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7. Fish and macrophyte assessment of Ciuperca Lake after rehabilitation works (Tulcea City, Romania)

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Abstract: In order to improve the quality of life, in urban ranges, there is a continuous effort for small-scale leisure areas maintenance in the benefit of inhabitants by means of provided environmental, social and psychological services. Nevertheless, much less concern is being given to nature preservation and species diversity that could be an ecological quality indicator for inner-city ecosystems. Therefore, the tendencies are to keep an attractive landscape architecture which, in many ways, cannot be self-sustained without human interventions and permanent costs. Our study case was developed on Ciuperca Lake (Tulcea City, Romania), an anthropic water body, which was recently re-opened as recreational park, along with a side-walk sector. The lake was desiccated at the end of 2008, the bottom lake was dredged, cleaned and part of the concrete banks on the lake shores were renovated in 2009, and it was re-flooded in 2010. The main purpose of this paper is to discuss on the species assessment after rehabilitation works with the aim of enhancing the importance of indigenous species diversity, within urban recreational areas, as a sustainable way for long term services provision. The surveys were carried out on macrophyte and fish species before (2008) and after (2015) rehabilitation works. Moreover, for the determination of heavy metals content, the fish tissue was analyzed. The results confirm, for both macrophyte and fish taxonomical groups, that there are less species in the lake. In terms of water analysis, none of the chemical parameters exceeds the approved limits.

Key words: Ciuperca Lake, fish species, macrophyte, fish tissue, heavy metals

INTRODUCTION

In general, the view of the lake, for the public, is related to a large surface of standing water body in which fish, water birds and vegetation can be found. Somehow, most of the people are drawn to the water bodies, natural or artificial, for fishing, animal breeding and agriculture or leisure activities such as bathing, angling, sport, and other activities that sustain the habitation development ([***5***]; [***10***]; [***16***]; [***40***]). The locally aquatic ecosystems can provide services with a substantial impact on the quality-of-life in urban areas and should be solved in land-use planning [***6***]. Presently, there is a rising trend for water quality improvement or maintenance of water body surfaces in urban areas, in most of the cases for recreational purposes ([***1***]; [***10***]). For instance, at the beginning of the 19th century, Ciuperca, along with Zaghen, were two natural lakes belonging to the upstream floodplain area near to the city of Tulcea [***31***]. The lakes, one in the northwest and the other one in the southeast part of the city, evolved differently. Over the past eighty years, due to human interventions, the features of Ciuperca Lake changed from natural wetland into a flood-protection area for the city and later into a recreational area, up to present [***9***]. The Zaghen Lake was constantly flooded until clogged up in a large reed bed area with no specific purposes for the inhabitants. Presently, it is under hydro-technical improvements for recreational purposes. However, there is a gap of knowledge in both management and scientific approach as less attention has been paid to inner-city lakes in comparison with natural ones ([***5***]; [***15***]; [***40***]). The perception is the urban lakes are more related to community interest for leisure and less to biodiversity conservation purposes because of the different provided services and functions ([***10***]; [***30***]; [***37***]). Until 2008, Ciuperca Lake was considered polluted, suffering from eutrophication, the aquatic environment and its surroundings were unattractive for recreational activities. Sewage inflow and discharge of waste water has degraded lake water quality with high concentrations of nutrients, organic matter and eutrophication problems by algal blooms. The water was usually green with very low visibility, algal blooms contained toxic cyanobacteria [***39***], and the banksides were in need of repair. The leaf trees above were constantly adding litter to the lake sediment thus creating great oxygen consumption. The lake was desiccated at the end of 2008, in 2009 the bottom lake was cleaned by garbage, levelled and dredged because of sediment content which was high in nutrients and heavy metals and with an unpleasant odour. The last renovation works were made on the concrete banks of the lake shores, and then, in 2010, the lake was re-flooded. After improvements, there were carried out studies on fish and macrophyte species and water analysis in order to monitor the changes of ecological state of the lake. Furthermore, we analysed the different densities of macrophyte in relation with fish species richness and biomass in order to reduce the offspring’s mortality from predation. It has been anticipated that build-up islets of helophytes or high densities of macrophyte, in certain areas of the lake, as refuge, would provide the protection and spawning areas for different species. This will be an added biodiversity value, for the lake, from the leisure perspective.

MATERIALS AND METHODS

The study area

Ciuperca Lake (45°10'55.72"N; 28°47'08.35"E) is located in the floodplain area of the lower Danube. Presently, it is included in the range city limits of Tulcea, near to Danube River (Tulcea branch), in the north-western part (**Fig. 1**). In pristine times, it was the smallest water body from the shallow lakes network along the Danube (Somova, Câșla, Ciuperca and Zaghen), covering a surface of approximate 29 ha **[31]**. Nowadays, the lake size is about 27 ha (275,406.08 m²) and the average depth of the lake is under 1,5 m in south-east part and up to 2,5 m in north-west part.

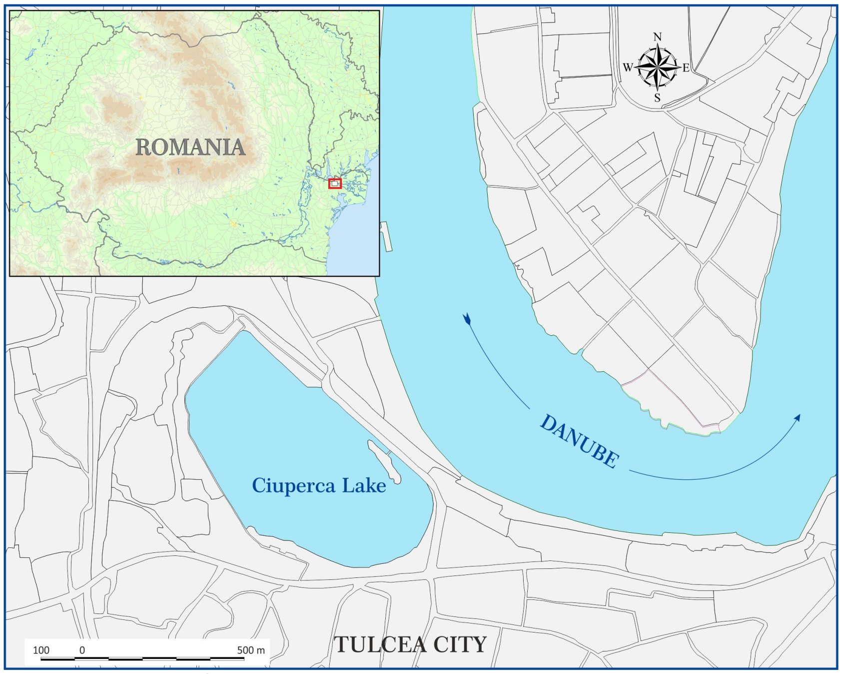

Fig. 1 Ciuperca Lake in Tulcea city, near Danube River

Fish sampling

Sampling period was in 2015, March for ichthyofauna. Sampling was done by two complementary methods: electric fishing and gillnets fishing (Nordic gillnets and commercial gillnets). These two methods are complementary: night fishing with gillnets in open deeper water and electric fishing are carried out on in the shallow banks (shoreline) in the occurrence and development of youth and juveniles.

The Nordic and commercial gillnets sampling method is based on statistical analysis method of ichthyofauna, having an action period of 12 hours, and the recommended function hours are 18-20 p.m. to 6-8 a.m.
Nordic gillnets used in The Danube Delta are numbered from 4 to 12 [***8*]**, depending on the surface of the lake, 30 m in length gill net panels 12 of 2.5 m in length with a mesh panel 5, 6.25, 8, 10, 12.5, 15.5, 19.5, 24, 30, 35, 43, 55 millimetres (mm). The used commercial gillnets were 3 pieces per lake (mesh size a = 40, 50 and 60 mm), each 30 meters long and 1.8 meters high. For Ciuperca Lake, there was use a specific number of gillnets like in **Table 1**.

The electric fishing appliance with SAMUS devices is performed by conducting a variable length transect in the banks, with a standardized effort up to 10 minutes per station. The lake was sampled by three electric stations.
According to Năvodaru [***24***], there were employed special appropriate methods to study the ichthyofauna in Ciuperca Lake. According to Nyberg & Degerman [***26***], depending on the depth of pools (which in delta lakes is the same, below 3 meters depth) and lake area, the number of Nordic gillnets for 27 ha lake surface with a depth below to 3 meters depth was determined. There were used 4 multifilament Nordic gillnets and 1 monofilament Nordic gillnet sampling for adequate control.

Table 1

Fishing effort for fish sampling from Ciuperca lake and obtained capture (ex = number of individuals, m = meters, min = minutes, g=grams) in 2015

Complex/Lake	Nordic gillnets	Length (m)	Electric (min.)	Commercial gillnets	Length (m)	Capture ex.	Capture g
Ciuperca	5	150	30	1 x 3= 3	90	98	122555
TOTAL	**5**	**150**	**30**	**3 gillnets /night**	**90**	**98**	**122555**

For biometric measurements, an ihtiometer precision of 1 mm / 40 cm length was used, while electronic scales accurate to 1 g / 10 kg weight were used.
Relative abundance and biomass are expressed by catch (grams) per unit effort (CPUE) or number per unit effort (NPUE). CPUE standardization is performed by a computer system, so that catches in different periods of time can be compared. Such catches are expressed for a standard of 100 m² effort gillnet / night.
As far as electric fishing is concerned, CPUE is standardized effort for 1 hour, assuming the hypothesis that it samples the same pool length in the banks or performs the same number of points of electricity per unit time (multipoint sampling water on a path).
For physical-chemical parameters, a Secchi disk, an electronic thermometer was used, while a binocular loupe (10X) and a microscope scale were used to determine the age.

Ecological indicators
The frequency of occurrence (F) or constancy (C) was calculated as proportion of samples containing a species and used to characterize species distribution according to Schwerdtfeger [***35***], quoted by Schindrilariu [***36***]:

$$Fi = bi/a \cdot 100\ (\%)$$

where: Fi = frequency of occurrence of species i; bi = the number of samples in which species was observed; a = total number of samples.
The relative abundance or dominance (D) was calculated as proportion of species to the total catch according to Mühlenberg [***22***]:

$$Di = ni/N \cdot 100\ (\%)$$

where: Di = dominance of species i; ni = individuals of the species i; N = total number of individuals.

Five classes of frequency, 6 for abundance/dominance and 7 for ecological significance were used for data interpretation (**Table 2**).

Table 2
Frequency (constancy), dominance and ecological significance classification ([***13***]; [***27***]; [***33***]; [***35***]; [***36***]):

Abundance /Dominance (D)		Frequency /Constancy (C)		Ecological significance (W)	
Class	%	Class	%	Class	%
				Accidental-adventitious*	W1A< 0.001
sporadic D1	<1	very rare	C1=0-10	accidental	W1< 0.1
subrecedent	1 (2^0) -	rare	C2=10.1-	accessory	W2=0.1-1
recedent	2 (2^1) -	widespread	C3=25.1-	associate	W3=1-5
subdominant D4	4 (2^2) -	frequent	C4=45.1-	complementary	W4=5-10
dominant	8 (2^3) –	very frequent	C5=70.1-	characteristic	W5=10-20
eudominant D6	>16 (2^4)			main, leading	W6>20

* Accidental-adventitious (accented) (W1A) is a proposal for The Danube Delta for accented-degree accidental fish species (used in Năstase phD thesis [***23***]. Accidental (W1) is more towards accessory values, but accidental by-catch is due to some multiple imperfection causes, such as unfavourable weather conditions, malfunction gear at a time, unfavourable natural condition for a moment, etc. However, these indicators should be viewed critically as values differ from season to season.

The biodiversity (Hs) was calculated according to the Shannon-Weiner formula ([***13***]; [***33***])

$$Hs = -\sum_{i=1}^{S} pi \times \ln(pi) \qquad pi = Nr/N$$

where: S = number of collected species; pi = abundance; Nr = number of individuals belonging to a certain species; N = total number of individuals in a sample.

The equitability ([***13***]; [***33***]) means the quantum of unequal distribution of different effective species proportion as an ideal community, where every species has the same number of individuals. The value of equity index is included between a range of 0 and 1.

$$E = Hs / Hmax$$

where: E=Evenness index
(equitability index)

The fish species were identified ([***3***]; [***4***]) and taxonomic name revision was performed ([***12***]; [***19***]; [***20***]; [***23***]; [***25***]; [***28***]).

Macrophyte sampling
Sampling period was in June 2015 for macrophyte species. Macrophytes were sampled in different plots, no larger than 100m x 100m. 38 vegetation surveys of the aquatic vegetation were carried out in order to test the Schaumburg (2004) reference index. All vegetation surveys were made in fully development of vegetation. Each vegetation survey had an approximate diameter of 5 m, and was made from the canoe. Submerged plants were collected by using a hand-held rake with a 20 meters rope, and the abundance of each species in the vegetation was visually estimated,

by using a 5-point scale: 1= 1 to ≤10%; 2= 10 to ≤25%; 3= 25 to ≤50; 4= 50 to ≤75; 5= 75 to ≤100 [***18***]. The purpose was to examine, on one hand, the aquatic plant communities within the entire study area, and, on the other hand, to determine species richness and to compare before and after rehabilitation works. A detailed description of each sample location was made, which may include information on water depth, transparency (Secchi-depth) and description of vegetation type with a species list. We considered the macrophyte species richness and composition important indicators on identifying changes. Macrophyte density was expressed as percentage of plant volume infested (%PVI). PVI was calculated as the area of macrophyte coverage multiplied by the plant height divided by the water depth [***7***]. For calculation of the Schaumburg trophic index in Ciuperca Lake, before and after, we use the reference list of species for the assesment of ecological status approached in the Danube Delta ([***14***]; [***29***]) and reference conditions based on the 'system B' lake typology of the WFD.

Calculation (1) is the same as the Reference Index in Schaumburg et al. (2004):

$$TI(S) = \frac{\sum_{i=1}^{nA} Q_{Ai} - \sum_{i=1}^{nB} Q_{Bi}}{\sum_{i=1}^{ng} Q_{gi}} * 100$$

Where:

TI (S) = trophy-index based on quantity (identical to the Reference index in Schaumburg *et al.* 2004), Q_{Ai} = quantity of species *i* in group A (see table 1), Q_{Bi} = quantity of species *i* in group B, Q_{gi} = quantity of species *i* in all groups, n_A = total number of species in group A, n_B = total number of species in group B, n_g = total number of species in all groups. Quantity = (semi-quantitative score) ^{3}.

Chemistry lab

For each fish, the species type and the total mass (g) were identified. Equal parts of muscle tissue were taken from each fish, being represented in a composite sample and representative.

For the determination of heavy metals from the fish samples, it was necessary the mineralization under pressure, which has been achieved by means of Anton Paar microwave oven, Multiwave 3000. (**[2]**) The heavy metal content was analyzed by using an ICP-MS Elan DRC-e, applicable to the determination of low concentrations of a large number of elements (62), which are nebulized and transformed into aerosols that are transported by argon plasma torch. The product ions are trained in the plasma and introduced through an interface to a mass spectrometer. [***42***]

Mercury concentrations were analyzed by using the atomic absorption spectrometry with cold vapor (CVAA), based on the absorption of a radiation at 253.7 nm, being a suitable method for determining the total mercury content in the range of concentrations of 0,01 and 20 µg/kg. ([***43***]; [***44***])

RESULTS AND DISCUSSIONS

Ciuperca Lake from Tulcea city was considered, from inhabitants' perspective, a "poisonous lake" and rightly so because, for a long time, residues have been discharged here from neighbouring districts, often having had devastating effects on the living body of the lake. It was very auspicious initiative of Tulcea Hall for a total ecological reconstruction in Ciuperca Lake, phenomenon began in 2010, in accordance to quitting the continuous discharge waste into the lake. One of the problems to be addressed lies in the aquatic parasites which, in a closed environment, grow faster than in the natural environment. They can cause mortality as it was the case of infected different-size fish species individuals of piscivorous, such as *Sander lucioperca* (zander) or *Perca fluviatilis* (perch) in 2014. However, regular maintenance and improvement of technical aeration equipment, backed by a regular scientific monitoring and keeping the lake and surroundings clean, will maintain a good quality ecological status of the lake. Researchers joined to the plan of Tulcea Municipality, and conducted an assessment study on macrophyte species and ichthyofauna in concern to permissible limits of heavy metals in the fish tissue from Ciuperca Lake in new conditions after total ecological reconstruction. The results of the study in 2015, the ecological status of macrophyte species, ichthyofauna, water chemical determination and the content of heavy metals in fish tissue in Ciuperca Lake, may become references for next studies.

Environmental conditions

Ciuperca Lake is almost isolated from the deltaic system, having contact with the Tulcea arm of the Danube River only through pipelines that serve the full water level of lake when necessary. So, it is a kind of natural "aquarium" with concrete banks, supportive medium and large stones and sandy hard ground, leaving no development of aquatic vegetation for typical swamp, except for the appearance of blooming algae, in warm periods, with potentially negative repercussions on species with less tolerance under the pressure of degrading living conditions [***39***]. The mean water temperature of the lake is 11ºC, turbidity is high, sometimes less than 30 centimetres transparency depth. The water temperature range is high, in almost every winter it forms, for a short period, a completely ice cover and in summer time it goes up to 20ºC. The bottom lake was changed from alluvial - mud to sandy - gravel in the central area and gravel - rock near to banks. The species composition, in the lake, before the rehabilitation evolved in conditions close to natural. Present conditions do not provide opportunity for its own ichthyofauna development, such as a typical natural lake, but the emergence and development of opportunistic, alohtoneous, eurytrope species, which may constitute food for certain species introduced for exploitation (such as the *Sander lucioperca*). The term "aquarium" comes from the inability to maintain ichthyofauna on long-term period without feeding the fish or any other human intervention (when high water levels accidentally lead to introduction of fish species from Danube) for the survival of individuals. When sampling was carried out at a 9ºC water temperature, the water transparency did not exceed 20 cm (**Table 3**).

Table 3
Environmental parameters from Ciuperca lake in sampling time (2015)

Lake	Depth (cm)	Transparency (cm)	Water temperature (ºC)	Sampling points (fish/macrophyte)	Habitat	
					Substrate	Vegetation
Ciuperca	40-250	20	9	11/38	Sandy-rocky (gravel)	Low presence

Vegetation
Vegetation cover and composition are fundamental indicators of ecosystem structure and function [***34***]. Usually, there is an assessment of species abundance, richness or vulnerability. In this case, there will be a comparison before and after rehabilitation works (**fig. 2, fig. 3, fig. 4**) in Ciuperca Lake. Long-term monitoring of species composition is required to assess the rate of change and trends in order to predict conditions. Species monitoring is particularly important for managers who must make complex assessments of ecosystem state ([***10***]; [***15***]; [***40***]). Before rehabilitation works, the total number of identified macrophyte species was 26 (**Table 4**), out of which 2 species were considered sensitive, 7 species were considered tolerant species and 16 species, along with helophytes, were considered indifferent species. In 2015, there were identified only 9 species, out of which 1 tolerant species (*Hydrocharis morsus-ranae*) and 8 indifferent species (*Ceratophyllum demersum, Cladophora glomerata, Elodea nuttallii, Lemna minor, Myriophyllum spicatum, Phragmites australis, Potamogeton crispus* and *Vallisneria spiralis*). However, 5 years after the rehabilitation works, there were no significant changes in parameters such as mean water depth (from 1.04 m increased to 1.35 m) and transparency (from 0.4 m reduced to 0.33 m). In terms of macrophyte species, it can be said that major changes occurred in the lake in concern with frequency and abundance for some of the species. There were identified compact areas of *Cladophora glomerata* with a higher PVI (≤50) than in 2008 (PVI ≤15), in which other species were absent or had low frequency. *Hydrocharis morsus-ranae* was identified in dense (PVI ≤30) floating vegetation along with *Myriophyllum spicatum* (PVI ≤20). Slightly differences in PVI were also registered for invasive thermophile species *Elodea nuttallii* (from 15 to 20) and *Vallisneria spiralis* (from 10 to 20), the highest PVI values were observed in June – July period. The ecological classification based on current monitoring data of macrophyte species was largely in accordance with the assessment based on other physical element such as water depth, transparency, the lake substrate. For instance, the species distribution depends on these parameters, but, at the same time, it influences the habitat development locally. In areas in which the transparency was higher, several species occurred, and one or dominant species were often identified in areas in which high turbidity is present. In the shallow hypertrophic Ciuperca Lake [***39***], the helophyte vegetation disappeared (*Butomus umbellatus, Typha angustifolia* and *T. latifolia*) or decreased considerably (*Phragmites australis*). Based on the comparison of 2004-2007 and current aerial images along with water depth data, we assume the vegetation had reduced, presumably mostly due to levelled and dredged bottom lake. Presently, most of the lakeshore line is a built-up concrete area and deeper than before. The biomass of aquatic vegetation, at the lake scale, has also been reduced significantly. If abundant, certain macrophyte species, such as *Ceratophyllum demersum* and *Myriophyllum spicatum,* can prevent algal blooming and support the fish development in the lake [***21***]. It is known that macrophyte species can keep the lake sediments that are water suspension and therefore can induce an improved water transparency of shallow lakes ([***16***]; [***17***]). Given the fact that all the fish samples were overlaid with macrophyte samples, in 2008 and 2015, we can assert that highest fish species richness were identified in areas in which macrophyte species forms dense canopies. Most of the areas were near to lakeshore. Obviously, natural lakeshore with vegetation (helophyte and submerged) can provide conditions for other taxonomical species group [***15***]. In our case, where natural shorelines are missing, built-up islets of vegetation in certain areas of the lake will ensure the helophyte, submerged and emergent macrophyte long-term development as habitat for other species. Different lake surroundings and

shoreline development have indeed an impact on lake water quality especially associated with eutrophication problems ([*15*]; [*16*]). According to Ecological Quality Ratio (EQR) and the five ecological status classes that are given in WDF Annex V, the lake status is poor. In this case, the ratio represents the relationship between the values of the biological parameters observed in 2015 and the values for these parameters under the reference conditions in 2008 on the same lake.

Table 4

Macrophyte species and water depth/transparency in comparison between 2008 and 2015 in Ciuperca Lake

Nr. crt.	Species name	2008					2015				
		Abundance/dominance	Frequency	Percent Volume Infested (PVI)	Water depth	Transparence Secchi	Abundance/dominance	Frequency	Percent Volume Infested (PVI)	Water depth	Transparence Secchi
1	*Butomus umbellatus* L.	3	1	15	0.6	0.4	-	-	-	-	-
2	*Ceratophyllum demersum* L.	3	1	15	1.8	0.3	2	1	20	1.2	0.4
3	*Cladophora glomerata* (Linnaeus) Kützing	2	2	10	1	0.5	4	1	50	1.4	0.3
4	*Elodea nuttallii* (Planch.) H. St. John	3	2	15	1	0.4	4	3	20	2.3	0.3
5	*Hydrocharis morsus-ranae* L.	3	2	20	1	0.6	4	3	30	1.3	0.3
6	*Lemna gibba* L.	3	2	15	1	0.3	-	-	-	-	-
7	*Lemna minor* L.	4	2	15	1.3	0.3	2	2	10	1.2	0.4
8	*Lemna trisulca* L.	3	2	20	1.6	0.3	-	-	-	-	-
9	*Myriophyllum spicatum* L.	2	3	30	1.5	0.3	1	1	20	1	0.4
10	*Nitellopsis obtusa* (Desv.) J. Groves	3	2	20	1	0.4	-	-	-	-	-
11	*Nuphar lutea* (L.) Sibth. & Sm.	3	2	15	1	0.4	-	-	-	-	-
12	*Nymphaea candida* Presl	2	2	15	1	0.4	-	-	-	-	-
13	*Phragmites australis* (Cav.) Trin. ex Steud.	3	2	15	1	0.5	1	1	1	0.5	0.3
14	*Potamogeton crispus* L.	4	1	20	0.4	0.4	1.9	1.5	2	1	0.3
15	*Potamogeton lucens* L.	1	2	20	0.5	0.5	-	-	-	-	-
16	*Potamogeton nodosus* Poir.	1	2	20	0.5	0.5	-	-	-	-	-
17	*Potamogeton perfoliatus* L.	1	3	30	1.0	0.6	-	-	-	-	-
18	*Potamogeton pusillus* L.	3	3	20	1.0	0.5	-	-	-	-	-
19	*Potamogeton trichoides* Cham. & Schltdl	3	3	10	1.0	0.3	-	-	-	-	-
20	*Salvinia natans* (L.) All.	2	1	15	1.3	0.3	-	-	-	-	-
21	*Spirodela polyrhiza* (L.) Schleid	3	1	20	1.2	0.3	-	-	-	-	-
22	*Stratiotes aloides* L.	3	1	20	1.1	0.6	-	-	-	-	-
23	*Trapa natans* L.	3	2	20	2.3	0.5	-	-	-	-	-
24	*Typha angustifolia* L.	3	2	15	0.3	0.3	-	-	-	-	-
25	*Typha latifolia* L.	3	2	15	0.3	0.3					
26	*Vallisneria spiralis* L.	2	2	10	1.4	0.4	4	3	20	2.3	0.3

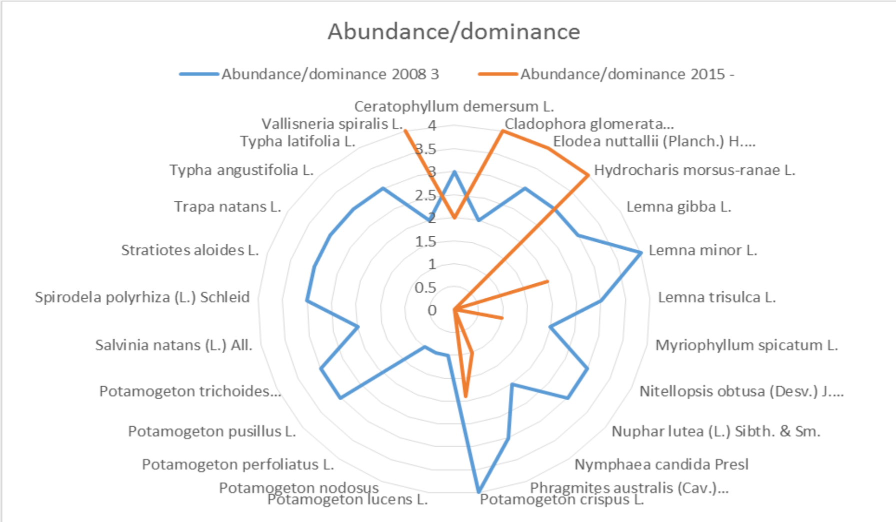

Fig. 2 Comparison of species abundance / dominance between 2008 and 2015

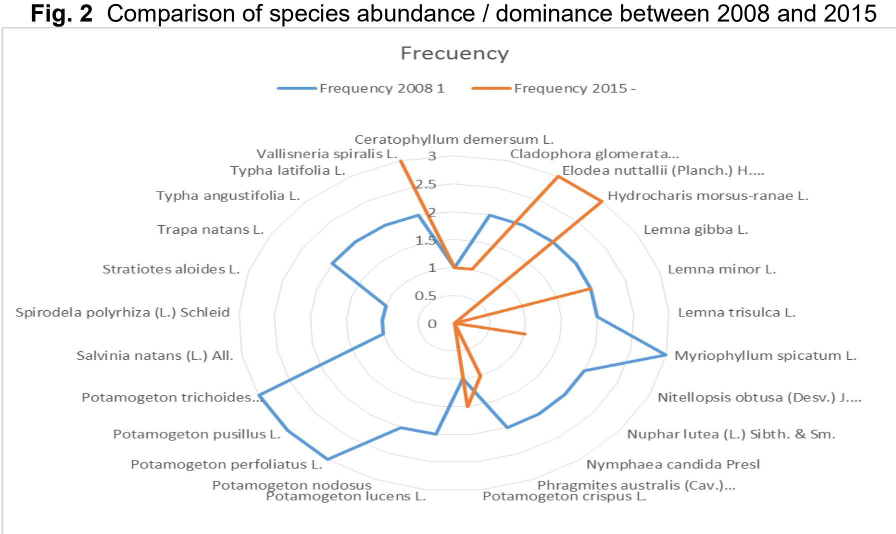

Fig. 3 Comparison of species frequency between 2008 and 2015

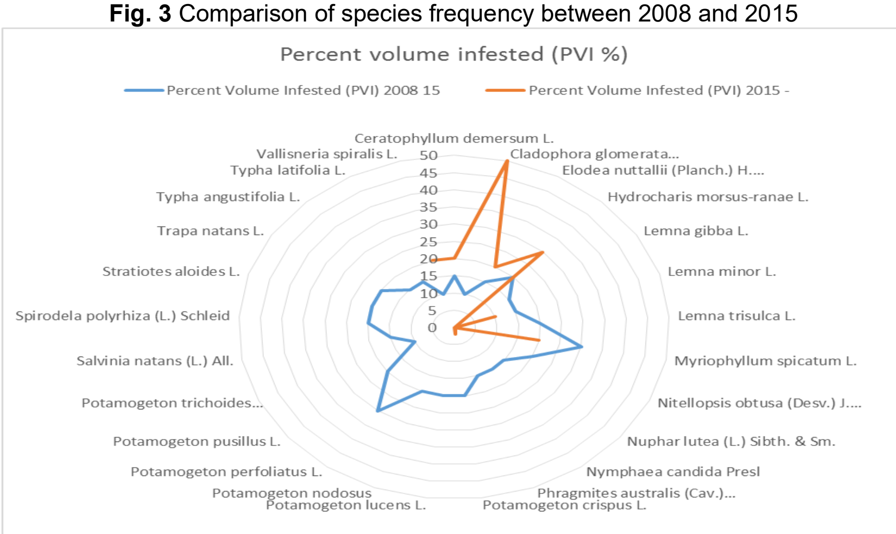

Fig. 4 Comparison of species PVI between 2008 and 2015

Fish species richness

In 2008, on Ciuperca Lake, there were captured 15 fish species. Under the circumstances of 2015 spring season, there were captured 11 fish species, which represents the fish fauna of the lake. The missing species in 2015 are *Silurus glanis, Esox lucius, Tinca tinca* and *Scardinius erythrophthalmus*. Out of the 11 species, only *Leuciscus aspius* (asp) and *Pelecus cultratus* (ziege) (**Table 5**) are in the Annexes of the Habitat Directive and Law 49/2011 on the regime of protected areas. However, the two species are commonly found in The Danube Delta Biosphere Reserve - DDBR, which makes their protection in DDBR slightly exaggerated [***28***]. Nonetheless, at community level (European), there is a reduced population.

Interestingly, the presence of a significant number of reophilous species, typical watershed (ziege, asp and others), is a sign of the connection with Tulcea branch of the Danube.

The majority of freshwater species are omnivorous or fish-eating raptors, such as the asp, zander and perch.

In the fish structure, introduced species for human exploitation such as zander, carp, giebel carp are present, but there are also other species, such as the roach, perch, silver bream or especially ziege and asp which came in the form of fertilized eggs, larvae, youth or subadult through ducts / pipes connecting the lake with The Danube.

Out of the 11 species caught in 2015, almost all were caught in gillnets (10 species), while only 6 fish species caught from the banks with electric devices, which is a sign that bank juvenile individuals are missing. The only small species is the bleak, many other species typical of stagnant water of DDBR are missing. The possible favourable future for the fish species, given the present conditions of the lake, is to provide optimum development conditions for other species such as gobies (Gobiidae family).

Table 5

Fish species richness in Ciuperca Lake and some ecological parameters, in 2015

No.	Species	Common name	Total present: Electric	Total present: Nets	Commercial values	Origin	Ecological parameters: Water current	Salinity	Adult feed	Tolerance to disturbed habitats
1	*Abramis brama* L. 1758	bream		1	**	n	stag-reo	dulc	omni	tole
2	*Alburnus alburnus* L. 1758	bleak	1	1	*	n	reo-stag	dulc	omni	tole
3	*Blicca bjoerkna* L. 1758	Silver bream		1	*	n	eury	dulc	omni	tole
4	*Carassus gibelio* L. 1758	Giebel carp	1	1	**	n	eury	dulc	omni	tole
5	*Cyprinus carpio* L. 1758	carp	1	1	***	n	stag-reo	dulc	omni	tole
6	*Hypophthalmichthys molitrix* Valenciennes, 1844	Silver carp		1	**	e	reo-stag	dulc	fito	tole
7	*Leuciscus (Aspius) aspius* L. 1758	asp		1	**	n	reo-stag	dulc	ihtio	into
8	*Pelecus cultratus* L.1758	ziege		1	*	n	Reo	euryh	zoopl	tole
9	*Perca fluviatilis* L. 1758	perch	1	1	**	n	stag-reo	dulc	ihtio	tole
10	*Rutilus rutilus* L. 1758	roach	1		**	n	eury	dulc	omni	tole
11	*Sander (Stizosteidon) lucioperca* L. 1758	zander	1	1	***	n	stag-reo	euryh	ihtio	into
	TOTAL		**6**	**10**	**11**	**1**				

Symbols used: 1=species presence; <u>Commercial values:</u> ***=high, **=secondary, *=low; <u>Origin:</u> n=native, e=exotic; <u>Water current:</u> migr.=migrator, stag=stagnant, reo=reophilous; eury=eurytope, <u>salinity:</u> dulc=freshwater, euryh=euryhaline; <u>adult feed:</u> omni=omnivorous, ihti=ichthyophagous (piscivorous), bent=bentophagous, erb=herbivore, zoopl=zooplanctonophagous, fito=fitophagous; <u>tolerance to disturbed habitats:</u> tole=tolerant, into=intolerant, inter=intermediary);

Relative abundance and biomass for fish species

Totally, 98 fish individuals were captured, weighing more than 122.5 kg, with a single specification that the silver carp (*Hypophthalmichthys molitrix*) was observed and estimated visually at about 8.5 kg (**Table 1**).

In terms of relative abundance (NPUE = number of individuals per unit effort), it is about 64 individuals (**Table 6**) by electric fishing, dominated by giebel carp and by means of the gillnets, the abundance is from 12 to 18.5 individuals (**Table 6**), where the asp is dominating species, clearly detached from other species (**Fig. 5**).

Table 6

Individuals number (NPUE) or grams (CPUE) in Ciuperca Lake in 2015

Parameters/Gear	Electric	Commercial gillnets	Nordic gillnets	Nylon Nordic gillnets
NPUE (individuals)	64	18.5	12.025	18.5
CPUE (grams)	12172	57108.27	9403.55	6528.65

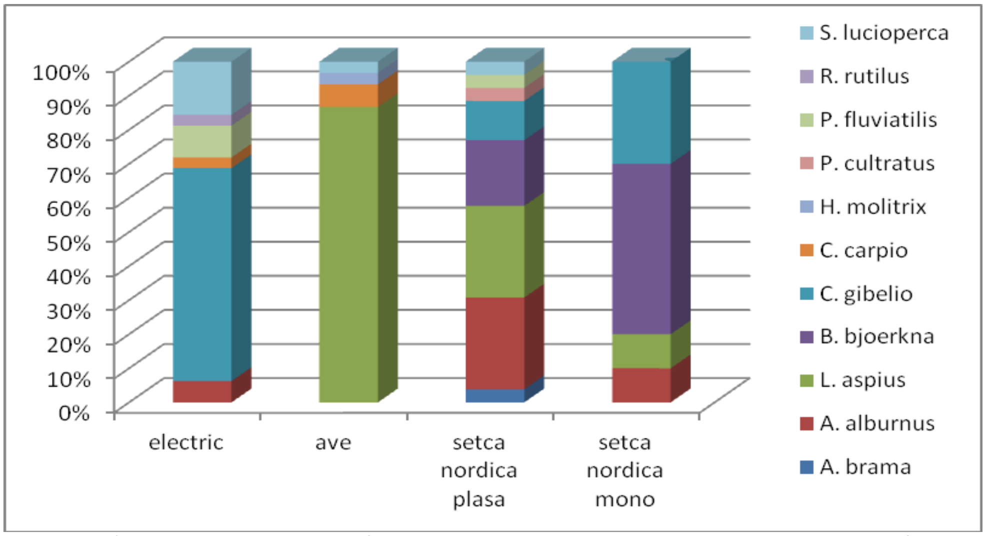

Fig. 5 Percentage of relative abundance in Ciuperca Lake in 2015 at electric devices and nets (ave=commercial gillnets, setca nordica plasa=Nordic gillnets, setca nordica mono=nylon Nordic gillnets)

The asp (*L. aspius*) and giebel carp (*C. gibelio*), in relative abundance percentage, are ranked first, followed by the perch, silver bream and bleak, with differences between sampling methods (**Fig. 5**).
Regarding the relative biomass (CPUE = number of grams per unit of effort), it has high values for both sampling methods: electric fishing (over 12 kg) and the nets (6.5 kg/100 m² Nordic gillnets/night to over 57 kg/100 m² commercial gillnets/night) (**Table 6**). With regard to the biomass, the asp and carp specimens are dominant, followed by the giebel carp and zander, with differences between sampling methods (**Fig. 6**).

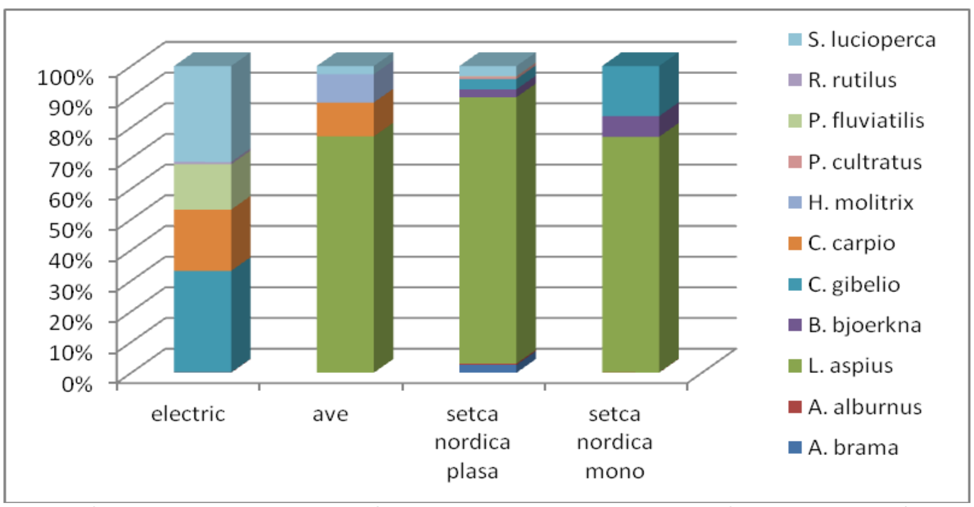

Fig. 6 Percentage for the relative biomass in Ciuperca Lake in 2015 at electric fishing and nets (ave=commercial gillnets, setca nordică plasa=Nordic gillnets, setca nordica mono=nylon Nordic gillnets)

Ecological significance and fish diversity parameters
The index of ecological significance shows the position of a species within a fish coenosis and incorporates the degree of dominance of a species (productive indicator) and frequency of a species in samples (structural indicator).
The ecological diversity study has great complexity, with several issues including the equitability (the index quantifies the unequal distribution of the livestock of various species per one ideal community, in which all species should be represented by the same number of individuals).
The rank of species within the fish fauna is presented in **Table 7,** separately for the two complementary sampling methods. Eudominant and euconstant for the electric fishing, the main species is the giebel carp, while for Nordic gillnets fishing, the asp, bleak and silver bream are eudominant and euconstant, with the asp as a main species.

(**Table 7**). Accidental species in Ciuperca Lake are *P. cultratus* (ziege) and *A. brama* (bream), with differences in sampling methods.

Tabel 7
Ecological status of fish fauna in Ciuperca Lake in 2015

Species/Gear	Electric			Nordic gillnets		
Ecological parameters	D	C	W	D	C	W
A. brama				D2	C1	W1
A. alburnus	D4	C4	W3	D6	C5	W5
L. aspius				D6	C5	W6
B. bjoerkna				D6	C5	W6
C. gibelio	D6	C5	W6	D6	C3	W4
C. carpio	D3	C3	W3			
H. molitrix						
P. cultratus				D2	C1	W1
P. fluviatilis	D5	C4	W4	D3	C2	W2
R. rutilus	D3	C3	W3			
S. lucioperca	D5	C5	W5	D3	C2	W2

The index of equitability show high values at electric fishing (0,667), but is much smaller than at Nordic gillnets fishing (0.828), which means a fish fauna more stable off-bank (open water) and less stable to the bank line (**Table 7, Fig. 7**). However, the values are above the average of 0.5, so that it can be stated that the fish fauna of lake is presently stable. There are some signs of concern for the future because there is a lack of juveniles, which are usually present in the proximity of the bank.

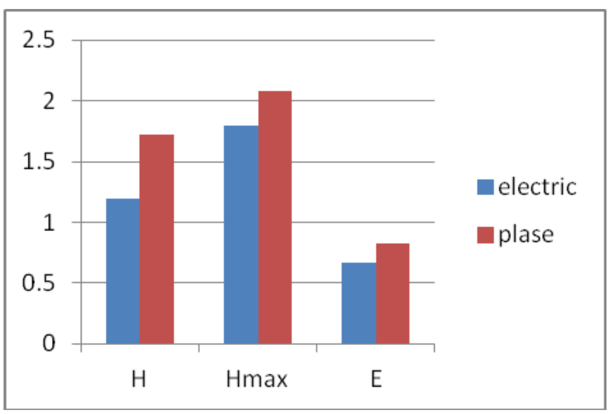

Fig. 7 Fish diversity parameters values in Ciuperca Lake in 2015 (H=Shannon-Wiener index, Hmax=maximal diversity, E=Evenness index of equitability) at electric and Nordic gillnets (plase)

Shannon Wiener biodiversity index (H) is small enough for both sampling methods (1.1 to1.7), which reinforces the idea of reduced fish fauna in Ciuperca Lake (**Fig. 7**).

Demographic fish structure
The ratio females / males is close to 1/1 (1.18 is slightly in favour of females), revealing that the potential of reproduction is normal to high.
However, there is a weak presence of subadult specimens (their number and biomass are almost imperceptible in **Fig. 8**), youth is almost missing, showing that juveniles did not even reach the stage of youth and almost no individual reaches sexual maturity in the water basin. Only deliberately or accidentally introduced species, which are in an advanced stage of development, develop.

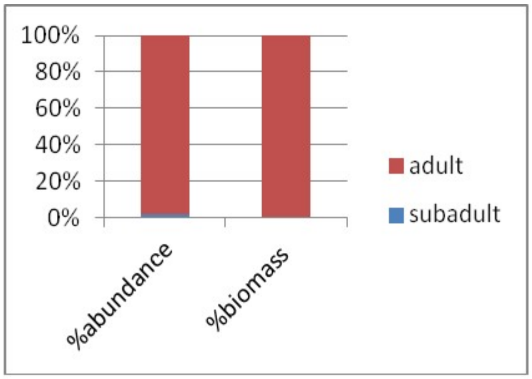

Fig. 8 Ratio percentage of adult/sub adult (in abundance and biomass)

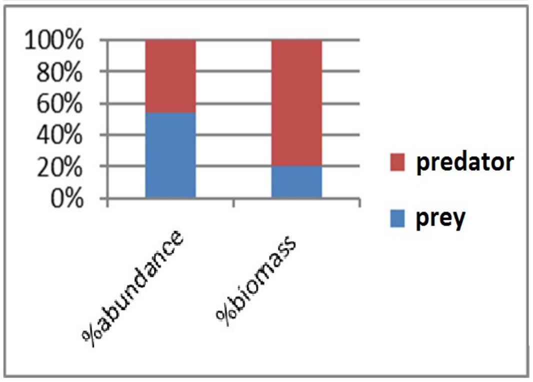

Fig. 9 The Ratio Percentage for the Prey/predator (raptor) (in abundance and biomass)

Juvenile's consumption by fish-eating species reaches an extremely high percentage (**Fig. 9**).There is a high proportion of fish-eating predators in Ciuperca Lake compared to the natural environment of the Danube Delta or another fish farm. While in the Danube Delta the percentage does not exceed 20-30%, the raptor (predator, ichthyofagous) percentage is close to 50% in abundance and over 80% in biomass in Ciuperca Lake.

The presence of raptors in such high number is mainly due to the presence of the asp (*L. aspius*), whose main food is the bleak (*A. alburnus*), accidentally driven here from the Danube River. The zander's main food source is the silver bream (specimens dissected in the laboratory had in their stomach especially individuals of silver bream); for the perch, the main food is represented by eggs and larvae of other species and even of their own, a cannibalism phenomenon common for a closed basin (as in fish farms), without refuge for young individuals. It is possible that the phenomenon of cannibalism to occur in all species of fish-eating species.

It should be noted that the raptors species (predators) are most vulnerable. Especially the zander (pike-perch) is a sensitive species to deterioration of environmental conditions, to most parasite species, mainly due to the fact that the lake was closed without any refuge area, under conditions of high temperatures of water and excessively development of organic matter in water. It can lead to blooming algae by reducing the amount of oxygen dissolved in water and overgrowth of parasites, with negative repercussions on the population of zander (pike-perch) in Ciuperca Lake, such as massive mortality among large specimens, with much higher needs of dissolved oxygen and highly susceptible to parasites.

Fishery data

Ciuperca Lake fish data are shown in **Table 8**, the main species, such as the asp, giebel carp, zander (pike-perch), carp and perch can be exploited. It is noticed that the main fish resource is the asp, with more than 91 Kg total captured biomass and large individuals both in length (Total Length - TL medium 63.7 cm) and especially in biomass (W average of 2.7 kg). The large size of the asp is due to the large bleak presence (average weight about 10 g). Each species has individuals above average size of all D.D.B.R., such as an example of specimen of perch, which had a total length of 35 cm and weight of 857 g maximum, observed as a Goliath among the perches caught in the last 15 years in the D.D.B.R.

Table 8

Fish data from Ciuperca Lake in 2015 (Symbols used: W=weight grams, TL=total length in centimetres, ex=individual, obs=observed values, min=minimal values, max=maximal values, med=medium values)

Species	Individuals number	Total W (g)	TLmedium (cm)/ex	W medium (g)/ex	TLmin.obs. (cm)	TLmax.obs . (cm)	Wmin.obs. (g)	Wmax.obs (g)
giebel carp	26	3273	18.1	125	13.7	27.7	53	410
asp	34	91723	63.7	2697	57	68.5	1864	3848
zander	7	5083	40.4	726	33	61	268	2509
carp	3	11463	58.1	3821	46	66	1215	6700
perch	4	923	16.7	230	6.2	35	7	857
Silver bream	10	759	15.8	76	8.5	23.4	7	233
bleak	10	94	7.3	9.4	8	15.4	3	29

The Fulton index (the rate of fattening) indicates a fatty giebel carp more than the average coefficient of specimens from the natural environment in the Danube Delta (**Table 9**). As in the case of the giebel carp, there were also specimens of asp and carp in a more advanced state of fattening than the average coefficient of specimens from the natural environment of the Danube Delta. The zander species is less obvious. Therefore, it can be inferred the rich presence of food, far more than enough for the individual development.

Asp is an active predator that enjoys abundant presence of large specimens bleak (**Table 8** – with 7-15 cm length individuals and an average of more than 9 grams to 30 grams), which came from Danube river.

Table 9

The Fulton index for the giebel carp compared between natural area of the Danube Delta and Ciuperca Lake

Fulton_year2007_DD	3.82
Fulton_ year2009_DD	3.63
Fulton_year2014_DD	3.67
Average	3.707
Fulton _giebel carp_Ciuperca	3.944

In terms of individuals age, the dominant are: the giebel carp - 2 and 3 years, the zander - 5-6 years and the asp (mostly 5 years old)- 3-6 years, the oldest being one specimen of carp - 9 years old.

Regarding the percentage of exploitability, it is observed that an extremely small percentage is below the legal measure of exploitation, but mostly biomass species have secondary commercial value, such as the asp, giebel carp and perch. However, the high commercially-valued zander and carp have a significant percentage, much higher than the average of those in The Danube Delta (**Fig. 10**).

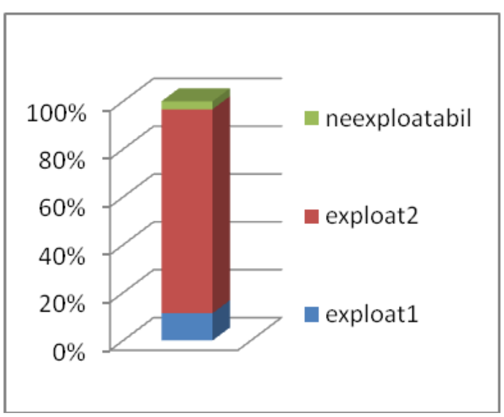

Fig. 10 Exploitability biomass percentage in Ciuperca Lake in 2015 (unexploitable=under exploitability limits, exploat2=secondary commercial value, exploat1=high commercial value)

Heavy metals fish tissue

The results obtained for heavy metals concentrations in fish muscle tissue sampling from Ciuperca Lake **(Fig. 11-16)** were reported to Regulation EC No 1881/2006, which sets maximum levels for certain contaminants in food (19th December 2009).

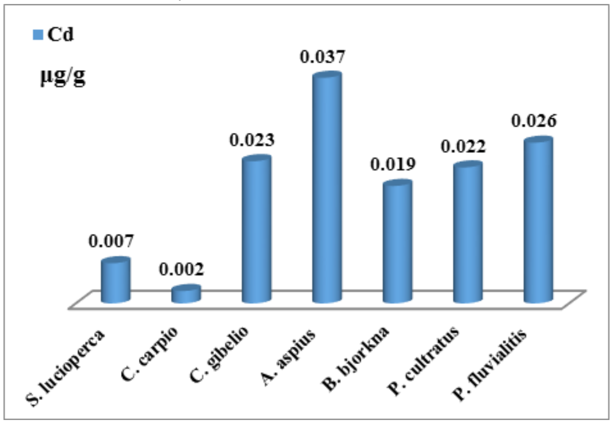

Fig 11 Cadmium accumulation in fish tissue from Ciuperca Lake

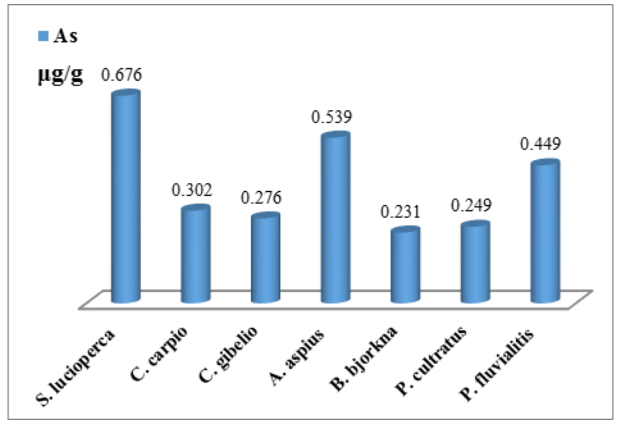

Fig 12 Arsenic accumulation in fish tissue from Ciuperca Lake

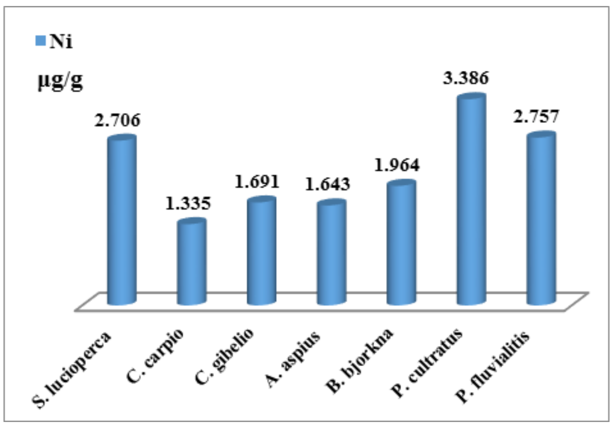

Fig 13 Nickel accumulation in fish tissue from Ciuperca Lake

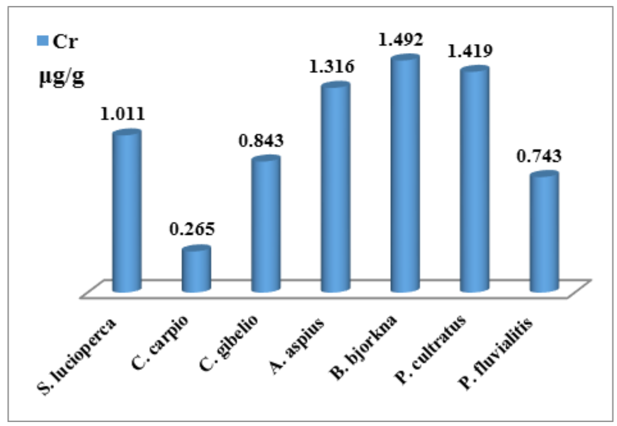

Fig 14 Chromium accumulation in fish tissue from Ciuperca Lake

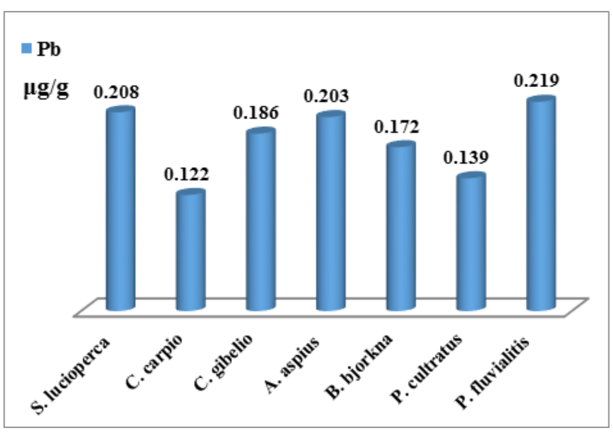

Fig 15 Lead accumulation in fish tissue from Ciuperca Lake

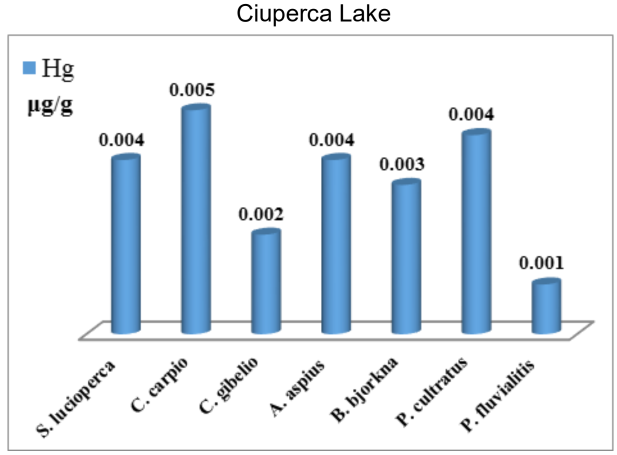

Fig 16 Mercury accumulation in fish tissue from Ciuperca Lake

Cadmium concentrations (**Fig. 11**) were in the range of 0.002 µg/g (wet substance) for *C. carpio* species and 0.037 µg/g (wet substance) for *L. aspius* species. According to the maximum permissible value of 0.3 µg/g (wet substance), established by Commission Regulation (EC) No. 1881/2006 that set maximum levels for certain contaminants in foodstuffs, there were no exceedances for cadmium concentrations in muscle tissues of species studied.

For arsenic (**Fig. 12**), the analysis showed that *S. lucioperca* and *L. aspius* have a higher accumulation capacity than the rest of the species studied, with concentrations between 0, 676 µg/g (wet substance) and, 0,539 µg/g (wet substance). The results are similar to the studies conducted by Farkas [***11***]. It is also noted that concentrations of arsenic in the fish species muscle are not covered by legislation at national or European levels, but the results obtained in our study did not show values below those known to cause harm to fish itself.

Compared to the studied heavy metals, nickel concentrations in the muscle tissue (**Fig. 13**) recorded the highest values and were in the range of 3,386 µg/g (wet substance) for the *P. cultratus* and 1,335 µg/g (wet substance) for *C. carpio.* A high accumulation capacity was observed in chromium (**Fig. 14**) situation, where the maximum values of 1,492 µg/g (wet substance) were identified in *B. bjorkna* species. As in arsenic concentrations, for nickel and chromium there are not provided maximum limits.
For lead (**Fig. 15**), the highest accumulation capacity has been identified for the *P. fluvialitis* (0.219 µg/g (wet substance)) and minimum values have been identified for *C. carpio* (0.122 µg/g (wet substance)). For all the studied species, there were not identified exceeding of the maximum permissible concentrations.
Compared to the mercury concentrations, (**Fig. 16**), we can observe relatively low values for all species, about 0.004 µg/g (wet substance). Analysing the domain variation, it appears that there have not been exceedance of the maximum permitted levels (0.005 µg/g (wet substance)). The maximum value of 0.005 µg/g (wet substance) was identified in the *C. carpio* muscle tissue.
Analysing the results obtained for the six heavy metals (cadmium, arsenic, nickel, chromium, lead and mercury) determined in seven fish tissues, it has been found that, for Ciuperca Lake, the changes in concentrations of the fish muscle tissues vary, depending on the studied species and the type of metal analysed. Also, it is noted that *C. carpio* had the lowest accumulation capacity for heavy metals, except arsenic and mercury.

Fish tissues from Ciuperca Lake in 2015 present low quantities of heavy metals, but no element exceeds both the maximum level of heavy metals tissue and water parameters according to legislation (See No. 18-22 / 21.04.2015 chemical analysis bulletin of DDNI Tulcea).

CONCLUSIONS

From leisure perspective, the rehabilitation works were a success. However, the species diversity is reduced both for fish species and macrophyte. Macrophyte scarcity, apparently, is one of the reasons for eutrophication. Increasing the surface cover of submerged macrophyte species, setting a build-up islets with helophytes in the lake can be a good management.
Actual chemical water parameters do not exceed the limits permitted by law.
The new conditions of life determine the development of opportunistic, eurytope fish species, which may constitute food for introduced species for exploitation (such as the zander).
Out of the 11 species of fish caught in 2015, *L. aspius* (the asp), *P. cultratus* (the ziege) and *A. alburnus* (the bleak) are specific to running water, typical for watershed, sign of lake connection with The Danube.
Small fish species are represented only by the bleak, many other species typical of stagnant water from DDBR being absent.
A possible future species appropriate for Ciuperca Lake, under the actual conditions of macrophyte scarcity, is the gobies species.
The percentage, for both abundance and biomass, is the highest for the asp and giebel carp, followed by the zander, carp, silver bream and bleak, with differences in sampling methods. The highest abundance were recorded were vegetation occurred.
Eudominant and euconstant main species are the asp and giebel carp, while the accidental species are the ziege and bream, with differences in sampling methods.

Equitability index is higher than the average values, signifying a fish coenosis presently stable, but less stable in the proximity of the bank, with some signs of concern for the future of the fish fauna in the lake, given by a lack of youth.
Juvenile's consumption by fish-eating species is extremely high in Ciuperca Lake, macrophyte species scarcity can be one of factors. The proportion of fish-eating predators is high in comparison with the natural environment of the Danube Delta or another fish farm. While in The Danube Delta percentage of predators does not exceed 20-30%, in Ciuperca Lake, the raptor (predator, ichthyofagous) percentage is close to 50% in abundance and over 80% in biomass (dominated by the asp).

The main fish resource is the asp, the total biomass is 91 Kg and it is large both in length (TL medium 63.7 cm) and especially in biomass (W average 2.7 kg). It eats especially large bleak (almost 10 grams average weight).
The Fulton index (the rate of fattening) indicates a fat giebel carp, fatter than the average coefficient of specimens from the natural environment of The Danube Delta.
Regarding the percentage of exploitability, it is observed that an extremely small percentage is below the legal measure exploitable. Most biomass species have secondary commercial value, such as the asp, giebel carp and

perch, however, those with high commercial value, such as the zander and carp, have a significant percentage, much higher than the average of The Danube Delta.

The investigations of heavy metals in the muscle tissue for fish species sampling from Ciuperca lake revealed interspecific highlighted important differences due to trophic and ecological particularities of each species.
Measurements of heavy metals concentrations in the selected fish species did not exceed the permissible limits regulated by legislation, with higher accumulations of heavy metals in predators (piscivorous) species.
Although there are still people who are afraid of eating fish from Ciuperca Lake, the actual fish meat in this lake shows no concern, no element of heavy metals fish tissues exceeds limits.
Regular sampling assessment is necessary to monitor abiotic and biotic elements for the evolution of the lake.

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