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The impact of amur sleeper (*Perccottus glenii* Dybowsky, 1877) on the riverine ecosystem: food selectivity of amur sleeper in a recently colonized river

by

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Abstract

The presented study aimed at comprehensive assessment of the *Perccottus glenii* (Amur sleeper) impact on the aquatic ecosystem. Our objective was to analyze the diet, the characteristics of the prey and the feeding behavior of the Amur sleeper. Fish (349 individuals) were captured by electrofishing in autumn 2012. To estimate the dietary importance of each prey category, we calculated the percentage or proportion of each food item and its frequency of occurrence. The Costello graphical method was applied to describe the feeding strategy and prey importance. A total number of 55 taxa of benthic macroinvertebrates were identified, amounting to a total of 2448 individuals. The digestive tract was empty in 48 individuals of the Amur sleeper. The most frequent prey items of the Amur sleeper were *Asellus aquaticus* L., *Baetis* spp., the Chironomidae family which was represented by 22 taxa identified to the genus and species levels, *Corixa* spp. and *Physa acuta* Drap. Depending on the frequency of prey items, two categories of size classes with specific diet compositions in the Amur sleeper populations were determined. Feeding strategy, cluster indicators of the size classes and traits of macroinvertebrates were the main aspects covered by our study of the Amur sleeper feeding behavior.

Key words: diet, feeding mode, Siret River, *Perccottus glenii*, invasive species

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Introduction

Species are transported accidentally or intentionally all over the world outside their native geographic areas (Williamson 1999) by man, who since early times has attempted to adapt and shape the world in which he lives to suit his own requirements (Elvira 2001). Although the main introductions of exotic fishes into countries outside their natural range are a relatively recent phenomenon, introductions of some species in Europe are believed to date back to Roman times, such as the carp (*Cyprinus carpio* L.), which was reared from the Danube River in ponds of Italy and Greece (Balon 1995). The round goby (*Neogobius melanostomus* Pall.), which is native to the Black and Caspian Sea region, expanded its range in Eurasia and become established in North America in the Great Lakes through a trans-Atlantic ballast voyage (Charlebois et al. 1997; 2001). Successful invasion by non-native fish species can affect the structure and functioning of native aquatic communities and may have important economic and ecological consequences (Lodge 1993).

The Amur sleeper (or Chinese sleeper), *Perccottus glenii* Dybowski, 1877, is a fish from the Odontobutidae family, Perciformes. The natural range of this fish is in Eastern Asia, from the Okhotsk Sea in the North, to the Yellow Sea in the South (Mori 1936; Berg 1949). This fish has expanded its range throughout Asia to Europe due to both intentional and non-intentional introductions (Koščo et al. 2003; Reshetnikov 2004; Jurajda et al. 2006; Hegediš et al. 2007). At the beginning of the last century, the species was introduced into Russia in two separate regions: the first introduction was in and around St. Petersburg in 1916 and the second was near Moscow in 1948 (Reshetnikov 2004). *Perccottus glenii* reached the Danube basin relatively recently in the late 1990s. It was recorded in the Tisa River, Hungary in 1997 (Harka 1998) and Serbia in 2001 (Gergely, Tucakov 2004), from where it reached the main course of the Danube in 2003 (Šipoš et al. 2004; Simonović et al. 2006). The first record in Romania comes from 2001, initially in the Suceava River, a tributary of the Siret (Nalbant et al. 2004). Shortly afterwards, in 2005, the Amur sleeper was captured near the Iron Gates, in the main course of the Danube (Popa et al. 2006).

Feeding ecology of a species is related to its population dynamics and further analysis gives us an understanding of habitat preferences, prey selection, predation, evolution, competition and energy transfer between ecosystems. This ecological information is of great value for the development of conservation strategies and for that reason, it is essential for the protection of species and ecosystems (Braga et al. 2012). The relationship between predator and prey indicates the persistence of species over time (Melián, Bascompte 2002) and the population dynamics is directly related to the community resistance to environmental perturbations (Dunne et al. 2002). Feeding ecology is of great importance due to the fact that diet composition shows from where the animals derive their sustenance and, at the same time, indicates potential food competitors and predator-prey interactions (Ahlbeck et al. 2012). Invasion of exotic species in a community with closely partitioned resources may lead to the elimination of native species as the existing food and the reduction of space resources (Moyle et al. 1986). The knowledge about the use of food resources by invading species, primary prey and feeding ecology gives us the opportunity to predict the effect of an alien species on the existing ecosystem (Carman et al. 2006).

There are many new studies regarding biological features of Amur sleeper, as parasitological studies (Sokolov et al. 2014; Sokolov, Zhukov 2014; Sokolov, Protasova 2014; Drobiniak et al. 2014) and molecular genetics studies (Xue et al. 2013; Chen et al. 2014), but the feeding ecology of this alien species has been poorly studied in the recent years. It appears that the only published papers on the diet of Amur sleeper in Europe are Koščo et al. (2008), Grabowska et al. (2009) and Kati et al. (2015). Food composition of the Amur sleeper seems to be highly size dependent. Zooplankton (microcrustaceans) are the main prey items for the young fish, macroinvertebrates – for intermediate size classes (larvae of insects, mollusks) and amphibian larvae or fish – for larger (older) specimens (Koščo et al. 2008; Pupina, Pupins 2012). However, the most dangerous aspect is the potential consumption of eggs and young fish by the Amur sleeper, which is a serious threat to native fish species (Koščo et al. 2008). The Amur sleeper may be considered as one of the most successful invaders of aquatic communities in shallow water bodies (Koščo et al. 2003).

The study aimed at comprehensive assessment of the Amur sleeper feeding behavior correlated with the possible competitiveness analysis of fish species in relation to the feeding mode. We investigated the food spectra of 349 specimens captured in autumn 2012 at 12 sampling sites on the Siret River, Romania. Our objective was to investigate the diet, the characteristics of the prey and the feeding behavior of the Amur sleeper. This is the first investigation into the diet of the *Perccotus glenii* population in southeastern Europe, Romania.

Materials and methods

Study area

The study was carried out in the Moldavian Plateau, the eastern Romania, in the Siret River (Fig. 1). The Siret has its source at 1238 m in the Ukrainian Carpathians, north of Mount Long (1382 m). In the territory of Romania, the Siret collects all tributaries descending from the eastern slopes of the Carpathians: Suceava, Moldova, Bistrița, Trotuș, Putna, Buzău and Râmnicu Sărat (right) and Bârlad (left; the only important tributary) and then flows into the Danube. The length of the watercourse is 726 km, the flow rate is 235 m^3/second and the total area of the Siret basin is 44 835 km^2, which make it the largest basin in Romania (Diaconu 1971). The climate is temperate continental.

Field and laboratory methods

All the fish (349 individuals) were captured by electrofishing at 12 sampling sites in the river during October of 2012. GPS coordinates and physicochemical parameters (altitude, water and air temperature, pH, conductivity) were measured for every sampling site.

The sampling sites were selected so as to accurately determine the biological aspects as well as the aquatic vegetation (periphyton, macrophytes), riparian vegetation (shrubs, reed, herbaceous plants) and the substrate structure (rockfill, gravel, sand, mud). After the correlation of all parameters mentioned above, we establish 3 representative sampling points – the Galbeni village where the fish sampling was conducted on two occasions, the Cleja village (3 fish samplings) and the Răcăciuni village (1 fish sampling).

Fish were deposited *in situ* on an ice bed, in a portable cooler box to avoid digestion of the stomach contents. In the laboratory, 349 fish were measured (standard and total lengths with an accuracy 0.5 mm), weighed (total weight with an accuracy of 0.5 mg) and eviscerated. The gut content was examined under stereo and binocular microscopes. Prey items were identified to the genus or species level, except for individuals largely digested, which were identified to the family level.

Data analysis

We calculated the abundance of prey and prey diversity. To estimate the dietary importance of each prey category, we calculated the percentage or proportion of each food category (i.e. the number of individuals of a prey type divided by the total number of individuals expressed as a percentage) and the frequency of occurrence (defined as a proportion of

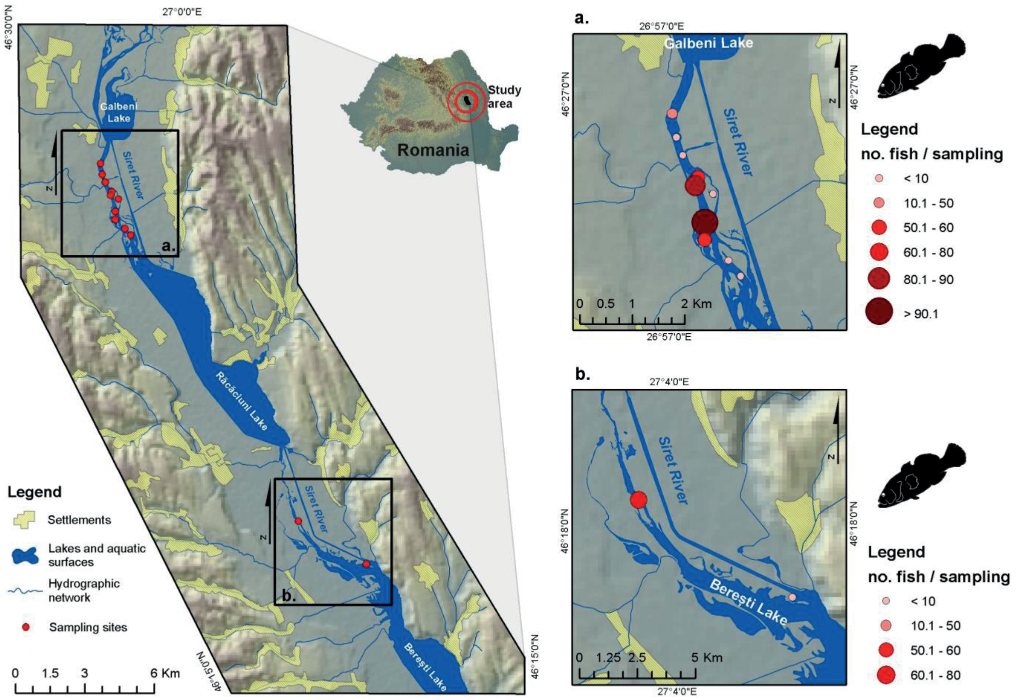

Figure 1

Sampling sites for Amur Sleeper in the Siret River, Romania fish containing a given prey category). The Costello (1990) graphical method was applied to describe the feeding strategy and prey importance: a plot of % vs. frequency of occurrence).

To analyze how the diet changes with fish length, we divided the Amur sleeper individuals into two functional size classes: < 70 mm Sl and ≥ 70 mm Sl, following Koščo et al. (2008).

Trait-based analysis of Amur sleeper diet was used to complement the taxonomic-based analysis. We used morphological (e.g. body size, body shape or morphological defences) and macroinvertebrate behavioral traits (e.g. drift tendency, locomotion or movement trajectory), following De Crespin De Billy, Usseglio-Polatera (2002). To find relationships between food selectivity and fish morphological features and environmental factors, the redundancy analysis (RDA) was used.

Results

Macroinvertebrates in the gut content

The diet of *P. glenii* in the Siret River was diverse. A total number of 54 macroinvertebrate taxa were identified, including such animal groups as crustaceans, insects and mollusks, summing up to a total of 2448 individuals (Table 1). The digestive tracts of 48 *P. glenii* individuals were empty and they were excluded from the analysis. The most frequent prey items of *P. glenii* were *Asellus aquaticus* (L.) (present in 75% of the gut contents), *Baetis* spp. (59%), the Chironomidae family (44%) – represented by 22 taxa identified to the genus and species level, and *Corixa* spp. along with *Physa acuta* (Drap.) (11% together). We identified 22 taxa that belong to the Chironomidae family (*Acricotopus lucens* (Zetterstedt), *Chironomus plumosus* (L.), *Cricotopus bicinctus* (Meig.), *Cricotopus flavocinctus* (Kief.), *Cricotopus sylvestris* (Fabr.), *Cricotopus triannulatus* (Marq.), *Cricotopus trifascia* (Edw.), *Cricotopus vierriensis* (Goeth.), *Dicrotendipes nervosus* (Staegr), *Dicrotendipes tritomus* (Kief.), *Diamesa* spp., *Glyptotendipes* spp., *Limnophyes prolongatus* (Kief.), *Monodiamesa bathyphila* (Kief.), *Orthocladius saxicola* (Kief.), *Paratanytarsus* spp., *Paratendipes* spp., *Polypedilum nubeculosum* (Meig.), *Procladius choreus* (Meig.), *Smittia* spp., *Tanytarsus* spp., *Thienemannimya lentiginosa* (Meig.)), but we used the taxa as a single group for the data analysis.

Cannibalism was observed in two cases. In several cases, we also found small pieces of plastic, stones and colored fibers in digestive tracts.

At all sampling sites, *Asellus aquaticus*, *Baetis* spp. and the Chironomidae family were the most important prey items in both size classes (Figure 2 and Figure 3). However, in the diet of larger individuals of Amur sleeper, *Asellus aquaticus* become more important in terms of frequency and relative abundance, while *Baetis* spp. and the Chironomidae family were less

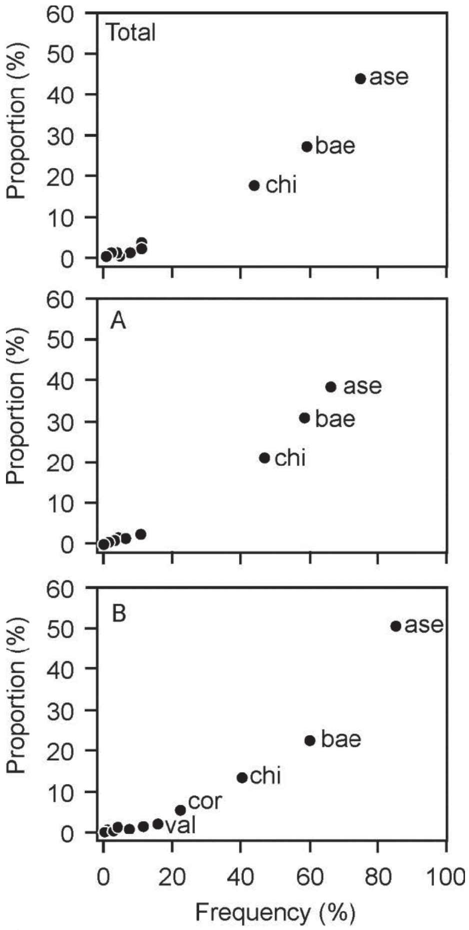

Figure 2

Feeding strategy displayed by the Costello (1990) graphic method for Amur sleeper in relation size classes – A (< 70 mm Sl) and B (≥ 70 mm Sl)

Acronyms used to abbreviate the macroinvertebrate groups, genus or species binomial nomenclature: **ase** - *Asellus aquaticus*; **bae** - *Baetis* spp.; **cae** - *Caenis* spp.; **cer** - Ceratopogonidae; **chi** - Chironomidae; **coe** - *Coenagrion puella*; **cbi** – *Cricotopus bicinctus*; **cor** - *Corixa* spp.; **ctr** – *Cricotopus triannulatus*; **dia** – *Diamesa* sp.; **dyt** - *Dytiscus* spp.; **elo** - *Elophila* spp.; **erp** - *Erpobdella octoculata*; **fag** - *Fagotia esperi*; **for** - Forcipomyinae; **gom** - *Gomphus* spp.; **hal** - *Haliplus* spp.; **hcu** - *Hydrovatus cuspidatus*; **hel** - *Helobdella stagnalis*; **hyd** - *Hydropsyche* spp.; **ind** - indeterminate; **lym** - *Lymnaea* spp.; **mel** – *Meladema* spp.; **oli** - Oligochaeta; **ost** – Ostracoda; **phy** - *Physa acuta*; **pis** - *Pisidium* spp.; **psy** – Psychodidae; **set** - *Setodes* spp.; **sim** - *Simpetrum* spp.; **str** – Stratiomyidae; **tip** - *Tipula* spp.; **trr** – Terrestrial macroinvertebrates; **val** - Valvatidae

Table 1

Mean frequencies and proportions of each taxa in the total content of *P. glenii* gut size classes

	Total		< 70 mm Sl		≥ 70 mm Sl	
	Frequency	Proportion	Frequency	Proportion	Frequency	Proportion
ase	75.08	43.90	66.26	38.19	85.51	50.22
bae	59.47	26.98	58.90	30.92	60.14	22.32
chi	44.19	17.48	47.24	21.09	40.58	13.22
cor	11.30	2.71	1.84	0.55	22.46	5.15
phy	11.30	1.85	11.04	2.23	11.59	1.30
val	8.31	1.33	1.84	0.74	15.94	1.93
hyd	8.64	1.23	6.13	1.13	11.59	1.36
hal	3.99	0.76	4.91	1.05	2.90	0.42
ind	3.65	0.56	3.07	0.50	4.35	0.63
tip	4.32	0.43	1.84	0.22	7.25	0.68
erp	1.00	0.38	1.23	0.64	0.72	0.08
coe	4.65	0.37	2.45	0.22	7.25	0.56
lym	1.66	0.34	1.84	0.33	1.45	0.35
cae	1.33	0.28	1.84	0.48	0.72	0.04
elo	2.33	0.26	1.23	0.22	3.62	0.29
sim	0.66	0.23	0.00	0.00	1.45	0.51
psy	1.66	0.15	1.23	0.17	2.17	0.12
ost	0.33	0.13	0.61	0.25	0.00	0.00
dyt	1.00	0.09	1.23	0.12	0.72	0.04
oli	1.00	0.08	0.61	0.09	1.45	0.07
pis	0.66	0.07	0.61	0.10	0.72	0.04
cer	1.00	0.07	1.23	0.07	0.72	0.07
trr	1.00	0.07	0.61	0.03	1.45	0.12
set	0.33	0.07	0.00	0.00	0.72	0.14
hcu	0.33	0.04	0.00	0.00	0.72	0.09
gom	0.33	0.03	0.00	0.00	0.72	0.07
fag	0.33	0.03	0.00	0.00	0.72	0.07
mel	0.66	0.03	0.61	0.02	0.72	0.04
str	0.33	0.02	0.00	0.00	0.72	0.05
hel	0.33	0.02	0.61	0.03	0.00	0.00
for	0.33	0.01	0.00	0.00	0.72	0.03

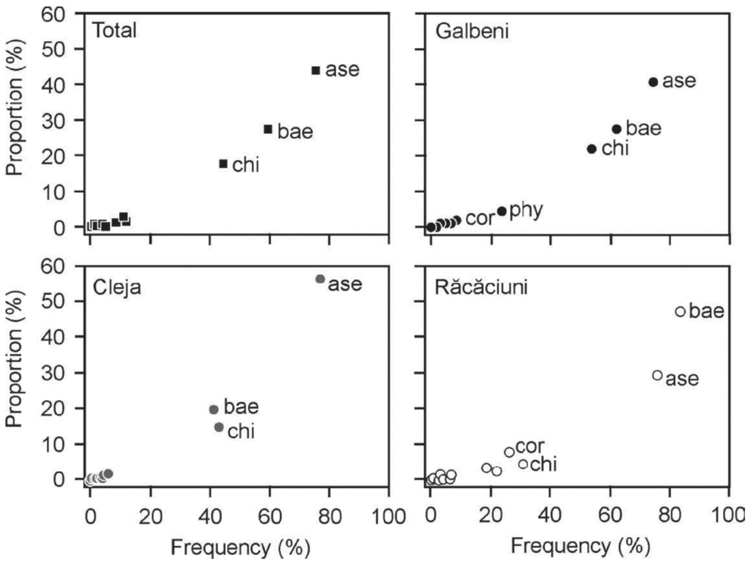

Figure 3

Feeding strategy displayed by the Costello (1990) graphic method for Amur sleeper in relation to sampling sites – Galbeni (n=132), Cleja (n=152), Răcăciuni (n=65)

Acronyms used to abbreviate the macroinvertebrate groups, genus or species binomial nomenclature – see fig. 2

important (Figure 2). Also RDA analysis shows strong positive correlation between the contribution of *A. aquaticus* and the size of Amur sleeper (Figure 4). In addition, other taxa such as *Corixa* spp. and *Valvata* spp. become more frequent in the gut contents of larger fish (≥ 70 mm). This means that the frequency of macrocrustaceans (*Asellus aquaticus* – Isopoda), mollusks (Gastropoda) and highly mobile macroinvertebrates (Hemiptera) increased with increasing size of the fish body.

With respect to the sampling sites, *Baetis* spp. was the most frequent prey item at the Răcăciuni village sampling site, having a higher proportion in gut contents compared to *Asellus aquaticus* (Figure 3 and Table 2), in contrast to the two other sites.

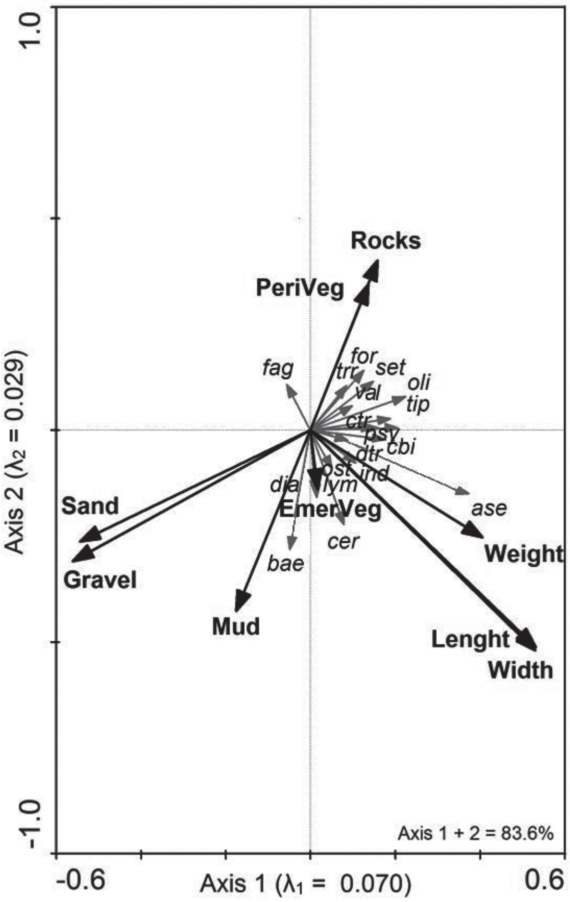

Figure 4

Redundancy analysis (RDA) of the relationship between Amur sleeper food composition and fish morphology (weight, length and width) and environmental parameters (characteristics of the bottom substrate: rocks, mud, gravel, sand and the prevailing type of vegetation)

Acronyms used to abbreviate the macroinvertebrate groups, genus or species binomial nomenclature – see fig. 2

Traits analysis

Regarding macroinvertebrate trait analysis, our data indicate that *P. glenii* individuals tend to feed on prey with a potential size of 1-2 cm (Table 3). If we differentiate between the two *P. glenii* size classes, small fish feed more on the prey size class 0.5-1 cm as compared to large fish. Considering the feeding habit traits of macroinvertebrates, we observed that *P. glenii* feeds primarily on shredders, but small individuals consumed more scrapers and deposit-feeders, while larger fish feed more on piercers and shredders.

P. glenii feeds on macroinvertebrates that lives in the zone of macrophytes (no differences were observed within the size classes), as well as it prefers to consume organic detritus- and litter-living organisms (Table 3).

Although *P. glenii* tends to eat prey that inhabits stagnant and slow-current waters, small individuals (< 70 mm) feed more on prey associated with medium- and fast-current water habitats compared to large ones.

The prey with low to moderate tendency to drift in the water column dominated in *P. glenii* gut contents. Macroinvertebrate trait analysis shows that *P. glenii* consumes prey that has a nocturnal drift behavior, followed by dawn and dusk drift.

P. glenii preferred prey with a continuous movement frequency, especially with a linear trajectory on the substrate, as well as prey with oscillatory movement, selected mainly by small-sized fish. Considering the agility and flexibility of the eaten prey, *P. glenii* selects macroinvertebrates characterized by high agility and body flexibility (Table 3).

P. glenii consumes prey that has a tendency to live in aggregations and prefers organisms that are solidly colored. Amur sleeper feeds mostly on cylindrical organisms, while flattened organisms become important in the diet of large individuals. *Perccottus glenii* eats mainly organisms without morphological defences.

Discussion

P. glenii is a predatory fish that feeds on insect larvae (Odonata, Hemiptera, Chironomidae), worms and small fish; cannibalism is often observed (Kirpichnikov 1945). The large number of food categories found in the stomach of *P. glenii* demonstrates that this fish in a non-selective predator

Table 2

Mean frequencies and proportions of each taxa at each sampling site – Galbeni (n=132), Cleja (n=152), Răcăciuni (n=65)

	Total		Galbeni		Cleja		Răcăciuni	
	F	P	F	P	F	P	F	P
ase	75.08	43.90	73.60	40.58	76.58	56.15	75.38	29.36
bae	59.47	26.98	61.60	26.98	43.24	15.28	83.08	46.96
chi	44.19	17.48	53.60	22.12	41.44	19.85	30.77	4.50
cor	11.30	2.71	8.80	1.81	5.41	0.76	26.15	7.76
phy	11.30	1.85	23.20	4.25	3.60	0.21	1.54	0.04
val	8.31	1.33	4.80	0.41	6.31	1.39	18.46	3.00
hyd	8.64	1.23	4.80	0.50	5.41	1.35	21.54	2.44
hal	3.99	0.76	4.00	0.37	6.31	1.65	0.00	0.00
ind	3.65	0.56	4.80	0.67	0.90	0.06	6.15	1.20
tip	4.32	0.43	3.20	0.27	4.50	0.65	6.15	0.36
erp	1.00	0.38	1.60	0.13	0.90	0.90	0.00	0.00
coe	4.65	0.37	6.40	0.55	4.50	0.38	1.54	0.04
lym	1.66	0.34	2.40	0.43	0.90	0.30	1.54	0.22
cae	1.33	0.28	0.00	0.00	0.00	0.00	6.15	1.29
elo	2.33	0.26	2.40	0.33	3.60	0.33	0.00	0.00
sim	0.66	0.23	0.00	0.00	0.00	0.00	3.08	1.08
psy	1.66	0.15	0.00	0.00	0.90	0.23	6.15	0.30
ost	0.33	0.13	0.80	0.32	0.00	0.00	0.00	0.00
dyt	1.00	0.09	0.00	0.00	0.00	0.00	4.62	0.39
oli	1.00	0.08	0.00	0.00	0.90	0.13	3.08	0.15
pis	0.66	0.07	0.00	0.00	0.90	0.15	1.54	0.08
cer	1.00	0.07	1.60	0.15	0.00	0.00	1.54	0.04
trr	1.00	0.07	0.00	0.00	2.70	0.19	0.00	0.00
set	0.33	0.07	0.00	0.00	0.00	0.00	1.54	0.31
hcu	0.33	0.04	0.00	0.00	0.00	0.00	1.54	0.19
gom	0.33	0.03	0.00	0.00	0.00	0.00	1.54	0.15
fag	0.33	0.03	0.80	0.07	0.00	0.00	0.00	0.00
mel	0.66	0.03	0.00	0.00	0.90	0.05	1.54	0.04
str	0.33	0.02	0.00	0.00	0.00	0.00	1.54	0.10
hel	0.33	0.02	0.80	0.04	0.00	0.00	0.00	0.00
for	0.33	0.01	0.80	0.03	0.00	0.00	0.00	0.00

with a wide range of diet. According to the comparison of size-related changes performed by Sinelnikov (1976) and Grabowska et al. (2009), there are three stages regarding the diet of Amur sleeper: planktonophagous (8-11 mm long; feeding on phytoplankton and zooplankton), benthophagous (12-100 mm long; malacostracan crustaceans, insects, mollusks) and piscivorous (above 100 mm long; fish, amphibians). Based on the frequency of food components, Koščo et al. (2008) distinguished two functional size groups of Amur sleeper – < 70 mm Sl and ≥ 70 mm Sl. All specimens examined in our study (Sl range 21-135 mm) belonged to two last size classes. The prey composition determined in the diet of Amur sleeper from the Siret River is similar to that found in the primary distribution area as well as in areas colonized in the former Soviet Union (Litvinov, O'Gorman 1996; Reshetnikov 2003; Miller, Vasil'eva 2003). The results of our investigation confirm previous observations of the Amur sleeper predation on fish and cannibalism. However, the fish had a very small representation in the total food uptake. Only in the case of less than 1% of the potentially fish consuming Amur sleepers – above 60 mm long (Sinelnikov 1976; Koščo et al. 2008; Grabowska et al. 2009) – single fishes were found in digestive tracts. Previous investigations (Sinielnikow 1976; Grabowska et al. 2009; Kati et al. 2015) indicated greater contribution of fish in the diet of Amur sleeper. This contradiction may be explained by the fact that in our study, fish sampling was conducted only in autumn. The intensity of Amur sleeper feeding on fish varies significantly during the year. In the late spring-summer period, the abundance of fish in the diet increases significantly, because *P. glenii* feeds then on fish larvae and juveniles (Kati et al. 2015). In autumn, growing young fish can be captured only by the largest specimens of Amur sleeper. Despite this, we expected a higher contribution of fish in the diet of *P. glenii*. It can swallow prey larger than one-third of the predator size and for the largest specimens, juvenile fish resources are still available in autumn (Grabowska et al. 2009). This indicates that in the case of abundant invertebrate food, the intake of fish is of lesser importance.

Table 3

Traits-based analysis for the total content of *P. glenii* gut size classes

Traits	Categories	Total		< 70 mm		≥ 70 mm	
		mean	SE	mean	SE	mean	SE
Potential size of the prey	0.5-1 cm	28.71	1.31	31.79	1.94	25.06	1.64
	1-2 cm	61.89	1.49	58.02	2.16	66.46	1.94
	2-4 cm	5.25	0.53	5.78	0.84	4.62	0.56
	4-8 cm	0.53	0.13	0.39	0.15	0.70	0.22
	5-25 cm	3.60	0.47	4.01	0.76	3.13	0.47
Locomotion and substrate relation	Flier	0.70	0.11	0.33	0.11	1.14	0.20
	Surface swimmer	0.22	0.06	0.19	0.08	0.25	0.10
	Full water swimmer	15.71	0.79	15.96	1.01	15.42	1.23
	Crawler	51.04	0.54	51.47	0.65	50.53	0.89
	Burrower	4.98	0.41	4.74	0.57	5.26	0.58
	Interstitial	22.91	0.62	22.32	0.86	23.61	0.90
	Temporarily attached	4.44	0.38	5.00	0.57	3.79	0.49
	Permanently attached	0.05	0.02	0.01	0.01	0.10	0.05
Food	Microorganisms	0.22	0.04	0.30	0.07	0.13	0.03
	Detritus < 1mm	19.35	0.38	20.52	0.55	17.96	0.50
	Dead plant ≥ 1mm	27.95	0.81	26.16	1.11	30.06	1.15
	Living microphytes	26.92	0.52	28.38	0.79	25.20	0.63
	Living macrophytes	14.40	0.28	14.16	0.44	14.70	0.31
	Dead animal ≥ 1mm	3.86	0.23	3.82	0.32	3.91	0.33
	Living microinvertebrates	3.87	0.28	3.24	0.33	4.61	0.46
	Living macroinvertebrates	3.34	0.34	3.29	0.45	3.39	0.52
	Vertebrates	0.09	0.05	0.13	0.08	0.05	0.04
Feeding habits	Absorber	0.02	0.01	0.02	0.02	0.02	0.01
	Deposit feeder	11.86	0.51	13.85	0.77	9.50	0.61
	Shredder	47.41	1.89	42.88	2.67	52.76	2.60
	Scraper	27.43	1.28	30.88	1.93	23.36	1.56
	Filter-feeder	5.18	0.45	5.30	0.66	5.04	0.60
	Piercer	2.50	0.41	1.19	0.41	4.03	0.74
	Predator	3.78	0.47	3.70	0.73	3.86	0.57
	Parasite	1.83	0.15	2.17	0.22	1.43	0.19
Substrate	Boulders/pebbles	13.52	0.35	14.83	0.51	11.96	0.45
	Gravel	8.35	0.14	8.86	0.20	7.74	0.19
	Sand	6.82	0.11	7.23	0.15	6.34	0.15
	Silt	1.92	0.16	2.20	0.24	1.59	0.18
	Macrophytes	30.83	0.41	30.04	0.57	31.75	0.57
	Microphytes	8.11	0.34	7.37	0.49	8.99	0.47
	Twigs/roots	12.43	0.19	12.78	0.28	12.02	0.23
	Organic detritus/litter	12.19	0.30	10.75	0.36	13.90	0.46
	Mud	5.84	0.21	5.95	0.33	5.70	0.25
Current velocity	Null	36.95	0.99	34.00	1.52	40.44	1.15
	Slow	38.29	0.45	37.29	0.65	39.48	0.61
	Medium	15.00	0.77	17.25	1.18	12.33	0.91
	Fast	9.76	0.51	11.46	0.78	7.75	0.59
Tendency to drift in the water column	None	2.22	0.39	1.78	0.62	2.73	0.43
	Weak	31.91	0.90	31.27	1.43	32.68	0.99
	Medium	41.59	0.46	40.46	0.66	42.92	0.63
	High	24.28	0.80	26.49	1.27	21.67	0.86
Tendency to drift at the water surface	None	9.00	0.77	6.32	0.93	12.17	1.21
	Weak	56.85	1.69	54.12	2.46	60.08	2.24
	Medium	22.44	1.02	25.93	1.51	18.33	1.23
	High	11.71	0.67	13.64	1.04	9.42	0.76
Trajectory on the bottom substrate or in the drift	None	18.20	0.98	19.67	1.45	16.46	1.26
	Linear	38.28	0.96	34.64	1.37	42.57	1.26
	By random	22.71	0.71	21.13	1.03	24.59	0.92
	Oscillatory	20.81	1.05	24.56	1.51	16.38	1.34
Movement frequency	Continuous	66.29	1.44	60.11	2.11	73.58	1.73
	Discontinuous	33.71	1.44	39.89	2.11	26.42	1.73
Diel drift behavior	None	9.42	0.70	9.18	1.00	9.69	0.97
	Nocturnal	31.72	0.68	29.91	0.95	33.86	0.94
	Dawn	21.75	0.24	22.29	0.37	21.11	0.29
	Daylight	13.93	0.43	14.81	0.63	12.90	0.55
	Dusk	23.17	0.28	23.79	0.43	22.44	0.33
Agility	None (sluggish)	5.16	0.68	4.36	0.99	6.10	0.90
	Weak	26.34	0.82	25.48	1.28	27.35	0.95
	High	68.50	0.96	70.16	1.47	66.55	1.14

Table 3 continued

Aggregation tendency	Weak	30.15	0.37	30.14	0.51	30.16	0.53
	High	69.85	0.37	69.86	0.51	69.84	0.53
Concealment	Fixed accessory	0.76	0.20	0.66	0.31	0.88	0.24
	Movable accessory	6.38	0.53	7.57	0.80	4.97	0.66
	Solidly colored	64.40	0.36	64.81	0.53	63.92	0.49
	Variable	12.02	0.44	10.03	0.59	14.37	0.61
	Patterned	16.44	0.42	16.93	0.64	15.86	0.52
Body shape	Cylindrical	60.18	1.50	66.32	2.14	52.93	1.93
	Spherical	1.35	0.25	0.32	0.17	2.56	0.49
	Conical	2.98	0.50	3.22	0.76	2.68	0.63
	Flattened	35.49	1.48	30.13	2.11	41.82	1.92
	Hydrodynamic	0.00	0.00	0.00	0.00	0.00	0.00
Body flexibility	None	8.58	0.91	5.53	1.08	12.19	1.47
	Weak	25.79	0.70	24.85	0.98	26.90	1.00
	High	65.63	0.93	69.62	1.25	60.91	1.29
Morphological defences	Cerci, silk, spine	18.79	1.12	21.39	1.75	15.72	1.27
	None	81.21	1.12	78.61	1.75	84.28	1.27

However, *P. glenii* may have a high potential impact on native fish species as it facilitates similar food resources and may negatively affect the reproductive success of native fish (Penczak et al. 2004). In our study, no Amur sleepers foraging on amphibians (eggs, tadpoles and adults) were observed, even though such events were reported by other researchers (Reshetnikov, Manteifel 1997; Reshetnikov 2003; Pupina, Pupins 2012). It should be noted, however, that rivers are not the most suitable habitats for amphibians and their eggs and tadpoles are not present in the autumn season when our study was carried out.

The population of *P glenii* inhabiting the Siret River primarily feeds on macroinvertebrates. Altogether we found 54 invertebrate taxa in its digestive tract, including: annelids, snails, crustaceans, and insects representing several orders. Crustaceans – *Asellus aquaticus* and insects (mayflies – Baetide and true flies from the Chironomidae family) were the main food items of the investigated fish species (80% of the invertebrate food uptake). Such taxonomic composition of the fish alimentary tract likely reflects the seasonal composition of macroinvertebrates in the Siret River. Koščo et al. (2008), Grabowska et al. (2009) and Kati et al. (2015) found that the diet composition of Amur sleeper varies during the year and follows the composition of invertebrates occurring in the ecosystem. We found that the food composition of *P. glenii* was significantly size-dependent. Small-sized specimens (< 70 mm Sl) preferred chironomids and ephemeropterans. Such food composition of juvenile Amur sleeper was also observed by Koščo et al. (2008) and may be explained by low mobility of chironomids and small body size of both taxa, which makes them easily accessible to juvenile fish (Grabowska et al. 2009). The contribution of chironomids decreases with the growing fish body size, while more mobile isopods – *A. aquaticus* – start to dominate and represent over 50% of the swallowed prey. Intensive consumption of isopods and the presence of free swimming insect taxa in the diet (*Corixa* ssp. or *Hydrovatus cuspidatus*) suggest that the larger individuals of *P. glenii* are sufficiently experienced and skillful to select this type of prey. The presence of *Corixa* spp. and adult coleopterans as important prey indicated that the Amur sleeper changes its feeding behavior while growing and starts to penetrate the water column. Greater body size and consequently increased swallowing capacity and food crumbling ability enable the large specimens (> 70 mm Sl) to prey more intensively on gastropods, especially *Valvata* ssp. However, the uptake of another snail species – *Physa acuta,* was similar both in small and large specimens. In autumn (when our investigations were carried out), gastropods become potentially more available for *P. glenii* as they breed entire summer to reach the greatest densities at the end of vegetative season (Grabowska et al. 2009). However, contribution of snails in the total content of Amur sleeper alimentary tracts was insignificant. This observation is in line with the suggestion of Kati et al. (2015) who believes that gastropods are of secondary importance to this fish species and are eaten only when other food resources are depleted. The presence of small pieces of plastic, stones and colorful fibers in the digestive tract of Amur sleeper indicates its voracious feeding behavior and the fact that it is lured not only by living animals but also by moving variegated small abiotic objects.

The results of Amur sleeper prey trait analysis are consistent with the current knowledge about the biology and feeding ecology of this species. Living generally in vegetated habitats of the littoral zone with muddy bottom and stagnating water, *P. glenii* preys on invertebrate species favoring macrophytes both as shelter and food. It prefers to capture specimens crawling on plants and muddy organic bottom as well as taxa inhabiting submerged plants tissues. However, our investigation demonstrated that in lotic environments, Amur sleeper occurs also in habitats characterized by fast water current, gravelly or rocky bottom with sparse hydromacrophytes and prevalence of periphyton. In such habitats, this fish feeds on specimens temporary attached to the bottom, shredders and grazers on CPOM. The digestive tract content as well as prey trait analysis show that in the riverine ecosystem, Amur sleeper is able to forage efficiently in the open water column and swimming invertebrates represent a significant contribution to the total amount of food. It is contradictory to the findings by Koščo et al. (2008) who stated that highly mobile organisms and those living in the open water zone or surface water are seldom selected by Amur sleeper. Our prey trait analysis shows that the observations made by Zaloznykh (1982) indicating the preferences of Amur sleeper for unarmored fish as prey may also apply to invertebrate food resources. *P. glenii* mainly chooses invertebrate species that do not have any spines or cerci.

In conclusion, Amur sleeper presents a generalistic and flexible feeding strategy by having the ability to feed on available food resources within easy reach, such a feeding behavior is characteristic of successful invaders (Koščo et al. 2008; Grabowska et al. 2009). By feeding on organisms inhabiting different niches of the riverine ecosystem, Amur sleeper is potentially able to rapidly expand its range and colonize a new river environment (Semenchenko et al. 2011). Studies of invasive fish species in European countries indicate that they hold similar characteristics such as opportunistic feeding strategy and a broad diet spectrum (Grabowska, Grabowski 2005).

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