TRANSYLVANIAN REVIEW OF SYSTEMATICAL AND ECOLOGICAL RESEARCH

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The Wetlands Diversity

Editors

Angela Curtean-Bănăduc & Doru Bănăduc

Sibiu - Romania
2016

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Angela Curtean-Bănăduc & Doru Bănăduc

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Editorial Assistants

IN MEMORIAM

Francis Crick
(1916 – 2004)

Francis Crick was a British molecular biologist, biophysicist, and neuroscientist, born and raised in Weston Favell, a small village near Northampton, in which Crick's father ran a boot and shoe factory.

Walter Crick, his grandfather, was an amateur naturalist. He published a review of local foraminifera, corresponded with Charles Darwin, and had two gastropods named after him.

From childhood, Francis was fascinated by science and by what he could learn about it. , His uncle, also Walter Crick, lived in a small residence in Abington Avenue, near his parent's home; Walter had a shed in his small garden where he instructed Francis do chemical experiments, blow glass, and to make photographic prints. When he was eight Francis moved to Northampton Grammar School. His teacher, Miss Holding, was an inspiring teacher and made all subjects attractive. After 14 years old, he won a scholarship to attend Mill Hill School in London, where he studied physics, mathematics, and chemistry. He shared the Walter Knox Prize for Chemistry in 1933 on Mill Hill School's Foundation Day 7 July, and he asserted that his achievement was stimulated by the quality of teaching he has enjoyed at Mill Hill.

At the age of 21, Crick earned a Bachelor of Science degree in physics from University College London (UCL). He began a PhD at UCL but was interrupted by World War II. He later became a PhD student and Honorary Fellow of Gonville and Caius College, Cambridge and for the most part worked at the Cavendish Laboratory and the Medical Research Council Laboratory of Molecular Biology in Cambridge. Crick was also an Honorary Fellow of Churchill College Cambridge and of University College London.

Crick began his PhD research project on the viscosity of water at high temperatures at University College London. During the second year of his PhD, he was awarded the Carey Foster Research Prize. He did postdoctoral work at the Polytechnic Institute of Brooklyn.

During World War II, he worked for the Admiralty Research Laboratory, from which emerged many notable scientists. He designed magnetic and acoustic mines.

In 1947, Crick started studying biology and was a part of an important migration of physicists into the area of biological research. Crick worked first on the physical properties of cytoplasm at the Strangeways Research Laboratory and Cavendish Laboratory, Cambridge.

Crick was interested mainly in fundamental problems of biology: how molecules make the transition from the non-living to the living, how the brain makes a conscious mind, the origin of life, etc.

He was most famous for being a co-discoverer of the structure of the DNA molecule in 1953 together with James Watson. In addition to his one-third share of the 1962 Nobel Prize, he received many honours and awards, among other things the Royal and Copley Medals of the Royal Society (1972 and 1975), and the Order of Merit (27 November 1991).

He married twice, fathered three children and was grandfather of six grandchildren.

Crick died of colon cancer on the morning of 28 July 2004, he was cremated and his ashes were scattered into the Pacific Ocean.

The Francis Crick Institute biomedical research centre located in north London, United Kingdom, is one of the largest such centres in Europe today.

The Editors

CONTENTS

Preface

In a global environment in which the climate changes are observed from few decades no more only through scientific studies but also through day by day life experiences of average people which feel and understand allready the presence of the medium and long-term significant change in the “average weather” all over the world, the most comon key words which reflect the general concern are: heating, desertification, rationalisation and surviwing.

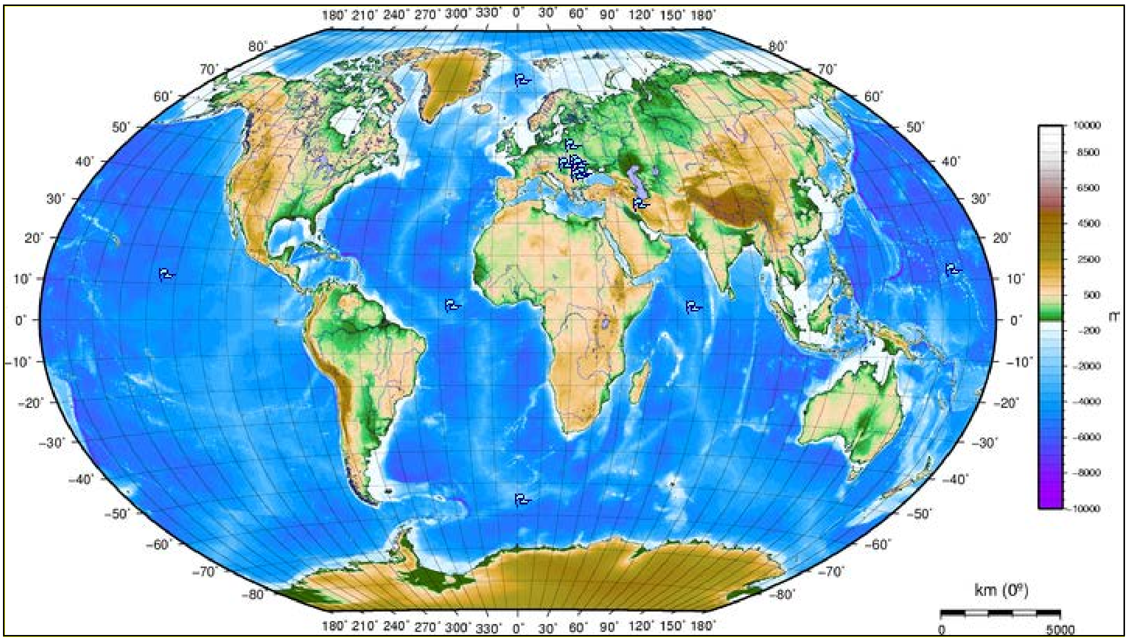
The causes, effects, trends and possibilities of human society to positively intervene to slow down this process or to adapt to it involve a huge variety of aproacess and efforts.

With the fact in mind that these aproaces and efforts shuld be based on genuine scientific understanding, the editors of the *Transylvanian Review of Systematical and Ecological Research* series launch a second annual volumes dedicated to the wetlands, volumes resulted mainly as a results of the *Aquatic Biodiversity International Conference*, Sibiu/Romania, 2007-2015 and The 41st International Association for Danube Research Cnference, Sibiu/Romania, 2016.

The therm wetland is used here in the acceptance of the Convention on Wetlands, signed in Ramsar, in 1971, for the conservation and wise use of wetlands and their resources. **Marine/Coastal Wetlands -** Permanent shallow marine waters in most cases less than six metres deep at low tide, includes sea bays and straits; Marine subtidal aquatic beds, includes kelp beds, sea-grass beds, tropical marine meadows; Coral reefs; Rocky marine shores, includes rocky offshore islands, sea cliffs; Sand, shingle or pebble shores, includes sand bars, spits and sandy islets, includes dune systems and humid dune slacks; Estuarine waters, permanent water of estuaries and estuarine systems of deltas; Intertidal mud, sand or salt flats; Intertidal marshes, includes salt marshes, salt meadows, saltings, raised salt marshes, includes tidal brackish and freshwater marshes; Intertidal forested wetlands, includes mangrove swamps, nipah swamps and tidal freshwater swamp forests; Coastal brackish/saline lagoons, brackish to saline lagoons with at least one relatively narrow connection to the sea; Coastal freshwater lagoons, includes freshwater delta lagoons; Karst and other subterranean hydrological systems, marine/coastal. **Inland Wetlands -** Permanent inland deltas; Permanent rivers/streams/creeks, includes waterfalls; Seasonal/intermittent/irregular rivers/streams/creeks; Permanent freshwater lakes (over eight ha), includes large oxbow lakes; Seasonal/intermittent freshwater lakes (over eight ha), includes floodplain lakes; Permanent saline/brackish/alkaline lakes; Seasonal/intermittent saline/brackish/alkaline lakes and flats; Permanent saline/brackish/alkaline marshes/pools; Seasonal/intermittent saline/brackish/alkaline marshes/pools; Permanent freshwater marshes/pools, ponds (below eight ha), marshes and swamps on inorganic soils, with emergent vegetation water-logged for at least most of the growing season; Seasonal/intermittent freshwater marshes/pools on inorganic soils, includes sloughs, potholes, seasonally flooded meadows, sedge marshes; Non-forested peatlands, includes shrub or open bogs, swamps, fens; Alpine wetlands, includes alpine meadows, temporary waters from snowmelt; Tundra wetlands, includes tundra pools, temporary waters from snowmelt; Shrub-dominated wetlands, shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils; Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils; Forested peatlands; peatswamp forests; Freshwater springs, oases; Geothermal wetlands; Karst and other subterranean hydrological systems, inland. **Human-made wetlands -** Aquaculture (e. g., fish/shrimp) ponds; Ponds; includes farm ponds, stock ponds, small tanks; (generally below eight ha); Irrigated land, includes irrigation channels and rice fields; Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture); Salt exploitation sites, salt pans, salines, etc.; Water storage areas, reservoirs/barrages/dams/impoundments (generally over eight ha); Excavations; gravel/brick/clay pits; borrow pits, mining pools; Wastewater treatment areas, sewage farms, settling ponds, oxidation basins, etc.; Canals and channels, ditches; Karst and other subterranean hydrological systems, human-made.

The editors of the *Transylvanian Review of Systematical and Ecological Research* started and continue this new annual sub-series (*Wetlands Diversity*) as an international scientific debate platform for the wetlands conservation, and not to take in the last moment, some last heavenly "images" of a perishing world …

This 18.1 volume included variated researches from diverse wetlands around the world.



The subject areas (flag symbol) for the published studies in this volume.

No doubt that this new data will develop knowledge and understanding of the ecological status of the wetlands and will continue to evolve.

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BACTERIOPLANKTON FROM TWO HUNGARIAN DANUBE RIVER WETLANDS (BEDA-KARAPANCSA, DANUBE-DRAVA NATIONAL PARK) AND ITS RELATIONS TO ENVIRONMENTAL VARIABLES

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KEYWORDS: bacterioplankton, wetlands, environmental variables, Hungary.

ABSTRACT

Seasonal and spatial distribution of bacterioplankton from two Hungarian oxbow lake type wetlands, Mocskos-Danube and Riha, was studied. They were both covered by macrophytes and they had different hydrological connectivity to the Danube. The six sampling campaigns from April to October 2014 included parallel samples from the Danube River at Mohács, Hungary. Bacterial abundance was the highest in spring and in Mocskos-Danube, followed by Mohács and Riha. Positive relationships existed between bacterioplankton and temperature on one hand and suspended solids, pH, PO_4-P and chl-a on the other. Negative correlations were with DOC, dissolved oxygen and NH_4-N.

ZUSAMMENFASSUNG: Das Bakterienplankton von zwei ungarischen Donaufeuchtgebieten (Beda-Karapancsa, Donau-Drau Nationalpark) und ihre Beziehungen zu Umweltfaktoren.

Die jahreszeitiliche und räumliche Verteilung des Bakterienplanktons von zwei ungarischen Altwasser-Feuchtgebieten, Mocskos-Donau und Riha, wurde untersucht. Sie waren mit Makrophyten bedeckt und hatten eine unterschiedliche hydrologische Konnektivität zum Hauptfluss. Die Feuchtgebiete wurden zwischen April und Oktober 2014, mit parallelen Probenahmen vom Donauhauptkanal bei Mohács, Ungarn sechs Mal untersucht Die Bakterienzahl war am höchsten im Frühling und in der Reihenfolge Mocskos-Donau, gefolgt von Mohács und Riha. Positive, statistisch signifikante Beziehungen wurden zwischen Bakterienabundanz und Temperatur, Schwebstoffen, pH, PO_4-P und Chlorophyll-a nachgewiesen. Negativ waren die Korrelationen mit der DOC, gelöstem Sauerstoff und NH_4-N.

REZUMAT: Bacterioplanctonul din două zone ale părţii ungare a fluviului Dunărea (Beda-Karapancsa, Dunăre-Parcul Naţional Drava), și relațiile sale cu variabilele de mediu.

A fost studiată răspândirea sezonieră și spațială a bacterioplanctonului din două zone umede de tip Oxbow din Ungaria, Mocskos-Dunarea și Riha. Ambele zone umede studiate au fost acoperite de macrofite și au diferite legături hidrologice cu Dunărea. Cele șase campanii de prelevare de probe, din aprilie până în octombrie 2014, au inclus eșantioane paralele din fluviul Dunărea la Mohács, Ungaria. Cea mai mare abundenţă a bacteriilor a fost primăvara, apoi la Mocskos-Dunăre, urmată de Mohacs și Riha. Relaţii pozitive există între bacterioplancton şi temperatură, pe de o parte, substanţe solide în suspensie, pH, PO_4-P şi clorofilă, pe de altă parte. Corelații negative au fost cu CCO, oxigenul dizolvat şi NH_4-N.

INTRODUCTION

Bacterioplankton, as a major component of plankton communities, plays an important role in the microbial food web as a food source, in the utilisation of dissolved organic carbon (DOC), in the decomposition of the dead organic matter and in the remineralisation of nutrients in the aquatic ecosystems (Havens, 1998; Cole, 1999; Jürgens and Matz, 2002; Vadstein et al., 2003). Factors controlling its abundance, size and morphology are important for the prognosis of organic matter removal from the aquatic systems or for the self-purification potential (Freese et al., 2007; Kalcheva et al., 2014).

Wetlands play an important role in the conservation of biodiversity, because of their high species richness and habitat diversity (Kalchev et al., 2010; Momeu et al., 2012; Tarjányi and Berczik, 2014). In large rivers, in particular the Middle and Lower Danube, the wetlands play an important role in nutrient cycling (Kalchev et al., 2014).

Different groups of aquatic communities, macrophytes and macroinvertebrates (Tarjányi and Berczik, 2014), zooplankton (Kiss et al., 2015), etc., have been studied in some Hungarian wetlands of Béda-Karapancsa floodplain, the Middle Danube, Danube-Drava National Park, but bacterioplankton development and its relation to environmental factors have not been studied yet, like in some wetlands along the Lower Danube River, in Bulgaria (Naumova and Kalcheva, 2012; Kalcheva et al., 2014).

The aim of the study was to determine the seasonal and spatial dynamics of bacterioplankton total number, biomass and the morphological and size structure in two wetlands of Béda-Karapancsa floodplain, oxbow lakes Mocskos-Danube and Riha, and in the Danube River near Mohács, situated in Danube-Drava National Park, Hungary. Furthermore, using statistical analyses, we tested their relations to the environmental factors.

MATERIAL AND METHODS

Different sites of two oxbow lake type wetlands, densely covered by macrophytes and with different hydrological connectivity, namely Mocskos-Danube (MDU) and Riha (RIH), first dominated by *Trapa natans* and the second with a *Ceratophyllum demersum* dominance were studied (Fig. 1). The wetlands are located in the protected side of Béda-Karapancsa, a highly valuable and protected (Natura 2000) area, part of the largest active floodplain of the Middle Danube River between rkm 1,447 and 1,440 (Fig. 1). Mocskos-Danube side arm (rkm 1,442-1,440), is approximately 3.4 km long, 60 m wide, with shallow water (average depth: 1.5 m) and very dense macrovegetation. It has a temporary connection with the Danube, the water flowing at 700 cm (gauge of Mohács rkm 1,447) at the upper end (MDU7, 45º58'18.3" N, 18º45'57.1" E) and at 550 cm at the lower end of the oxbow (MDU1, 45º57'24.8" N, 18º46'24.7" E, in details, Kiss et al., 2015). The water of MDU rarely flows (one to five times per year). Riha oxbow (46°00' N, 18°44' E) is located on the protected side of the floodplain and it has no connection with the main channel. It is 4.5 km long and 80 m wide. The average water depth is approximately 1-1.5 m. It is a strictly protected nature reserve area covered by dense macrovegetation.

The research was carried out in 2014 during six sampling visits and parallel samples were also taken from the main channel of the river Danube at gauge of Mohács (MOH, rkm 1,447), beyond the harbour of the ferry (45º56' N, 18º46' E) (Fig. 1). The sampling dates were established according to the Danube water regime, given the fact that the downstream connectivity of Mocskos-Danube is around 550 cm. A total of 61 water samples were taken in April-May, July-August and September-October.

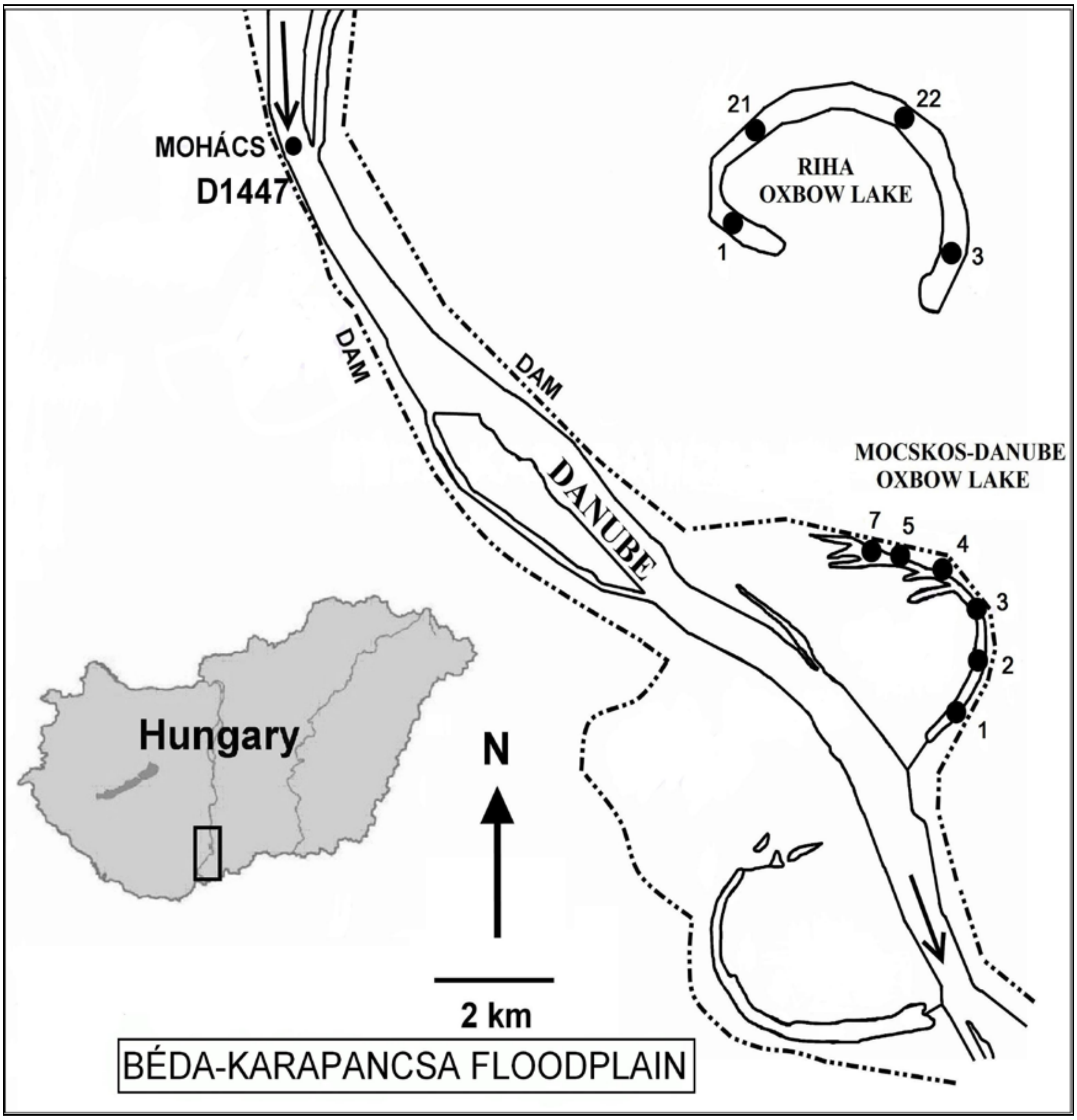

Figure 1: Overview of the study area in Hungary,
Béda-Karapancsa floodplain, Danube-Drava National Park,
and localisation of the sites in Mocskos-Danube (MDU; 1, 2, 3, 4, 5 and 7),
Riha (RIH; 1, 21, 22 and 3) and Mohács (MOH; 1, 2 and 3).

The number of bacteria was determined by the method of a direct count with a phase-contrast microscope (Carl Zeiss, Jena, Germany) by the ocular grid at a magnification of 1,600x after preliminary fixation with 2% formalin and staining with erythrosine (Razumov's method, updated by Naumova in Grudeva et al., 2006), described in detail in Kalcheva et al. (2008). Biomass was calculated in carbon content using Norland's formula (Straškrabová et al., 1999) after determination of the mean cell volume (MCV). Bacterioplankton was counted separately for cells (cocci and rods) freely dispersed on the filter (with 0.2 µm pore size) and for cells that were associated with detritus particles, since morphological groups were provisionally divided in four groups (free cocci and rods and attached cocci and rods). Biovolumes of cells of different morphological groups were determined by the geometric method (Antipchuk, 1983) and Naumova (Grudeva et al., 2006) provided simplified versions of formulas that use the median of the size class (for example the median of the sizes between 0.2 and 0.5 µm was 0.35 µm). The sizes of bacteria, from 0.2 to 4.2 µm, were divided into size classes (Pernthaler et al., 1996; Kalcheva et al., 2008; Chróst et al., 2009). Morphological index (M index = %rods/%cocci) was calculated, which allowed to determine the extent of pollution and the stage of self-purification, because the increase in the quantity and morphological diversity of rod cells, especially with the relatively large sizes was an indication of increased organic content in the water (Pernthaler, 2005). The number of detritus particles with attached bacteria was also counted.

Water samplings for environmental variables included in situ measurements of temperature, pH, dissolved oxygen, oxygen saturation and conductivity by a WTW Multi 403i meter. In the laboratory TOC (total organic carbon), DOC (dissolved organic carbon) and TN (total nitrogen) were determined by a TOC analyzer (Elemetar-liqui-TOC). Standard analytical methods (Golterman et al., 1978) were used to determine suspended solids, NO_3-N, NH_4-N, PO_4-P, TP (total phosphorus), and Chl-a (chlorophyll-a). The macrophyte cover in the wetlands was examined in % (Tarjányi and Berczik, 2014).

Multivariate statistical analysis Redundancy Analysis (RDA) with the program CANOCO for Windows 4.5 (ter Braak and Smilauer, 2002), single factor analysis of variance (one-way ANOVA), nonparametric correlations of Spearman (R_{Sp}) and regressions (linear correlations) with the computer program STATISTICA 7.0 (Fowler et al., 1998) were used. Bacterioplankton variables were included in RDA as dependent variables, while environmental factors were included as independent variables. Statistical evaluations were performed using a level of significance p (probability) with 5% risk of error (α or $p \leq 0.05$).

RESULTS AND DISCUSSION

Bacterioplankton dynamics

The total number of bacterioplankton ranged from 8.12×10^4 to 6.93×10^5 cells.ml^{-1}. It was higher in Mocskos-Danube, increasing in sites moving away from the lower inflow of the river, followed by samples from Mohács distinguished by many detritus particles with attached bacteria in the deeper areas (Figs. 2 and 3). The lower values were observed in Riha oxbow where the macrophyte cover was significant. Most probably the reason in RIH also is the lack of connection with the river, which would import additionally nutrients and organic matter necessary for the bacteria. The maximum in abundance was in MDU3, measured only in spring (April and May, MDU1 and MDU2 were without sampling), suggesting that the water from the Danube River inflow, due to spring flooding in 2014, was rich in organics. Kovalova et al. (2010) observed the decrease in bacterioplankton number in wetlands further from the Danube River and in their opinion this was caused by a decrease in the distance from the Danube River and from the Danube discharge influence carrying allochthonous organic matter and nutrients. The decrease of bacteria from MDU7 (upper inflow) to MDU1 (lower inflow) might be explain considering that opinion. Palijan et al. (2007) in Kopački Rit, Croatia, and Kalcheva et al. (2014) in Danube wetlands on Belene Island, Bulgaria, found spring maximum of bacterial abundance during high water level of the Danube River, as observed in this study.

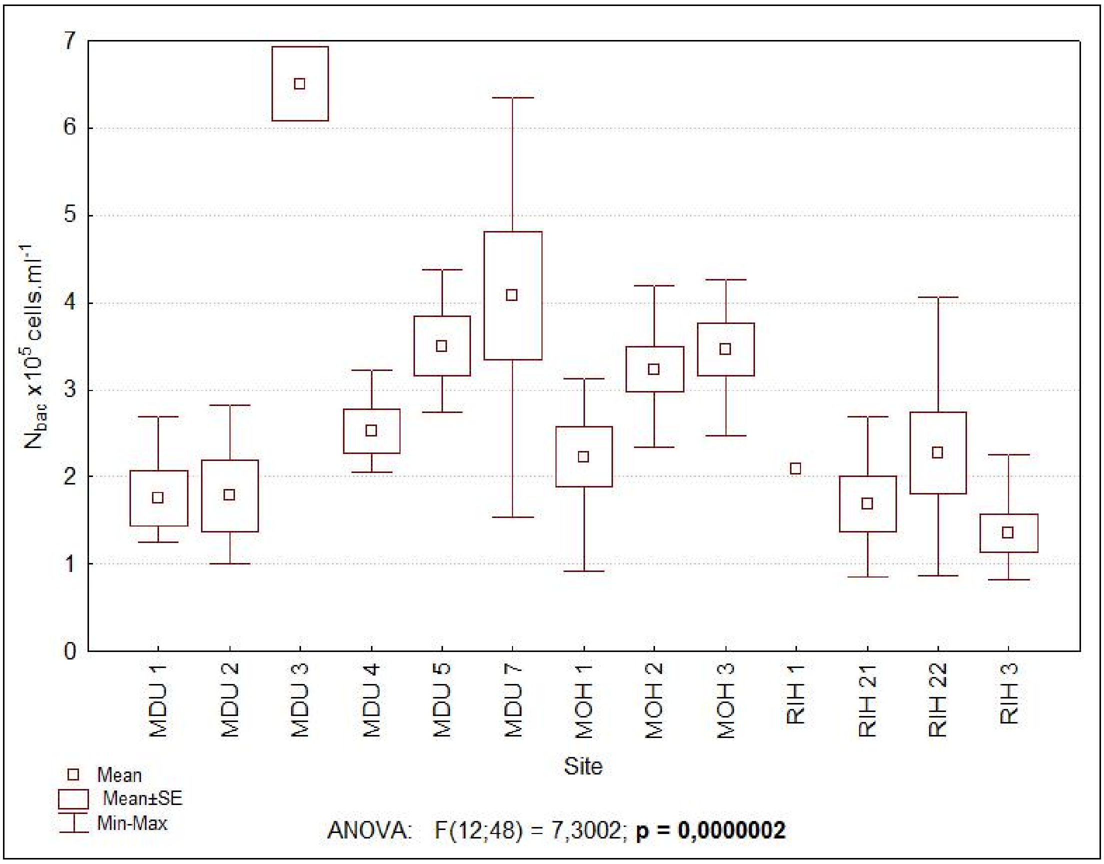

Figure 2: Spatial distribution of bacterioplankton total number (N bac) in different points of three sites, Mocskos-Danube (MDU, 1, 2, 3, 4, 5 and 7), Riha (RIH, 1, 21, 22 and 3) and Mohács (1-3), situated in Béda-Karapancsa floodplain in 2014.

The biomass varied from 0.91 to 10.80 $\mu gC.L^{-1}$ and its dynamics followed the abundance's dynamics, except the maximum in summer (August), while the mean cell volume (MCV) ranged from 0.033 to 0.08 μm^3 (Figs. 3 and 4), which was a relatively small biovolume because of the prevalence of bacteria from the smallest size class, which was the group 0.2-0.5 µm. Domination of bacteria from the smallest size class has been found in freshwater ecosystems with different trophic state (Pernthaler et al., 1996; Šimek et al., 1997; Cole, 1999; Jürgens and Matz, 2002; Pernthaler, 2005; Chróst et al., 2009) and is a normal phenomenon owing to abiotic factors outside of the optimum (temperature, pH, etc.), nutrient limitation (mainly of organic C or inorganic P), increased number of bacterivores or inactive state of the bacterial cells (Kalcheva et al., 2014).

The total number of bacteria (Figs. 2 and 3) and the biomass and MCV (Fig. 3) showed significant differences between the sampling sites ($p < 0.01$, ANOVA), while the biomass and MCV showed significant differences between the seasons ($p < 0.05$, ANOVA, Fig. 4). Morphotypes and cell sizes differed significantly by sites ($p < 0.01$) with prevalence of free-living cocci (36-88%). Only the rod-shaped bacteria differed significantly by seasons ($p = 0.03$, ANOVA) having a minimum in autumn. The average ratio free/attached bacteria in % was 78:22, indicating that a significant part of the bacterioplankton community in the water column is included in detritus particles with attached bacteria from the bottom (sediment) during continuous processes of resuspension and sedimentation of organics which is typical for shallow water bodies. Detritus particles had the highest values in MOH with a level of significance by sites $p = 0.0002$. Morphological index (Mindex) was with significant spatial ($p = 0.00004$) and seasonal differences ($p = 0.047$), higher in MOH3 and MDU7, but less than one, which was an indication of easily degradable organic matter in the water column.

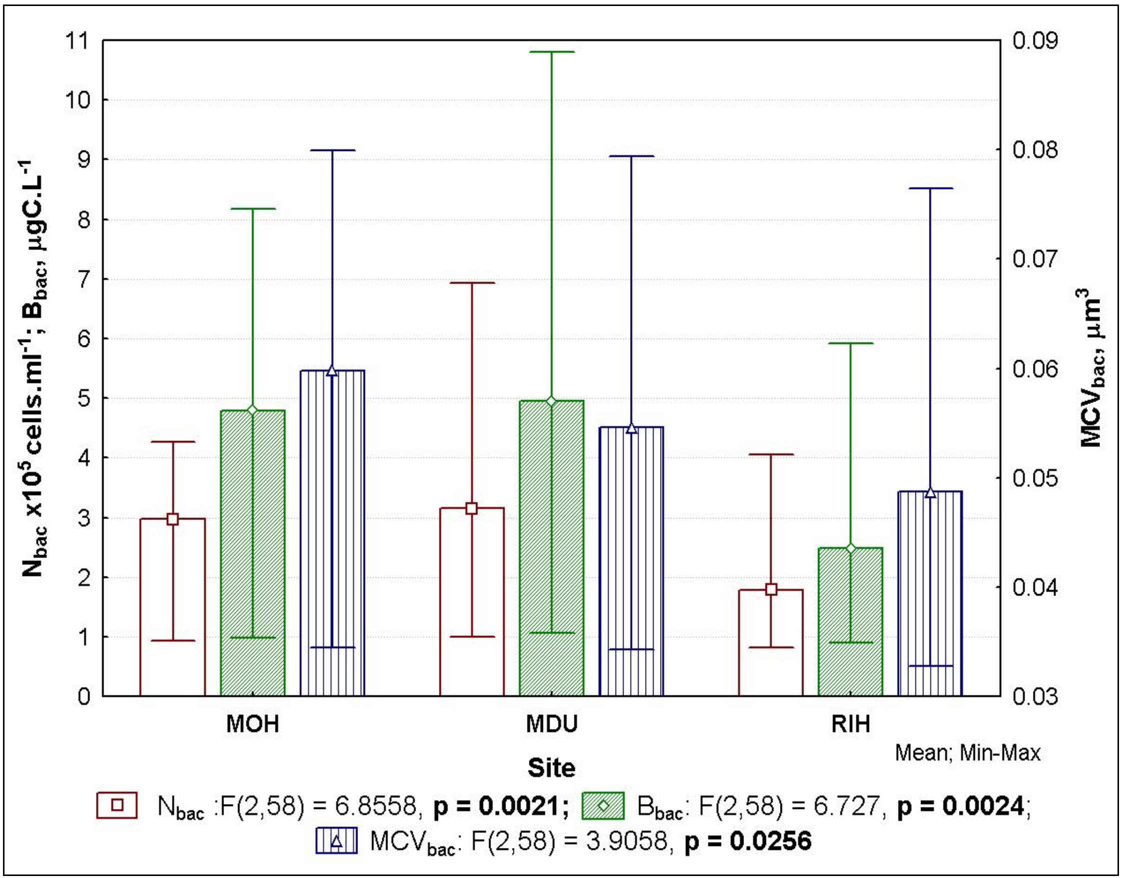

Figure 3: Spatial dynamics of bacterioplankton total number (N bac), biomass (B bac) and mean cell volume (MCV bac) in two wetlands, Mocskos-Danube (MDU) and Riha (RIH) and in the Danube River at the harbour of Mohács (MOH), situated in Béda-Karapancsa floodplain in 2014.

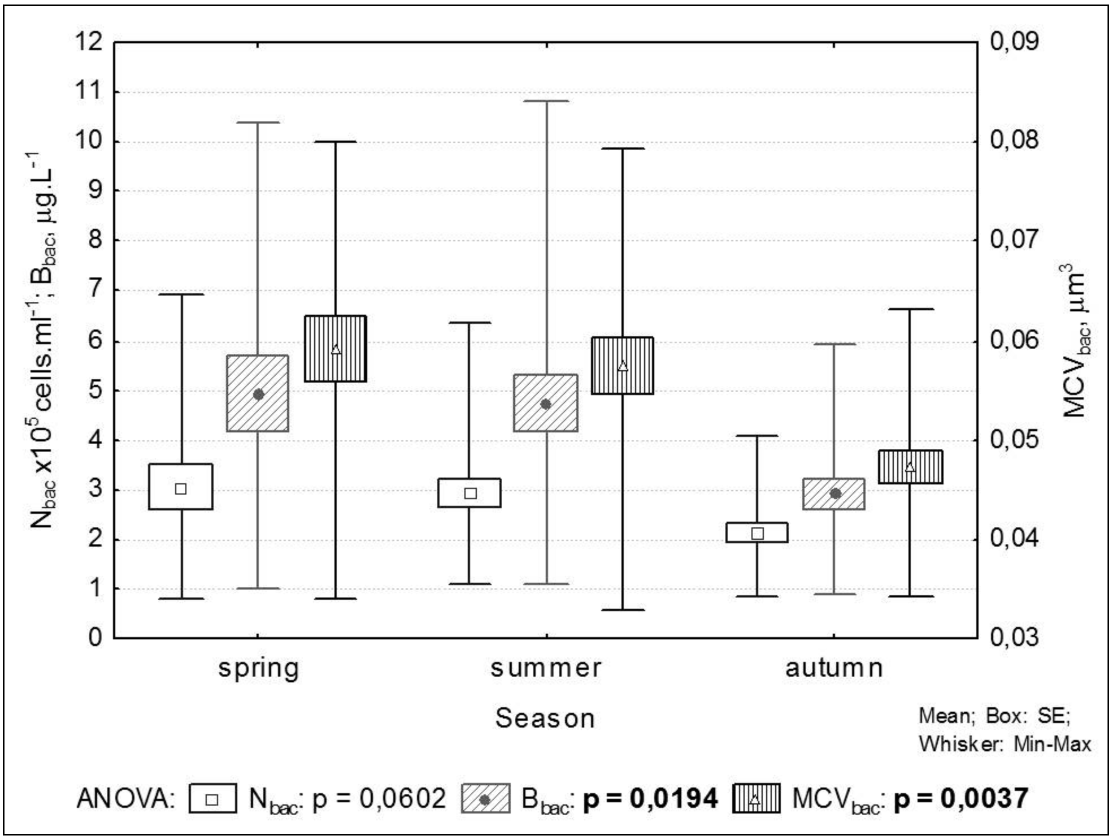

Figure 4: Seasonal dynamics (spring, summer and autumn) of bacterioplankton total number (N bac), biomass (B bac) and mean cell volume (MCV bac) in the wetlands Mocskos-Danube and Riha (Béda-Karapancsa floodplain) and in the Danube River near Mohács in 2014.

Relations of bacterioplankton to environmental variables

Direct relationships existed between bacterioplankton (total number and biomass) and temperature, suspended solids, pH, PO_4-P and Chl-a ($0.47 < r < 0.80$, $p < 0.5$). The multivariate redundancy analysis (Fig. 5) and Spearman's nonparametric tests also confirmed these correlations. As expected, the DOC decreased with the increase of planktonic bacteria, because of its utilization (r = – 0.49, p = 0.009). Furthermore, the correlations of dissolved oxygen and NH_4-N with the attached bacteria and between conductivity and the number and biomass of bacteria were similar, negative. Macrophyte cover in %, the highest in summer in MDU, was related positively to the temperature ($R_{Sp} = 0.48$), negatively to TN ($R_{Sp} = -0.55$) and conductivity, but very weak negatively only to the quantity of the attached bacteria (r = – 0.18, p = 0.17, not significant). *Ceratophyllum demersum* increases the dissolved oxygen and decreases COD and the pollution in the water and can be an effective biosorbent for phosphorus, ammonium and nitrate (Foroughi, 2011). Most probably such processes might have happened in Riha oxbow with dominance of this macrophyte species, reflecting with lower bacterioplankton development.

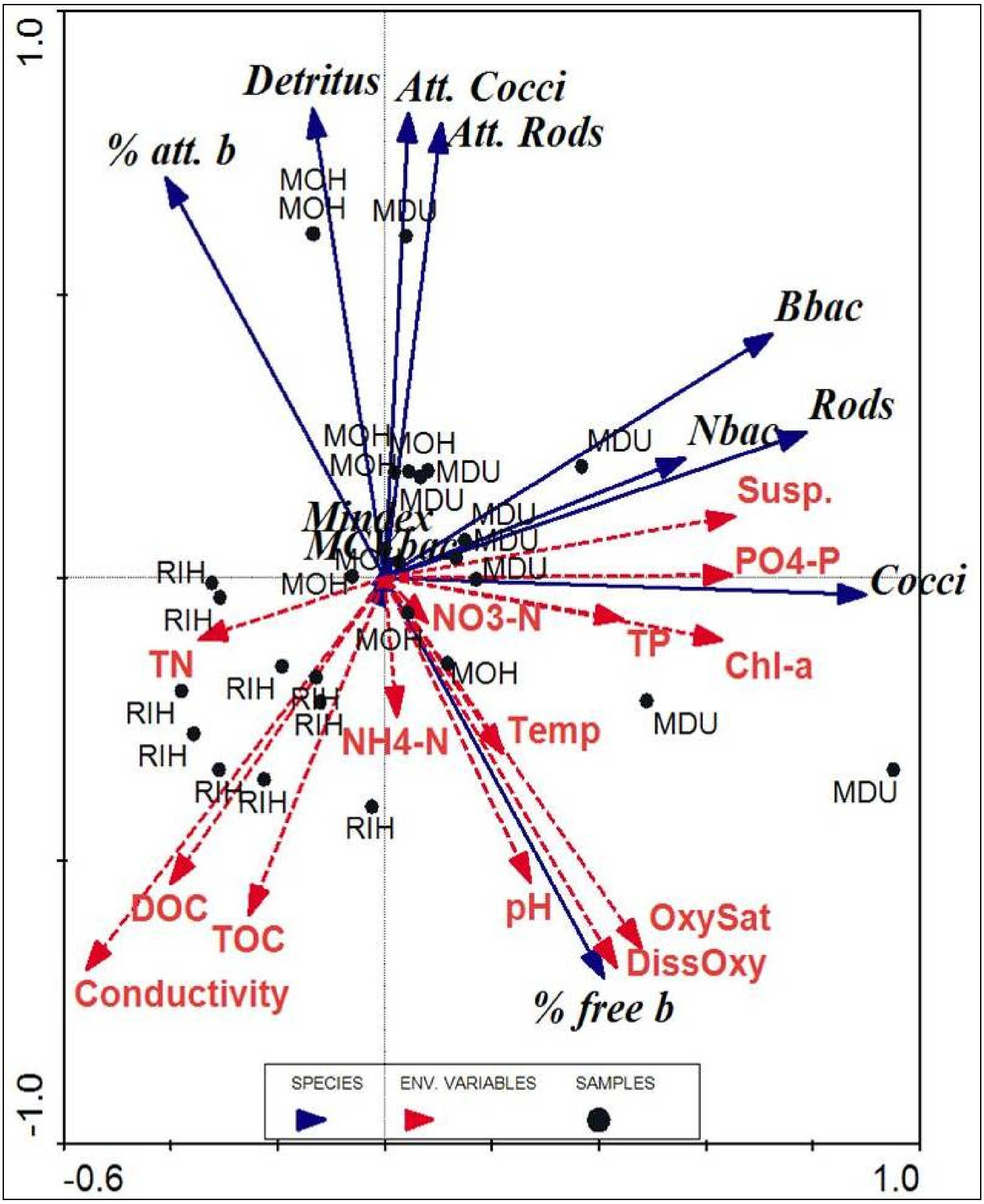

Figure 5: RDA triplot of correlations between bacterioplankton variables (species) and environmental variables (env. variables) by sites (samples) and the Monte Carlo test, given in the text, with p-value = 0.0240. Abbreviations: N − number, B − biomass, b = bac − bacteria, att. − attached, Mindex − morphological index, MCV − mean cell volume, RIH – Riha oxbow, MDU − Mocskos-Danube oxbow lake, MOH − Mohács, Temp − temperature, Oxy − oxygen, Sat − saturation.

The RDA analysis (Fig. 5) showed that 78.9% of all included environmental factors (canonical eigenvalues CanEV) explained the changes in all bacterioplankton variables by sites (MOH, MDU and RIH) and the correlations between them were significant (AllEV = 1.000, CanEV = 0.789, F-ratio = 3.478, p-value = 0.0240) of which 89% were correlations by the axis one. Suspended solids, PO_4-P, TP and chl-a, with their maximal values in MDU, correlated positively with the number and biomass of bacteria and with the numbers of free-living cocci and rods. Negative were the correlations with DOC, TOC, conductivity and TN, having the highest values in RIH. The % of free-living bacteria increased where the temperature and oxygen content were high. Attached bacteria and detritus particles, with the highest values in MOH, correlated negatively with the nutrients NH_4-N and NO_3-N, temperature, oxygen content and other factors. Mindex and MCV had weak variations by sites and the correlations were not clearly visible, but were positive with the nutrients, temperature and dissolved oxygen. P-limitation very often is the reason for weak utilization of DOC by bacterioplankton, because of C:N:P ratio out of the optimum, according to Vadstein et al. (2003).

CONCLUSIONS

Seasonal dynamics of bacterioplankton in the wetlands Mocskos-Danube and Riha, Béda-Karapancsa floodplain, Danube-Drava National Park, Hungary, demonstrates spring maximum what is also typical for other wetlands along the Middle and Lower Danube River during spring floodings.

The seasonal and spatial development of bacterioplankton and its relation to DOC, PO_4-P, TP, NO_3-N, NH_4-N and chl-a suggest that bacterioplankton actively participates in the decomposition of the dead organic matter and self-purification of water and in remineralisation of nutrients to be used by primary producers (phytoplankton and macrophytes) in the wetlands. Macrophyte dominance of *Ceratophyllum demersum* probably also helps in the removal of nutrients and against the pollution of water.

The lower bacterioplankton number in summer and autumn is probably connected with the increase of zooplankton pressure and competition with macrophytes and phytoplankton for nutrients.

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TROPHIC RELATIONSHIPS AND STATUS OF RESERVOIRS WITH AND WITHOUT OCCURRENCE OF *DREISSENA* SSP. (MOLLUSCA, BIVALVIA) BUILT ON BULGARIAN DANUBE RIVER TRIBUTARIES

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ABSTRACT

The trophic status and relationships between Secchi depth transparency (SD) chlorophyll-a (CHL) and total phosphorus (TP) concentrations from nine non-infested and five infested areas with invasive alien species, *Dreissena* ssp. reservoirs, situated on the Bulgarian Danube River tributaries were studied. The trophic status index (TSI) values after Carlson (1977), and showed statistically significant differences for all three variables between infested and non-infested reservoirs. The three linear regression equations between SD x CHL, CHL x TP and SD x TP were statistically significant for the group of non-infested reservoirs, while in the infested reservoirs only the SDxCHL regression was statistically significant for $P < 0.05$. Our results showed that the *Dreissena* invasion destroyed the linear relationship between CHL x TP and SD x TP and seems to affects the accurate application of Carlson TSI.

RESUMEN: Las relaciones tróficas y el estado de los embalses con y sin existencia de *Dreissena* ssp. (Mollusca, Bivalvia) basado en los afluentes búlgaros del Río Danubio.

El estado trófico y las relaciones entre la transparencia-profundidad del disco de Secchi (SD), concentraciones de clorofila-a (CHL) y fósforo total (TP) de nueve embalses no infestados y cinco infestados con a especie exóticas invasoras *Dreissena* ssp. fueron estudiados. Se estudiaron los embalses situados en los afluentes búlgaros del río Danubio. Los valores de índice de estado trófico (TSI) según Carlson (1977) mostraron diferencias estadísticamente significativas para las tres variables entre embalses infestados y no infestados. Las tres ecuaciones de regresión lineal entre SD x CHL, CHL x TP y SD x TP fueron estadísticamente significativas para el grupo de los embalses no infestadas, mientras que en los embalses infestados solamente la regresión SDxCHL fue estadísticamente significativa con $P < 0,05$. Nuestros resultados mostraron que la invasión de *Dreissena* destruyó la relación lineal entre CHL x TP y SD x TP y parece que afecta a la aplicación precisa de Carlson TSI.

REZUMAT: Relații trofice și starea lacurilor de acumulare cu și fără populații de *Dreissena* ssp. (Mollusca, Bivalvia) constituite pe afluenții dunăreni de pe teritoriul bulgăresc.

S-a studiat starea trofică și relațiile între transparența măsurată cu discul Secchi (SD) și concentrațiile de clorofilă-a (CHL) și de fosfor total (TP) din nouă lacuri de acumulare neinfestate și cinci infestate cu specia invazivă *Dreissena* ssp., situate pe afluenții de pe malul bulgăresc al Dunării. Valorile indicelui de eutrofizare după Carlson (1977) au variat statistic semnificativ în cazul tuturor celor trei variabile de la un lac la altul. Cele trei ecuații de regresie liniară între SD x CHL, CHL x TP and SD x TP s-au corelat semnificativ din punct de vedere statistic pentru grupul de lacuri neinfestate, în timp ce în cazul lacurilor infestate numai regresia SD x CHL a prezentat semnificație statisică cu $P < 0,05$. Rezultatele noastre demonstrează că invazia de *Dreissena* ssp. a anihilat relația liniară între CHLxTP și SDxTP și pare să afecteze aplicarea corectă a indicelui de eutrofizare Carlson.

INTRODUCTION

The substantial increase during recent decades in mobility and all kinds of contact of mankind around the globe is leading to an intentional and non-intentional fast spreading of biological species far beyond their natural areal. The Danube River is not an exception (Bănăduc et al., 2016).

Those alien species which are threatening the biodiversity of invaded native ecosystems are considered invasive (IUCN, 2000).

Some invasive alien species like *Dreissena* ssp. are also able to strongly affect not only the biodiversity but also the habitat and functioning of aquatic ecosystems. Through this, they are affecting relationships and metrics developed for the estimation of ecological status and implementation of the Water Framework Directive of EC (Qualls et al., 2007; Arndt et al., 2009; De Winton et al., 2012).

Until now, the widely used trophic state index (TSI) developed by Carlson (1977), for trophic status estimation of standing aquatic ecosystems was still not tested if its applicability is also influenced by invasive alien species; despite the fact that the relationship underlying for TSI between chlorophyll-a (CHL) and total phosphorus (TP) was reported to be strongly affected by *Dreissena* ssp. (Qualls et al., 2007; Atalah et al., 2010). Therefore, we have set our goal to study the effect of *Dreissena* ssp. occurrence on the three SD x CHL, CHL x TP and SD x TP relationships, which are fundamental for derivation of TSI of Carlson (1977).

MATERIAL AND METHODS

Measurements of water column transparency by Secchi disc (SD) chlorophyll-a (CHL) and total phosphorus (TP) concentrations from a total of 14 freshwater reservoirs situated in the Danube River catchment on Bulgarian territory were available for testing the effect of *Dreissena*'s ssp. occurrence.

There are two main data sources providing the mentioned measurements. The first one was the publication of Tosheva, Traykov (2012), consisting of data collected between June and September, 2009-2011. The second one was represented by the three own extensive sampling campaigns on five stations of Ogosta Reservoir in the same period. The already published list of reservoirs with and without *Dreissena* ssp. by Kalchev et al. (2014), helps us to identify the two groups.

The group without *Dreissena* ssp. includes eight reservoirs: Barzina Asparuhov, Yastrebino, Kovachitsa, Pancharevo, Kula, Poletkovtsi Chr. Smirnenski; the data for which are available in Tosheva, Trykov (2012). The data of the ninth Rasovo Reservoir without *Dreissena* ssp. originates from our own accidental measurements carried out in 2015. The group with *Dreissena* ssp. contains five reservoirs, data for four of which (Telish, Rabisha, Gorni Dabnik, Stoykovtsi) was obtained from Tosheva, Trykov (2012), while Ogosta Reservoir was presented by 15 own and one additional set of measurements was also taken from Tosheva, Traykov (2012) (Fig. 1).

The three trophic variables (SD, CHL, and TP) despite originating from two different sources, were measured by means of the same methods (CHL by ISO 10260 (1992) and TP by MERCK products – kits and Nova 60 photometer both manufactured by MERCK) which makes them good by comparison.

The formulas published by Carlson (1977), served for calculation of trophic state indices for SD, CHL, and TP. The statistical analysis was carried out by PAST statistical package (Hammer et al., 2001).

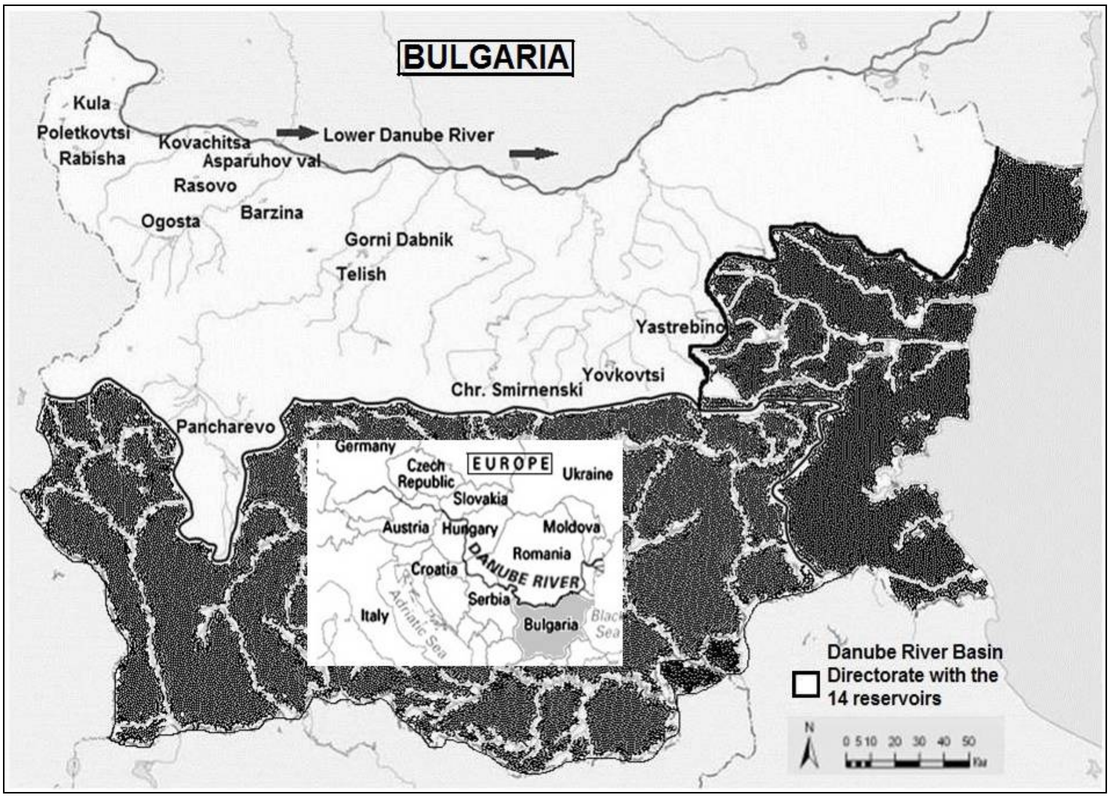

Figure 1: Bulgaria map with catchment area of the Danube River on Bulgarian territory and distribution of investigated reservoirs.

RESULTS AND DISCUSSION

Mean value differences of trophic variables between invaded and non-invaded reservoirs

The most investigated reservoirs are scattered in the north-western part of Bulgaria (Fig. 1).

Because of different standard deviations, unknown frequency distribution and a limited number of samples of the compared two groups, we applied a non-parametric test of Kruskal-Wallis which showed an already known picture (Kalchev et al., 2014), with statistically significant lower CHL and higher SD values in infested than in non-infested waters.

However, in this specific study, for original TP values the Kruskal-Wallis test did not show statistically significant differences between infested and in non-infested reservoirs (Fig. 2).

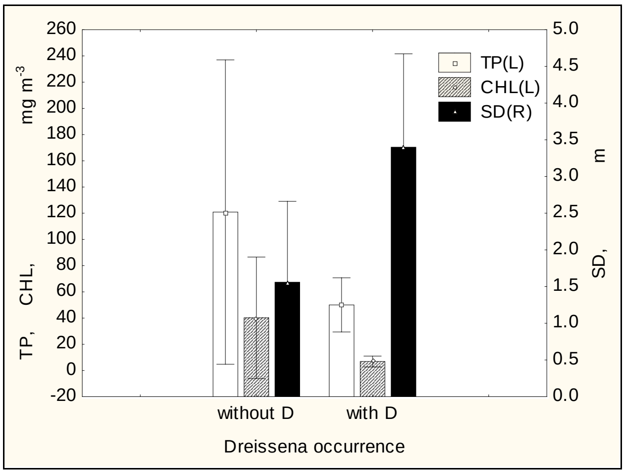

Figure 2: Arithmetic means and standard deviations of total phosphorus (TP), chlorophyll-a (CHL) and water column transparency (SD) in reservoirs with and without *Dreissena* ssp. The comparison of infested and non-infested with *Dreissena* ssp. waters by means of Kruskal-Wallis delivered the following results: TP: KW-H(1;29) = 1.564; p = 0.2111, CHL: KW-H(1;29) = 10.8889; p = 0.0010, SD: KW-H(1;28) = 9.4629; p = 0.0021.

The calculation of TSI by removing a possible lack of normal distribution and delivering equal standard deviations makes the comparison of mean values by parametric t-tests possible, which now shows a significant difference between infested and non-infested reservoirs for all three compared TSI (Fig. 3).

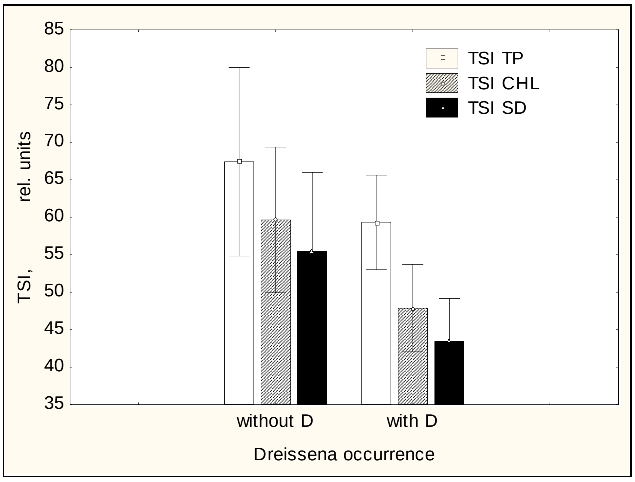

Figure 3: Arithmetic means and standard deviations of trophic state indices (TSI) for TP, CHL and SD in reservoirs with and without *Dreissena* ssp. The comparison of infested and non-infested with *Dreissena* ssp. waters by means of t-test for independent samples delivered the following results: for TSI_{TP}: t-value = 2.64; p < 0.02, TSI_{CHL}: t-value = 4.42; p < 0.0002, TSI_{SD}: t-value = 4.32; p < 0.0002.

The three TSI mean values of infested reservoirs demonstrate lower trophicity than the non-infested. A weak decrease, significant for $P < 0.01$ in epilimnion and an insignificant increase of soluble reactive phosphorus in hypolimnion of Zhrebchevo Reservoir after the *Dreissena* ssp. invasion (Kalchev et al., 2013) seems to be a result of *Dreissena* ssp. which caused a shift of big share of energy and matter flow from pelagic to benthic pathways.

However, the results of Qualls et al. (2007) showed no significant differences between concentrations of pre and post invasion periods in the Lower Green Bay of lake Michigan, USA.

Moreover, if they include the measured high TP values of the last two years in statistical analyses, then statistically significant differences in favor of post-invasion period appeared. Strayer et al. (1999), also reported an increase of soluble reactive phosphorus after the *Dreissena* ssp. invasion.

On one hand this TP increase might be attributed to outer sources (Qualls et al., 2007), but on the other, Strayer et al. (1999), explained it by a reduced uptake of phytoplankton.

The differences between TSI mean values of the three variables on figure 3 could be applied for evaluation of prevailing phytoplankton limitation conditions in the two reservoir groups, which are showing similar behavior in infested and non-infested with *Dreissena* ssp. waters. Thus, the negative difference between TSI means of CHL and TP indicates that most reservoirs of both groups seem to be non-phosphorus limited. On the other hand, the positive difference between TSI means of CHL and SD let us suppose in most cases that the lack of phytoplankton limitation is caused by non-algal turbidity.

Regression differences between trophic variables in invaded and non-invaded reservoirs

All three studied variables (CHL, SD, and TP) are considered almost similar in power to determine the trophic status of standing water bodies. Therefore, Carlson (1977), used the strong mutual correlations between them to derive his trophic state index applied worldwide for estimation of trophic status of standing surface water bodies (Jarosiewicz et al., 2011; Sheela et al., 2011; Tosheva and Traykov, 2012).

As already shown above on figure 1 and 2 and in literature sources (Idrisi et al., 2001; Kalchev et al., 2013, 2014), the CHL and SD variables are changing almost in synchrony as a result of the *Dreissena* ssp. invasion, while the TP does not. This tendency is confirmed when the three variables are correlated with each other successively. The lnCHL and lnSD are showing statistically significant linear regression equations in both groups, (invaded and non-invaded reservoirs). Despite the regression slopes, the groups are also not statistically deferent; there is a clear decrease of percent variation of lnSD explained by lnCHL in the group of infested reservoirs ($R^2 = 0.2761$) than in non-infested ones ($R^2 = 0.6687$) (Fig. 4).

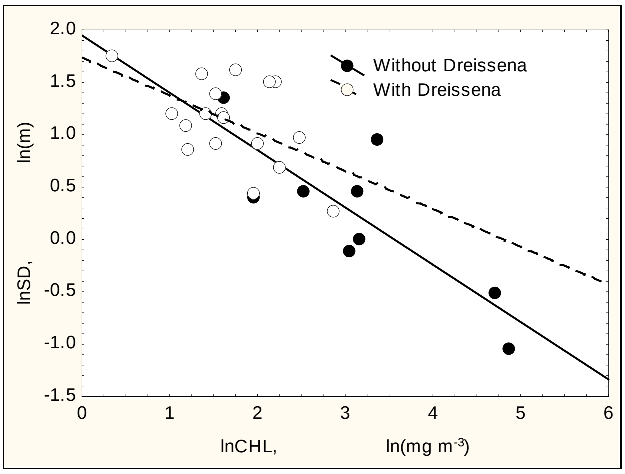

Figure 4: Linear regression equations between natural logarithm values of CHL and SD in reservoirs without *Dreissena* ssp. lnSD = 1.948 – 0.5472* lnCHL r^2 = 0.6687; r = – 0.8177; p = 0.0071; and with *Dreissena* ssp. lnSD = 1.7371 – 0.3613* lnCHL r^2 = 0.2761; r = – 0.5254; p = 0.0251.

The next regression between lnCHL and lnTP (Fig. 5) strengthens this tendency. The regression slopes in the two groups are again not statistically different, but the slope of regression equation of infested reservoirs was slightly beyond the significance border and the R^2 = 0.1828 gets lower, while that of non-invaded remains almost unchanged (R^2 = 0.6176).

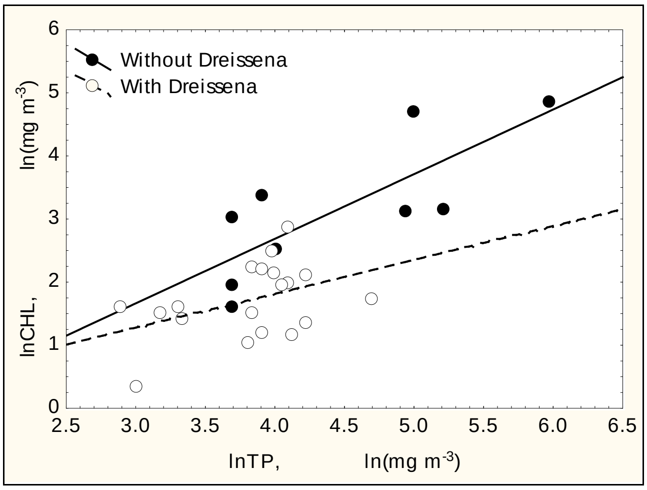

Figure 5: Linear regression equations between natural logarithm values of CHL and TP in reservoirs without *Dreissena* ssp. lnCHL = – 1.4099 + 1.0243* lnTP r^2 = 0.6176; r = 0.7858; p = 0.0121; with *Dreissena* ssp.; lnCHL = – 0.3331 + 0.5371* lnTP r^2 = 0.1828; r = 0.4275; p = 0.0679.

The third regression equation between lnSD and lnTP is again highly significant for the group of non-invaded reservoirs, while in the invaded ones it does not achieve a statistically significant level (Fig. 6). The percentage explained the variation of lnSD by lnTP in the group of infested reservoirs as it decreases further (R^2 = 0.0332) and despite the continuous decrease of the same percentage for non-infested (R^2 = 0.5464); the difference between them becomes bigger than previous regressions.

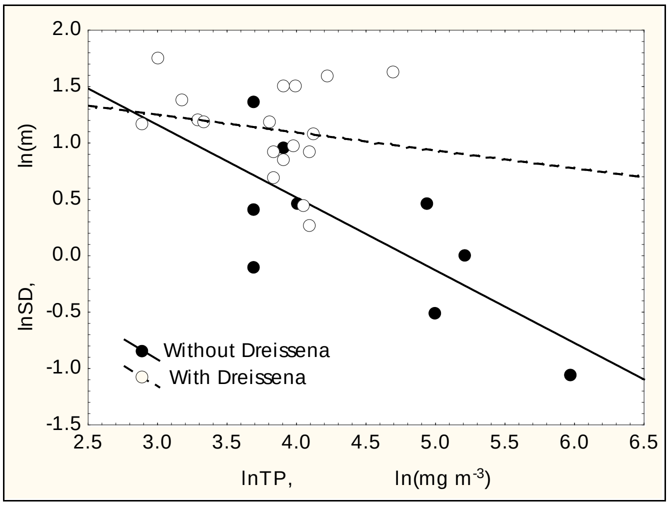

Figure 6: Linear regression equations between natural logarithm values of SD and TP in reservoirs without *Dreissena* ssp. lnSD = 3.095 – 0.6448* lnTP r^2 = 0.5464; r = – 0.7392; p = 0.0229; and with *Dreissena* ssp. lnSD = 1.7274 – 0.1587* lnTP r^2 = 0.0332; r = – 0.1822; p = 0.4692.

Qualls et al. (2007), reported similar changes under the influence of *Dreissena* ssp. on the linear regression between log-values of CHL and TP. At low and average *Dreissena* ssp. densities (5.6, 396 ind/m^{-2}) the regression equations between CHL and TP data of pre- and post-invasion periods remain statistically significant; while at high densities (581 ind/m^{-2}) the relationship of the post-invasion period became insignificant. Simultaneously, with an increasing *Driessena* ssp. density, the percentage of CHL explained of TP by linear regression decreases in the post-invasion period gradually from 0.32 to 0.18 and finally to 0.01; while that of pre- invasion remains approximately unchanged. Atalah et al. (2010), confirmed the destructive effect of the *Dreissena* ssp. invasion on important relationships between TP and several metrics of zoobenthos serving as indicators for ecological status. Obviously, the invasion of such species strongly impacts the functioning and biodiversity of the area and questions the applicability of approved methodologies for measuring the trophic and ecological status of aquatic ecosystems. Atalah et al. (2010), concluded that separate metrics have to be developed for invaded and non-invaded aquatic ecosystems. However in the case of *Driessena* ssp. invasion, this approach seems difficult because as shown by Qualls et al. (2007), the invader influence strongly depends on its density. First, the density is rarely presented in the studies due to difficult and time consuming measurements and second (especially in reservoirs), the density of this mussel inhabiting the upper three to four m depth layers is variable as a result of frequent and considerable water level fluctuations characteristic for this water. Unfortunately, until now there are no investigations published dealing with adaptations of Carlson's TSI to the *Dreissena* ssp. influence, and the only reasonable recommendation would be when applying the TSI to take care of the *Dreissenidae* sp. occurrence. Our limited number of samples involved in analyses indicates that the usage of TP for calculation of TSI is risky if *Dreissena* ssp. is present. As already stated, the *Dreissena* ssp. caused a big shift of energy and matter flow from pelagic into benthic pathways (Strayer et al., 1999), and therefore values of pelagic space variables are getting less informative for characterization of trophic status of the whole ecosystem. Thus, CHL of phytoplankton and SD seem to remain more restricted to pelagic space while TP is increasingly related to benthic processes and pathways, and as a result seem to correlate less strongly with pelagic characteristics under the *Dreissena* ssp. influence. Further investigations will show that if the widely used, trophic state index of Carlson could be successfully adapted to challenges caused by strong *Dreissena* ssp. invaders.

CONCLUSIONS

The trophic status determination by means of index of Carlson has brought a considerable progress in the process of classification of aquatic ecosystems by reducing it to determination of a few easy to measure variables and applying them not only for estimation of trophic status but also for studying conditions limiting the phytoplankton growth. Initially developed for only three variables (SD, CHL, and TP) soon it was supplemented with total nitrogen data accounting for increasing frequency of nitrogen limitation in aquatic ecosystems. Now, in recent days the application of Carlson TSI, like of many other similar metrics used for status estimation of aquatic ecosystems, are confronted with accelerated worldwide spreading of alien species. The accurate application of these metrics requires their further development by accounting for more or less strong effects the alien species exert on invaded aquatic ecosystems.

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THE EFFECT OF *DREISSENA POLYMORPHA* ON BACTERIOPLANKTON, NEMATODE FAUNA AND THEIR RELATIONS TO ENVIRONMENTAL FACTORS IN OGOSTA RESERVOIR (DANUBE BASIN)

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ABSTRACT

Spatial, seasonal, and annual bacterioplankton dynamics in recently infested by the species *Dreissena polymorpha* Ogosta Reservoir were studied for the first time during three year period. Bacterioplankton total number was higher in spring in ecotone zones, than in summer at thermocline. NH_4-N, PO_4-P, turbidity, dissolved oxygen, COD and chlorophyll-a correlate positively, while transparency and Ca^{2+} negatively with bacteria. Nematode species composition, included 22 species studied (13 rarely found and *Rhabditis brevispina* new for Bulgaria) belonging to nine families. The *D. polymorpha* impact is positive on nematodes and phytoplankton, negative on zooplankton and bacterioplankton, but weak positive on larger bacteria, rods and attached bacteria.

RESUMEN: Efecto de *Dreissena polymorpha* en el bacterioplancton y la fauna de nemátodos y su relación con factores ambientales en el Reservorio Ogosta.

Por primera vez se estudia la dinámica espacial y estacional del bacterioplancton durante una invasión reciente de la especie *Dreissena polymorpha* en el Reservorio Ogosta, a lo largo de tres años. En términos numéricos, el bacterioplancton fue más abundante en los ecotonos durante la primavera y durante el verano en la termoclina. Los NH_4-N, PO_4-P, la turbidez, oxígeno disuelto, COD y la clorofila-a mostraron una correlación positiva con la abundancia de bacterias, en tanto que la transparencia y el Ca^{2+} se correlacionaron negativamente. La composición de especies de nemátodos, que también estudiada por primera vez, incluye 22 especies (13 raramente encontradas y *Rhabditis brevispina*, una especie nueva para Bulgaria) pertenecientes a nueve familias. El impacto de *D. polymorpha* es positivo sobre los nemátodos y el fitoplancton, pero negativo sobre el bacterioplancton y el zooplancton; se encontró una relación débil con las bacterias de gran tamaño y con aquellas que tienden a adherirse.

REZUMAT: Efectul speciei *Dreissena polymorpha* asupra bacterioplanctonului, faunei de nematode și relațiilor acestora cu factorii de mediu în lacul de acumulare Ogosta.

A fost studiată în trei ani, dinamica spaţială, sezonieră şi anuală a bacterioplanctonului în recentul invadat bazin Ogosta de către specia *Dreissena polymorpha*. Numărul total al bacterioplanctonului a fost mai mare primăvara în zonele de ecoton, decât vara la termoclină. NH_4-N, PO_4-P, turbiditatea, oxigenul dizolvat, CCO şi clorofila-a s-au corelat pozitiv, în timp ce transparenţa şi Ca^{2+} s-au corelat negativ cu bacteriile. Compoziţia speciilor de nematode, studiate pentru prima oară, include 22 de specii (13 rare şi *Rhabditis brevispina* nouă pentru Bulgaria) aparţinând la nouă familii. *D. polymorpha* are un impact pozitiv asupra nematodelor şi fitoplanctonului, negativ asupra zooplanctonului şi bacterioplanctonului, dar uşor pozitiv asupra bacteriilor mai mari, a bacililor şi a biofilmului.

INTRODUCTION

The investigation of *Dreissena polymorpha* (Pallas, 1771) effect on reservoir ecosystems is very important, especially for countries like Bulgaria, where main freshwater resources are in reservoirs built on rivers (Kalchev et al., 2013). Dreissena ssp. (*D. polymorpha* and *D. bugensis*, Bivalvia: Dreissenidae) are known as successful aquatic invaders that have great potential to directly or indirectly impact the biodiversity and ecosystem functioning. Due to their ability to filter the seston in large volumes of water, they cause huge ecosystem changes summarized as a shift of energy flow from pelagic to benthic food chain (Karatayev et al., 2002). Factors that limit the growth and spread of the invasive species *D. polymorpha* include low and high temperatures (below 10ºC or above 26-32ºC), low concentration of calcium ions (Ca^{2+}), and very high or very low production in lakes (Strayer, 1991). In Bulgaria the species is found at depths between three m to 10 m in reservoirs with moderate amounts of nutrients (Trichkova et al., 2008; Kozuharov et al., 2009).

Planktonic bacteria are important for nutrient remineralisation and participate as a key trophic source in pelagic food webs (Straškrabova et al., 1999; Cotner and Biddanda, 2002; Jürgens and Matz, 2002; Pernthaler, 2005). The necessity of studying bacterioplankton development and its interaction with environmental factors, including some invasive species like zebra mussel (*D. polymorpha*) found in many lakes in the world, but also in Eastern Europe and in some Bulgarian reservoirs (Cotner et al., 1995; Karatayev et al., 1997; Trichkova et al., 2008; Kozuharov et al., 2009; Kozuharov and Stanachkova, 2015) is an indication of understanding the biogeochemical processes in aquatic ecosystems in the period of global warming and climate changes (Häder et al., 2007). It is found that the sizes and morphology of aquatic species are essential for trophic relationships between them (Havens, 1998), and bacterioplankton is without exception (Cotner et al., 1995; Cole, 1999; Hahn and Höfle, 2001; Pernthaler, 2005). Research for the ecological role of bacterioplankton in standing waters in Bulgaria is numerous (Beshkova et al., 2008; Kalcheva, 2011; etc.), but has not been performed in long-term experiments with inclusion of different trophic levels in reservoirs with the invasive species *Dreissena polymorpha*.

Free-living Nematoda play a main ecological role, as primary consumers displaying saprophagous or bacterivorous feeding habits, and take part in the nutrient cycling control. Data about Nematoda in Bulgaria was given by Valkanov (1934), Russev (1979) and Stoichev (1996, 1998). This study gives the first information about the free-living freshwater nematode of the Ogosta Basin and its relation to the environmental factors and *Dreissena polymorpha*.

This study establish the spatial, seasonal, and annual bacterioplankton dynamics and free-living nematode species diversity and to determine, the influence of environmental factors on them and the effect of *Dreissena polymorpha* occurrence on their development.

MATERIAL AND METHODS

The study was conducted in the period 2009-2011 in Ogosta Reservoir in Bulgaria, infested with the invasive species *Dreissena polymorpha*. The Ogosta Reservoir (Fig. 1) is situated in North-West Bulgaria close to the town of Montana at an altitude of 203 m a.s.l. (43°22’31” N, 23°10’56” E). It is built on the river Ogosta, a direct tributary of the Danube River and gathers the waters of other two rivers, Zlatitsa and Barzeya. The reservoir area is 2,360 ha, its length by diagonal is 14 km and the total water volume is 506 million m^3 (Kenderov et al., 2014). A total of 58 samples were taken for bacterioplankton in late summer of 2009 (in beginning of September), spring (April) and autumn (September/October) of 2010 and in summer (July) of 2011 from five stations (Fig. 1), divided from the wall (station 1) to the tail (station 5) of the reservoir and from different depth horizons starting at 0.3 m to maximum depth of each station, but one m above the bottom (35 m in station 1, the wall).

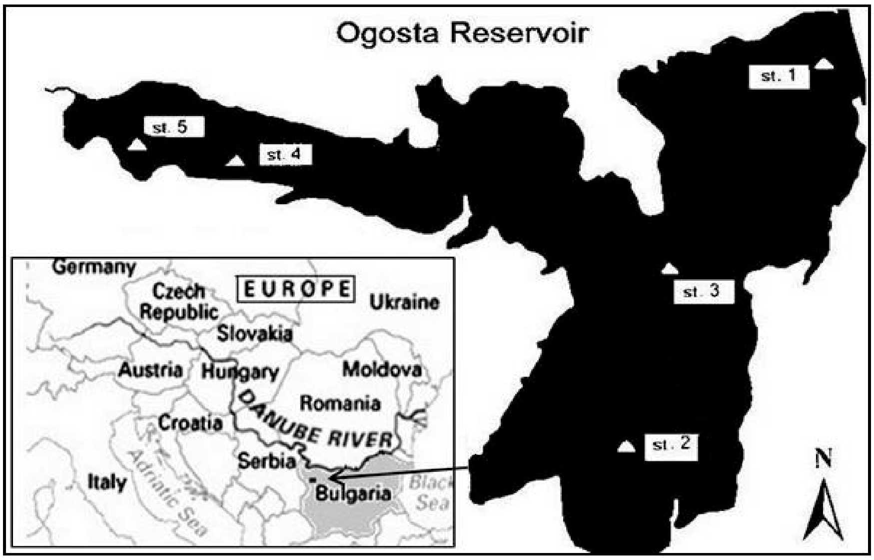

Figure 1: Overview of the study area in Bulgaria as a part of the Danube River basin countries in Europe and localisation of the measuring points (stations 1-5) in Ogosta Reservoir.

The number of bacteria is determined by the method of a direct count with a phase-contrast microscope (Carl Zeiss, Jena, Germany) by the ocular grid at a magnification of 1,600x after preliminary fixation with 2% formalin and staining with erythrosine (Razumov's method, updated by Naumova in Grudeva et al., 2006), described in detail (Kalcheva et al., 2008; Kalcheva, 2011). Biomass is calculated in carbon content by Norland's formula (Straškrabova et al., 1999) after determination of the mean cell volume (MCV). Bacterioplankton is counted separately for cells (cocci and rods) freely dispersed on the filter (0.2 µm pore size) and for cells that are associated with detritus particles, since morphological groups are provisionally divided in four groups (free cocci, rods and attached cocci, rods). The sizes of bacteria are divided into size classes (Pernthaler et al., 1996; Kalcheva et al., 2008; Chróst et al., 2009). The number of detritus particles with attached bacteria is also counted.

The material for free-living nematodes was collected with Ekman-Birge grab in spring, summer, and autumn of 2010 and in the summer of 2011. A total of 25 samples were collected. The results were adjusted for one m^2. The nematode samples were rinsed on sieves, with mesh sizes of 500 µm and 50 µm. A careful heating up to 60ºC was performed, by which the nematodes become stacked and erected and thus convenient for measuring. Then the nematodes were fixed in 4% formalin. Nematodes were identified according to Gagarin (1981) and measured on the basis of the formula of De Man (1886). The monograph of Loof (1999) was also used to determine the nematodes.

Parallel measurements for the three year period were made for 15 environmental factors, in situ for some physicochemical factors and hydrochemical sampling for laboratory analyses, also for chlorophyll-a and *D. polymorpha*, but only in 2009 for phytoplankton and zooplankton. Abiotic factors temperature, pH, dissolved oxygen, and oxygen saturation are measured with oximeter type WTW 315i/SET, transparency by Secchi disc, Ca^{2+} by a standard method in a chemical laboratory at the University of Innsbruck. The other factors, NH_4-N, NO_3-N, NO_2-N, PO_4-P, TN, TP, Fe, Si, and COD are analyzed with kits of Merck (Germany) and by a spectrophotometer Spectroquant® NOVA60 and a thermoreactor (Merck, Bulgaria

EAD). Standard methods for phytoplankton (Beshkova et al., 2008), zooplankton (Kozuharov and Stanachkova, 2015), chlorophyll-a (ISO 10260, 1992) and *D. polymorpha* are used (Trichkova et al., 2008). Quantitative results about *Dreissena polymorpha* have not been presented and used in this study, but only the assessment of its development in five categories (absent, only shells, small, middle and high quantities) from the five stations and the sampling depths is performed for statistical analyses. Data of all environmental factors, abiotic and biotic, are also not presented, but only used in statistical analyses.

The multivariate statistical Redundancy Analysis (RDA) with the program CANOCO for Windows 4.5 (ter Braak and Smilauer, 2002), single factor analysis of variance (one-way ANOVA), nonparametric correlations of Spearman (R_{Sp}) and regressions (linear correlations) with the computer program STATISTICA 7.0 are used. Bacterioplankton variables are included in RDA as dependent (response) variables, while environmental factors (abiotic, biotic and the zebra mussel) as independent (explanatory) variables. Where RDA includes Nematoda species as dependent variables, bacteria are presented as independent. Statistical evaluations are performed using a level of significance P (probability) with 5% risk of error (α or $P < 0.05$).

RESULTS AND DISCUSSION

The total number of bacterioplankton in the period 2009-2011 varied in the range from 4.70×10^4 to 5.83×10^5 cells.ml^{-1} (Fig. 2). The biomass in carbon content varied from 0.69 to 10.24 μg C.L^{-1} and the mean cell volume (MCV) was in the range between 0.0493 and 0.0797 μm^3 (Fig. 3). The abundance was higher than in other studied reservoirs (Beshkova et al., 2008; Kalcheva, 2011). Abundance and biomass decreased towards 2011, but were higher in spring in stations close to inflows of the main and other two rivers (ecotone zones, 2 and 5), and in summer at the deeper layers with a maximum at thermocline (at a depth of 15 m) in the deepest station 1 (the wall) and at five m in other stations (Figs. 3 and 4), where the organic matter and biodegradation increased. The differences between the seasons were statistically significant (Fig. 3, ANOVA), between the years they were close to the level of significance ($p = 0.07$), while between the five stations they were not significant. The MCV was relatively low with the dominance of the smallest size class of 0.2-0.5 μm (49-83% of the total). This is typical for eutrophic waters (Šimek et al., 1997; Pernthaler et al., 1996; Chróst et al., 2009).

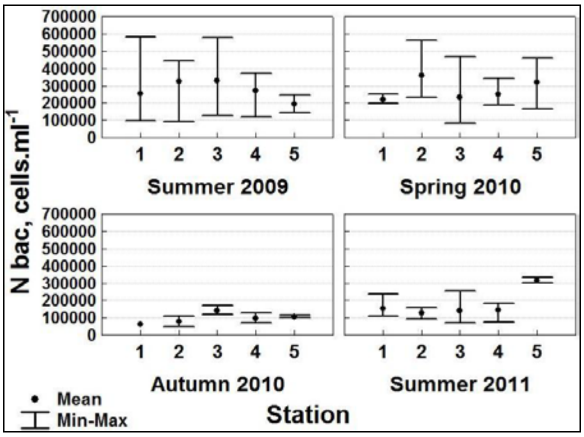

Figure 2: Spatial, seasonal and annual dynamics of bacterioplankton total number (mean, minimum and maximum) at sampling stations (1-5) in the Ogosta Reservoir during 2009-2011.

Free-living cocci were 24-59% and prevailed over the other morphotypes, but larger bacteria (< one μm) and bigger quantities of attached to detritus bacteria were found in 2009-2010 when the development of *D. polymorpha* was stronger than in 2011. The attached bacteria varied widely from three to 80% and were higher in summer. Most probably it is connected with the organic matter excreted by the zebra mussels, and also with their filtration of small sized seston including bacteria (Cotner et al., 1995; Dionisio Pires et al., 2004). The number of free-living large bacteria were higher in spring especially in stations 2 and 5, ecotone zones, where the inflows of the rivers (probably due to the rainfalls), had more organic matter and nutrients. The increase in the quantity of rod cells, especially with the relatively large sizes means, increased organic content in the water (Pernthaler, 2005). The detritus particles number was higher in 2009 summer in station 2 and at the depth layers between 0.3 m and 15 m. We assume that the reason, again, is excreted organic matter by *D. polymorpha*.

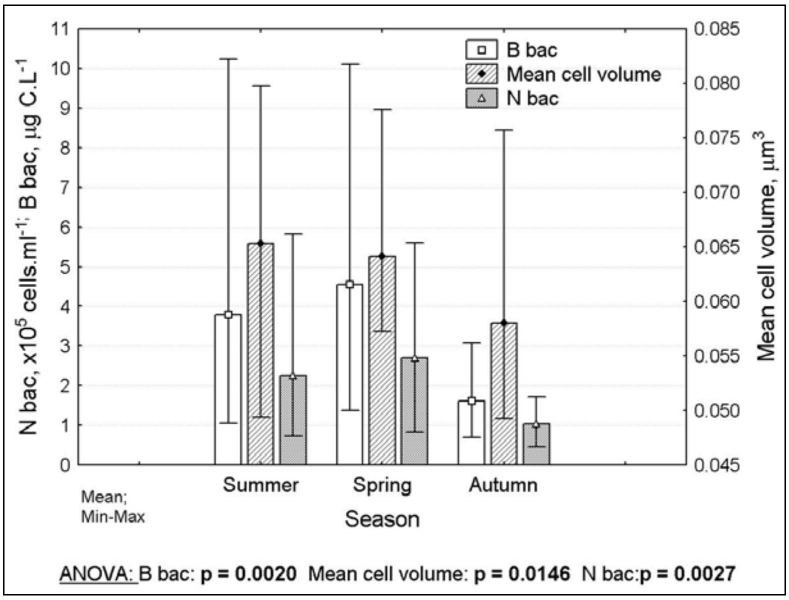

Figure 3: Seasonal dynamics of bacterioplankton total number, biomass and mean cell volume (mean, min-max) in Ogosta Reservoir for the three year period (2009-2011) and f-test with given p-values (ANOVA).

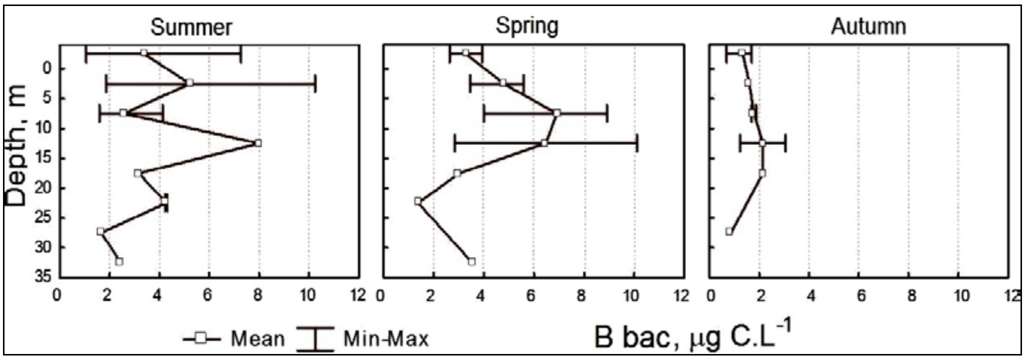

Figure 4: Seasonal dynamics of the bacterial biomass (B bac) in different depth layers in Ogosta Reservoir in the period 2009-2011.

22 species from 12 genera, nine families, and five orders were determined in Ogosta Reservoir (Tab. 1). The species *Monhystera stagnalis*, *Monhystera filiformis* and *Dorylaimus stagnalis* were found in all sites. One species (*Rhabditis brevispina*, marked by +) is new to the Bulgarian hydrofauna. The Nematoda diversity in Zhrebchevo Reservoir (Stoichev and Danova, 2012), 26 species, was close to the species number in Ogosta Reservoir, both infested by *Dreissena polymorpha*. While in the non-infested Koprinka Reservoir and Stambolijski Reservoir the species number is lower, 15 and 11 respectively (Stoichev, 1996). The number of species that we found is close to the data given by Traunspurger (2002), who reported that the species richness in general ranges between 30 and 70 in lakes and rivers. The results from the dominance analysis of the species (pF, DF and Dt in %) are shown in table 1. Beside species with high values of frequency of occurrence and range of dominance (*Monhystera stagnalis*, *Monhystera filiformis*, *Dorylaimus stagnalis*), are also species with high values of range of dominance, low frequency of occurrence, and frequency of dominance can be found (*Cylindrolaimus communis*, *Rhabditis filiformis*, *Prodesmodora circulata*).

In 2009-2011 for *D. polymorpha* and *D. bugensis* (Andrusov, 1897, the impact was not assessed in this study, see in Stanachkova et al., 2015), were found at a depth of 0.30 to 30 m. *D. polymorpha* more often was found at depths up to 15 m, while *D. bugensis*, which is deep-water species, at 24-30 meters (at station 1, the wall). According to the measured temperature (7-29ºC, but except the extreme values) and chl-a (0.7-8.9 µg.L^{-1}, mesotrophy), Ogosta Reservoir is appropriate for the development of *D. polymorpha* (Strayer, 1991).

Table 1: Nematoda species by stations and dominant analysis (pF%, DF% and Dt%).

Taxa	Stations					Dominant analysis		
	1	2	3	4	5	pF %	D %	Dt %
<u>Monhysterida</u>								
Monhysteridae								
Monhystera stagnalis Bastian, 1865	X	X	X	X	X	74.28	54.3	73.07
Monhystera filiformis Bastian, 1865	X	X	X		X	62.85	51.4	81.81
Monhystera sp.				X		2.85		
<u>Dorylaimida</u>								
Dorylaimidae								
Dorylaimus stagnalis Dujardin, 1845	X	X	X	X	X	88.57	62.8	70.96
Dorylaimus sp.			X			2.85		
Paradorylaimus filiformis (Bastian, 1896) Andrassy, 1969				X		5.71		
Paradorylaimus sp.		X				2.85		
Mesodorylaimus sp.			X			2.85		
Qudsianematidae								
Eudorylaimus carteri (Bastian, 1865) Andrassy, 1969	X		X		X	31.42	14.3	45.44

Table 1 (continued): Nematoda species by stations and dominant analysis (pF%, DF% and Dt%).

Taxa	Stations					Dominant analysis		
	1	2	3	4	5	pF %	D %	Dt %
Cylindrolaimidae								
Cylindrolaimus communis De Man, 1880		X				8.57	2.85	33.25
Cylindrolaimus sp.				X		2.85		
Plectidae								
Plectus cirratus Bastian, 1865			X	X		22.85	17.1	75.01
Plectus assimilis Bütschlii, 1873		X				5.71		
<u>Rhabditida</u>								
Rhabditidae								
Rhabditis filiformis Bütschlii, 1873	X	X				17.14	11.4	66.62
Rhabditis brevispina (Claus, 1862) Bütschlii, 1873			X			2.83		
<u>Enoplida</u>								
Tripylidae								
Tripyla glomerans Bastian, 1865	X		X	X		51.42	45.7	88.89
Tobrilus gracilis Bastian, 1865			X			11.42		
Tobrilus sp.			X			2.85		
Enoplidae								
Tobrilus gracilis Bastian, 1865			X			11.42		
Tobrilus sp.			X			2.85		
Enoplidae								
Enoploides fluviatilis Micoletzky (1923)	X	X		X		14.28	5.71	39.98
Enoploides sp.		X				2.85		
<u>Chromadorida</u>								
Microlaimidae								
Prodesmodora circulata (Micoletzky, 1913) Micoletzky, 1915		X	X	8.57	2.85	33.25		
Prodesmodora sp.				X		2.85		

Interactions of bacterioplankton and nematodes with environmental factors and the effect of *D. polymorpha* occurrence

From environmental factors, mainly abiotic, positive relationships exist between bacterioplankton and nutrients, NH_4-N (r = 0.38), PO_4-P (r = 0.34), TP, turbidity, dissolved oxygen, Fe ions, COD (Fig. 5B), phytoplankton biomass (r = 0.58), and chlorophyll-a. Negative relations are found with pH, transparency (Fig. 5A), and Ca^{2+} (r = – 0.33). The ratio of the nutrients N and P is very important for bacterioplankton development (Vadstein et al., 2003; Chróst et al., 2009). Temperature, in most cases, shows negative relation with bacteria except cell volume (sizes), but probably is very high and beyond the optimum under conditions of global warming and shallowness of the water bodies, which affects all organisms.

A negative correlation existed between *D. polymorpha* and the bacterial abundance (and biomass) in 2009, while in 2010-2011 it was positive, close to the level of significance with p-value = 0.08 and p-value = 0.07 respectively (RDA, Fig. 5A, B). Negative correlations were confirmed, also by nonparametric tests, for the whole period (2009-2011) as weak, but significant of *D. polymorpha* with bacterioplankton abundance (r_{Sp} = – 0.287) and biomass (r_{Sp} = – 0.298). The results are in agreement with previous findings reported in similar studies. We assume that the increase of larger sized free-living bacteria in Ogosta Reservoir is related to the findings of Dionisio Pires et al. (2004) about preferential filtration by *D. polymorpha* of two seston size groups, 0-1 μm and 30-100 μm. Filtration by zebra mussels of free-living bacteria with sizes under one μm leads to better transparency and that is pointed out with the positive relation of *D. polymorpha* with transparency, and negative with bacteria (Fig. 5A).

The relation of bacterioplankton with the other two plankton communities (Fig. 5A), determined in 2009, showed a positive correlation with phytoplankton biomass (due to extracellular release of DOC), but negative with zooplankton number (due to predation). The effect of *D. polymorpha* on the plankton was positive impact on phytoplankton number, but negative on zooplankton number, bacterioplankton number, and biomass (Fig. 5A).

Two important environmental factors, COD and oxygen saturation, correlated significantly to the spatial diversity of nematode species (RDA, p = 0.026, not shown). Bacterioplankton total number and COD (Fig. 5B) had higher values in stations 2 and 5. These stations represent ecotone zones, because of the inflow of the rivers Zlatitsa and Barzeya and respectively Ogosta, where the quantity of dead organic matter coming from the rivers to the reservoir, is higher and the processes of its degradation is more intensive.

Negative correlations were found between bacteria and *Tripyla glomerans* (r = – 0.98, p = 0.002, T. glomerans = 36,0076-0,0001*x) and between detritus and *Enoploides fluviatilis* (r_{Sp} = – 0.88, p < 0.05). *Tobrilus* genus was found in the sampling station 3 and correlated negatively with the oxygen saturation. The individuals of *Tobrilus* are represented at a high density in the sediments of lenthic ecosystems, especially in eutrophic lakes (Traunspurger, 2002), and are considered as tolerant of low oxygen conditions (Vidakovic and Bogut, 2004). Positive correlations were found between *D. polymorpha* and *M. filiformis* and *R. filiformis* (Fig. 5B), most probably utilizing detritus particles excreted by the zebra mussels.

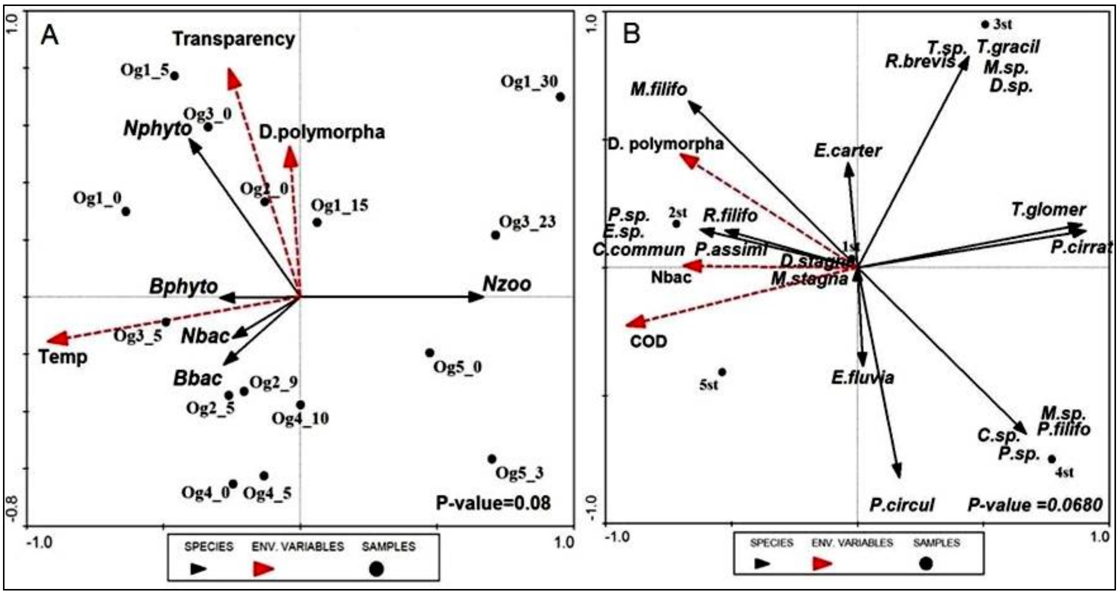

Figure 5: RDA triplots presenting the correlations (with given p-values) between:
(A) bacterioplankton, phytoplankton and zooplankton (dependent variables, species)
and environmental factors and *D. polymorpha* (env. variables)
by stations and depth horizons (samples) in 2009,
(B) Nematode species composition (species) and environmental factors, bacterioplankton and *D. polymorpha* (env. variables) by stations (samples) in 2010-2011. Abbreviations: N – number, B – biomass, bac – bacterioplankton, phyto – phytoplankton, zoo – zooplankton, COD – chemical organic demand, st – stations from 1 to 5; coding of Og2_5 = Og (Ogosta), 2 (the station number), 5 (from five m depth); for full names of Nematode species see in table 1.

CONCLUSIONS

The effect of *Dreissena polymorpha* on bacterioplankton in investigated Ogosta Reservoir is indirect, manifested with higher bacterial abundance, due to weakened zooplankton pressure. Direct effects are a slightly negative impact on the number and biomass (during the whole period), and a slightly positive impact on larger bacteria, rods, and attached bacteria.

The effect of *Dreissena polymorpha* on phytoplankton, transparency and COD, is positive, but leading to eutrophication and more organic matter, while it is negative on zooplankton, leading indirectly to lower fish production and diversity.

The Nematoda community in the ecosystem of Ogosta Reservoir is composed of species with high ecological valence as well as species with different level of specialization and adaptation to the environmental conditions, and also to the infestation of the invasive species *Dreissena polymorpha*. Nematode species richness is higher than in others studied, not in investigated reservoirs in Bulgaria, proving prosperity of detritivores in the invested reservoir. Nematodes species richness is higher than in others in Bulgarian reservoirs, proving prosperity of detritivores in this studied case.

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SUPORT SYSTEM FOR THE MANAGEMENT OF THE *SABANEJEWIA AURATA* (DE FILIPPI, 1863) POPULATIONS OF THE ROSCI0227 – SIGHIȘOARA-TÂRNAVA MARE

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KEYWORDS: Natura 2000 network, ROSCI0227 site administration, golden spined loach, Transylvania, Romania.

ABSTRACT

ADONIS:CE was used to design a computer model for the management of *Sabanejewia aurata* (De Filippi, 1863) populations in the Natura 2000 site of Sighişoara-Târnava Mare (ROSCI0227). The recommended management model is based on the environmental needs of the species, inventoried according to the local habitats, as well as the indicators of conservation status and relevant management measures, and takes into account human pressures and threats identified in the research area. Such computer models were established for all protected fish species found at the site ROSCI0227.

RÉSUMÉ: Un Support Système pour la gestion des populations de *Sabanejewia aurata* (De Filippi, 1863) du site ROSCI0227 – Sighişoara-Târnava Mare.

ADONIS:CE a été utilisé afin de concevoir un modèle de gestion des populations de *Sabanejewia aurata* (De Filippi, 1863) du site Natura 2000 Sighişoara-Târnava Mare. Le modèle de gestion recommandé est basé sur les besoins environnementaux de l’espèce, l’inventaire des habitats locaux ainsi que sur les indicateurs de l’état de conservation et sur les mesures de gestion pertinentes, dans un contexte de pressions et de menaces anthropiques identifiées dans la zone de recherche. Des modèles de gestion similaires ont été élaborés pour toutes les espèces de poissons protégées dans le site ROSCI0227.

REZUMAT: Sistem suport pentru managementul populațiilor de *Sabanejewia aurata* (De Filippi, 1863) din ROSCI0227 – Sighişoara-Târnava Mare.

ADONIS:CE a fost utilizat pentru proiectarea unui model de management al populaţiilor de *Sabanejewia aurata* (De Filippi, 1863) din situl Natura 2000 Sighişoara – Târnava Mare. Modelul de management recomandat se bazează pe nevoile legate de mediu ale acestei specii, inventariate în conexiune cu habitatele locale, pe indicatorii statutului de conservare şi măsurile relevante de management, în contextul presiunilor şi ameninţărilor umane identificate în zona de cercetare. Astfel de modele de management au fost elaborate pentru toate speciile de peşti protejate în ROSCI0227.

INTRODUCTION

The EU Habitats Directive was established in 1992 to safeguard the survival of sensitive species in Europe. The signatory countries have to guarantee that the vital conditions are present, for the preservation of the species and habitats listed under Annex 2 of the Habitats Directive, along with the ultimate goal to protect and (if possible) to increase their ecological status. The acceptance of the designated Natura 2000 sites relies upon unambiguous criteria such as: permanent, pristine and healthy fish populations, typical habitats, favourable geographic positioning, and minimal human impact. A few key elements are promoted through the European Union Natura 2000 initiative to improve the condition of nature and protected areas, including: improving specific information; broadening of the protected areas; institutional capacity development; suitable on-the-ground assessment and monitoring; relevant management activities in complex management programs in the areas with conservation status (Bănăduc, 2007; Bănăduc et al., 2012).

The golden spined loach, *Sabanejewia aurata* (De Filippi, 1863) is a fish species of conservation value. The golden spined loach is a demersal and freshwater species, generally living in the middle and upper sectors of streams and rivers. The presence of sandy riverbeds is a vital habitat quality. The species feeds predominantly on macroinvertebrates (Bănărescu, 1964; Bănărescu and Bănăduc, 2007).

Fish species assemblages in areas where *Sabanejewia aurata* are found in the Sighişoara-Târnava Mare Natura 2000 site indicates a diminishing population as a result of human impact. The reduction in the area inhabited by this species and their low relative abundance highlights the diminishing natural condition of the Târnava Watershed (Curtean-Bănăduc et al., 2005; Bănăduc et al., 2016). This reflects a wider global deterioration in water quality and river and stream habitat globally as a result of human-induced pressures (Curtean-Bănăduc and Bănăduc, 2012).

River habitats are complex and unique, and generic management schemes for protected areas tend not to be satisfactory. Ideally, the main habitat components of each site should be assessed at the beginning of any management process, and any generic scheme adjusted accordingly to support specific species and habitats present at that site.

In conservation, modelling processes are mainly used to get a "large-scale picture" of separate systems and/or actions of definite domains. The parts of the process are helpful in discriminating the different stages of efficient species and habitat management. Using software products such as ADONIS:CE, models can be created that help organisations o understand their protected area management tasks in an easy-to-use way. Models focus on three areas of operation, all important for protected area managers: 1) to validate the current state, 2) to assess the results of modifications and 3) to suggest a program to modify the actual state in a desired manner. In the end, a variety of diagrams can be generated to display specific management elements (Hall and Harmon, 2005).

This research paper aims to: highlight the present state of *Sabanejewia aurata* populations in Sighişoara-Târnava Mare Natura 2000 site; emphasize human pressures and threats at the site; and use a specially created management model to devise management recommendations to support the rehabilitation of the studied fish species and improve its conservation status. The model integrates habitat preconditions and habitat indicators as a management system for the decision makers.

MATERIAL AND METHODS

The Sighişoara-Târnava Mare Natura 2000 site (ROSCI0227) is located in central Romania, in the counties of Brașov, Sibiu and Mureș (85,815 ha, 315-829 m a.s.l.; latitude E 24°49'16", longitude N 46°8'4"). This site was designated as a Natura 2000 site for a few fish species which belong to the Annex 2 of the Habitats Directive (92/43/EEC), including: *Sabanejewia aurata* Natura 2000 code 1146; *Barbus meridionalis* code 1138, *Gobio kessleri/Romanogobio kesslerii* code 2511, and *Gobio uranoscopus* code 1122. (*) Natura 2000 Standard data from http://natura2000.mmediu.ro/upl//formulare/ROSCI0227%20-%20F.pdf.

The sampling locations where *Sabanejewia aurata* were sampled are displayed below in figure 1. The samples were taken during 2010-2013, using fishing nets to capture individuals. The individuals were freed after an in situ identification in their natural habitat.

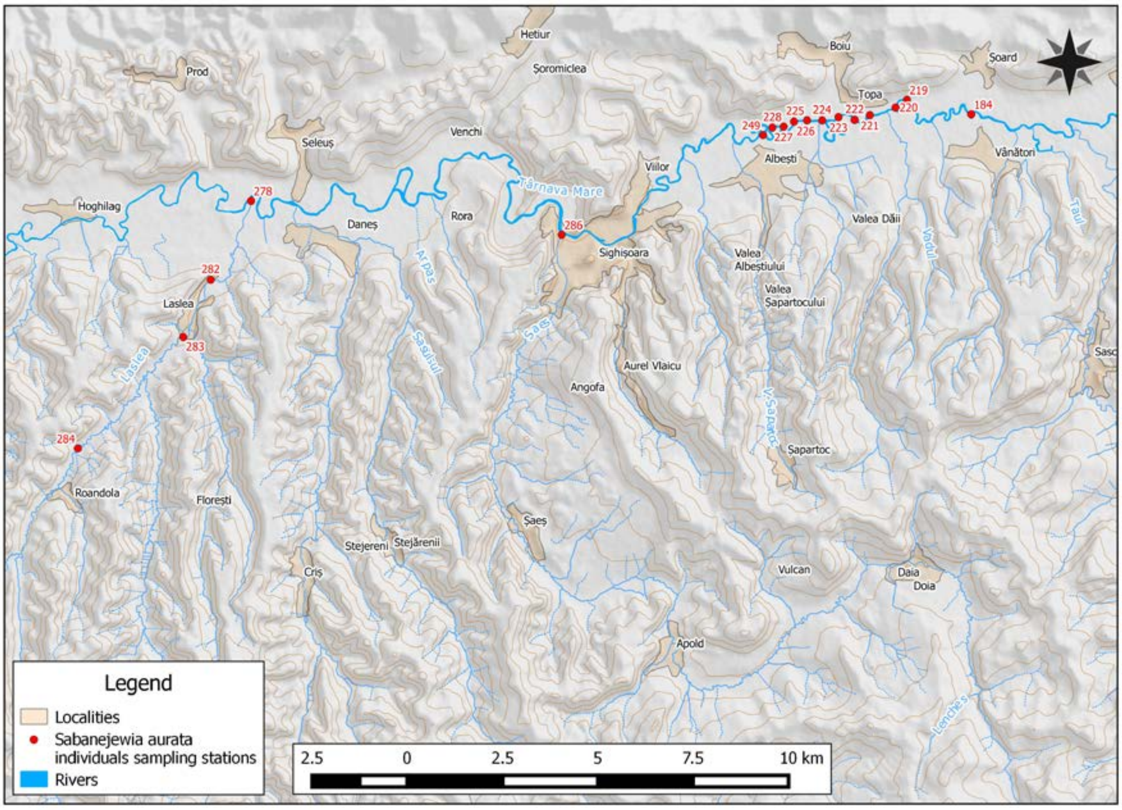

Figure 1: *Sabanejewia aurata* individual sampling stations in: Târnava Mare River (184, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, and 249); Șaeș Stream (286); Laslea Stream (278, 282, 283, and 284), (Geographic Information System support Mr. Pătrulescu A.).

The evaluation and ecological situation of *Sabanejewia aurata* was assessed in relation to the identified human activities, pressures and threats that the natural habitats and population face.

The habitat characteristics of the fish populations were evaluated using specific criteria including: population size, size of range, the equilibrated allocation of fish in age classes, and high/low number of individual fish species in the local fish assemblages.

The habitat needs, pressures, and threats of *Sabanejewia aurata* were studied in connection with their ecological status, the interrelations between them and the conservation circumstance of *Sabanejewia aurata*.

An adaptable and flexible management model was recommended to develop a fitting management plan that would effectively preserve the fish species that are living in the research area, with an emphasis on necessary processes. The software ADONIS:Community Edition (ADONIS:CE), a free software designated and offered by the Business Object Consulting (BOC) Group, was used. ADONIS:CE is an easy, stand-alone form of ADONIS with some limitations (in comparison with the commercial version). It uses a Business Process Model and Notation (BPMN), a standardized modelling language which assists in making clear distinct processes. ADONIS:CE is typically used as an access point to Business Process Management. These processes can be modelled using compatible notation.

RESULTS AND DISCUSSION

Ecological status assessment of *Sabanejewia aurata* populations

The ecological status of *Sabanejewia aurata* in the Târnava Mare River sampling sections (Fig. 1) ranges from very good to low. Very good status was found in sections 227 and 228 sections, good status in 249 and 220, and low status in 184, 219, 221, 222, 223, 224, 225, and 226. This matches the degree of habitat degradation in each section.

The ecological status of *Sabanejewia aurata* in the Șaeș Stream sampling stations is low (section), and the habitat is in an average/low condition.

The ecological status of *Sabanejewia aurata* in the Laslea Stream varies between good in sections 278, 284, and 283 and low in the section 282, again matching the quality of habitat in each location.

Human pressures and threats

This study reveals the fact that the principal pressures on *Sabanejewia aurata* are: lotic habitat changes in lentic habitats, water chemical pollution, and poaching.

Specific requirements

In most cases, *Sabanejewia aurata* lives in lotic sectors with a medium water flow speed, a riverbed composed, at least on the surface, of sand mixed with pebbles or pure sand and riparian ligneous plants. Breeding takes place between May-July. Both the juveniles and adults are easily affected by pollution. (Bănărescu, 1964; Bănărescu and Bănăduc, 2007)

Specific habitat indicators

In the studied habitats, two main habitat indicators are proposed as explanation for the presence/absence and relative abundance of *Sabanejewia aurata*: medium water flowing surface speed, proportion (50%) combined with sandy-pebbles (33%) or sandy riverbed surface proportion (33%), and river banks with riparian vegetation proportion (50%).

Management measures

Management measures have been, for a long time, the goal for theoretical study, as well as management specialists. Consequently there is a range of alternative approaches and models which vary based on origin, measurement systems and complexity. The management indicators can be developed within a process made up of six steps which are represented in figure 2, based on the Mertins and Krause affirmations (Mertins et al., 1999).

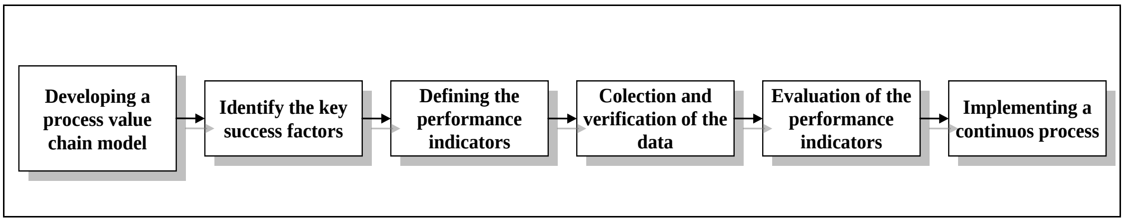

Figure 2: Stages for building an indicator set in the Fraunhofer Approach.

The points of this approach are: it is based on a fundamental model; it is assisted by the learning process which happens while drawing up the process maps; and it identifies the need for management measures planning built around the record sheets of management measures. Therefore it is important to emphasize that starting from the idea and need to identify an indicator set for assessing an entity’s overall performance, the presented model identifies the main value delivery process, to which an indicator set for process assessment can be assigned, which are determined by identifying the key success factors, for the process itself but also for the entity’s global performance (Miricescu, 2011, 2014).

Krahn (1998, 2001) proposes the following reference model for a systematic definition of indicators and for building a solid Process Monitoring System (PMS) (Fig. 3). PMS has evolved from process management concepts, comprising design, control and development of business processes.

Objectives	Retrieving and measuring process quality
Features	• Obtaining an integrative view and an overview of the process. • Serious process coordination. • Objective support – oriented improvement process. • Determining the changes in process quality. • Comparability of process quality. • Performance oriented incentive scheme.

Figure 3: Objectives and features for the Process Monitoring System (PMS) (Krahn, 1998).

The right determination of process quality depends on the definitions given by the indicators. The reference model is fixed on a hierarchical system of indicators. The three levels are: 1. Indicators for process coordination – this refers to the entity’s objectives and involves the process quality in relation to long-term objectives. These are provided for strategic decisions for guidance, purpose and structure of the process. 2. Indicators proper to the process – these are applied to the actual objectives of the project. They ensure the recognition of process potential. 3. Performance indicators for the process – these take into account the objectives of a single activity from the process. The operational potential is determined by these factors.

The reference model will be based on all these three architectural levels, following a particular procedure with three sequential phases.

Phase 1: Defining the objectives. Objectives are determined at the level of the entity, the process and the activity.

Phase 2: Defining the success factors. The critical success factors are, according to Rockart (1979) "the limited number of areas in which the results will ensure successful performances". This statement is applied in the Process Monitoring System (PMS). The critical success factors are identified on each level (Mende, 1995).

- Generic success factors
- Procedural success factors
- Specific success factors

This phase ends by pinpoint the success factors for the important activities of the process.

Phase 3: Defining the indicators). To ensure the success of a procedure from top to bottom, the definition of the indicators begins at the process coordination level. The success objectives and factors carried by the analysed process must be established. The chosen indicators must reflect the achievement of these objectives and factors over the course of the project. The measurements and results mirrored by the indicators will show how the entity's objectives are accomplished by the analysis process. These measurement units have to meet the measurement necessities for the processes objectives and for the success factors.

In line with this model we consider that the main management measures for this specific case study are: preservation of the natural morphology of the lotic systems and their banks, a ban on the disposing of any type of waste in streams and rivers, control of the pollution and mineral overexploitation of the riverbeds, and the creation of a monitoring system for ichthyofauna conducted by qualified/specialised personnel.

Any hydrotechnical work that will significantly diminish the river water flow of some lotic systems will decrease the number of individuals for this species to the point of local extinction, so creation of lentic areas are not recommended. In this regard, it is strongly recommended that any bridge construction, culverts, or any other modifications of the water speed regime are to be performed during the maximum multiannual levels, so that the impact would be as low as possible.

In all river sectors, the illegal phenomenon of poaching is quasi-permanent and intense and requires more efficient control.

It is necessary to prohibit the abandonment of any kind of waste in the river bed and surrounding wetlands of watercourses.

Seasonal integrated monitoring is recommended. This should include the monitoring of water charging elements with organic substances.

In the Şaeş and Laslea streams, a continuous water flow must be provided, namely reducing the flow takeover during dry periods. On the same streams, the effects of organic and chemical pollution should to be reduced.

Adjusted model for the site management

In this paper, an overview image of ecological requirements of *Sabanejewia aurata* species was tried on a section of the Sighișoara-Târnava Mare Natura 2000 site. To create this management model we used ADONIS:CE, a tool for modelling business processes, which has been used to view this species' management measures that need to be taken in order to preserve favourable conservation status. For this model, the following modelling objects were used: activities (blue rectangles), describing species characteristics (green ovals), decisions (yellow diamonds). These check the current state of each indicator compared to favourable conservation status, parallelism and merging objects by describing the activities that occur at the same time, variables and generators that help in determining the percentage of achievement of each indicator in hand.

Model description (Fig. 4): The model starts with a suite of seven activities that describe the scientific name of the species and common names, the critical requirements of habitat – including detailed habitat types – what the species needs for reproduction, shelter and food, possible indicators, and lastly presents the current state of indicators (measured on the ground) compared to favourable conservation status. When all of these requirements (specific and critical), have been described, by making use of decisions, the four indicators are checked (sandy substrates, gravel substrates, surface covered with water and riparian vegetation sides), to see if the values measured in the field comply with favourable conservation status.

If all indicators comply with favourable conservation status, then continue with the activity of creating a monitoring system conducted by trained personnel in this field and check again whether the conservation status is favourable. If so, then the model is continued by six activities – filling in a species sheet – describing observations in the field, other ecological requirements, current pressures, threats, reproduction and distribution in the protected area and the model ends. If it does not fulfil favourable conservation status, then return to activity. Repeat the model until the actual state versus the favourable conservation state match, and every indicator suggests a favourable conservation status.

Given that possible indicators listed above do not fulfil the conservation of the species, then using parallelism and merging objects, management measures are presented to be followed by activities that take place at the same time. In the case of this species, regardless of which indicator is checked the same management measures in the form of three activities have to be taken: preserving the natural morphology of the lotic systems and their banks, banning pollution and the disposal of any type of waste in the rivers and streams, and controlling mineral overexploitation of the riverbeds. The modelling process continues with the activity of implementing a monitoring system to verify whether the conservation status is favourable, and if so, as described above, follows six activities with completions of species sheet. If not, the process forms a loop and returns to activity. Actual state versus the favourable conservation state will go again through possible indicators related to decisions.

Figures 4 and 5 show different paths that follows the process if they choose branch "YES" to the first indicator (decision: "Current state of sandy substrate weight is 33%?" probability: 90% for "YES" branch, 10% for "NO" branch) the "NO" branch of the second indicator (decision: "The current state of gravel substrate weight is 33%?" probability: 33% for "YES" branch and 67% for "NO" branch), and "YES" branch if the decision is in favourable conservation status (probability 75% for "YES" branch and 25% for "NO" branch) – the path is shown by the thickening border of process objects.

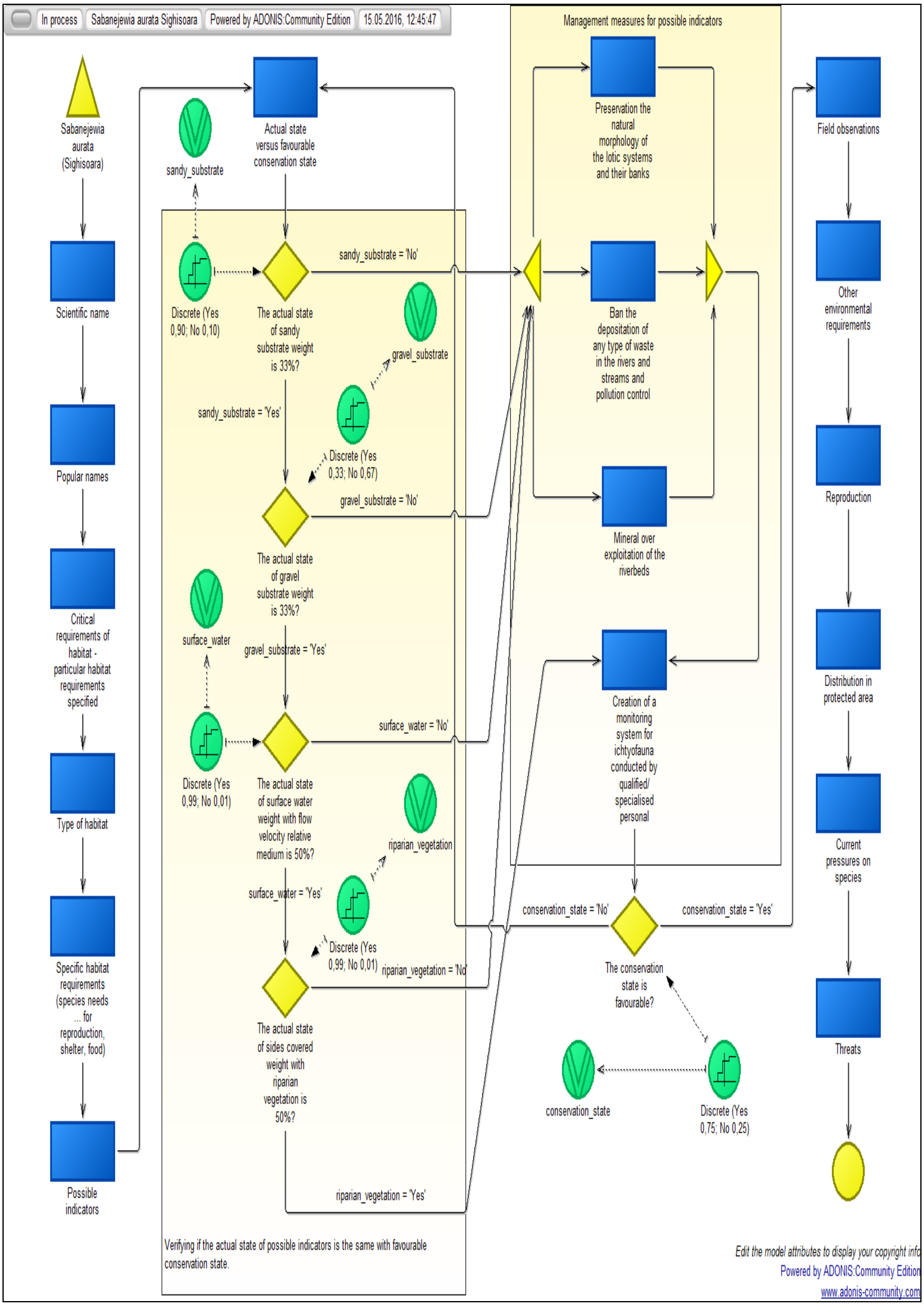

Figure 4: *Sabanejewia aurata* process model.

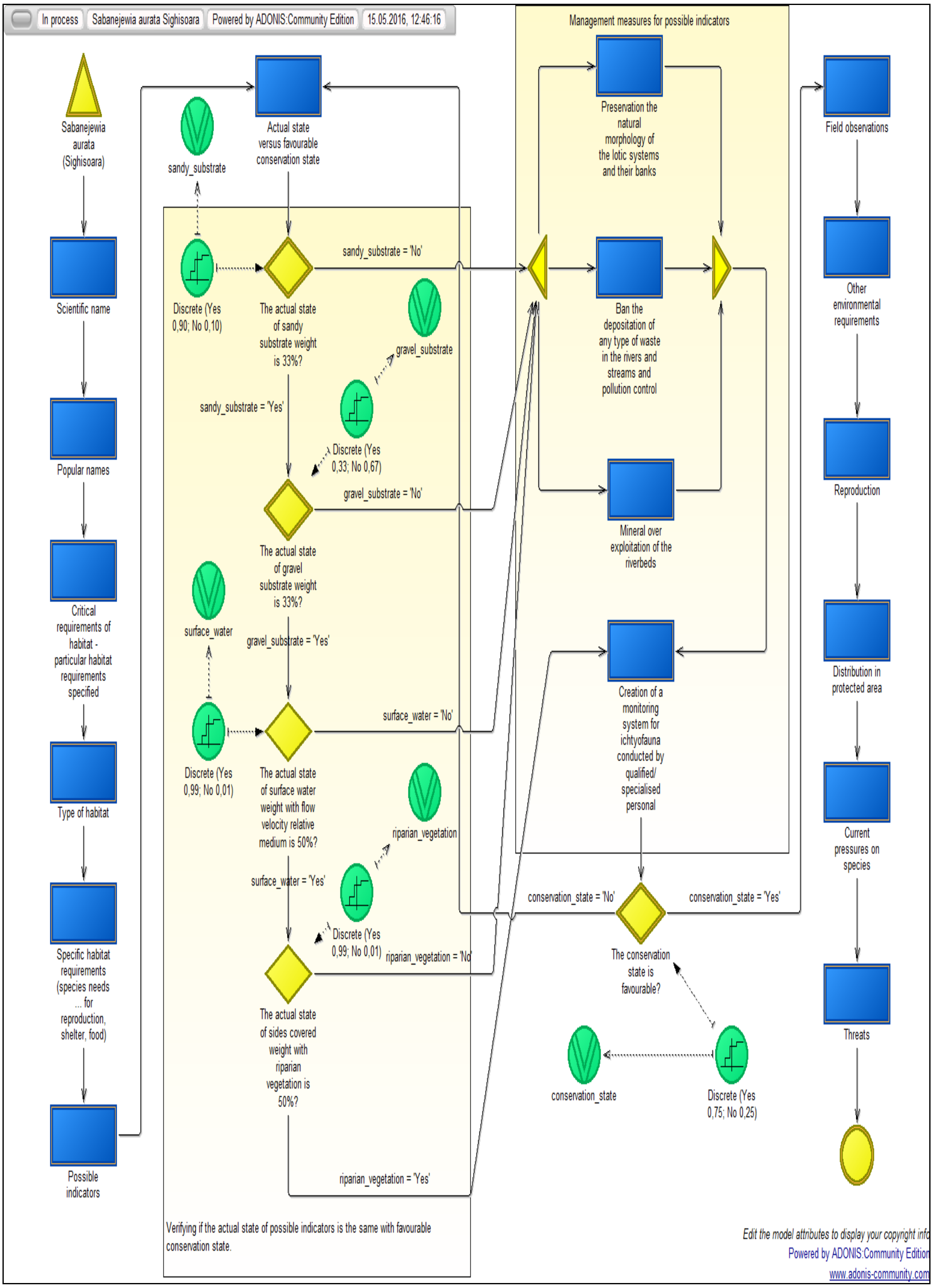

Figure 5: Process animation for *Sabanejewia aurata* species.

CONCLUSIONS

The main pressures preventing the golden spiny loach, *Sabanejewia aurata*, from having a good conservation status and healthy populations in the studied site are: changing the lotic habitats into lentic ones, and suppressing water chemical pollution and poaching.

Significant elements that need to be solved for the conservation of *Sabanejewia aurata* are as follows: conservation of the natural morphology of the streams, rivers and their banks, banning the disposal of any category of waste in the river and stream areas, pollution management, preventing mineral overexploitation of the riverbeds, and the establishment of a monitoring system for ichthyofauna conducted by qualified/specialised personnel.

In this study, a targeted management model designed to sustain the populations of *Sabanejewia aurata* in Sighişoara-Târnava Mare Natura 2000 site was developed using ADONIS:CE.

The ADONIS:CE was applied here in the nature protection framework, illustrating a management model of *Sabanejewia aurata* that circumscribes its necessities in relation to the habitat, the indicators that characterize a good ecological status, and the relevant management actions needed to prevent and/or remove the pressures and threats which influence these fish populations.

If the suggested management elements are put into action, *Sabanejewia aurata* will have a decreasing trend in the next 12-30 years in the studied area.

This particular on-site, on-habitats and on-species management model for *Sabanejewia aurata*, must be assimilated in an integrated management model for the Sighişoara-Târnava Mare Natura 2000 site ichthyofauna.

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APPROACHING THE POTENTIAL OF WORLD MARINE FISHERIES

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KEYWORDS: carrying capacity, FAO statistics, developing fisheries, maximum likelihood, fisheries management.

ABSTRACT

During the last 60 years, the world marine fisheries potential has been estimated between $22 \cdot 10^6$ tons and $1\,400 \cdot 10^6$ tons.

However, there are no certain indications of when and with what probability such potential will be reached.

By fitting a logistic curve to the observed world marine catch, corrected for discards and illegal, unreported and unregulated fishing, here we calculated that such potential stands between $132 \cdot 10^6$ tons and $153 \cdot 10^6$ tons and might be achieved as soon as the year 2027, with 95% confidence.

RESUMEN: Potential de la captura marina global.

En los últimos 60 años, el potencial de la pesca marina mundial se ha estimado entre $22 \cdot 10^6$ toneladas y $1\,400 \cdot 10^6$ toneladas.

Sin embargo no aún no existen indicios de cuándo ni con qué probabilidad dicho potencial será alcanzado.

Ajustando un modelo logístico a datos de captura marina mundial, corregidos para descartes, captura ilegal, no reportada y no regulada, en la presente contribución se estimó que la captura máxima potencial de la pesca marina se encuentra entre $132 \cdot 10^6$ toneladas y $153 \cdot 10^6$ toneladas; cifras que podrán alcanzarse, con el 95% de confianza, tan rápidamente como en el año 2027.

REZUMAT: Abordarea potenţialului mondial marin de pescuit.

În ultimii 60 de ani, potențialul pescuitului marin global a fost estimat între 22×10^6 tone şi 1.400×10^6 tone.

În orice caz, nu există indicații sigure când şi cu ce probabilitate acest potențial va fi atins.

Prin ajustarea unei curbe logistice a capturii marine mondiale, corectate pentru capturi ilegale, nedeclarate şi nereglementate de pescuit, am calculat că un astfel de potențial ar fi între 132×10^6 tone şi 153×10^6 tone şi ar putea fi realizat până în anul 2017, cu 95% confidență.

INTRODUCTION

Since 1950 there has been a major concern about how much the global marine catch can increase. While 60 years ago the estimations of the potential of the world oceans were as optimistic as 1 $400{\cdot}10^6$ tons (Pike and Spilhaus, 1962), in 1996 we witnessed a very distant maximum catch of ~ $88{\cdot}10^6$ tons (www.fao.org). Since then, the global marine catch has been between roughly 80 and $85{\cdot}10^6$ tons and the latest available estimates of the fisheries potential range from $100{\cdot}10^6$ tons (Garcia and Grainger, 1996) to $146{\cdot}10^6$ tons (Chassot et al., 2010). Obviously, there must be a limit to the marine capture fisheries in the climate changes and human impact circumstances in which negative signals in this respect were registered all over the world (Ruchimat, 2012; Khoshnod et al., 2015; Bănăduc, 2016); however how much more the total marine catch can increase and when this limit will be achieved are questions that still need a reliable answer. The aim of the present paper is to offer such an answer.

MATERIAL AND METHODS

We fitted a logistic model to the corrected world marine catch using the maximum likelihood method in order to estimate the marine fisheries potential, or the asymptotic theoretical catch. We computed the associated confidence intervals, the calendar year when this level will be achieved and compared our estimation with several others made by different authors.

World marine catch statistics (1950-2007) were obtained from FAO’s FIGIS system (http://www.fao.org/figis). Search fields included: (country) all continents excluding China (Watson and Pauly, 2001); (fishing areas) marine areas; (species) aquatic plants, crustaceans, marine fishes, miscellaneous aquatic animals (excluding reptiles and amphibians) and mollusks. Aquatic tetrapods were excluded from the analysis because landings are reported as numbers rather than biomass.

Time series were corrected for discards and for illegal, unreported and unregulated fishing (IUU) that can represent a substantial amount of fisheries catches. The historical maximum percentage of discards (1992-2001) and IUU (1980-2003) have been estimated in 25% and 21% respectively, in relation to the total marine fisheries recorded catches (Alverson et al., 1994; SOFIA, 2008; Agnew et al., 2009). Because we are referring to the maximum possible potential, the summation of both percentages (46%) was considered for correcting the entire world catch time series (Fig. 1).

Logistic curve fitting and confidence intervals estimation

We used the logistic model proposed by Quinn and Deriso (1999):

$$C_{est,t} = \frac{K_C C_i e^{rt}}{K_C - C_i + C_i e^{rt}}$$

Equation 1

where $\underline{C_t}$ is the corrected catch at time t; $\underline{K_C}$ is the carrying capacity of the global marine catch, or the marine fisheries potential, expressed in millions of tons; $\underline{C_i}$ is the initial catch record of the time series; and $\underline{r}$ is the rate of increase. We fitted Equation 1 to the corrected world catch using the maximum likelihood method.

The likelihood approach is useful to: 1) find parameters of a given model that provide the best fit to the data and explicitly incorporates the uncertainty (maximum likelihood estimator); 2) compare alternative hypothesis between different values of the parameters (likelihood profile); and 3) calculate confidence bounds on parameters (likelihood ratio test). Given initial guess-estimate values of $\underline{K_C}$, $\underline{C_i}$ and $\underline{r}$ and the history of global catches, Equation 1 allow us to generate an estimation of the catch for any time ($\underline{C_{est,t}}$) which is then compared to the observed data.

According to Ritz and Streibig (2008), the log-likelihood estimator is:

$$LL_t = -\frac{n}{2}[2\pi + 1 - \ln(n) + \ln(RSS)]$$

Equation 2
where *RSS* is defined as:

$$RSS = \sum_{t=1}^{n} \frac{\left(C_t - C_{est,t}\right)^2}{n}$$

Equation 3

Equation 2 is maximized across the parameters K_C, C_i and *r*. The resulting values provide the best possible fit to the observed data.

We computed the 95% confidence intervals for the parameter K_C following three consecutive procedures. First we constructed a likelihood profile, consisting in a systematic search over K_C for finding the log-likelihood associated to other values of this parameter (from 100 to 200 in steps of 0.003) while keeping C_i and r as constants in those values that maximized the log-likelihood. Henceforth, this profile will be called P1. Secondly, we applied the likelihood ratio test, or R:

$$R = 2[L(Y|p) - L(Y|p_{MLE})]$$

where $L(Y|p_{MLE})$ is the log-likelihood associated with the maximum log-likelihood estimate (MLE) of K_C and $L(Y|p)$ is the log-likelihood of another value of the parameter. This formula was calculated for all values of the profile. Lastly, considering that R has a chi-square distribution (X^2) with one degree of freedom, we estimated the 95% confidence intervals by noting that the probability or Pr ($X^2 < 3.84$) = 0.95 (Hilborn and Mangel, 1997). Since R is a symmetric function around the p_{MLE}, the extreme parameter values within the range of values that satisfies Pr are the lower and upper confidence bounds. We calculated the percentage of the estimated K_C that each $C_{est,t}$ represents, observing the year when 95% and 99% of this parameter was attained.

Finally, for comparing different available estimates of the maximum potential catch we constructed another profile, which will be called P2. In this case, we made 30 000 fits by fixing the parameter K_C (from 100 to 200 in steps of 0.003) while setting C_i and r to vary freely and recording the maximum log-likelihood of each fit. We also computed confidence bounds following the procedures described above.

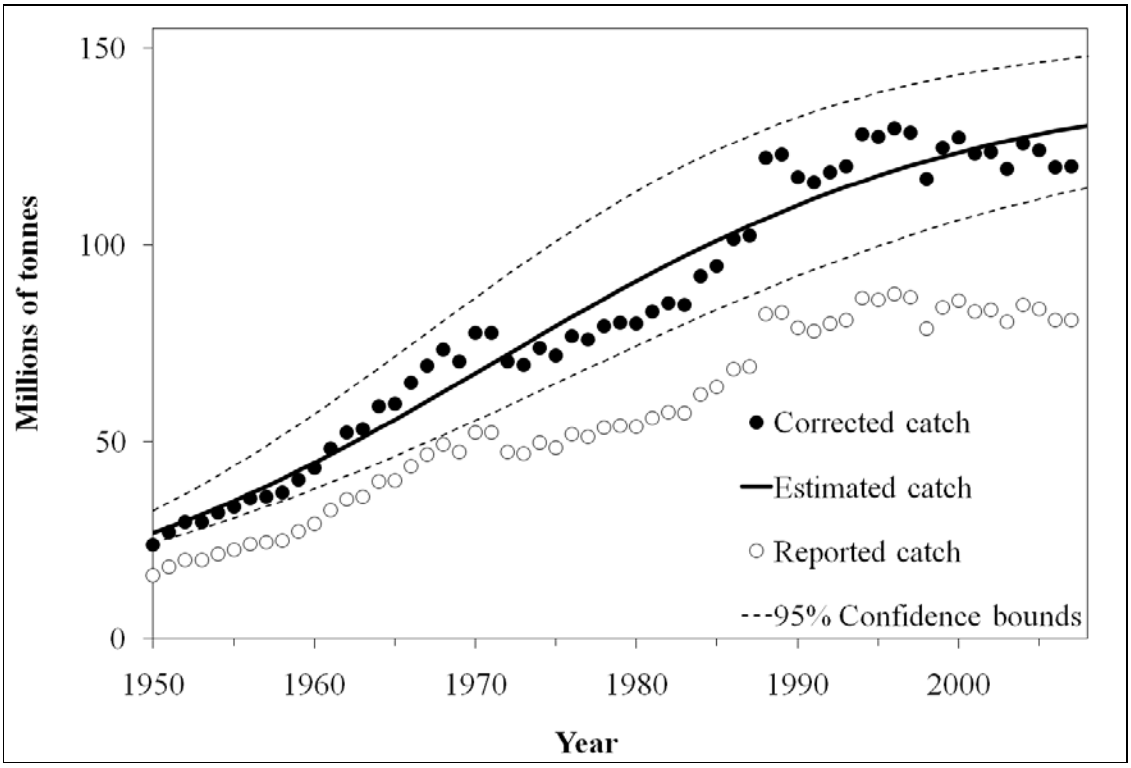

Figure 1: Corrected (filled circles) and reported (empty circles) world marine fisheries production. Correction consisted in the addition of 46% to the reported catches; 25% corresponds to discards (Alverson et al., 1994; SOFIA, 2008) and 21% for illegal, unreported and unregulated fishing (Agnew et al., 2009). Solid line represents the estimated catch using a logistic model; dotted lines are the 95% confidence bounds.

RESULTS

Reported and corrected world marine catch, as well as the logistic curve fitted to the corrected data and related confidence bounds, are shown in figure 1.

Both log-likelihood profiles and the comparison between several estimates of the marine fisheries potential are shown in figure 2. P1 indicates that for a single fit the estimate of $\underline{K_C}$, from 30 000 other different values of this parameter, is the best one given the observed data (for the fit that maximized the log-likelihood, $\underline{K_C}$ was set as a free parameter and $\underline{C_i}$ and $\underline{r}$ were kept as constants). On the other hand, P2 represents the maximum log-likelihood associated to 30 000 different fits for the same dataset (setting $\underline{C_i}$ and $\underline{r}$ as free parameters while keeping $\underline{K_C}$ as a constant in each fit).

A value of $141 \cdot 10^6$ tons for $\underline{K_C}$ maximized the log-likelihood in both profiles. The 95% confidence limits for P1 are $137 \cdot 10^6$ tons and $145 \cdot 10^6$ tons; for P2 are $132 \cdot 10^6$ tons and $154 \cdot 10^6$ tons. By looking the MLE in P2, 95% of $\underline{K_C}$ may be surpassed in 2015 and 99% of the potential will be reached around the year 2039 (Tab. 1).

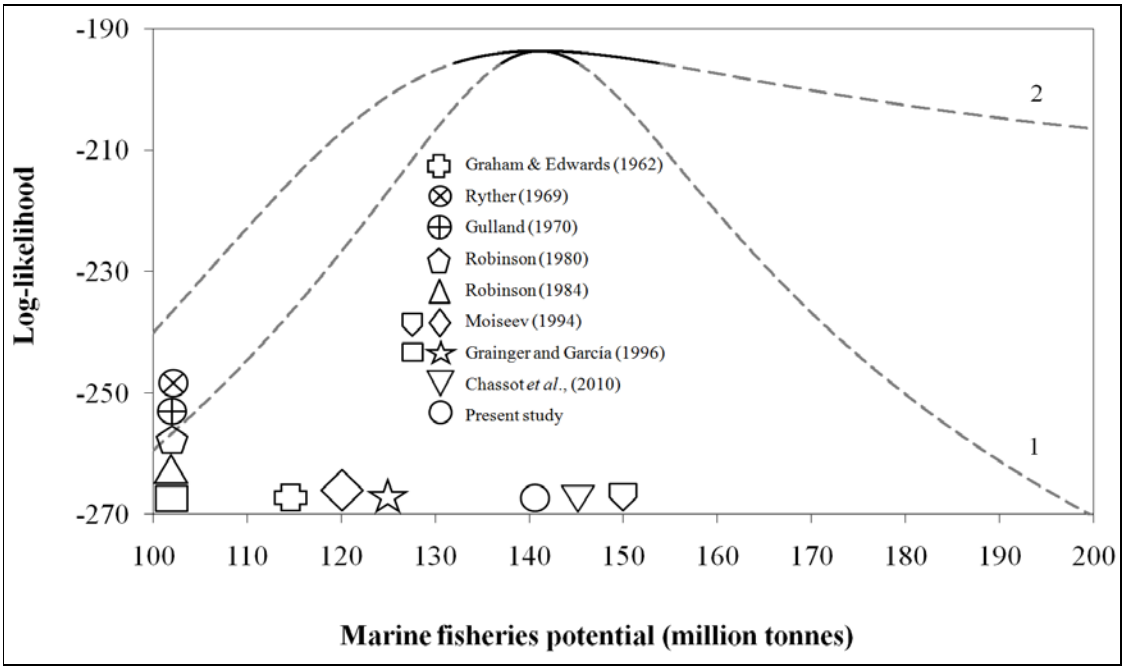

Figure 2: (1) Log-likelihood profile for the parameter $\underline{K_C}$ (marine fisheries potential) of the logistic model, expressed in million tons, applied to the world marine catch (1950-2007; corrected for discards, illegal and unreported fishing); and (2) profile of the maximum log-likelihood associated to different fits applied to the same historical data. Symbols represent the magnitude of different estimates of the marine fisheries potential and the authors of those estimates. In some cases, author(s) presented more than one estimate. Estimates higher than $200 \cdot 10^6$ tons and lower than $100 \cdot 10^6$ tons are not shown. Solid black lines represent 95% confidence bounds. Dotted lines are the log-likelihood values outside the confidence limits.

Table 1: Parameter values of the logistic model estimated by the maximum likelihood method, applied to the corrected world marine catch. Values correspond to the best possible fit, from a total of 30,000 runs. The carrying capacity ($\underline{K_C}$) and the initial estimated catch ($\underline{C_i}$) expressed in million tons; $\underline{r}$ is the intrinsic rate of increase; 95% $\underline{K_C}$ and 99% $\underline{K_C}$ is the calendar year when that percentage of the parameter will be achieved. LL: lower limit; MLE: maximum likelihood estimate; UL: upper limit (95% confidence bounds).

Parameter	Profile 2		
	LL	MLE	UL
$\underline{K_C}$	132	141	153
$\underline{r}$	0.06	0.07	0.08
$\underline{C_i}$	23	26	30
95% $\underline{K_C}$	2028	2015	2006
99% $\underline{K_C}$	2056	2039	2027

DISCUSSION

The results derived from both profiles converged in the value of the parameters that maximized the log-likelihood and also in the magnitude of the maximum log-likelihood, thus making P1 a particular case of P2. This is, from 30 000 fits made in P2, the one in which $\underline{K_C}$ was fixed in $141{\cdot}10^6$ tons resulted in the same values of $\underline{C_i}$ and $\underline{r}$ that maximized the log-likelihood in P1. However, the size of the confidence bounds in P2 is 2.5 times bigger than in P1. This difference is due to the covariance (the product of individual variances; Mendenhall and Schaeffer, 1973) between the parameters $\underline{C_i}$ and $\underline{r}$ (in P1 only $\underline{K_C}$ varies). Moreover, the confidence bounds in P1 are symmetrical but in P2 are 30% slanted to the right hand of the profile in relation to $141{\cdot}10^6$ tons. Our interpretation is that the corrected catch, whose historical maximum is $129{\cdot}10^6$ tons, provides stronger support to those fits in which $\underline{K_C}$ was fixed near this maximum. As $\underline{K_C}$ moves farther from $129{\cdot}10^6$ tons, the uncertainty progressively increases because there is no observed data greater than that figure. This also can be seen in the overall shape of P2 in contrast to P1 (Fig. 2).

Estimate versus estimate

Pauly (1996) and Garcia and Grainger (2005) compiled several estimates, made since 1950, of the maximum marine fisheries potential, ranging from $22{\cdot}10^6$ tons to $1400{\cdot}10^6$ tons. Some of these are based on the observed catch trends (Thompson, 1951; FAO 1953; Finn 1960; Meseck, 1962; Gulland, 1970; Grainger and Garcia, 1996), others are extrapolations from known areas to the global ocean (FAO, 1953; Finn, 1961; Graham and Edwards, 1962; Gulland, 1970), several consist in computations from primary production and food chains (Pike and Spilhaus, 1962; Graham and Edwards, 1962; Chapman, 1965; Schaefer, 1965; Ricker, 1969; Ryther, 1969; Gulland, 1970; Chassot et al., 2010) and two are inferred from biomass estimations (Moiseev, 1994). In P2 we compared our estimate of the marine fisheries potential with those estimates falling between $100{\cdot}10^6$ tons and $200{\cdot}10^6$ tons. With the data available until 2007, any approximations falling outside these limits are unrealistic (Fig. 2).

For instance, there is a discrepancy between the lower limit of $\underline{K_C}$ ($132{\cdot}10^6$ tons) and the upper limit of the maximum potential global catch estimated by Grainger and Garcia (1996) which is $125{\cdot}10^6$ tons. Such difference may rely in the fact that they did not correct historical global catches for discards nor IUU fishing, therefore their figure does not correspond to our MLE ($141{\cdot}10^6$ tons; Tab. 1). This means that if the goal is to maximize the likelihood of our fit in some statistically meaningful value by fixing $\underline{K_C}$, while letting the other two parameters to vary freely, it must be fixed at least in $132{\cdot}10^6$ tons. In fact, those estimates around $100{\cdot}10^6$ tons are also derived from catch records uncorrected for other sources of additional biomass. On the other hand, the estimate of $146{\cdot}10^6$ tons made by Chassot et al., (2010), derived the primary production available for marine fisheries, does incorporates the IUU catch and falls within the 95% confidence bounds, further supporting our conclusions. The estimates of Moiseev (1994), based on the total biomass of large fish and other organisms and their production-biomass ratios are also similar and statistically significant. The log-likelihood associated to all other estimates is negligible (Fig. 2).

There is another prediction of the marine fisheries potential that, although not statistically significant with respect to ours, must be acknowledged. Robinson (1979) calculated that the demand for fish for direct human consumption would reach roughly $97{\cdot}10^6$ tons (including freshwater fish) by the year 2000. If we subtract the observed catch from continental waters to the total marine production in that same year, disregarding discards and IUU fishing, then Robinson’s projection results surprisingly accurate.

Moreover, the difference between some estimates of the maximum potential marine catch and the correspondent observed catch, indicative of how close we are to that level, has been exponentially reducing since the 1970's and may become as small as four million tons in the next 40 years (Fig. 3). Such trend cannot be attributable to a lowering in the carrying capacity of the world oceans, because since 1996 the total corrected catch has fluctuated within a limited range of ~ $10 \cdot 10^6$ tons (Fig. 1) and the rate of catch increase shows a slightly negative value (– 0.003; Grainger and Garcia, 1996). Worryingly then, these evidences point out that we are rapidly approaching the limit of the world marine fishery production.

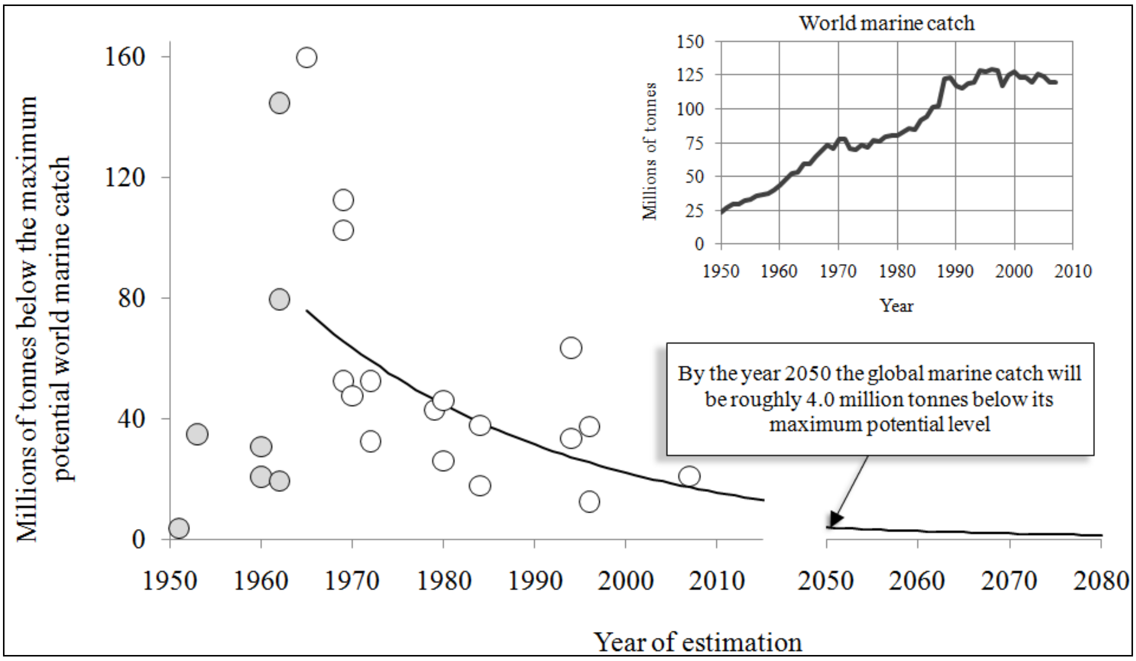

Figure 3: Differences between some estimates of the marine fisheries potential and the corresponding observed catch. Except for the last observation, all data are uncorrected for discards, illegal and unreported fishing. Estimates were taken from Gulland (1983), Pauly (1996) and Garcia and Grainger (2005). A negative exponential line was fitted to the empty circles. The world marine catch is approaching its maximum potential level as the difference between the two is getting smaller. Inner graph (historical marine catch from 1950 to 2007, corrected for illegal and unreported fishing) highlights that such approach is not due to a lowering in the fisheries carrying capacity.

Fisheries potential and climate change

Climate change is currently recognized as a major driver for marine ecosystems changes at different scales; however, considerable uncertainties and research gaps remain on its potential synergies with other factors such as pollution and fishing pressure (Barange and Perry, 2009). We believe that our estimation will not change under the expected climate change scenarios because of two observations: first, that the World Ocean is warming but trends are not geographically homogeneous. For example, there is mounting evidence indicating that eastern boundary currents regions, where a large proportion of industrialized fisheries operate, have been cooling for the last few decades (Bakun, 1990; Demarq, 2009). Secondly, the global fisheries have already experienced climate variations much larger than those expected from climate change, at least for the timeframe of the next few decades.

Marine fisheries potential

We have identified at least three different factors that might lead the current global (corrected) catch levels towards the maximum marine fisheries potential. First, although Watson and Pauly (2001) cast doubt on the veracity of the catch records from China, whatever that amount is must be added to the actual total production. There are estimations from knowledgeable authors pointing out that during the last decade, the catch from marine fisheries in China has fluctuated around 12.3 and 12.7 million tons (Huanh Shuolin, Shanghai Ocean University, personal communication), which represents 35% of the estimated potential (i.e. the difference between the upper and lower limit of our estimate and the maximum observed catch).

Secondly, as food demand increases, new fisheries may be eventually recruited to the current list of world fished stocks (i.e. deep sea resources, lantern fishes, myctophids, pelagic red crab, krill, etc.). For example, according to the Marine Stewardship Council (www.asoc.org), the krill fishery in the Southern Ocean (certified as sustainable in June 2010) yielded 118 000 tons during the 2007/2008 fishing season and the Total Allowable Catch in 2010 was set in 620 000 tons, but it has not yet been achieved. If this species, being a first level consumer, produced a modest increment in the global marine catch, we can expect an even smaller contribution from new fisheries targeting higher trophic levels.

Although more uncertain than the former, the potential available catch from underexploited and overexploited marine stocks may also be an additional source of biomass, assuming that all marine fisheries could be driven to their maximum productivity level. Nonetheless, we are now aware that the interdependence between exploited populations of different species within an ecosystem makes it impossible to simultaneously maintain them all at their maximum sustainable yields (Link, 2002). This implies that the current relative proportion between underexploited, fully exploited and overexploited marine stocks should not change substantially. Hence, the amount of catch that can be obtained from this source will also be rather limited. Garcia and Grainger (2005) suggested an alternative way to produce significantly more catch: increasing fishing pressure on top predators, reducing presently abundant cetaceans to reduce in turn their consumption, further increasing the abundance of prey and thereby allowing an increase in their harvest. In spite that such a strategy represents a sort of “ecosystem management”, the authors consider that it may have undesirable ecological consequences (hyper-fluctuating ecosystems, massive oxygen depletion).

According to our calculations, the likelihood that the sum of all these additional sources exceeds $34{\cdot}10^6$ tons, with respect to the corrected catch in 2007 ($119{\cdot}10^6$ tons) and to the upper limit of $\underline{K}_C$ ($153{\cdot}10^6$ tons), is statistically insignificant.

During the last decade, the percentage of fully exploited, overexploited and underexploited marine stocks has been related to the fishery system efficiency. However, as we approach to the maximum potential catch, other indicators may arise. For example, the speed and distance at which the total marine catch would depart below the lower limit of $\underline{K}_C$ might be regarded as a new fishery management compass. If more stocks were to become systematically overexploited and depleted, then the total catch would be expected to decline. Alternatively, if more fisheries are managed at their maximum productivity levels, then the total catch will tend to remain stable. Even the large fluctuations of massive fish resources such as small pelagics (averaging 30% of total marine catch) will produce a limited range of variation around $\underline{K}_C$, likely smaller than the range between the estimated confidence bounds, since the maxima and minima of these species are not in phase (Lluch-Belda et al., 1989; Omori and Kawasaki, 1995), making our estimation still more robust.

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PROPOSING A TECHNICAL SOLUTION FOR RESTORING LONGITUDINAL CONNECTIVITY IN THE BRĂDENI/RETIŞ ACCUMULATION AREA ON HÂRTIBACIU RIVER

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KEYWORDS: anthropogenic wetland, Hârtibaciu River, Romania, fish conservation.

ABSTRACT

The fish fauna of the Hârtibaciu River has experienced a disrupted connectivity due to the hydrotechnical works and the Brădeni/Retiş Dam located across the Hârtibaciu watercourse being one of this significant obstacles. The newly proposed constructed wetlands can improve the habitat quality for the fish species of conservative interest sampled in the Brădeni/Retiş Dam proximity *Rhodeus amarus*, and can increase the individuals' number of this population. Also can benefit the local populations of *Phoxinus phoxinus* and *Gobio obtusirostris*. Using gravitational force and also the underground layout, a proposed technical solution gives maximum safety regarding the water supply for the newly proposed to be created wetlands.

RESUMÉ: Solution technique proposée pour la réhabilitation de la connectivité longitudinale du réservoir de Brădeni/Retiş sur la rivière de Hârtibaciu.

La connectivité de l'ichtyofaune de la rivière de Hârtibaciu River est interrompue en partie à cause des aménagements hydrotechniques, y compris le barrage de Brădeni/Retiş qui traverse complétement la rivière, un des obstacles les plus signifiants. Les zones humides qui viennent d'être proposées peuvent améliorer la qualité de l'habitat pour l'espèce de poisson d'intérêt conservatif échantillonnée près du barrage de Brădeni/Retiş, *Rhodeus amarus*, a accroitre le nombre d'individus de la population en cause. D'autres espèces peuvent en tirer bénéfice, notamment *Phoxinus phoxinus* et *Gobio obtusirostris*. Utilisant la force gravitationnelle ainsi que le contexte pétrographique, la solution technique proposée offre une sécurité maximale de l'alimentation en eau pour les zones humides à venir.

REZUMAT: Propunere de soluție tehnică pentru refacerea conectivității longitudinale a râului Hârtibaciu în zona lacului de acumulare Brădeni/Retiş.

Conectivitatea faunei piscicole a râului Hârtibaciu este întreruptă și datorită lucrărilor hidrotehnice, barajul Brădeni/Retiş, situat pe cursul Hârtibaciului, fiind unul dintre obstacolele cele mai importante. Zonele umede propuse a fi create pot ameliora calitatea habitatului pentru speciile de pești de interes conservativ precum *Rhodeus amarus* (Bloch, 1782), specie găsită în apropierea barajului Brădeni/Retiş, cu efecte favorabile la nivel populațional. De asemenea, speciile *Phoxinus phoxinus* și *Gobio obtusirostris* pot beneficia de amenajarea propusă. Cu ajutorul gravitației și a substratului existent în zonă, soluția tehnică propusă oferă siguranță maximă în privința furnizării de apă pentru zonele umede propuse spre înființare.

INTRODUCTION

Connectivity fragmentation of lotic systems and the effects on aquatic diverse biota (algae, zooplankton, benthic macroinvertebrates, amphibians, fish, etc.) is a significantly increasing problem worldwide (Fuller et al., 2015; Dudgeon et al., 2005; Grill et al., 2014) and the Transylvanian hydrographical net is not an exception from this perspective (Onciu et al., 1999; Curtean-Bănăduc, 2005; Momeu et al., 2009; Bănăduc et al., 2016; Moshu et al., 2006).

According to Water Framework Directive, the ecological potential of waters is characterized by the following criteria: biological (the structure and wealth of aquatic flora, benthic invertebrate communities structure, wealth and age structure of fish fauna), hydromorphological (hydrological system, watercourse continuum, morphological conditions) and physico-chemical (salinity, acidification, thermal conditions, biogenic, oxygenation, pollution) (Water Framework Directive 2000/60/EC, 2000).

The longitudinal and lateral connectivity are severely affected by many causes, first and foremost being the hydraulic structures (dykes, dams, hydropowerplants, etc.) built along river courses. Hârtibaciu River (Cibin River basin/Olt River basin/Danube River basin) is not an exception from this non-functional wetland areas perspective. The proposed technical solution will support the lotic system restoration, in low flows conditions upstream of the Brădeni/Retiş Dam in the hot season, season with mobility and survival problems for the local ichthyofauna. The proposed constructed wetlands will circumvent the problems caused by sewage entering the river and – flood control systems of the Hârtibaciu River. Due to the proposed constructed wetlands. Each solution effectively uses the characteristics of soil and different existing hydro technical works. These wetland locations cause no impact on the hydro-technical constructions or civil structures. In fact they represent an advantage due to lower costs necessary for these types of projects. Simple yet effective design based on gravity flow water certifies the functionality of these technical solutions.

This study proposes a viable solution for improving the Hârtibaciu River continuum, in the Brădeni/Retiş Dam sector in accordance with Water Framework Directive 2000/60/EC needs.

MATERIAL AND METHODS

To assess the need for the proposed investment the fish communities structure was studied in the local Hârtibaciu River sector, upstream and downstream the Brădeni/Retiş Dam. The fish individuals were sampled with a mountain fishing net, in time and effort unit, identified and immediately released in their habitat.

RESULTS AND DISCUSSION

Upstream of the dam and 20 meters from the two sluices (Fig. 1), a trapezoidal earth dyke with large base of ~ 10.5 meters and small base of ~ 6.5 meters is to be built. In order to start working on the earth dyke, the Hârtibaciu River will be temporarily redirected by using a metal sheet pile wall system on the right side of the dyke (Fig. 2) in a rectangular channel with minimum five m depth and 1.5 m width. The distance between the earth dyke and the dam is 10 m.

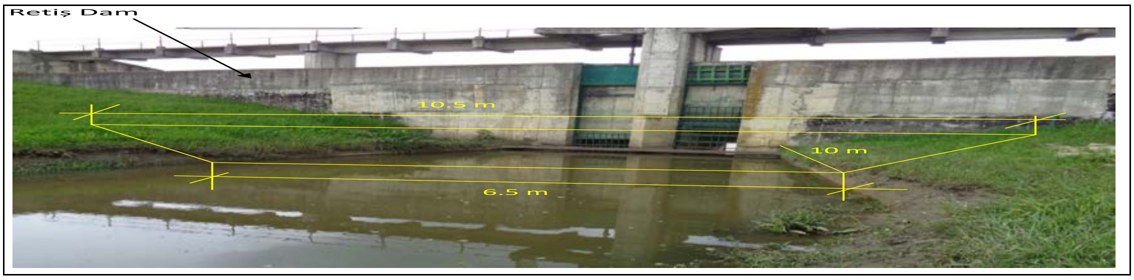

Figure 1: Positioning of the earth dyke – representative scheme.

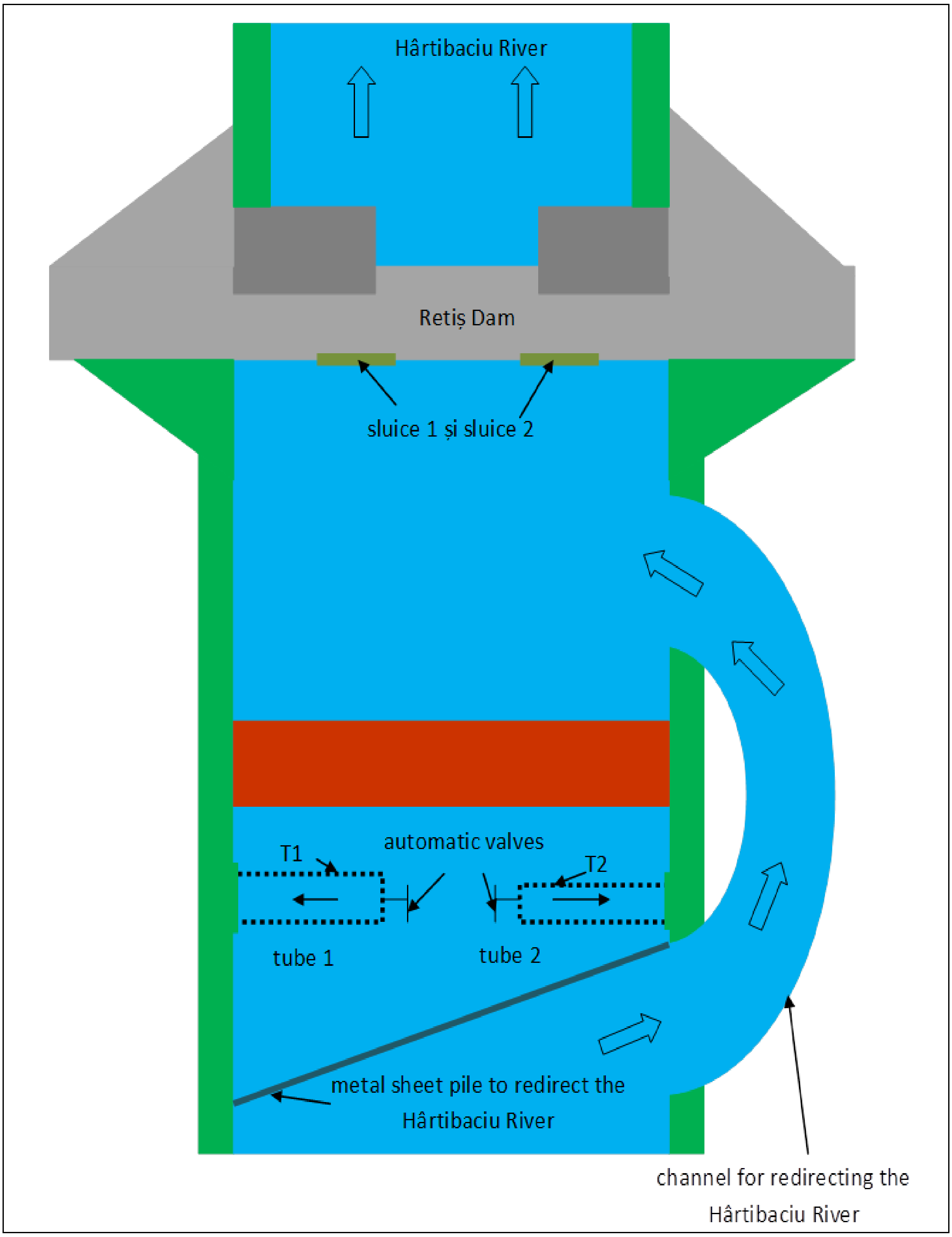

Figure 2: Locating the temporary channel to temporarily redirect the Hârtibaciu River – representative scheme.

After completing the construction of the temporary channel for redirecting the Hârtibaciu River, the earth dyke construction begins. Once the earth dyke is constructed, the two concrete tubes located underground, each equipped with automatic or manual valves (Fig. 2) are installed. The tube T2 has a smaller diameter than tube T1 (Fig. 2). After installing the concrete tubes the construction of the two basins on both sides of the Hârtibaciu River is started. Each basin has a depth of ~ 1.5 meters and two sides (a and b, a' and b' respectively) will follow the Hârtibaciu River bed (Fig. 3).

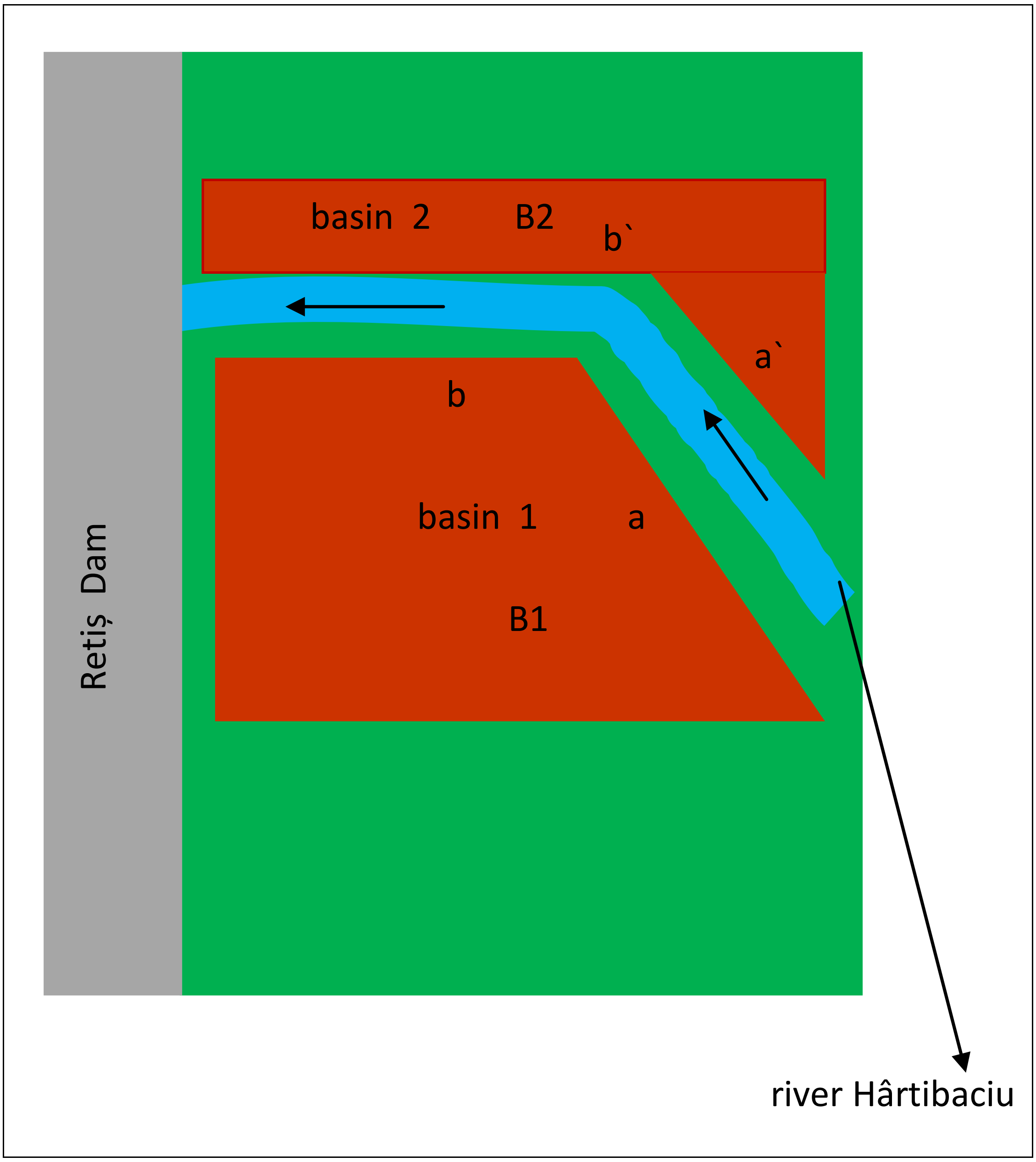

Figure 3: The location of the two basins/wetlands – representative scheme.

The banks of the two basins/wetlands 1 and 2 will be sloped. To provide stability and connectivity to the wetland proper, it is recommended that relatively fast-growing native woody species, preferably shrubs or multi-stemmed low growing trees to be planted/installed (e.g. *Alnus* sp., *Salix* sp., etc.). Tree species are not recommended due to the possibility of wind throw.

It is not advisable to use species with tap roots. Herbaceous plants with fascicular roots (e.g. sedge, fescue, etc.) also are good choices. It is also recommendable to use moisture loving species that through evapotranspiration can eliminate water from the bank, thus further contributing to stability. On the lower half of the bank partially located in water it is recommended to plant native reed, sedge, fescue, etc., and on the upper half of the bank install native woody vegetation (*Populus* sp., *Alnus* sp., *Salix* sp., etc.) (Fig. 4). This type of vegetation will grow and thrive on the banks of river and wetlands 1 and 2 providing healthy habitat areas and strong riparian connections for various species of amphibians, waterfowl, birds and other aquatic organisms.

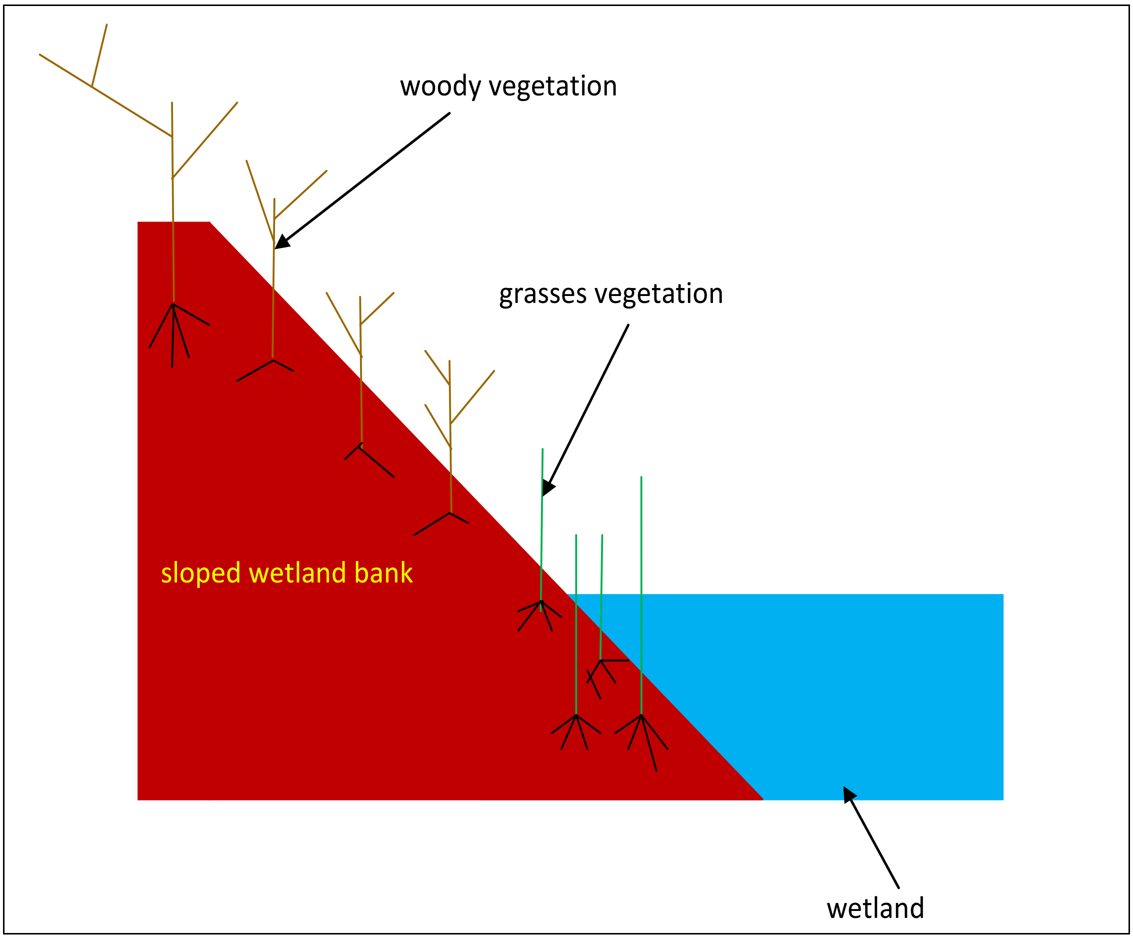

Figure 4: River bank stabilization using native woody and herbaceous vegetation – representative scheme.

The tubes (T1 and T2) are designed to supply basins 1 and 2 with water and are calculated so that they can undertake more than the annual average flow but not the maximum flow of the Hârtibaciu River. In the case of a flood event, the two spillways inside the dam will release the excess water.

In order for the water level in the two basins to remain constant (one m) and for the proper functioning of the wetland two rectangular channels C1 and C2 must be constructed in the two slopes of the dam (Fig. 5). Both channel C1 and channel C2 can accept double the amount of water in tubes 1 or tube 2. In the event of flooding both channels C1 and C2 can take a significant amount of water, thus assisting the two sills located inside Brădeni/Retiş Dam.

To prevent clogging, both tubes 1 and 2, as well as channels C1 and C2 are constructed with metal grids.

After operating the water supply system for the two basins/wetlands B1 and B2, the temporary channel for redirecting the river will be removed. The constructed wetlands will be surrounded by three m height metal fences to prevent people and animals from entering these areas (Fig. 6). As an additional environmental enhancement for amphibians and small animals, etc. openings (approximately 10 cm high and one m long) will be installed along the bottom of these fences, connecting the wetlands to the forest.

Soil bioengineering methods such as live fascines, brush layers and brush mattress offers a strong initial foundation and as such, are recommended for the stabilization and revegetation of the newly constructed wetland banks. These methods will provide immediate surface stability, long term soil reinforcement, water removal capabilities and over time a diverse, well connected and healthy riparian habitat.

The proposed system regarding the water supply for wetlands B1 and B2 does not affect the flow of the Hârtibaciu River nor Brădeni/Retiş Dam structure (Fig. 6).

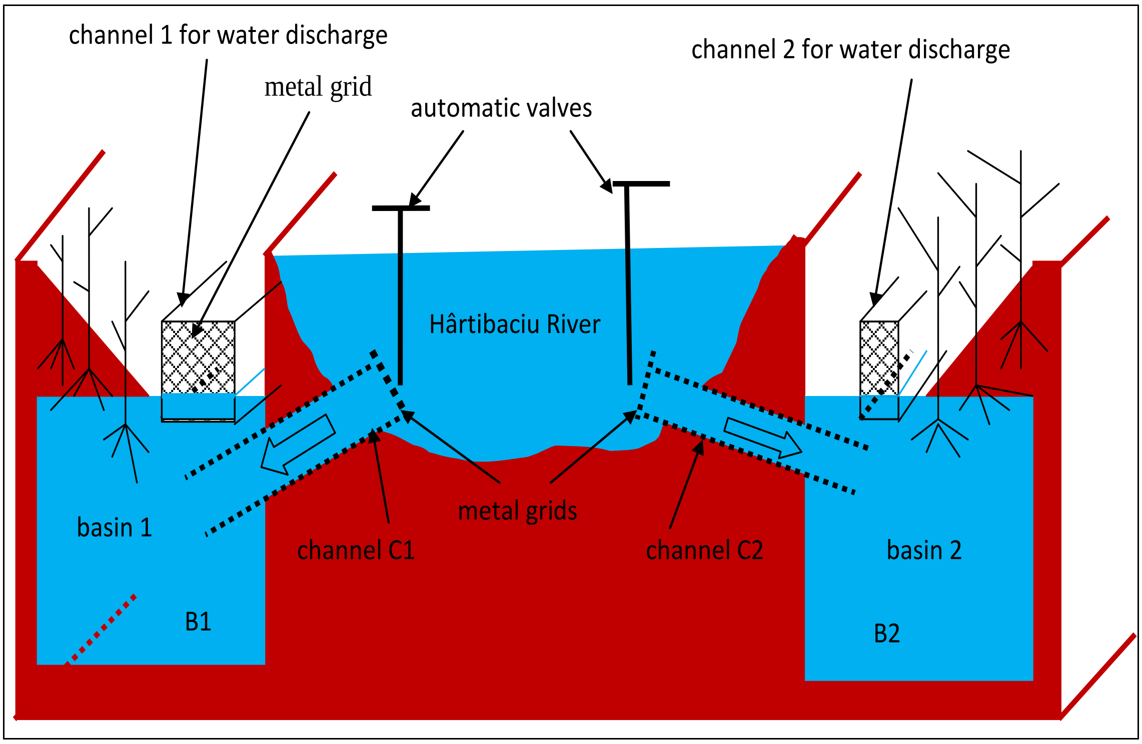

Figure 5: Positioning channels C1 and C2 – representative scheme.

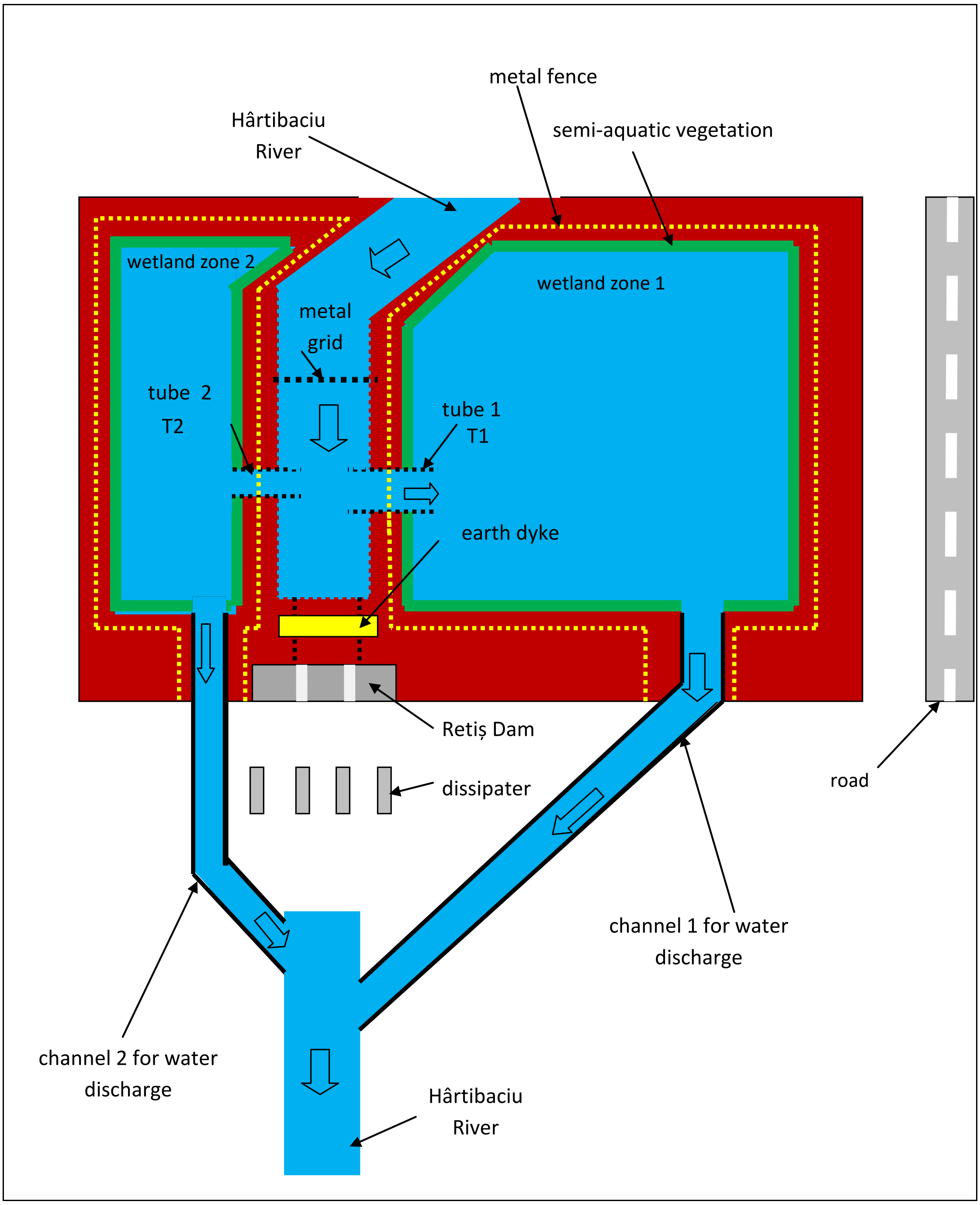

Figure 6: Wetlands and proposed system for their water supply
– general representative scheme.

Using gravity to fill the two basins B1 and B2 and also the underground layout of the two tubes (channels) T1 and T2, respectively gives maximum safety regarding the water supply for the newly proposed constructed wetlands.

Advantages for the local ichthyofauna conservation.

The Hârtibaciu River fish fauna includes a relatively high number of fish species, such as the followings: *Squalius cephalus* (Linnaeus, 1758), *Alburnus alburnus* (Linnaeus, 1758), *Alburnoides bipunctatus* (Bloch, 1782), *Rhodeus amarus* (Bloch, 1782), *Gobio obtusirostris* Valencienes, 1842, *Romanogobio kessleri* (Dybowski, 1862), *Barbus meridionalis* Risso, 1827, *Barbatula barbatula* (Linnaeus, 1758), *Misgurnus fossilis* (Linnaeus, 1758), *Cobitis taenia* Linnaeus, 1758, *Sabanejewia romanica* (Băcescu, 1943), and *Sabanejewia aurata* (De Filippi, 1863) (Bănărescu, 1964).

In the period of this study *Phoxinus phoxinus* (Linnaeus, 1758) was the first time recorded in the Hârtibaciu River watershed (Fig. 7).

Figure 7: Sampled individual of *Phoxinus phoxinus*.

In the sector of 25 m downstream of the Brădeni/Retiş Dam on the Hârtibaciu River only three fish species were recorded: *Phoxinus phoxinus* with a relative abundance of 79.17%, *Rhodeus amarus* with 12.5%, and *Gobio obtusirostris* with 8.33%.

In the sector of 25 m upstream of the Brădeni/Retiş Dam only *Phoxinus phoxinus* was found. The information gathered reveals the barrage and devastating role this dam has on the ichthyofauna, less for *Phoxinus phoxinus* and more accentuated for the other two fish species.

The newly proposed constructed system foundation and enhanced habitat that will be created by nature over time, should also be favourable and can be colonised by the bivalve species *Anodonta cygnea* (Linnaeus, 1758), which is present in Hârtibaciu River (Curtean et al., 1999; Sîrbu et al., 1999), a species which can have a positive affect for the *Rhodeus amarus* species reproduction (Bănărescu and Bănăduc, 2007) and for the water self-cleaning processes.

Phoxinus phoxinus fish species is usually present in Romania in the trout and grayling and Mediterranean barbell ichthyological zones, here being in an unusual association with *Rhodeus amarus* characteristic species for the much lower barbell zone and *Gobio obtusirostris* Valencienes, 1842 characteristic for the chub zone. The dam, the banks and the human impacted riverine vegetation explains this unnatural fish occurrence.

It is also important to note that *Rhodeus amarus* (Fig. 8) is a protected species under the Habitats Directive (92/43/EEC). The new proposed constructed wetland can increase its abundance in the area as it provides this species with a habitat characterised by stagnant or semi-stagnant water with soft bottom (Bănărescu and Bănăduc, 2007).

Figure 8: Sampled individual of *Rhodeus amarus*.

The two new proposed constructed wetlands can constitute a buffer zone for fish especially in the dry and could (with long frozen periods) seasons, and also an easy crossing passage. Aquatic and semi-aquatic birds, amphibians, molusks and aquatic and semi-aquatic vegetation can benefit also by this wetland in the future. It will continue to evolve becoming stronger and naturally more diverse, healthy and self-supporting over time.

CONCLUSIONS

Using gravity and also the underground layout of the two tubes (channels), the proposed technical solution gives maximum safety regarding the water supply for the newly proposed constructed wetlands.

All the local fish species presently experience major disrupted movement due to the Brădeni/Retiş Dam located across the Hârtibaciu watercourse. The newly proposed constructed wetlands sets in place the foundation for the rehabilitation of the connectivity and the enhanced habitat quality for the single fish species of conservative interest sampled in the Brădeni/Retiş Dam proximity *Rhodeus amarus*, and increases the number of individuals of this population. Also the local fish population of *Phoxinus phoxinus* and *Gobio obtusirostris* will most certainly benefit from this renewed and increased connectivity.

ACKNOWLEDGEMENTS
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MEASURING THE EXTENT OF THE ENVIRONMENTAL POLLUTION IN THE WATERS OF THE AL-DIWANI RIVER BY CERTAIN TRACE ELEMENTS RESULTING FROM AL-DIWANI TEXTILE FACTORY USING SPECTROSCOPIC METHODS

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KEYWORDS: textile factory, Al-Diwani River, trace elements, Iraq.

ABSTRACT

The textile industry is a key source of pollution in fresh water. The concentration of key heavy metal pollutants (cobalt, nickel, lead, mercury, cadmium, copper, and iron) as well as pH value and conductivity were measured in water samples taken from the input and output (waste water) of Al-Diwani textile factory on the Al-Diwani River, Iraq. These samples were measured using two methods, flame atomic absorption spectrophotometry and spectrometry. This paper considers the relative effectiveness of each method for measuring the concentrations of the elements, and discusses which method is best for which element. It was found that the first method is more accurate for measuring the concentrations for all elements except iron.

RÉSUMÉ: La détermination par des méthodes spectroscopiques de la pollution dans les eaux de la rivière de Al-Diwani avec certains éléments-trace provenant de l’usine textile de Al-Diwani.

L’industrie textile est une importante source de pollution de l’eau douce. La concentration des polluants de la catégorie des métaux lourds (cobalt, nickel, plomb, mercure, cadmium, cuivre et fer), ainsi que le pH et la conductivité ont été mesurés dans des échantillons d’eau pris à l’entrée et à la sortie (eaux usées) de l’eau dans l’usine textile Al-Diwani située sur la rivière Al-Diwani en Iraq. Les concentrations des éléments mentionnés ci-dessus ont été déterminées par deux méthodes: la spectrophotométrie d’absorption atomique sur flamme et la spectrométrie. Cet article se penche sur l’efficacité relative de chaque méthode pour déterminer les concentrations des éléments et discute quelle est la meilleure méthode pour chaque élément. Dans le cas de tous les éléments, sauf le fer, la première méthode a été prouvée comme plus précise pour mesurer les concentrations.

REZUMAT: Măsurarea prin metode spectroscopice a nivelului de poluare a apelor râului Al-Diwani cu anumiți contaminanți proveniți de la fabrica de textile Al-Diwani.

Industria textilă este o sursă importantă de poluare a apei dulci. Concentrația poluanţilor din clasa metale grele (cobalt, nichel, plumb, mercur, cadmiu, cupru şi fier) precum şi pH-ul şi conductivitatea au fost măsurate în probe de apă recoltate la intrarea şi ieşirea folosinţei de apă a fabricii de textile Al-Diwani, situată pe râul Al-Diwani din Irak. Probele au fost determinate prin două metode: spectrofotometria prin absorbţie atomică pe flacără şi spectrometria. Prezentul studiu analizează eficacitatea relativă a fiecărei metode în măsurarea concentraţiilor elementare şi discută adecvarea fiecărei metode pentru fiecare element. S-a concluzionat că prima metodă prezintă o precizie mai bună pentru măsurarea concentrațiilor tuturor elementelor analizate cu excepția fierului.

INTRODUCTION

Water was and still is important for life and human society (Moyle and Leidy, 1992; Curtean-Bănăduc et al. 2007), and it is vital to industry, being used in industrial processes either directly, or indirectly (Nemerow, 1971; Zhou and Smith, 2002). Many rivers form important surface water sources, and may contain many salts and other elements from natural or anthropogenic sources, which vary depending on erosion of underlying geology and the nature of human activities (Ramathan et al., 2003).

Water used in industrial processes often contains harmful substances and must be treated before it is put to returned to water sources such as rivers. The textile industry is one of the most water-consuming industries, with much water being used to grow cotton or turn raw wool or nylon fibers derived from petro-chemical industries into textile products (Report EPA-600, 2002; Fred Gurnham, 1985). The water required in this industry needs to be of high quality, and therefore must be treated before it is used in the industry. The waste water from the textile industry is often full of complex and diverse water pollutants such as dyes, fibers, nylon and other materials including remnant fibres (Ramathan et al., 2003). Pollutants vary from plant to plant depending on the type of fiber used, the parts of the production processes and the quality and quantity of materials (Koziorowski and Kucharski, 1987).

The effect of pollutants are broad-ranging, from organic waste that absorbs dissolved oxygen and adheres to the river bed (Cromption, 2007) to solids and coloured liquids such as oil derivates and grease floating on the surface of rivers that hinder the arrival of the sun's rays into the water and threaten aquatic life (Atkins and Lowe, 2010). Inorganic contaminants such as salts affect the water hardness and increase both salinity and the proportion of heavy elements in the water of the rivers (Zhou and Smith, 2002; Ramathan et al., 2003). The acidic and alkaline debris of pollutants affect the life of the fish in the river as the waste-water from industrial plants often affects the pH and presence of toxic substances, and damages sewage systems (Report EPA-600, 2002; Atkins and Lowe, 2010) is also. As materials decompose, they release hydrogen sulphide gas, affect the amount of free chlorine and reduce the self-purification capacity of the river (Koziorowski and Kucharski, 1987).

The most important pollutants are toxic trace elements which form deposits on the surface of rivers and kill the plant and animal life by affecting water transparency and blocking the sun's rays. These effects also affect humans. We measure the extent of the environmental pollution of the waters of the river Al-Diwani, specifically pollution arising from the Al-Diwani textile factory, which is a threat through its release of contaminated waste water to the Al-Diwani River (Setyorin et al., 2005; Liu and Han, 2002). We measured concentrations of elements in the water entering, the water emerging and river water near the factory by using atomic absorption technique (Atomic Absorption Spectrophotometry, AAS), which has a sensitivity and high selectivity for measuring concentrations in the samples at a wavelength appropriate for each studied element (Surard and Chiranjepri, 2005). We carried out a comparative analysis of this method against the appropriate standard spectral method for each component in the same models to demonstrate the accuracy, sensitivity and precision of the method for measurement of trace elements, and discuss the results in the context of environmental pollution caused by waste water released into the river from the factory.

MATERIAL AND METHODS

Devices used: Sensitive Balance, Sortoris, Germany, Ph-meter – knick – digital (Ph-meter), Pye Unicom flame Atomic absorption Spectrophotometry, Spectrophotometry PD-303 (UV-VIS) Spectrophotometry Digital Conductivity, India, Glass. **Material used:** All the materials used were of a high degree of purity and equipped from companies listed in table 1.

Preparation of samples: 1 litre (1l) water samples were taken of wastewater and input water from the laboratory Liquidation Station at Al-Diwani textile factory for four consecutive weeks. The waste water is removed once a week from the factory, and input water is typically used for four weeks before being ejected as waste water, so this sampling period is sufficient. From each of the 1l samples, 200 ml were taken and filtered by filtration paper (0.45 µm) to remove waste material and to measure the concentrations of elements through atomic absorption and spectral methods. A standard solution for each ion was prepared at 10 ppm concentration in 100 ml of distilled water as a stock, detailed in table 2. Solutions used in spectroscopic measurements: 1-alpha-nitrous-beta-naphtol solution: Prepared by dissolution of one gm in 100 ml acetic acid; 2-Dithiazon solution: Prepared by dissolution of 0.002 gm in 100 ml chloroform; 3-di methyl glyoximato (DMG solution): Prepared by dissolution of one gm in 100 ml ethanol; 4-1.10-phenanthroline solution: Prepared by dissolution of 0.25 gm in 100 ml distilled water that was made acidic with 0.1 M of hydrochloric acid.

Table 1: All the materials and the source company used in the research.

	Material names	Formula	Purity	Source companies
1.	Cobalt nitrate hexhytrate	$Co(NO_3)_2.6H_2O$	99.9%	Merck
2.	Nitric acid	HNO_3	70%	Merck
3.	Di-methyl glyoximato	$C_4N_2O_2H_8$	95.5%	Merck
4.	Nickel chloride hexhydrate	$NiCL_2.6H_2O$	99.9%	Merck
5.	Lead nitrate	$Pb(NO_3)_2$	98%	Merck
6.	– Naphthol β – nitrose – α	$ONC_{10}H_6OH$	99%	Merck
7.	Mercury nitrate monohydrate	$Hg(NO_3)_2.\ H_2O$	99%	Fluka
8.	Cadmium chloride	$CdCL_2$	98%	Fluka
9.	Copper Sulphate pentahytrate	$CuSO_4.5H_2O$	98%	Fluka
10.	Ferric chloride trihytrate	$Fe\ CL_2.3H_2O$	98%	Fluka
11.	Ethanol	C_2H_5OH	75%	Aldrich
12.	Chloroform	$CHCl_3$	95%	Aldrich
13.	1 10-phenanthroline	$C_{12}H_8N_2$	98%	Aldrich
14.	Carbon tetra chloride	CCl_4	99%	Britsh Drug houses
15.	Sodium hydroxide	NaOH	98%	Britsh Drug houses

Table 2: Chemical compositions and weights of materials used for standard solutions.

Weight (gm/100 ml)	Material	Element
0.0023	$Ni\ CL_2.6H_2o$	Nickel
0.0028	$Co(NO_3)_2.6H_2o$	Cobalt
0.0034	$Hg(NO_3)_2.H_2o$	Mercury
0.0024	$Cu(NO_3)_2.5H_2o$	Cupper
0.0018	$CdCl_2$	Cadmium
0.0033	$Pb(NO_3)_2$	Lead

RESULTS AND DISCUSSION

Measured ions: calibration curve was made for each ion through the two methods (atomic absorption spectroscopic method and spectroscopic methods) appropriate for each ion.

1-lead ion (Pb^{+2}): Concentrations of lead in samples were measured by atomic absorption spectroscopic methods and spectroscopic methods, by calculating the absorbance of the complex lead with Dithiazon. Maximum absorbance was at 510 nm (Merczenko, 2005). The calibration curves are presented in figures 1a, b, and the results are presented in table 3.

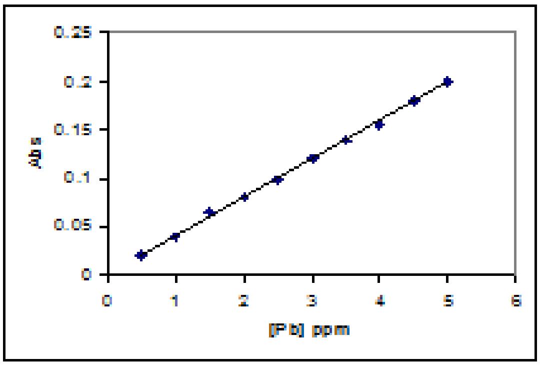

Figure 1a: Calibration curve for lead (spectroscopic method).

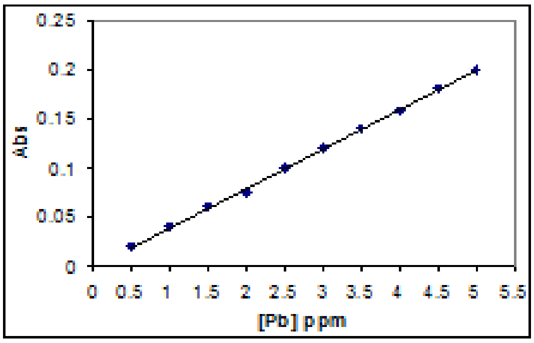

Figure 1b: Calibration curve for lead (atomic absorption method).

Table 3: Lead ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
98.50%	– 1.50	1.40%	0.9993	3.31	Atomic absorption	Waste water
98.50%	– 4.50	4.60%	0.9989	3.38	spectroscopic method	Waste water
97%	– 3	1.51%	0.9993	3.05	Atomic absorption	Input water
96.50%	– 3.5	4.20%	0.9989	3	spectroscopic method	Input water
98.30%	– 1.70	1.40%	0.9993	3.5	Atomic absorption	River water
93.50%	– 6.50	4.60%	0.9989	3.6	spectroscopic method	River water

The results (Tab. 3) note the presence of high concentrations of lead in water entering the factory and in factory waste water. The factory does not currently treat the water to remove it. The waste water contains a high concentration of lead because they use galvanized pipes, and the synthetic dyes used in textile production four-ethyl lead, a fuel derivative (Abdal-Radha et al., 2002). There is, therefore, a high concentration of lead ions in the river water, at levels which are in excess of the International Standard of 0.05 ppm for lead concentration. Lead and its compounds are toxic, and accumulations leads to brain damage, anaemia, damage to the digestive tract and kidneys, and can lead to the death of plants (Gaw and Cowana, 2007). The results presented here suggest that, based on the r correction factor, RSD%, Erel and Re%, the atomic absorption method gives a more accurate and sensitive estimation of the concentration of lead ions than the spectral method for all the measured samples.

2-Mercury Ion (Hg^{+2}): Mercury ion concentration in the samples was measured by atomic absorption spectroscopy, a process that, for mercury, requires cold atomization. The spectroscopic method was measured by the absorbance of the complex output of mercury and dithiazon reagent with the maximum wave length at 485 nm (Merczenko, 2005). Figures 2a, b presents the calibration curves and the results of the analysis are shown in table 4.

The results in table 4 indicate that there is no mercury in input water samples to the factory where it is processed through the formation of complexes. However, in the factory wastewater we note the presence of very high concentrations of mercury, most likely due to the formation of complexes with the addition of chlorine in some of the industrial processes in the factory (Surard and Chiranjepri, 2005). These concentrations are well in excess of the recommended maximum concentration of mercury in surface water which is equal to 0.005 ppm. Mercury is highly toxic but commonly used in many dyes and in the synthesis of many organic compounds used in the industry (Vekhande, 2006).

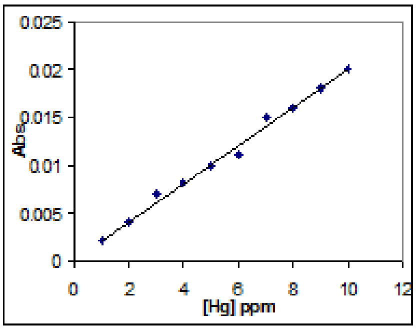

Figure 2a: Calibration curves for mercury (spectroscopic method).

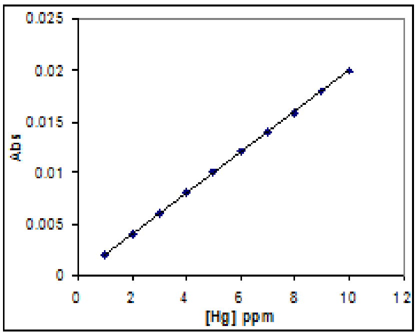

Figure 2a: Calibration curves for mercury (atomic method).

Table 4: Mercury ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc.of element (ppm)	Method	Water type
96.50%	– 3.50	2.40%	0.9999	1.18	Atomic absorption	Waste water
95%	– 5	4%	0.9955	1.4	Spectroscopic method	Waste water
0	0	0	0.9999	ND	Atomic absorption	Input water
0	0	0	0.9955	ND	Spectroscopic method	Input water
98%	– 2	1.40%	0.9999	1.14	Atomic absorption	River water
96%	– 4	3%	0.9955	1.51	Spectroscopic method	River water

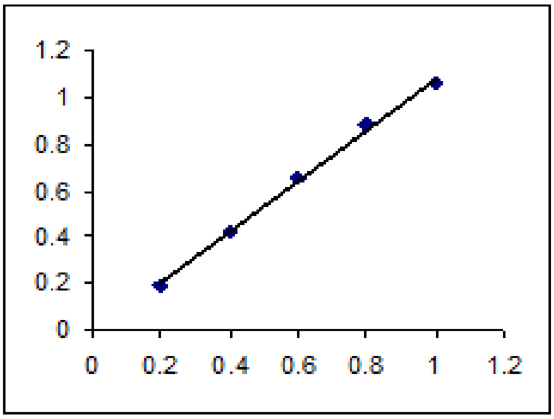

Figure 3a: Calibration curves for cadmium (spectroscopic method).

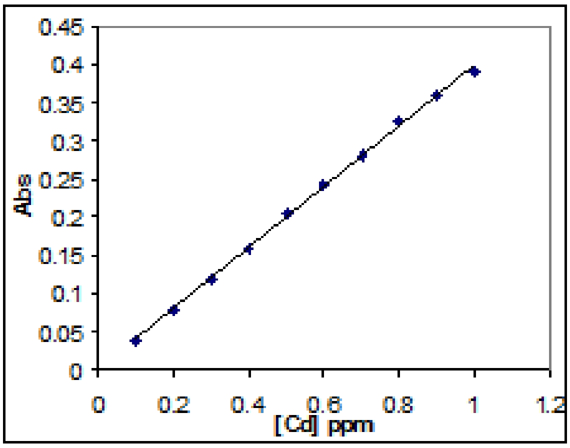

Figure 3b: Calibration curves for cadmium (atomic absorption method).

Mercury poisoning causes flicker vertigo, lung damage, blindness and infertility and its accumulation causes brain damage (Lee, 2007). Mercury also has a significant effect on aquatic life: where it is deposited by bacteria, the alkali mercury doubles the threat in the bottoms of rivers and high concentrations (1.5 ppm or higher) will lead to the death of river fish (Al-sadai, 2009). From the results in table 4, based on the r correction factor, RSD%, Erel and Re%, the atomic absorption method gives a more accurate and sensitive estimation of the concentration of mercury ions than the spectral method for all the measured samples.

3-Cadmium Ion (Cd^{+2}): Cadmium ion concentration was measured in the samples using atomic absorption spectroscopy and spectroscopic methods by calculating the absorbance of the complex cadmium with Dithiazon at the maximum absorbance at 520 nm (Merczenko, 2005). The calibration curves are shown in figures 3a, b. The results are presented in table 5.

Table 5: Cadmium ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
98.70%	– 1.30	1.232%	0.9994	0.375	Atomic absorption	Waste water
98%	– 2	3%	0.9988	0.210	Spectroscopic method	Waste water
0	0	0	0.9994	ND	Atomic absorption	Input water
0	0	0	0.9988	ND	Spectroscopic method	Input water
98%	– 2	1.52%	0.9994	0.390	Atomic absorption	River water
95%	– 5	3.10%	0.9988	0.400	Spectroscopic method	River water

From table 5 it is clear that there is an absence of cadmium in the input water to the factory, in part due to a treatment for cadmium by forming insoluble complexes with chlorine (Surard and Chiranjepri, 2005). However, the water waste and river water samples show the presence of high concentrations of cadmium caused by waste from the factory, at levels higher than the recommended maximum concentration of 0.04 ppm in surface waters. These concentrations are likely to be the result of cadmium ions being present in pigments and coating materials, and being used in the composition of many plastic substances used in the industry. Cadmium forms strong bonds with carbon and is soluble in organic and inorganic solvents. Cadmium affects humans through interaction with DNA or RNA which result in effects on genes (Khlool, 2005). The accumulation of cadmium leads to the dissolution of the bones, affects the metabolism of fatty acids, affects life cycles and growth in aquatic organisms and affects plants in the aquatic environment (Surard and Chiranjepri, 2005). From the results in table 5, based on the r correction factor, RSD%, Erel and Re%, the atomic absorption method gives a more accurate and sensitive estimation of the concentration of mercury ions than the spectral method for all the measured samples.

4-Nickel ion l (Ni^{+2}): Nickel ion concentration was computed in the samples atomic absorption spectroscopy and spectroscopic methods by calculating the absorbance of the complex between nickel and di-methyl glyoximato (DMG) at a maximum wavelength of 445 nm (Merczenko, 2005). The calibration curves are shown in figures 4a, b. The results are presented in table 6.

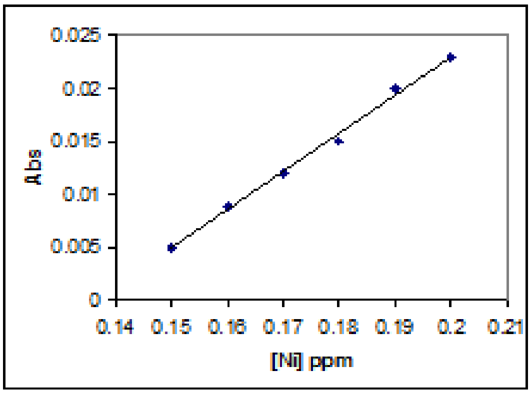

Figure 4a: Calibration curves for nickel (spectroscopic method).

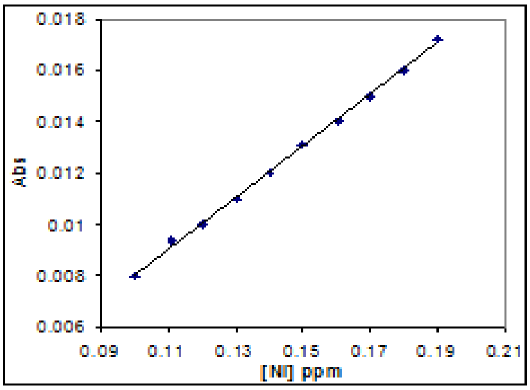

Figure 4b: Calibration curves for nickel (atomic absorption method).

Table 6: Nickel ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
98%	– 2	1.60%	0.9997	0.135	Atomic absorption	Waste water
96%	– 4	2.50%	0.9991	0.14	Spectroscopic method	Waste water
97%	– 3	1.70%	0.9997	0.115	Atomic absorption	Input water
95.90%	– 4.10	2.40%	0.9991	0.12	Spectroscopic method	Input water
98.50%	– 1.50	2.84%	0.9997	0.16	Atomic absorption	River water
97%	– 3	3.50%	0.9991	0.19	Spectroscopic method	River water

The results indicate that there is nickel in both input water samples and waste water samples. Of particular concern is the concentration of nickel ions in the waste water samples, which lie outside the threshold limit of 0.02 ppm for surface water. The concentration of nickel ions in water waste is likely to be due to its use in the synthesis of dyes and in the use of many alloys (Kassam, 2005). Nickel concentrations of one ppm are deadly to aquatic environment (Allway, 2000). Nickel leads to a lack of growth, it has effects on the blood (high number of red blood cells), affects the production of protein in the kidneys (Gupta et al., 2002) and affects plant life through its influence on the solubility of ion exchange in plants (Allway, 2000). The results in table 6 indicate that, based on the correction coefficient r, RSD%, Erel and Re%, the atomic absorption method is more accurate and sensitive to the estimation of nickel ions than spectral methods for all the measured samples.

5-Cobalt ion (Co^{+2}): Cobalt ion concentration was calculated in the samples by atomic absorption spectroscopy and spectroscopic methods by calculating the absorbance of the complex between cobalt ions and alpha-nitrous-beta-naphtol at a maximum wavelength of 415 nm (Merczenko, 2005). The calibration curves are presented in figures 5a, b and the results shown in table 7.

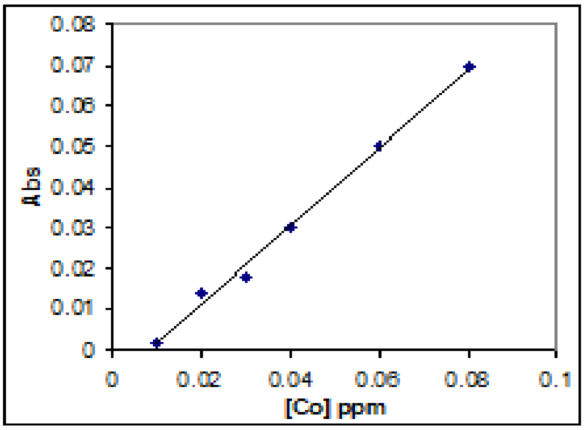

Figure 5a: Calibration curves for cobalt (spectroscopic method).

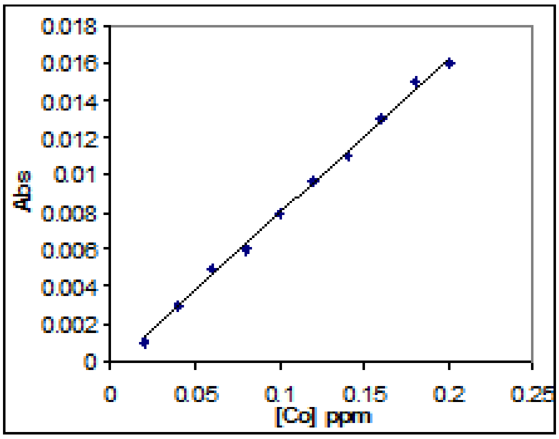

Figure 5b: Calibration curves for cobalt (atomic absorption method).

The results indicate little cobalt entering the factory via the input water but a clear presence of cobalt in waste water and river water samples, although the concentration is within the allowable limit threshold range which is equal to 0.05 ppm. The ion enters in the steel pipe industry and in the installation of dyes used in the textile industry (Mahdi et al., 2004). It is commonly present in low concentrations in sea water and drinking water, and it forms insoluble complexes that settle to the bottom of the aquatic environment. Cobalt affects plants, animals and human growth (Sheekh et al., 2003). The results in table 7 indicate that, based on the correction coefficient r, RSD%, Erel and Re%, the atomic absorption method is more accurate and sensitive to the estimation of nickel ions than spectral methods for all the measured samples.

Table 7: Cobalt concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
97.80%	– 2.20	3.20%	0.9992	0.043	Atomic absorption	Waste water
96.70%	– 3.10	5.50%	0.9980	0.73	Spectroscopic method	Waste water
97.50%	– 2.50	3.22%	0.9992	0.025	Atomic absorption	Input water
96.60%	– 3.40	4.90%	0.9980	0.021	Spectroscopic method	Input water
97.90%	– 2.10	3.30%	0.9992	0.06	Atomic absorption	River water
96%	– 4	4.80%	0.9980	0.06	Spectroscopic method	River water

6-Copper ion (Cu^{+2}): Copper ion concentration was calculated in the samples by atomic absorption spectroscopy and spectroscopic methods by calculating the absorbance of the complex between copper and Dithiazon at a maximum wavelength of 550 nm (Merczenko, 2005). The calibration curves are presented in figures 6a, b, and the results in table 8.

Table 8 indicates that there is copper present in water entering and leaving the factory, and that the concentration of copper in the waste water is higher than that in the input water. The concentrations of copper in both waste and input water are within the range allowed for the concentration of copper in surface waters which is equal to one ppm. Copper enters the waste water through the use of copper pans, plates, copper drilling and copper cylinders used in textile printing and in paint (Purachat et al., 2001). The toxicity of copper emerges after absorption of large amounts of the element via food and from contaminated water. It primarily accumulates in the liver where it causes haemolytic issues and jaundice (Dirilgen, 2001; Zhao et al., 2001). The results in table 8 indicate that, based on the correction coefficient r, RSD%, Erel and Re%, the atomic absorption method is more accurate and sensitive to the estimation of nickel ions than spectral methods for all the measured samples.

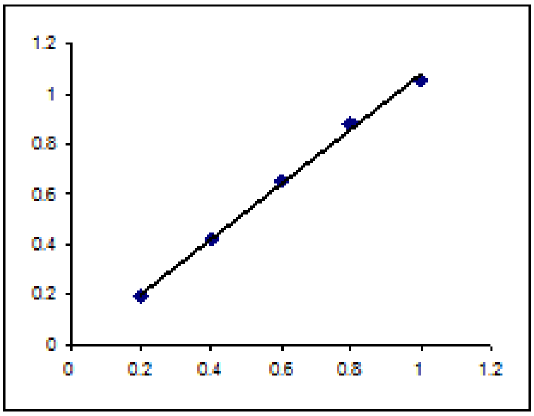

Figure 6a: Calibration curves for Copper (spectroscopic method).

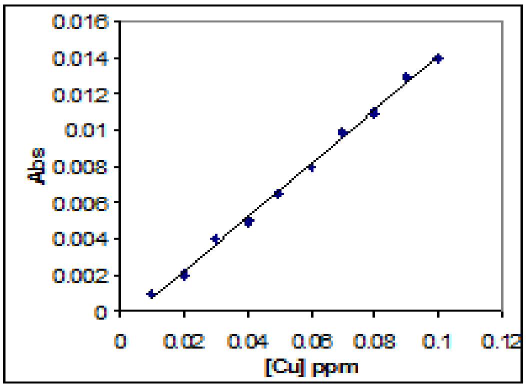

Figure 6b: Calibration curves for Copper (atomic absorption method).

Table 8: Copper ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
96.50%	– 3.50	3%	0.9991	0.5	Atomic absorption	Waste water
96.40%	– 3.60	3.10%	0.9987	0.41	Spectroscopic method	Waste water
96.80%	– 3.20	2.90%	0.9991	0.05	Atomic absorption	Input water
96.50%	– 3.50	3.20%	0.9987	0.04	Spectroscopic method	Input water
96.90%	– 3.10	3.23%	0.9991	0.52	Atomic absorption	River water
96.70%	– 3.30	3.40%	0.9987	0.51	Spectroscopic method	River water

7-Iron ion (Fe^{+2}): Iron ion concentration was calculated in the samples by atomic absorption spectroscopy and spectroscopic methods by calculating the absorbance of the complex between iron ions and 1.10-phenanthroline solution at a maximum wavelength of 512 nm (Merczenko, 2005). The calibration curves are presented in figures 7a, b and the results in table 9.

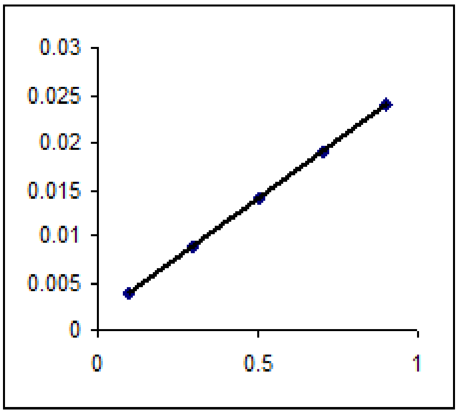

Figure 7a: Calibration curve for Iron (spectroscopic methods).

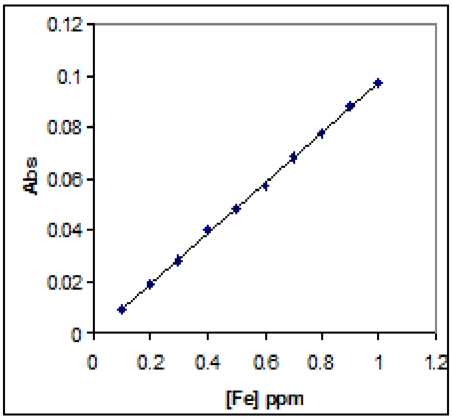

Figure 7b: Calibration curve for Iron (atomic absorption methods).

Table 9: Iron ion concentration in water samples.

Re%	E_{rel}	RSD%	values (r)	Avg. conc. of element (ppm)	Method	Water type
97%	– 3	3.29%	0.9994	0.06	Atomic absorption	Waste water
97.50%	– 2.50	3.19%	0.9996	0.055	Spectroscopic method	Waste water
96.50%	– 3.50	3.20%	0.9994	0.02	Atomic absorption	Input water
96.80%	– 3.20	3.10%	0.9996	0.03	Spectroscopic method	Input water
97%	– 3	2.95%	0.9994	0.4	Atomic absorption	River water
96.70%	– 3.30	3.10%	0.9996	0.2	Spectroscopic method	River water

Table 9 indicates that there is a concentration of iron in the input water samples in the factory, and a high concentration of iron in water waste and in the water of the river near the factory. These concentrations are all within the range allowed for iron ion concentration in surface waters which is equal to 0.3 ppm. The presence of iron in water waste is likely to be as a result of iron pipelines transferring water within the factory and surrounding area and the rust that commonly occurs in such pipes (Jsail et al., 2003). Iron ions are commonly found in the textile industry, where iron salts are used in making many hazardous and noxious dyes notably yellow colours. Iron is also a catalyst for many processes around dyeing and colouring of textiles (Russell et al., 2007). Iron has a significant impact on the lives of plants and animals in the river when it accumulates (Jsail et al., 2003). The results in table 9 indicate that, based on the correction coefficient r, RSD%, Erel and Re%, the spectral method is more accurate and sensitive to the estimation of nickel ions than the atomic absorption method for all the measured samples. This is due to the oxidation of iron (Fe^{+2}) to (Fe^{+3}) by air within the atomic absorption oven which leads to an overlap in the absorption pattern, giving a lack in accuracy of this method for this element (Gupta et al., 2002).

8-Acidic function influence (pH): The acidic function (pH) was measured in the various water samples (input water, waste water, river water) taken from the Al-Diwani textile factory for four consecutive weeks. The ranges of pH values are presented in table 10.

Table 10: pH range for samples.

pH Range	Sample
(6.5-7.2)	Waste water
(7.39-7.75)	Input water
(7.55-8)	River water

The results indicate that the waste water is more acidic than input water, most likely due to the addition of textile products which change the relatively alkaline input water to highly acidic waste water (Jsail et al., 2003). The pH of the river water was within the recommended range for surface water which is equal to 8 – 6.5, because the acidic waste from the factory combines with neutral substances found in the river to form neutral salts which may settle to the bottom of the river (Al-sadai, 2009).

9- Measurement of electrical conductivity: Conductivity was measured with a connectivity measuring device and calibrated with a solution of KCl and deionized water (Russell et al, 2007). Table 11 presents the ranges of conductivity of samples for a period of four weeks.

Table 11: Electrical conductivity Ranges for samples.

Electrical conductivity ms/cm	Sample
(1913-1210)	Waste water
(1193-1162)	Input water
(1054-1082)	River water

The results show a significant increase in conductivity in waste water compared to input water, most likely the result of the addition of factory waste containing a high concentration of complex and metallic ions. The river water has a low conductivity due to the impact of the aquatic environment where ions are commonly precipitated to the river bottom, which reduces the conductivity of water (Al-sadai, 2009). The conductivity in all the water samples is higher than the allowable limit in surface water which is equal to 1,000 ms/cm.

CONCLUSIONS

This paper aimed to find out the extent of the environmental pollution of the waters of the river Al-Diwani by the Al-Diwani textile factory by measuring the concentration of heavy metal trace elements in the water entering and leaving the factory, and the impact of contamination on the nearby waters of the river. This was done using two different methods, atomic absorption spectroscopy and spectroscopic methods, to demonstrate which method is best suited to each ion.

The results indicate that the most concentrated heavy metal is lead (up to 3.31 ppm), and that the least concentrated heavy metal is cobalt (up to 0.043 ppm). The other measured elements, cadmium, mercury, nickel, copper and iron, fall between the concentrations of lead and cobalt. Mirroring this finding, measures of the acidic function and electrical conductivity of the samples indicated that waste water samples had the most acidic pH values (5.6 to 2.7) and had the highest connectivity values (1,210-1,913 ms/cm).

It is clear from these findings that the current filter unit located in the factory waste water process is inefficient, removing only a small amount of the contaminants and leaving the majority to enter the river. This study strongly suggests a need to install a new waste treatment unit based on modern methods of treatment, such as oxidation, photo oxidation by catalysts, ion exchange, use of polymers, and deposition of strong alkalis to precipitate and thus remove heavy metal contaminants from the factory waste water and minimise the extent of river water contamination.

The use of two methods to measure concentrations of elements allows a comparison to be made between the methods. The atomic absorption method was found to be the most accurate and sensitive for all the elements except iron, when the second method, spectroscopic method, was found to be more accurate.

Given the extent of contamination from the textile factory, and the finding that different methods work better for different elements and ions, we suggest that it is important to extent this work to consider the environmental pollution from other industries, such as tyre and cement manufacture, using the methods as outlined here to ensure accuracy and sensitivity to possible contamination. We also recommend further study of this case study site, to help identify the extent of environmental contamination and to develop suitable treatment methods that promote recycling.

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LAND-USE CHANGE SCENARIOS OF CHOSEN SMALL WATER BODY – PUBLIC PARTICIPATION FOR A NEW REALITY

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KEYWORDS: building scenario, suburban area, user needs.

ABSTRACT

The object of this study was a small water body adjacent to the Zemborzycki Reservoir. The aim of the study was to find an optimal way of management of the small water body's surroundings based on scenario building and public participation. The three following scenarios of the small water body's surroundings' management with a leading role were used: a) ecological and educational, b) representative and recreational, and c) left in its current form. As a result of the public participation conducted in 2011, it was shown that the ecological and educational scenario is the most optimal for the respondents; and in 2012, implementation had been undertaken. In the decision-making process, a public participation seems to play an important role because actions are accepted, thus fulfilling needs of most users and allowing for identification of the society within a given place.

RESUMEN: Escenarios de cambio de uso de suelo en un pequeño cuerpo de agua – participación ciudadana en la creación de una nueva realidad.

El objeto de este estudio fue el pequeño cuerpo de agua adyacente al embalse de Zemborzycki. El objetivo fue elegir el tipo óptimo de manejo de dicho cuerpo, basado en la construcción de escenarios y la participación ciudadana. Los tres escenarios más significativos de manejo del entorno del cuerpo de agua son: a) ecológico y educativo; b) representativo y recreativo; y c) como se encuentra y se usa actualmente. Como resultado de la participación ciudadana llevada a cabo en 2011, el escenario ecológico y educativo resultó ser óptimo para los encuestados, mismo que se implementó en 2012. En el proceso de la toma de decisiones, la participación ciudadana parece desempeñar un papel importante, porque gracias a ésta se aceptaron las medidas adoptadas, se cubrieron las necesidades de la mayoría de los usuarios y se identificó un lugar específico para la sociedad en el proceso de manejo.

REZUMAT: Scenariile privind schimbarea utilizării terenurilor a corpurilor mici de apă – participarea cetăţenească la crearea unei noi realităţi.

Obiectul acestui studiu a fost corpul mic de apă adiacent la rezervorul Zemborzycki. Scopul studiului a fost alegerea optimă de gestionare a mediului corpului mic de apă, pe baza elaborării de scenarii şi participarea cetăţenească. Cele trei scenarii diferite mai semnificative de gestionarea a mediului corpului mic de apă sunt: a) ecologic şi educaţional, b) reprezentativ şi recreativ, c) aşa cum se găseşte şi se foloseşte în prezent. Ca urmare a participării cetăţeneşti care a avut loc în anul 2011, scenariul ecologic şi educaţional s-au dovedit a fi cea mai optimă pentru respondenţi, şi în anul 2012 punerea în aplicare a fost efectuată. Participarea cetăţenească la procesul de luare a deciziilor pare să joace un rol important, datorită acestui fapt sunt acceptate măsurile adoptate, nevoile majorităţii utilizatorilor sunt acoperite şi se permite identificarea societăţii cu un anumit loc.

INTRODUCTION

In times of declining water resources and their progressive degradation, each aquatic ecosystem should be investigated because of its values. An important meaning in enriching water resources have small water bodies (Hajdu and Kelemen, 2009), often missed in research. In addition to the poor quality of surface waters, there are problems associated with the management of many reservoirs' surroundings, especially in suburban areas (Chełmicki, 2012).

Water reservoirs are one of the environmental elements of importance with their valuable function, like water retention for municipalities (Mioduszewski, 2006; Sender and Kułak, 2010). Furthermore, they are perceived as high-value enclaves of the natural environment, as well as objects with recreation function for the rest (Mioduszewski, 1999; Celiński et al., 2001). Small water bodies are an integral part of the rural and urban landscape, significantly enriching their biodiversity (Szpakowska and Życzyńska-Bałoniak, 1994; Hłyńczak et al., 1995; Patro and Zubala, 2010), as well as in the river valleys (Kopeć, 2007).

Because of small size, small water bodies, more often than other reservoirs, are exposed to drying and eutrophication processes that cause disturbances in the species' composition and their degradation (Kalbarczyk, 2003; Kuczera and Misztal, 2007).

The meaning of research methods based on scenario building is increasing (Verburg et al., 2006), particularly in times of global warming and climate change monitoring and modelling landscape dynamics gained in significance (Houet et al., 2010). Visualization of scenarios is a great way to discover and predict inhabitants' needs. Gibon et al. (2010) illustrates the need of integration and participation that considers socio-ecological processes in the modelling and elaboration of scenarios.

The aim of this study was the choice of an optimal way of management of the small water body's surroundings based on scenario building and public participation.

MATERIAL AND METHODS

Study area

A small water body being researched is located in the administrative boundaries of the Lublin city, in the surroundings of the Zemborzycki Reservoir with leading recreational functions. This area belongs to the Bystrzyca River valley (Fig. 1). In the area development plan, this area was designed as a green area, whereas local plans of spatial development did not include it.

In 2007, after the construction of the bike and walk path on a substantial section of the western shore of the Zemborzycki Reservoir, a separate small water body was created in the immediate vicinity of the reservoir as a result of cutting off one of its bays after the construction works of the embankment; but it is still staying connected with the reservoir by a concrete culvert.

Instead of localization of the small water body in the city and fields, it is intensively used as an agricultural constitute for a significant part of the catchment.

From the east, a single-family housing is a dominant way of land use, and on the eastern part there is the Zemborzycki Reservoir.

The small water body has only 0.13 hectares and is a land depression constantly filled with water. Up until 2010, it acted as a receiver of pollutants and was also used as an illegal dumping ground. In that state it did not have any natural and landscape values.

Figure 1: Localization of small water body under study.

Sampling analysis and measurements

In the concept development process of the small water body's management, several studies were conducted; because of this, it was possible to carefully study the specificity of the area and create an optimal solution important to the interests of nature and landscape conservation (Sender and Kułak, 2010; Kułak et al., 2011).

Different scenarios of management and functioning of the small water body area, as well as its surroundings, were based on earlier questionnaire surveys carried out in the surrounding area of the Zemborzycki Reservoir, regarding the needs and recreation preferences over water areas (Kułak and Waryszak, 2010; Kułak, 2013).

A public consultation that was carried out by a questionnaire of 80 people resting nearby the object under the study was the next step of our research. We wanted to find out the demands of the people visiting the study area and involved its users.

The questionnaire consisted of two parts. The first part included a graphic presentation (photographs) and descriptions of the object, concerning its current status, functioning and use, as well as values and problems. In the second part, three scenarios of different ways of management were presented to respondents: a) ecological and educational, b) representative and recreational, c) left in its current form. For each scenario, the descriptive functional and spatial program (Fig. 2) a location plan (a top view) and four 3D visualizations were presented.

Next, people were asked to tell us which of the presented scenarios is preferred by them and if it would be of worth to conduct the implementation. In case the respondents did not agree with any of the presented options, they had also a possibility of not pointing out any particular scenario, as well as the ability to free expression. Choice was written down in each questionnaire given to the respondents.

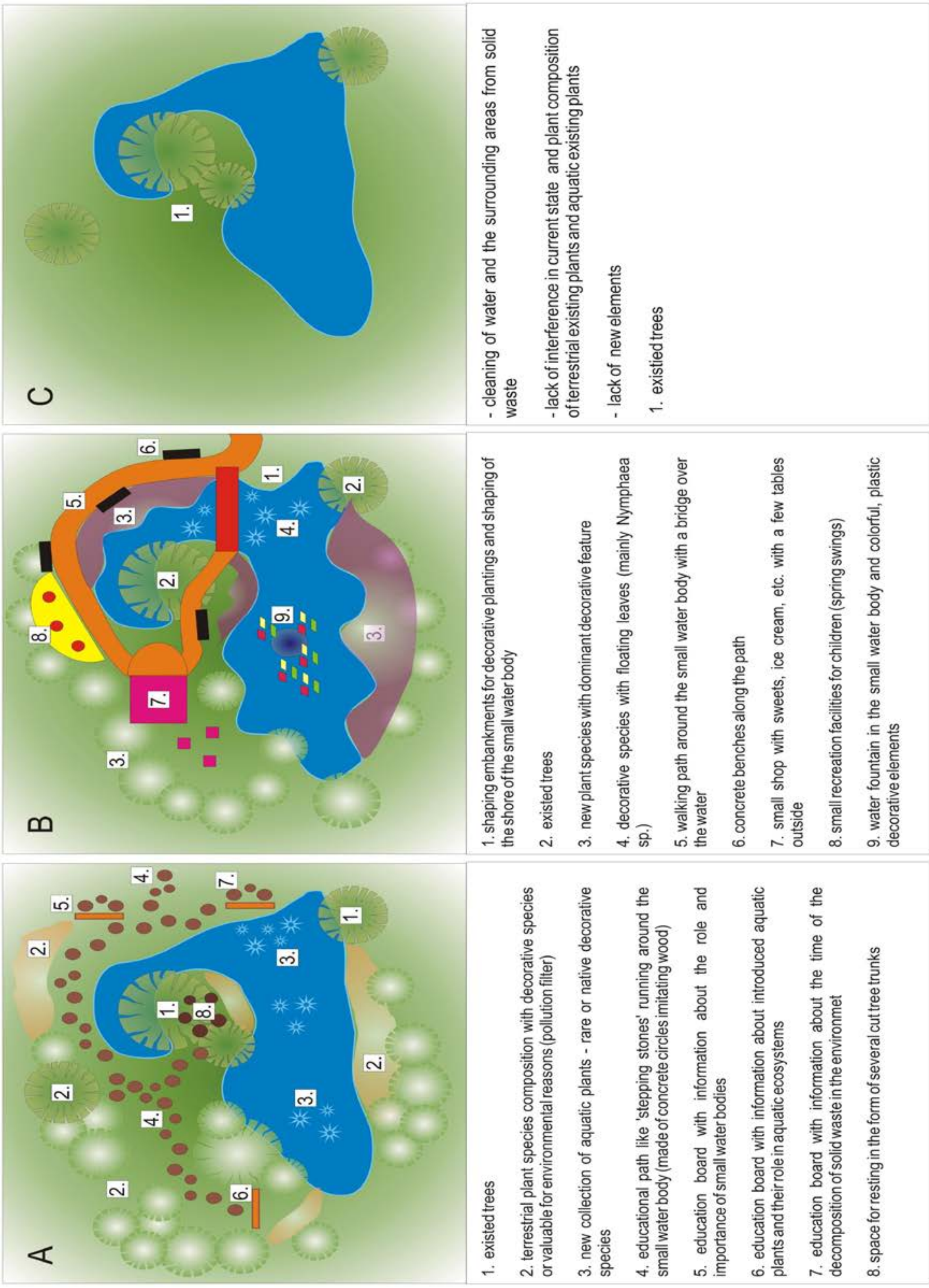

Figure 2: Visualization of three different scenarios of the small water body.

Each concept included five categories of information about the following: land use around the small water body vegetation, elements of infrastructure, materials used, and a target group (Tab. 1).

Table 1: Three scenarios of different ways of management: a) ecological and educational, b) representative and recreational, c) left in its current form.

	The concept of expanded ecological and educational function	The concept of expanded representative and recreational function	The concept of leaving its current form
Area	Assumptions: • cleaning of water and the surrounding areas from solid waste; • stabilization of the water level in the small water body (valve on the conduit); • a small interference with the natural terrain and shores of the small water body, including necessary levelling for the introduction of a walk and bike path.	Assumptions: • cleaning of water and the surrounding areas from solid waste; • stabilization of the water level in the small water body (valve on the conduit); • a great interference with the natural terrain and shores of the small water body, including levelling of the ground, shaping embankments for decorative plantings and shaping of the shore of the small water body according to the project.	Assumptions: • cleaning of water and the surrounding areas from solid waste; • lack of water level stabilization in the small water body (possible periodic drying); • lack of interference with the natural terrain and shores of the small water body.
Vegetation	• a small interference in the current state and plant composition of existed vegetation; • removal of a small amount of plants that obstruct or prevent the free use of land; • enrichment of terrestrial plant species' composition of decorative species or value for environmental reasons (pollution filter); • leaving most of the existing aquatic plants and the implementation of a new collection of aquatic plants – rare or native decorative species.	• a great interference in current state and plant composition of existed vegetation; • 80% removal of existing vegetation; • planting new plant species with dominant decorative feature; • removal part of existing aquatic plants (especially underwater); • planting of decorative species with floating leaves (mainly *Nymphaea* sp.).	• lack of interference in the current state and plant composition of existing terrestrial plants; • lack of interference in the current state and plant composition of existing aquatic plants.

Table 1 (continued): Three scenarios of different way of management: a) ecological and educational, b) representative and recreational, c) left in its current form.

Infrastructure elements	• creation of an educational path like "stepping stones" running around the small water body (made of concrete circles imitating wood); • the placing of three education boards located at the educational path. The first with information about the role and importance of small water bodies. The second with information about introduced aquatic plants and their role in aquatic ecosystems. The third board is designed for the youngest users, made up of rotating elements that will contain information about the time of the decomposition of solid waste in the environment; • creation of space for resting in the form of several cut tree trunks, set under the largest tree	• creation of paved walking path around the small water body with a bridge over the water; • setting concrete benches along the path; • location of a small shop with sweets, ice cream, etc. with a few tables outside; • setting up a small recreation facility for children (spring swings); • introduction of a water fountain into the small water body and colorful, plastic decorative elements.	• lack of new elements.
Materials	• natural or imitating natural – wood, stone, gravel, bark, concrete with wood-effect, etc.; • no color contrast, low-key, natural.	• metal or artificial – plastic, resin, gum; • contrast colours.	• lack of putting new elements.
Target group	Each age group.	Each age group with the main children function.	Difficult access – limited use.

RESULTS AND DISCUSSION

Visualizations of three land use management scenarios were prepared to collect information about users' needs (Fig. 2).

The interviews were suitable to obtain information about standards of the way of spending free time. The action was received positively, respondents willingly took part in the survey, expressing the joy of interest in this place that was up to now quite neglected. They appreciated the fact that their opinion is important for designers and will have a significant impact on the development of a concrete implementation.

Of the basic conducted questionnaire survey, the vast majority of respondents chose the first scenario that was chosen by 62% of respondents (Fig. 3.)

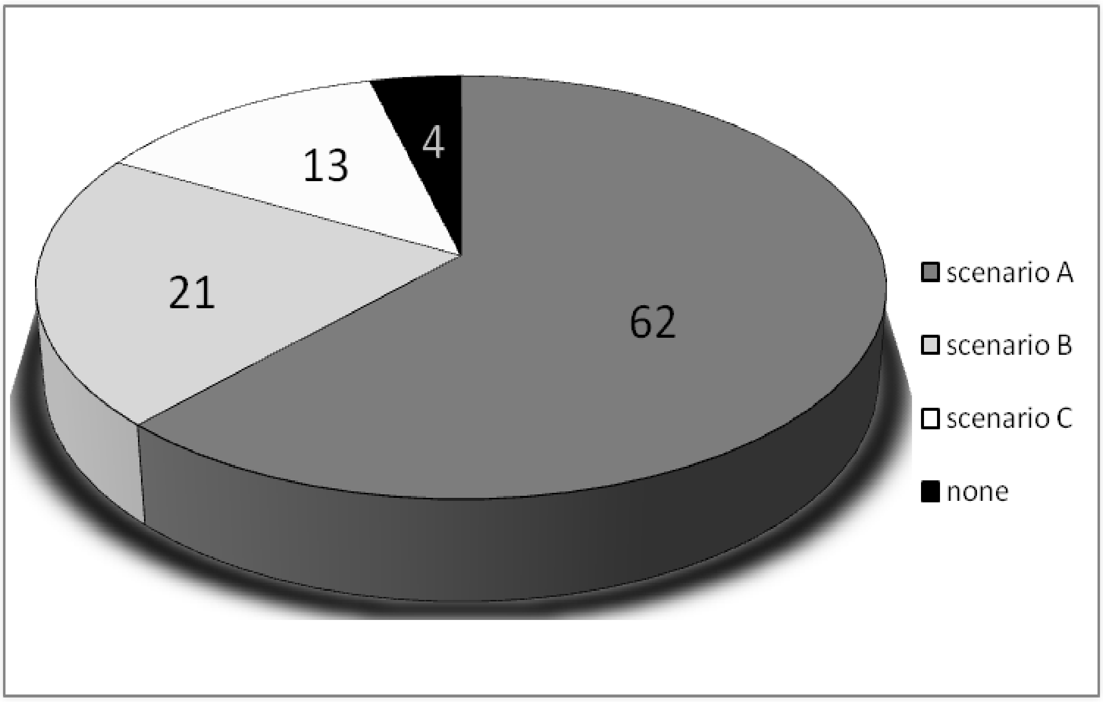

Figure 3: Percentage share of chosen by respondents' scenarios.

The representative and recreational scenario was chosen by 21% of respondents, whereas 13% chose leaving the current state of the area. Only 4% of asked people were not interested in any future works in this area. The results revealed the importance of a piece of nature in suburban areas. Chosen by respondents, the ecological and educational scenario of the small water body management was implemented in 2012 (Figs. 4a-d). Results showed that the project of revitalization of the small water body was very important for interviewees. The area surrounding the small water body belongs to the Lublin city, and that is why the work was supported by the Department of Natural Protection in the Municipality Lublin.

Figure 4a: Area under the study before (2011).

Figure 4b: Area under the study before (2011).

Figure 4c: Area after the revitalization (2012).

Figure 4d: Area after the revitalization (2012).

DISCUSSION

Small water bodies have a great biological function. Together with the surrounding vegetation and soils, they constitute an ecological system for wild flora and fauna species (Goławski and Kasprzykowski, 2007). Simultaneously, they provide an increased biodiversity of the surrounding area (Kalbarczyk, 2003). Furthermore, small water bodies affect the level of groundwater and soil water management of the surroundings areas (Fiedler, 1997). They constitute suitable habitats for the development of aquatic vegetation – macrophytes (Hartog and Segal, 1964; Cook, 1983; Wołek, 1996; Maślanko et al., 2011). Macrophytes in the small water body shape abiotic and biotic conditions, influencing mainly on the fertility of the waters, plants and animals species composition, provide a place of feeding, breeding and refuge for many aquatic invertebrates and fish; as well as habitats for avifauna (Kornijów and Radwan, 2000). Moreover, they can act as a barrier in the form of capturing and neutralizing a filter of elements flowing from the catchment (Wiater, 2005). Probably because of planting, many different submerged and emergent macrophytes species, the biodiversity of the small water body under the study will increase.

For landscape architects, it is crucial to understand peoples' needs and expectations, because they are responsible for creating a new reality. The best way to understand them is to allow people to express their opinions. Buchecker et al. (2003) found that direct participation in the landscape changes raises residents' responsibility for their living environment, creates basis for sustainable development and enables social and cultural integration as the consequence of higher interest in regional and national politics. Participation in environmental activities has been acknowledged to play a role in increasing scientific literacy in a broader sense (Conrad and Hilchey, 2010), as helping to promote a reconnection between people and nature (Devictor et al., 2010; Hobbs and White, 2012), as well as raising awareness of environmental issues (Brossard et al., 2005; Jones-Walters and Cil, 2011). The local space users are usually addressed by interviews made in the field (Hinterberger et al., 2000; Volk, 1992). To obtain general valid information, a high number of interviews need to be conducted (Janovsky and Becker, 2003). In the decision-making process, a public participation seem to play an important role, because thanks to it, taken actions are accepted, thus fulfilling needs of most users and allowing for identification of the society with a given place. Thanks to a public participation, a new and improved reality, balancing the needs of society and nature conservation can be shaped.

A concept of revitalization of small water bodies in suburban areas is an example of creating "green areas" in the city. It provides possibilities of outdoor recreations for Lublin inhabitants. Designing of this kind of recreation should be accomplished so that the sustainability of these areas is preserved and it should provide the future generation with the opportunity to enjoy the natural values of the outdoor recreation at an even higher level (Bell, 2007). Natural attractions in suburban areas are one of the recreational resources in ecotourism and these attractions are located in most of rural areas in the world. Conducted research pointed out that ecological and educational types of scenarios are needed. We concluded that probably the Zemborzycki Reservoir fulfils an intensive type of recreation in Lublin city, whereas people also need some enclaves of nature close to their homes.

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