilum* *nubeculosum* (Malacea, 1969). The high biomass of *Limnodrilus hoffmeisteri* and *Procladius choreus* species from the $S_1$ sampling site is caused by the presence of the harder clayey substratum preferred by those species while at the sampling sites $S_2$ and $S_3$ the substratum is softer and oozy.

At the sites close to the floating cages, the numerical density grows from 1.3 times at the site 2 to 24.3 times at the site 3, and the biomass from 2.1 times at the site 2 to 3.5 times at the site 3, comparative to the control site (Table 1). The significant increase of the macroinvertebrates density in the area affected by the aquaculture is conjugated with the appearance and development of the species characteristic for biodegradable organic substances, and shows a slight eutrophication of the lake in those areas.

Examining the content of organic substance, organic nitrogen and total phosphorus in sediments, in aquaculture area, regarding to other areas of the lake (Table 3), and the concentration of the main nutritive elements in the interstitial water of the same sediment samples respectively (Table 4), we can observe that the influence of the material emission from the fishing farms upon chemical characteristics of the sediments is evident, as well as the differences of chemical composition do not correspond to the high quantities of organic and mineral material additionally introduced in the ecosystem through the aquaculture activity.

Bottom currents occur in Potoci area, driving away a part of the material originated in the aquaculture activity and disseminating it downstream, on broad areas. Another part of the same material (unconsumed forage, faeces), quantitatively important, is consumed by the wild fish during the sedimentation process or after the deposition on the reservoir bottom (Andersson et al., 1988) while a third part is mineralized by the microorganisms living in the water column and at the sediment surface, after deposition.

An important part of the organic matter from the sediment surface is used like food by the benthic macroinvertebrates (reaching a high density in the aquaculture area in Potoci area, compared with the control site, uninfluenced by the intensive trout aquaculture).

Concerning the differences between the values of the same parameters corresponding to the two series of samples, the cause is represented by the influence of the environmental temperature increase, from April to June, which leads to an intensification of the biochemical processes in the sediments, increasing the reducing character of the environment (reflected by the higher values of $NH_4^+$ ion concentration and of the ratio N- $NH_4^+$ / N- $NO_3^-$ in interstitial water) and, like a consequence, releasing of an important quantity of P-$PO_4^{3-}$ from the interstitial water of the sediments in the water column above the sediments.

The dynamics of the substance and energy exchange at the water-sediment interface showed that $PO_4^{3-}$ ion release from the sediment interstitial water into the reservoir water column precedes $NH_4^+$ ion release with approx. one month (Apetroaei, 2003).

## 5. CONCLUSIONS

The release of the waste material from the floating farms results in the introduction of organic material to the receiving environment (water column and sediments), which may alter the physico-chemical nature of sediments below and in the farms neighboring area (the sediments become anoxic, gases such as ammonium and hydrogen sulfide can be released).

The influence of the trout aquaculture in floating cages upon the chemical characteristics of the actual sediments in the farms neighboring area is reduced by a series of factors which cause that just a part of the organic and mineral matter introduced in the ecosystem to arrive on the bottom, under the cages. The relationship between water depth and current velocity will determine the dispersal of organic wastes.

The degree of impact of the trout aquaculture in floating cages on the receiving environment will depend on the rate at which suspended solids (uneaten food pellets and faeces) are released from the farm. Uneaten food pellets and faeces are either dispersed through the water column, or do accumulate on the sediments. While low sedimentation rates can actually increase benthic productivity through the addition of nutrients, higher rates can have detrimental effects on the benthic community due to changes in the physical and chemical conditions of the sediments. The accumulation of organic material and the subsequent potential for adverse impacts to the water column will affect the sedimentation rate and the accumulation of waste material in the vicinity of the trout aquaculture in floating cages.

Increased nitrogen and phosphorus concentrations into a receiving environment can lead to hypernutrification and potential algal blooms which may result in the subsequent death of cultured and/or wild fish due to decreasing dissolved oxygen levels or toxins released by algal blooms.

Increases in organic material above ambient levels can cause physico-chemical changes in both the sediment and water column. Although small increases in organic material can actually stimulate benthic production, levels which are higher than the assimilative capacity of the benthic environment will lead to: increases in nutrient levels (nitrogen, phosphorus) and reduction of oxygen levels.

The trout aquaculture in floating cages influences the structure of the benthic macroinvertebrates' communities by simplifying it, increasing the abundance and the weight of the detritivorous oligochets. These effects appear on limited areas in the farms neighboring area and may be explained as forms of a limited eutrophication.

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