

# DOES FEEDING ACTIVITY OF NON-COMMERCIAL FISH FRY CAUSE A DECREASE IN ZOOPLANKTON ABUNDANCE IN RESERVOIRS?

## Způsobuje potravní aktivita plůdku doprovodných druhů ryb snížení početnosti důležitého filtrujícího zooplanktonu ve vodárenské nádrži?

Tomáš ZAPLETAL\*, Václav KOZA, Jan ŠPAČEK

\* River Elbe Board s. e., Vita Nejedlého 951, 500 03 Hradec Králové, Czech Republic; e-mail: zapletal1970@gmail.com; phone: + 420 605 402 077

The dietary composition of perch (*Perca fluviatilis*, L.), bream (*Abramis brama*, L.) and roach (*Rutilus rutilus*, L.) fry were studied in a mesotrophic reservoir in the Bohemian-Moravian highlands of the Czech Republic. The fry were sampled along the shallow banks of the reservoir using a fry beach seine, with a minimum of twenty specimens per 0+ juvenile size group taken in each sampling period. Cladoceran zooplankton were the dominant dietary item of bream and perch fry over the whole season, with detritus dominant in roach fry diet. Specific food preferences of fry were directly related to availability over time. Our data indicated that large-scale removals of non-commercial fish fry could contribute significantly to the development of filtering zooplankton populations.

Keywords: diet, 0+ juvenile fish, *Abramis brama*, *Rutilus rutilus*, *Perca fluviatilis*, biomanipulation

Klíčová slova: potrava, 0+ juvenilní ryby, *Abramis brama*, *Rutilus rutilus*, *Perca fluviatilis*, biomanipulace

### Introduction

Water supply reservoirs are artificial water bodies whose primary aim is the delivery of drinking water to the local population. The quality of pre-treatment drinking water is closely connected with the resident zooplankton community, with improved water quality associated with abundant zooplankton populations. A number of studies have examined the relationship between improved trophic status of reservoirs and zooplankton community status and have attempted to identify optimal zooplankton composition and biomass (DOKULIL and TAUBNER 2000, GANNON and STEMBERGER 1978). In general, protection of water quality depends heavily on the protection and maintenance of the zooplankton filtrator community as a drastic reduction in their populations can lead to blooms of toxic blue-green algae (cyanobacteria). One of the most common causes of zooplankton population crashes is intense fish predation.

In the absence of sufficient predators (e. g. pike *Esox lucius*, zander *Sander lucioperca*), younger (i. e. 0+ and 1+) perch *Perca fluviatilis*, roach *Rutilus rutilus* and bream *Abramis brama* can consume a large proportion of filtering zooplankton, with a consequent negative role in water quality (ADÁMEK et al. 2004, PETERKA and MATĚNA 2011, TREASURER 1992,

VÁŠEK et al. 2003). These species are typically dominant in reservoirs of the Czech Republic. Over recent decades there have been numerous efforts to 'biomanipulate' fish populations in such water bodies by reducing the biomass of such species (adult and young) and increasing the proportion of fish predators by stocking (PREJS et al. 1994, BERG et al. 1997), thereby inducing a 'top-down' change in the food chain (e. g. see JURAIDA et al. 2013, KUBEČKA et al. 1995, VIJVERBERG et al. 1990).

The aim of this study was to observe any change in the structure and biomass of filtering zooplankton following a five-year biomanipulation of fish stocks in a mesotrophic drinking water reservoir. We hypothesise that the removal of a large proportion of resident adult and juvenile cyprinids, along with piscivore stocking, will result in an increase in zooplankton abundance and biomass, resulting in improved pre-treatment drinking water quality.

### Study area

This study took place at the Hamry reservoir (49°43'52" N, 15°55'1" E, elevation 602.86 m), near the town of Hlinsko in the Bohemian-Moravian highlands of the Czech Republic (Fig. 1). The 42.3 ha reservoir, which was built between 1907 and 1912 and is fed by the River Chrudimka, serves a catchment area of 56.8 km<sup>2</sup>. The reservoir has an average depth of 2 m, with a maximum depth of 7.5 m at the 17.4 m dam. The reservoir presently serves as a drinking water source for Hlinsko and its surroundings. About half of the shoreline comprises bankside meadow with a low slope with flooded littoral macrophytes at higher water levels. The rest of the shoreline comprises coniferous forest with steep, gravelly banks and rocks. The inlet area is shallow, with soft sediments and a thick layer of detritus from decaying meadow grass and common reed (*Phragmites* sp.) beds.

### Methods and material

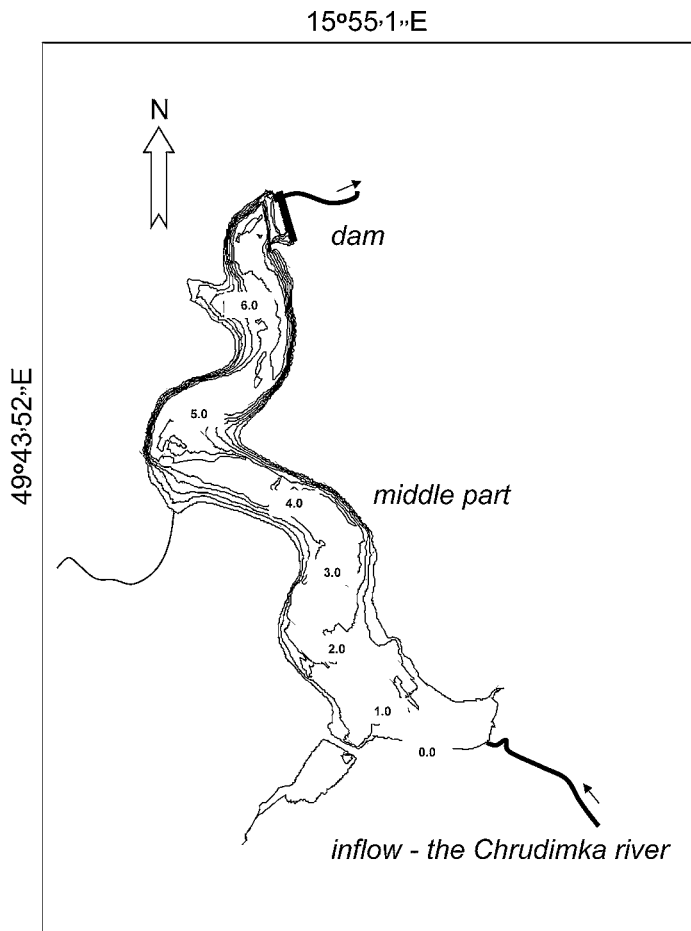
The zooplankton population was monitored five times each year between 2007 and 2014 over three depth profiles. Samples from the upper (inlet) part of the reservoir (depth 1.5 m) were taken using a standard 20 cm diameter zooplankton net towed horizontally for 6 m. Samples from the middle (depth 4 m) and lower (dam-outlet; depth 7 m) sites were taken using the same equipment but retrieving the net vertically from depths of 4 and 6 m, respectively (PŘIKRYL 2006). All zooplankton samples were immediately preserved in 4% formaldehyde. Depending on the volume of zooplankton retrieved, 4–6 ml was taken from a known volume of each plankton sample and placed into a counting chamber. Zooplankton were determined and counted, expressed as number of individuals per m<sup>3</sup>.

The fish community was also sampled from the three zones, as close to the time of zooplankton sampling as possible, using a fry beach seine (15 m long, 2 m depth, 4 mm mesh size) along the shallow banks of the reservoir during the day. Perch were sampled between June and October 2011 and in July 2012 (SL 16–58 mm); bream in August 2012, July 2013 and September 2014 (SL 17–57 mm); and roach in August 2012 and July 2013 (SL 35–52 mm). On each occasion, 40 0+ fish of each species were taken for diet analysis. In the laboratory, the fish were weighed (to the nearest 0.1 g), measured (standard length [SL]; to the nearest 1 mm) and dissected, with the gut of bream and roach and the stomach contents only of perch removed for further analysis. Gut contents were weighed and preserved in 4% formaldehyde for later analysis in the laboratory.

In the laboratory, taxa were determined under a 40–450× magnification binocular microscope and the proportion of total food intake represented by each category evaluated using a modified version of Hyslop's (1980) indirect method, using the formula:

$$\% W_i = 100 * (W_i / \Sigma W_i)$$

where  $W_i$  is the weight of a particular food component and  $\Sigma W_i$  the weight of all food items combined.



**Fig. 1:** Map of the Hamry water supply reservoir, with mean depth, inlet and outlet indicated.

**Obr. 1:** Mapa vodárenské nádrže Hamry s vyznačením středních hloubek, přítoku a odtoku.

Frequency of occurrence of food items was calculated according to PIVNIČKA (1981), using the formula:

$$\% FO_i = 100 * (n_i / \Sigma n_i)$$

where  $n_i$  represents the number of guts containing a particular dietary item and  $\Sigma n_i$  is the number of all guts.

These two criteria are combined in order to express an index of preponderance (IP), using the formula:

$$IP = 100 * ((W_i * FO_i) / \Sigma (W_i * FO_i))$$

where  $W_i$  is the weight percentage of a particular food component and  $FO_i$  is the frequency of occurrence of that food component. This provides a relevant measurable basis for sorting particular components (NATARAJAN and JHINGRAN 1961).

The degree of selection for particular dietary items was evaluated using Ivlev's index of electivity (E) (STRAUSS 1979), using formula:

$$E = r_i - p_i / r_i + p_i$$

where  $r_i$  is the relative abundance of prey item  $i$  in the gut and  $p_i$  is the relative abundance of the same prey item in the environment.

Significant differences in the percentage of each food item was assessed separately by ANOVA ( $P < 0.05$ ), using the STATISTICA 12® programme.

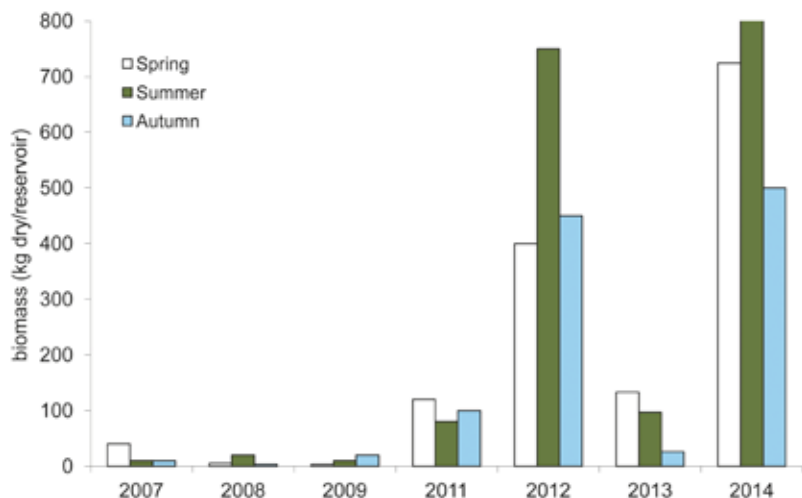
We declare that this study has been carried out in accordance with valid legislation of the Czech Republic, specifically Law No. 114/1992 Coll. No. 246/1992 Coll. and Instruction No. 554/77-34. None of the organisms sampled are ranked as protected species in the Czech Republic and no permission is required for their manipulation.

## Results

We noted a rapid increase in filtering zooplankton very soon after biomanipulation began in 2007 (Fig. 2). Zooplankton production appeared to decrease dramatically in May 2013 (Fig. 2); however, this was due to flooding that year, which resulted in a complete turnover of water volume as the sluices were opened fully. By the next year (2014), zooplankton levels were again at similarly high levels to those in 2012.

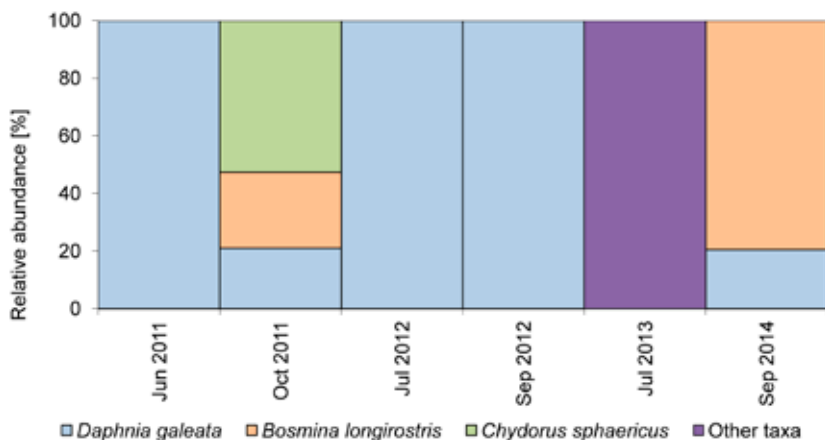
The greatest increase was noted in members of the order Cyclopoida, particularly after 2009. In almost all years, *Daphnia galeata* totally dominated the zooplankton community, with *Bosmina longirostris* and *Chydorus sphaericus* subdominant in autumn of 2011 and 2014 (Fig. 3; ANOVA,  $P < 0.05$ ).

In June 2011, *B. longirostris* was dominant in perch diet ( $IP 60.3 \pm 26.8$ ), with detritus ( $IP 12.4 \pm 0.0$ ) and *D. galeata* subdominant. In both autumn 2011 and summer 2014, however, *D. galeata* were strongly dominant, with copepods subdominant (Fig. 4). In both cases, all other items were taken at very low levels ( $P < 0.05$ ). Bream consumed mainly *D. galeata* ( $IP 64.1 \pm 9.8$ ), with *B. longirostris* and copepods subdominant in August 2012,



**Fig. 2:** Development of total zooplankton biomass at the Hamry water supply reservoir (biomass in kg/reservoir) over spring, summer and autumn between 2007 and 2014.

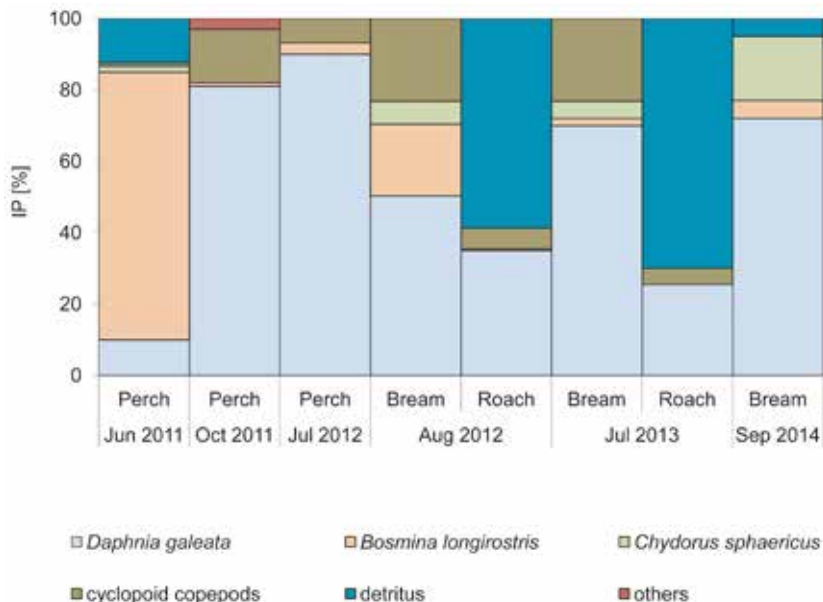
**Obr. 2:** Vývoj celkové biomasy zooplanktonu vodárenské nádrže Hamry (biomasa v kg/nádrž) v jarním letním a podzimním období let 2007–2014.



**Fig. 3:** Seasonal zooplankton structure at Hamry water supply reservoir.

**Obr. 3:** Sezónní struktura zooplanktonu ve vodárenské nádrži Hamry.

copepods in July 2013 and *C. sphaericus* in September 2014 (Fig. 4; all other items taken at low levels [ $P < 0.05$ ]). Roach diet was dominated by detritus/plant material in both August 2012 and July 2013 (IP  $64.4 \pm 5.7$ ), with *D. galeata* subdominant (IP  $30.3 \pm 48$ ;  $P < 0.05$ ) and copepods recessive in each year (Fig. 4).



**Fig. 4:** Seasonal dietary composition (IP) for 0+ bream, perch and roach at Hamry reservoir between 2011 and 2014.

**Obr. 4:** Sezónní složení potravy (IP) cejna, okouna a plotice 0+ ve vodárenské nádrži Hamry v období let 2011–2014.

There was significant agreement between the quantities of cladoceran zooplankton present in the reservoir (particularly *D. galeata* and *B. longirostris*) and that observed in fish diet (ANOVA,  $P < 0.05$ ), with perch and bream showing a strong preference for cladoceran zooplankton (Ivlev's index;  $E = 0.7$ ) and roach fry feeding primarily on detritus (Ivlev's index;  $E = 1.0$ ).

## Discussion

Aside from July 2013 (when zooplankton populations crashed following opening of the reservoir sluices to prevent flooding), Cladoceran zooplankton dominated in samples in all sampling seasons. These same cladoceran zooplankton, especially *D. galeata*, also dominated the diet of fish fry. Cladoceran zooplankton are frequently observed as important dietary items for non-commercial fish fry in both biomanipulated (e. g. KAKAREKO 2001 [Chydoridae], VAŠEK et al. 2004 [*D. galeata*], KRATOCHVÍL et al. 2008 [*Daphnia* sp.]) and non-biomanipulated reservoirs (e. g. GANNON and STEMBERGER 1978). It has been suggested that *D. galeata* tend to dominate fry diet in such water bodies as they are

a relatively large species, perhaps making them more visible to fry. Furthermore, they are likely to provide more energy per individual than smaller zooplankton (BOGUT et al. 2010, LAZZARO 1987).

While roach, bream and perch fry dominated the 0+ fish community in Hamry reservoir, roach are unlikely to have any major impact on zooplankton populations as their diet was dominated by detritus/plant material (Fig. 4), with Zooplankton subdominant (IP < 40 %; Fig. 4). This is a fairly typical representation of roach diet and a similar pattern has been observed in many other waters (e. g. HAMMER 1985, PONTON and GERDEAUX 1988, GILES et al. 1990, PETERKA and MATĚNA 2009). This dietary pattern is not necessarily universal, however, with TARVAINEN et al. (2002) reporting zooplankton as dominant in 0+ roach diet in a shallow 12.5 km<sup>2</sup> lake in Finland (Lake Koylionjarvi).

Unlike roach, cladoceran zooplankton represented an important and dominant (IP > 50 %) dietary element of both perch and bream fry. Indeed, *Daphnia* sp. has been described as an important dietary item of perch fry by numerous authors. KRATOCHVÍL et al. (2008), for example, described *Daphnia* as dominant in perch fry diet at depths of 0–4 m in Slapy reservoir (Czech Republic) during May 2002, and *Diaphanosoma brachyurum* dominant and *Daphnia* sp. subdominant in June 2002. Similarly, GINTER et al. (2012) described *B. longirostris* as dominant in perch diet in Lake Votsjarv (Estonia). *Daphnia* sp. tend to be taken significantly less often in the diet at greater depths as the Cladocera density decreases and temperatures and visibility is reduced, perch being adapted to higher light and temperature conditions (ALI et al. 1977). MATĚNA (1995), however, also noted Copepods as an important dietary item in perch fry diet in the deeper (16.0 m) Římov reservoir (Czech Republic), apparently as local conditions resulted in an increased availability of such organisms at greater depth. Feeding activity of perch has also been observed to change in relation to horizontal migrations of zooplankton over time. WOJTAŁ et al. (2003), for example, noted that both *D. cucullata* and *D. longispina* displayed horizontal migrations at the inshore zone of the shallow Sulejow reservoir (Poland), and that these migrations were closely reflected in the feeding behaviour of both perch and roach fry.

The importance of zooplankton in 0+ common bream diet has been reported widely (e. g. KAKAREKO 2002, VAŠEK et al. 2006), with cladoceran zooplankton usually the dominant food item. Both WOLNOMIEJSKI and GRYGIEL (2002) and NAUMENKO (2011), for example, report filtering zooplankton as dominant in 0+ bream diet in the shallow Szczecin Lagoon in Poland. Exceptionally, KAKAREKO (2002) reported benthic Chydoridae as dominant in bream fry diet as in the shallow, highly eutrophic Wloclawek Basin (Poland), suggesting exceptional dominance of this group in the reservoir due to the eutrophic conditions as a reason.

In this study, we were able to show that (aside from 2013) the large-scale removal of 0+ perch, bream and roach, along with the stocking of predators to further reduce and maintain 0+ fish density, resulted in an increase in the total biomass of filtering zooplankton. Indirectly, therefore, this confirms our hypothesis that “feeding activity of non-commercial fish fry causes a decrease in zooplankton abundance in reservoirs”, with consequent negative effects on water quality.

### Acknowledgements

We would like to thank all the members of the Institute of Vertebrate Biology, Czech Academy of Sciences, who helped with field work. The authors would also like to thank Dr. K. Roche for help with English correction.

## References

- ADÁMEK Z., MUSIL J., SUKOP I., 2004: Diet Composition and Selectivity in 0+ Perch (*Perca fluviatilis* L.) and its Competition with Adult Fish and Carp (*Cyprinus carpio* L.) Stock in Pond Culture. *Agriculturae Conspectus Scientificus* 69 (1) : 21–27.
- ALI M. A., RYDER R. A., ANCTIL M., 1977: Photoreceptors and visual pigments as related to behavioral responses and preferred habitats of perches (*Perca* spp.) and pikeperches (*Stizostedion* spp.). *Journal of the Fisheries Research Board of Canada* 34: 1475–1480.
- BERG S., JEPPESEN E., SØNDERGAARD M., 1997: Pike (*Esox lucius* L.) stocking as a bio-manipulation tool. 1. Effects on the fish population in Lake Lyng (Denmark). *Hydrobiologia* 342/343: 311–318.
- BOGUT I., ADÁMEK Z., PUŠKADIJA Z., GALOVIĆ D., BODAKOŠ D., 2010: Nutritional value of planktonic cladoceran *Daphnia magna* for common carp (*Cyprinus carpio*) fry feeding. *Ribarstvo* 68 (1): 1–10.
- DOKULIL M. T., TEUBNER K., 2000: Cyanobacterial dominance in lakes. *Hydrobiologia* 438 (1–3): 1–12. DOI: 10.1023/A:1004155810302.
- GANNON J. E., STEMBERGER R. S., 1978: Zooplankton (especially crustaceans and rotifers) as indicators of water quality. *Transactions of the American Microscopical Society*, 97 (1): 16–35. DOI: 10.2307/3225681.
- GILES N., STREET M., WRIGHT M., 1990: Diet composition and prey preference of tench, *Tinca tinca* (L.), common bream, *Abramis brama* (L.), perch, *Perca fluviatilis* L. and roach, *Rutilus rutilus* (L.), in two contrasting gravel pit lakes: potential trophic overlap with wildfowl. *Journal of Fish Biology* 37: 945–957.
- GINTER K., KANGUR K., KANGUR A., KANGUR P., HALDINA M. 2012: Diet niche relationships among predator and prey fish species in their early life stages in Lake Vortsjarv (Estonia). *Journal of Applied Ichthyology* 28: 713–720. DOI: 10.1111/j.1439-0426.2012.02008.x.
- HAMMER C., 1985: Feeding behaviour of roach (*Rutilus rutilus*) larva and the fry of perch (*Perca fluviatilis*) in Lake Lankau. *Archiv Für Hydrobiologie* 103 (1): 61–74.
- HYLSLOP E. J., 1980: Stomach contents analysis – a review of methods and their application. *Journal of Fish Biology* 17 (4): 411–429. DOI: 10.1111/j.1095-8649.1980.tb02775.x.
- JURAJDA P., ADÁMEK Z., JANÁČ M., VALOVÁ Z., REDERER L., ZAPLETAL T., KOZA V., ŠPAČEK J., 2013: Zhodnocení čtyřletého úsilí o uplatnění biomanipulačních opatření na vodárenské nádrži Hamry. [Evaluation of a four-year effort in biomanipulation measures on the Hamry water supply reservoir]. *Vodní nádrže 2013 – Sborník příspěvků: 114–117.* (In Czech)
- KAKAREKO T., 2001: The diet, growth and condition of common bream, *Abramis brama* (L.) in Wloclawek reservoir. *Acta Ichthyologica et Piscatoria* 31 (2): 37–53. ISSN 0137-1592.
- KAKAREKO T., 2002: The importance of Benthic fauna in the diet of small common bream *Abramis brama* (L.), roach *Rutilus rutilus* (L.), pikeperch *Sander lucioperca* (L.) and ruffe *Gymnocephalus cernuus* (L.) in the Wloclawek reservoir. *Archives of Polish Fisheries* 10 (2): 221–231.
- KRATOCHVÍL M., PETERKA J., KUBEČKA J., MATĚNA J., VAŠEK M., VANÍČKOVÁ I., ČECH M., SEĎA J., 2008: Diet of larvae and juvenile perch, *Perca fluviatilis* performing diel vertical migrations in a deep reservoir. *Folia Zoologica* 57 (3): 313–323.
- KUBEČKA J., SEĎA J., MATĚNA J., VYHNÁLEK V., HEJZLAR J., 1995: Biomanipulation of Czech water supply reservoirs – summary of 18 years. *Vodní hospodářství 11–12/1995: 374–376.*
- LAZZARO X., 1987: A review of planktivorous fishes: their evolution, feeding behaviours, selectivities, and impacts. *Hydrobiologia* 146: 97–167.



- MATĚNA J., 1995: The role of ecotones as feeding grounds for fish fry in a Bohemian water-supply reservoir. *Hydrobiologia* 303 (1–3): 31–38. DOI: 10.1007/BF00034041.
- NATARAJAN A. V., JHINGRAN A. G., 1961: Index of preponderance – a method of grading the food elements in the stomach analysis of fishes. *Indian Journal of Fisheries* 8: 54–59.
- NAUMENKO E. N., 2011: Effect of food availability in early ontogenesis on the rate of growth and numbers of bream *Abramis brama* L. in Kursh Bay of the Baltic Sea. *Russian Journal of Developmental Biology* 42 (3): 192–197. DOI: 10.1134/S1062360411030118.
- PETERKA J., MATĚNA J., 2009: Differences in feeding selectivity and efficiency between young-of-the-year European perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) – field observations and laboratory experiments on the importance of prey movement apparency vs. evasiveness. *Biologia* 64 (4): 786–794. DOI: 10.2478/s11756-009-0133-4.
- PETERKA J., MATĚNA J., 2011: Feeding behaviour determining differential capture success of evasive prey in underyearling European perch (*Perca fluviatilis* L.) and roach (*Rutilus rutilus* L.). *Hydrobiologia* 661(1): 113–121. DOI: 10.1007/s10750-010-0507-1.
- PIVNÍČKA K., 1981: Ekologie ryb: odhady základních parametrů charakterizujících rybí populace. [Ecology of fish: estimates of basic parameters characterizing fish populations], SPN Praha, 1<sup>st</sup>. ed. 251 pp. (In Czech)
- PONTON D., GERDEAUX D., 1988: Quelques aspects de l'alimentation de deux poissons planctonophages du lac Léman: Le cōregone (*Coregonus Schinzii* Palea Cuv. et Val.) et le gardon (*Rutilus rutilus* L.). [Some aspects of the diet of two planktivorous fish from Lake Geneva: whitefish (*Coregonus schinzii* Palea Cuv. et Val.) and roach (*Rutilus rutilus* L.)]. *Bulletin Francais de la Pêche et de la Pisciculture* 308: 11–23. DOI: 10.1051/kmae:1988011. (In French)
- PREJS A., MARTYNIAK A., BORON S., HLIWA P., KOPERSKI P., 1994: Food-web manipulation in small, eutrophic lake Wirbel, Poland – Effect of stocking with juvenile pike on planktivorous fish. *Hydrobiologia* 275: 65–70.
- PŘÍKRYL J., 2006: Metodika odběru a zpracování vzorků zooplanktonu stojatých vod. [The methodology of collecting and processing samples of zooplankton in standing waters]. *Metodika VÚV TGM Praha*. 14 pp. (In Czech).
- STRAUSS R. E., 1979: Reliability Estimates for Ivlev's Electivity index, the Forage Ratio, and a Proposed Linear Index of Food Selection. *Transactions of the American Fisheries* 108: 344–352.
- TARVAINEN M., SARVALA J., HELMINEN H., 2002: The role of phosphorus release by roach [*Rutilus rutilus* (L.)] in the water quality changes of a biomanipulated lake. *Freshwater Biology* 47 (12): 2325–2336. DOI: 10.1046/j.1365-2427.2002.00992.x.
- TREASURER J. W., 1992: The predator-prey relationship of perch, *Perca fluviatilis*, larvae and zooplankton in two Scottish lochs. *Environmental Biology* 35 (1): 63–74. DOI: 10.1007/BF00001159.
- VÁŠEK M., KUBEČKA J., SEĎA J., 2003: Cyprinid predation on zooplankton along the longitudinal profile of a canyon-shaped reservoir. *Archiv Für Hydrobiologie* 156 (4): 535–550. DOI: 10.1127/0003-9136/2003/0156-0535.
- VÁŠEK M., KUBEČKA J., 2004: In situ diel patterns of zooplankton consumption by subadult/adult roach *Rutilus rutilus*, bream *Abramis brama*, and bleak *Alburnus alburnus*. *Folia Zoologica* 53 (2): 203–214.
- VÁŠEK M., KUBEČKA J., MATĚNA J., SEĎA J., 2006: Distribution and Diet of 0+ Fish within a Canyon-Shaped European Reservoir in Late Summer. *International Review of Hydrobiology* 91 (2): 178–194. DOI: 10.1002/iroh.200510835.

- VIJVERBERG J., BOERSMA M., VANDENSEN W. L. T., HOOGENBOEZEN W., LEMMENS E. H. R. R., MOOIJ W. M., 1990: Seasonal-variation in the interaction between piscivorous fish, planktivorous fish and zooplankton in a shallow eutrophic lake. *Hydrobiologia* 207: 279–286. DOI: 10.1007/BF00041466.
- WOJTAL A., FRANKIEWICZ P., IZYDORCZYK K., ZALEWSKI M. 2003: Horizontal migration of zooplankton in a littoral zone of the lowland Sulejow Reservoir (Central Poland). *Hydrobiologia* 506–509: 339–346.
- WOLNOMIEJSKI N., GRYGIEL I., 2002: Food of common bream (*Abramis brama* L.) in the Szczecin Lagoon (Great Lagoon). *Bulletin of the Sea Fisheries Institute* 1 (155): 61–68.

*Reviewed by assoc. prof. Radovan Kopp, Ph.D.*

*Received: 4 November 2015*