FEEDING ECOLOGY OF TWO SYMPATRIC FISH SPECIES IN A RIVER ECOSYSTEM

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Abstract. Feeding ecology of a species is linked to its population dynamics, the further analysis giving us an understanding for the habitat preferences, prey selection, evolution, competition and energy transfer within the ecosystem. The main objective of this study is to investigate the macroinvertebrate based diet, the characteristics of the prey and a possible competitiveness for food resources between two sympatric ray-finned fish species, *Salmo trutta* and *Barbatula barbatula*, generally known as feeding competitors. All the fish (111 individuals) were captured by electrofishing on a 23 km section of the Trotuş River, between Ciobănuş and Dofteana localities, during summer of 2009. To estimate the dietary importance of each prey category, we calculated the prey-specific abundance of each food category (A%) and the frequency of occurrence (FO). The Costello graphical method was applied to describe the feeding strategy and prey importance. We also calculated the prey diversity – Shannon (H), species evenness – Pielou (J), niche breadth measures (Levins – B; Hurlbert – BA), and niche overlap (MacArthur & Levins’ measure – M, and Pianka’s index – O). *Salmo trutta* and *Barbatula barbatula* were defined as specialist feeders with low values of niche overlap between the two species, indicating a reduced competition for food resources.

Keywords: prey, feeding strategy, niche breadth, niche overlap

Rezumat. Ecologia hrănirii a două specii simpatrice de peşti într-un ecosistem de apă curgătoare. Ecologia hrănirii unei specii este legată de dinamica populaţiei şi contribuie la analiza unor subiecte foarte importante cum ar fi preferinţele de habitat, selecţia prăzii, evoluţie, competiţie şi transferul de energie în cuprinsul ecosistemului. Scopul principal al acestui studiu este analiza dietei bazată pe macronevertebrate, caracteristicilor prăzii şi a unei posibile competiţii pentru resursele trofice între două specii simpatrice de peşti, *Salmo trutta* şi *Barbatula barbatula*, cunoscute în general ca fiind competitoare la nivel trofic. Peştii (111 indivizi) au fost capturaţi prin electronarcoză pe o secţiune de 23 km a râului Trotuş, între localităţile Ciobănuş şi Dofteana, în vara anului 2009. Pentru a estima importanţa fiecărei categorii de pradă, am calculat abundenţa (A%) şi frecvenţa (FO) prăzii. Metoda grafică Costello a fost aplicată pentru a descrie strategia hrănirii şi importanţa prăzii. De asemenea, am calculat diversitatea prăzii – Shannon (H), echitabilitatea – Pielou (J), lărgimea nişelor trofice (metoda Levins (B) – Hurlbert (BA)) şi suprapunerea nişelor trofice (metoda MacArthur & Levins – M şi indicele Pianka – O). *Salmo trutta* şi *Barbatula barbatula* au fost definite ca specii cu mod de hrănire specialist, cu un grad scăzut de suprapunere al nişelor trofice, indicând o competiţie redusă între cele două specii pentru resursele trofice.

Cuvinte cheie: pradă, strategia hrănirii, nişă trofică, suprapunerea nişei trofice

Introduction

Feeding ecology of a species is linked to its population dynamics, the further analises giving us an understanding for the habitat preferences (Wetherbee & Cortes, 2004), prey selection (Motta & Wilga, 2001), evolution (Collar *et al.*, 2009), competition (Stergiou & Karpouzi, 2002; Svanback & Bolnick, 2007) and energy transfer within the ecosystem (Nakano & Murakami, 2001; Baxter *et al.*, 2004, 2005; Rezende *et al.*, 2008).

Diet composition shows from where animals derive their sustenance, indicating at the same time potential food competitors and predator-prey interactions (Ahlbeck *et al.*, 2012).

The Brown Trout (*Salmo trutta* Linnaeus, 1758) is a salmonid fish native to upper Danube and Volga drainages and widely distributed in Europe and Asia. It is usually found in streams, ponds, rivers and lakes (Scott & Scott, 1988). The Brown trout prefers cold and well-oxygenated upland waters, especially in the mountainous areas, with submerged rocks, undercut banks and overhanging vegetation (de Moor & Bruton, 1988). The Stone loach (*Barbatula barbatula* Linnaeus, 1758) is a cyprinid fish widely distributed in Europe (Kottelat & Freyhof, 2007) and Asia (Wheeler, 1992). It is usually found in flowing stretches of streams with gravel to stony bottom, sandy canals and lake shores.

The main objective of this study was to investigate the macroinvertebrate based diet, the characteristics of the prey and a possible competitiveness for food resources between two sympatric ray-finned fish species, *Salmo trutta* and *Barbatula barbatula*, generally known as feeding competitors (Hartley, 1947; Smyly, 1955).

Material and Methods

Study Area

The study was carried out on Trotuș River, a tributary of the Siret River, Eastern Romania. Trotuș has a length of 162 km, a flow rate of 35 m^3/sec^{-1} and a catchment area of 4456 km^2. The altitude of the river ranges from 1380 m at its source (Ciuc Mountains) to 97 m at its confluence with Siret, near the town of Adjud.

Field and Laboratory Methods

All the fish (111 individuals) were captured by electrofishing on a 23 km section of the river, between Ciobănuș and Dofteana localities, during the summer of 2009. The sampling sites have been established to intercept as accurate as possible 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). Fish were frozen *in situ* with a portable freezer to avoid digestion of the stomach contents. In the laboratory, fish individuals were eviscerated and the gut contents were examined under the stereo- and binocular microscopes. Prey items were identified to the genus or species level. There were exceptions for the individuals largely digested which were identified to higher taxonomic ranks or assigned to an undetermined category.

Data Analysis

To estimate the dietary importance of each prey category, we calculated the prey-specific abundance of each food category (A%) and the frequency of occurrence (FO). The Costello (1990) graphical method was applied to describe the feeding strategy and prey importance.

We also calculated the prey diversity – Shannon (H) (Magurran, 2004), species evenness – Pielou (J) to evaluate specialization in the diet (Oscoz *et al*., 2005), niche breadth measures (Levins – B, and Hurlbert – BA) (Hurlbert, 1978), and niche overlap (MacArthur & Levins' measure – M, and Pianka's index – O) (MacArthur & Levins, 1967; Pianka, 1973).

Results and Discussion

A total number of 37 macroinvertebrates taxa/groups were identified in the gut contents of brown trout and stone loach, summing a total of 3839 prey items (Table 1). The most abundant macroinvertebrates identified were diptera (chironomids), ephemeroptera (*Baetis* spp., *Ecdyonurus* spp.), plecoptera (*Perla* spp.) and trichoptera larvae (*Hydropsyche* spp., *Polycentropus* spp.), a strong dominance of the Class Insecta (86.48%) being observed.

From the total of 111 gut contents analysed, 57 belonged to *Salmo trutta* and 54 to *Barbatula barbatula*.

Table 1. Presence and abundance of each macroinvertebrate taxon/group identified in the gut contents of brown trout, and of stone loach.

Macroinvertebrate taxon/group	*Salmo trutta*	*Barbatula barbatula*	Macroinvertebrate abundance in gut contents	
			Salmo trutta	*Barbatula barbatula*
Antocha spp.	+	+	**3**	**4**
Baetis spp.	+	+	**587**	**423**
Ceratopogonidae		+		**5**
Chironomidae	+	+	**53**	**2142**
Coenagrion puella	+		**1**	
Dixa spp.	+		**6**	
Drusus spp.	+		**4**	
Ecdyonurus spp.	+	+	**17**	**44**
Elmis spp.	+		**2**	
Elophila spp.	+		**4**	
Ephemera spp.		+		**7**
Gammarus spp.	+	+	**1**	**1**
Gerris spp.	+		**3**	
Haliplus spp.	+		**1**	
Helobdella stagnalis		+		**1**
Hydracarina	+		**1**	
Hydraena spp.	+		**1**	
Hydrophilus spp.	+		**2**	
Hydropsyche spp.	+	+	**117**	**104**
Hydroptila spp.	+		**1**	
Indeterminate	+	+	**17**	**14**
Isogenus spp.	+	+	**12**	**2**
Limnephilus spp.		+		**9**
Limnius spp.	+		**3**	
Limoniidae	+	+	**1**	**8**
Nemoura spp.		+		**1**
Notonecta spp.	+		**1**	
Oligochaeta	+		**6**	
Perla spp.	+	+	**1**	**46**
Platambus spp.	+		**2**	
Polycentropus spp.	+	+	**18**	**13**
Rhagionidae		+		**3**
Rhyacophila spp.		+		**2**
Simuliidae	+	+	**19**	**18**
Tabanus spp.	+		**3**	
Terrestrial	+	+	**37**	**63**
Tipula spp.	+	+	**1**	**4**
TOTAL			**925**	**2914**

Following the analysis of the brown trout diet, a total number of 30 macroinvertebrates taxa/groups were identified summing a total of 925 individuals. The most important prey items found in the diet of *Salmo trutta* were *Baetis* spp. (A%=63.45; FO=78.94%), *Hydropsyche* spp. (A%=12.64%; FO=82.45%) and chironomids (A%=5.72%; FO=43.85%) (Fig. 1, Table 2).

The dietary analyses for the brown trout indicated medium values regarding prey diversity for Shannon index (H=1.5029) and Pielou index (J=0.4419) and a narrow niche breadth (B=2.3506; B_A=0.0466) (Fig. 3).

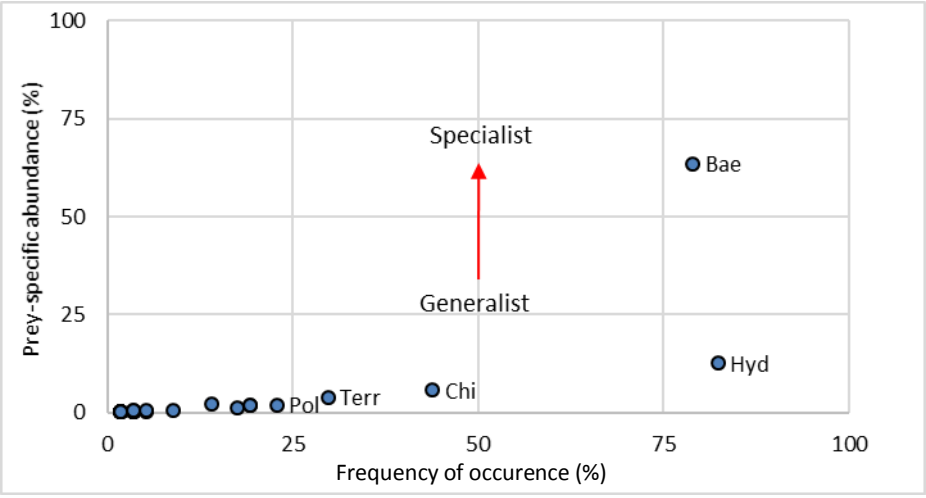

Figure 1. Feeding strategy displayed by the Costello (1990) graphical method for the brown trout (*Salmo trutta*).

Table 2. Prey-specific abundance (A%) and frequency of occurrence (FO) values of each taxon identified in the gut contents of brown trout, and of stone loach.

	Salmo trutta		***Barbatula barbatula***	
	A%	**FO%**	**A%**	**FO%**
Ant	0.32	3.50	0.13	1.85
Bae	63.45	78.94	14.51	85.18
Cer	*	*	0.17	7.40
Chi	5.72	43.85	73.50	94.44
Coe	0.10	1.75	*	*
Dix	0.64	3.50	*	*
Dru	0.43	5.26	*	*
Ecd	1.83	19.29	1.51	27.77
Elm	0.21	3.50	*	*
Elo	0.43	3.50	*	*
Eph	*	*	0.24	9.25
Gam	0.10	1.75	0.03	1.85
Ger	0.32	3.50	*	*
Hal	0.10	1.75	*	*
Hst	*	*	0.03	1.85
Hrn	0.10	1.75	*	*
Hna	0.10	1.75	*	*
Hus	0.21	3.50	*	*

	Salmo trutta		*Barbatula barbatula*	
	A%	**FO%**	**A%**	**FO%**
Hyd	12.64	82.45	3.56	46.29
Hla	0.10	1.75	*	*
Indet	1.83	19.29	0.48	22.22
Iso	1.29	17.54	0.06	3.70
Lus	*	*	0.30	9.25
Lim	0.32	5.26	*	*
Lmn	0.10	1.75	0.27	9.25
Nem	*	*	0.03	1.85
Not	0.10	1.75	*	*
Oli	0.64	8.77	*	*
Per	0.10	1.75	1.57	40.74
Pla	0.21	3.50	*	*
Pol	1.94	22.80	0.44	1.,81
Rha	*	*	0.10	5.55
Rhy	*	*	0.06	1.85
Sim	2.05	14.03	0.61	3.70
Tab	0.32	3.50	*	*
Terr	4	29.82	2.16	35.18
Tip	0.10	1.75	0.13	7.40

In the stomach contents of *Barbatula barbatula*, 21 macroinvertebrates taxa/groups were identified summing a total of 2914 individuals. The Costello graphical method indicated that chironomids (A%=73.50%; FO=94.44%), *Baetis* spp. (A%=14.51%, FO=85.18%) and *Hydropsyche* spp. (A%=3.56%, FO=46.29%) were the most important prey items (Table 2, Fig. 2). There were observed low values for prey diversity of stone loach (H)=1.0211; (J)=0.3354, a narrow niche breadth (B=1.7739; B_A=0.0387) being indicated (Fig. 3).

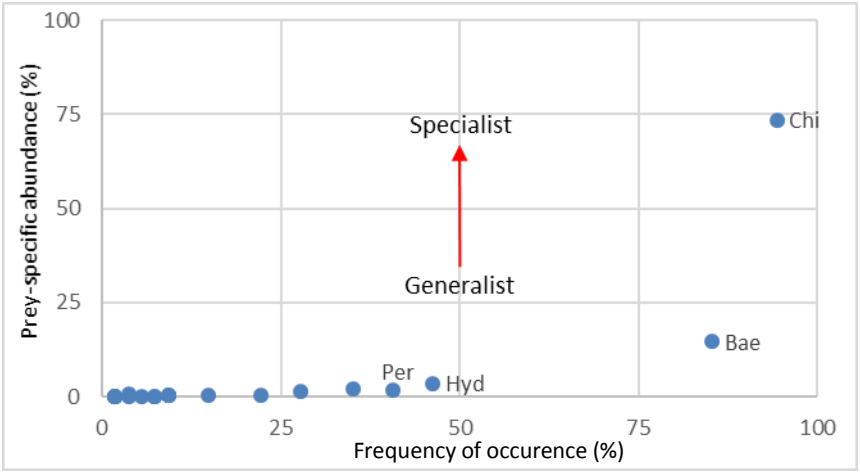

Figure 2. Feeding strategy displayed by the Costello (1990) graphical method for the stone loach (*Barbatula barbatula*).

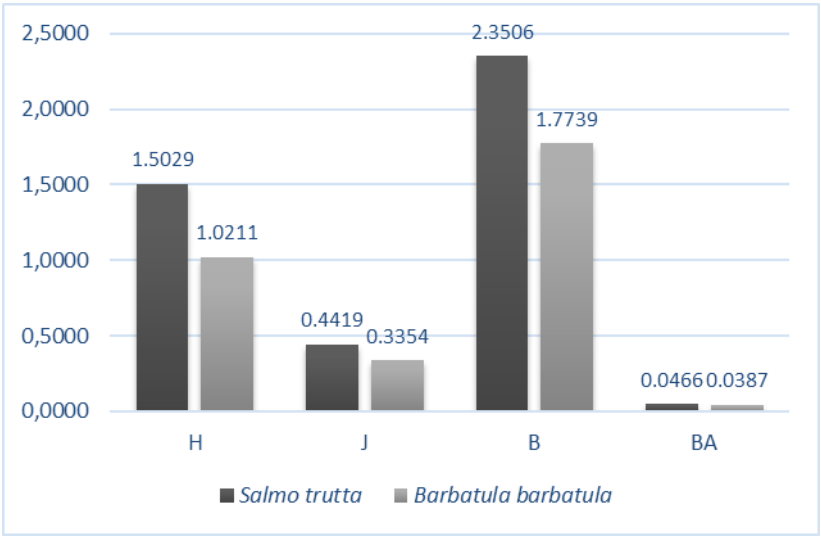

Figure 3. Diversity indices and niche breadth values of brown trout, and of stone loach.

In several cases we found in the digestive tracts small pieces of plastic, stones and colored fibers.

Salmo trutta is a diurnal and nocturnal predator (Heggenes *et al.*, 1993), mainly feeding on benthic prey but also on surface prey (Cadwallader & Backhouse, 1983; Rochard & Elie, 1994). The major part of its diet consists of insects, mainly ephemeroptera, trichoptera, diptera and plecoptera larvae (Ureche *et al.*, 2008, 2010).

According to Cada *et al.*, 2003, amphipods and diptera larvae (Chironomidae) consisted a large part of the brown trout diet. However, our study showed that these prey categories were poorly selected by the fish.

The brown trout tend to feed on molluscs during the summer (Oscoz *et al.*, 2000). Despite that, the gut contents of the brown trout lacked of molluscs of any kind.

Barbatula barbatula is an opportunistic species particularly active at night (Fischer, 2004) mainly feeding on diptera larvae, mostly chironomids (Hartley, 1947; Smyly, 1955; Maitland, 1965; Perrin, 1980). Other predominant preys are ephemeropterans, plecopterans and trichopterans, especially in spring and summer (Sauvonsaari, 1971).

The stone loach diet indicated a constant preference for certain prey types (Nicoară *et al.*, 2006), particularly for diptera larvae (Chironomidae).

According to Oscoz *et al.*, 2004, amphipods were selected by the stone loach in significant numbers (A%=5.29%). However, our investigation indicated that *Barbatula barbatula* fed on this type of prey in lower numbers (A%=0.03%).

The dietary analyses, based on macroinvertebrates, showed low values of niche overlap (M=0.2488-0.3296; O=0.2863) between the two species, indicating a reduced competition for food resources.

Overall, *Salmo trutta* and *Barbatula barbatula* were defined as specialist feeders with a narrow niche breadth. Both species presented an opportunistic feeding behavior (Ureche *et al.*, 2008).

The stone loach tend to choose less mobile prey, with preference for the benthic zone while highly mobile organisms are preferred by the brown trout.

According to Hartley, 1947 and Smyly, 1955, *Salmo trutta* and *Barbatula barbatula*, were generally known as feeding competitors, although our study revealed a reduced competition for food resourses based on niche overlap analysis.

Conclusions

Consequent to the analysis of the brown trout and stone loach diets, a strong dominance of the Class Insecta (86.48%) in the food spectra of the two fish species was observed.

A total number of 37 macroinvertebrates taxa/groups were identified in the gut contents of the brown trout and of stone loach, summing a total of 3839 prey items. The most abundant macroinvertebrates identified were diptera (chironomids), ephemeroptera (*Baetis* spp., *Ecdyonurus* spp.), plecoptera (*Perla* spp.) and trichoptera larvae (*Hydropsyche* spp., *Polycentropus* spp.).

In terms of prey diversity, the dietary analysis for the brown trout, indicated higher values, compared with the stone loach.

The two species presented narrow niche breadth and low values of niche overlap, a reduced competition for trophic resources between the two species being observed.

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Appendix: Acronyms used to abbreviate the macroinvertebrate groups, genus or species binomial nomenclature:

Ant – *Antocha* spp.
Bae – *Baetis* spp.
Cer – Ceratopogonidae
Chi – Chironomidae
Coe – *Coenagrion puella*
Dix – *Dixa* spp.
Dru – *Drusus* spp.
Ecd – *Ecdyonurus* spp.
Elm – *Elmis* spp.
Elo – *Elophil*a spp.
Eph – *Ephemera* spp.
Gam – *Gammarus* spp.
Ger – *Gerris* spp.
Hal – *Haliplus* spp.
Hst – *Helobdella stagnalis*
Hrn – Hydracarina
Hna – *Hydraena* spp.
Hus – *Hydrophilus* spp.
Hyd – *Hydropsyche* spp.
Hla – *Hydroptila* spp.
Indet – Indeterminate
Iso – *Isogenus* spp.
Lus – *Limnephilus* spp
Lim – *Limnius* spp.
Lmn – Limoniidae
Nem – *Nemoura* spp.
Not – *Notonecta* spp.
Oli – Oligochaeta
Per – *Perla* spp.
Pla – *Platambus* spp.
Pol – *Polycentropus* spp.
Rha – Rhagionidae
Rhy – *Rhyacophila* spp.
Sim – Simuliidae
Tab – *Tabanus* spp.
Terr – Terrestrial
Tip – *Tipula* spp.