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DIET AND PREY SELECTIVITY BY AGE-0 BROWN TROUT (*SALMO TRUTTA* L.) IN DIFFERENT LOWLAND STREAMS OF LITHUANIA

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Abstract. In Lithuania brown trout (*Salmo trutta* L.) is the dominant species in fish communities of cold-water streams. We documented a variation in food consumption and prey selection by age-0 brown trout (*Salmo trutta* L.) in different lowland streams in the western part of Lithuania. The research was done in 9 streams in August–September 2004. The diet of 82 brown trout individuals was described for the purpose of registering the number and frequency of prey objects per fish, and their selection of invertebrate fauna. Samples of invertebrate fauna were also gathered. Mayflies (*Baetis*) (Ephemeroptera) frequency 70% dominated the diet of brown trout. Secondary dietary items included larvae of midges (Chironomidae) – 43%, caddisflies (Trichoptera, except *Hydropsyche* genus) – 33%, and bugs (Elmidae) – 30%. The share of terrestrial invertebrates in the diet of this fish was not considerable. Generally, the quantity of aquatic invertebrates consumed by brown trout is greater than that of terrestrial invertebrates. Statistically significant difference in the quantity of the above mentioned dietary items consumed by brown trout was recorded only in one stream. The most preferable are objects of substrate surface or active drifting prey such as simulids, ephemeropterans (*Ephemerella*, *Baetis*), trichopterans, coleopterans. The food niche breadth of brown trout was relatively wide in different streams, which indicates that trout tend to be euriphagous. This study shows that stream dwelling brown trout feed on a variety of prey items, their diet and feeding behaviour changing by habitat.
Key words: brown trout, feeding, selectivity, lowland streams

INTRODUCTION

The study of brown trout (*Salmo trutta* L.) feeding habits is one of the basic ways to understand its biology. Analysis of the fish diet not only reveals its trophic requirements, but also provides indirect information about its mode of feeding and interaction other species (e.g. competition, predation). There is a number of studies in Europe dealing with brown trout feeding habits (Greenberg *et al*. 1997; Kreivi *et al*. 1999; Oscoz *et al*. 2005). In salmonids, feeding is accomplished by visual foraging (Wankowski & Thorpe 1979). Three potential groups of brown trout food can be distinguished: substrate-associated prey, suspended drift and surface drift prey. Also, its food sources could be divided into those of terrestrial (invertebrates accidentally falling into streams) and aquatic origin.

However, some studies do not agree on the diet composition of this fish, i.e. whether it is primarily composed of prey obtained from drift (Tippets & Moyle 1978; Dahl 1998) or from benthos (Bridcut & Giller 1993a; Kreivi *et al*. 1999). Bridcut and Giller (1993b) demonstrated that trout diet is largely determined by the habitat in which these fish forage.

There are more than 180 rivers in Lithuania where viable populations of brown trout are found. This species is dominant in biomass in fish communities of cold-water streams (i.e. when the mean water temperature is below 17°C in summer) (Virbickas 1998). Most studies of brown trout feeding are done in highland streams and rivers (Bridcut 2000; Oscoz *et al*. 2005). Lowland rivers are characterised by low discharge and slow water current, especially in summer. Although trout predation may have profound ecosystem level effects, only one study is available (Kazlauskas 1963) on the influence of mayflies, stoneflies and caddisflies on trout feeding in lowland streams of Lithuania.

The current paper analyses diet variations and prey selectivity by age-0 brown trout in different lowland streams in the western part of Lithuania.

MATERIAL AND METHODS

Study site

The study area comprises a series of third-and fourth-order streams (Table 1). The streams are low gradient and originate at an elevation ranging between 150 m and 200 m. Riparian vegetation at sample sites includes alders (*Alnus* sp.), birches (*Betula* sp.) and oaks (*Quer-*

Table1. Characteristics of the nine streams studied in summer in 2004.

Streams	Stream order	Distance from headwaters (km)	Mean river width (m)	Mean velocity (m/s)	Mean depth (m)	Riffle/run/pool (%)	Regulation of riverbed	Overhead canopy (%)
Blendžiava	4	19.3	5.5	0.24	0.25	15/50/35	Natural	90
Mišupis	4	18.8	5.0	0.07	0.30	5/10/85	Natural	100
Veiviržas	3	24.9	8.0	0.30	0.25	10/70/20	Natural	70
Šalpė	4	23.1	5.0	0.05	0.35	5/15/80	Natural	90
Aisė	3	22.7	4.0	0.20	0.15	5/20/75	Natural	50
Šlužmė	4	18.0	3.0	0.01	0.35	3/2/95	Natural	95
Smiltelė	3	13.7	2.0	0.28	0.35	5/35/60	Regulated	10
Kulšė	2	15.2	2.0	0.05	0.50	0/5/95	Regulated	0
Dratvinys	3	13.9	3.0	0.15	0.20	5/50/45	Natural	50

Table 2. Age-0 brown trout characteristics in investigated streams in summer.

Stream	Total, n	Fish density (ind./m²)	Mean length (cm)	Mean weight (g)
Blendžiava	10	0.20	6.7 ± 0.3	2.74 ± 0.64
Mišupis	8	0.10	7.5 ± 0.5	4.23 ± 0.56
Veiviržas	10	0.07	6.8 ± 0.1	2.94 ± 0.38
Šalpė	10	0.11	7.2 ± 0.3	3.69 ± 0.68
Aisė	10	0.14	7.0 ± 0.3	3.48 ± 0.84
Šlužmė	6	0.07	6.8 ± 0.8	3.29 ± 1.04
Smiltelė	10	0.18	9.8 ± 0.8	6.26 ± 2.89
Kulšė	10	0.06	8.2 ± 1.0	6.46 ± 2.38
Dratvinys	9	0.25	7.3 ± 1.0	4.16 ± 2.53

cus sp.) (details in Table 1). All these streams are in the western part of Lithuania (Fig. 1).

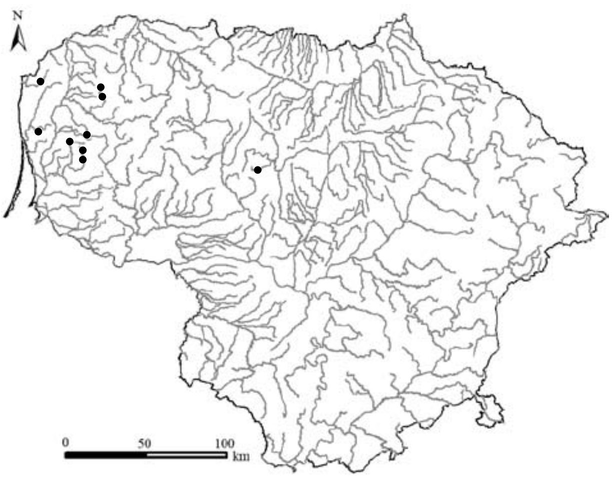

Figure 1. Location of the nine sampled sites in the western part of Lithuania.

The population density of brown trout at these sites was relatively high compared with other Lithuanian streams (0.07–0.25 ind./m²; Kontautas 2005) (Table 2). Other fish species dwelling in these streams are as follows: bullhead (*Cottus gobio* L.), European minnow (*Phoxinus phoxinus* L.), and loach (*Barbatulus barbatulus* L.).

Sampling protocol and data analysis

Age-0 brown trout were collected from August to September 2004. Fish were caught by electrofishing in stream sections longer than 100 m. Three successive electrofishing passes were carried out at intervals of 45 min. The theoretical density of individuals of each fish species was calculated by Zippin's method (Zippin 1958). Fish densities were extrapolated to values for one square meter (ind./m²).

Captured fish ranged from 6.7 cm to 9.8 cm in fork length and from 2.74 g to 6.46 g in wet mass in different populations (for sample size, fish length (L, cm) and weight (Q, g); see Table 2).

Fish collected for stomach content analysis were euthanized and put into plastic bags with formalin (4%). We examined stomach contents of each fish specimen, determined the number of organisms belonging to each particular taxon, and recorded blot-dry wet weights to the nearest milligram. A scale sample was taken for age determination. In the laboratory, stomach contents and benthic invertebrates were identified to the lowest feasible taxonomic unit (usually genus, family for dipterans, larvae for coleopterans and for some caddisflies; order for terrestrial prey).

Samples of benthic invertebrates were taken by the kick-sampling methods in three 0.1 m² areas at each study site. Samples of macrozoobenthos were taken according to a stratified random design based on the proportion of each stream biotope area (Meyer 1991). Samples were always taken from the shallow stream section. Brown trout (of 0+) prefer shallower habitat section (25–40 cm) in summer (Mäki-Petäys *et al*. 1997).

V. S. Ivlev's selectivity index (Ivlev 1961) was used to measure feeding selectivity. Analysis of brown trout (*Salmo trutta* L.) diet selectivity was conducted on those aquatic taxa that constituted 10% and more of the total abundance in a benthic community and in fish guts.

The diet diversity of the sampled population (H) was calculated using Shannon-Wienner's diversity index (Shannon & Weaver 1949). The use of Shannon-Wienner's index provides a relatively objective indication of niche breadth (Marshall & Elliott 1997). Low values indicated diets with few prey items (specialist predators) and high values indicated generalist diets. Furthermore, in order to evaluate specialisation in the diet of brown trout, an evenness index (E = H/H max) (Marshall & Elliott 1997) was calculated assuming that values close to zero indicate a stenophagous diet and those closer to one point to a euryphagous diet.

The mass of prey in fish stomachs was grouped into that of terrestrial and aquatic prey. The *t*- test was employed to compare the mean mass of terrestrial and aquatic prey per fish in the same stream. One-way ANOVA was used to compare the mean mass of prey per fish, food niche breadth of brown trout and macroinvertebrate abundance in different streams. If significant differences were found, Tukey's multiple comparison procedures were employed to locate the source of any differences (Sokal & Rohlf 1997). The numbers and masses of prey items were $\log_{10}$ transformed to remove the dependency of variance on the mean (Sokal & Rohlf 1997).

Results

Invertebrate abundance

The mean abundance of aquatic invertebrates in the studied streams was 4,233 ind./m² and ranged from 2,767 ind./m² in the Šalpė stream to 6,197 ind./m² in the Dratvinys stream (Fig. 2). Oligochaeta, Chironomidae and molluscs (Bivalvia) were the most abundant invertebrate groups (Fig. 3). The abundance of invertebrates did not differ significantly among the streams (one-way ANOVA, df = 8, F = 1,139, p = 0.385).

Analysis of brown trout diet

A total of 1,011 aquatic and terrestrial prey items were detected in trout stomachs and there were no empty guts found. The detected invertebrates represented 13 orders of insects, one of crustaceans, two of molluscs, two of spiders. The analysis showed that brown trout consumed a wide diversity of food items, but aquatic prey constituted the major part of its food. The occurrence of terrestrial prey in brown trout diet was very low. The latter component of the fish diet mainly consisted of Diptera and Aranei. Larvae of mayflies (*Baetis* spp.), detected in 66 percent of the brown trout guts examined in summer, proved to be the most frequent aquatic prey of brown trout. The prey composition of brown trout, which mainly consisted of ten components, was quite similar in all the streams (except the Šlužmė). In the Šlužmė stream the main component of brown trout food was terrestrial prey (Diptera imago and Lepidoptera larvae). Figure 4 shows the percentage of each prey in the total prey biomass in each stream.

The combined mean mass of prey ingested per fish at all sites was 39.11 mg/fish (ranging from 12.83 to 76.67).

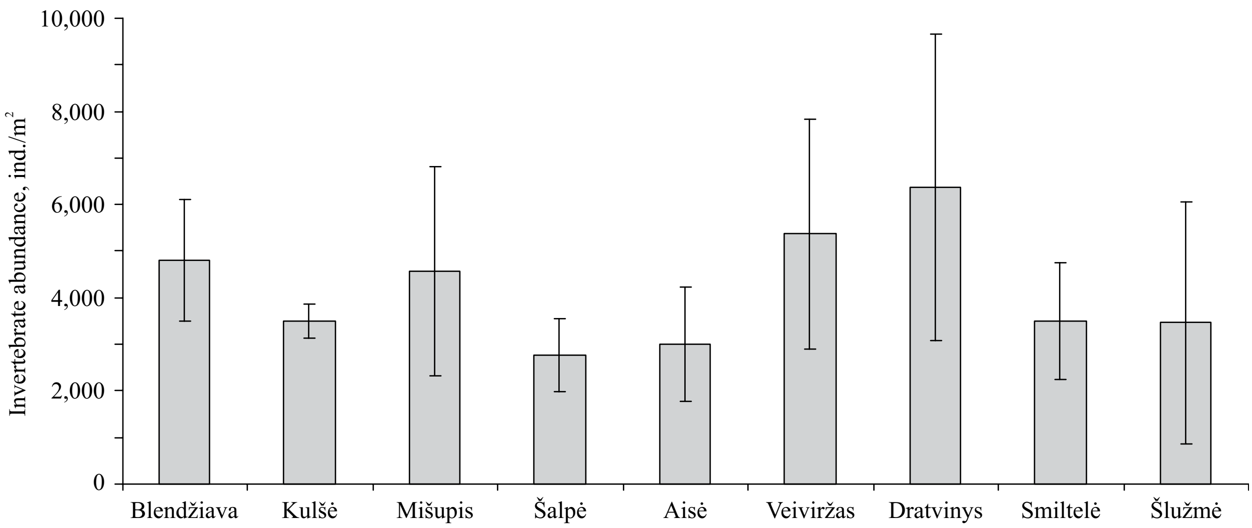

Figure 2. Invertebrate abundance in the western part of Lithuania in summer.

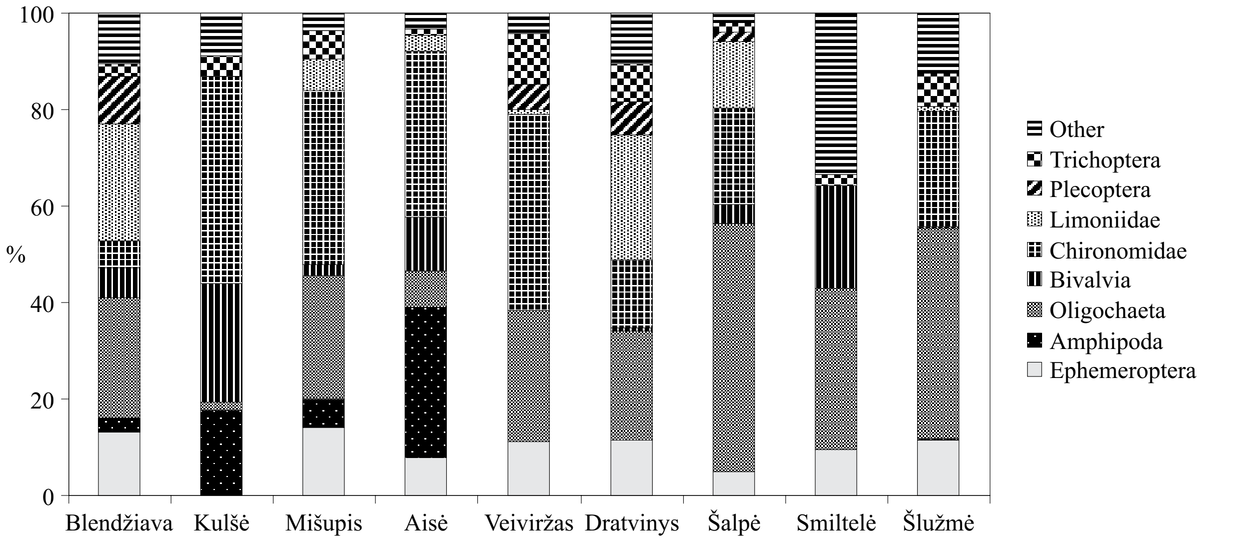

Figure 3. Relative abundance of macroinvertebrates in studied streams in summer.

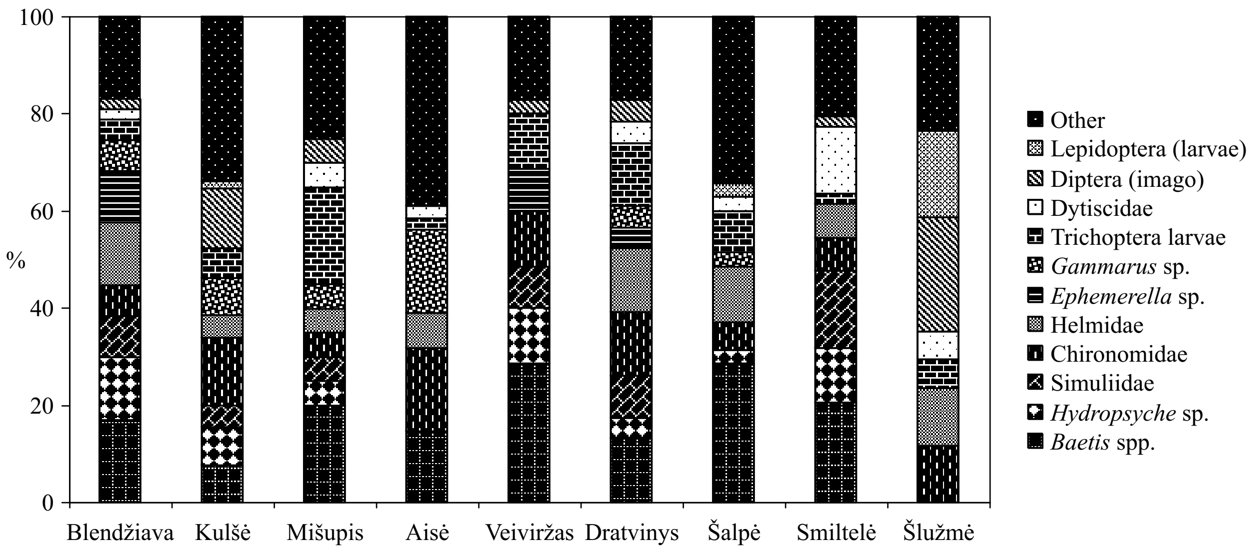

Figure 4. Composition of prey (in %) consumed by brown trout in the western part of Lithuania.

Invertebrates of aquatic origin constituted 66% of the total identifiable prey mass. Terrestrial invertebrates made up 34% of the diet mass.

Generally, the quantity of aquatic invertebrates consumed by brown trout was greater than that of terrestrial invertebrates. However, a significant difference in the share of the above mentioned components in brown trout diet was recorded only in the Smiltelė stream (t-test, df = 18, t = 4.94, p = 0.0001). Only in the Šlužmė stream, terrestrial invertebrates were primary prey of brown trout (t-test, df = 10, t = 2.25, p = 0.05 (Fig. 5).

Food selectivity by brown trout

The study showed that larvae of water insects are the main component of brown trout food. The most preferable were substrate surface or active drifting prey such as simulids, ephemeropterans (*Ephemerella*, *Baetis*), trichopterans and coleopterans (Table 3). The obtained results suggest that brown trout avoid sediment burrowing invertebrates such as bivalve molluscs and oligochaetes.

Food niche breadth of brown trout

Food niche breadth of brown trout was relatively wide; it averaged H = 1.43 in different streams and ranged from H = 0.98 to 2.08 (for all population) (Fig. 6). Niche breadth of brown trout did not differ significantly among streams (one-way ANOVA, df = 8, F = 1.33, p = 0.24). The evenness index of brown trout varied from 0.58 to 0.83 (for pooled population).

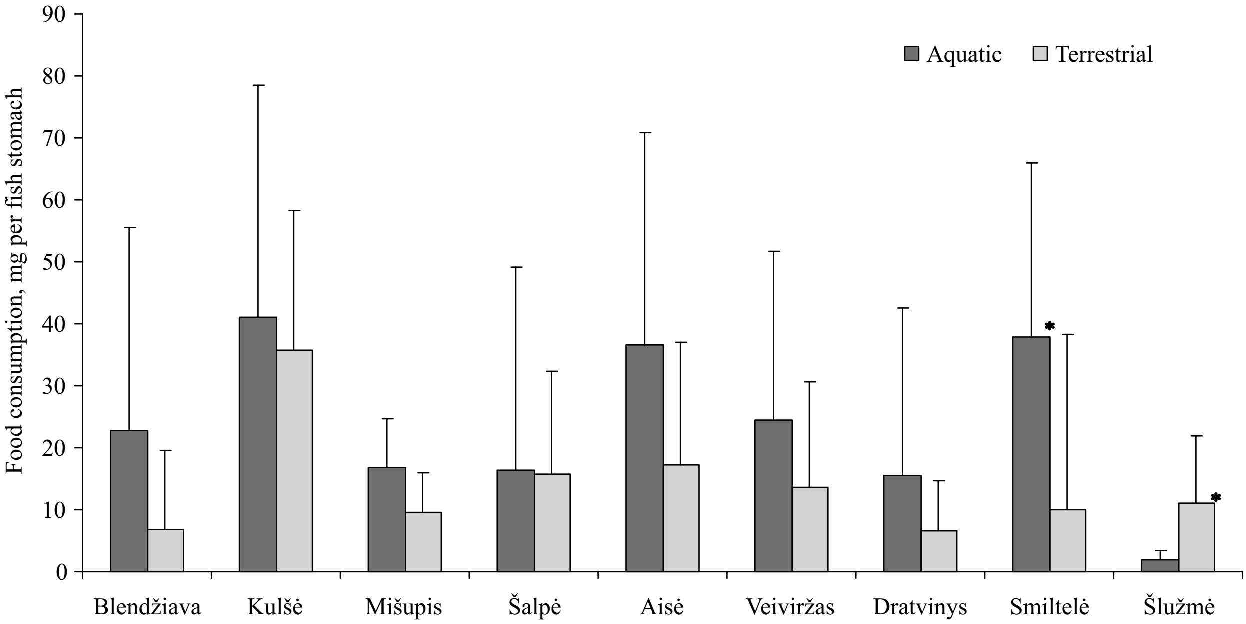

Figure 5. Mean mass of aquatic and terrestrial invertebrate prey consumed by brown trout (asterisk means significant difference).

Table 3. Ivlev's selectivity index for the most common macroinvertebrate taxa in brown trout diet in different streams in summer.

Prey taxa	Blendžiava	Kulšė	Mišupis	Šalpė	Aisė	Veiviržas	Dratvinys	Smiltelė	Šlužmė
Simuliidae	1		1			0.9	1	1	
Ephemerella sp.	1					1	1		
Hydropsyche sp.	0.7	1	1	0.5		0	1	1	
Baetidae	0.7	1	1	0.9	0.7	0.6	1	0.9	-1
Dytiscidae			1				0.8	0.7	
Helmidae	0.2		1	0.7	0.6		0.9	1	0.7
Trichoptera larvae		-0.1	0.5	0.6		0.8	0.2		
Gammarus sp.	0.4	-0.4	-0.1		-0.2		1		
Leuctra sp.	-0.2			0.1			-0.1		
Chironomidae	0.2	-0.5	-0.7	-0.6	-0.2	-0.6	0	-0.8	0.5
Tipuliformes	-0.8		-1	-1			-1		
Pisidium sp.	-1	-1		-1	-1			-1	
Ephemera sp.	-1		-1	-1			-1		
Oligochaeta	-1		-1	-1		-1	-1	-1	-1

Discussion

Stomach contents of brown trout were extremely diverse. Our study showed that aquatic invertebrates were the most frequent prey in the diet of age-0 parr brown trout in the investigated streams, which is in good agreement with findings reported earlier in other studies (Kreivi *et al*. 1999). The diet of age-0 brown trout in rivers principally consists of mayflies, as it was pointed out in earlier studies (Kreivi *et al*. 1999; Bridcut 2000).

However, there were variations in the relative importance of some other items among the streams. In the Šlužmė stream brown trout consumed more dipterans and fewer trichopterans in comparison with other streams in the western part of Lithuania. These slight differences were probably due to differences in prey availability and habitats among the streams (Power 1992; Oscoz *et al.* 2005).

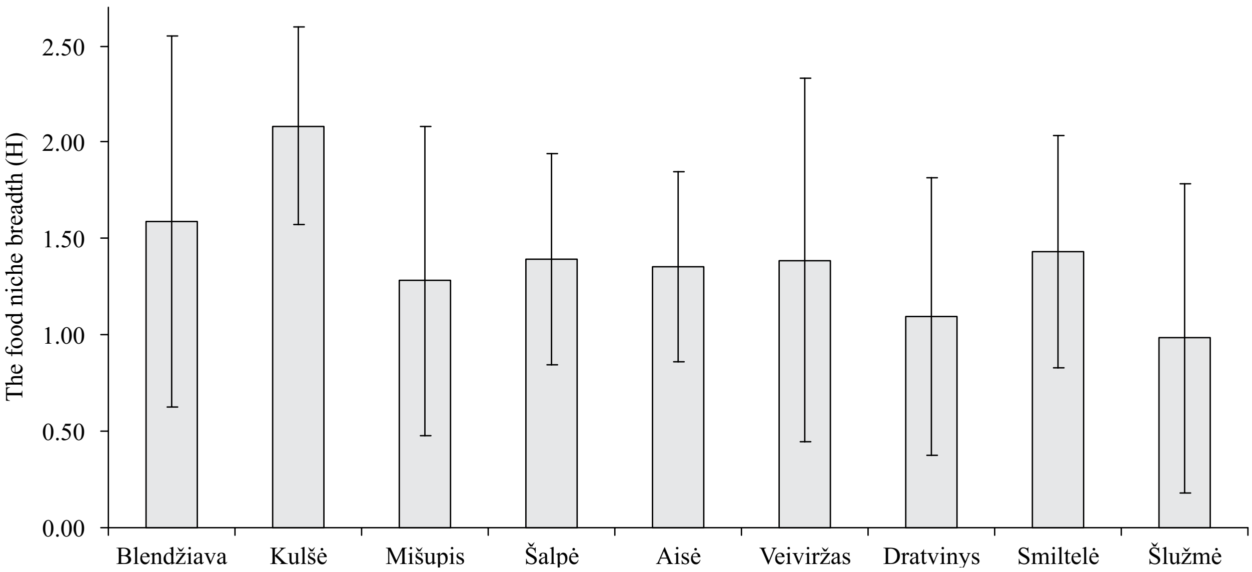

Figure 6. Food niche breadth of brown trout in different streams.

This study showed that both ephemeropterans and trichopterans were the main food for brown trout in all the streams, with the exception of the Kulšė, Aisė and also Šlužmė streams, where other invertebrates prevailed. In the Aisė and Kulšė streams, crustaceans (*Gammarus* sp.) are one of the dominant species in the macroinvertebrate community. So, brown trout can capture this invertebrate easily. This crustacean is also found in the majority of Danish streams and it is probably the most important food source for trout (Friberg *et al*. 1994). Kazlauskas (1963) mentioned ephemeropterans (both larvae and imago) as predominant food for brown trout in the eastern part of Lithuania, with trichopterans as an additional food source.

Brown trout ingested not only aquatic prey, but also a wide array of terrestrial invertebrates in the streams. Diptera, Araneida and Coleoptera, as terrestrial invertebrates, contributed the greatest mass to the diet of brown trout. Invertebrates of aquatic and terrestrial origin constituted 66% and 34% of the biomass of identifiable organisms in the diet of brown trout. This fact was also observed in Spain, where aquatic invertebrates form more than half of the diet in summer (Oscoz *et al*. 2005).

In many lotic systems, trout require external inputs of terrestrial invertebrates, particularly in summer, to satisfy energetic demands (Nakano *et al*. 1999a; Kawaguchi & Nakano 2001). The contribution of terrestrial invertebrates to the diet of brown trout can be considerable in summer, which is characterised by a low biomass of benthic invertebrates (Nakano *et al*. 1999b). Terrestrial invertebrates occasionally constitute 50–90% of the fish diet during summer and are often preferable to aquatic prey in forested headwater streams (Nakano *et al*. 1999a; b). Our study showed that the higher consumption of terrestrial prey was predetermined by the stream habitat peculiarity. The Šlužmė stream is characterised by big pools and small riffle sections with slow water current and there is no aquatic invertebrate drift in this stream. Therefore, brown trout ingest mainly terrestrial prey, which fall down on the stream surface.

Brown trout are visual predators and prefer active benthic invertebrates (especially ephemeropterans (genus *Baetis*, *Ephemerella*), dipterans (family Simuliidae) and water beetles (Dytiscidae and Elmidae)) that have high drift rates. The above mentioned prey items as preferable trout food were mentioned in earlier studies (Kreivi *et al*. 1999). Smaller prey items (i.e., chironomids) or those that camouflage or hide in the substratum (i.e. oligochaetes, molluscs and mayfly (*Ephemera* sp.) are more difficult to detect, so a lower consumption of these items could be expected (Oscoz *et al*. 2005).

This study suggests that food niche breadth of brown trout is relatively wide. In all other studied streams, food niche breadth was wider in the warm season when the diet of brown trout was more diverse (Nakano *et al*. 1999b). The findings of the present study seem to suggest that brown trout is mostly omnivorous. In other areas, brown trout is also known to be an opportunist species that eats everything what is available (Kelly-Quinn & Bracken 1990).

In conclusion, this study shows that stream dwelling brown trout feed on a variety of prey items, and the diet and feeding behaviour are habitat-dependent.

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Vyraujančios 0+ amžiaus grupės upėtakių (*Salmo trutta* L.) mityba Vakarų Lietuvos upeliuose

T. Ruginis

Santrauka

Upėtakis yra dominuojanti žuvis mažuose šaltavandeniuose upeliuose. Šios žuvys daro poveikį mažų upelių ekosistemai tiek kiekybiškai, tiek kokybiškai. Darbo tikslas – nustatyti vyraujančios 0+ amžiaus grupės upėtakių mitybą Vakarų Lietuvos upeliuose. Tyrimai buvo atliekami 2004 m. rugpjūčio–rugsėjo mėnesiais. Iš viso buvo tiriami 9 upeliai. Taip pat buvo imami vandens bestuburių mėginiai. Upėtakių pagrindinis maistas buvo lašalų (*Baetis*) lervos, kurios buvo aptiktos beveik 70% tirtų žuvų skrandžiuose. Kitų mitybos komponentų rasta žymiai rečiau: uodo trūklio (Chironomidae) lervų – 43%, apsiuvų (Trichoptera, išskyrus genties *Hydropsyche*, kuri sudarė 26%) lervų – 33%, vabalų (Elmidae) – 30%. Be vandens bestuburių, žuvys mito ir sausumos bestuburiais, tačiau šių komponentų buvo randama rečiau. Upėtakiai pagal biomasę suvartojo daugiau vandens bestuburių, negu sausumos bestuburių, tačiau tokie duomenys gauti tik ištyrus Smiltelės upės upėtakių mitybą. Daugiausia upėtakiai mito mašalų, lašalų, apsiuvų ir vabalų lervomis. Šių žuvų mitybos niša buvo plati, tai reiškia, kad mažų upelių žuvims būdinga polifagija. Kaip parodė tyrimas, upėtakiai minta įvairiais bestuburiais ir šių žuvų mityba priklauso nuo tiriamos upės buveinės ypatumų.

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