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Nutrients and silt in the Bahlui river system

with special focus on the Parcovaci and Tansa reservoirs

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OVERALL CONCLUSIONS

Exploratory research has been conducted regarding nutrient and silt in the Bahlui river system. The reservoirs at Tansa and Parcovaci and several stretches of the river were studied. The two parts of this report describe the results of the research. The conclusions are summarized in this chapter.

Nutrients:

1. Nutrient concentrations are high in the Bahlui river and the reservoirs.
2. Most of the nutrients are probably from natural origin. In addition there are some emissions from point sources (water treatment plants and diary factories).
3. The high nutrient concentrations do not cause excessive algal growth in the reservoirs.

Silt:

4. Silt concentrations are high in the river and in the reservoirs.
5. The high silt concentrations prevent excessive algal growth, due to light limitation.
6. The high silt concentrations are partly from natural origin, but probably to a large extent from erosion in the river bed. This erosion is caused by the building of dams, which results in an adaptation of the bed slopes. Erosion of agricultural land does not contribute to the high silt contents.

Fish:

7. There are differences in species composition and biomass of fish between the reservoirs. These differences are the result of fish stocking in the Tansa reservoir.
8. The differences between the fish communities result in differences in the algae-communities as well.

Consequences for management:

9. The nutrient concentrations can be reduced somewhat by sanitation of the point sources. However, the concentrations will remain high and the effect on algal growth in the reservoirs will be nihil.
10. It is almost impossible to reduce the silt concentrations and these concentrations must be accepted.
11. Therefore, the ecological targets for the Water Framework Directive (the Maximum and Good Ecological Potential) must take into account high concentrations of silt and nutrients.
12. For the Tansa reservoir, the Good Ecological Potential cannot be reached, because the fish and algae communities differ

strongly from the natural situation due to the fish stocking. Options are stopping the fish stocking or to ask for derogation.

Further recommendations:

13. The quality and quantity of data is limited. To get more firm conclusions the monitoring program should be updated.
14. In order to get a better understanding of the natural conditions and the possibilities of restoration measures, better insight in the flow patterns of water, nutrients and silt in undisturbed subcatchments is needed.

Part 1. Nutrient balance study

1. Introduction

This report describes the results of research to eutrophication problems in the Bahlui river and its reservoirs. This study was initiated as a pilot for the entire Iaşi area. The reason for this pilot was that from earlier studies it was concluded that many of the reservoirs suffer from eutrophication problems and that a major portion of the nutrient loads in rivers were unaccounted for. The goals of this pilot were:

1. To get a better insight of the fluxes of nutrients through a part of the Bahlui river system
2. To identify possible sources of nutrients.

In order to answer these questions, the existing monitoring programme along the river Bahlui was extended with a number of sites, the frequency of the sampling was increased and the standard programme of chemical analysis was expanded with determinations of total-P and Kjehldahl-N.

2. Description of the area

Prut River

The Prut is the last tributary of the Danube river and for 742 km it forms the natural border between Romania, Ukraine and the Republic of Moldova. The river bed and the adjacent wetlands of the rivers in the Romanian part of the river Prut have changed due to the building of reservoirs and other hydraulic constructions, in the Prut river itself and in the streambeds of several tributaries. These changes as well as the human influence on water quality have strongly affected the ecological values.

Bahlui River

The Bahlui River basin is situated in the N - E part of Romania on the Moldavian Plain. The river springs from Dealu Mare (The Great Hill) at an altitude of about 500 m above Black Sea Level (BSL). The river Bahlui is the most important tributary of the river Jijia. The surface of the Bahlui river basin is 1960 square km. The river length, between the source and the confluence with the River Jijia is 119 km. At the confluence with the river Jijia the water level is 34 m above BSL.

The river basin has a hilly relief with large subsequent valleys and terraces. The valleys are deep and narrow with high hills without forests (the slope of the hills is almost 10%). The average altitude of the river basin is about 155 m and the mean slope of the river system is about 3‰ in the most upstream part, about 1,6 ‰ in the middle part and about 0,5 ‰ in the downstream part.

The river basin has a general orientation north - west to south - east. The river discharge has a large variation over the year, which is common for rain fed rivers. Also there can be a large difference between the discharge distribution and mean annual discharge of various years. The daily hydrograph for the station Podu Iloaiei on the river Bahlui, presented in the figure 3, gives an indication of the variation of the discharge over a year. At the confluence with the River Jijia, the average discharge of the river Bahlui is about 4 m3/s. Along The Bahlui and his tributaries twelve hydrometric stations are situated.

The run – off from precipitation is the main source of water supply for the river; in the upstream part some of the small tributaries are also fed by groundwater. The Bahlui river basin is situated in the area with a precipitation of about 500 mm per year.

In the Bahlui River basin seventeen reservoirs are situated. These reservoirs have an influence on the hydrodynamics of the river system, because of their storage capacity, especially during high floods. Some of these reservoirs are only for flood protection; others have a combined function (flood protection, water storage for the dry summer period). Especially for the permanent reservoirs the evaporation is important. Due to the continental weather the evapotranspiration is about 670 mm per year (hydrometric station of Iaşi).

The River Bahlui between Pircovaci reservoir and the city of Iasi has a permanent flow; this is called the main river system. Also in dry summer periods there is a discharge due to the ground water inflow and reservoir operation. The Bahlui ends in the Jijia about 6 km before the latter flows into the Prut, 390 km upstream from the confluence of the Prut with the Danube.

Most of the time the discharge of the Bahlui at the confluence with the Jijia consists for about 75% of the effluent of the WWTP of Iaşi, which enters the Bahlui 3 km upstream from the confluence.

The land is used largely for agriculture and cattle grazing applying to the entire 5476 km^2 county of Iai, that includes the Bahlui basin. The population density and industrial activities are relatively high, mainly due to the city of Iaşi, which has approximately 350,000 inhabitants. Other concentrations of population and economical activities are the towns of Târgu Frumos (13875 inhabitants), Hârlău (11708 inhabitants), Belceşti (10987 inhabitants), and Podu Iloaiei (8776 inhabitants).

Tributaries

The River Bahlui has many tributaries but a large number of those tributaries are dry during summer time. About 30% of the length of the network has permanent flow. In almost all tributaries this permanent flow is caused by groundwater inflow for instance the River Bahluet at Tirgu Frumos. In the area between Parcovaci and Tansa reservoirs, the following tributaries are monitored: Buhalnita, Magura and Vulpoiu.

Reservoirs

Starting with the 60's a lot of reservoirs have been constructed in the Bahlui river basin. These reservoirs have different functions, five reservoirs are only used for flood protection and twelve reservoirs have a combined function (flood protection and water storage). The total volume of the reservoirs is 219 millions m^3. Beside the main reservoirs, there is a great number of fishponds, for example on the River Gurguiata and the River Valea Oii. On the River Gurguiata the total volume of the ponds is about 6.7 million m^3 (without Tansa reservoir) and on the River Valea Oii the total volume upstream Sirca reservoir is about 2.5 million m^3 (without Sirca reservoir). In case the upstream dams collapse the volumes can be retained in the downstream reservoir (e.g. Sirca reservoir, Plopi reservoir). In all the reservoirs the water level is monitored twice a day. In periods of river floods or high water levels in the reservoirs the monitoring is intensified. The main reservoir in the River Bahlui is the Tansa reservoir, the main reservoir in the largest tributary, the River Bahluet, is the Podu Iloaiei reservoir.

The Parcovaci and Tansa reservoirs are used for drinking water for Harlau city and Tansa locality. In the last period, the water quality is decreasing.

Land use and morphology

Land use in the Bahlui basin, based on data of the county (judeţ) of Iaş I:

Land use	Surface area	
	km²	%
Populated and industrial area	147.76	7.5
Agriculture (arable land)	725.65	36.9
Pastures	31.92	1.6
Hayfields (perennial culture)	350.74	17.9
Surface water (wetland)	18.98	0.9
Forest	692.47	35.2
Total	1.967	100

In the Bahlui river basin the soil erosion processes during periods with high precipitation are so large that it sometimes this leads to land slides. The transport of fine soils (suspended matter) to the river system is therefore relatively high. The river bottom in the middle and downstream part of the river system consists out of fine material.
The morphology of the river and the reservoirs in the basin is complex because:

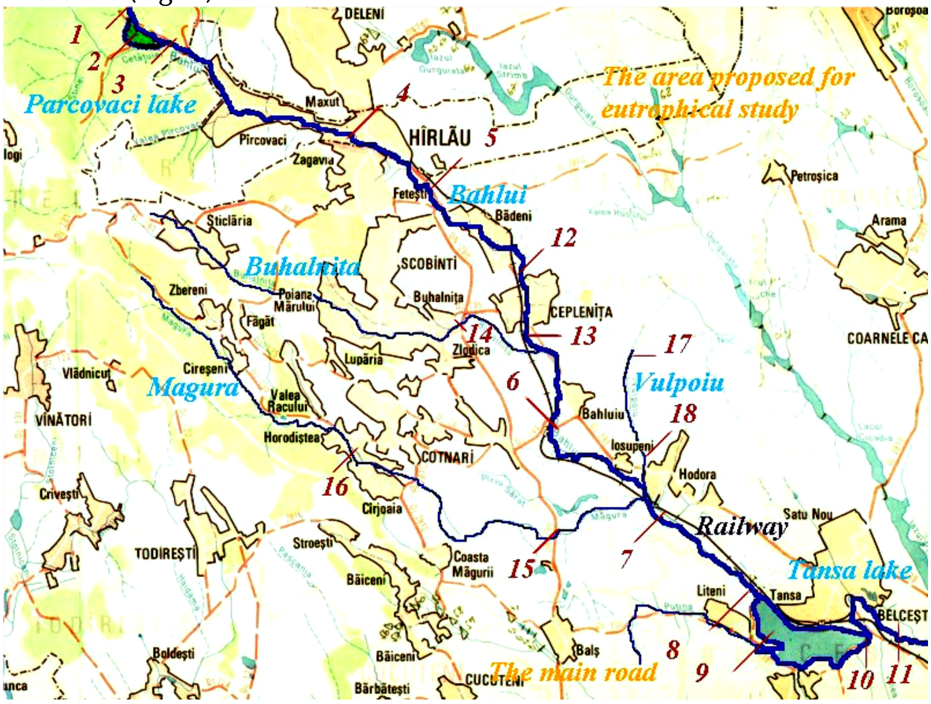
- the river bed can erode severely during flood waves; even the upstream part of the reservoirs can erode during extreme flood waves;
- due to soil erosion (specially of land used for agriculture) the rivers contain a high concentration of suspended solids, especially during periods with high discharges;
- the reservoirs and the river bed is continuously change under influence of sedimentation;
- in all reservoirs net sedimentation occurs; not only the dead volume (volume under the lowest water level in the reservoir) diminishes but also the volume for water storage and flood protection.

The erosion rate in the River Bahlui basin is an order of magnitude higher than in the River Rhine basin. Because of these high transport rates and the hydrological variation, the bottom level of the river system is very variable.

3. The water quality monitoring system

3.1 The monitoring sites.

These are (Fig. 1)



Bahlui upstream the reservoir Parcovaci
Bahlui upstream Parcovaci reservoir
The reservoir Parcovaci
Bahlui downstream Parcovaci reservoir
Bahlui upstream WWTP Harlau city
Bahlui downstream WWTP Harlau city
Bahlui upstream Ceplenita locality
Bahlui downstream Ceplenita locality
Bahlui Railway station of Cotnari locality
Bahlui upstream Tansa reservoir
The Tansa reservoir
Bahlui downstream Tansa
Tributary Buhalnita upstream Bahlui confluence.
Tributary Magura at Carjoaia village.
Tributary Magura upstream Bahlui confluence.
Tributary Vulpoiu upstream Iosupeni village.
Tributary Vulpoiu downstream Iosupeni village.

3.2 The sampling frequency

The river water sampling frequency was once a month or more in case of heavy rains. The reservoirs are sampled at a number of points: near the dam, from the both sides, and near the point where the river inflow. Finally there are only three analyses: inlet, outlet and the mixed samples of all the lake samples. The sampling frequency of the reservoirs was the same, once a month or more (for inlet-in case of heavy rains). In

The *point sources* of pollution along the Bahlui river and its tributaries, communal and industrial wastewater discharges, are monitored with respect to quantity and quality. The sampling frequencies range were 12 per year.

3.3 The parameters

The measured parameters were: pH, temperature, transparency, suspended matters, BOD5, COD-Mn, COD-Cr, NO_2, NO_3, NH_4, N-kj, total-P, PO_4, Cl^-, TDS, Ca, Mg, K, Mn, Zn, Cu, Fe, SO_4 and CO_3. Tot-N is not measured, but calculated as the sum of N from NO_3 and from N-kj.

3.4 Methods of calculating loads

1. **The database** of this study is composed by the monthly concentrations of the parameters, during all the period of the monitoring programme. For the months with more than one sample, we calculated first, the normal average of the concentrations. In this way, we had for all the period only one value for each month. In addition, a database of daily discharges is available.
2. **Method of calculating loads by normal average**. One can use, for each the cross section, the formula:

$$m_{param} = \frac{\sum_{i=1}^{n} q_i \cdot c_i}{n} \qquad [\text{ g/s}]$$

where:

m_{param} – load of the parameter

q_i – river discharge corresponding to the " i " sample

c_i – parameter concentration corresponding to the " i " sample

n - total number of the cross-section samples

The disadvantage of this calculation method is that information of daily discharges of the whole study period is not used. Only discharges on the day of sampling are used. Therefore, another method seems to be more appropriate:

3.4 Method of calculating loads by discharge weighted average.

In this method first is calculated the discharge weighted average concentration using the sampling data:

$$\bar{c}_{param} = \frac{\sum_{i=1}^{n} q_i \cdot c_i}{\sum_{i=1}^{n} q_i} \quad [mg/l]$$

Next, this average concentration is multiplied by the discharge of the whole period, ΣQ_m. This gives the load for the whole period. This load, divided by the number of the sampling days (=study days=m) gives the weighted load [g/s]:

$$m_{param} = \left(\frac{\sum_{i=1}^{n} q_i \cdot c_i}{\sum_{i=1}^{n} q_i}\right) \cdot \left(\sum_{1}^{m} Q_m\right) \cdot \left(\frac{1}{m}\right) \quad [g/s]$$

In our study, we used this method of calculating loads: by discharge weighted average.

4. Results

4.1 General

In this section the findings of the monitoring programme are discussed. The discussion is limited to the most important parameters, namely total P, total N and suspended matter. In general, data over de period august 2001-2003 were available. However, in most cases for total N data were only available from April 2003 on and a few earlier data. This is because of problems with the determination of Kjeldahl-N, one of the components of total-N.
Another limitation of the data is that the frequency of measuring is usually once per month. In combination with the highly fluctuating discharges this leads to inaccuracies in the determination of loads.

4.2 The theoretical discharges of N, P from WWTPs

Discharges of N, P from the Wastewater treatment plants were monitored. They were compared with theoretical discharges. These were calculated from the number of inhabitants, connected to the WWTP and literature data for the theoretical input per person and removal efficiencies:

1 habitant theoretical input

Ntot [kg/an]		**Ptot [kg/an]**	
Romania	UE	Romania	UE
3,6	4	0,7	1

Generally, the removal efficiency of the WWTP is:

WWTP	Case study	Efficiency [%]	
Steps:		N	P
Mechanic and biological	Harlau	30	40
Mechanic	Belcesti	20	10

Using these data, we calculated the theoretical input and the theoretical output of Ntot and Ptot. The data were compared with the results of t the mass balance (like an output data):

Locality		Harlau	Belcesti
Total population	[nr]	11708	10987
Connected population	[nr]	5270	1150
Theoretic **habitant input**	Ntot [g/s] Ptot [g/s]	0.602 0.117	0.131 0.026
Theoretic habitant output	Ntot [g/s] Ptot [g/s]	0.421 0.070	0.105 0.023
Mass balance habitant output	Ntot [g/s] Ptot [g/s]	0.455 0.122	0.033 0.006

The conclusions are:
WWTP Harlau:

- N tot from the mass balance is comparable with the theoretical value.
- Ptot from the mass balance is, generally the same with Ptot from theoretical input. So, the reduction of efficiency is zero or there are unaccounted inputs.

WWTP Belcesti:

- N tot and Ptot from the mass balance are, generally less than the value of the theoretical input or output. The conclusion is that, in the last period, more population is disconnected from the WWT (in reality there are fewer people than our figures).

4.3 Concentrations

The concentrations of both total P and total N are relatively high, in the range 0,2-0,8 mg P/l and 5-10 mg N/l, respectively. These values are well above the Dutch quality standards for P (0.15 mg P/l) and N (2.2 mg P/l). Already at the entering of Pircovacy the concentrations are high (0.28 mg P/l and 4 mg N/l). These concentrations are probably of natural origin, because there are no sources of pollution upstream Pircovacy.
In the river stretch downstream Pircovaci the differences in concentration are relatively small, with the exception of the first two sections after the reservoir. This will be discussed in the next section.

Average concentrations (calculated from “mixed without entering”)

	Parcovaci	Tansa
Suspended Matter	37,5	76
Ptot	0,17	0,3
Ntot	4,6	4,7
P-PO4	0,022	0,025
N-(NO3+NH4)	0,61	1,3
BOD	6,4	12

Suspended Matter Parcovaci (samples mixed; 3 or 4 /year)

1992	1996	1997	1998	1999	2000	2001	2002	2003
25	19	23	42	24.5	19	15	27	46

Average concentrations (calculated from “mixed without entering”)

	Parcovaci		Tansa		
	2002	2003	2001	2002	2003
Suspended Matter	27	46	15	47	66
Ptot	0,179	0,167	0,447	0,143	0,247
Ntot	1,86	5,1	6,47	5,65	4,54
NO3	0,628	1,525	2,23	1,7	1,88
NH4	0,607	0,295	1,18	0,68	0,425
PO4	0,094	0,031	0,188	0,108	0,065

4.4 Mass balances.

In this section the results of mass balances of the Bahlui for water, total N, total P and suspended matter (SM) will be discussed. First we will discuss the results per section, starting with the entrance of reservoir Pircovaci and ending with the Bahlui after reservoir Tansa and after that the overall balance of the whole system.
A general remark is that the accuracy of the mass balances is not always very large. The number of samples per year is rather large and especially for total N there are missing data. As a consequence in some cases most of the annual loads is determined by one or two measurements during high discharge events.

4.3.1 Results per section.

1. Reservoir Pircovaci
Only the inlet point of the Bahlui, the reservoir itself and the outlet point are sampled. According to the data the outflow of water is almost 50% higher than the inflow. An obvious reason is that the other stream flowing into Pircovaci from the south is not measured and therefore not included in the water balance. Another reason could be the inflow of groundwater.
The outflow of both N-tot and P-tot is higher than the calculated inflow. Normally, there is retention of both N-tot and P-tot in a lake or reservoir. The most likely reason is that the inputs of both N-tot and P-tot are underestimated, partly because of the input from the other stream is not included, partly because the water quality measured at "entrance" is not truly the quality of the stream near the reservoir, but already influenced by the reservoir itself (see discussion furtheron on Tansa reservoir).
The characteristic data of Parcovaci and Tansa reservoirs are:

Reservoir	River	Surface NNR* [ha]	Volume NNR [x10^6 m^3]	Total volume NNR [x10^6 m^3]
Parcovaci	Bahlui	90	2,75	8,80
Tansa	Bahlui	352	7,88	27,12

* at normal retention level

In spite of the underestimation of the loading, the retention of SM in the reservoir is high, at least 60%. The average SM concentration at entrance is at least 360 mg/l and probably even higher. Because there are only minor human activities in the streams upstream Pircovaci, the most likely cause of these high suspended matter concentrations is natural erosion in combination with peaks in water discharge.

2. Pircovaci Dam-Bahlui up Harlau.
The output of water from this section is substantially higher than the input (+40%). This is probably caused by the input of groundwater into the stream. Also the outputs of P-tot (+106%), N-tot (+95%) and SM (+200%) are substantially higher than the inputs. Point sources of pollution are not present in this section, so the most likely source is erosion. This is supported by observations in the fields. Possibly there are additional inputs from groundwater (except for SM).

3. Bahlui up Harlau-Bahlui down Harlau.
The wastewater treatment plant of Harlau discharges in the Bahlui in this section. The input and output of water are almost equal. The output of N-tot is much larger than the input (+200%). This cannot be explained by the discharge from the treatment plant, this is 25% of the input. The output of P-tot is 65% higher than the input. This is less than the discharge from the treatment plant (110% of the input). The estimated discharges of N-tot and P-tot from the treatment plant are not very accurate, because they are based upon a very limited number of measurements, especially the N-tot concentrations. However, the measured discharge of N is almost equal to the theoretical discharge calculated from the number of households connected to the plant, the theoretical input per connection and the theoretical treatment efficiency. The measured discharge of P is almost twice as high as the theoretical discharge (see table).

Locality		**Harlau**
Total population	[nr]	11708
Connected population	[nr]	5270
Theoretic habitant input	Ntot [g/s] Ptot [g/s]	0.602 0.117
Theoretic habitant output	Ntot [g/s] Ptot [g/s]	0.421 0.070
Mass balance habitant output	Ntot [g/s] Ptot [g/s]	0.455 0.122

A likely reason is that diary factories discharge directly into the river. Effluents from diary factories are known to be rich in nitrogen and this is likely the cause of the high nitrogen load from this river section. The estimated nitrogen load from diary factories is 3.3 g N/day.
Also the load of SM increases substantially in this section (+50%). This is likely caused by further erosion.

4. Bahlui down Harlou-up Ceplenita
The output of water from this section is a bit higher than the input (+12%), maybe due to input of groundwater. The load of P-tot is almost equal and the load of N-tot decreases (-30%). This could be due to retention processes. The load of SM doubles in this section, probably due to further erosion.

5. Bahlui up Ceplenita-down Ceplenita
Again, the amount of water increases a bit. The loads of P-tot and N-tot increase with 50 and 30%, respectively. This could come from the houses along the stream.
The SM load increases further with 25%.

6. Bahlui down Ceplenita-Bahlui at Railway station Cotnari
In this stretch the tributary called Buhalnita enters the Bahlui. The average discharge of this tributary is about 33 L/sec or 7% of that of the Bahlui. The output of water of the section equals the sum of the input in the section and the discharge of the Buhalnita.
The output of P-tot is about 35% lower as the sum of the input in the section and the discharge from **Buhalnita**. This could be due to retention processes, but an alternative explanation is that the riverine load of P-tot at the station "Bahlui down Ceplenita" is overestimated. This will result in an increase of the P-tot load is section 5, followed by a decrease in section 6.
The output of N-tot is about 10% higher than the sum of the as the sum of the input in the section and the discharge from **Buhalnita**. We have no explanation for this increase.
The output of SM is slightly lower than the sum of the inputs (-6%).

7. Bahlui at Railway station Cotnari –Bahlui up Tansa
This is a complex section, with two tributaries (Magura and Vulpoiu) entering the stream, a wastewater treatment plant from a wine factory discharging into the stream and several villages near the stream. Moreover, in the downstream part of this section there is an open connection with a drainage system from agricultural lands.
The output of water from the section is about 15% lower than the sum of all inputs. This could be due to evaporation in this large system. The outputs of both P-tot and N-tot are substantially lower than the inputs (0.18 g P/s or 46% of the inputs and 2.2 g N/s or 88% of the inputs, respectively). This could be due to retention processes in this section (sedimentation, uptake by plants, denitrification).
Only the output of SM is substantially higher than the inputs (+60%).

8. Tributary Magura between Carjoaia village and road
This section of Magura is bordered mainly by wine yards. The water discharge near Bahlui is small, average 76 L/sec or 11% of the average discharge of the Bahlui. In the stretch between the two sampling stations the discharge of the Magura increases with 70%, probably mainly from small wells and from other groundwater sources. The loads of both SM and P-tot increase substantially (+170% and +100%, respectively), whereas the load of N-tot remains practically the same (-

8%). The cause of the increase of SM and P-tot could be runoff from the wine yards.

9. Tributary Vulpoiu between up and down Iosupeni village
This tributary was selected, because high amounts of domestic animals are present in the watercourse. The average water discharge near Bahlui is small, about 85 L/sec or 12% of the average discharge of the Bahlui. The load of SM increases tremendously, from 2 to 19 g/sec, and the load of P-tot increases with 240%, whereas the load of N-tot almost halves. The increases of SM and P-tot are probably the effect of the animals. The decrease of N-tot is not easy to explain. It could be an artefact caused by inaccuracies in sampling, determination or load calculation.

10. Bahlui between up Tansa and Tansa entering
This is a small section between the last sampling station and the inlet of the Bahlui in Tansa reservoir.
The average water discharge decreases by 25%. The cause is not clear. All loads decrease substantially. This could be partly due to an error in the discharge estimate; the rest of the explanation is that the retention processes in Tansa reservoir already influence the station at the inlet.

11. Bahlui between entrance and dam.
There is a 12% increase in water discharge. There is a small river entering the reservoir from the south. The strong increase in loads of SO_4^{2-} and Cl^- indicate that there is also input of water with a high mineral content, probably groundwater.

12. Bahlui between dam and down Tansa
The wastewater treatment plant of Belcesti discharges in this section. The discharge of water increases with 30% in this section. This could be additional input from the town (urban runoff) and/or inflowing groundwater. The load of P-tot increases with 12%, that of N-tot with 80% and of SM with 60%, indicating that there is an additional source of nitrogen, but not of phosphorus.

4.3.2 Overall results

Water:
A water balance for the Bahlui between Pircovaci dam and up Tansa is presented in table 1.

INPUTS (in m^3/sec)		OUTPUTS	
Pircovaci dam	0.274	Bahlui up Tansa	0.611
Bahalnita	0.033		
Vulpoiu	0.085		
Magura	0.067		
WWTP Harlau	0.022		
WTTP Cotnari	0.010		
TOTAL	0.491	TOTAL	0.611
unaccounted for	0.12		

According to these data, the output at Tansa exceeds the sum of the inputs by 0.12 m^3/s, or 24% of the known inputs. As discussed above, this is mainly caused by unknown inputs in the first section after Pircovaci. More downstream there seem to be several other small unknown inputs, but these are largely compensated by losses in section 7.

Suspended matter:
Both the load and the concentration of suspended matter increase steadily during the entire river stretch. At Pircovaci dam the average concentration is 100 mg/l and the average load 29 g/s, the station Bahlui up Tansa they are increased to 1000 mg/l and 600 g/s. Almost the whole increase is caused by unidentified sources, probably mainly erosion. Almost 90% of the suspended matter load is retained in Tansa reservoir.

P-tot:
The overall P-balance for the river stretch is presented in table 2.

INPUTS (in g P/sec)		OUTPUTS (in g P/sec)	
Pircovaci dam	0.054	Bahlui up Tansa	0.163
Banality	0.029		
Vulpoiu	0.016		
Magura	0.017		
WWTP Harlau	0.122		
WTTP Cotnari	0.077		
TOTAL	0.315	TOTAL	0.163
unaccounted for	-0.152		

According to these data the sum of the inputs exceeds the output near Tansa. This in mainly due to the large retention in section 7 (0.18 g P/s). A small retention is calculated in some other upstream sections (3, 6), but unaccounted sources of the same size are calculated for the neighbouring sections (2,7). It is possible that these are the result of inaccuracies of the balance. An error in the load at one station will influence the balances of both the section before and after this station. The calculated load at the station "Bahlui down Ceplenita" may serve as an example. This load is 0.27 g P/sec, well above the values at the up- and downstream stations (0.18 and 0.20 g P/sec, respectively). This appears to be mainly caused by one measurement at 28-3-2002, at a flow of 21 m^3/sec. The measured P-tot concentration at this station is 0.6 mg P/l and at the neighbouring stations 0.38 and 0.43 mg P/l. This relatively small difference in measured concentration is responsible for the entire difference in calculated P-load between the station and the two other stations.

N-tot:
The overall balance for N-total for the river stretch is presented in table 3.

INPUTS (in g N/sec)		OUTPUTS (in g N/sec)	
Pircovaci dam	0.94	Bahlui up Tansa	3.42
Bahalnita	0.22		
Vulpoiu	0.21		
Magura	0.26		
WWTP Harlau	0.46		
WTTP Cotnari	0.61		
TOTAL	2.70	TOTAL	3.42
unaccounted for	0.72		

According to these data, the sum of the inputs exceeds the output from the section by 0.72 g N/s or 20%. More detailed analyses show a much larger unaccounted input (3.2 g N/s) in Harlou, although the loss of nitrogen in the next section might indicate an overestimation of this input. This could be caused by the limited number of measurements. According to the calculations, there is a loss of about 2.2 g N/s in section 7.

The difference in behaviour between suspended solids on one hand and phosphate and nitrogen on the other is striking: there is an enormous increase of the suspended solids load throughout the part of the Bahlui in study, but the increase in loads of N and P is much lower and is even considerably reduced in the last section. Moreover, the strongest increase of the N-load is during passage of Harlou. It indicates that most of the behaviour of N and P is not associated with erosion of particulate material. Again, the strongest indications are found in section 7: the loads is P and N are reduced with 50 and 40% of the total inputs in this section, while the load of suspended solids increases with 80%. Another indication is the lack of correlation between the concentration of particulate P and suspended solids (R^2=0.004, fig. 1

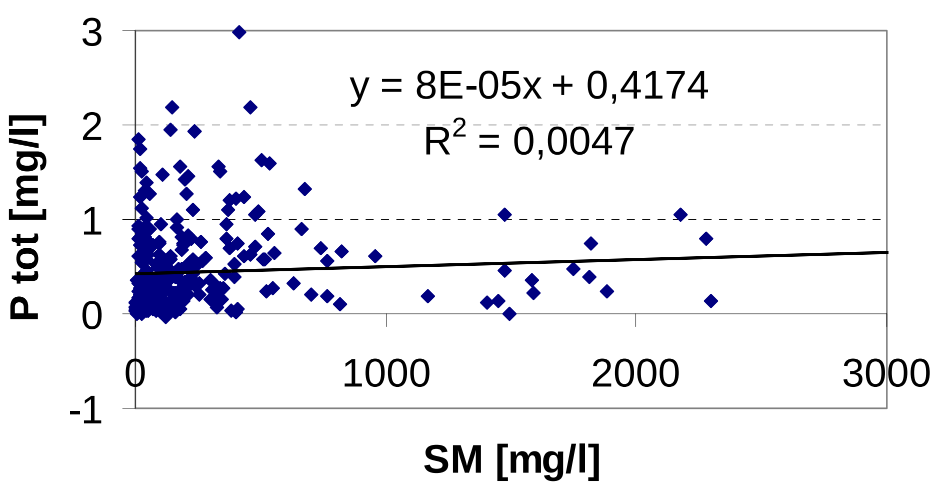


Fig 1. Relation between Suspended matter concentration and total P concentrations in the Bahlui

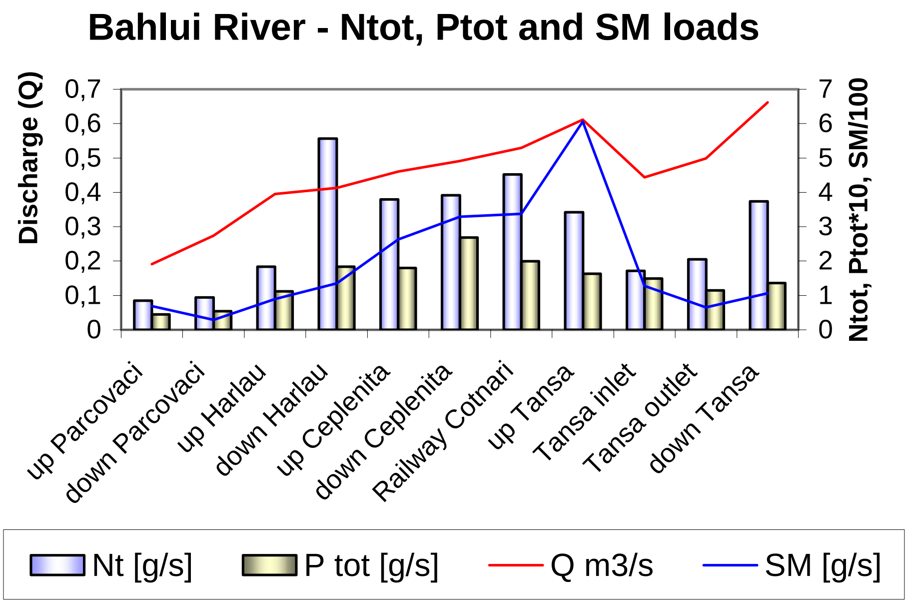


Fig. 2. Discharges and loads of Ntot, Ptot and suspended mater along the river Bahlui.

5. Discussion and Conclusions

The eutrophication study in the Bahlui was set up to find patterns in contamination with nutrients and suspended solids. Although the frequency of the measurements is sometimes rather low, the rather large number of sampling stations along the river made it possible to evaluate the results of the measurements.

There is little doubt that the concentrations of nutrients in the river Bahlui system are rather high and can easily result in eutrophication problems. The high concentrations already present in the Bahlui before the river enters Pircovaci reservoir indicate that probably most of the nutrients in the water are not from human but from natural origin.

In most of the river between the reservoirs of Pircovaci and Tansa there are little indications of substantial emissions of nutrients. The only exceptions are the first section, between Pircovaci and Harlou, and the second section, while passing Harlou.

The most likely origin of nutrients in this first section is runoff from agriculture; the most likely origin in the second section is the treatment plant of Harlou and other industrial discharges in Harlou.

The data do not support an earlier hypothesis that erosion of soil material is also an important source of nutrients. Especially the facts that the loads of nutrients and suspended solids follow different patterns and that the concentrations of total P and suspended solids are not correlated undermine this hypothesis.

A.1 The river sections.

Upstream Parcovaci. The control section is the point of the entering of the water in the lake. The area is wooded, 20.2 km downstream the spring. There are no sources of pollution. This is the reference section. The discharge of the Bahlui river is small and the soil contains a mixture of sand and loess. During the high rains, the discharge increases from more times, and the water is not so clean. The cross-section of the monitoring system is the point of the entering of the water in the lake.

Parcovaci reservoir Purpose: flood protection and drinking water for Harlau city.

The characteristic data of Parcovaci and Tansa reservoirs are:

Reservoir	River	Surface NNR* [ha]	Volume NNR [mill cm]	Total volume NNR [mill cm]
Parcovaci	Bahlui	90	2,75	8,80
Tansa	Bahlui	352	7,88	27,12

* normal retention level

The Cetatuia river, which coming too in the Parcovaci reservoir, is not monitored.

Parcovaci outlet The control cross-section is at the spillway (the water surface).

Bahlui upstream Harlau The section is placed upstream the Harlau city, 29 km from the springs, in an area with high-deforested hills, where the loess prevails. There are no point pollution sources. Usually, here, after high rains, there are landslides.

Bahlui downstream Harlau The section is placed downstream the Harlau city, 32 km from the springs, and 200 m downstream the WWTP of Harlau, in the flat town area. The valley is very steep, with erosion. It is possible some pollutants to be discharged through Bahlui from the town (upstream the cross-section).

The aria between Harlau and Tansa, includes the cross-sections:

Bahlui upstream Ceplenita (is placed upstream the Ceplenita locality, 33 km from the springs)
Bahlui downstream Ceplenita (is placed downstream the Ceplenita locality, 34 km from the springs)
Bahlui Railway Station Cotnari(is placed downstream the Railway Station Cotnari locality, 38,5 km from the springs)
Bahlui upstream Tansa The cross-section is placed upstream the Tansa-Belcesti reservoir, 50 km from the springs. All these cross-sections are situated in an area (from Harlau to here) with

a large and deforested flood plain, where the loess prevails. The river streambed is very steep, with high erosion.

The discharge of the WWTP of the Cotnari win factory (SC Cotnari SA) is between the confluences of the Bahlui Rivers with the tributaries Buhalnita and Vulpoiu.

The tributaries of Bahlui river : Buhalnita, Vulpoiu and Magura. There are two sampling cross-sections for each these tributaries. One of them is near by the spring, and the other is near by the confluence with Bahlui.

Buhalnita crossing the villages: Poiana Marului, Luparia and Buhalnita, in an area with deforested hills. All the animals from these villages use the Buhalnita river water. The length of the river is 16 km, and the surface 33 km^2. The ratio between the altitude at the spring and the confluence with Bahlui is: 470/109 [m].

Vulpoiu The length is 5 km and the surface of the river basin is 8 km^2. The ratio between the altitude at the spring and the confluence with Bahlui is: 160/107 [m]. It is a deforested area, with a lot of poultry and domestic animals. The river has very different level of the water in the dry or wet periods.

Magura The length is 25 km and the surface of the river basin is 78 km^2. The ratio between the altitude at the spring and the confluence with Bahlui is: 466/100 [m]. It is an agriculture area used for the cultivation of the vine.

Tansa reservoir Purpose: flood protection, fishing and drinking water for Tansa locality. The characteristic data of Tansa reservoirs are shown in the table.
The Putina river, which coming too in the Tansa reservoir, is not monitored.

Tansa outlet The control section is at the spillway (the water surface) – 58 km downstream the spring. At 1 km downstream Tansa reservoir, the WWTP Tansa-Belcesti discharge in the river Bahlui.

Bahlui downstream Tansa-Belcesti The section is placed 59.5 km downstream the springs, upstream the confluence with Gurguiata river. The left bank consists of deforested hills formed mostly by loess, and the right bank is a flat plain, with grass.

A.2 The analysis methods

parameter	analysis method
BOD5	standard BOD5
COD-Mn	oxidation with potassium permanganate
COD-Cr	oxidation with potassium dichromate
NO2	photo spectrometry with □-naphtilamine
NO3	photo spectrometry with natrium salicilate
NH4	photo spectrometry with Nessler reagent
Nkj	photo spectrometry with persulphat (mineraliz), Nessler reagent
total-P	photo spectrometry, with ammonium molybdate and persulphate
ortho-P	photo spectrometry, with ammonium molybdate
Cl^-	titrimetric method, with silver nitrate
TDS	gravimetric method
Ca	volumetric method with EDTA
Mg	photo spectrometry with Titanium yellow
K	flame-photometry
Mn	photo spectrometry with potassium persulphat
Zn	photo spectrometry with ditizone
Cr	photo spectrometry with diphenilcharbazide
Cu	photo spectrometry with diethildithiocarbamat
Fe	photo spectrometry with ortho phenantroline
SO4	photo spectrometry with barium chloride
CO3	volumetric method with HCl 0,02 N

Part 2.Effects of silt and silvercarp on the ecological condition of Tansa and Parcovaci

Summary

In this study we analysed the impact of fish culture and silt on the ecology of two reservoirs in the Prut river basin district with emphasis on silver carp, phytoplankton and silt. The Tansa reservoir is intensively used for fish culture, whereas Parcovaci is hardly exploited because of too many obstacles preventing efficient fishing. The algal biomass is very low in both reservoirs and shows clear differences with respect to biomass and size composition of the phytoplankton community. The nutrient loads and nutrient concentrations cannot explain the low biomass and the differences in composition. The high concentrations of silt particles are probably the main cause of limitation in biomass. The silt is responsible for a high light extinction and a low availability of phosphorus as P is fixed to the silt particles. The silt is probably not responsible for the difference in composition. The best explanation for this difference is the direct impact of silver carp on the phytoplankton biomass and size composition. The lower limit of the consumed particles by silver carp is 0,1 –1 μg^{-3}, whereas the average size in Tansa is ca. 0.2 μg^{-3}, and in Parcovaci ca. 2 μg^{-3}. This is a good indication that in Tansa silver carp is grazing down the algae up to the size that limits the uptake. Considering a density of ca. 500 kg ha-1 and a total algal biomass of 3,3 g m^{-2} (=33 kg ha^{-1}) the daily consumption (between 4 and 10% of body weight) will approach the daily production of phytoplankton. The ecological condition of both reservoirs is poor, although somewhat better in Pircovaci. The main problem is silt and only measures to reduce the silt load will be effective to improve the ecological condition. Apart from that also the stocking of silver carp, common carp and gible carp have negative effects on the ecological condition because they almost replace the autochthones fish community and have direct negative effects on the phytoplankton community. But is this effect is of secondary importance compared to the silt.

1.Introduction

In Romania many reservoirs were constructed in the 60s and 70s as protection against flooding, for drinking, industrial water and irrigation. The water quality of these reservoirs is poor and characterized by high nutrient loads, high silt concentrations, low water transparency and a general lacking of aquatic vegetation. The fish community is completely dominated by introduced species for fish culture and is intensively exploited. The poor water quality of these reservoirs seem to be caused by high nutrient loads and problems of erosion. Apart from that the very intensive fish culture in these reservoirs is also likely to have a direct and indirect impact on the water quality (Ping & Jiankang 2001).

In this study we analysed the impact of fish culture on water quality by comparing two reservoirs in the Prut river basin district with respect to water quality and fish community. The Tansa reservoir is intensively used for fish culture, whereas Parcovaci is hardly exploited because of too many obstacles preventing the fishing. Regarding water quality Boers & Perjoiu (2005) analyzed nutrient loads (P and N), nutrient concentrations, and suspended matter concentrations for the period 1991-2004, whereas phytoplankton and zooplankton were analyzed in this study. The fish community and its exploitation was analyzed using the information of the local fishermen on the composition and biomass of the yearly catches. Apart from that we made an independent monitoring of the fish community in both reservoirs.

2. Methods

Study site

The reservoirs Tansa-Belcesti and Pircovaci are located in the northeastern part of Romania, are part of the Prut basin and managed by the water authority Apele Romane. The reservoirs were finished by closing the dams in the 1970-s. The surface area of Tansa is 352 ha, the mean depth is 5.6 m. The sediment is mainly silt. The reservoir was build for protection against flooding, but the water was also used for irrigation (3355 ha), drinking and industrial water and fish culture. The reservoir is yearly stocked with silver carp (*Hypophthalmichthys molitrix/nobilis)*, common carp (*Cyprinus carpio*) and Prussian carp (*Carassius gibelio*). The fish is 1 and 2 years old when stocked.

The Tansa reservoir is fed by the river Bahlui, which streams through agricultural area and the most important villages in the area. Erosion can be observed in the fields as a consequence of unwise land exploitation and causes siltation problems. As no measures are taken against erosion, large amounts of soil material are washed into the reservoirs. The reservoir is therefore quite turbid without any aquatic macrophytes. There are only some reed associations (*Phragmites communis*) along one of the shores.

The surface area of Parcovaci is 90 ha, the mean depth is 3.5 m. The sediment is mainly silt. The reservoir was build for protection against flooding, but the water was also used for irrigation, drinking and industrial water. The reservoir is not suitable for fish culture as there are many obstacles (remains of trees, concrete blocks) preventing an efficient fishing.

The Parcovaci reservoir is fed by the river Bahlui, which streams through forest area and some villages in the area. Erosion seems to be less important than in Tansa. The reservoir is yet quite turbid without any aquatic macrophytes. There is no emergent vegetation along the shores.

Monitoring

In the current monitoring programme four sampling-locations were choosen at both reservoirs: one at the inlet of the reservoir, one at the outlet and two at both borders. Samples were taken from the shore. In the period 1991-2001 samples were taken 3 times per year, in April, June and September, since 2002 samples are taken monthly. Phytoplankton and zooplankton were collected with a bucket. For phytoplankton a water sample of half a liter was collected and preserved with a 1% lugol solution. Cels were counted in a Burker-Turk counting chamber. Per sample 3 chambers were counted. For zooplankton 50 liters were filtered over 50 μm mesh size nets and concentrated and preserved with 1% lugol solution in 50 ml. 0.5 ml was counted completely in a Sedgewick-Rafter.

Fish surveys were carried out in autumn of 2004 using gill nets with mesh sizes of 10, 20, 30, 40 and 50 mm (knot to knot). The separate nets were 100 m in length and 4 m in depth. 10 nets (2 x 5 mesh sizes) were set overnight. All fishes were measured with an accuracy of 1 cm.

3.Results

Suspended solids, P, N and BOD

The results of suspended solids, P, N and BOD are described in Boers & Perjoiu (2005). Here we give a brief summary of these parameters. Suspended solids, total P, dissolved N and BOD are on average 2 times higher in Tansa than in Pircovaci. Particularly suspended solids (37,5 resp. 76 mg l^{-1}) are quite high and it is likely that P and BOD correlate with suspended solids because a large part of the suspended solids is organic and stores a proportional part of phosphorus. The similar concentrations of SRP indicate that it is probable that P is limiting most of the time (when light is not limiting) and not N. The high concentration of dissolved N confirms this.

Table 1. Suspended solids, P, N and BOD averaged for both lakes and the whole period.

	Pircovaci	Tansa
SM	37.5	76
tot P	0.17	0.3
tot N	4.6	4.7
SRP	0.022	0.025
diss. N	0.61	1.3
BOD	6.4	12

Phytoplankton

In Tansa the density of phytoplankton is 4-5 times higher than in Parcovaci, whereas the biomass is almost 2 times lower. The total wet biomass in both lakes is relatively low compared to other eutrophic lakes. The wet algal biomass is 0,5-1 mg l^{-1} (tabel 2), which is comparable to 1μg l^{-1} chlorophyl, and therefore extremely low. Usually the biomass is 50 to 100 times higher, considering total P concentrations > 0,1 mg l^{-1}. For a period of 11 years the average cell weight in Tansa is almost seven times lower than in Parcovaci. The average cell weight in Tansa is 3,211*10^{-4} μg and 20,095*10^{-4} μg in Parcovaci.

Table 2. *Phytoplanktonic density and wet algal biomass*

	yearly average (cells/l)		yearly average (mg/l)	
	Tansa	**Pircovaci**	**Tansa**	**Pircovaci**
1991	1181600	944866	0.808	1.770
1992	385600	459875	0.094	0.610
1993	2701000	905164	0.387	0.560
1994	1445100	328381	0.215	0.624
1995	4148000	273000	0.473	0.870
1996	4860000	512223	0.561	0.936
1997	807375	255015	0.123	0.480
1998	1492875	527515	0.160	0.020
1999	2344800	287355	0.108	1.080
2000	1929075	453733	0.237	2.650
2001	1068095	105243	1.360	0.240
2002	1428635	107171	0.949	0.225
2003	386952	112730	2.29	0.98
Average	1859931	405559	0.597	0.850

The phytoplankton community is not proportionally equally distributed between the groups in both lakes, but dominated by different groups (figure 1). In Tansa the community is dominated by green algae (47%), diatoms (29%) and cyanobacteria (19%), in Parcovaci these percentages are 13%, 34% and 18% respectively. Chrysophyta and Pyrrophyta constitute ca. 25% and 9% in Parcovaci, but less than 1% and 3% in Tansa (figure 2).

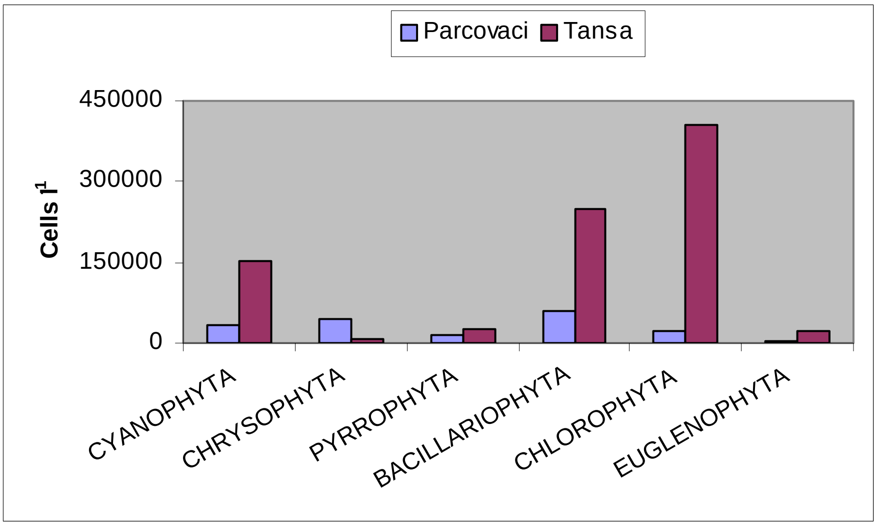


Figure 1. Density of phytoplankton plotted for different groups as an average for the period 1991-2003

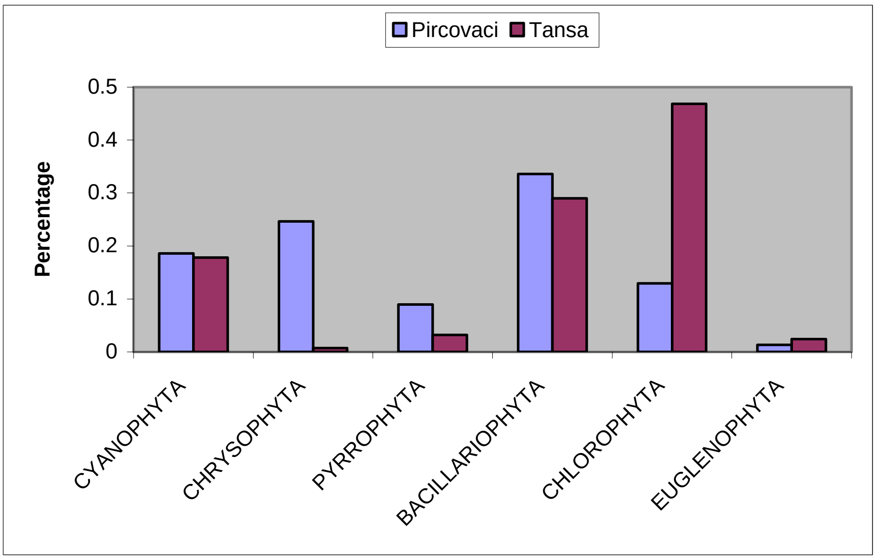


Figure 2. Percentage of phytoplankton plotted for different groups as an average for the period 1991-2003

Zooplankton

The zooplankton density in Tansa is somewhat larger than in Pircovaci, but is relatively low compared to other eutrophic lakes (figure 3). The low algal biomass is probably the main cause of this low biomass.

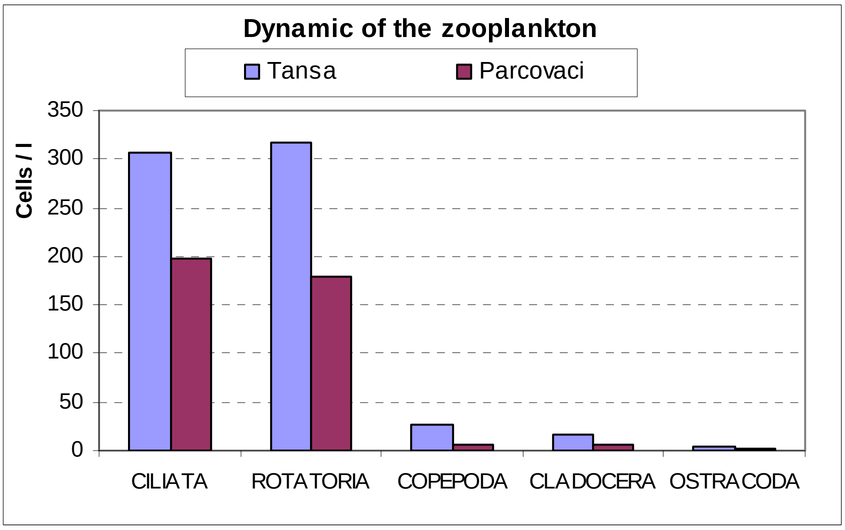


Figure 3. Density of zooplankton plotted for different groups as an average for the period 1991-2003.

Fish community

In Tansa the fish community is dominated by silver carp *(Hypophthalmichthys molitrix*). Subdominant fish species are common carp *(Cyprinus carpio)* and Prussian carp (*Carassius auratus gibelio*). All these fish species are stocked and are not a natural part of the fish community. Other more natural occurring fish species are perch (*Perca fluviatilis)*, pikeperch (*Stizostedion lucioperca*), roach (*Rutilus rutilus)*, ruffe (*Gymnocephalus cernua*). The natural part of the fish community is ca. 1% in biomass of the total fish community. The size and age composition of the fish community is biased towards the small and young fish as silver carp has no opportunity to reach large sizes because of the intensive fishery (figure 4).

In Parcovaci the fish community is dominated by chub (*Leuciscus chephalus)* en Prussian carp. Silver carp were occasionally stocked and constitute a much smaller part of the fish community than in Tansa (figure 5). Chub is also a natural occurring fish species.

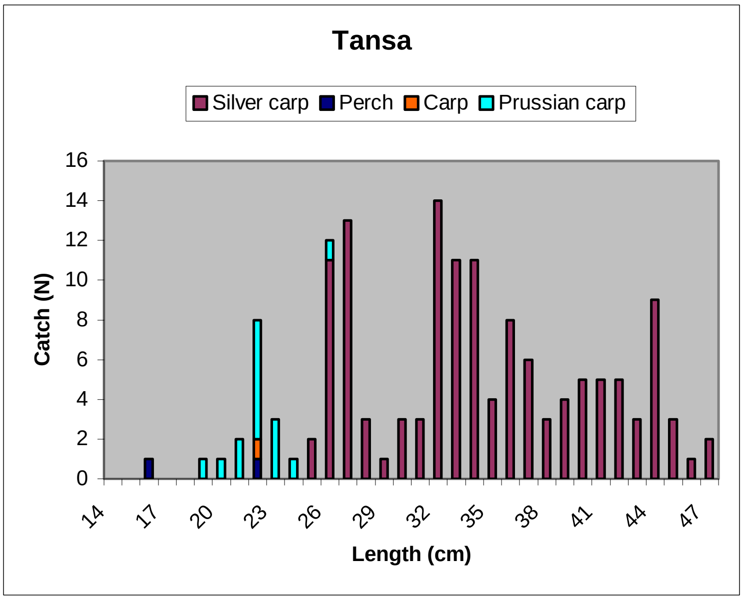


Figure 4. Size composition of catch per night with gill nets in Tansa.

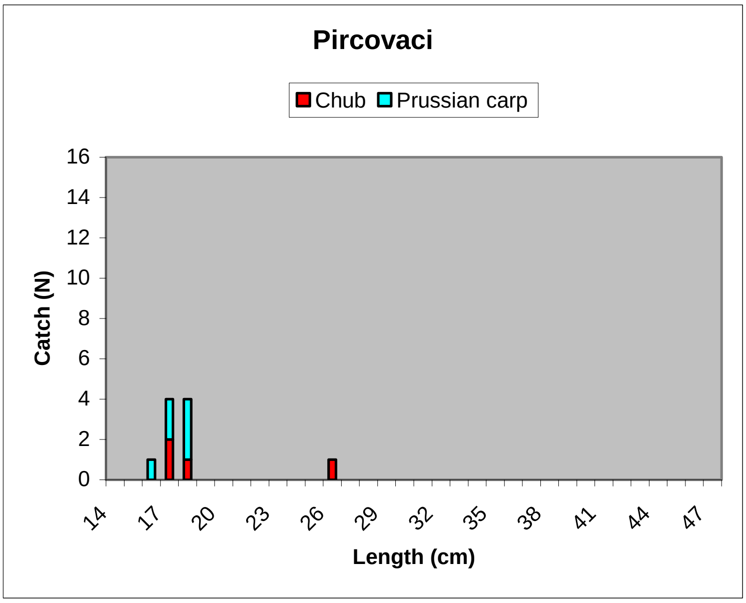


Figure 5. Size composition of catch per night with gill nets in Parcovaci.

4. Discussion

Although the nutrient loads and nutrient concentrations in Tansa and Pircovaci are quite high, the algal biomasses in the reservoirs are quite low. Usually eutrophic lakes with total P concentrations of 150-300 μg as in Tansa and Pircovaci l^{-1} have a total wet weight of algae of 75-150 mg l^{-1}. In Tansa and Pircovaci the total wet weight is usually lower than 1 mg l^{-1}. It is most likely that there is limitation of light and P considering the low SRP concentration and the low transparency in both reservoirs. The concentration of dissolved N is quite high and certainly not limiting (Table 1). So although the nutrient load is quite high (see Boers & Perjoiu, 2005), the reservoir seems to be oligotrophic considering the algal biomass. Despite this there is a high production of silver carp, which is feeding directly on the algae. The effect of this grazing affects the composition of the phytoplankton community. Ping (1999, 2001) estimated that the lower limit of the consumed particles by silver carp is 0,1 –1 μg^{-3}. This limit corresponds quite well to the average size of cells in Tansa (ca. 0.2 μg^{-3}) and is a good indication that silver carp is grazing down the algae up to the size that limits the uptake. In Parcovaci this size is much higher (ca. 2 μg^{-3}), as the biomass and the grazing pressure of silver carp is quite low. In Tansa the production of the silver carp population is therefore limited by the production of algae.

The production of other fish, which are dependent on zooplankton and zoobenthos, is quite low, as the production of these food sources is low because of the low production of algae. In similar eutrophic lakes the biomass of the fish community dependent on the food sources is usually ca. 200 kg ha^{-1}. However, in these reservoirs the biomass of carp, gibel carp, pikeperch and perch is not more than 25-50 kg ha^{-1}, which is also typical for oligotrophic conditions. Usually the biomass of zooplankton and zoobenthos in eutrophic lakes is 1-10 g m^{-2}, but in these reservoirs the biomass is much lower than 1 g m^{-2}, although there was an accurate estimation of the zoobenthos biomass is lacking.

The high background turbidity is caused by a high concentration of mineral particles and will limit the production of algae as well. It was not possible to determine whether light or P is more limiting.

According to the data of the fish company the fish yield in Tansa varies between 200 and 1000 kg ha^{-1}. A simple calculation shows the enormous feeding pressure. If we consider 500 kg ha^{-1} as a normal fish yield per year then the average biomass during summer will be at least 500 kg ha^{-1}. This corresponds to 50 grams m^{-2}. According to the phytoplankton data ca. 3,3 gram algae m^{-2} is present. 75-90 % of the fish is silvercarp feeding directly on algae. To realize growth the fish needs to consume ca. 4-10% of its body weight (= 2-5 g m^{-2}). This implies that the part of the algal biomass which can be retained by the sieve of the silver carp will be harvested up to a level that the daily production equals the daily consumption. This high feeding pressure on the algae will be the main cause of the relatively low biomass and small cell size in Tansa compared to Parcovaci, where no high biomass if silver carp is present.

The fish community in Tansa is far from natural. Silvercarp, Prussian carp and common carp have been introduced and completely dominate the fish community. From the perspective of fish yield this is the best solution given the potential of the reservoir. Considering the dominant role of silt in the ecology of the reservoirs the alternative situation more or less resembles that in Pircovaci.: a low fish biomass with riverine species as chub, but also the introduced gibel carp, which species reproduces successfully in this reservoir in contrast to common carp and silver carp. As a consequence the algal community contains a higher percentage of Chrysophyta and Pyrrophyta, which are more vulnerable for grazing. The large amounts of silt in water and on the bottom have also a negative impact on grazing of zooplankton and are not a suitable substrate for most benthos species.

The ecological condition of both reservoirs is poor, although somewhat better in Pircovaci. The main problem is silt and only measures to reduce the silt load will be effective to improve the ecological condition. Apart from that also the stocking of silver carp, common carp and gible carp have negative effects on the ecological condition because they almost replace the autochthones fish community and have direct negative effects on the phytoplankton community. But is this effect is of secondary importance compared to the silt.

5. Literature

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