Aquatic Ecology
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 69 (3), 2017: 349-360

Ecological Status of Fish Fauna in Arms of the Danube Delta (Danube Delta Biosphere Reserve, Romania) at the Beginning of the Third Millennium

Aurel NĂSTASE*, Vasile OŢEL & Ion NĂVODARU

Danube Delta National Institute for Research and Development (DDNIRD), 165 Babadag Street, 820112 Tulcea, Romania; E-mail: aurel.nastase@ddni.ro

Abstract: In the last century, water flow distribution varied in the Danube River and its arms due to its continuous correction and dredging. In the Lower Danube River, 77 fish species are currently recorded. In the Danube Delta arms and the adjacent running waters from the Danube Delta Biosphere Reserve (DDBR), 66 species are recorded, 2/3 of them of commercial value. The fish species are mostly native while six only are exotic species. A newly recorded species (in 2007) is *Perccottus glenii*. Most species are migratory, rheophilous or rheophilous-stagnophilous, a quarter are stagnophilous-rheophilous and another quarter are stagnophilous, which might reach incidentally as near as the headwaters of the Danube River in adjacent channels or in places away from water current, with more aquatic vegetation. Dominant in abundance is *Alburnus alburnus*, followed by *Rutilus rutilus*, *Blicca bjoerkna* and *Neogobius* spp., while dominant in biomass are *Carassius gibelio*, *Cyprinus carpio*, *Esox lucius*, *Leuciscus aspius*, *Sander lucioperca*, *Silurus glanis* and *Blicca bjoerkna*, with some differences for the three sampling types (shoreline, pelagic zone and bottom) studied by different methods. *Alburnus alburnus* is the eudominant and the most frequent species. Fish diversity parameters indicate a stable fish community, with the highest stability indicators in shoreline area.

Key words: ichthyofauna, relative abundance, relative biomass, fish ecological status, biodiversity indices

Introduction

The Chilia, Sulina and Sfantu Gheorghe Arms of the Danube Delta are the major water paths towards the Black Sea. Before branching at Ceatal Chilia, the multi-annual mean flow of the Danube River has been estimated at 6473 m³/s (1921-1980) and 6515 m³/s (1921-2000). The Chilia Arm is 120 km long and has a mean width of 340 m; it is the branch with the greatest contribution to the discharge of the Danube into the Black Sea. In the last century, the share of the Chilia Arm flow has decreased from 72% (1910) to 58% (1990) and 52% during the last few years. On the other hand, the flow share of the Tulcea Arm (17 km long between Ceatal Chilia and Ceatal Sfântu Gheorghe, 296 m mean width) has increased from 38% to 48%. This is due to the increase of the flow shares of both Sfântu Gheorghe Arm and Sulina Arm. The share of the Sfântu Gheorghe Arm (109 km long, 348 m mean width) has increased from 23% to 25%, with further growing trends. The Sulina Arm (63.7 km long plus 8 km in the sea, 146 m mean width) has increased its flow share from 8% to 20-23% due to the continuous correction and dredging. The water flow in the three units of the Danube Delta (Letea, Caraorman and Dranov) has decreased to 5% (1991-2000) plus additional 5% after spring floods, thus only up to 10% of the river flow discharging through the lake complexes (Driga 2004, Gâştescu & Ştiucă 2008).

The Danube River supplies with water all the lakes in the Danube Delta. The diversity and structure of the fish community varies among lakes and

*Corresponding author

can be regarded as a good indicator for the ecological state of lakes. The diversity of fish species in lakes depends on changes in their hydrology and water quality as major factors influencing fish communities. The dominating catches from the lakes varies from eurytopic species ("grey fish") to limnophilous species ("black fish"). This range is associated with the differences in the lake morphometry, type of substrate, hydrological distance from the river and the presence of aquatic vegetation. The condition of the lakes ranges from pristine to moderately affected but, as a whole, the floodplains have maintained their fish communities (Oostemberg et al. 2000, Năvodaru et al. 2002, 2005). The species richness of the Danube Delta lakes is related with the richness of fish species in the Danube as most of the species are potamodromous and are migrating between lakes and the river (entering lakes with floods but receding to river with lower water levels).

The aim of this study was to describe ecological status of river fish fauna from the Danube Delta arms and the adjacent network of natural and artificial channels based on recent fish surveys, information from fisheries and published information.

Materials and Methods

Study area and sampling period

The study area (Fig. 1) included sectors from the Danube River, Chilia Arm, Tulcea Arm, Sfântu Gheorghe Arm, Sulina Arm, Sulina basin (artificial lake connected to Sulina Arm near Sulina), meanders (ample curve parts of the arms), dead arms ("Old Danube" with slow water flow) and natural or artificial canals (Canal 36, Caraorman – Crisan canal). Ichthyofauna was sampled in late August 2009 for most sites and the beginning of September 2009 for the Danube River up to Ceatal Chilia and Chilia Arm except for Sulina basin, which was sampled in October 2009. Additional observations (2003-2014) were also used, mostly from dead arms of the Danube, meanders and natural and artificial channels. These observations provided additional information of the discharges from the Danube or from the arms in various sectors and enriched the main data on the fish fauna from 2009.

Fish sampling

The following fish sampling methods for the Danube and its arms in CPUE (Catch Per Unit Effort) were used:

- Electric fishing with DEKA 7000 electrofisher at multiple sampling points for 10 minutes per site, standardised at individuals/grams per 1 hour (for shoreline to the first threshold of the river).

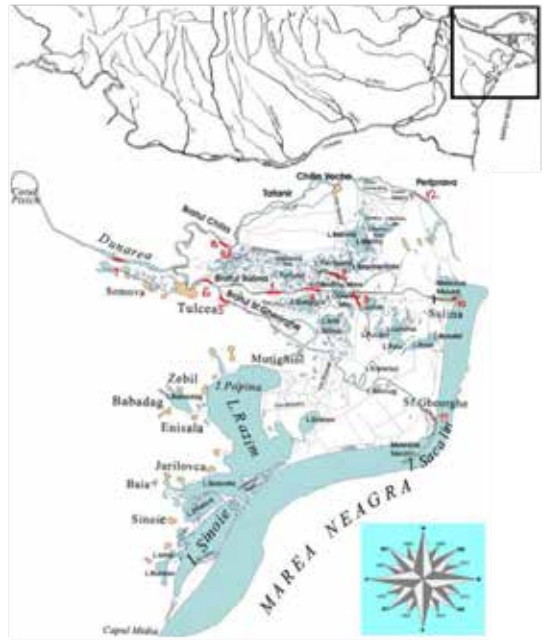

Fig. 1. Study area from the final part of Lower Danube River and three arms in the Danube Delta in 2009 (sampling point from 1 to 12)

- Passive (stationary in low current, 12 hours by night, standardisation at 100 m² gillnets/night) and active (drifting with standardisation at 100 m² gillnet and 1 km drift) gillnets fishing: commercial gillnets or multi-mesh gillnet fishing with Nordic gillnets (30 m length x 1.8 m high each). The Nordic gillnets have 12 randomly joined panels, 2.5 m length of each panel, with multiples meshes: 6, 6, 8, 10, 12, 16, 20, 24, 30, 35, 45 and 55 mm (Nyberg & Degerman 1988, Cernişencu et al. 2008, DIN EN 147, CEN/TC 230 (fishing in the arms and adjacent water bodies, i.e. in pelagic waters).

- Bottom dredge-track fishing done for 200 meters length per site with iron D-shaped frame and bottom chain with bag nets with 7 mm knot to knot mesh size, towed by a 150 hp engine ship.

- Planktonic and benthic net fillets for fry or larvae capture (standardisation to filtered volume individuals/m³ filtered).

- Directly observed species at angling and some traditional fishing tools (cluck, hand cast net, others). It was used only for determination of fish species, without other standardisation.

Other observations included survey of dead individuals or parts of individuals found by us, summary control fishing by experts, direct contact with authorised commercial and amateur fisherman, questionnaires at the first points of fish supply, fish captured with high-voltage of electric fishing device used by poachers arrested by guards at the Danube

Delta Biosphere Reserve (DDBR) and observations of alive individuals jumping out of water (as *Hypophthalmichthys molitrix*), some of them without standardisation.

Taxonomy and Ecology

The fish species were identified following Antipa (1909), Bănărescu (1964, 2004), Oţel et al. (1992), Kottelat (1997), Oţel (2001, 2007), Şindrilariu et al. (2002), Nelson (2006), Kottelat & Freyhof (2007), Năstase (2009), Năvodaru & Năstase (2011) and Froese & Pauly (2016). The frequency of occurrence (F) or constancy (C) was calculated as the proportion of samples containing a species and was used to characterise species distribution (Schwerdtfeger 1975, Şindrilariu et al. 2002). The relative abundance or dominance (D) was calculated as the proportion of a species in the total catch (Muhlenberg 1993, Şindrilariu et al. 2002). Five classes were used for frequency, six classes for abundance or dominance and seven classes for ecological significance (Table 1). Accidental-adventitious category (W1A < 0.001) is a proposal for distinctly accidental fish species (Năstase 2009). Accidental (W1 > 0.001, between 0.001-0.1) is more towards to accessory transitional values but accidental by-catch due to some multiple imperfection causes like bad time for river sampling for some species, gear malfunction, bad natural condition, etc. However, ecological significance indicator should be viewed critically, since sometimes values significantly differ for same periods or conditions.

The Shannon-Wiener Biodiversity Index (H) and Evenness Index were calculated (Odum 1975, Botnariuc & Vădineanu 1982, Gomoiu & Skolka 2001, Sârbu & Benedek 2004).

Results

In the Lower Danube River, 77 fish species are known on the basis of studies by Romanian and Bulgarian authors (Antipa 1909, Drensky 1948, Kolarov 1960, Bănărescu 1964, Undzhiyan 1964, Busnită & Brezeanu 1967, Marinov 1978, Bacalbasa-Dobrovici 1989, Bacalbasa-Dobrovici et al. 1990, Dill 1993, Karapetkova

Table 1. Species dominance, frequency (constancy) and ecological significance classes used in the present study (Odum 1975, Schwerdtfeger 1975, Botnariuc & Vădineanu 1982, Muhlenberg 1993, Gomoiu & Skolka 2001, Şindrilariu et al. 2002, Sârbu & Benedek 2004)

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

Table 2. Fish species not being captured for at least 15 years in the Lower Danube River (LDR). The final stretch of LDR is DDBR (Danube Delta Biosphere Reserve)

No.	Species	Common name	Actual situation in Lower Danube River	Reason of not being captured in DDBR
1	*Ballerus ballerus*	blue bream	very rare	accidental in DDBR
2	*Acipenser nudiventris*	fringebarbel sturgeon	not captured for many years	disappeared
3	*Acipenser sturio*	common sturgeon	not captured for many years	disappeared
4	*Alburnus chalcoides*	Danube bleak	not captured for many years	very rare
5	*Eudontomyzon danfordi*	lamprey	unknown	never in DDBR
6	*Gambusia affinis*	mosquitofish	not acclimatised	never in DDBR
7	*Hucho hucho*	Danube salmon	unknown	never in DDBR
8	*Cobitis elongata*	Balkan loach	present in Nera River	never in DDBR
9	*Gobio gobio*	gudgeon	very rare	never in DDBR
10	*Romanogobio Antipai*	Danube Delta gudgeon	extinct	disappeared

1995, 1998, Karapetkova et al. 1998, Otel 2001, 2007, Pehlivanov 2000, Şindrilariu et al. 2002, Vassilev 2003, Vassilev & Pehlivanov 2003, Velkov et al. 2004, Schiemer et al. 2004, Năvodaru & Năstase 2006, Paraschiv et al. 2006, Polacik et al. 2008). However, ten of them have not been captured during the last 15 years in the area (Table 2). During the period of the present study, totally 66 fish species were captured in the arms of the Danube Delta and adjacent waters. These belonged to two classes, 13 orders and 18 families (Table 3).

It is important to note that some non-native fish species recently recorded in natural environments within the Lower Danube River basin enrich the number of fish species in the river. These are *Perccottus glenii*, with the first record in Romania by Nalbant et al. (2004) and the first record in DDBR by Năstase (2007), and *Ameiurus melas* (Popa et al. 2006). Other exotic species seem to have been adapted to the natural environment; these are *Polyodon spathula* or *Clarias gariepinus* (caught by fishermen) as well as *Ictiobus cyprinellus*, *I. niger* and *I. bubalus* maintained in aquaculture before 1989 (Bacalbasa-Dobrovici 1989).

From 66 fish species captured or observed in the Danube River and its delta arms, nearly 1/3 are without commercial value (small fish) and 2/3 (41 fish species) with commercial value. From these 41 valuable fish species more than 1/3 species have high food and commercial value (high value: sturgeons, shad, zander, catfish, barbel, carp, eel and pike), almost half of species have medium food and market value (like Giebel carp, rudd, roach, tench, perch, bream species, etc.) and almost 1/5 have low economic value such as gobies (Table 3).

Most species are native and six are exotic species (*Perccottus glenii*, *Hypophthalmichthys nobilis*, *H. molitrix*, *Ctenopharyngodon idella*, *Lepomis gibbosus* and *Pseudorasbora parva*). While almost half of the species are migratory, rheophilous or rheophilous-stagnofilous occurred rarely in lakes being found only in rivers. More than 1/4 are stagnofilous-rheophilous and another 1/4 species are stagnophilous but sometimes can reach near the Danube arms and adjacent channels, neighbouring or even into the arms fairway but in area away from current, with more aquatic vegetation (Table 3).

Most adult fishes are benthophagous (about 1/3 of the species), almost 1/4 are omnivores and 1/4 piscivorous (ichthyophagous). The remaining species have other feeding preferences. Most species are tolerant of habitat degradation (more than 1/2 of the species), 1/3 are sensitive to habitat degradation, the remaining 1/7 species are intermediate (Table 3).

The main species (eudominant, very frequent) in the Danube River and arms of the delta and adjacent waters is *Alburnus alburnus* (bleak), while most species are accessory and accidental. There are some differences between sampling methods for the three representative main habitat types: shoreline (from 10 cm to the first threshold depths of 1.5 m), water body and bottom (Table 4). Some species live in the shoreline (small or medium fish which prefer low water current and vegetation) and others prefer the bottom or pelagic open waters, but there are some of them in all water columns.

Species with high relative abundance calculated on the basis of the numbers (CPUE) were bleak, roach, bitterling, bream and Black Sea tadpole-goby; however, most fish species were sporadic, with some differences between the three collecting methods used (Fig. 2). Relative biomass (CPUE) was dominated by pike, giebel carp, asp, zander, roach, bream and goby species (Fig. 3).

Silver carp and bighead carp individuals were captured (with active fishing nets and hand cast nets) or observed by sport fishermen. Individuals of different generations (0+, 1+, 2+ and more stage individual development) were observed, exhibiting that these species have been acclimated in DDBR and reproduce naturally (confirming Staraş & Oţel 1999).

The Danube River and Delta arms and the adjacent water bodies diversity indices indicated a stable ecosystem and a stable fish communities, with values of equitability (E) more than 0.5 for each sampling method. Shannon-Wiener index had higher values, exceeding 1.7–2.0, with the maximum being calculated for the shorelines. All fish diversity indices decreased from the shoreline to the water body and to the bottom, meaning that the shoreline area was the most stable (Fig. 4).

Discussion

The Danube River brings in DDBR (including all complexes of lakes within the Danube Delta) large amounts of water and solids, being the main water way. The Danube River is a large water body with 5-20 meters medium and maximum water depth 45 m in DDBR, where important commercial fisheries is running. This large river is a habitat for large fish species (the biggest recorded fish was a beluga sturgeon, about 1 ton and 8 meters long, see Antipa 1909, Bănărescu 1964, Otel 2007) but normally the body size of captured individuals does not exceed 3 m and 300 kg (sturgeons and cat fish). The reduced individual size of fish in catches is obvious as an effect of overfishing, which more aggressive in last century.

Table 3. Present ecological status of fish species in the Danube Delta arms and adjacent water bodies of the Danube Delta Biosphere Reserve (DDBR). Legend: Economical value: *** = high, ** = medium, * = low, - = none. Origin: n = native, e = exotic. Preference to water current: eury = eurytopic, migr. = migratory, reo = rheophilous, stag = stagnophilous. Salinity: fresh = freshwater, euri = Euryhaline. Adult food: omni = omnivorous, ihti = piscivorous, bent = benthophagous, fito = phytoplaktonophagous, erb = herbivore, zoo = zoophagous, zoopl = zooplanktonophagous, plank = planktonophagous, periphiton = periphitonophagous, molusco = molluscophagous. Tolerance to habitat degradation: tole = tolerant, into = intolerant, inter = intermediary)

No.	Class/Order/Family/Species	Common name	Economical value	Origin	Preference for water current	Salinity	Food of adult	Tolerance to degradation	Actual status in DDBR based on expert judgment
	Class Cephalospidomorphi								
	Order Petromyzoniformes								
	Family Petromyzonidae								
1	*Eudontomyzon mariae*	Ukrainian brook lamprey	-	n	reo	fresh	bent	into	accidental
	Class Actinopterygii								
	Order Acipenseriformes								
	Family Acipenseridae								
2	*Acipenser ruthenus*	Sterlet	***	n	reo	fresh	bent	into	decreasing
3	*Acipenser stellatus*	Starry sturgeon	***	n	migr	euri	bent+ihti	tole	decreasing
4	*Acipenser gueldenstaedtii*	Danube sturgeon	***	n	migr	euri	bent+ihti	tole	decreasing
5	*Huso huso*	Beluga	***	n	migr	euri	ihti	tole	decreasing
	Order Clupeiformes								
	Family Clupeidae								
6	*Alosa tanaica*	Azov shad	**	n	migr	euri	zoo	tole	common
7	*Alosa immaculata*	Pontic shad	***	n	migr	euri	Ihti	tole	decreasing
8	*Clupeonella cultriventris*	Black Sea sprat	*	n	migr	euri	zoopl	tole	common
	Order Salmoniformes								
	Family Salmonidae								
9	*Salmo labrax*	Black Sea salmon	***	n	migr	euri	ihti	into	very rare
	Order Esociformes								
	Family Esocidae								
10	*Esox lucius*	Pike	***	n	stag	fresh	ihti	into	common
	Family Umbridae								
11	*Umbra krameri*	Mudminnow	-	n	stag	fresh	zoopl	into	lacustrine
	Order Cypriniformes								
	Family Cyprinidae								
12	*Abramis brama*	Bream	**	n	stag-reo	euri	bent	tole	common
13	*Ballerus sapa*	White-eyed bream	**	n	reo	fresh	bent	into	common
14	*Blicca bjoerkna*	Silver bream	**	n	stag-reo	fresh	omni	tole	common
15	*Alburnus alburnus*	Bleak	*	n	reo-stag	fresh	plank	tole	common
16	*Leuciscus (Aspius) aspius*	Asp	**	n	reo-stag	fresh	ihti	into	common
17	*Hypophthalmichthys nobilis*	Bighead carp	***	e	stag-reo	fresh	zoopl	tole	common
18	*Hypophthalmichthys molitrix*	Silver carp	***	e	stag-reo	fresh	fito	tole	common
19	*Ctenopharyngodon idella*	Grass carp	***	e	stag-reo	fresh	erbi	tole	rare
20	*Cyprinus carpio*	Carp	***	n	stag-reo	fresh	omni	tole	common
21	*Carassius gibelio*	Prussian (giebel) carp	**	n	eury	fresh	omni	tole	common
22	*Carassius carassius*	Crucian carp	**	n	stag	fresh	bent	inter	lacustrine
23	*Chondrostoma nasus*	Sneep	**	n	reo	fresh	periphiton	into	rare
24	*Barbus barbus*	Barbel	***	n	reo	fresh	bent	inter	rare

Table 3. Continuation

No.	Class/Order/Family/Species	Common name	Economical value	Origin	Preference for water current	Salinity	Food of adult	Tolerance to degradation	Actual status in DDBR based on expert judgment
25	*Romanoobio vladykovi*	White-finned gudgeon	-	n	reo	fresh	bent	tole	common
26	*Romanogobio kessleri*	Kessler's gudgeon	-	n	reo	fresh	bent	tole	very rare
27	*Leucaspius delineatus*	Belica	-	n	stag	fresh	plank	into	lacustrine
28	*Leuciscus idus*	Ide	**	n	reo-stag	fresh	omni	into	common
29	*Pelecus cultratus*	Ziege	**	n	reo-stag	euri	omni	tole	common
30	*Petroleuciscus borysthenicus*	Dnieper chub	-	n	stag	fresh	omni	inter	lacustrine
31	*Pseudorasbora parva*	Stone moroko	-	e	stag-reo	fresh	omni	tole	common
32	*Rhodeus amarus*	Bitterling	-	n	stag-reo	fresh	erbi	into	lacustrine
33	*Rutilus rutilus*	Roach	**	n	eury	fresh	omni	tole	common
34	*Scardinius erythrophthalmus*	Rudd	**	n	stag	fresh	omni	into	common
35	*Tinca tinca*	Tench	**	n	stag	fresh	omni	inter	common
36	*Vimba vimba*	Vimba bream	**	n	reo-stag	euri	bent	inter	common
37	*Squalius cephalus*	Chub	**	n	reo	fresh	ihti	into	accidental
	Family Cobitidae								
38	*Cobitis elongatoides*	Spine loach	-	n	eury	fresh	bent	inter	common
39	*Sabanejewia bulgarica*	Goldside loach	-	n	reo	fresh	bent	inter	common
40	*Misgurnus fossilis*	Weatherfish	-	n	stag	fresh	omni	tole	lacustrine
	Order Siluriformes								
	Family Siluridae								
41	*Silurus glanis*	Wels, Cat fish	***	n	stag-reo	fresh	ihti	into	common
	Order Anguilliformes								
	Family Anguillidae								
42	*Anguilla anguilla*	European eel	***	n	migr	euri	ihti+zoo	tole	very rare
	Order Gadiformes								
	Family Lotidae								
43	*Lota lota*	Burbot	***	n	reo	fresh	ihti	into	accidental
	Order Gasterosteiformes								
	Family Gasterosteidae								
44	*Pungitius platygaster*	Southern nine-spined stickleback	-	n	stag	fresh	bent	inter	lacustrine
45	*Gasterosteus aculeatus*	Three-spined stickleback	-	n	stag	fresh	bent	into	lacustrine
	Order Syngnathiformes								
	Family Syngnathidae								
46	*Syngnathus abaster*	Black-striped pipe fish	-	n	stag-reo	euri	zoopl	tole	common
	Order Perciformes								
	Family Percidae								
47	*Perca fluviatilis*	Perch	**	n	stag-reo	fresh	ihti	tole	common
48	*Sander lucioperca*	Zander	***	n	stag-reo	euri	ihti	into	common
49	*Sander volgensis*	Volga pikeperch	**	n	reo-stag	euri	ihti+zoo	tole	accidental
50	*Gymnocephalus baloni*	Balons ruffe	-	n	reo	fresh	bent	into	common
51	*Gymnocephalus cernuus*	Ruffe	-	n	stag	fresh	bent	tole	lacustrine
52	*Gymnocephalus schraetser*	Schraetzer	-	n	reo	fresh	bent	into	rare
53	*Zingel streber*	Danube streber	**	n	reo	fresh	bent	into	very rare

Table 3. Continuation

No.	Class/Order/Family/Species	Common name	Economical value	Origin	Preference for water current	Salinity	Food of adult	Tolerance to degradation	Actual status in DDBR based on expert judgment
54	*Zingel zingel*	Zingel	**	n	reo	fresh	bent	into	rare
	Family Gobiidae								
55	*Babka gymnotrachelus*	Racer goby	-	n	stag	euri	bent	tole	common
56	*Benthophilus nudus*	Black Sea t adpole-goby	-	n	stag-reo	euri	bent	tole	common
57	*Benthophiloides brauneri*		-	n	stag-reo	euri	bent	into	very rare
58	*Knipowitschia caucasica*	Caucasian dwarf goby	-	n	stag	euri	bent	tole	lacustrine
59	*Neogobius fluviatilis*	Monkey goby	*	n	stag-reo	euri	bent	tole	common
60	*Neogobius melanostomus*	Round goby	*	n	stag-reo	euri	molusco	tole	common
61	*Ponticola eurycephalus*	Ginger goby	*	n	stag-reo	euri	ihti-bent	into	common
62	*Ponticola kessleri*	Bighead goby	*	n	stag-reo	euri	ihti	into	common
63	*Proterorhinus semilunaris*	Tubenose goby	-	n	stag	euri	bent	tole	common
	Family Centrarchidae								
64	*Lepomis gibbosus*	Pumpkinseed	-	e	stag	fresh	Ihti	tole	common
	Family Odontobutidae								
65	*Perccottus glenii*	Amur sleeper	-	e	stag	fresh	ihti	tole	increasing
	Order Atheriniformes								
	Family Atherinidae								
66	*Atherina boyeri*	Big-scale sand smelt	-	n	migr	euri	bent	tole	rare
		***	16	e6					
		**	19	n60					
		*	6						
		-	25						

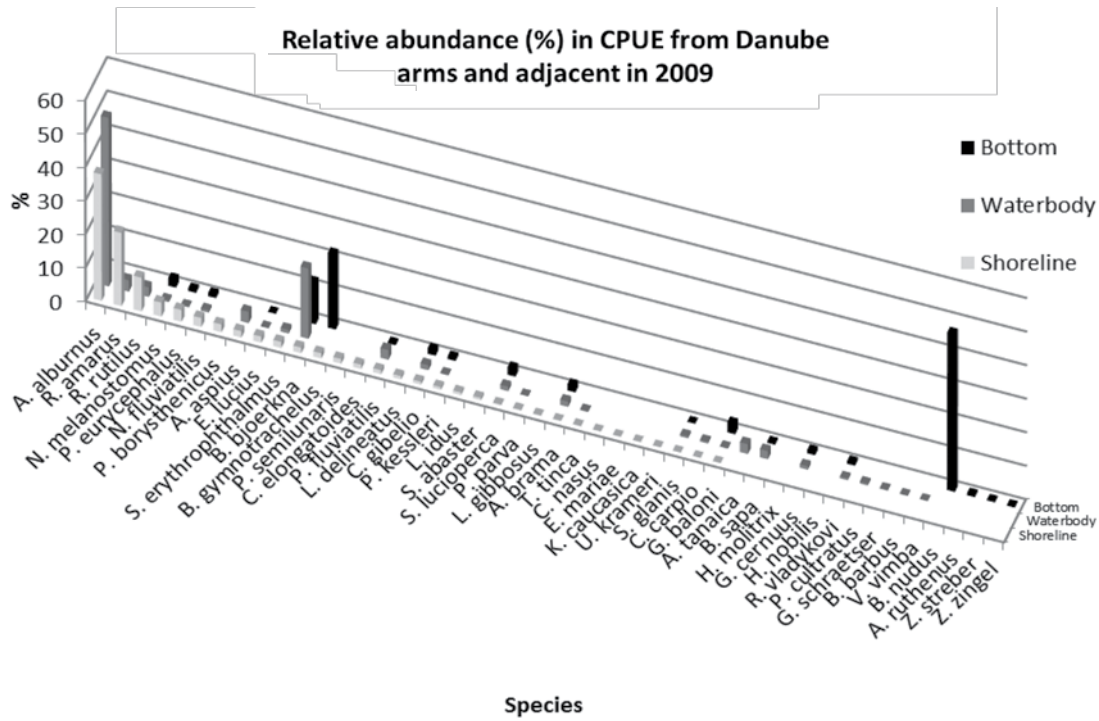

Fig. 2. Relative abundance (CPUE) in the Lower Danube River and Delta arms in 2009

Table 4. Ecological significance of fish species from the Danube River and Delta arms: the classes "Present, Common, Rare, Very rare or Accidental" were added for species which could not be standardised; C = Frequency (constancy), D = dominance and W = ecological significance

	Shoreline			Waterbody (Pelagic)			Bottom (benthic)		
Species	**D class**	**C class**	**W class**	**D class**	**C class**	**W class**	**D class**	**C class**	**W class**
Abramis brama	D1	C1	W1	D2	C2	W2	D2	C2	W2
Ballerus sapa				D3	C3	W2	D1	C2	W1
Acipenser ruthenus							D1	C2	W1
Alburnus alburnus	D6	C5	W6	D6	C4	W6			
Alosa tanaica				D3	C2	W2			
Hypophthalmichthys nobilis	Present			Present					
Leuciscus aspius	D2	C3	W2	D3	C3	W2			
Barbus barbus				D1	C1	W1			
Bentophilus nudus							D6	C3	W5
Blicca bjoerkna	D2	C4	W2	D6	C5	W5	D5	C4	W4
Carassius gibelio	D1	C4	W2	D2	C2	W2	D2	C3	W2
Chondrostoma nasus	D1	C1	W1A						
Cobitis elongatoides	D2	C3	W2						
Cyprinus carpio	D1	C1	W1	D1	C1	W1			
Esox lucius	D2	C4	W2	D1	C1	W1A	D1	C1	W1A
Eudontomyzon mariae	D1	C1	W1A						
Romanoobio vladykovi				D1	C2	W1	D1	C2	W2
Gymnocephalus baloni	D1	C1	W1A	D1	C1	W1A	D3	C2	W2
Gymnocephalus cernuus				D2	C2	W2	D2	C2	W2
Gymnocephalus schraetser				D1	C1	W1A			
Hypophthalmichthys molitrix	Present			Present					
Knipowitschia caucasica	D1	C1	W1A						
Lepomis gibbosus	D1	C2	W1						
Leucaspius delineatus	D1	C2	W2						
Leuciscus idus	D1	C3	W2						
Ponticola eurycephalus	D3	C3	W3	D1	C1	W1A	D1	C1	W1
Neogobius fluviatilis	D3	C4	W3	D1	C2	W1	D2	C2	W2
Babka gymnotrachelus	D2	C4	W2				D6	C3	W4
Ponticola kessleri	D1	C2	W2	D1	C1	W1A	D1	C1	W1
Neogobius melanostomus	D4	C4	W3	D1	C1	W1	D3	C2	W2
Pelecus cultratus				D1	C1	W1			
Perca fluviatilis	D2	C4	W2	D3	C2	W2	D1	C2	W1
Petroleuciscus borysthenicus	D3	C3	W2						
Proterorhinus semilunaris	D2	C3	W2						
Pseudorasbora parva	D1	C3	W1	D1	C1	W1A			
Rhodeus amarus	D6	C4	W5	D3	C2	W2			
Rutilus rutilus	D5	C4	W4	D3	C2	W2			
Sander lucioperca	D1	C2	W1	D2	C2	W2	D3	C3	W2
Scardinius erythrophthalmus	D2	C3	W2	D2	C2	W2			
Silurus glanis	D1	C2	W1A	D1	C1	W1	D2	C2	W2
Syngnathus abaster	D1	C3	W2						
Tinca tinca	D1	C2	W1	D1	C1	W1A			
Umbra krameri	D1	C1	W1A						
Vimba vimba				D1	C1	W1A			
Zingel streber							D1	C1	W1
Zingel zingel							D1	C1	W1

Table 4. Continuation

Species	Shoreline			Waterbody (Pelagic)			Bottom (benthic)		
	D class	C class	W class	D class	C class	W class	D class	C class	W class
Perccottus glenii	Present								
Anguilla anguilla							Rare		W1
Alosa immaculata				Present					
Ctenopharyngodon idella				Present					
Squalius cephalus				Accidental		W1A			
Lota lota				Accidental		W1A			
Misgurnus fossilis	Accidental		W1A						
Romanogobio kessleri							Rare		W1
Pungitius platygaster	Accidental		W1A						
Gasterosteus aculeatus	Accidental		W1A						
Sabanejewia bulgarica							Common		
Sander volgensis				Accidental		W1A			
Carassius carassius	Accidental		W1A						
Clupeonella cultriventris				Rare			Rare		
Acipenser stellatus				Present			Present		
Huso huso				Present			Present		
Acipenser gueldenstaedtii				Present			Present		
Atherina boyeri				Present					
Salmo labrax							Very rare		
Bentophiloides brauneri							Very rare		

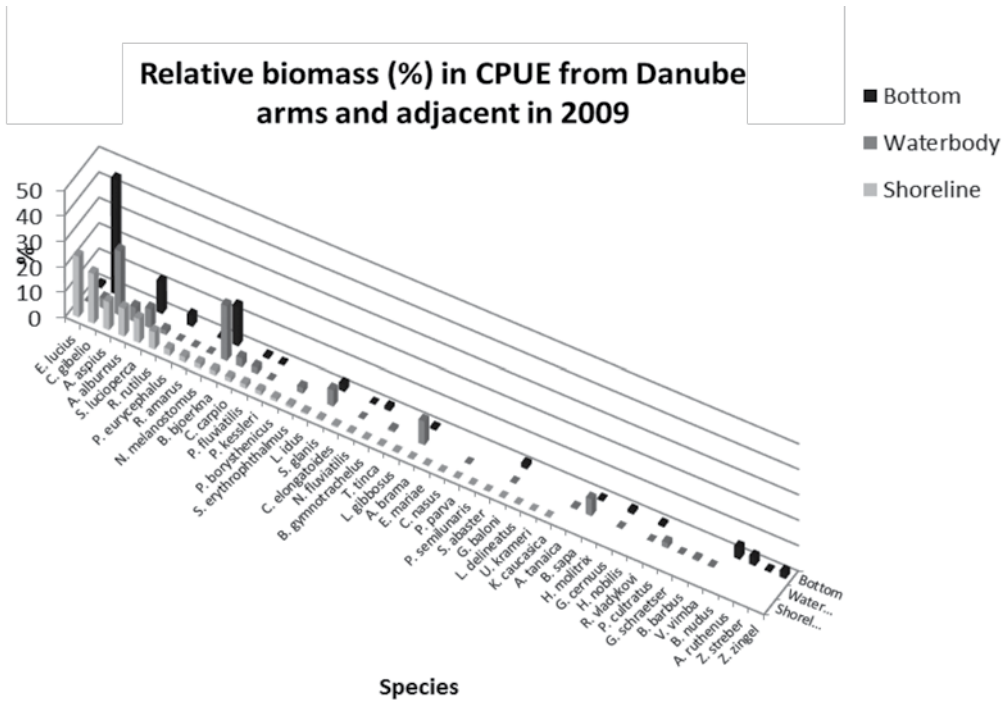

Fig. 3. Relative biomass (CPUE) in the Danube River and Delta arms in 2009.

In the present study, large fish like catfish and sturgeons were observed only from pit areas and were difficult to sample (other sampling methods are needed for pit areas). However, large individuals are rare. More accurate sampling methods are needed especially for bottom sampling. Probably one of these methods is bottom electrical fishing (as seen from arrested poachers' captures). The extreme depletion of sturgeons (two species out of six have not been recorded since 1960) was caused by many,

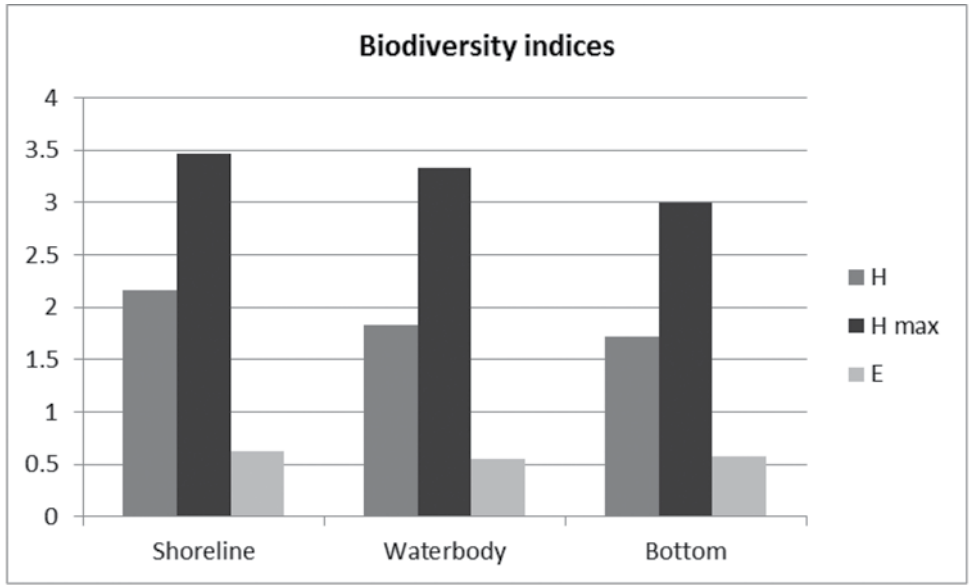

Fig. 4. Biodiversity indices in the Lower Danube River and Delta arms in 2009. H = Shannon-Wiener biodiversity index, Hmax = maximal biodiversity index, E = Evenness equitability index

primarily anthropogenic factors, which affected the Danube River and the Black Sea continental shell during the last decades. Bacalbasa-Dobrovici (1997) recommended measures necessary for saving anadromous sturgeons in the lower Danube. More studies to evaluate the health of the stock using YOY (young-of-the-year) estimation (Paraschiv et al. 2006) are needed, especially after enforcing the ten-year protection since 2006 and continuing implementation of some beneficial measures for sturgeon species protection, like hatchery programmes, perspective to re-opening the migration route at Iron Gate dam and other measures (Suciu et al. 2008, 2013).

Our results show that populations of gobies have been increasing as compared to the period before 1991-1992 (Otel et al. 1992). This is valid especially for *Neogobius melanostomus*, which has increased its number because of the explosion of *Dreissena* spp. in the Danube River, which are the main food sources of this goby.

About 77 species of fresh- and brackish water fishes are known from Romania (Bănărescu 1967), of which 73 species are found in the Romanian sector of the Danube River and its adjacent water bodies (Bacalbasa-Dobrovici 1989). The present list is more comprehensive, since Busnită & Brezeanu (1967) presented a list of 66 fish species belonging to 19 families from the Romanian Danube. Out of the 77 fish species described from the Lower Danube River (from Iron Gates to DDBR), ten are with unknown status due to their rarity, one exotic species is introduced through fish culture into natural environment and 66 fish species present also in Danube Delta arms. Almost 2/3 species are of commercial value; most of them are native and six exotic species are known (*Perccottus glenii*, *Hypophthalmichthys nobilis*, *H. molitrix*, *Ctenopharyngodon idella*, *Lepomis gibbosus* and *Pseudorasbora parva*).

The present study reveals *Alburnus alburnus* (bleak) as dominating species for the Danube Delta arms. There is a great variation in the occurrence of among fish species, which reflect their diversity and variation in the preferences to environmental factors as well as the heterogeneity of habitats in the delta landscape. The recorded species richness and the diversity indices indicate a relatively stable condition of the fish community in the Danube Delta. Nevertheless, the detected changes of the occurrence, numbers and individual size of several fish species show that the monitoring of the fish fauna should continue in order to detect further changes and plan appropriate management measures.

Acknowledgements: This work was funded by the Romanian Government through "Nucleu Programme 2009-2011". We are grateful to the DDNIRD technicians, fishermen and crew for their help in the field.

References

Antipa G. 1909. Fauna ichtiologica a României. (Publicaţiunile Fondului Vasile Adamachi, 16), Bucureşti: Edit. Acad., 294 p.

Bacalbasa-Dobrovici N. 1997. Endangered migratory sturgeons of the lower Danube River and its delta. Environmental Biology of Fishes 48: 201–207.

Bacalbasa-Dobrovici N. 1989. The Danube River and its Fisheries. In: Dodge D. P. (Ed.) Procedings of the International Large River Symposium. Can. Spec., Publ. Fish, Aquat. Sci. 106: 455-468.

Bacalbasa-Dobrovici N., Nicolau N. & Nitu C. 1990. Fisheries management and the hydraulic regime in the Danube Delta. IN: Van Densen W.L.T., Steinmetz B. & Hudges R.H. (Eds.) Management of freshwater fisheries: proceedings of a symposium organized by the European Inland Fisheries Advisory Commission, Göteborg, Sweeden, 31 May–3 June 1988. Pudoc, Wageningen. pp. 447-461.

Bănărescu P. 1964. Fauna R.P.R., vol. 13. Pisces – Osteichthyes. Bucureşti: Edit. Acad. R.P.R.. 962 p.

Bănărescu P. 1967. Analiza zoogeografică a faunei din sectorul romanesc. In: Limnologia sectorului românesc al Dunării. Studiu monografic. Bucharest, Academia Republicii Socialiste România, pp. 473–499.

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 14: 7-11.

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

Busnita T. & Brezeanu G. 1967. Ihtiofauna. In: Limnologia sectorului romanesc al Dunării. Ed. Acad. RSR, 651 p.

Cernişencu I., Staraş M., Năvodaru I. & Năstase A. 2008. Aplicaţii. Evaluarea stării resursei pescăreşti şi capturilor durabile admisibile din Delta Dunării, IN: Năvodaru I., editor, Estimarea stocurilor de peşti şi pescăriilor. Edit. Dobrogea, Constanţa, pp. 93–138.

Dill W.A. 1993. Inland fisheries of Europe. EIFAC Technical Paper. No. 52 Suppl. Rome, FAO. 281 p.

Drensky P. 1948. Synopsis and distribution of fishes in Bulgaria. Ann. de l`Univ. de Sofia, Fac. Phys. Math. 44 (3): 11-71. (In Bulgarian).

Driga B.V. 2004. Delta Dunării. Sistemul circulaţiei apei. Acad. Română, Institut. De geografie, Edit. Casa Cărţii de Ştiinţă, Cluj-Napoca, 256 p.

Froese R. & Pauly D. (Eds.) 2016. FishBase. World Wide Web electronic publication. www.fishbase.org, version (03/2016).

Gâştescu P. & Ştiucă R. 2008. Delta Dunării Rezervaţie a Biosferei. Edit. CD Press, 400 p.

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

Karapetkova M. & Zivkov M. 1995. Fishes in Bulgaria. Sofia: Gea-Libris, 247 p. (In Bulgarian).

Karapetkova M. 1998. Class Pisces (Fishes). In: Michev T., Georgiev B. B., Petrova A. & Stoineva M. (Eds.) Biodiversity of the Srebarna Biosphere Reserve. Checklist and Bibliography. Sofia: Context & Pensoft, pp. 84-85.

Karapetkova M., Zivkov M. & Alexandrova-Kolemanova K. 1998. The freshwater fishes of Bulgaria. In: Bulgaria's Biological Diversity: Conservation Status and Needs Assessment, Vol. 1. (C. Meine, ed.), Pensoft Publishers, pp. 375-393.

Kolarov P.1960. A rare finding in the Danube River – lamprey *Eudontomyzon danfordi* Regan, 1911. Priroda (Nature), 3: 70 p.

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.

Marinov B. 1978. Die Fischfauna im bulgarischen Donauabschnitt und ihre Bedeutung fuer die Wirtschaft. In: Limnologie des bulgarischen Donauabschnitts (Russev, B. & W. Naidenow, eds.), Bulgarische Akademie der Wissenschaften, Sofia, 201-228. (In Bulgarian).

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

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 47: 279-284.

Năstase A. 2007. First record of Amur sleeper *Perccottus glenii* (Perciformes, Odontobutidae) in the Danube delta (Dobrogea, Romania). Acta Ichtiologica Romanica 2: 167-174.

Năstase A. 2009. Researches of ichthyofauna diversity in the Danube Delta for sustainable management of fish resources. PhD thesis, Univ. „Dunărea de Jos", Galaţi, 269 p. (In Romanian).

Năvodaru I., Buijse A. D. & Staraş M. 2002. Effects of hydrology and water quality on the fish community in Danube Delta lakes, Internat. Rev. Hydrobiol. 87: 329-348.

Năvodaru I., Staras M., Buijse A. D. & De Leew J. J. 2005. Changes in fish population in Danube delta lakes: effects of hydrology and water quality change. Review of results and potential for rehabilitation. Ecohydrology and Hydrobiology 5(3): 245–256.

Năvodaru I. & Năstase A. 2011. Quantitative inventory of fish fauna from Danube River around Cama Dinu islets. Scientific Annals of the Danube Delta Institute 12: 97-102.

Năvodaru I. & Năstase A. 2011. What fish and how many there are in Danube delta lakes? Scientific Annals of the Danube Delta Institute 17: 71-82.

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

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

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

Oosterberg W., Buijse A. D., Coops H., Ibelings B. W., Menting G. A. M., Staraş M., Bogdan L., Constantinescu A., Hanganu J., Năvodaru I. & Török L. 2000. Ecological gradients in the Danube Delta lakes (Present state and man-induced changes). In: RIZA report 2000.015, pp. 119-138.

Oţel V., Bănărescu P., Nalbant T. H., Bacalu P. & Cociaş Ş. 1992. Investigaţii asupra ihtiofaunei dulcicole a Deltei Dunării în anul 1991. Scientific Annals of the Danube Delta Institute 1: 145-153.

Oţel V. 2001. Actual status of ichthyofauna in the Danube Delta Biosphere Reserve-Romanian sector: systematics and conservation. In: 10-th European Congress of Ichthyology-Praga, Book of Abstracts: pp. 61.

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

Paraschiv M., Suciu R. & Suciu M. 2006. Present state of sturgeon stocks in the Lower Danube River, Romania. Proceedings 36th International Conference of IAD. Austrian Committee Danube Research, Vienna. pp. 152-158.

Pehlivanov L. 2000. Ichthyofauna in the Srebarna Lake, the Danube Basin: state and significance of the management and conservation strategies of this wetland. International Association for Danube Research 33: 317-322.

Polacik M., Trichkova T., Janac M., Vassilev M. & Jurajda P. 2008. The ichthyofauna of the shoreline zone in the longitudinal profile of the Danube River, Bulgaria. Acta Zoologica Bulgarica 60(1): 77-88.

Popa L. O., Popa O. P., Pisică E. I., Iftime A., Matacă S., Diaconu F. & Murariu D. 2006. The first record of *Perccottus glenii* Dybowski, 1877 (Pisces: Odontobutidae) and *Ameiurus melas* Rafinesque, 1820 (Pisces: Ictaluridae) from the Romanian sector of the Danube. Travaux du Muséum National d'Histoire Naturelle «Grigore Antipa» 49: 323–329.

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

Schiemer F., Guti G., Keckeis H. & Staras M. 2004. Ecological status and problems of the Danube River and its fish fauna: a review. In: Proceedings of the second symposium on the management of large rivers for fisheries, Vol. I, Welcomme R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2004/16, pp. 273-279.

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

Staraş M. & Oţel V. 1999. Evidences regarding the natural spawning of the silver carp species (*Hypophthalmichthys molitrix* Val.) in the Danube River. Scientific Annals of the Danube Delta Institute 7: 183-187.

Suciu R. 2008. Sturgeons of the NW Black Sea and the Lower Danube River Countries. International Expert Workshop on CITES Non-Detriment Findings, Cancun, Mexico, November 17–22, 2008, 27 pp.

Suciu R., Onără D., Paraschiv M., Holoştenco D. & Hontz Ş. 2013. Sturgeons in the Lower Danube River (Danube News No. 28). Bulletin of the International Association for Danube Research 15: 10-12.

Şindrilariu P. D., Bacalbaşa-Dobrovici N., Freyhof J. & Wolter C. 2002. The juvenile fish community of the Lower Danube and Danube Delta. Brezeanu G. and R. Ştiucă (eds). International Association for Danube Research 34: 517 – 526.

Undzhiyan E. 1964. On a finding of a lamprey in the Danube. Izv. Nar. Muzei, Russe, 1.

Vassilev M. 2003. Spawning sites of Beluga sturgeon (*Huso huso* L.) located along the Bulgarian-Romanian Danube River stretch. Acta Zoologica Bulgarica 55(2): 91-94.

Vassilev M. & Pehlivanov L. 2003. Structural changes of Sturgeon catches in the Bulgarian Danube section. Acta Zoologica Bulgarica 55(3): 97-102.

Velkov B., Pehlivanov L. & Vassilev M. 2004. *Umbra krameri* Walbaum, 1792 (Pisces, Umbridae): a reinstated species for the Bulgarian ichthyofauna. Acta Zoological Bulgarica 56(2): 233-235.

Received: 12.04.2016
Accepted: 18.08.2017