SUMMER DIET COMPOSITION OF GRASS CARP, *CTENOPHARYNGODON IDELLA* VAL. (ACTINOPTERYGII: CYPRINIFORMES: CYPRINIDAE) IN AN ARTIFITIAL CHANNEL

Složení letní potravy amura bílého, *Ctenopharyngodon idella* Val. (ACTINOPTERYGII: CYPRINIFORMES: CYPRINIDAE), v umělém vodním kanálu

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In this study, we report on the diet of grass carp (*Ctenopharyngodon idella* L.) feeding in an artificial channel overgrown by aquatic plants (Opatovický, Czech Republic). Fish were sampled during the daytime in summer (July) of 1998 and 2013. Two adult size groups were examined: 20 × 7+ fish of 571–671 mm standard length in 1998 and 20 × 9+ fish of 654–814 mm in 2013. Diet composition was evaluated by means of standard gravimetric methods. Aquatic plants were the dominant dietary item taken by grass carp, with benthic macroinvertebrates, fruit (stones of *Prunus sp.*) and detritus forming only a minor part of the diet in both years.

Keywords: Grass carp, diet composition, artificial channel, aquatic plants
Klíčová slova: amur bílý, složení potravy, kanál, vodní rostliny

Introduction

The herbivorous grass carp (*Ctenopharyngodon idella* Val.) has become an important species due to its potential biomelioratory effect against invasive aquatic macrophytes in many types of water body around the world (Adámek et Kokorďák 1982, Krupauer 1989), its successful acclimatisation only really limited by a mean temperature isotherm of around 5 °C (Opuszyński 1969, Carter et al. 1992). Grass carp are relatively well known to fish farmers in the Czech Republic (Krupauer 1967), having been introduced into Czech ponds in 1961 in order to provide biotechnological control of aquatic weeds and, at the same time, to increase fish production (Adámek et al.1996, Kubů et Lusk 1962). Today, grass carp represent an important part of pond fish stock. In some cases, however, the species can cause significant limnological changes to pond ecosystems due to its dietary preference for aquatic plants (Pípalová et al. 2009).

Between 1995 and 1998, around 1 000 adult grass carp were stocked into the Opatovický channel each year in order utilise this biomelioratory effect to clear the channel of weed growth, the channel having become overgrown with aquatic plants in the early 1990s. Since then, the accumulation of plant production in the channel has decreased.

We hypothesise that diet composition of adult grass carp may have changed following this reduction in aquatic plant biomass; hence, the aim of this study was to evaluate whether and how diet composition of grass carp changed between 1998, when stocking ceased, and 2013, 15 years later.

Study area

The study took place along the upper stretch of the Opatovický channel, at the town of Opatovice nad Labem, eastern Bohemia, Czech Republic (Fig. 1; 50°9′13.4″ N, 15°47′41.7″ E and 50°8′38.4″ N, 15°47′28.1″ E).

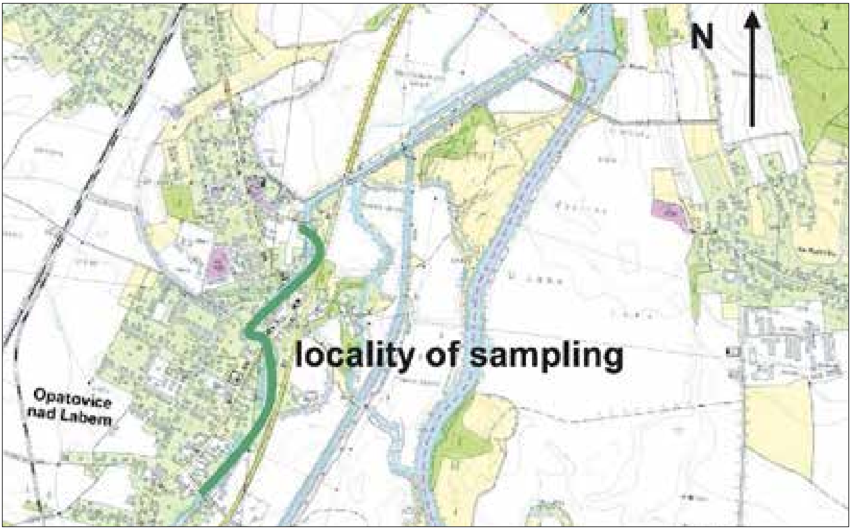

Fig. 1: The Opatovický channel study area.

Obr. 1: Opatovický kanál studovaný úsek.

Methods and material

Fish were sampled by means of angling and electrofishing in July of 1998 and 2013. Twenty 7+ individuals were sampled for diet analysis in 1998 (571–671 mm standard length [SL], Wt 1 300–7 300 g) and 20 9+ individuals in 2013 (SL 654–814 mm, Wt 3 050–12 500 g).

In the laboratory, the fish were weighed (to the nearest 0.1 g) and measured (SL; to the nearest 1 mm), then dissected and the gut separated for further analysis. The gut contents were weighed and preserved in 4% formaldehyde for later laboratory analysis. Samples were observed under a binocular microscope and the remains separated into taxa and examined under a 40–450× magnification binocular microscope for more precise determination. Remains of terrestrial plants were not determined to taxonomic level and were registered as 'macrophyte fragments' only. The proportion of total food intake represented by each category was evaluated via the modified indirect method of Hyslop (1980), using the formula:

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

where W_i is the weight of a particular food component and ΣW_i is the weight of all food components combined.

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 is the number of guts containing a particular dietary component and Σn_i is the number of all guts examined.

These two criteria were 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 percentage weight 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 and presents results that are a combination of frequency of occurrence and weight contribution of particular components (Natarajan et Jhingran 1961).

Food bulk weight was assessed to the nearest mg and presented as an index of gut fullness (IF) in $^{0}/_{000}$, calculated as the ratio between food (w) and fish (W) weights using the formula:

$$IF = 10^4 * (w/W)$$

Variation in the percentage of each food item was compared separately using ANOVA ($P < 0.05$), provided in the STATISTICA12® statistical software programme.

We declare that this study has been carried out in accordance with valid legislation of the Czech Republic.

Results

Food resources

In 1998, approximately 70 % of the channel's surface was covered in a mixture of river water-crowfoot *Ranunculus fluitans* (70 %), fan-leaved water-crowfoot *Ranunculus circinatus* (20 %) and variegated reed sweet-grass *Glyceria aquatica* (10 %) (Fig. 2). This situation remained relatively constant until sometime between 2004 and 2007, when plant biomass dropped significantly (ANOVA; $P < 0.05$). By 2013, only fan-leaved water-crowfoot occurred at the pond, and this covered just 3 % of the water's surface.

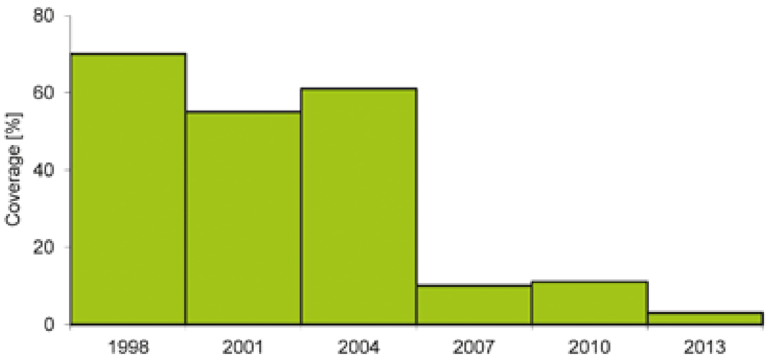

Fig. 2: Aquatic plant coverage at the study area between 1998 and 2013.

Obr. 2: Pokryvnost sledovaného úseku vodním rostlinstvem v období let 1998–2013.

Diet composition

Macrophyte fragments (terrestrial vegetation) were dominant in the summer diet of grass carp in both 1998 and 2013 (IP 41.5 – 1998, IP 74.1 – 2013). In 1998, aquatic plants (mainly fan-leaved water-crowfoot) were a subdominant dietary item (IP 34.6), but were recedent in 2013 (IP 8.1). Detritus was consumed at low levels (IP 13.3) and was only registered in 2013 (Fig. 3). Benthic invertebrates (IP 0.2 in 1998 and IP 1.5 in 2013) and fruit remains (stones of *Prunus sp.*; IP 5.2 in 1998 and IP 3.0 in 2013) were always recedent. IF values were 116 $^{o}/_{ooo}$ in 1998 and 198 $^{o}/_{ooo}$ in 2013. The results indicate that grass carp consumed significantly more aquatic plant material and less terrestrial vegetation during the biomanipulation exercise than 15 years later ($P < 0.05$), i.e. there has been a shift toward terrestrial vegetation as availability of aquatic vegetation has declined.

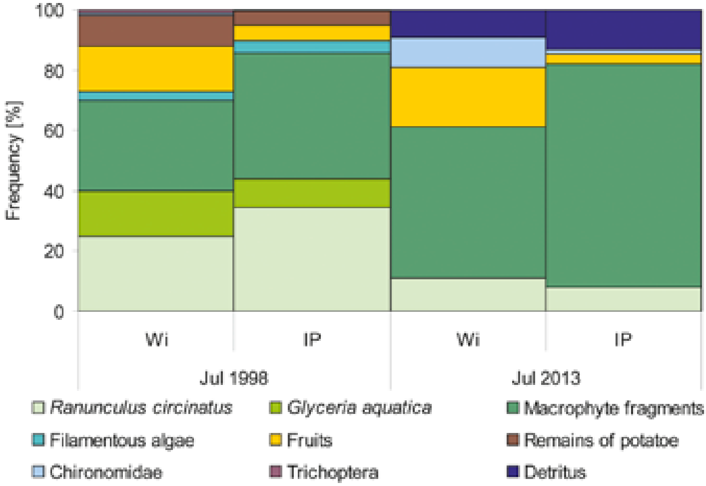

Fig. 3: Diet composition of grass carp in 1998 and 2013 – weight proportion (Wi) of total food intake and index of preponderance (IP).

Obr. 3: Složení potravy amura bílého – hmotnostní podíl jednotlivých složek (Wi) celkové přijaté potravy a index převahy (IP).

Discussion

We studied changes in the diet of grass carp in the Opatovický artificial channel in the summers of 1998 and 2013, i.e. at the end of fish stocking and 15 years later. The grazing effect of grass carp over this period has been considerable, with plant coverage significantly (ANOVA; $P < 0.05$) decreased from 70 % to just 3 % and two previously relatively common species (fan-leaved water-crowfoot and variegated reed sweet-grass) eradicated. We can say, therefore, that biomanipulation at this locality has been successful.

Aquatic plants were the dominant dietary category for grass carp in the channel over the summer sampling season in both years, with detritus, fruit remains (and remains of potato) and aquatic invertebrates recedent. Grass carp undergo a strong ontogenetic shift in diet at around 82 mm, with the main dietary items taken shifting from *Cladocera*, *Rotatoria* and *Copepoda* to aquatic plant material (Adámek et Sanh 1977); hence, adult grass carp do not markedly affect zoobenthos by direct feeding (Terrell 1975, Pípalová

2006). Consequently, as only adult fish were examined in this study, macrozoobenthos (mainly represented by chironomid larvae and Trichoptera) were not an important dietary component.

Many authors have reported aquatic plants as the most important feeding resource for adult grass carp. Catarino et al. (1997), for example, found that grass carp of 2+ and older in the largest Portuguese irrigation systems consumed primarily parrotfeather watermilfoil *Myriophyllum aquaticum*, *Potamogeton pectinatus*, fennel pondweed *Eichhornia crassipes* and duckweed *Lemna sp.* Masser (2002) found that, thanks to their preference for plant material, grass carp at some US localities were capable of providing effective control of invasive aquatic vegetation, and particularly of submerged vegetation. A similar biomelioratory effect was registered by Kokorďák (1972). Kiambi et Zdinak (1980) also reported aquatic macrophytes as the dominant dietary category, with a consumption coefficient (Iljin 1966) in the range of 12–57.

Note, however, that excessive consumption of macrophytes can also have negative consequences. For example, aquatic macrophytes are an important ecological component for positive water quality development in standing water bodies, such as water supply reservoirs (Canfield et al. 1985). In such cases, it is essential that grass carp are removed (or prevented from entering in the first place) in order to protect both water and ecological quality (Randák et al. 2013).

Grass carp, therefore, are clearly generalist feeders (though specialised on plant material) that can vary their feeding behaviour according to the aquatic habitat in which it finds itself. In shallow artificial channels, such as that examined in this study, they can play an important role in maintaining water discharge.

Conclusion

Diet composition of 7+ and 9+ grass carp was studied in the summers of 1998 and 2013 at the Opatovický artificial channel. Aquatic macrophytes were the dominant item found in gut contents in both years. This has had an important biomelioratory effect on the channel, with aquatic plant biomass reduced significantly over the 15 year study period. As a consequence, water discharge along the channel has improved significantly.

Acknowledgements

We thank Czech Anglers Union for permission to sample in the channel and for valuable support, and Dr. K. Roche for language revision of the manuscript.

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Received: 17 June 2014