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THE DIET OF ROACH, *RUTILUS RUTILUS* (L.), AND BLEAK, *ALBURNUS ALBURNUS* (L.) LARVAE AND FRY IN THE SHALLOW LITTORAL ZONE OF A HEATED LAKE

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ABSTRACT. This paper presents the results of analyses of the dietary composition of 0+ roach, *Rutilus rutilus* (L.), and bleak, *Alburnus alburnus* (L.) inhabiting Lake Gosławskie. The following hypotheses were verified: (i) the dietary composition of fish changes over time; (ii) fish somatic growth causes variation in the spectrum of dietary components. Species richness in the diets of roach and bleak larvae and fry was high. In comparison with other dietary components studied, cladocerans were dominant. The tendencies for change in the indicators of feed variety during the study cycle in both fish species were very similar. In the initial period, the diets of roach and bleak larvae and fry were not varied. After the age of two months, the feed composition of the diets widened progressively, and reached its maximum in August. The variety of the dietary composition of early developmental stages of roach and bleak was strictly correlated to body length. The diet of roach fry (16-30 mm) was significantly more varied than that of larvae (6-15 mm) and the largest fish (>30 mm). With bleak, the dietary variety indicator increased proportionally to body length until they reached a length of 30 mm.

Key words: ROACH, BLEAK, LARVAE, FRY, FEED COMPOSITION, DIETARY VARIETY, HEATED LAKES

INTRODUCTION

The planktivorous juvenile stages of roach, *Rutilus rutilus* (L.), and bleak, *Alburnus alburnus* (L.), often exhibit substantial dietary similarity, which is an indication that interspecific competition exists that can lead to a "bottleneck" in the survival of the juvenile forms of these fish. One of the ecological adaptations that helps prevent this is the sequential exploitation of food resources. This is achieved by staggered spawning periods and differences in the lengths of embryonic and larval development periods (Keast 1978, Persson 1987). In lakes heated with post-cooling waters, however, fish spawning processes become distorted. Temperatures that are higher than those under natural conditions cause accelerated and lengthened spawning periods (Wilkońska

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and Żuromska 1977), as well as changes in the gonad maturation cycle (Lukšienė et al. 2000). The simultaneous occurrence of many age cohorts of various fish species in a lake with an increased water temperature can lead to increased food competition that can result in the lower survival rates of juvenile fish stages.

The aim of the current study was to answer the following questions: (i) what is the dietary composition of juvenile fish stages; (ii) how do the diets of the larvae and fry of the studied fish species change over time; (iii) to what degree does fish somatic growth impact variation in dietary composition.

MATERIALS AND METHODS

The study was conducted for two years (2001-2002) in Lake Gosławskie (52°18'N, 18°20'E), which is a shallow eutrophic natural pond-type lake (surface area 454.5 ha; mean depth 3.0m; maximum depth 5.3 m) located in central Poland. The lake basin is of a regular shape with little development along the shoreline. Since 1970, the lake has been used as a reservoir of cooling water and simultaneously as a receptacle for heated waters from the Konin Power Plant (Zdanowski 1994). The littoral zone is poorly developed and is mostly limited to a narrow strip along the lake shore. Only in the western part of the lake do macrophytes cover a significant part of the bottom.

Roach and bleak larvae and fry (Table 1) were caught in shallow habitats from April to August in monthly cycles with an experimental net (length 5 m, depth 0.8 m, mesh size 1.0 mm). To reduce the impact of diel variation in fry activity, catches were made on sunny days during the same time period (12:00-15:00). The fish were immediately preserved in a 4% formaldehyde solution, and then sorted by species in the laboratory (Koblickaya 1966, Mooij 1989, Pinder 2001). They were measured and weighed and then segregated into arbitrary 5 mm length classes based on body length. The food composition was determined based on the analysis of the alimentary tract contents of ten specimens chosen from each length class in which full alimentary tracts were confirmed previously. The zooplankton that occurred in the fish food was identified to the species (Flössner 1972, Kiefer and Fryer 1978, Koste 1978), the abundance was determined with the Hensen method (Starmach 1955), while the biomass was determined according to the recommendations of Hillbricht-Ilkowska and Patalas (1967), Bottrella et al. (1976), Ruttner-Kolisko (1977), and Ejsmont-Karabin (1998).

Benthic organisms were identified to higher taxonomic units (Romaniszyn 1958, Rybak 1971, 1996, 1997, Kołodziejczyk and Koperski 2000), and standard weights were used to determine insect larval biomass (Prejs and Colomine 1981). The analysis of the food composition was based on the relative proportion (NI) and relative biomass (BI) of the various food components (Szypuła 1995) and food variation index (FVI) (Szypuła 1971). The evaluation of the dietary composition was determined for each species regardless of body length, while dietary variation was analyzed in relation to fish body length and the subsequent months in which the fish were caught.

TABLE 1

Description of early developmental stages of roach and bleak from Lake Gosławskie that were subjected to food analysis

	Number of fish		Mean and range (min – max) fish length (mm)	
Date	Roach	Bleak	Roach	Bleak
26.04.2001	48	-	11.58 (7.82 - 15.49)	-
21.05.2001	70	60	19.75 (12.33 - 29.65)	13.55 (8.53 - 22.04)
18.06.2001	30	10	29.73 (23.00 - 36.78)	28.05 (22.64 - 35.92)
02.07.2001	40	20	37.51 (32.47 - 43.34)	25.45 (20.41 - 28.75)
13.05.2002	60	38	16.70 (11.57 - 20.34)	12.51 (7.84 - 19.50)
08.07.2002	6	40	35.61 (31.02 - 35.78)	13.41 (8.69 - 19.60)
01.08.2002	10	59	36.03 (32.99 - 40.39)	20.73 (11.14 - 28.90)
Total	264	227		

Comparing the structure of the fish assemblages in the two years of the study and the share of dominating species was done with the Chi^2 test (Stanisz 1998). The significance of differences between the values of the roach and bleak food variation indicators in comparable months and size groups was determined with analysis of variance (ANOVA). After obtaining statistically significant values, the data was analyzed with a post-hoc test (Stanisz 1998). Using the criterion of permanence of occurrence (frequency), cluster analysis was performed, which allowed identifying mutual relationships between the fish species. Euclidean distance was used to measure the distance between individual objects, while the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) was used to join them. This permitted identifying groups of objects that represented fish species, while confirming that some of them are characterized by the highest similarity of permanence of occurrence. The statistical analyses of the data obtained was performed with the Statistica 6.0 (StatSoft Inc.).

RESULTS

The species richness of the diet of roach and bleak early developmental stages was high. Overall, their diets were comprised of a similar number of taxa at 50 and 48, respectively. Among plankton, the most numerously represented were the cladocerans (Cladocera); twenty species were identified in the roach diet and nineteen in that of bleak. Copepods (Copepoda) were the least numerously represented with just 4 and 3 species, respectively. Benthic organisms were also identified in the food composition of both the fish species, and while they had a very low number share, they often dominated in the weight share (Fig. 1).

Only roach larvae were detected in April in the Lake Gosławskie littoral zone. The most abundant component of their diet was rotifers (*Notholca* sp. and *Brachionus angularis*) and juvenile stages of *Mesocyclops leuckarti* (Fig. 1a). By weight, the main dietary component was the cladocerans *Simocephalus vetulus* (66%) and *Chydorus sphaericus* (11%). In May the number share of rotifers in roach diet decreased with the increasing importance of crustaceans, both pelagic (*Leptodora kindti*) and those that occur among vegetation, including *Alona affinis*, *Eucyclops serrulatus*, and *Eurycercus lamellatus* (Fig. 1b). Bleak food was dominated by naupli copepods and Rotifera (*Keratella cochlearis*). In June the food composition of bleak underwent a significant transformation (Fig. 1c). The number share of these rotifers in the diet decreased and was replaced by the copepodit *M. leuckarti*, and the cladocerans were dominated by *L. kindti* and *A. rectangula*. The roach diet in this period was comprised mainly of crustaceous plankton, both pelagic (*L. kindti*) and littoral (*E. lamellatus*), and insect larvae (Odonata, Chironomidae). In May and June, a substantial part of the food mass of both species (despite the small number share) was comprised of Odonata larvae (Fig. 1b, c). In July (2001), the basic diet of bleak was comprised of the copepodits *M. leuckarti* and *L. kindti*, while in 2002, the dominants were substantially smaller organisms such as naupli and *Ch. sphaericus* (Fig. 1d). The main component of the diet of juvenile stages of roach during the same period was *L. kindti* (in both years), *M. leuckarti*, *E. serrulatus*, Gammaridae, Chironomidae larvae (2001), and *E. lamellatus* and *Ch. sphaericus* (2002). In August, the diet of roach was still dominated numerically by large cladocerans (*L. kindti*, *E. lamellatus*), and by weight by larval Odonata, Gammaridae, and *E. lamellatus* (Fig. 1e). However, the foundation of the bleak diet was

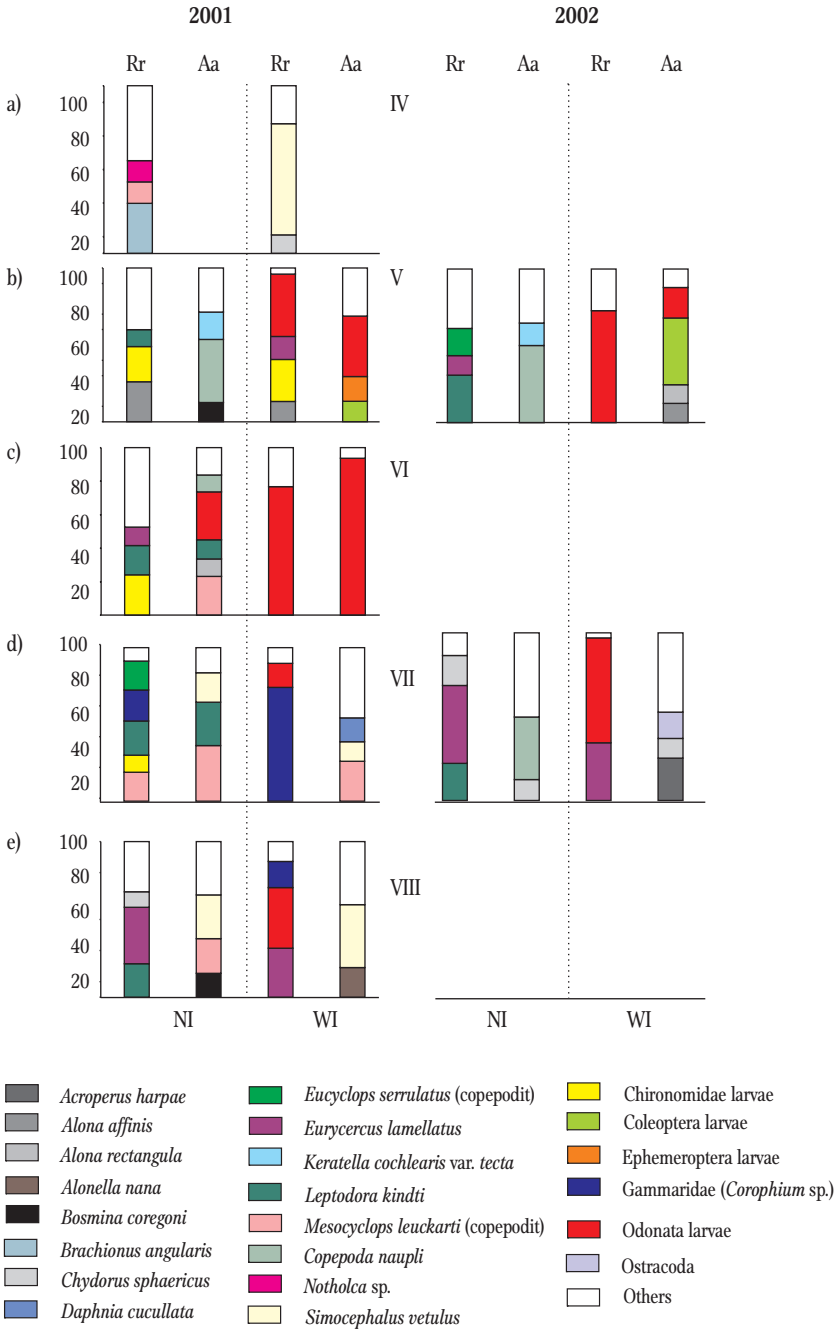

Fig. 1. Number share (NI) and weight share (WI) of the main food components (above 10%) in early developmental stages of roach (Rr) and bleak (Aa) in Lake Gosławskie in 2001-2002.

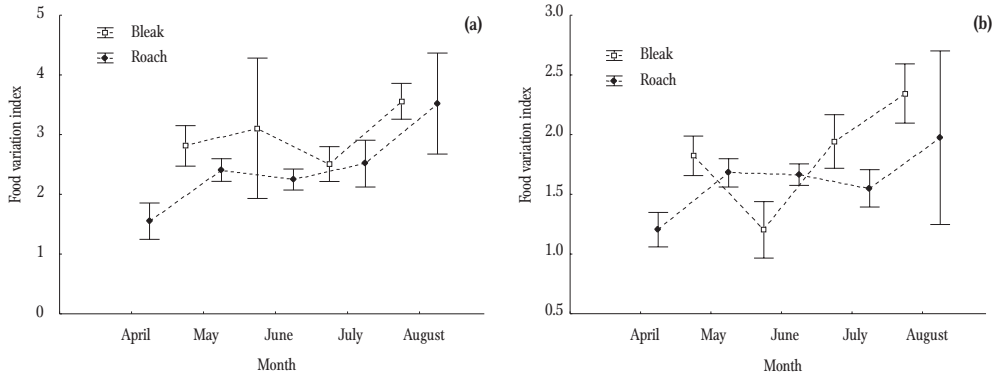

Fig. 2. Temporal variation in the food variation index of early developmental stages of roach and bleak (mean ±0.95 confidence interval) calculated with number share (a) and weight share (b).

cladocerans, among which dominated the littoral species *S. vetulus* and *B. coregoni* (2001, 2002), *L. kindti* (2001), and *Alonella nana* (2002). Additionally, in 2002 a large share of juvenile stage *M. leuckarti* was noted.

The variation in the dietary composition of juvenile stages of roach and bleak calculated with the NI of food components was higher in comparison to the results obtained using the BI (U-test, $P < 0.0001$). Similar changes in the FVI in a yearly cycle were noted in both species (Fig. 2), although the distribution of FVI calculated with NI and BI differed significantly statistically (test Chi^2, $P < 0.001$). The bleak diet was substantially more varied than the food composition of roach (Cochran-Cox test, $P < 0.0001$). At the beginning of the study period the fish diet was not varied, while the highest variation in the roach and bleak diets was noted in August (BI; ANOVA $F = 3.161$, $P = 0.024$). Cluster analysis of dietary variation of juvenile stages of roach and bleak identified three periods that differed in the degree of food component variation (Fig. 3a). During the analyzed period, August was the most outstanding, as this is when the diets of both species had the highest variety indices.

The dietary variety of early developmental stages of roach and bleak was largely dependent on body length (Fig. 4). The differentiation in food composition of individual specimens of roach and bleak segregated by length class was very high (ANOVA, $P < 0.0001$). The diets of roach fry with body lengths of 16-35 mm was much more varied than that of larvae (6-15 mm) and the largest fish analyzed (36-40 mm). However, dietary variation continued to increase with bleak body length until it

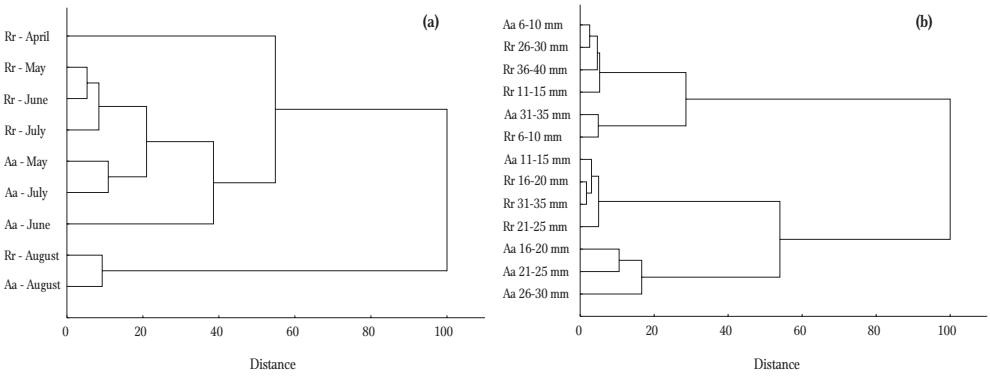

Fig. 3. Hierarchical classification of dietary variation in juvenile stages of roach (Rr) and bleak (Aa) in Lake Gosławskie in relation to the catch period (a) and fish body length (b).

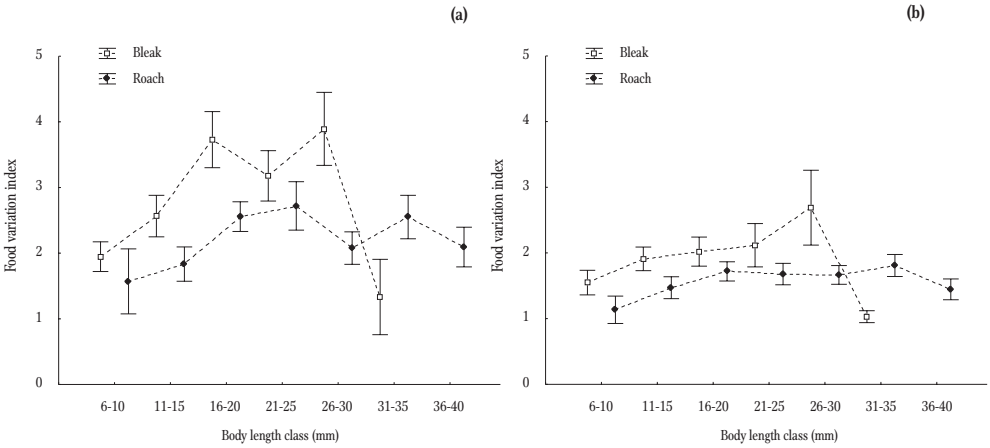

Fig. 4. Food variation index of early developmental stages of roach and bleak (mean ±0.95 confidence interval) calculated with number share (a) and weight share (b) in relation to body length (length class).

reached approximately 30 mm. The lowest variation in food composition was noted for larvae of a body length of 6-10 mm and for fry measuring more than 30 mm (ANOVA, $F=16.271$, $P < 0.0001$). The comparison of variation in the diets of juvenile stage roach and bleak confirmed that the diet of the larvae was of similar variation in the largest specimens analyzed (Fig. 3b), while the dietary variation of older bleak larvae (11-15 mm) and fry was similar to that of roach fry.

DISCUSSION

Changes in the dietary structure of juvenile fish is correlated with the seasonal succession of zooplankton occurrence (Sommer et al. 1986) and their improving ability to capture prey. During the transitional period to exogenous feeding, the dietary composition of fish is limited by mouth size, an inability to find prey, weak swimming ability, and access to food resources (Cunha and Planas 1999, Mehner and Thiel 1999, Hjelm et al. 2003). This is why the basis of the fish diet during the initial period of larval development includes algae, rotifers, small cladocerans, naupli, and copepodits (Hammer 1985, Keast 1980). Additionally, temporal variation in the spawning of various fish species inhabiting a lake means that juvenile fish of co-occurring species use food resources sequentially (Keast 1978). Roach larvae in Lake Gosławskie appear in late April, and then, depending on water temperature, other fish begin spawning, including bleak. The diet of early larval stages of roach and bleak (6-15 mm) in Lake Gosławskie was low in both variation and species richness. In April, roach larvae fed on rotifers (*B. angularis*, *Notholca* sp.) and juvenile stages of copepods (*M. leuckarti*), while the basis of the diet of bleak that hatch later was naupli copepod, *K. cochlearis*, and *B. coregoni*. The zooplankton assemblages in the lake studied were dominated by planktonic organisms with small body sizes (Bogacka-Kapusta 2007), but their significance in the diets of roach and bleak declined as the fish developed.

The food requirements of fish grow along with body size (Keast 1980), which, in the case of roach and bleak fry in Lake Gosławskie is met by the wider food spectrum and the catching of larger prey. The decline in the variation of the food composition of roach fry measuring > 35 mm was linked to the increased share in the diet of benthic organisms. The decided preference of a certain type of prey by 0+ roach and bleak might be dictated by the resources of it in the water column as is confirmed by the conclusions of Lammens (1985) that environmental prey density determines the spectrum of dietary composition. The domination of the species *B. coregoni* in May (2001) in the diet of roach was the consequence of its high share in the water (61%) (Bogacka-Kapusta 2007), and the decline in the biomass of cladocerans. The changes in the dietary composition of bleak in Lake Gosławskie might have also stemmed from the high level occurrence of potential prey in the environment, or the lack of them from over consumption. In the beginning of July, bleak fry food contained a smaller share of

dragonfly larvae and a larger share of crustaceous zooplankton such as copepodit copepods and large cladocerans (*S. crystallina* and *L. kindti*). The food of both of the fish species analyzed highlights the very large share of the copepodits *M. leuckarti* and the cladoceran *L. kindti*, which are food components that are rather not preferred by planktivorous fish. Copepods occur rarely in the diets of planktivorous fish because of their ability to escape from predators (Alajärvi and Horppila 2004). However, for planktivorous fish that visually locate zooplankton, *L. kindti* is difficult to catch because of its transparency due to its extremely reduced body elements (predator defense strategy) (Hessen 1985, Liu and Uiblein 1996). The abundant occurrence of this species in the roach diet is even more surprising as the catches were made in the shore zone and *L. kindti* is a pelagic species. This can be explained by the movements of roach, which, in heated waters, are a response to the clear thermal gradient (Hadderingh 1975, 1978). Fish search for thermal zones that meet their physiological requirements (van Densen and Hadderingh 1982). Although the temperature in the littoral zone of Lake Gosławskie was within the range of thermal tolerance for roach, this could have stimulated the fry to move to deeper parts of the lake. As an open water species, bleak feeds in the pelagic zone, and is predisposed to consume large prey that creates substantial water vibration since it can receive such signals with its lateral lines (Wanzenböck and Schiemer 1989, Liu and Uiblein 1996).

In the summer months a general decline in the abundance and biomass of zooplankton is noted in the Konin lakes because of the high temperature and water flow (Hillbricht-Ilkowska and Simm 1988, Tunowski 1994, 2001). One consequence of lower zooplankton abundance in the water is that juvenile fish shift more quickly to feeding on benthic organisms. According to Wu and Culver (1992), the beginning of consuming macroinvertebrates is regulated by the dynamics of the development of crustaceous plankton, the lack of which accelerates and the abundance of which delays the shift in the type of food consumed. Due to the low numbers of cladocerans in the water in Lake Gosławskie in June, roach fry (20-50 mm) began feeding on insect larvae (Chironomidae, Gammaridae, Ephemeroptera). However, as confirmed by Bohl (1980) and Linfield (1980), the dominating food in small roach fry (< 50 mm) were substitute components (Chironomidae, gammarids, dragonflies), which indicates that trophic conditions were deteriorating and this could lead to impaired fish growth. For roach with body lengths exceeding 10 mm, the typical food is cladocerans (Keast 1980,

Wienfield and Townsend 1988), as they are predisposed to capturing this type of prey by performing the so-called "cladoceran jump". Furthermore, roach is more adept at finding invertebrates in waters without vegetation, since their feeding behavior depends on the quick capture of prey without "selecting" them (Winfield 1986, Diehl 1988). This type of feeding is optimal when feeding on cladocerans in open waters, but it is not good in varied environments with a lot of plants (Wienfield 1986, Persson and Eklöv 1995). That roach caught substitute food (Chiromomidae, Odonata, Amphipoda) safeguards its basic metabolic processes, but it cannot compensate for the energy losses incurred by the decreased share of cladocerans in its diet (Diehl 1988, Persson 1993). The occurrence in the roach diet of insect larvae, copepods that are difficult to catch, and the transparent, nearly-invisible *L. kindti*, might be evidence of the disadvantageous food conditions in Lake Gosławskie for roach and bleak fry.

The results presented in this paper provide the basis for concluding that the anthropogenic stress placed upon this temperate zone natural lake in the form of additional energy that is reflected in the increased water temperature does not translate into the greater availability of food at the higher trophic level occupied by juvenile cyprinids. Quite to the contrary, the results of the study indicate that there is a higher risk of increased food competition for the limited zooplankton resources produced by the impaired natural production of Lake Gosławskie.

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STRESZCZENIE

ODŻYWIANIE LARW I NARYBKU PŁOCI, *RUTILUS RUTILUS* (L.) I UKLEI, *ALBURNUS ALBURNUS* (L.) W LITORALU PŁYTKIEGO, PODGRZEWANEGO JEZIORA

Praca przedstawia wyniki analiz składu diety wczesnych stadiów rozwojowych płoci i uklei występujących w Jeziorze Gosławskim. Weryfikowana jest zasadność hipotez: (i) skład diety ryb zmienia się w czasie; (ii) wzrost somatyczny ryby powoduje zróżnicowanie spektrum składników diety. Bogactwo gatunkowe diety larw i narybku płoci i uklei było wysokie. Liczebność wioślarek w zestawieniu z innymi komponentami diety badanych ryb była dominująca. Tendencje zmian wskaźnika zróżnicowania pokarmu w cyklu badawczym u obu gatunków ryb były bardzo podobne. W początkowym okresie dieta larw i narybku płoci i uklei była mało urozmaicona. Po osiągnięciu wieku 2 miesięcy stopniowo wzrastało zróżnicowanie składu pokarmu, osiągając maksimum w sierpniu. Różnorodność składu pokarmu wczesnych stadiów rozwojowych płoci i uklei było ściśle skorelowane z długością ich ciała. Dieta narybku płoci (16-30 mm) była znacznie bardziej różnorodna niż dieta larw (6-15 mm) i największych ryb (> 30 mm). W przypadku uklei wskaźnik zróżnicowania diety wzrastał proporcjonalnie z długością ciała ryb do osiągnięcia przez nie długości 30 mm.