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Changes in roach (*Rutilus rutilus* (L.)) diet and growth in relation to river water quality

Virginija Pliūraitė,

Tomas Virbickas*,

Vesta Skrodenytė-Arbačiauskienė

Nature Research Centre,
Akademijos 2,
LT-08412 Vilnius-21, Lithuania

Diet composition and growth of the roach (*Rutilus rutilus* (L.)) was studied in three Lithuanian rivers, differing in water quality. In the pristine river roach fed on various taxa of macroinvertebrates and plant material with similar frequency, none of food categories clearly dominated in the guts of fish. The overall diversity of food items in the diet as well as abundance and diversity of macroinvertebrates in the benthic assemblages were the greatest in the moderately polluted river, but plant material formed the major part of food and was consumed most frequently, presumably as a result of inter-specific competition for the food resources. Percentage of the plant material in the diet was the smallest in the heavily polluted river, where roach predominated over the rest of fish. The growth rates of roach did not differ among reference and heavily polluted river, but in the moderately polluted river fish grew much slower. It is likely that habitat degradation to an extent when majority of less tolerant fish and macroinvertebrate species do not survive seems to be favorable for roach, if the degradation reduces inter-specific competition for food resources.

Key words: roach, diet, growth, river, pollution

INTRODUCTION

Diet of fish may be an indicator of habitat use (Werner et al., 1983) and vary in relation with habitat structure and quality (Giles et al., 1990; Vinni et al., 2000; Tarkowska-Kukuryk, 2008; Holopainen et al., 2008). Tolerant fish species, best adapted to environmental changes, may be a suitable object for comparison of diet and growth at marginal conditions, thus providing additional information on the functioning of aquatic ecosystems under the impact of human activities.

The roach *Rutilus rutilus* is among the most commonly found and most widely distributed fishes in Europe (Kottelat & Freyhof, 2007), best adapted to river canalization and pollution (Penczak & Koszalinska, 1993). It is known to be an opportunist species that can feed on zooplankton, benthic invertebrates, planktonic algae, epiphytes, macrophytes and detritus (Brabrand, 1985; Rask, 1989; Giles et al., 1990; Horppila, 1994; Specziar et al. 1997); feeding behavior may vary in relation to the environment (Jamet et al., 1990).

In natural conditions the growth rate of roach depends on a combination of several factors – duration of the growing season, water temperature, and food availability (Persson, 1983; Cryer et al., 1986; Nunn et al., 2003; Britton et al., 2004; Lappalainen et al., 2008). Shifts in river productivity resulting from changes in water quality may also have impact on growth rates (Beardsley & Britton, 2012). Therefore, abiotic variables having important roles in determining

* Corresponding author. E-mail: tvirbickas@takas.lt

fish growth rates in temperate freshwaters, the effects of water quality also require consideration (Persson, 1991; Schlinder et al., 2000). Roach can suffer decreased growth in unfavorable conditions (Burrough & Kennedy, 1979).

There are numerous publications on roach feeding and growth, but only few of them analyze variation of these parameters in relation to water quality (Vinni et al., 2000; Holopainen et al., 2008; Jamet et al., 1990; Beardsley & Britton, 2012). Such an analysis was conducted in a current study, the objective being to assess roach diet composition and growth in the context of food availability in the rivers, considerably differing in water quality. We tested the hypothesis that growth of roach would be slower in the more polluted river.

MATERIALS AND METHODS

Study area

The study was conducted in three national surveillance intensive monitoring sites situated in the Žeimena (55°12'0.34'', 25°58'45.36''), the Mūša (56°15'8.05'', 24°22'18.51'') and the Sidabra (56°20'27.83'', 23°36'50.5''E) rivers. The Žeimena River is one of the most natural rivers in Lithuania, least impacted by human activities. Nearly half of the rivers catchment is covered by lakes (7%), forests (31%) and bogs (10%). Area of the catchment is 2 793 km^2, river length – 80 km, and average flow – 27 m^3 s^{-1}. River width at the sampling site ranges from 13 to 18 m, depth – 0.6–2 m, average slope of river bed – 0.25 m/km, bottom substrate – sand with gravel insertions. River banks are covered by natural riparian vegetation. The Mūša River flows through agricultural lands and hayfields (83% of the catchment area). Since the lands of intensive agriculture predominate in the catchment, the river receives considerable diffused pollution. Area of the catchment is 5 462 km^2, river length – 157 km, and average flow – 25 m^3 s^{-1}. River width at the sampling site ranges from 40 to 60 m, depth – from 0.9 to more that 2.5 m, average slope of river bed – 0.26 m/km, bottom substrate – sand with occasional insertions of pebble, river banks are totally deforested. The Sidabra River is a tributary of the Mūša River. Length of the river is 46 km, catchment size – 144 km^2, and average flow – 0.4 m^3 s^{-1} (Gailiušis ir kt., 2001). River width at the sampling site ranges from 6 to 9 m, depth – 0.5–1.6 m, average slope of river bed – 0.96 m/km, bottom substrate – sand, covered by thin layer of silt. River banks are deforested, covered by solitary scrubs. The River Sidabra is considerably polluted by the nutrients, getting into the river with effluents of the municipal waste water treatment plant. River also receives diffused pollution from agricultural lands.

Macroinvertebrates and fish analysis

Macroinvertebrates and fish were sampled at the monitoring site in the River Mūša in the first decade of June 2011, and at the monitoring sites in the Žeimena and Sidabra rivers in the first decade of June 2012. Macroinvertebrates were sampled from four 0.1 m^2 areas by the kick-sampling method (Kleemola & Söderman, 1993), duration of each individual kick-sampling being 1 minute, and by taking multihabitat samples collected over the 10-minute period with a hydrobiological dip net from all possible biotopes at each study site. Samples were sieved using a 500 μm mesh transferred into plastic flasks and stored in a 4% formaldehyde solution. In the laboratory, all animals were separated, counted, and identified to species or genus level (except *Oligochaeta*) under a binocular dissecting microscope. The total macroinvertebrate abundance (ind. m^{-2}), and absolute and relative abundance (%) of macroinvertebrate taxonomic groups have been assessed.

Continuous single run electrofishing using backpack unit with the pulsed current were undertaken in the 1–2 km length and 3 m width stretches around the monitoring site in each river, until at least 60 roach specimens were collected in each of the sampled river stretch. Specimens of the rest fish species were continuously counted, weighed (g), recorded and released back at the point of capture. Coordinates of the beginning and the end of sampled sections were established with GPS device. Section lengths were measured from the high resolution aero map. Section length and width data were used to calculate sampled area. In order to enable comparison of fish density and biomass, actual number and weight of fish were recalculated to those per unit of area (100 m^2).

Roach individuals were weighed (g) and measured for standard and total length (cm). The digestive tracts of the specimens were removed in the field and preserved in 70% ethanol, and scale sample of each individual was taken for age determination. In the laboratory, the food items were identified under a dissecting microscope to the lowest taxonomic level possible, whether family, genus, or species. To assess the relative importance of different food categories, data were expressed in terms of frequency of occurrence (F% = number of guts containing a specific food category / total number of examined guts × 100) and percent average wet weight (Wm%) per all guts examined.

As the body size spectrum of roach specimens in the studied rivers differed, roach individuals which fell within the body size range present in all three rivers (10–19 cm; standard length) were selected for comparative diet analysis to avoid possible bias in diet composition determined by variance in fish sizes. Relative importance of different food categories in the diet of roach in each river site was assessed per all specimens, and sub-dividing specimens to two groups of equal range of standard length: 10–14.5 cm and 14.6–19 cm.

The age of roach individuals was established analyzing scales under dissecting microscope. Since roach specimens were sampled in the rivers at the same season in 2011 and 2012 (the first decade of June), the age and body size of specimens were not back calculated.

The General Linear Model ANOVA and Fisher LSD test were used to determine differences in roach diet metrics and roach growth rates among river sites. Calculations were done with Statistica for Windows 6.0.

Data on the main chemical variables, measured monthly from January till June 2011 in the monitoring site in the Mūša River, and from January till June 2012 in the monitoring sites in the Žeimena and Sidabra rives were obtained from the Environmental Protection Agency of Lithuania. The measured values of the main physiochemical variables in the investigated river sites are presented in Table 1. According to classification of the status of surface water bodies in Lithuania (Valst. žinios, 2010), water quality in the Žeimena River is excellent according to all chemical parameters. The Mūša River is moderately eutrophicated; the concentrations of nitrates (NO_3-N) and total nitrogen are elevated and slightly exceed maximum permissible concentration. The Sidabra River is heavily eutrophicated; according to nitrate (NO_3-N) and N total values, the water quality is very bad, and according to those of PO_4-P and P, the water quality is moderate (Table 1).

RESULTS

Ten fish species were recorded in the stretches of each Žeimena and Mūša rivers, and six species in the Sidabra River (Table 2). Roach is the most abundant fish species in all rivers, amounting to 27.3% of total fish abundance in the River Žeimena, 42.2% in the Mūša and 70.8% in the River Sidabra.

Macroinvertebrate assemblages in the Žeimena and Mūša rivers are dominated by several taxonomic groups: *Ephemeroptera*, *Trichoptera*, *Mollusca* (both rivers), *Hemiptera*, *Simuliidae* (the Žeimena), *Amphipoda* and *Chironomidae* (the Mūša). Macroinvertebrate assemblage in the

Table 1. **The values of chemical variables (mean ± SE) (data from the Environmental Protection Agency of Lithuania)**

Variables	Rivers		
	Žeimena	Mūša	Sidabra
BDS_7 mg0_2l^{-1}	1.5 ± 0.2	2.4 ± 0.5	1.6 ± 0.5
NH_4-N mgl^{-1}	0.03 ± 0.01	0.12 ± 0.04	0.2 ± 0.1
NO_3-N mgl^{-1}	0.4 ± 0.1	3.7 ± 1.2[a]	11.1 ± 1.5[a]
N total mgl^{-1}	0.6 ± 0.1	5.9 ± 1.3[a]	15.7 ± 2.2[a]
PO_4-P mgl^{-1}	0.01 ± 0.003	0.03 ± 0.01	0.1 ± 0.03[a]
P total mgl^{-1}	0.04 ± 0.004	0.05 ± 0.01	0.143 ± 0.03[a]

[a] – exceeds maximum permissible concentration

Table 2. **Fish number (N, ind.) and weight (W, g) per area (100 m²)**

Fish species	Žeimena		Mūša		Sidabra	
	N (ind.)	W (g)	N (ind.)	W (g)	N (ind.)	W (g)
Alburnoides bipunctatus	2.3	11	1.5	15	–	–
Alburnus alburnus	2.2	26	6.3	61	–	–
Barbatulus barbatulus	0.4	3	2.6	7	–	–
Abramis bjoerkna	–	–	4.1	58	–	–
Carassius carassius	–	–	–	–	0.8	137
Cobitis taenia	–	–	–	–	1.8	4
Esox lucius	0.1	10	–	–	0.8	251
Gobio gobio	0.9	7	3.7	43	1.8	10
Squalius cephalus	0.1	23	3.0	393	–	–
Leuciscus leuciscus	1.1	40	0.2	2	–	–
Perca fluviatilis	0.3	3	0.9	9	0.8	8
Phoxinus phoxinus	1.4	3	–	–	–	–
Rutilus rutilus	3.3	107	16.7	638	13.8	1 479
Vimba vimba	–	–	0.4	137	–	–
Total	12.1	233	39.6	1 365	19.5	1 890

Sidabra River is predominated by one taxonomic group, the chironomids (Table 3).

In total, 44 items of fauna and flora were identified per 143 examined guts of roach per all three rivers: 21 item in the Žeimena River (42 guts), 33 in the Mūša (52 guts) and only 9 items in the Sidabra River (49 guts). In the Žeimena River roach fed on plant material, caddisflies (mostly *Brachycentrus subnubilus*), mollusks (*Bithynia tentaculata, Pisidium* sp., *Theodoxus fluviatilis, Gyraulus albus*) and midges with similar frequency. The share of individual food categories in the guts of roach did not exceed 29% (Table 4). Larger roach individuals fed more on hemipterans (*Aphelocheirus aestivalis*) and less on *Simulium* sp. larvae, comparing with smaller ones ($F = 11.3$, $P < 0.01$; Fisher LSD $P < 0.01$) (Figure).

Aquatic plants (*Elodea canadensis*, *Potamogeton* sp., filamentous algae) dominated in the roach diet in the Mūša River, irrespective of the size of roach individuals, but the percent of plant material is higher in the guts of smaller fish ($F = 4.2$, $P < 0.05$; Fisher LSD $P < 0.01$). Caddisflies (mostly

Table 3. **Absolute (ind. m^{-2}) and relative (%) abundance of macroinvertebrate taxa (mean ± SE)**

Macroinvertebrate taxa	Žeimena		Mūša		Sidabra	
	ind. m^{-2}	%	ind. m^{-2}	%	ind. m^{-2}	%
Oligochaeta	77 ± 12	6.4	25 ± 5	1.2	270 ± 15	8.2
Mollusca	200 ± 11	16.6	287 ± 14	14.4	117 ± 9	3.5
Amphipoda	–	–	280 ± 49	14.0	17 ± 3	0.5
Isopoda	–	–	13 ± 2	0.7	23 ± 3	0.7
Ephemeroptera	173 ± 7	14.3	517 ± 25	25.9	–	–
Plecoptera	110 ± 6	9.1	20 ± 4	1.0	–	–
Trichoptera	213 ± 12	17.6	420 ± 23	21.0	30±6	0.9
Hemiptera	183 ± 9	15.2	–	–	–	–
Coleoptera larvae	70 ± 6	5.8	32 ± 5	1.6	–	–
Chironomidae	20 ± 5	1.6	315 ± 27	15.8	2 786 ± 135	84.6
Simuliidae	137 ± 3	11.4	20 ± 4	1.0	-	-
Others	24	2	68	3.4	50	1.6
Total	1 207 ± 36		1 997 ± 74		3 293 ± 158	

Table 4. **Frequency of occurrence (F%) and percent average wet weight (Wm%) of food components**

Food components	Žeimena		Mūša		Sidabra	
	F%	Wm%	F%	Wm%	F%	Wm%
Plant material	59.5	16.3[a]	100.0	78.2[a]	34.7	2.0[a]
Trichoptera	57.1	10.7	76.9	7.8	85.7	74.2[a]
Chironomidae	26.2	3.3	86.5	6.3	51.0	23.2[a]
Mollusca	42.9	28.3[a]	25.0	5.6	6.1	0.4
Simuliidae	52.4	28.8[a]	3.8	0.2	–	–
Ephemeroptera	4.8	0.5	5.8	0.2	–	–
Odonata	2.4	0.02	1.9	0.2	2.0	0.1
Hemiptera	26.2	11.5	–	–	–	–
Coleoptera	2.4	0.05	1.9	0.02	–	–
Isopoda	–	–	–	–	2.0	0.1
Cladocera	–	–	7.7	0.2	–	–
Rotatoria	–	–	1.9	0.02	–	–
Diptera	–	–	1.9	0.1	–	–
Arachnida	–	–	1.9	0.02	–	–
Detritus	9.5	0.6	17.3	1.2	–	–

[a] – differences are significant at $p < 0.01$

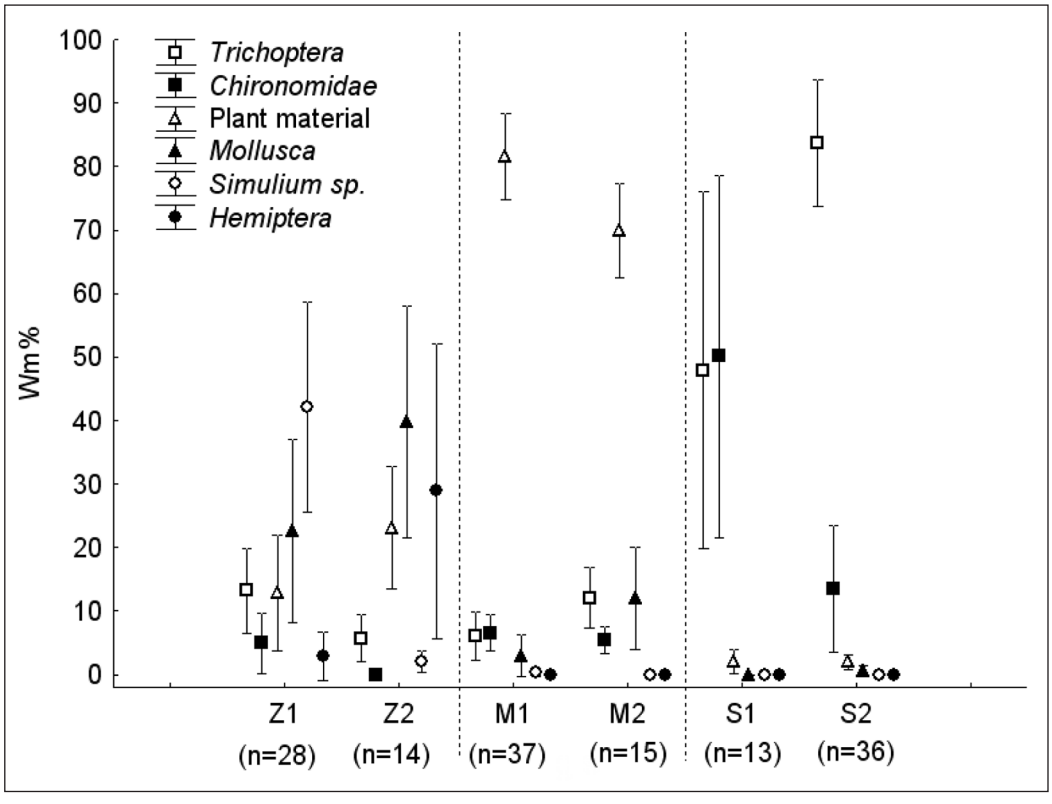

Figure. Percent wet weight (mean and 0.95 confidence intervals) of the main food components in the guts of 10–14.5 cm length (1) and 14.6–19 cm length (2) roach individuals in the rivers Žeimena (Z), Mūša (M) and Sidabra (S); in brackets number of examined guts

Brachycentrus subnubilus and *Hydropsyche* spp.) and chironomids (*Cricotopus algarum*) frequently occurred in the diet, but in low proportions.

In the Sidabra River smaller roach individuals fed on chironomids (*Cricotopus algarum*) and caddisflies (genera *Limnephilus, Anabolia* and

Molana), while larger ones – mainly on caddisflies alone (F% – 91.7, Wm% – 83.7) (Figure).

Comparing the diet of roach among the rivers, differences are in the contribution of plant material (all rivers), caddisflies and chironomids (the Sidabra River), and mollusks (the Žeimena River) (F = 165.4, P < 0.01; Fisher LSD P < 0.01) (Table 4). Simulids and hemipterans are also important components of the roach diet in the Žeimena River.

The length and weight of roach individuals in the Mūša River are smaller comparing with individuals of the same age in two other rivers (Fisher's LSD test, P < 0.01). There are no differences in the size of roach of the same age in the rivers Žeimena and Sidabra (Table 5).

DISCUSSION

There have been numerous studies in the rivers and lakes on the diet of roach. It is known that the most common macroinvertebrates in the diet are caddisflies, chironomids and midges, but plant material also forms much of roach food (Cowx, 1989; Collares-Pereira et al., 1995; Balestrieri et al., 2006; Kakarenko, 2002). The above mentioned macroinvertebrate taxa and plant material were the most frequently eaten by roach in the studied Lithuanian rivers. However, the overall composition and percentage of various food categories in the diet considerably differ in the natural and nutrient-polluted rivers. In the natural Žeimena River roach feed on various taxa of macroinvertebrates and plant material with similar frequency; none of food categories clearly dominate in terms of Wm %. Comparing the composition of the diet with the structure of macroinvertebrate assemblages, roach feed on those macroinvertebrate taxa in the Žeimena River which are the most abundant. Contribution of different taxa to the diet changes together with the size of individuals, and this is in line with known general pattern (Horppila, 1994; Jamet et al., 1990). The overall diversity of food items in the diet of roach in the moderately polluted Mūša River is greater, but plant material forms a major part of the food and was consumed most frequently irrespective of the size of roach individuals, although abundance of many macroinvertebrate taxa on which roach feed is nearly twice greater than that in the Žeimena River. Roach diet in the heavily polluted River Sidabra is least diverse, and this can be explained by narrow spectrum of available pray. Fish selectively feed on caddisflies (particularly – larger roach individuals), and this might be the reason of very low abundance of this taxon in the Sidabra River, compared with two other rivers.

According to Horppila (1994), the frequent use of plant food indicates a low availability of animal prey. But this cannot be an explanation in case of the Mūša River, where macroinvertebrate taxa are numerous and diverse. Given that fish abundance

Table 5. **The total length (L, cm), standard length (l, cm) and weight (W, g) of 5–8 years old roach individuals in the rivers Žeimena, Mūša and Sidabra (mean ± SE)**

River	Age[a]	L, cm	l, cm	W, g
Žeimena	5 (n = 9)	14.8 ± 0.3	11.8 ± 0.1	31 ± 1
	6 (n = 8)	16.7 ± 0.4	13.5 ± 0.3	56 ± 4
	7 (n = 9)	19.8 ± 0.3	16.1 ± 0.3	94 ± 4
	8 (n = 5)	22.8 ± 0.3	18.4 ± 0.2	143 ± 4
Mūša	5 (n = 14)	13.7 ± 0.1	11.1 ± 0.1	27 ± 1
	6 (n = 10)	14.9 ± 0.1	12.0 ± 0.1	37 ± 2
	7 (n = 9)	17.1 ± 0.3	13.9 ± 0.3	53 ± 3
	8 (n = 7)	19.6 ± 0.3	16.0 ± 0.2	89 ± 6
Sidabra	5 (n = 5)	15.0 ± 0.3	11.9 ± 0.2	36 ± 2
	6 (n = 10)	16.9 ± 0.4	13.6 ± 0.4	57 ± 5
	7 (n = 21)	20.0 ± 0.2	16.2 ± 0.2	94 ± 3
	8 (n = 13)	23.1 ± 0.2	18.6 ± 0.1	148 ± 3

[a] – in brackets number of individuals

and biomass per area in the Mūša River are respectively 3 and 6 times greater in comparison with reference conditions, the reason of roach dietary shift towards plant material could be induced by competition for macroinvertebrates (Persson and Greenberg, 1990). Similar pattern is noted by Balestrieri (2006), who found that contribution of plant material in the overall diet of roach in the presence of other cyprinids species is greater compared with the diet composition in allopatry. In confirmation to this, the share of plant material in the diet of roach is the smallest in the Sidabra River (Wm – 2%), where fish species diversity is lowest and roach predominates over the rest of fish in terms of both density and biomass per area.

The growth rates of roach in the Mūša River are significantly slower compared with two other rivers. This is in line with findings of other authors that roach feeding mainly on plant material grows slower than that feeding on animal food (Vinni et al., 1990; Persson, 1983). According to growth classification system designed for Lithuanian lakes (Balkuvienė ir kt., 1975), the roach grow equally fast in both reference Žeimena and contaminated Sidabra rivers. In the Žeimena River presumable suppression of growth by less eutrophic conditions (Beardsley & Britton, 2012) might be counterweighed by optimal (preferred) habitat (Cowx, 1989), while in the Sidabra River the roach diet is not affected by the abundance of competitors (Werner et al., 1983).

The study confirmed expectations of marked differences in roach diet at marginal conditions. However, considerable alterations in water quality and coherent changes in quantitative and qualitative composition of available food did not result in decrease of growth rates of roach. Habitat degradation to an extent, when majority of less tolerant fish and macroinvertebrate species do not survive, seems to be favorable for roach, if the degradation reduces interspecific competition for food resources.

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Virginija Pliūraitė, Tomas Virbickas, Vesta Skrodenytė-Arbačiauskienė

KUOJOS (*RUTILUS RUTILUS* (L.)) MITYBA IR AUGIMAS SKIRTINGOS VANDENS KOKYBĖS UPĖSE

S a n t r a u k a

Trijose Lietuvos upėse, besiskiriančiose vandens kokybe, tirtas kuojų augimas ir mityba, paraleliai nustatant maistui naudojamų bestuburių organizmų gausą ir įvairovę dugno bestuburių bendrijose. Švarioje upėje gyvenančios kuojos įvairiais augalinės ir gyvūninės kilmės maisto objektais mito panašiu dažnumu, nei viena iš maisto kategorijų žuvų skrandžiuose neišsiskyrė didesniu gausumu. Vidutiniškai užterštoje upėje maistui naudojamų organizmų įvairovė, o taip pat ir dugno bestuburių įvairovė buvo didžiausi, tačiau augalinės kilmės maistas sudarė didžiąją kuojų skrandžio turinio dalį bei buvo vartojamas dažniausiai. Smarkiai užterštoje upėje, kur kuojos buvo vyraujanti žuvų rūšis bendrijoje, kuojų skrandžiuose vyravo gyvūninės kilmės objektai, augalinės kilmės maistas sudarė labai mažą dalį. Švarioje bei smarkiai užterštoje upėse kuojų augimo tempai buvo panašūs, tačiau vidutiniškai užterštoje upėje, kur didžiąją kuojų mitybos dalį sudarė augalai, kuojų augimas tempas buvo statistiškai reikšmingai lėtesnis. Šie dėsningumai leidžia manyti, kad buveinės degradacija, sąlygojanti daugelio jautresnių žuvų bei dugno bestuburių išnykimą yra palanki kuojoms, jeigu ši degradacija sumažina tarprūšinę konkurenciją dėl maisto išteklių.

Raktažodžiai: kuoja, mityba; augimas, upė, tarša