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Authors: Anton-Pardo, Maria, Hlaváč, David, Másílko, Jan, Hartman, Pavel, and Adámek, Zdeněk

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## Natural diet of mirror and scaly carp (*Cyprinus carpio*) phenotypes in earth ponds

Maria ANTON-PARDO\*, David HLAVÁČ, Jan MÁŠILKO, Pavel HARTMAN and Zdeněk ADÁMEK

University of South Bohemia in České Budějovice, Faculty of Fisheries and Protection of Waters, South Bohemian Research Centre for Aquaculture and Biodiversity of Hydrocenoses, Institute of Aquaculture, Husova tř. 458/102, 370 05 České Budějovice, Czech Republic; e-mail: pardo@frov.jcu.cz

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**Abstract.** The natural diet of two different common carp (*Cyprinus carpio*) phenotypes (mirror and scaly) was studied in earth ponds in the Czech Republic. The proportion of different items was assessed through analysis of gut contents in order to establish differences and similarities between the phenotypes. In addition, temporal changes through the growing season, the influence of fish weight on proportion of main items ingested and the relationship between gut content and natural food availability was also assessed. The results showed no difference in feeding behaviour between mirror and scaly carp, the two phenotypes displaying a diet overlap of around 0.8. A shift in food resources from benthic to planktonic organisms was observed between early and late summer, which was reflected in changes in electivity index for some taxa. Fish weight did not influence the proportion of organisms ingested. No correlation was found between natural food in the pond and that in the gut, any variation in diet probably reflecting the microhabitats in which individual carp choose to feed.

**Key words:** gut content, zooplankton, crustaceans, zoobenthos, carp culture, carp pond

### Introduction

Common carp, *Cyprinus carpio* (L.), is the most cultured fish species in Central and Eastern Europe, with production levels reaching more than 80 % of total fish production in some countries (Wojnarovich et al. 2010, Adámek et al. 2012). The species is commonly reared in earth ponds using extensive and semi-intensive management regimes, thereby allowing use of natural resources for growth and development (Adámek et al. 2012). Adult carp are considered to be an omnivorous species utilising a relatively high proportion of animal prey in its diet, mainly chironomids and other benthic invertebrates (Michel & Oberdorff 1995, Colautti & Remes Lenicov 2001, Khan 2003, Rahman et al. 2008a). For carp larvae and fry, zooplankton are the main component in the diet, the size of organism ingested increasing as the carp grow (Osse et al. 1997, Chakrabarti & Sharma 1998, Dulić et al. 2011).

Currently, a high number of breeds and strains of common carp exist, genetically improved as a result of intraspecific hybridisation over centuries (Bakos & Gorda 1995, Hulata 1995). These selection processes have resulted in the two main phenotypes now cultured in Central European fish ponds, the

scaly and mirror carp, delineated based on their scale patterns (Hulata 1995, Hulák et al. 2010). Despite the regular occurrence of these phenotypes in Central European pond culture and their clear morphological differences, studies focused on common carp usually omit the breed used. While many carp pond fish farmers, based on long-term experience, feel that the two phenotypes differ in growth, behaviour and feeding patterns when cultured together, there is a general lack of information on the biology of these two phenotypes, and especially that related to feeding ecology. Such knowledge is vital in order to improve growth and general performance of fish pond stocks. Studies on natural fish diet in earth ponds have generally used a range of methodologies to study gut contents (Hynes 1950, Hyslop 1980). Many factors can influence the diet of common carp, however, including age and weight, natural food resource availability, season, etc. (Rahman et al. 2009, Kloskowski 2011).

The main objective of this work was to determine diet of the two common carp phenotypes (mirror and scaly) when cultured together in an earth pond without supplementary feeding. Specifically, the aims were (i) to assess any differences in food composition between

\* Corresponding Author

the two phenotypes and establish the level of diet overlap; (ii) to determine temporal variations in the proportion of different organisms ingested over one growing season; (iii) to assess whether variations in fish weight are reflected in feeding behaviour; and (iv) to determine whether the proportion of food organisms in the gut reflects their availability in the environment.

## Material and Methods

### *Study site*

The study was performed in an experimental earth pond at the Faculty of Fisheries and Protection of Waters, University of South Bohemia, in Vodňany (Czech Republic; 49°9'27" N, 14°9'44" E). The pond has a surface area of 0.11 ha, a mean depth of 0.7 m and was filled with water from the River Blanice, 14 days before stocking. Two-year-old common carp were stocked into the pond in May 2013 (20 kg of each phenotype, corresponding to a total density of 363 kg ha<sup>-1</sup>). Mean biomass per individual mirror carp was 329.9 ± 53.5 g, and 365.5 ± 86.9 g for scaly carp. Lime was applied at 150 kg ha<sup>-1</sup> CaCO<sub>3</sub> before stocking, and 500 kg ha<sup>-1</sup> organic manure spread on the water's surface. No supplementary feeding was applied throughout the experiment.

The average water temperature over the study period was 18.2 (± 3.3) °C, conductivity 174.7 (± 11.6) µS cm<sup>-1</sup>, pH 7.8 (± 0.9) and oxygen saturation was always above 50 % (mean 76.1 ± 28.5 %). According to the traditional management in fish ponds from Central and Eastern Europe, fish were harvested on September 2013.

### *Zooplankton and macrozoobenthos*

Samples of zooplankton were taken fortnightly (from May to September 2013), though only those samples coinciding with monthly gut content samples were considered for comparison. The samples were obtained using a plankton net (22 cm diameter, 80 µm mesh-size) towed along 5 m from the pond bank, from the bottom to the surface. The organisms retained in the net were transferred to a bottle and fixed with 4 % formaldehyde. In the laboratory, zooplankton were counted using a Sedgewick-Rafter cell in an inverted microscope. At least 1 ml of sample was examined and counting continued until at least 500 individuals of the most abundant species was reached. The relative abundance of copepods and the main genera of cladocerans were calculated in order to allow a comparison with organisms in the gut contents.

Samples of benthic macroinvertebrates were taken using a 225 cm<sup>2</sup> Eckman dredge at monthly intervals.

The samples collected, along with any organic and inorganic debris, were sorted using a 500 µm mesh sieve and preserved in a 4 % formaldehyde solution. Retained macroinvertebrates were sorted in the laboratory, weighed to the nearest 1 mg and determined to family level.

### *Gut content*

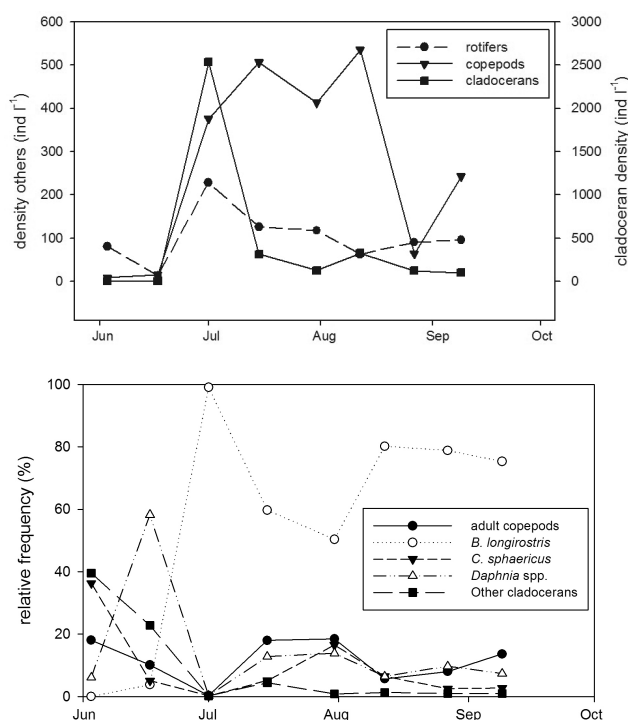
Fish were collected monthly (from June to September 2013) using two different fishing methods: seine netting and rod and line. The number of replicates for each phenotype varied each month depending on the success of the catch, and ranged from 2 to 7. Before gut content sampling, fish were anaesthetised with 0.3 ml l<sup>-1</sup> of clove oil. For each individual, the gut contents were extracted by introducing a plastic tube into the mouth and pumping around 100 ml of clean water in with a syringe. As a result, the gut contents were expelled through the anus into a collecting tray (Faina 1975). Through this methodology, fish were released back to the pond once the gut content was extracted, so the variation in fish density in the pond during the study period was avoided. The resulting sample was transferred into a bottle and preserved with 4 % formaldehyde. In the laboratory, the sample was split between three Petri dishes and prey items identified using a stereo-microscope. Due to the high amount of detritus and organic sediment, the points method (Hynes 1950) was used to estimate the proportion of main items in the gut. This requires that a score (0, 1, 2, 4, 8, 16) is assigned depending on the abundance of organisms and their volume. In addition, a similar proportion of crustaceans and zoobenthic organisms (25 % of a Petri dish for the three replicates in each sample) were counted in order to assess their relative frequency in all samples. Individuals were identified to different taxonomic levels, i.e. cladocerans and rotifers to genera; copepods to order; insects to family; hydracarina to clade, oligochets to subclass, ostracods to class, and nematodes to phylum.

### *Data analysis*

All fish were weighed at the time of stocking and harvesting, and specific growth rate (SGR) calculated as:

$$\text{SGR} = [(\ln w_t - \ln w_0)/t] \times 100$$

where  $w_t$  is the final body weight in kg,  $w_0$  is the initial body weight in kg and  $t$  is the culture period in days. Percentage occurrence was calculated as the proportion of individuals that contained an item divided by the total number of individuals examined. The Schoener overlap index ( $\alpha$ , Schoener 1970) was



**Fig. 1.** Temporal variation of density of the main zooplankton groups in water samples over the study period (upper), and the relative frequency of main crustacean taxa (lower).

calculated in order to assess food competition between the two phenotypes. The Schoener overlap index is calculated as:

$$\alpha = 1 - 0.5 \sum |P_{xi} - P_{yi}|$$

where  $P_{xi}$  is the proportion of prey item  $i$  in the diet of species (phenotype)  $x$ , and  $P_{yi}$  is the proportion of prey item  $i$  in the diet of species (phenotype)  $y$ . The resulting value varies from 0, indicating no overlap in diet, to 1, indicating complete overlap in diet. Following Wallace (1981), values above 0.6 were taken to indicate significant competition between two species (phenotypes).

To determine the effect of fish size on diet, the relationship between individual weight and the proportion of main items found in the gut was assessed through linear regression.

Multivariate analysis was performed to ordinate gut content samples for each individual examined. Principal Components Analysis (PCA) ordines samples along principal component axes that account for as much of the variance as possible. These axes are linear combinations of the different items in the gut (i.e. the original variables). The data was first converted to frequencies and then transformed using arcsin ( $\sqrt{x}$ ). PCA was performed on this data using PAST software (Hammer et al. 2001).

Only crustaceans (copepods and cladocerans) were considered when comparing gut content with

zooplankton in the environment. Adult copepods were considered to order (Cyclopoida and Calanoida), while cladocerans were compared to genus. Proportions of benthic organisms in gut content and environment were also compared. For these comparisons, Spearman correlations were performed using PAST software (Hammer et al. 2001).

Ivlev's electivity index (Jacobs 1974) was applied to evaluate food selectivity using data on food supply composition. Ivlev's electivity index is calculated as:

$$E = (r - p)/(r + p)$$

where  $r$  represents the percentage of a food item taken by a fish and  $p$  represents the percentage of that prey item available in the environment. Thus, a value of  $E = 0$  means that consumption of a particular food item corresponds to its occurrence in the environment, while  $-1 < E < -0.01$  and  $0.01 < E < 1$  indicate negative (i.e. consumption less than expected from estimates of food item abundance) and positive (i.e. consumption more than expected from estimates of food item abundance) selectivity for a particular food item, respectively. This value was calculated for both phenotypes each month for those prey items found most frequently in the environment and in gut contents.

## Results

At the end of the study period (September 2013), the average weight of mirror carp was  $580.9 \pm 116.2$  g and  $666.6 \pm 154.1$  g for scaly carp. Despite the different weights, SGR was similar for both phenotypes at 0.35 and 0.37 % d<sup>-1</sup> in mirror and scaly carp, respectively.

### Zooplankton and zoobenthos

The most abundant zooplankton group in the ambient environment throughout almost the whole study period were copepods. These were mainly represented by juvenile nauplii and copepodites, and especially in July and August when they reached densities of more than 500 individuals l<sup>-1</sup> (Fig. 1). Rotifers were the dominant group in the first sampling in June, when the main taxon was the genus *Synchaeta*. Other abundant rotifer species found were *Polyarthra vulgaris*, *Keratella cochlearis*, as well as several species of the genera *Asplanchna* and *Brachionus* (Fig. 1). Cladocerans showed a peak in density in July, mainly due to the presence of more than 2500 individuals of *Bosmina longirostris* per litre (Fig. 1); following which their density declined to 228 ind. l<sup>-1</sup>. Other taxa with relevant densities included *Chydorus sphaericus*, *Daphnia* spp. and *Ceriodaphnia* sp.

Tubificids (Tubificidae, Clitellata) and midge fly larvae (Chironomidae, Diptera) dominated pond

**Table 1.** Proportion of main dietary items found in the gut of mirror and scaly carp over the study period and the dietary overlap index ( $\alpha$ ).  
Note: N = individuals examined; - = absent.

	June		July		August		September	
	Mirror	Scaly	Mirror	Scaly	Mirror	Scaly	Mirror	Scaly
N	6	6	4	2	7	5	5	4
Average weight (g)	460.8	505.8	505.0	800.0	670.0	545.0	603.0	752.5
Zooplankton and nekton	21.3	18.1	32.8	16.2	46.6	43.2	57.0	50.3
<i>Bosmina</i> sp.	3.8	3.1	9.0	2.8	13.0	11.8	10.1	10.9
<i>C. sphaericus</i>	4.2	2.5	5.5	2.0	6.5	5.7	6.8	7.1
<i>Daphnia</i> sp.	1.8	2.6	4.5	2.8	3.9	4.6	5.7	7.1
<i>Moina</i> sp.	1.6	3.2	-	-	2.0	2.0	-	-
<i>Simocephalus</i> sp.	0.2	0.1	-	-	-	0.8	0.8	-
<i>Ceriodaphnia</i> sp.	1.3	1.4	4.5	2.3	2.6	1.4	6.5	4.1
<i>Alona</i> sp.	0.6	0.1	0.9	-	-	-	-	-
<i>Scapholeberis</i> sp.	1.1	-	0.3	1.5	-	-	1.0	-
<i>Macrothrix</i> sp.	-	0.2	-	-	-	-	-	-
<i>Pleuroxus</i> sp.	0.2	-	1.0	-	3.4	3.7	10.3	4.1
<i>Ilyocryptus</i> sp.	-	-	-	-	-	-	-	1.5
<i>Diaphanosoma</i> sp.	-	-	-	-	-	-	0.8	-
Overall								
Cladocerans	14.7	13.2	25.6	11.4	31.4	30.0	42.0	35.0
Copepods	3.1	2.7	5.4	2.8	5.4	5.8	9.8	12.4
Rotifers	-	-	-	-	-	1.1	-	-
Nektonic insects	3.5	2.2	1.8	2.0	9.5	4.4	5.2	2.9
Hydracarina	-	-	-	-	0.4	2.0	-	-
Zoobenthos	14.3	8.4	5.1	10.8	10.1	11.3	5.8	7.9
Chironomidae	11.3	6.0	4.5	10.3	4.7	6.1	2.3	3.4
Other dipterans	1.3	1.1	-	0.5	1.3	1.5	-	-
Ostracoda	1.6	1.1	0.5	-	3.2	3.7	3.5	4.5
Oligochaeta	0.1	0.1	-	-	0.5	-	-	-
Nematoda	-	0.2	-	-	0.4	-	-	-
Varia	64.4	73.4	62.1	73.0	43.3	45.5	37.2	41.8
Plant debris	20.9	24.1	25.9	39.2	12.7	19.1	11.2	5.8
Detritus	43.5	49.2	28.3	33.7	30.1	26.4	26.0	36.0
Seeds	-	-	7.9	-	0.4	-	-	-
$\alpha$	0.88		0.74		0.87		0.81	

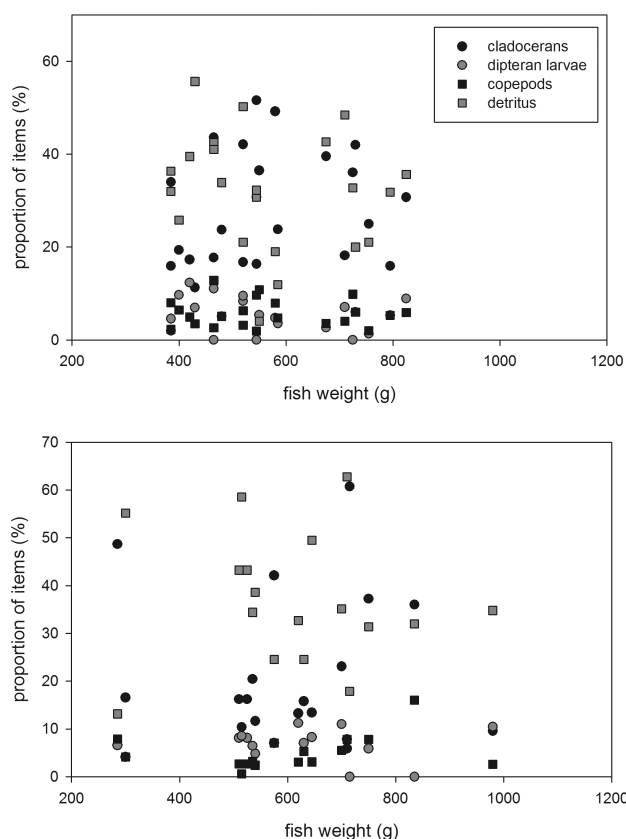
macrozoobenthos, with a total density of 69.8 and 28.4 %, and a biomass of 53.4 and 42.7 %, respectively. Zoobenthos density and biomass were lowest in June, at 355.6 ind. m<sup>-2</sup> and 3.2 g m<sup>-2</sup>, respectively, and highest in July, at 5733.3 ind. m<sup>-2</sup> and 33.4 g m<sup>-2</sup>, respectively.

#### Gut content

Twenty-two mirror carp (weight 385 to 825 g) and 17 scaly carp (285 to 980 g) were examined for gut

content analysis. The diet of mirror carp comprised 21 items and that of scaly carp 23 items (Table 1). Both phenotypes took planktonic and benthic items equally. Detritus represented the highest proportion of gut content in both phenotypes in June and July (especially in June when it reached almost 50 % in scaly carp), as did plant debris, which varied between 20 and 39 %. Cladocerans (*Chydorus*, *Bosmina* and *Moina* in particular) and chironomids were the most abundant taxa taken in June and July. The proportion





**Fig. 2.** Proportion of main dietary items (cladocerans, detritus, copepods and dipteran larvae) found in the gut in relation to individual weight of mirror carp (upper) and scaly carp (lower).

of cladocerans increased to 30-40 % (dominated by the genus *Bosmina*) in August and September, while chironomids decreased, especially in September. Copepods (represented mainly by cyclopids) were more important in September (approaching 10 %). Rotifers were only reported in August (scaly carp only), when a few individuals of the genus *Asplanchna* were found. Planktonic (nektonic) insects were reported in low proportions, with the exception of samples in August and September when a high abundance of corixids was observed. Insects were mainly represented by benthic chironomid larvae and other Diptera, though their importance in the diet of both phenotypes decreased over the study period.

Plant debris, detritus, copepods and the cladoceran *Bosmina* had an occurrence of 100 %, i.e. they appeared in all individuals examined (Table 2). *Chydorus sphaericus* appeared in all mirror carp but showed lower occurrence in scaly carp. *Daphnia* spp. and chironomids also had high percentage occurrence of > 80 % (Table 2).

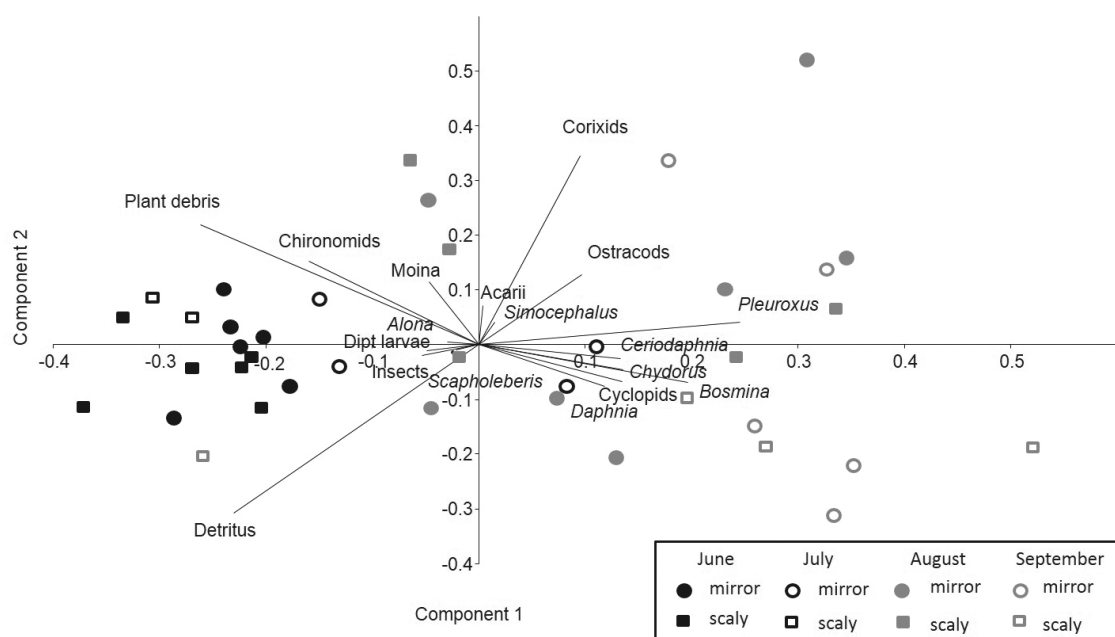
The Schoener overlap index showed little variation over the study period, ranging from 0.88 in June to 0.74 in July (Table 1). No correlation was found

**Table 2.** Frequency of occurrence (%) of main dietary items in total gut contents of mirror and scaly carp over the study period.

		Mirror	Scaly
Zooplankton and nekton	<i>Bosmina</i> sp.	100.0	100.0
	<i>C. sphaericus</i>	100.0	94.1
	<i>Daphnia</i> sp.	86.4	94.1
	<i>Moina</i> sp.	36.4	52.9
	<i>Simocephalus</i> sp.	9.1	11.8
	<i>Ceriodaphnia</i> sp.	77.3	52.9
	<i>Alona</i> sp.	18.2	5.9
	<i>Scapholeberis</i> sp.	22.7	11.8
	<i>Macrothrix</i> sp.	0.0	11.8
	<i>Pleuroxus</i> sp.	68.2	41.2
	<i>Ilyocryptus</i> sp.	0.0	5.9
	<i>Diaphanosoma</i> sp.	4.5	0.0
	Overall Cladocerans	100.0	100.0
	Copepods	100.0	100.0
Zoobenthos	Rotifers	0.0	5.9
	Nektonic insects	77.3	70.6
	Acarii	13.6	17.6
	Chironomidae	86.4	88.2
	Other dipterans	31.8	35.3
	Ostracoda	68.2	64.7
	Oligochaeta	9.1	5.9
	Nematoda	4.5	5.9
	Plant debris	100.0	100.0
	Detritus	100.0	100.0
Varia	Seeds	9.1	0.0

between the proportion of cladocerans, dipteran larvae, copepods or detritus and individual weight of mirror or scaly carp (Fig. 2).

The first two components of the PCA accounted for 51.3 % of total variance (34.8 % on the first axis and 16.5 % on the second). The first axis was negatively correlated with the proportion of detritus, plant debris and chironomids (Fig. 3), and positively correlated with the proportion of some cladoceran genera (especially *Pleuroxus*, *Bosmina* and *Chydorus*) and other taxa such as cyclopids and corixids. The second axis showed a low positive correlation with corixids and a low negative correlation with detritus. Plotting of the sampling points in the space formed by these two axes indicated an ordination along the first axis. Most samples from June and July were located at the negative end of component one, correlated with a higher proportion of



**Fig. 3.** A two-dimensional PCA biplot (51.3 % of total variance explained by the two first axes) showing the position of sampling points in relation to the different dietary items found in the gut of mirror and scaly carp.

detritus, plant debris and chironomids; while samples from August and September were located at the central and positive end of the axis, with a higher relationship with cladocerans and other planktonic taxa.

A total of 10 cladoceran species were found in the environmental zooplankton samples, with just one not found in gut samples (*Peracantha truncata*). On the other hand, three taxa found in gut content samples did not appear in environment zooplankton samples (genera *Diaphanosoma*, *Ilyocryptus* and *Simocephalus*). No correlation was found between the relative frequency of crustaceans (cyclopids and cladocerans) in the environment and gut contents. Similarly, the proportion of zoobenthos in the gut was not correlated with their frequency in sediment samples.

Electivity index values were similar for both phenotypes (Table 3). Mirror and scaly carp showed negative selection for cyclopids and *Ceriodaphnia* sp. in June but positive selection over the rest of the study period. This pattern was reversed for *Bosmina* sp., with strong positive selection in June and negative selection in July, August and September. *C. sphaericus* was positively selected by both phenotypes throughout the study, whereas *Daphnia* spp. and *Moina* sp. were usually negatively selected for. Among the zoobenthos, Tubificidae were negatively selected for throughout the study, occasionally reaching values of  $-1.0$  due to their absence in the gut content. Chironomidae were positively selected by both phenotypes in June and July and avoided at the end of summer.

**Table 3.** Electivity index results for the most frequent items in mirror and scaly carp diet over the study period.

		June		July		August		September	
		Mirror	Scaly	Mirror	Scaly	Mirror	Scaly	Mirror	Scaly
Copepods	Cyclopids	-0.09	-0.06	0.02	0.09	0.34	0.43	0.21	0.65
Cladocerans	<i>Bosmina</i> sp.	0.83	0.85	-0.04	-0.21	-0.10	-0.08	-0.40	-0.51
	<i>Ceriodaphnia</i> sp.	-0.22	-0.38	0.14	0.18	0.54	0.74	0.57	0.48
	<i>C. sphaericus</i>	0.72	0.46	0.34	0.12	0.46	0.24	0.45	0.20
	<i>Daphnia</i> sp.	-0.86	-0.71	-0.18	0.30	-0.20	-0.31	-0.59	-0.44
	<i>Moina</i> sp.	-0.22	0.12	-1.00	-1.00	-0.54	-0.32	-1.00	-1.00
Zoobenthos	Chironomidae	0.71	0.68	0.73	0.74	-0.25	-0.18	-0.20	-0.15
	Tubificidae	-0.99	-0.73	-1.00	-0.89	-0.67	-0.25	-1.00	-1.00

## Discussion

The results indicate that the two phenotypes of common carp (mirror and scaly) studied show no important differences in feeding ecology over the growing season. Indeed, there was a high degree of dietary overlap (close to 0.9), indicating a high level of food similarity.

It is commonly accepted that older common carp (both mirror and scaly) are benthic feeders, eating mainly chironomids and other insect larvae, molluscs, detritus, plants and seeds (Michel & Oberdorff 1995, Khan 2003, Rahman et al. 2008a). The importance of zooplankton in the diet of older carp has been highlighted in many studies (Adámek et al. 2003, Khan 2003, Rahman et al. 2006, Marković et al. 2009, Woynarovich et al. 2010, Kloskowski 2011). Its trophic niche is wide, however, and some studies link this with the success of carp as an “invasive” species round the world (Britton et al. 2007, Weber & Brown 2009). In our study, a shift in diet was observed in both phenotypes between early and late summer. However, this interpretation should be taken with caution since there was a low sample size in some months (e.g. only two individuals of scaly carp were caught in July) and some different tendencies could not be reflected in the presented results. In June and July, detritus and plant debris were the predominant items; however, plants are not considered to be a main food item for carp as they are unable to digest them completely (Sibbing et al. 1986). The ingestion of detritus and plant material, therefore, is probably related to accidental ingestion while taking invertebrates from the sediment. Chironomid larvae become a preferred food item in early summer (Coulatti & Remes Lenicov 2001, Adámek et al. 2003), since later on, their abundance in the sediment is reduced due to the emergence of adults (Iwakuma 1992, Kajak & Prus 2003). Tubificid and midge fly larvae density decreased from July to August; while cladocerans and other planktonic taxa (cyclopids, corixids) increased their importance in August and September. Most cladoceran taxa found in the gut were of small-sized species, mainly individuals of the genera *Bosmina*, *Chydorus* or *Pleuroxus*. In general, cladocerans are more abundant in carp diet as they are larger and show a lower escape velocity compared to copepods (Drenner et al. 1978, Lu et al. 2002, Dulić et al. 2011). Rotifers were not found in gut samples, except for very minor occurrence in scaly carp diet in August. These results were not totally surprising considering the age and weight of the fish cultured (two-years-old and around 500 g per individual),

as rotifers usually only appear in the diet of larval and juvenile common carp (Chakrabarti & Sharma 1998, Woynarovich et al. 2010). In adult carp, rotifers and other such small organisms are not included in the diet as the branchial sieve retains organisms larger than 0.25 mm (Sibbing et al. 1986, Dulić et al. 2011). On the other hand, their absence in gut samples could also be explained by rapid degradation in the fish gut (Sutela & Huusko 1997) or due to their low abundance in the environment (compared to crustacean density).

Changes in carp feeding habits have previously been related to a number of factors. First, changes may be related to physiological changes during the fish's life-cycle (Rahman et al. 2009, Kloskowski 2011). As this study took place over just one season, and the fish were of an advanced age, the shift from benthic to planktivorous feeding observed could only have been related to availability of food resources. Rahman et al. (2010) pointed out that, when carp have no access to sediment (e.g. in concrete bottomed tanks), their feeding niche shifted from bottom sediment to the water column. In addition, we observed no relationship between variation in diet and weight of the individuals examined (Fig. 3). It is possible, however, that microhabitat use may have had some influence (Garcia-Berthou 2001, Saikia & Das 2009). Although the studied pond was small (0.11 ha), the presence of vegetation along the shore, shaded areas, varying depth and differences in substrate could all have had an influence on invertebrate community composition and consequently their abundance in carp diet. Some studies support the hypothesis that food availability in the environment is the main cause for temporal changes in carp diet (Coulatti & Remes Lenicov 2001, Kloskowski 2011). In our study, however, there was no correlation between the proportion of crustaceans in water samples and in the gut content.

The electivity index partially agreed with this change as chironomids were positively selected for in June and July (when they were more abundant in the gut content), while cladoceran and copepod taxa were preferred items in late summer. Positive selection for copepods and chironomids and negative selection for *Bosmina* and *Daphnia* has also been observed in previous studies (e.g. Adámek & Sukop 2001). On the other hand, other studies have shown that benthic macroinvertebrates are always positively selected for, and selection for zooplankton decreases with increasing carp size (Rahman et al. 2009).

These results suggest that these two carp phenotypes should not be cultured together in high densities as the



high value of diet overlap suggests high competition for food (Schoener 1970, Wallace 1981). Hartvich et al. (2003) studied the growth of these two phenotypes when cultured together and observed that there were no significant differences in weight gain between mirror and scaly carp. They concluded that both phenotypes have similar genetic potential to grow in ponds. Our results are in accordance with this study, the specific growth rates obtained indicating no remarkable difference between phenotypes. Both phenotypes are commonly reared in ponds with a variety of other fish species (polyculture), in order to more fully utilise the natural resources of the pond ecosystem. In order to increase the efficiency of this practice, therefore, the species cultured should display low competition in their respective niche, and especially in their feeding behaviour. As a result, common carp are usually cultured with species displaying different feeding behaviours in order to diminish competition between species and ensure that the natural food produced in ponds in different biotopes is exploited completely (Woynarovich et al. 2010). Such species include tench, *Tinca tinca* (L.); grass carp, *Ctenopharyngodon idella* (Valenciennes, 1844); bighead carp, *Hypophthalmichthys nobilis* (Richardson, 1845); rohu, *Labeo rohita* (H.), and others, depending on geographical location (Adámek et al. 2003, 2012, Rahman et al. 2006). Normally, these species are primarily planktivorous as adult carp are considered benthivorous (Michel & Oberdorff 1995, Rahman et al. 2010). Our results, however, highlight the importance of planktivorous organisms for growth of carp, particularly in late summer, and

this shift in feeding behaviour needs to be considered when choosing species for polyculture in future.

In conclusion, there were no significant differences in the feeding ecology of mirror and scaly carp, which show a high degree of dietary overlap in earth ponds. Both phenotypes fed mainly on benthos in early summer (June and July), but shifted to a preference for planktonic organisms, mainly cladocerans, in late summer (August and September). However, as the sample size was low in some dates (caused by the low number of available fish), it is recommended to increase the number of samples in further studies, to obtain a bigger sample of the carp population in the pond. Fish weight had no influence on the proportion of items ingested within the size range of the carp examined (285–980 g) and the proportion of taxa in the environment showed no correlation to their proportion in the gut, indicating a change in carp feeding behaviour related to changes in preferred food microhabitats. The study contributes to the knowledge of juvenile scaly and mirror carp diet in fish ponds, but further studies must be developed to examine the diet of these two phenotypes along their whole life cycle (from larvae to adults).

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