Analysis of diet of piscivorous fishes in Bovan, Gruža and Šumarice Reservoir, Serbia

Pavlović M.[1]; Simonović P.[2]; Stojković M.[3]; Simić V.[1*]

Received: August 2013 Accepted: June 2015

Abstract

Diet of adult pikeperch *Sander lucioperca*, Eurasian perch *Perca fluviatilis*, northern pike *Esox lucius* and European catfish *Silurus glanis* as top predators in aquatic ecosystems in Serbia was investigated during 2011, in order to understand their relationship to their prey and to investigate their food consumption, feeding and assimilation rate, cannibalism, and habitat segregation. Northern pike, Eurasian perch, pikeperch and European catfish were collected in three reservoirs in Serbia. Prey items that were found in all four species included fish, mollusks, insect larvae and crustaceans. A total of 11 taxonomic groups were found, but they were not all represented as a prey in all four species. Eurasian perch were present in the diet of all four predatory fish species, mollusks were recorder only in that of European catfish. Roach *Rutilus rutilus* and bleak *Alburnus alburnus* were prey to all species, except northern pike. Chub *Squalius cephalus*, bream *Brama brama* and *Gammaridae* were found only in stomach of pikeperch. Analysis of similarity showed that difference for diet between predatory fish species was significant for their due to significant differences existing between northern pike and pikeperch and northern pike and Eurasian perch.

Keywords: Predation, Freshwater fish, Diet, Reservoirs, Stomach content

1- University of Kragujevac, Faculty of Science, Institute of Biology and Ecology, Radoja Domanovića 12, 34000 Kragujevac, Serbia.

2- University of Belgrade, Faculty of Biology, Institute of Zoology, Studentski trg 16, 11000 Belgrade, Serbia.

3- University of Niš, Faculty of Science and Mathematics, Department of Biology and Ecology, Višegradska 33, 18000 Niš, Serbia.

*Corresponding author's email: simic@kg.ac.rs

Introduction

Piscivorous fish are top predators in many aquatic systems and the knowledge on the size of their prey is essential to identify their potential impact in structuring populations at lower trophic levels. Northern pike (*Esox lucius* L.), pikeperch (*Sander lucioperca* L.), Eurasian perch (*Perca fluviatilis* L.) and occasionally eel (*Anguilla anguilla* L.) are common piscivores in fish communities of many European lakes with low water transparency (Dörner *et al*., 2007). Predation by piscivorous fish is an important structuring force in freshwater ecosystems and a number of studies have shown that piscivores may have strong effects down on both pelagic and benthic food chains (Turesson and Brönmark, 2007).

Predation by piscivores may affect both density and size structure of their prey populations (Wysujack and Mehner, 2005), being often the major source of mortality for fish (Link and Garrison 2002). Predation is a key factor that structures communities and drives food web dynamics. Natural communities often have multiple predators (Carey and Wahl, 2010). Effects of piscivores on prey population density and size structure may, in turn, result in changes in community dynamics (Turesson *et al*., 2006) and play an important part in the structure and the dynamics of multispecies communities (Sumontha *et al*., 2008).

Most species of piscivorous fish pass through a phase feeding on smaller food items such as zooplankton and benthic invertebrates before switching to a fish diet (Persson and Brönmark, 2002). When foraging, predators typically use different foraging modes. Predators have generally been categorized as either sit-and-wait, i.e., ambush predators, or actively searching foragers (Eklöv, 1992). Top predators can have different foraging modes that may alter their interactions and effects on food webs (Carey and Wahl, 2010). Northern pike are ambush predators that rely on aquatic vegetation for cover. Therefore, their density is highest in the littoral zone of shallow weeded lakes and streams (Haught and Von Hippel, 2011). Eurasian perch is a sight-dependent diurnal predator, unlike pikeperch. Eurasian perch and pikeperch are actively searching predators. Northern pike and pikeperch are solitary foragers, while Eurasian perch is known to hunt co-operatively (Turesson and Brönmark, 2004). Plankton is the primary source of food for small-sized Eurasian perch. As Eurasian perch grow, they switch to larger food items, such as benthic macroinvertebrates, before eventually turning to piscivory at a length of 13-20 cm. As a piscivore, Eurasian perch is able to consume its former competitors (Linløkken *et al*., 2007). Pikeperch has been described as a piscivorous ambush-pursuit predator patrolling the pelagic zones of lakes (Dörner *et al*., 2007). European catfish is the world's third largest (and the largest European) inland water species (Syväranta *et al*.,

2010) and is also an actively searching predator. European catfish has strictly nocturnal feeding activity and during day time it is located in the littoral zone and spends extended periods of the day hidden in concealed habitats (Alp *et al*., 2011).

The aims of this study were to investigate the diet of adults in four piscivorous fish species (pikeperch, Eurasian perch, northern pike, and European catfish), and to evaluate whether the abundance and biomass of predators are correlated to each other.

Materials and methods

Study site

The study included three reservoirs in Serbia: Bovan, Gruža and Šumarice (Fig. 1), the latest one being the only with northern pike and with no European catfish. Morphometric characteristics and trophic status of studied reservoirs are given in Table 1. The fish community in the Šumarice Reservoir consisted mainly of rudd *Scardinius erythrophthalmus*, roach *R. rutilus*, pumpkinseed *Lepomis gibbosus* and brown bullhead *Ictalurus nebulosus*. In the Bovan Reservoir, dominant species are bream *B. brama*, Eurasian perch, pikeperch, roach and Prussian carp *Carassius gibelio*. Four species dominated in the fish community of the Gruža Reservoir: Prussian carp, pikeperch, roach and bream.

Table 1: Morphometric characteristics and trophic status of the studied lakes.

	Surface (km^2)	Altitude (m)	Max depth (m)	Trophic status
Bovan Reservoir	4.0	267	50	eutrophic (Ostojić, 2006)
Šumarice Reservoir	0.22	220	14	eutrophic (Ranković *et* (*al*. 2006
Gruža Reservoir	9.34	273	35	eutrophic (Rankovi and Simić, 2005)

Figure 1: Geographic location of the investigated reservoirs.

Stomach content analyses

Northern pike, Eurasian perch, pikeperch and European catfish were collected from three reservoirs in Serbia, from May to the end of September 2011. These four species are the dominant piscivorous species in Serbian reservoirs. Fish were sampled using gillnets (of mesh size from 10 to 120 mm), offshore, and electrofishing in the littoral zone. Fish were sampled using the DC electrofisher ”Aquatech” IG 1300 (2.6 kW, 80-470 V). Each fish was measured to the nearest mm in total lenght (TL) and to the nearest g in weight. Immediately after capture and measuring fish were dissected and their gut was removed, preserved in 4% formalin and transported to laboratory. Analysis of the stomach contents was accomplished after Elliot *et al*. (1996). Stomachs were dissected and prey items were sorted, weighted to the nearest g, identified tothe lowest possible taxonomic level, counted under binocular and preserved in 70% ethanol. In cases when a prey item was largely digested, pharyngeal teeth (cyprinids), opercular bones, vertebrae, scales and position of the eyes and mouth were used for identification.

Percent in frequency of occurrence (F.O%), percent by number (N%), and percent by weight (W%) were calculated for each prey type for each of four species (Hyslop 1980). The main food items were identified using the Index of Relative Importance (IRI), calculated according to Pinkas *et al*. (1971) by combining F.O%, N% and W%:

$$IRI = (W\% + N\%) \times F.O\%$$

Percent IRI (IRI%) was used to facilitate interpretation and was calculated by summing IRI values of all prey types and calculating percent of each prey type's contribution to the total (Cortés, 1997). Empty stomachs were excluded from the calculation.

Statistical analyses

To explore diet similarities among and within these four species, we applied multivariate techniques, since diet of piscivorous fish included several prey taxa. First, we divided each fish species in two classes based on their total length (Table 3) and checked similarities in diet. We made the classification by taking the exact values closest to the mean values of the TL of all individuals of each species from all researched reservoirs. IRI% of each prey taxon in the diet was used as input data. IRI% values were logarithmically transformed ($\log_{10}[x+1]$) prior to analysis. We used Bray-Curtis similarity coefficient to generate similarity matrix, which was then used as an input for nonmetric multidimensional scaling ordination (MDS, PRIMER v.6, Clarke and Gorley, 2006), in order to visualize the relationship among and within fish species in the 2-dimensional space. In addition, to analyze the differences in diets among fish species and size classes, we used a multivariate analysis of similarities (ANOSIM, PRIMER v.6, Clarke and Gorley, 2006) that tests differences among and within comparison units based on the Bray-Curtis similarity matrix (Clarke *et al*., 2005).

Biomass estimates typically begin with an estimate of the population size, which is then multiplied by a mean weight for the population to derive biomass. This can be expressed in terms of total biomass for a population, but more often it is expressed as weight per unit area (Anderson and Neumann, 1996), as we implemented. Abundance is estimated per unit area, too. The relationship between an abundance and biomass of predatory species was analyzed using the Pearson's Correlation Coefficient (R) calculated using SPSS 16.0 statistical package programs for Windows (SPSS Inc., Chicago, IL, USA).

Results

The total number of analysed piscivorous fish was 105. Only three fish (2.85%) had empty stomach. The total length and weight of the analyzed species are shown in Table 2.

Table 2: The total length (TL-cm) and weight (W-g) of the analyzed species (mean±SD)

	Bovan Reservoir		**Gruža Reservoir**		**Šumarice Reservoir**	
	TL	**W**	**TL**	**W**	**TL**	**W**
Pikeperch	42.25 ± 9.03	614.33 ± 549.87	42.32 ± 5.40	701.04 ± 842.28	43.14 ±3.23	627.42 ± 143.08
Eurasian perch	19.20 ± 4.02	109.80 ± 49.64	17.42 ± 6.87	99.71 ± 120.19	28.00 ± 2.33	346.00 ± 74.73
Northern pike	-	-	-	-	32.33 ± 9.61	281.11 ± 257.39
European catfish	65.93±20.66	2347.75 ±2236.85	72.50±24.74	3188.00 ±2916.108	-	-

Prey items that were found in all four species included fish, mollusks, insect larvae and crustaceans. A total of 11 taxonomic groups were found, but they are not all represented as a prey in all four species. The results of percentages of the IRI of prey items are presented in Table 3. The relative importance of prey categories (IRI%) indicated differences among the species. Pikeperch (TL>40 and TL≤40) from the Bovan Reservoir had bleak as dominant prey (75.66%, 72.13%), while roach had minor importance for this species with %IRI value 6.04% and 2.5%. Pikeperch (TL≤ 0) from Bovan Reservoir only had a chub in their guts (7.48%). Eurasian perch from Bovan Reservoir fed mainly with bleak (67.93%), with low participation of roach (11.47%). European catfish (TL>60 and TL≤60) had the largest IRI for Eurasian perch (90.46%, 85.09%), while roach and river snail *Viviparus viviparus* had low participation in diet. Predatory fishes from the Gruža Reservoir had the following values of the IRI. Pikeperch (TL≤40) consumed primarily bleak (81.41%), followed by roach (18.41%). Other class of pikeperch had unidentified units of Cyprinidae as dominant prey. Eurasian perch (TL≤20) had as dominant prey fishes from their own family (Percidae–58.65%) and roach (41.34%), while other class of the same species fed mainly with Eurasian perch (56.93%), followed with bleak and roach. European catfish (TL>60) diets were dominated by Eurasian perch (41.74%), bleak (27.54%) and roach (26.17%). European catfish (TL≤60) had roach as dominant prey (42.82%) and zebra mussel *Dreissena polymorpha* as least represented prey (17.3%). In the Šumarice Reservoir pikeperch (TL>40) fed mainly with bleak (49.91%), followed with rudd and Eurasian perch. Pikeperch (TL≤40) had more uniform diet (roach–30.97%, rudd– 30.25%, and Eurasian perch–38.94%). Both classes of Eurasian perch had the largest IRI for bleak (42.69% and 65.24%) and one class (TL>20) had insects as its prey (14.9%). Northern pike (TL>30) diets included Eurasian perch (85.01%), and pikeperch (14.99%), and other class had rudd (85.82%) and pikeperch (14.17%) as its prey.

Table 3a: IRI% values of prey items found in the stomachs of pikeperch, Eurasian perch, northern pike and European catfish in these reservoirs.

	Bovan Reservoir						Gruža Reservoir					
	Pikepech		Eurasian perch		European catfish		Pikeperch		Eurasian perch		European catfish	
	TL>40	TL≤40	TL>20	TL≤20	TL>60	TL≤60	TL>40	TL≤40	TL>20	TL≤20	TL>60	TL≤60
Pisces												
Fam Cyprinidae												
Roach	6.04	2.5	11.47	-	3.83	1.54		18.41	17.22	41.34	26.17	42.82
Chub		7.48		-								
Rudd				-								
Bleak	75.66	72.13	67.93	-			7.54	81.41	25.85		27.54	39.87
Bream	0.38			-								
Unidentified				-			62.56				1.46	
Fam Percidae												
Pikeperch				-		6.59						
Eurasian perch	17.66	3.62	20.59	-	90.46	85.09	28.56		56.93		41.74	
Unidentified	0.10			-	4.65					58.65	3.07	
Insects												
Unidentified		14.26		-								
Mollusks												
River snail				-	1.04	6.82						
Zebra mussel				-								17.3
Crustacean												
Fam Gammaridae				-			8.69					

Table 3b: IRI% values of prey items found in the stomachs of pikeperch, Eurasian perch, northern pike and European catfish in these reservoirs.

	Šumarice Reservoir					
	Pikeperch		Eurasian perch		Northern pike	
	TL>40	TL≤40	TL>20	TL≤20	TL>30	TL≤30
Pisces						
Fam Cyprinidae						
Roach		30.79		34.69		
Chub						
Rudd	18.97	30.25				85.82
Bleak	49.91		42.69	65.24		
Bream						
Unidentified						
Fam Percidae						
Pikeperch					14.99	14.17
Eurasian perch	31.11	38.94			85.01	
Unidentified			25.38			
Insects						
Unidentified			31.92			
Mollusks						
River snail						
Zebra mussel						
Crustacean						
Fam Gammaridae						

Multi-dimensional scaling (MDS) of IRI% values revealed five distinct groups at 40% similarity (Fig. 2). The stress value of the ordination was 0.1, which indicated a reliable visual representation of diet similarities among units in 2-dimensional space. Three groups were composed of only one fish species, with a particular length class. The remaining two groups contained more than one species. In the Gruža Reservoir Eurasian perch were alone in their group (TL≤20) because they only had high IRI% for roach and unidentified prey from fam. Percidae, while pikeperch (TL>40) were also alone, because they had low IRI% for bleak and they only had shrimps from Gammaridae in their gut. On the other hand, northern pike from the Šumarice Reservoir which had high IRI% for rudd was alone in their group (TL≤30), too. Northern pike (TL>30), from Šumarice Reservoir and both classes of European catfish from Bovan Reservoir formed fourth group. The fifth group contained all other classes of fishes.

According to ANOSIM (analysis of similarity), fish species significantly differed in terms of diet (Global R=0.194, $p<0.05$). Significant differences in diet existed between northern pike and pikeperch (R=0.656, $p<0.05$) and northern pike and Eurasian perch (R=0.782, $p<0.05$). However, there was no significant differences in diet with the length classes in concern (Global R=0.038, $p>0.05$).

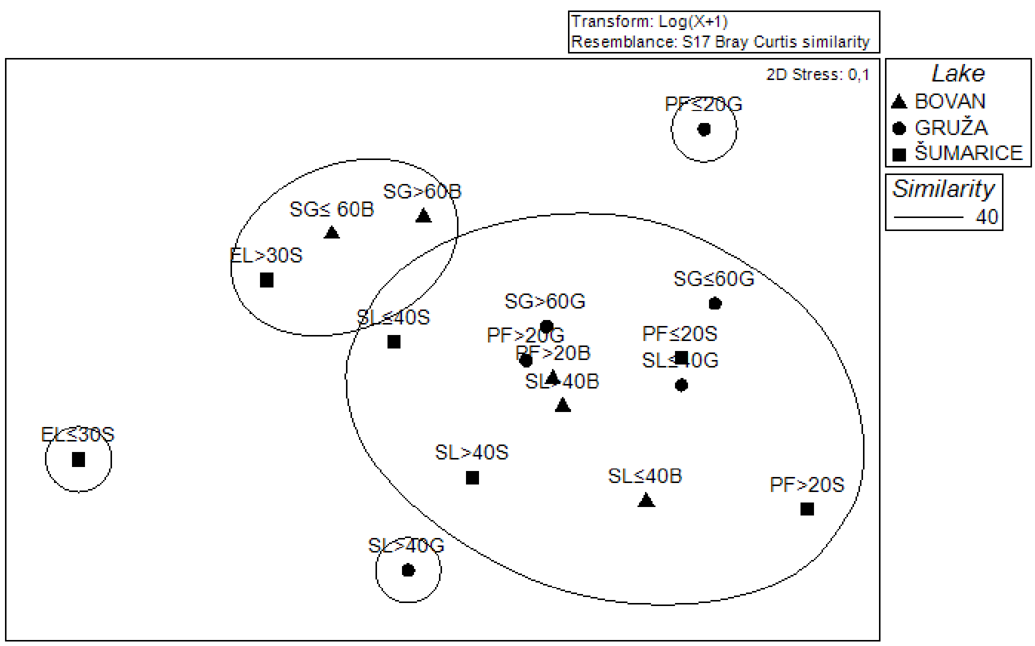

Figure 2: MDS ordination of diet similarities among two classes of each fish species from each reservoir. Ordination was based on a matrix of pair-wise Bray-Curtis similarity coefficients constucted from transformed ($\log_{10}[x+1]$) IRI% values of all prey taxa for each comparison unit. Piscivorous species are indicated by simbol type as follows: Pikeperch (SL), Eurasian perch (PF), northern pike (EL) and European catfish (SG). After the each species code, the lenght class and the abbreviation for lake are included.

Significant correlation between abundance and biomass of piscivorous fishes was noticed in two of four predatory species (Table 4), i.e., northern pike and pikeperch had the significant positive correlation. Abundance and biomass of European catfish were also positively, though not significantly correlated. The abundance and biomass of Eurasian perch were negatively correlated and insignificant, as well.

Table 4: Correlation between abundance and biomass of piscivorous fishes.

	R	*p*-value
Pikeperch	0,973	0,027
Eurasian perch	- 0,490	0,510
Northern pike	1**	0,000
European catfish	0,959	0,184

**perfect positive linear correlation

Discussion

Although general food categories consumed by pikeperch, Eurasian perch, northern pike and European catfish were similar, each species had its own predominant prey item different from those of others.

Pikeperch becomes piscivorous during their first summer, but fish may constitute a considerable proportion in their diet already when the length of pikeperch is 2-3 cm (Kangur *et al*., 2007). The main prey item of pikeperch from each Reservoir were bleak (Table 3), exept for pikeperch (TL>40) from Gruža reservoir. For these pikeperch (TL>40) is recorded high IRI% for unidentified individuals from Cyprinidae and it is very possible that among these individuals were bleak. Bleak is known to be the ideal shape for pikeperch prey, and it is also easily digestible and has a high nutritive value (Argillier *et al*., 2003). The next one to bleak was Eurasian perch. Since the mouth gape of Eurasian perch is smaller than that of the pikeperch, thus resulting in a higher predator:prey size ratio than for pikeperch (Mehner *et al*., 1996). That corresponds to the Dörner *et al*. (2007) inference on the dominance of small Eurasian perch in the diet of pikeperch indicating the importance of Eurasian perch as prey for them. Eurasian perch were not recorded as prey for one class (TL≤40) of pikeperch from Gruža Reservoir. Moderate proportion of roach is to be considered as a consequence of both their slim (i.e., low body) shape in young age and great abundance in all reservoirs in concern. Brabrand and Faafeng (1993) analyzed gut content of pikeperch and showed that roach was far as the most dominant food item. The refuge for roach is expected to be in littoral areas when predation risk in open waters increases, even in lakes where predation risk from littoral predators in high. Our results show that pikeperch consume roach moderately, except pikeperch (TL≤40) from Šumarice Reservoir, which have relatively high IRI% value for roach (30.79%). The low proportion of bream in the diet of pikeperch comes from the limitation of their gape and lower capability to swallow fish prey that feature greater body depth (Dörner *et al*., 2007). Our results supported this statement. Kangur *et al*. (2007) noted that the relative importance of bream in the diet of pikeperch was small. Pikeperch (TL>40) from Bovan Reservoir had only the bream in their gut, with the very low IRI% (0.38%) value. Only pikeperch from Šumarice Reservoir had rudd as a prey, because rudd were found only in this Reservoir, lacking from others. Although chub was not found in sampling nets in the Bovan reservoir, pharyngeal teeth in stomach of pikeperch (TL≤40) indicated that they occur there. Occurrence of insects and shrimps from Gammaridae in the stomach content of pikeperch (TL>40) who do not eat commonly this food items can be explained by remnants of food items consumed by omnivorous fish that were eaten and digested by pikeperch, as suggested also by Kopp *et al*. (2009), who found feeding preference of pikeperch to omnivorous fishes like roach and bleak, as well as to Eurasian perch. Because of that, pikeperch (TL>40) from Gruža Reservoir, which only have IRI% for Gammaridae, is separated in Fig. 2. Argillier *et al*. (2003) showed that food spectrum of pikeperch was dominated by cyprinids, while percids were less represented in their diet. No pikeperch were found in stomach of pikeperch analysed, which indicates that cannibalism was not a common phenomenon in the studied reservoirs.

Cannibalism was also recorded in Eurasian perch in Bovan and Šumarice Reservoirs, but in a less extent. The intensity of cannibalism can vary because it is strongly coupled to the growth of cannibal individuals and to the growth of victim individuals (Persson *et al*., 2004). In many north European lakes, Eurasian perch and roach are common species that compete for food resources because they have overlapping feeding niches (Syväranta and Jones, 2008; Syväranta *et al*., 2011). Roach participated less in the diet of Eurasian perch than bleak and Eurasian perch. The exceptions are Eurasian perch (TL≤20) from Gruža and Šumarice Reservoirs which have relatively high IRI% values for roach. Depending on size and resource distribution, Eurasian perch may feed on pelagic zooplankton, benthic macroinvertebrates, or fish (Persson *et al*., 1996). Dörner *et al*. (2003) showed that invertebrates were the main food components of the large Eurasian perch. Our results showed that only one class (TL>20) of Eurasian perch from the Šumarice Reservoir had insects in their stomach. Difference in proportion of occurrence of roach, bleak and Eurasian perch as prey items in the stomach contents of Eurasian perch from different reservoirs was concordant to the finding of Wziątek *et al*. (2004), who described that the diet of Eurasian perch was highly diversified and consisted of roach, Eurasian perch, white bream *Abramis bjoerkna*, gudgeon *Gobio gobio* and bleak.

Like pikeperch, northern pike become piscivorous during their first summer (Kangur and Kangur, 1998). The greatest number of northern pike with full stomach was caught from Šumarice Reservoir, where Eurasian perch and rudd dominated in abundance. The predominant prey for smaller northern pike (TL≤30) was rudd, with the very high IRI% (85.82%) value, followed with pikeperch (14.17%). For the larger class (TL>30) of northern pike, the main prey item were Eurasian perch, who are often an important prey for them. Though, northern pike as an opportunistic predator may include many other fish species in the diet (Amundsen *et al*., 2003). The main factors deciding whether a gape-limited piscivore such as northern pike can ingest a potential prey fish are the gape size of the predator and the body depth of the prey (Magnhagan and Heibo, 2001). Because of that, larger northern pike can eat deep-bodied prey species as Eurasian perch (Kangur and Kangur, 1998), as our results showed. Both classes have almost the same IRI% for pikeperch. Kangur and Kangur (1998) described that the share of pikeperch in the food of northern pike has increased probably in connection with the growing abundance of the pikeperch population in the lake. Northern pike can change their prey selection relatively rapid in response to changes in the abundance and vulnerability of prey species. Our research agreed with the report of Liao *et al*. (2002) that northern pike concentrate primarily on fish prey, while Magnhagen and Heibo (2001) noted that two young unidentified birds were found in northern pike. Winfield *et al*. (2011) showed that five species (Arctic charr *Salvelinus alpinus*, brown trout *Salmo trutta*, Eurasian perch, northern pike and roach) constituted 98% of identifiable fish consumed by northern pike, and Wysujack *et al*. (2001) reported that roach and small Eurasian perch were the main prey for northern pike.

Northern pike and pikeperch in the Šumarice Reservoir shared two common prey items, rudd and Eurasian perch, which corresponds well to report of Kangur and Kangur (1998), who revealed that those two predatory species can share up to six common fish species as prey items, including both of species we noted.

European catfish feed on invertebrates, amphibians, fish, mammals and aquatic birds (Simonović, 2001). The dietary spectrum of European catfish is greater than, for example, northern pike or pikeperch and thus may be able to exploit the breadth of available food more comprehensively and completely (Copp *et al*., 2009). The predominant prey item of European catfish from Bovan Reservoir with very high IRI% values were Eurasian perch (Table 3). Since young Eurasian perch live in schools (Simonović, 2001), they are easily assessible to European catfish with the great mouth gape in compare to other piscivores such as northern pike (Wysujack and Mehner, 2005). European catfish from the Gruža Reservoir had more various diet than from the Bovan Reservoir, with similar values of IRI% for Eurasian perch, roach and bleak. Similar as in Copp *et al*. (2009), only one class of European catfish (TL≤60) from Bovan Reservoir fed on pikeperch. That, together with the high IRI% values for Eurasian perch separated them in the distinct assemblage, holding also larger northern pike (TL>30) from Šumarice Reservoir (Fig. 2). European catfish fed also on mollusks such as river snail (e.g., both classes from the Bovan Reservoir) and zebra mussel (e.g., smaller class TL≤60 from the Gruža Reservoir) (Table 3). Since zebra mussel have a sharp edge of shell, unsuitable for ingestion, it might be that European catfish as an indiscriminate hunter probably picked them from the bottom by chance, i.e., unintentionally. It has been stated that cyprinid fishes like roach, bleak and bream as well as ruffe, burbot *Lota lota* and eel are principal items of European catfish (Wysujack and Mehner, 2005). Since stomach contents of European catfish reveals a dominance of cyprinid fishes, particularly those in the smaller size groups. Syväranta *et al*. (2010) stated that European catfish occupy a trophic position typical of piscivorous fish and equal to that of northern pike, regrdless of benthic prey items (mollusks and crustaceans) found also there. In contrast to them, Carol (2007) said that in some Spanish populations, the diet is based on red swamp crayfish (*Procambarus clarkii*, fam. Astacidae), rather than fish, which implies they might be opportunistic in an appropriate circumstances.

To conclude, piscivory is a common phenomenon in aquatic ecosystems. Piscivory is the largest source of fish removals in most aquatic ecosystems. Stocked piscivorous fish can have important implications for native species and food webs. The introduction of top predators and the subsequent reduction and loss of native fishes likely have cascading effect on the composition, structure and functioning of aquatic communities.

Acknowledgement

This investigation was supported by Grant No. 173025 of the Ministry of Education and Science of the Republic of Serbia.

References

Alp, A., Kara, C., Üçkardes, F., Carol, J. and García-Berthou, E., 2011. Age and growth of the European catfish (*Silurus glanis*) in a Turkish reservoir and comparasion with introduced populations. *Reviews in Fish Biology and Fisheries*, 21, 283-294.

Amundsen, P,A., Bøhn, T., Popova, O.A., Staldvik, F.J., Reshetnikov, Y.S., Kashulin, N.A. and Lukin, A.A., 2003. Ontogenetic niche shifts and resource partitioning in a subarctic piscivore fish guild.

Hydrobiologia, 497, 109-119.

Anderson, R. and Neumann, R., 1996. Lenght, weight, and associated structural indices. In: Murphy, B. and Willis, D., (ed) Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, MD, pp. 447–481.

Argillier, C., Barral, M. and Irz, P., 2003. Growth and diet of pikeperch *Sander lucioperca* (L.) in two French reservoirs. *Archives of Polish Fisheries*, 11, 99-114.

Brabrand, Å. and Faafeng, B., 1993. Habitat shift in roach (*Rutilus rutilus*) induced by pikeperch (*Stizostedion lucioperca*) introduction: predation risk versus pelagic behaviour. *Oecologia*, 95, 38-46.

Carey, M.P. and Wahl, D.H., 2010. Interactions of multiple predators with different foraging modes in an aquatic food web. *Oecologia*, 162, 443-452.

Carol, J., 2007. Ecology of an invasive fish (*Silurus glanis*) in Catalan reservoirs. Dissertation, University of Girona.

Clarke, K.R., Warwick R.M, Somerfield P.J. and Gorley, R.N., 2005. Change in marine comminities: an approach to statistical analysis and interpretation, 3rd edn. PRIMER-E Ltd, Plymouth, UK

Clarke, K.R. and Gorley, R.N., 2006. PRIMER v.6: User Manual/Tutorial. PRIMER-E Ltd, Plymouth, UK .

Copp, G.H., Britton, J.R., Cucherousset, J., Garcia-Berthou, E., Kirk, R., Peeler, E. and Stakenas, S., 2009. Voracious invader or benign feline? A review of the environmental biology of European catfish *Silurus glanis* in its native and introduced ranges. *Fish and Fisheries*, 10, 252-282.

Cortés, E., 1997. A crtical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. *Canadian Journal of Fisheries and Aquatic Sciences*, 54, 726-738.

Dörner, H., Berg, S., Jacobsen, L., Hülsmann, S., Brojerg, M. and Wagner, A., 2003. The feeding behaviour of large perch *Perca fluviatilis* (L.) in relation to food availability: a comparative study. *Hydrobiologia*, 506, 427-434.

Dörner, H., Hülsmann, S., Hölker, F., Skov, C. and Wagner, A., 2007. Size-dependent predator - prey relationships between pikeperch and their prey fish. *Ecology of Freshwater Fish*, 16, 307-314.

Eklöv, P., 1992. Group foraging versus solitary foraging efficiency in piscivorous predators: the perch, *Perca fluviatilis*, and pike, *Esox lucius*, patterns. *Animal Behaviour*, 44, 313-326.

Elliot, R.F., Peeters, P.J., Ebener, M.P., Rybicki, R.W., Schneeberger, P.J., Hess, R.J., Francis, J.T., Eck, G.W. and Madenjian, C.P., 1996. Conducting diet studies of Lake

Michigan piscivores-A Protocol. For the Lake Michigan Technical Committee.

Haught, S. and Von Hippel, F.A., 2011. Invasive pike establishment in Cook Inlet Basin lakes, Alaska: diet, native fish abundance and lake environment. *Biological Invasions*, 13, 2103-2114.

Hyslop, E.J., 1980. Stomach content analysis: a review of methods and their application. *Journal of Fish Biology*, 17, 411- 429.

Kangur, A. and Kangur, P., 1998. Diet composition and size-related changes in the feeding of pikeperch, *Stizostedion lucioperca* (Percidae) and pike, *Esox lucius* (Esocidae) in the Lake Peipsi (Estonia). *Italian Journal of Zoology*, 65, 255-259.

Kangur, P., Kangur, A. and Kangur, K., 2007. Dietary importance of various prey fishes for pikeperch *Sander lucioperca* (L.) in large shallow lake Võrtsjärv (Estonia). *Proceedings of the Estonian Academy of Sciences, Biology, Ecology*, 56, 154-167.

Kopp, D., Cucherousset, J., Syväranta, J., Martino, A., Céréghino, R. and Santoul, F., 2009. Trophic ecology of the pikeperch (*Sander lucioperca*) in its introduced areas: a stable isotope approach in southwestern France. *Comptes Rendus Biologies*, 332, 741-746.

Liao, H., Pierce, C.L. and Larscheid, J.G., 2002. Diet dynamics of the adult piscivorous fish community in Spirit Lake, Iowa, USA 1995-1997. *Ecology of Freshwater Fish*, 11, 178-189.

Link, J.S. and Garrison, L.P., 2002. Changes in piscivory associated with fishing induced changes to the finfish community on Georges Bank. *Fisheries Research*, 55, 71-86.

Linløkken, A., Bergman, E., Greenberg, L. and Seeland, P.A.H., 2007. Environmental correlates of population variables of perch (*Perca fluviatilis*) in boreal lakes. *Environmental Biology of Fishes*, 82(**4**), 401-408.

Magnhagen, C. and Heibo, E., 2001. Gape size allometry in pike reflects variation between lakes in prey availability and relative body depth. *Functional Ecology*, 15, 754-762.

Malyukina, G.A. and Martem'yanov, V.I., 1981. An electrocardiographic study of chemical sensitivity in some freshwater fishes. *Journal of Ichthyology*, 21, 77–84.

Mehner, T., Schultz, H., Bauer, D., Herbst, R., Voigt, H. and Benndorf, J., 1996. Intraguild predation and cannibalism in age-0 perch (*Perca fluviatilis*) and age-0 zander (*Stizostedion lucioperca*): Interactions with zooplankton succession, prey fish availability and temperature. *Annales Zoologici Fennici*, 33, 353-361.

Ostojić, A., 2006. Zooplankton of the Bovan reservoir. *Kragujevac Journal of Science*, 28, 115-122.

Persson, A. and Brönmark, C., 2002. Foraging capacity and resource synchronization in an ontogenetic diet switcher, pikeperch (*Stizostedion lucioperca*). *Ecology*, 83, 3014-3022.

Persson, L., Andersson, J., Wahlström, E. and Eklöv, P., 1996. Size-specific interactions in lake systems: predator gape limitation and prey growth rate and mortality. *Ecology*, 77, 900-911.

Persson, L., Claessen, D, Roos, A.M.D., Byström, P., Sjögren, S., Svanbäck, R., Wahlström, E. and Westman, E., 2004. Cannibalism in a size-structured population: energy extraction and control. *Ecological Monographs*, 74, 135-157.

Pinkas, L.M., Oliphant, S. and Iverson, I.L.K., 1971. Food habits of albacore, bluefin, tuna and bonito in California waters. *California Fish and Game*, 152, 1-105.

Ranković, B. and Simić, S., 2005. Phytoplankton of the Gruža Reservoir. In: Čomić, Lj. and Ostojić, A., (ed) The Reservoir Gruža – monography. Faculty of Science, Kragujevac, pp. 65-78.

Ranković, B., Simić, S. and Bogdanović, D., 2006. Phytoplankton as indicator of water quality of lakes Bubanj and Šumarice during autumn. *Kragujevac Journal of Science*, 28, 107-114.

Simonović, P., 2001. Ribe srbije. NNK International, Beograd. Zavod za zaštitu prirode Srbije i Biološki fakultet Univerziteta u Beogradu. 247P.

Sumontha, M., Nootmorn, P., Keereerut, P., Jayasinge, R.P.P.S,, Jagannath, N. and Sinha, M.K., 2008. Stomach content of the large pelagic fishes in the bay of Bengal. The Ecosystem-Based Fishery Management in the Bay of Bengal. pp. 206-220.

Syväranta, J. and Jones, R.I., 2008. Changes in feeding niche widths of perch and roach following biomanipulation, revealed by stable isotope analysis. *Freshwater Biology*, 53, 425-434.

Syväranta, J., Cucherousset, J., Kopp, D., Crivelli, A., Céréghino, R. and Santoul, F., 2010. Dietary breadth and trophic position of introduced European catfish *Silurus glanis* in the River Tarn (Garonne River basin), southwest France. *Aquatic Biology*, 8, 137-144.

Syväranta, J., Högmander, P., Keskinen, T., Karjalainen, J. and Jones, R.I., 2011. Altered energy flow pathways in a lake ecosystem following manipulation of fish community structure. *Aquatic Sciences*, 73, 79-89.

Turesson, H. and Brönmark, C., 2004. Foraging behaviour and capture success in perch, pikeperch and pike and the effects of prey density. *Journal of Fish Biology*, 65, 363-375.

Turesson, H. and Brönmark, C., 2007. Predator-prey encounter rates in freshwater piscivores: effect of prey density and water transparency. *Oecologia*, 153, 281-290.

Turesson, H., Brönmark, C. and Wolf, A., 2006. Satiation effect in piscivore prey size selection. *Ecology of Freshwater Fish*, 15, 78-85.

Winfield, I.J., Fletcher, J.M. and James, B.J., 2011. Long-term changes in the diet of pike (*Esox lucius*), the top aquatic predator in a changing Windermere. *Freshwater Biology*, pp. 1-11.

Wysujack, K., Laude, U., Anwand, K. and Mehner, T., 2001. Stocking, population development and food composition of pike *Esox lucius* in the biomanipulated Feldberger Haussee (Germany) – implications for fisheries management. *Limnologica*, 31, 45-51.

Wysujack, K. and Mehner, T., 2005. Can feeding of European catfish prevent cyprinids from reaching a size refuge? *Ecology of Freshwater Fish*, 14, 87-95.

Wziątek, B., Poczyczyński, P., Kozłowsk,i J. and Wojnar, K., 2004. The feeding of sexually mature European perch (*Perca fluviatilis* L.) in lake Kortowskie in the autumn-winter period. *Archives of Polish Fisheries*, 12, 197-201.