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7. The Fish Communities of Lake-Complexes from Danube Delta Biosphere Reserve (DDBR) in Spring-Summer and Autumn of 2016

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Abstract: Fish from Danube delta spawn in spring grows over the summer and in autumn season juveniles recruit to the population. Ichthyofauna was sampled in May-July (spring-summer) after spawning and September-October (autumn) after the juvenile's recruitments. A number of 136 fish species are quoted in references for Danube Delta Biosphere Reserve (DDBR) (included marine species) belonging to 3 Classes, 20 Order, and 45 Families (representing more than 70% of Romania's ichthyofauna). Using 4 methods of sampling, from what two in accordance with UE fish sampling standard methods, were sampled 11 representative lakes in 249 stations: electric fishing in 55 sites (fishing effort over 9 hours), 164 sites with multimeshes size Nordic gillnets (4,920 m-net^{-1}·night^{-1} meaning 29225 m²-net·night^{-1} fishing effort) plus 23 sites with commercial gillnets (1950 m-net^{-1}·night^{-1}meaning 3758 m²-net·night^{-1} fishing efforts) and 7 sites using seine fishing (in the Razim lake). In 2016 in 6 lake-complexes were identified 45 species of fish (majority are limnophilic), included *Perccottus glenii* first recorded in 2016 in Razim-Sinoie lakes-complex. Totally were captured over 60,000 fish individuals with almost 1 t weighting. Using Catch Per Unit Effort (CPUE) for relative biomass grams·h^{-1} electric or 100 m²-net·night^{-1}, NPUE for relative abundance individuals·h^{-1} electric or 100 m²-net·night^{-1}) standardization, it was analyzed species richness and ecological parameters, like relative abundance, relative biomass, dominance (D), constancy/frequency (C), ecological significance (W), biodiversity index (Shannon-Wiener indices Hs and Evenness indices E). Present work will characterize the ichthyocoenoses and estimate conservation status of fish fauna from lake-complexes of DDBR. Main fish species, eudominant and euconstant is *Alburnus alburnus*, characteristic fish species are *Scardinius erythrophthalmus* and *Rutilus rutilus,* complementary fish species are *Blicca bjoerkna* and *Perca fluviatilis,* mostly species are associate or accessory, but most of them are accidental in lake-complexes, with differences between seasons and sampling methods. The main fish resources species is Gibel carp (*Carassius gibelio)* with up to 50 % in sampling with commercial gillnets of 50 mm mesh size knot to knot.
Keywords: fish fauna, Danube Delta, lakes, ecological status, ichthyo diversity

INTRODUCTION

The overall objective of the paper is to estimate the conservation state of fish fauna to reduce the risk of the decline of biodiversity in Danube Delta Biosphere Reserve (DDBR). The first step in order to conserve fish population is to find appropriate methods for estimation of ecological status for the ichthyofauna in DDBR.
In DDBR, currently are quoted 136 species of fish included into 3 Classes, 20 Orders, and 45 Families. From actual number of 136 species, 81 species are present in the freshwaters (limnophilic backwater or running waters) and others 55 fish are exclusive marine species presents in Black Sea coastal area of DDBR, more 69 marine fish species are potentially present in Black Sea coastal area of DDBR (Antipa, 1909, Bănărescu, 1964, Oțel et. al. 1992, 1993, 2001, 2007, Năstase, 2007, 2009, Niculaev and Anton, 2008, Radu and Radu, 2008, Năvodaru and Năstase, 2011).

Some fish species like *Acipenser sturio* and *Acipenser nudiventris*, which has always been rare in Black Sea-Danube River system, are unrecorded for almost 50 years in DDBR; others like *Sander volgensis* which were recorded in Crisul-Repede river (Bănărescu, 2004), was found in RBDD area in 2006 in Danube River near Tulcea town, also in Parcheş Lake (in 2007) and one more near Sacalin island of Black Sea (in 2007). In addition to the first two unrecorded species for more than 50 years, there are three other species of roach (*Rutilus*): *R. pigus* (quoted by Antipa, 1909 in the Danube River and the its floodplain), *R. haekeli* (species with uncertain status, a small number of specimens in Razim and in the mouth of the Sulina arm) and *R. frisii* (found in Razim lake in 1956, probably exemplary stray) (Bănărescu, 2004), which have not been recorded in the last period of time, most of them being visitor species from Dniester River delta.
For monitoring of fish fauna and its ecological status for conservative purposes it is important to use a congeries of ecological parameters beginning with species richness, abundance, biomass, continuing with analytical and synthetically ecological parameters with their limits used from literature or observed by experts judgment in the field, but for further studies will be welcomed Index of Biological Integrity (IBI index) (Karr 1981, adapted for Romanian rivers by Battes in Ureche, 2008), with necessity to future adapt for big rivers and lakes.
Fish fauna of DDBR lakes has a great ecological and economic value in the area and its ecological status is the subject of this paper, which aims to consolidate the state-of-the-art knowledge and to bring new data on the ecology and biology of the fish populations for 3 different seasons of the 2016 year's spring, summer, and autumn.

MATERIALS AND METHODS

Periods of sampling in year 2016 was in 3 different seasons: first season after breeding in Spring (May), second in Summer (July) and third season in Autumn (in September-October), when 6 complexes of lakes, respectively Somova-Parches (Tilincea and Parcheș lakes), Sontea-Furtuna (Furtuna and Băclănești Mari lakes), Gorgova-Uzlina (Isac and Cuibul cu Lebede lakes), Matita-Merhei (Merhei and Babina lakes), Rosu-Puiu (Iacob and Roșu lakes) was sampled for fish with two complementary methods, gillnet fishing in open water and electro-fishing in border vegetated zone of lakes; additionally Razim-Sinoie lakes-complex was sampled (Razim lake) with another fishing methods – seine fishing (**Fig.1**).

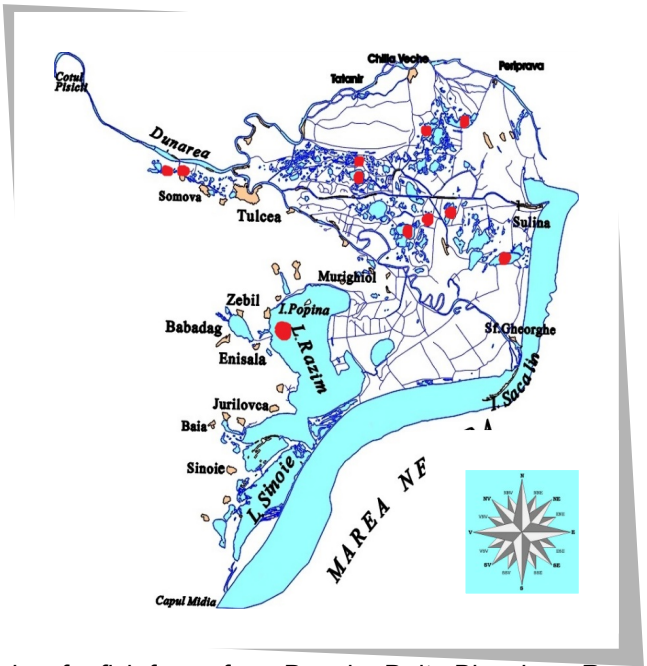


Figure 1 Sampling lakes for fish fauna from Danube Delta Biosphere Reserve (DDBR) in 2016
Electric fishing was performed with SAMUS 1000 W electrofisher device, during 10 minutes per site, 3 sites per lake and multi meshes gillnet fishing with Nordic gillnets (30 m length x 1.8 m high each). The Nordic gillnets are composed by 12 randomly joined panels, 2,5 m length each panel, with multiples meshes: 6, 6, 8, 10, 12, 16, 20, 24, 30, 35, 45, 55 mm (Năvodaru, 2008, *DIN EN 147:2005 Water quality - Sampling of fish, *CEN/TC 230, „Water analysis" 2002, Water quality – Sampling of fish with gillnets multi-mesh gillnets). Razim lake was sampled with seine (2 wings of 100 m length each and a cod end of 7 mm knot to knot mesh size). (**Table 1**).

Altogether in 3 different sampling seasons, 11 representative lakes were sampled, which means 249 stations, of which 59 electric fishing stations (fishing effort over 9 hours), Nordic gillnets fishing (4920 m-net^{-1}·night^{-1} fishing) (**Table 1**), then 23 commercial gillnets fishing stations (1890 m-net^{-1}·night^{-1} monofilament and 60 m-net^{-1}·night^{-1} relon) and 7 sites for seine fishing in the Razim lake. In total, 61,309 fish individuals catch weighing almost 1 tone were captured in 2016, the largest quantities were in Rosu-Puiu complex with over 309 kg and also Razim lake with over 246 kg, and the smallest in the Somova-Parcheş complex over 83 kg (**Table 1**).
The catch per unit effort (CPUE) was standardized to individual and/or biomass (grams) per 1-hour electric fishing and individuals and biomass per 100 m²-net·night^{-1} for gillnet fishing. For seine fishing in Razim lake abundance and biomass was standardized to a haul seine.
Electric fishing was carried out during the day time, in the border zone with shallow water, with rich vegetation, while fixed gillnet fishing took place during the night (12 hours), in the open deep water of lake, with relatively scarce floating and submerged vegetation.

Table 1 Distribution of the number of northern gillnets with multiple meshes size, used by surface of lakes and depth (Nyberg and Degerman, 1988); (used symbols: No. = the number of gears used, L = gillnet length, min = minutes, m = meters, ex = individual, g = grams, S-P = Somova-Parcheş, G-U = Gorgova-Uzlina, S-F = Şontea-Furtuna, M-M = Matiţa-Merhei, R-P = Roşu-Puiu,)

	Nordic Gillnets		Electric	Nylon Commercial gillnets		Relon Commercial gillnets		Seine	Total captures	
Lake/Tool	No.	L (m)	(min.)	No.	L (m)	No.	L (m)	haul	ex.	g
Iacob_may2016	8	240	30	3	270	2	60	0	13647	161503
Rosu_may2016	12	360	30	1	90	0	0	0	1682	37373
Iacob_sept2016	8	240	30	3	270	0	0	0	1059	39865
Rosu_sept2016	12	360	30	0	0	0	0	0	5056	71245.2
total R-P	**40**	**1200**	**120**	**7**	**630**	**2**	**60**	**0**	**21444**	**309986.2**
CuibcuLebede_may2016	8	240	30	0	0	0	0	0	140	6527
Isac_may2016	12	360	30	1	90	0	0	0	4402	34580
Isac_sept2016	12	360	30	0	0	0	0	0	3711	54954.5
total G-U	**32**	**960**	**90**	**1**	**90**	**0**	**0**	**0**	**8253**	**96061.5**
Merhei_may016	12	360	30	2	180	0	0	0	2006	51948
Babina_may2016	12	360	30	2	180	0	0	0	10069	60518
Merhei_sept2016	12	360	30	0		0	0	0	423	18065
total M-M	**36**	**1080**	**90**	**4**	**360**	**0**	**0**	**0**	**12498**	**130531**
Furtuna_may2016	12	360	30	2	180	0	0	0	1697	50803
Baclanestii Mari_may2016	8	240	30	2	180	0	0	0	1149	31866
Furtuna_sept2016	12	360	30	0		0	0	0	1502	25659
total S-F	**32**	**960**	**90**	**4**	**360**	**0**	**0**	**0**	**4348**	**108328**
Parches_July2016	8	240	30	2	180	0	0	0	3651	42782
Tilincea_July2016	8	240	30	2	180	0	0	0	1035	19521
Parches_oct2016	8	240	30	0		0	0	0	1679	21120
total S-P	**24**	**720**	**90**	**4**	**360**	**0**	**0**	**0**	**6365**	**83423**
Razim_July2016	0	0	40	1	90	0	0	4	6639	189739.4
Razim_oct2016	0	0	30	0	0	0	0	3	1762	57070.8
total Razim	**0**	**0**	**70**	**1**	**90**	**0**	**0**	**7**	**8401**	**246810.2**
TOTAL	**164**	**4920**	**550**	**21**	**1890**	**2**	**60**	**7**	**61309**	**975139.9**

The fish species were identified after Antipa 1909, Bănărescu (1964 and 2004), and taxonomic name after revision by Kottelat 1997, Kottelat & Freyhof 2007, Nelson 2006, Nalbant 1993 and Froese and Pauly 2018 www.fishbase.org 2018).

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 Botnariuc and Vădineanu 1982, Schwerdtfeger 1975 quoted by Schindrilariu et al. 2002: Fi = bi/a•100 (%), where, Fi = frequency of occurrence of specie i, bi = the number of samples in which species i was observed and a = total number of samples.
The relative abundance or dominance (D) was calculated as proportion of species to the total catch according to Mühlenberg (1993): Di = ni/N ·100 (%), where, Di = dominance of species i, ni = individuals of the species i, and N = total number of individuals.
Five classes of frequency and 6 for abundance/dominance was used for data interpretation (**Table 2**)

Table 2 Frequency (constancy), dominance and ecological significance classification (Odum 1975, Botnariuc & Vădineanu 1982, Gomoiu & Skolka, 2001, Sârbu & Benedek, 2004, Schwerdtfeger 1975, Şindrilariu et. al. 2002)

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	D2	1 (2^0) - <2	rare	C2=10.1-25	accessory	W2=0.1-1
recedent	D3	2 (2^1) - <4	widespread	C3=25.1-45	associate	W3=1-5
subdominant	D4	4 (2^2) - <8	frequent	C4=45.1-70	complementary	W4=5-10
dominant	D5	8 (2^3) – 16	very frequent	C5=70.1-100	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 ph.D thesis (Năstase, 2009). Accidental (W1) is more towards accessory values, but accidental is due to some multiple imperfection causes, such as unfavorable weather conditions, malfunction gear at a time, unfavorable 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 (Gomoiu & Skolka, 2001; Sârbu & Benedek, 2004)
The equitability (Gomoiu and Skolka, 2001; Sârbu and Benedek, 2004) 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.
Accordingly with Water Framework Directive (*****, 2000), it is desirable to test and apply known ecological parameters that could improve the methods of assessing the conservation status, using where no other methods are available, even expert judgements analysis (this analysis was thought and used in a European project in 2014: Black Sea e-Eye **-** Innovative Instruments for Environmental Analysis in North Western Black Sea Basin (*****, 2014), to improve methodology after Moss et. al. 2003 (Ibram et.al, 2015).
Ecological lake classification matrix for implementing Water Framework Directive (*****, 2000) have 5 classes using 2 parameters (abundance - CPUE and Biomass – BPUE, expressed as Catch per Unit Effort – number or biomass of fish on 100 m²-net·night^{-1}) and 2 diversity indices (Shannon-Wiener and Equitability) (**Table 3**).
Actually, there is no yet developed statistically threshold limits for those 5 WFD quality classes using these indicators, but expert judgment was used. The Shannon-Wiener index varies from values of 0 for communities with one species, to various other values for more species mixes. The Equitability index ranges between 0 and 1. Class limits was proposed by authors based on field experience and expert judgment, thresholds wait for validation.

Table 3 Ecological matrix class for fish parameters assessment in accordance with WFD conservation (expert judgment based on 15 years of measurement in the field) according to "one out all out" principle: NPUE-Number Per Unit Effort, CPUE-Catch (grams) Per Unit Effort, Hs= Shannon-Weiner biodiversity index, E=Evenness index (equitability index)

Status	Colors	Class	NPUE (n)	CPUE (g)	Hs	E
Very bad	Red	I	<25	<500	<1	<0.2
Bad	Orange	II	25-100	500-2000	1 - 1.4	0.2-0.4
Moderate	Yelow	III	100-250	2000-5000	1.4 - 1.8	0.4-0.6
Good	Green	IV	250-500	5000-10000	1.8 - 2.2	0.6-0.8
Very good	Blue	V	>500	>10000	>2.2	>0.8

RESULTS AND DISCUSSIONS

Species richness

Following the sampling of representative lakes from DDBR in 2016, 45 fish species (**Table 4**) were captured, of which 27 commercial species, as origin 41 native species and 5 non-native species, including *Perccottus glenii* (Amur Sleeper) first time found in Romania in Suceava river in 2001 (Nalbant et.al., 2004), and in the Danube Delta in 2007 (Năstase, 2007, 2009), and after 10 years is acclimated to Danube Delta conditions and expand into Razim-Sinoie lake-complex, this paper indicate first record of species in Razim lake in 2016 (**Table 4**).

Mostly of species (more than ½) are limnophilic, specific to lacustrine waters. There are some species characteristic of the Razim-Sinoie lake complex (like *Percarina demidoffi, Ponticola syrman*), but in general, all species are spread more or less uniformly throughout the DDBR waters (**Table 4**). Many species are omnivorous, a significant part of species are piscivorous, the rest having another diet.

The richness of the species per lakes-complexes highlights the increase in the number of species from the pre-delta area (Somova-Parcheş S_P) to the Black Sea. The closer we are to the sea, number of species grows, demonstrating that the euryhaline species not only coexist in both medium freshwater and marine waters, but they are adapting, expanding new territories (like Gobiids, like *Syngnathus abaster*) (**Table 4**).

Relative Abundances (NPUE) and relative biomass (CPUE)

Electric fishing (in border vegetated zone of lakes) shows that the abundance is dominated by the roach (*Rutilus rutilus*), bitterling (*Rhodeus amarus*), bleak (*Alburnus alburnus*) and giebel carp (*Carassius gibelio*), but in biomass other species are dominant like carp (*Cyprinus carpio*), pike (*Esox lucius*) and giebel carp (*Carassius gibelio*), with differences between seasons. An interesting observation is that only *Carassius gibelio* has abundance and biomass balanced (13.93% abundance with 11.38% biomass), the rest of the species having high abundance and low biomass (small species) or low abundance and large biomass (large species such as carp, pike and catfish *Silurus glanis*) (**Figure 1** Up-abundance and Down-Biomass).

Nordic gillnets fishing is dominated both in abundance and in biomass by medium and small size species such as bleak (*Alburnus alburnus*), rudd (*Scardinius erythrophthalmus*), roach (*Rutilus rutilus*), perch (*Perca fluviatilis*), white bream (*Blicca bjoerkna*) and bitterling (*Rhodeus amarus*), so there is a balance between abundance and biomass, but most species have small abundance and biomass under 0.1% for 60 % of species, with differences between seasons (**Figure 2** Up-abundance and Down-Biomass).

Table 4 The richness of species per lakes-complexes in 2016 (Symbols used: 1 = species presence, Family Cy = Cyprinidae, Pe = Percidae, Cl = Clupeidae, At = Atherinidae, Go = Gobiidae, Ga = Gasterosteidae, Es = Escidae, Si = Siluridae, Sy = Syngnathidae, Um = Umbridae; Origin: n = native, e = exotic; S_P = Somova-Parcheş, G_U = Gorgova-Uzlina, S_F = Şontea-Furtuna, M_M = Matiţa-Merhei, R_P = Roşu-Puiu, DDBR = Danube Delta Biosphere Reserve; Preference of water current: Migr.=migrator, Limn=limnophilic, Stag=stagnant, Reo=rheophilic; eurit=eurytope,)

No.	Species	Family	S_P	S_F	G_U	M_M	R_P	Razim	Origin	Preference of water current
1	*Abramis brama*	Cy	1	1		1	1	1	n	reo-stag
2	*Alburnus alburnus*	Cy	1	1	1	1	1	1	n	reo-stag
3	*Alosa tanaica*	Cl	1		1	1	1	1	n	Migr
4	*Atherina boyeri*	At			1	1	1		n	Migr
5	*Bentophilus nudus (stellatus)*	Go						1	n	reo-stag
6	*Blicca bjoerkna*	Cy	1	1	1	1	1	1	n	stag-reo
7	*Carassius carassius*	Cy		1	1	1		1	n	Limn
8	*Carassius gibelio*	Cy	1	1	1	1	1	1	n	Eurit
9	*Clupeonella cultiventris*	Cl	1		1	1		1	n	Migr
10	*Cobitis elongatoides*	Co	1	1	1	1	1		n	Stag-reo
11	*Cobitis tanaitica*	Co						1	n	Limn
12	*Cobitis megaspila*	Co					1		n	Limn
13	*Ctenopharyngodon idella*	Cy			1			1	e	Stag-reo
14	*Cyprinus carpio*	Cy	1	1	1		1	1	n	reo-stag
15	*Esox lucius*	Es	1	1	1	1	1	1	n	Limn
16	*Gymnocephalus cernuus*	Pe	1	1	1	1	1	1	n	Limn
17	*Knipowitschia caucasica*	Go						1	n	Limn
18	*Lepomis gibbosus*	Ce	1		1	1	1	1	e	Limn
19	*Leucaspius delineatus*	Cy	1	1	1	1	1	1	n	Limn
20	*Leuciscus aspius*	Cy	1	1	1	1	1	1	n	reo-stag
21	*Leuciscus idus*	Cy						1	n	Reo
22	*Misgurnus fossilis*	Co		1		1			n	Limn
23	*Ponticola (Neogobius) eurycephalus*	Go		1				1	n	stag-reo
24	*Neogobius fluviatilis*	Go			1		1	1	n	stag-reo
25	*Babka (Neogobius) gymnotrachelus*	Go		1	1	1	1	1	n	Limn
26	*Ponticola (Neogobius) kessleri*	Go				1		1	n	stag-reo
27	*Neogobius melanostomus*	Go						1	n	Limn
28	*Ponticola (Neogobius) syrman*	Go						1	n	Limn
29	*Pelecus cultratus*	Cy						1	n	reo-stag
30	*Perca fluviatilis*	Pe	1	1	1	1	1	1	n	stag-reo
31	*Percarina demidoffi*	Pe						1	e	Limn
32	*Perccottus glenii*	Od	1	1	1	1	1	1	e	Limn
33	*Petroleuciscus borysthenicus*	Cy	1	1	1	1	1	1	n	Limn
34	*Proterorhinus marmoratus*	Go	1	1	1	1	1	1	n	Limn
35	*Pseudorasbora parva*	Cy	1	1	1	1		1	e	Limn
36	*Pungitius platygaster*	Ga		1	1	1		1	n	Limn
37	*Rhodeus amarus*	Cy	1	1	1	1	1	1	n	Stag-reo
38	*Rutilus rutilus*	Cy	1	1	1	1	1	1	n	Eurit
39	*Sander lucioperca*	Pe	1				1	1	n	stag-reo
40	*Scardinius erythrophthalmus*	Cy	1	1	1	1	1	1	n	Limn
41	*Silurus glanis*	Si		1	1	1	1		n	reo-stag
42	*Syngnathus abaster*	Sy			1	1	1	1	n	Limn
43	*Tinca tinca*	Cy		1	1	1	1	1	n	Limn
44	*Umbra krameri*	Um					1	1	n	Limn
45	*Vimba vimba*	Cy					1	1	n	reo-stag
	Grand total	19Cy 4Pe	22	25	29	29	30	40	5e 40n	

Seine fishing sampling in Razim Lake shows a balance between the percentages of abundance and the biomass being dominated of species such as roach (*Rutilus rutilus*), some Gobiids (*Neogobius fluviatilis, N. melanostomus*), pike-perch (*Sander lucioperca*), but most species have abundance and biomass with low values under 0.1 % for 25% of species, with differences between seasons (**Figure 3**

Up-abundance and Down-Biomass). Significant great values of abundance and biomass has some typically freshwater species like rudd (*Scardinius erythrophthalmus*) and perch (*Perca fluviatilis*) considering transition of Razim-Sinoe complex from brackish lagoon to a freshwater system after closing communication with Black Sea at Portita mouth.

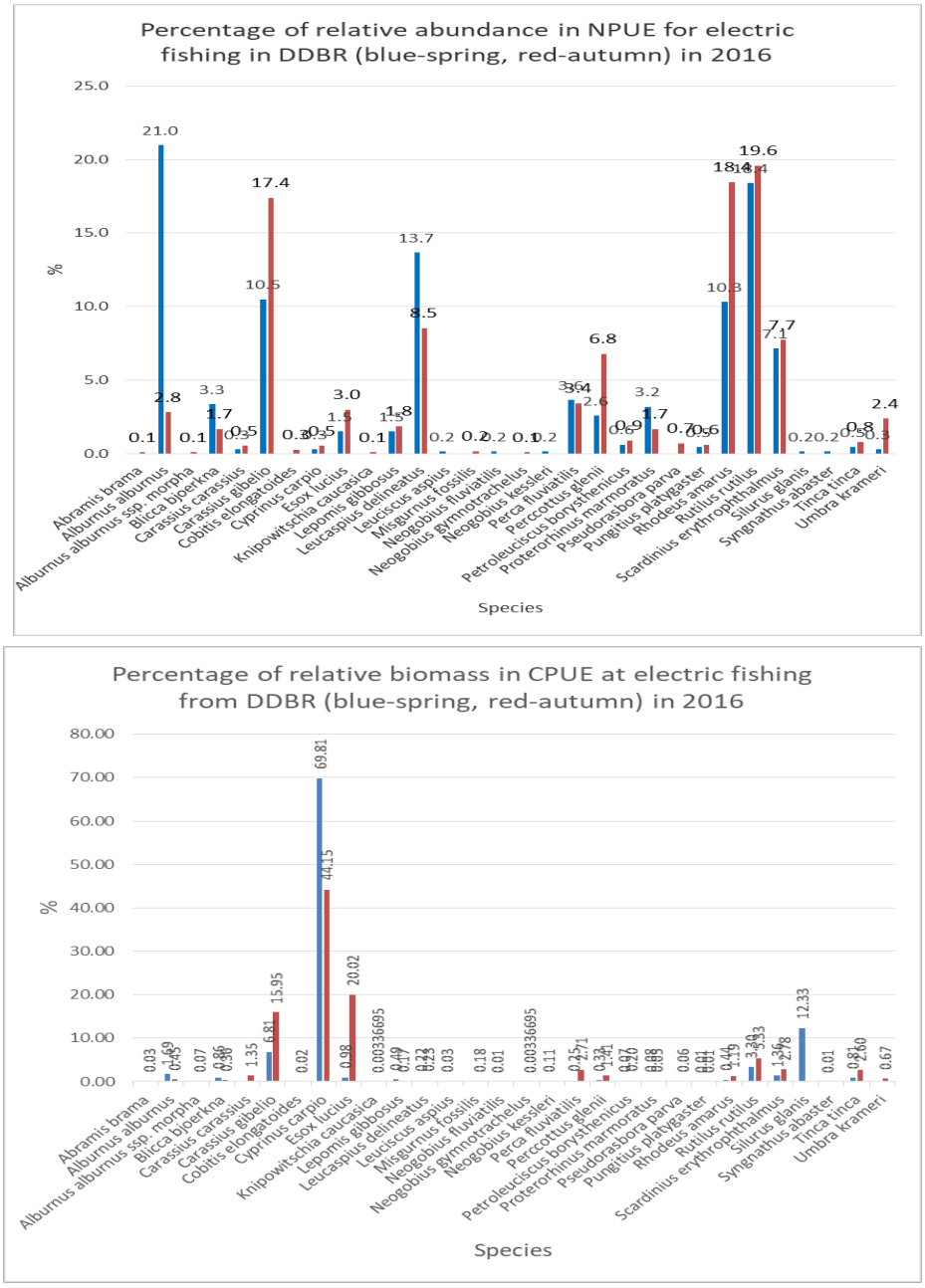
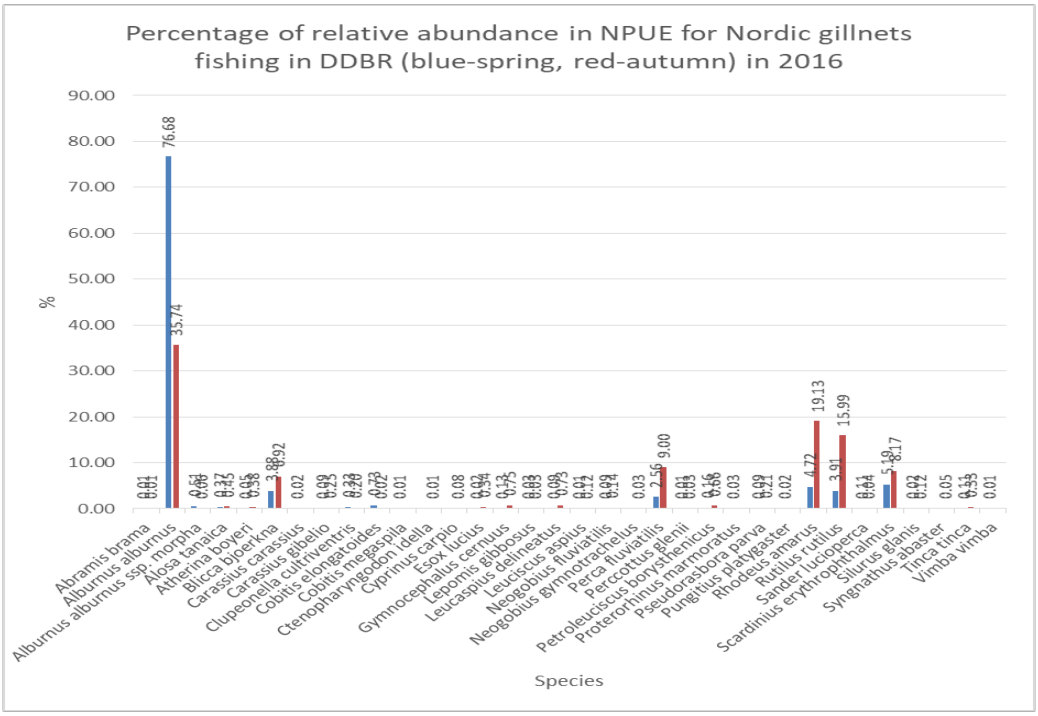


Figure 2 Relative abundances (up) and biomass (down) in the DDBR lakes in the studied periods, at electric fishing (lakes and canals) (blue-spring-summer season, red-autumn season)

Concluding, the abundance and biomass of fish species captured in 2016 in the studied part of DDBR lakes, it can say that the dominant species in abundance are bleak (*Alburnus alburnus*), roach (*Rutilus rutilus*), rudd (*Scardinius erythrophthalmus*), perch (*Perca fluviatilis*), white bream (*Blicca bjoerkna*), Giebel carp (*Carassius gibelio*) and some Gobiids species (especially in Razim lake), and for biomass dominates the roach (*Rutilus rutilus*), the rudd (*Scardinius erythrophthalmus*), the Giebel carp (*Carassius gibelio,* even some large species such as pike (*Esox lucius*), carp (*Cyprinus carpio*), catfish (*Silurus glanis*) for Danube delta lakes and zander (*Sander lucioperca*) only for Razim lake has great values, with some differences between sampling methods and seasons, but most captured fish species have low values under 0.1% both in abundance and biomass for more than 40% of species.



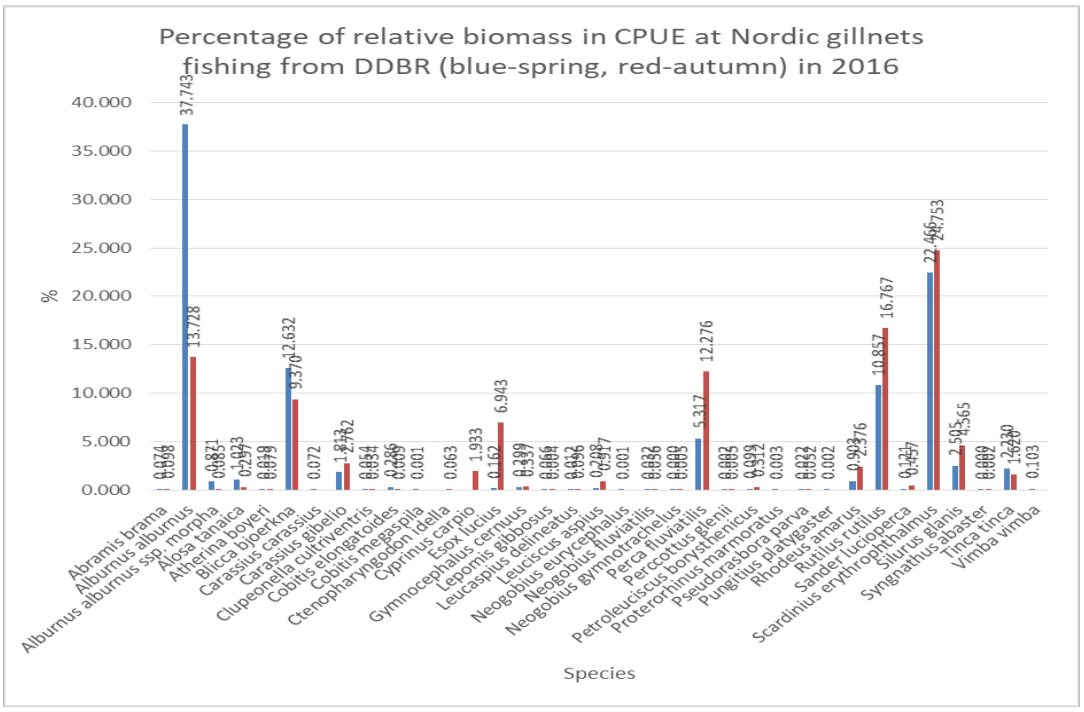
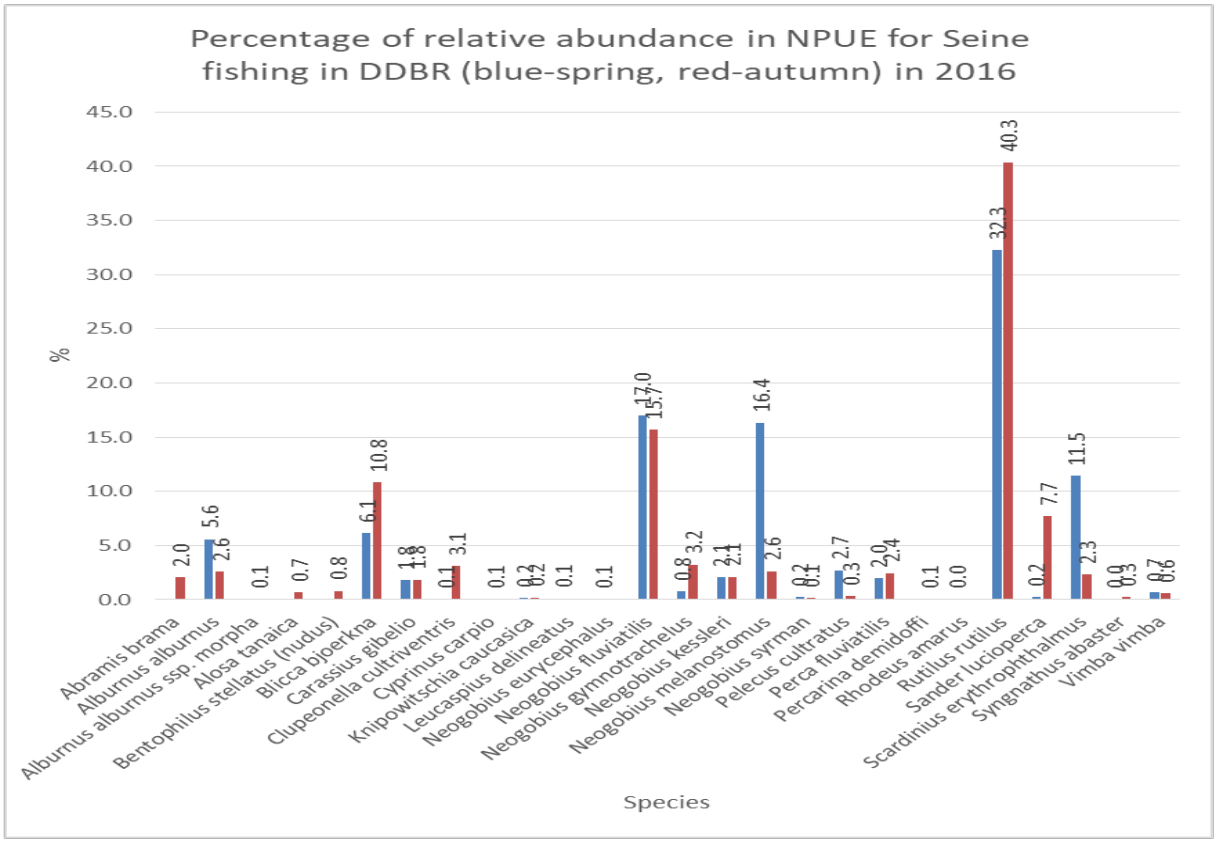


Figure 3 Relative abundances (up) and biomass (down) in the DDBR lakes in the studied periods, at Nordic gillnets fishing (lakes and canals) (blue-spring-summer season, red-autumn season)



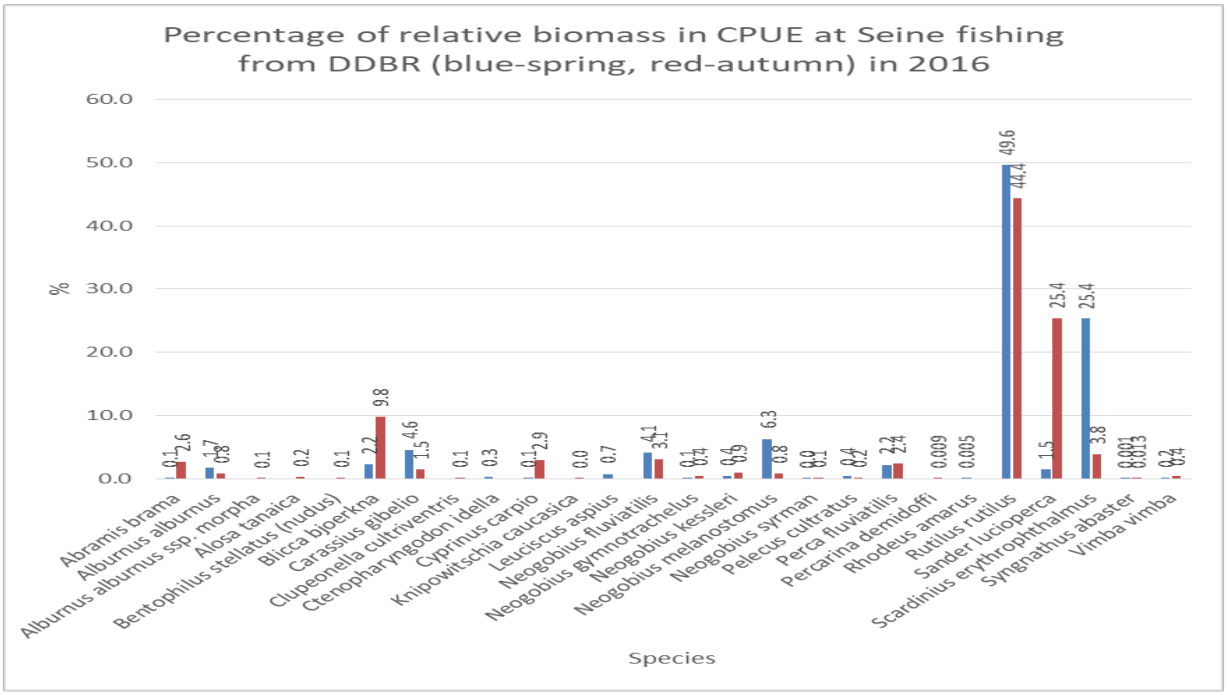


Figure 4 Relative abundances (up) and biomass (down) in Razim lake, at seine fishing (blue-spring-summer season, red-autumn season)

The question for the aquatic environment of the DDBR would be: how the delta would look like without the presence and dominance in both abundance and biomass of small and medium sized fish species such as bleak (*Alburnus alburnus*), roach (*Rutilus rutilus*), rudd (*Scardinius erythrophthalmus*), white bream (*Blicca bjoerkna*) unfair considered to be non-important species? The answer can be easily perceived as being the main source of food for piscivorous fish species, but also for piscivorous birds

that are continuously increasing (these birds species are not selective on economically valuable fish), so increasing population of piscivorous birds species could be a possible indicator for good status of fish fauna, especially for those small-sized species, however, same time it may indicate an unbalanced fish community and age structure disruption of fishes. An significant impact of piscivorous wild birds in DDBR is for economic qualitative fish fauna in some specific habitats of lakes preferred by valuable commercial fish species, where, after the fish breeding period, but before recruitments in population, the abundance of fish juvenile is higher (mostly juvenile of commercially valuable fish species having specific habitat needs). Further studies are required in this fragile zones (little deep vegetated with macrophytes waters) from breeding period till to recruitments of juveniles to the population period, also possible useful measures are welcomed for that valuable fish species. Conservation status of fish fauna includes both fish species categories (non-commercial and more or less valuable commercial fish species) and the results show that valuable commercial fish species are more affected not only by piscivorous birds, but much more by other well-known factors, however, piscivorous birds contributed to a significant impact of specific spawning, nursing and growing habitats of especially young fish.

The biomass for commercials gillnets sampling shows the massive dominance of *Carassius gibelio*, which is up to 50%, followed by *Blicca bjoerna, Silurus glanis, Cyprinus carpio,* with differences between seasons (**Figure 5**). The low percentage of the roach+rudd commercially category, which is numerically and gravimetrically dominant in fish research sampling, are explained by commercially fishing gillnet selectivity with mesh size equal or larger than 50 mm that retain fewer biomass as population potential. It seems to be a gap between the legal size of exploitation of the rudd+roach species bigger than 15 cm (standard length) and the mesh size of the net of 50 mm, so with this mesh size it can be captured only bigger individuals with a standard length of over 20 cm, so that the roach+rudd category is always underexploited.

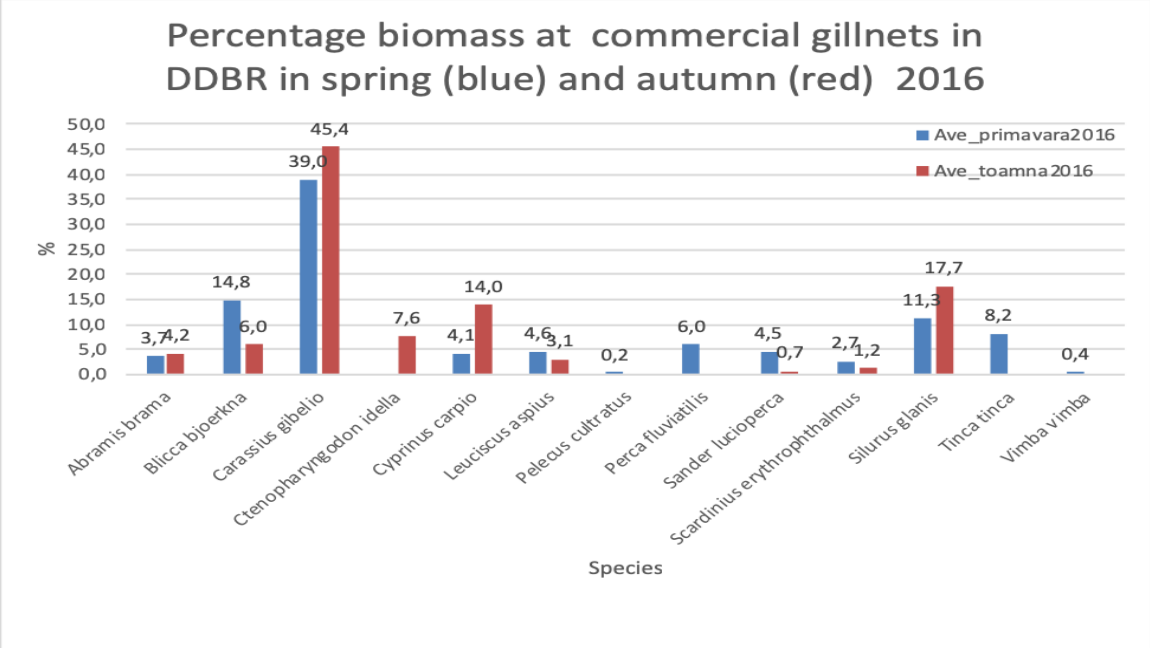


Figure 5 Relative biomass in sampling with commercial gillnets (mesh size =50mm) fishing from DDBR in spring (blue) - autumn (red) of 2016 year

The status of ichthyocoenosis. In 2016, the main eudominant and euconstant species is *Alburnus alburnus*, the dominant and constant characteristic species are*Scardinius erythrophthalmus* and *Rutilus rutilus,* complementary species are *Rhodeus amarus* and *Blicca bjoerkna*, associated species are *Perca fluviatilis* and *Carassius gibelio*, accessory species are *Tinca tinca, Alosa tanaica, Esox lucius*, even *Perccottus glenii* belong to this category due to the rapid ascension in recent years, as well as other species can be classified in different categories but with differences between seasons and between sampling methods. However, most species are accidental, sporadic or very rarely fish species sampled in DDBR lakes-complexes (**Table 5**).

Table 5 Ecological parameters in the year 2016

	SPRING-SUMMER 2016 (MAY-JULY)									AUTUMN 2016 (SEPTEMBER-OCTOBER)								
	electric			Nordic Gillnets			Seine			electric			Nordic Gillnets			Seine		
SPECIES/TOOLS	D	C	W	D	C	W	D	C	W	D	C	W	D	C	W	D	C	W
A .brama				D1	C1	W1A	D1	C2	W1	D1	C1	W1	D1	C1	W1	D3	C5	W3
A. alburnus	D6	C2	W3	D6	C5	W6	D4	C5	W4	D3	C3	W3	D6	C5	W6	D3	C5	W3
A. ssp. morpha				D1	C1	W1				D1	C1	W1	D1	C1	W1	D1	C3	W1
A. tanaica				D1	C3	W2							D1	C2	W2	D1	C5	W2
A. boyeri				D1	C1	W1							D1	C2	W1			
B. nudus																D1	C5	W2
B. bjoerkna	D3	C2	W2	D3	C5	W3	D4	C5	W4	D2	C2	W2	D4	C5	W3	D5	C5	W5
C. carassius	D1	C1	W1	D1	C1	W1				D1	C2	W1						
C. gibelio	D5	C2	W3	D1	C2	W1	D2	C4	W3	D6	C5	W5	D1	C3	W1	D2	C5	W3
C. cultriventris				D1	C2	W1	D1	C4	W1				D1	C1	W1	D3	C4	W3
C. elongatoides				D1	C4	W2				D1	C2	W1	D1	C1	W1			
C. megaspila				D1	C1	W1A												
C. tanaitica							D1	C2	W1									
C. idella							D1	C1	W1				D1	C1	W1A			
C. carpio	D1	C1	W1				D1	C3	W1	D1	C2	W1	D1	C2	W1	D1	C3	W1
E.lucius	D2	C2	W2	D1	C1	W1				D3	C4	W3	D1	C3	W2			
G. cernuus				D1	C2	W1	D1	C2	W1				D1	C3	W2			
K. caucasica							D1	C4	W2	D1	C1	W1				D1	C5	W2
L. gibbosus	D2	C2	W2	D1	C2	W1	D1	C1	W1	D2	C3	W2	D1	C1	W1			
L. delineatus	D5	C4	W4	D1	C2	W1	D1	C4	W2	D5	C4	W4	D1	C3	W2			
L. aspius	D1	C1	W1	D1	C1	W1A	D1	C2	W1				D1	C2	W1			
L. idus							D1	C1	W1									
M. fossilis										D1	C1	W1						
N. eurycephalus				D1	C1	W1A	D1	C3	W1									
N. fluviatilis	D1	C1	W1	D1	C1	W1	D6	C5	W5				D1	C1	W1	D5	C5	W5
N. gymnotrachelus				D1	C1	W1A	D1	C5	W2	D1	C1	W1	D1	C1	W1	D3	C5	W3
N. kessleri	D1	C1	W1				D3	C5	W3							D3	C5	W3
N. melanostomus							D6	C5	W5							D3	C5	W3
N. syrman							D1	C4	W2							D1	C4	W1
P. cultratus							D3	C4	W3							D1	C5	W2
P. fluviatilis	D3	C3	W3	D3	C4	W3	D2	C5	W3	D3	C4	W3	D5	C5	W4	D3	C5	W3
P. demidoffi																D1	C3	W1
P. glenii	D3	C3	W2	D1	C1	W1				D4	C4	W3	D1	C1	W1			
P. borysthenicus	D1	C1	W1	D1	C3	W1				D1	C3	W2	D1	C3	W2			
P. marmoratus	D3	C3	W3	D1	C1	W1				D2	C3	W2						
P. parva				D1	C3	W1				D1	C2	W2	D1	C2	W1			
P. platygaster	D1	C1	W1	D1	C1	W1				D1	C2	W2						
R. amarus	D5	C3	W3	D4	C5	W3	D1	C2	W1	D6	C5	W5	D6	C5	W5			
R. rutilus	D6	C4	W4	D4	C5	W3	D6	C5	W6	D6	C5	W5	D5	C5	W5	D6	C5	W6
S. lucioperca				D1	C2	W1	D1	C5	W2				D1	C1	W1	D4	C5	W4
S. erythrophthalmus	D4	C3	W3	D4	C5	W3	D5	C5	W5	D4	C4	W4	D5	C5	W4	D3	C5	W3
S. glanis	D1	C1	W1	D1	C1	W1							D1	C2	W1			
S. abaster	D1	C1	W1	D1	C1	W1A	D1	C2	W1				D1	C1	W1	D1	C4	W2
T. tinca	D1	C1	W1	D1	C3	W1				D1	C3	W2	D1	C3	W2			
U. krameri	D1	C1	W1							D3	C2	W2						
V. vimba				D1	C1	W1	D1	C4	W2							D1	C5	W2

Biodiversity

Regarding to biodiversity indices, it is noted that for the whole DDBR and in all three sampling methods, the Shannon-Wiener index (Hs) is around the value of 2 (exception Nordic gillnets fishing) and the equitability index (E) is above the average of 0.5 (except for gill-fishing where it is 0.425) reaching in some cases more than 0.7, which means that lotic ecosystems are stable from the point of view of the ichthyofauna, sometimes over medium (**Table 5**).

Ecological status classes

The parameters used in the ecological characterization of DDBR from the point of view of the ichthyofauna show that they fall into the moderate class, most of the indicators having moderate and good values, but according to the "one out all out" principle there are some indicators in the moderate

state class, which makes us assert that DDBR in 2016 had Moderate state class, indistinct sense is Bad status in the spring-summer seasons and in the autumn season is Moderate status (**Table 6**).

Table 6 Ecological status of DDBR waters using abundance, biomass and biodiversity indices (Hs and E)

	NPUE (number)			CPUE (grams)			Hs			E		
Season	electric	Nordic gillnets	Seine	electric	Nordic gillnets	Seine	electric	Nordic gillnets	Seine	electric	Nordic gillnets	Seine
Spring-Summer	116.1	709.2	1613	4069.6	6875.6	45397.05	2.319	1.03	2.022	0.739	0.295	0.607
	Moderate	Very Good	Very Good	Moderate	Good	Moderate	Very Good	Bad	Good	Good	Bad	Good
Autumn	325.4	357.4	505.3	8485.8	5499.1	15488.9	2.397	1.867	2.088	0.745	0.554	0.665
	Good	Good	Very Good	Good	Good	Very Good	Very Good	Good	Good	Good	Moderate	Good
Total 2016	220.7	533.3	1059.1	6277.7	6187.3	30442.9	2.358	1.449	2.055	0.742	0.425	0.636
	Moderate	Very Good	Very Good	Good	Good	Very Good	Very Good	Moderate	Good	Good	Moderate	Good

CONCLUSIONS

Using 2 complementary methods of sampling for lakes and 1 specific for Razim Lake (seine) according EU fish sampling standard was sampled 6 lakes-complexes of DDBR in 2 periods (after breeding in spring-summer and after recruitments in autumn) of 2016 being captured 45 fish species, mostly limnophilic, which meaning 33% species from 136 total number of fish species present in all DDBR (included marine waters).
Main fish species, eudominant and euconstant is *Alburnus alburnus*, characteristic fish species are *Scardinius erythrophthalmus* and *Rutilus rutilus,* complementary fish species are *Blicca bjoerkna* and *Perca fluviatilis,* mostly species are associate or accessory, but the most of them are accidental in lake-complexes, with differences between seasons and sampling methods.
The main fish resources species is Gibel carp (*Carassius gibelio)* with up to 50 % in sampling with commercial gillnets of 50 mm mesh size knot to knot.
The most increased range in abundance in short time (9 years) was reached by *Perccottus glenii*, new invasive fish species in Danube Delta from accidentally fish species in 2007 till to associate fish species in 2016, with first record in Razim lake in 2016.
In abundance are dominant *Alburnus alburnus, Scardinius erythrophthalmus* and *Blicca bjoerkna* in spring and *Carassius gibelio, Rutilus rutilus* in autumn, but in biomass most dominant are *Cyprinus carpio, Alburnus alburnus, Scardinius erythrophthalmus* and *Silurus glanis* in spring, also *Esox lucius*, *Perca fluviatilis, Sander lucioperca* in autumn with differences between seasons, sampling methods and typology of the lake.
Conservation status of delta lakes using expert judgement in water ecological quality (EQ) classification and WFD principle “one out all out” by using ichthyofauna as biological quality (BQ) indicator results Bad EQ for spring-summer and Moderate for autumn, but for all year long 2016 is Moderate.
This new mechanism of assessing ecological status don’t taking into account the rare fish species in the study area (even some endangered or vulnerable species are neglected), also the trophic relations between the species are omitted, which is why for the more complete studies is needed to use additionally the IBI index method estimation, that should be adapted for large rivers and lakes.

SUMMARY ON ROMANIAN LANGUAGES

Ihtiohauna RBDD este compusă din 136 specii de pești care fac parte din 3 Clase, 20 de Ordine cu 45 de Familii. Dintre acestea, 81 sunt specii dulcicole (de apă stătătoare, curgătoare sau în ambele categorii). În complexele lacustre (apele stătătoare) viețuiesc sau intră pentru reproducere și hrănire 51 specii, iar circa 30 de specii sunt întâlnite doar în apele curgătoare, care pot intra accidental în lacuri, bălți sau canalele din deltă. Din cele 51 de specii limnofile, stagnofil-reofile sau reofil-stagnofile în cele 3 sezoane de eșantionare din 2016 s-au capturat 45 specii lipsind doar câteva specii rare pentru habitatul deltaic, dar in 2016 a fost semnalată pentru prima dată specia *Perccottus glenii* în

complexul Razim-Sinoie, specie cu capacitate mare de răspândire în tot teritoriu RBDD. Principala specie întâlnită este *Alburnus alburnus*, urmată de speciile caracteristice *Scardinius erythrophthalmus* și *Rutilus rutilus,* speciile complementare precum *Blicca bjoerkna* și *Perca fluviatilis,* multe dintre specii fiind asociate sau accesorii, iar cele mai multe sunt specii accidentale, rare în lacurile RBDD. Principala specie ca resursă piscicolă în RBDD este *Carassius gibelio* cu până la 50 % în biomasa eșantioanelor de cercetare cu setci comerciale cu ochi de 50 mm pe latură. Din punct de vedere al ihtiofaunei, statutul ecologic al lacurilor deltaice este unul prost pentru primăvara-vara lui 2016, dar unul moderat pentru toamna aceluiași an, per total fiind un statut Moderat cu un ușor trend spre Bine. Utilizarea unei noi metode de estimare a statutului ecologic al corpurilor de apă din RBDD, utilizând ca indicator ihtiofauna (conform Directivei Cadru Apă) este un pas înainte, dar este necesară validarea pragurilor claselor de calitate, la care un plus l-ar adăuga utilizarea Indexului Biologic de Integritate (IBI), care necesită adaptarea acestuia pentru râuri mari, fluvii și lacuri.

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REFERENCES

***** 2016-2017 – Evaluarea stării de conservare a speciilor de peşti din lacurile RBDD, 4 Rapoarte în 4 Faze / proiect nr. PN 16 28 01 11 04 (coord. Aurel NĂSTASE) al contractului nr. 47N/ANCS/2016, Anexa 1/2017 (executant: INCDDD - Tulcea). Tulcea, România.

***** Innovative instruments for environmental analysis in North Western Black Sea basin (BLACK SEA e-EYE). MIS-ETC No 1475. Joint Operational Programme “BLACK SEA BASIN 2007-2013”. DDNI coordinators Ion Năvodaru. GA1: 35 p.

*****, 2000 EU Water Framework Directive, 2000. Directive of European parliament and of the council 2000/60/EC establishing a framework for community action in the field of water policy. Official Journal of the European Communities 22.12.2000 L 327/1.

*****CEN/TC 230, „Water analysis” 2002 - Water quality – Sampling of fish with gillnets.

Antipa G., 1909. Fauna ihtiologică a României. Edit. Acad., Bucureşti, IX, 294 pp + Tabela XXXI.

Bănărescu P., 1964, Fauna R.P.R., Pisces-Osteichthyes, XIII Ed. Academiei R.P.R., Bucureşti: 962 p.

Bănărescu P., 2004. Situaţia actuală a ihtiofaunei de apă dulce a României sub aspect faunistic, taxonomic şi al protecţiei. Studia Univ. „Vasile Goldiş”, Seria Şt. Vieţii, vol. 14, Arad, pp 7-11.

Botnariuc N., Vădineanu A., 1982. Ecologie. Edit. Did. Şi ped., Bucureşti, pp. 359 – 418 (Anexele 1 – 12) (In Romanian).

Froese R., Pauly D. (eds.), 2018. FishBase. IN: World Wide Web electronic publication. www.fishbase.org, version (12/2018).

Gomoiu M.T., Skolka M., 2001. Ecologie. Metodologii pentru studii ecologice, Ovidius University Press, Constanţa.

Ibram O., Tudor I.-M., Cioacă E., Teodorof L., Năstase A., Tudor M., Cernișencu I., 2015. Metode de analiză şi prezentare a datelor. în Tudor M. (ed.), Ghid metodologic de monitorizare a factorilor hidromorfologici, chimici şi biologici pentru apele de suprafaţă din Rezervaţia Biosferei Delta Dunării, Editura Centrul de Informare Tehnologică Delta Dunării, Tulcea, 124-137.

Karr, James R. (1981). "Assessment of biotic integrity using fish communities". Fisheries. **6**: 21 27.doi:10.1577/1548-8446(1981)006<0021:AOBIUF>2.0.CO;2.ISSN1548-8446.

Kottelat M., 1997. European freshwater fishes. Heuristic checklist. Biologia 52, Suppl.5, 271p.

Kottelat M., Freyhof J., 2007. Handbook of European Freshwater Fishes. Cornol, Switzerland and Freyhof, Berlin, Germany, 646 p.

Moss B.D., Stephen Alvarez C., Becares E., Van De Bund W., Collings S.E., Van Donk E., DE Eyto E., Feldmann T., Fernandez-Alaez C., Fernandez-Alaez M., Franken R.J.M., Garia-Criado F., Gross E.M., Gyllström M., Hansson L.A., Irvine K., Jarvalt A., Jensen J.P., Jeppesen E., Keiresalo T., Kornijow R., Krause T., Künap H., Laas A., Lill E., Lorens B., Ott H.I., Peczula W., Peeters E.T.H.M., Phillips G., Romo S., Russell V., Salujõe J., Sceffer M., Siewersen K., Smal H., Tesch C., Timm H., Tuvikene L., Tonno I., Virro T., Vicente E, Wilson D., 2003. The determination of ecological status in shallow lakes - a tested system (ECOFRAME) for implementation of the European Water Framework Directive. In Aquatic Conservation: Marine and Freshwater Ecosystems 13 (6): 507-549.

Mühlenberg M., 1993. Freilandökologie, 3. überarbeitete Auflage. - UTB für Wissenschaft 595, Quelle & Meyer, Heidelberg, Wiesbaden. 512 p

Nalbant T., 1993. Some problems in the systematics of the genus Cobitis and its relatives (Pisces, Ostariophysi, Cobitidae), Rev. Roum. Biol., Biol. Anim.38-101-110.

Nalbant T., Battes K.W., Pricope F., Ureche D. 2004. First record of the sleeper Perccottus glenii (Pisces: Perciformes: Odontobutidae) in Romania. Travaux du Museum National d'Histoire, vol. XLVII, pp. 279-284.

Năstase A., 2007. First record of Amur sleeper *Perccottus glenii* (Perciformes, Odontobutidae) in the Danube delta (Dobrogea, Romania). Acta Ichtiologica Romanica II, Romanian Ichthyological Society Publication, Sibiu/Romania, 167-174.

Năstase A., 2009. Reseaches of ichthyofauna diversity in the Danube delta for sustainable management of fish resources. PhD thesis, Univ. „Dunărea de Jos", Galaţi, 269p.

Năvodaru I., editor, 2008. Estimarea stocurilor de peşti şi pescăriilor. Edit. Dobrogea, Constanţa, ISBN 978-973-1839-47-9, p. 295. Partea a II-a: Aplicaţii. Evaluarea stării resursei pescăreşti şi capturilor durabile admisibile din Delta Dunării – Irina Cernişencu, Staraş M., Năvodaru I., Năstase A., p. 93 – 138.

Năvodaru I., Năstase A., 2011. What fish and how many there are in Danube delta lakes? Sc. Annalls I.D.D., vol. 17, Tulcea (Romania), p. 71-82.

Nelson J. 2006. Fishes of the World. Fourth Edition. John Wiley & Sons, Inc., Hoboken, New Jersey, 601.

Niculaev S., Anton E., 2008. Atlas al principalelor specii de peşti din Marea Neagră. Pescuitul Marin Românesc. Edit. Virom, Constanţa, 293 p.

Nyberg P., Degerman E., 1988. Standardised test-fishing with survey nets. Inform., Inst. Freshw. Res., Drottningholm 1988 (7). 18 p. (In Swedish with English summary).

Odum E.P., 1975 - Ecology: The link Between the Natural and the Social Sciences. Second Edition. A Holt International Edition, 244 p.

Oţel V., 2001. Actual status of ichthyofauna in the Danube Delta Biosphere Reserve-Roumanian sector: systematics and conservation. The 10-th Europ.Congr. of Ichthyology -Praga, Book of Abstracts: 61.

Oţel V., 2007. Atlasul peştilor din Rezervaţia Biosferei Delta Dunării, Editura Centrul de Informare Tehnologică Delta Dunării, INCDDD, Tulcea, pg. 481.

Oţel V., Bănărescu P., Nalbant T., Baboianu C., 1993. Rezultatele investigaţiilor ihtiologice din teritoriul Rezervaţiei Biosferei Delta Dunării în anul 1992. Analele ICPDD, 2, Tulcea: 145-162.

Oţel V., Bănărescu P., Nalbant T., Bacalu P., Cociaş Ş., 1992. Investigaţii asupra ihtiofaunei dulcicole a Deltei Dunării - Rezervaţia Biosferei în anul 1991. Analele ICPDD, Tulcea: 141-152.

Radu G., Radu E., 2008. Determinator al principalelor specii de peşti din Marea Neagră. Edit. Virom, Constanţa, 558 p.

Sârbu I., Benedek A.M., 2004. Ecologie practică. Edit. Univ. „Lucian Blaga", Sibiu, 260 p.

Schwerdtfeger F., 1975. Ökologie der Tiere Band 3: Synökologie. Paul Parey Verlag. Hamburg, Berlin.

Şindrilariu P.D., Bacalbaşa-Dobrovicl N., Freyhof J., Wolter C., 2002. The juvenile fish community of the Lower Danube and Danube Delta. Brezeanu G. and R. Ştiucă (eds). Internat. Assoc. Danube Res. 34: p 517 – 526.

Ureche D., 2008. Studii ecologice asupra ihtiofaunei în bazinul mijlociu și inferior al râului Siret. Edit. PIM, Iași, 223 p (In Romanian).

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