



Feeding habits of *Carassius carassius* (Cyprinidae) in Beni Haroun Dam (north-east of Algeria)

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Abstract. Feeding habits of *Carassius carassius* (Linnaeus, 1758) were analyzed from 334 specimens collected from Beni Haroun Dam (north-east of Algeria) between January 2015 to December 2015. Of the total number of the guts examined, 78 were empty corresponding to a total vacuity index (VI = 23, 35%). Feeding intensity was strongly seasonal, being higher during summer and lower during winter. The difference in feeding intensity between size classes was statistically significant ($p < 0.05$), decreased with size classes. 10558 prey items were identified to the possible taxonomic groups, exhibiting a diversified food spectrum of this species. Numeric indexes (numerical, weight percentage of abundance, and frequency of occurrence) and a composite index (IRI - index of relative importance) were applied to establish the feeding strategy of the species. The diet of *C. carassius* consisted mainly of phytoplankton (algae), followed by zooplankton (cladocerans, copepods, rotifers), then by insects (Dipterans). Other groups: nematodes, bivalves and fish were a minority. The percentage of IRI varies significantly according to season and size classes (ANOVA, $p < 0.001$). Analysis of the occurrences data was performed by the Principal Component Analysis (PCA) method with Statistica 8 software, showed that algae was the food mainly consumed during winter and spring, the contributions of animal origin food categories (zooplankton and insects) were important in the diet in summer and autumn. The contributions of algae and rotifers (*Brachionus* sp., *Keratella* sp.), were important in the diet of small fish whereas zooplankton: cladocerans (*Daphnia* sp. and *Bosmina* sp.), dipterans (*Chironomus* sp.), copepods (*Cyclops* sp) and fish were important in the diet of adults. The Amundsen diagram shows that the *C. carassius* have a generalist feeding strategy, the diet breadth index Shannon Wiener shows a moderately wide spectrum of diet ($H = 2.39$).

Key Words: feeding habits, *Carassius carassius*, feeding intensity, numeric indices, Amundsen diagram, feeding strategy.

Introduction. The study of the food and feeding habits of fresh water fish species is a subject of continuous research because it constitutes the basis for the development of a successful fisheries management programmed on fish capture and culture (Oransaye & Nakpodia 2005). The dietary analysis of organisms in their natural habitat enhances the understanding of the growth, abundance, productivity and distribution of organisms (Fagade & Olaniyan 1972).

Carassius carassius (Linnaeus, 1758) is a freshwater cyprinid that is widely distributed in Eurasia: Spain across Europe, and north-central Asia to Northern China (Vostradovisky 1973; Economidis 1991; Kottelat 1997). It has been successfully introduced into fresh waters throughout the world (Welcomme 1988; Seegers et al 2003). It occurs in shallow ponds, lakes rich in vegetation and slow moving rivers (Vostradovisky 1973). It burrows in mud in the dry season or winter (Allardi & Keith 1991). Since it is a fast growing and hardy fish that can withstand adverse environmental conditions, is widely recognized to be resistant to some ecological conditions and is known for its morphological plasticity (Szczerbowski et al 1998; Copp et al 2008). *C.*

carassius was found in Algeria for the first time in the Ain Zada reservoir (Northeastern Algeria), probably part of the 2006 summer introduction of carps (Kara 2012).

The physiological and ecological characteristics of *C. carassius* have been studied by Holopainen & Hyvärinen (1985), Hyvärinen et al (1985), and Holopainen et al (1986), in an attempt to gain an understanding of the life of this species. But only few studies exist on comparing populations of different water bodies and ecosystems, which are imperative for formulating policies concerning sustainable exploitation and conservation, in order to understand the performance of *C. carassius* in different wild environments. Various investigators have studied the food and feeding habits of *C. carassius* in the world (Prejs 1973; Paszkowski et al 1989; Penttinen & Holopainen 1992; Paszkowski et al 1996; Holopainen et al 1997).

According to Penttinen & Holopainen (1992), the feeding of *C. carassius* showed differences based on its diet and seasonal feeding activities. Planktonic and benthic invertebrates form dominant part of the diet (Szlauer 1971; Andersson et al 1978; Penttinen & Holopainen 1992; Paszkowski et al 1996). No strong ontogenetic diet shift was observed.

In Algeria this species has a commercial importance for fishing in Beni Haroun Dam. Despite its importance, there is no published information about its biology and ecology, the feeding habits, and the interaction with other species. Such information is considered important for the conservation of this species in this dam.

The aim of this work was therefore to study the diet composition of *C. carassius* in Beni Haroun Dam (Algeria), to highlight changes in diet according to season and size classes, and to evaluate their food strategy in Beni Haroun Dam.

Material and Method

Study area. The Beni Haroun Dam is the largest in Algeria, located downstream of the confluence of Oued Rhumel and Oued Endja (northwest of El Grare of Mila region), some 40 km north of Constantine (36°33'18.55"N / 6°16'10.93"E) and an equivalent distance per contribution to the mouth of Oued Kebir (Mediterranean Sea). Its filling began in August 2003, covers an area of 5328 km², or more than 60% of the total area of the Basin Kebir-Rhumel, which is a part of it (Kerdoud 2006) (Figure 1).

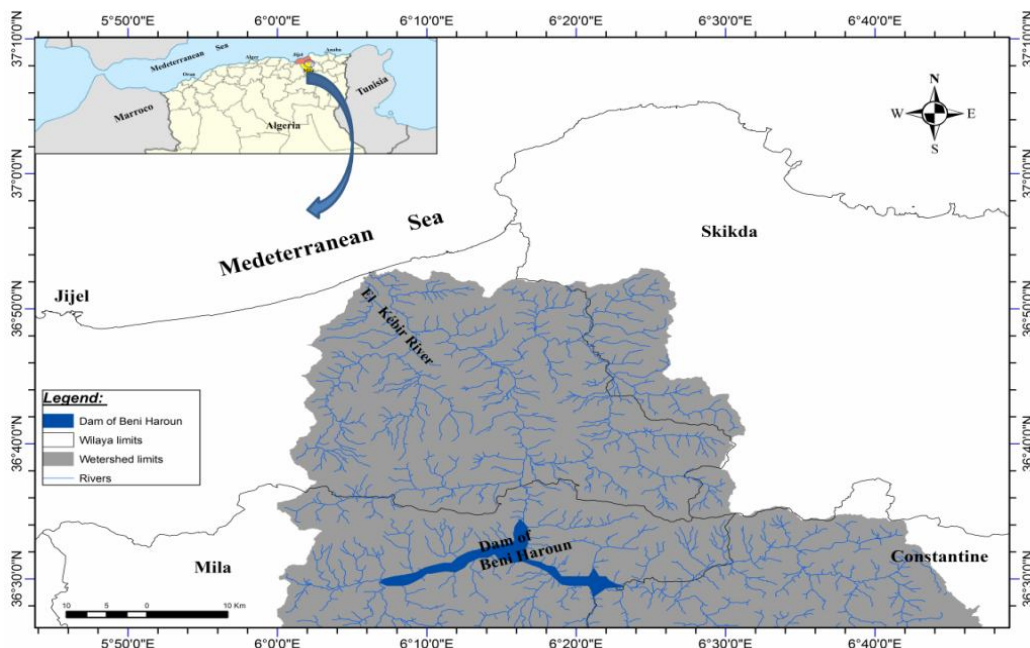


Figure 1. Map of study area showing the geographic location of Beni Haroun Dam (north-east of Algeria).

Field sampling and laboratory work. Fish specimens were collected from the Dam monthly between January 2015 and December 2015. They were procured from daily catch of artisanal fishermen and taken to the laboratory. Measurement of total length was taken on the left side of the fish by an ichthyo-meter. The guts were removed and preserved in 5% formalin until the contents were analyzed. Each food item in the stomach was identified to the lowest possible taxonomic level, and counted under a binocular microscope. The taxonomic identification of the different food items was made using appropriate guides: Loir (2004), Moisan (2010), Rumeau & Coste (1988).

Data analysis. Several indices were used to quantify the importance of different prey items in the diet of *C. carassius*:

$$\text{Vacuity index (VI)} = (\text{number of empty stomachs}) / (\text{total number of stomachs analysed}) \times 100$$

(Hureau 1970)

$$\text{Percentage frequency of occurrence: (F)} = \text{Nie/Net} \times 100$$

where Nie = number of stomachs containing item i and Net = total number of full stomachs examined (Rosecchi & Nouaze 1987);

$$\text{Numerical percentage of abundance: (N)} = \text{Ni/Nt} \times 100$$

where Ni = total number of individuals of item i and Nt = total number of all food items (Hyslop 1980);

$$\text{Weight percentage: (W)} = \text{Wi/Wt} \times 100$$

where Wi = total weight of item i and Wt = total weight of all food items inventoried (Lauzanne 1977).

The diet was determined using the index of relative importance (IRI) of Pinkas et al (1971). This index combines the occurrence (F), numerical (N) percentages, and weight percentage (W):

$$\text{IRI} = \text{F\%} \times (\text{N\%} + \text{W\%})$$

All analyses were performed with Statistica (data analysis software system) version 8.0. The χ^2 test was employed to compare the vacuity index by seasons and size classes ($p < 0.05$). ANOVA statistical analyze and analysis of principal components was used in order to determine similarities between the diets of species related to season and size classes.

Feeding strategy. We used the graphical analysis proposed by Amundsen et al (1996) (Figure 2), to interpret the feeding strategy by a two-dimensional representation of prey abundance and frequency of occurrence (Amundsen et al 1996; Deus & Petrere-Junior 2003):

$$P_i = (aS_i/aSt_i) \times 100$$

where P_i is the prey-specific abundance of prey_i, S_i is the stomach content (number) comprised of prey_i, and St_i is the total stomach content in only those predators with prey_i in their stomach).

In Figure 2, the prey importance is represented in the diagonal from lower left (rare prey) to upper right (dominant prey); the feeding strategy is represented in the vertical axis from bottom (generalisation) to top (specialisation); and the relationship between feeding strategy and the between- or within-phenotype contributions to the niche width is represented in the diagonal from lower right, which represents a high within-phenotype component (WPC), to upper left, which means a high between-phenotype component (BPC). A population with a narrow niche must necessarily be composed of individuals with narrow and specialized niches. A population with a broad niche may, on the other hand, consist of individuals with either narrow (high BPC) or wide (high WPC) niches (Amundsen et al 1996).

The diet breadth was assessed by calculating the Shannon-Wiener index (H') (Krebs 1989):

$$H = -\sum p_i \times \ln p_i$$

where p_i is the proportion of a specific prey category for 'n' categories of prey.

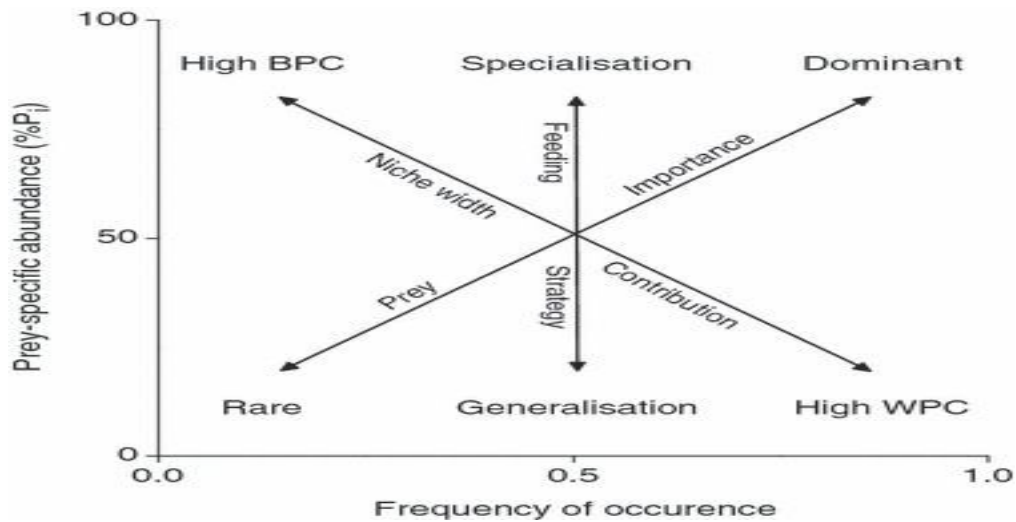


Figure 2. Feeding strategy diagram of Amundsen et al (1996).

Results

Feeding intensity. The gut contents of 334 *C. carassius* were examined to determine their diet compositions. The size of fish ranged from 16.3 to 32.4 cm total length. Figure 3 shows that the dominant length class was [22-25] (Frequency, $F = 67.37\%$). By season the dominant effective of specimen was in spring (Frequency, $F = 28.14\%$), autumn (Frequency, $F = 27.55\%$). Seventy eight (78) stomachs were empty which corresponds to a total vacuity index ($VI = 23.35\%$). The vacuity percentages were different between the size classes. It was significantly higher for [22-25] size class ($VI = 38.03\%$) ($\chi^2 = 19.38$; $df = 4$, $p < 0.001$). The lowest percentage observed in the second size class ($VI = 5.88\%$), for the first size class we not observed any empty gut ($VI = 0\%$). The vacuity index varied with season. It was significantly higher in autumn ($VI = 29.34\%$) and winter ($VI = 25\%$) ($\chi^2 = 20, 69$; $df = 3$, $p < 0.001$), the lowest percentage observed in summer ($VI = 17.64\%$).

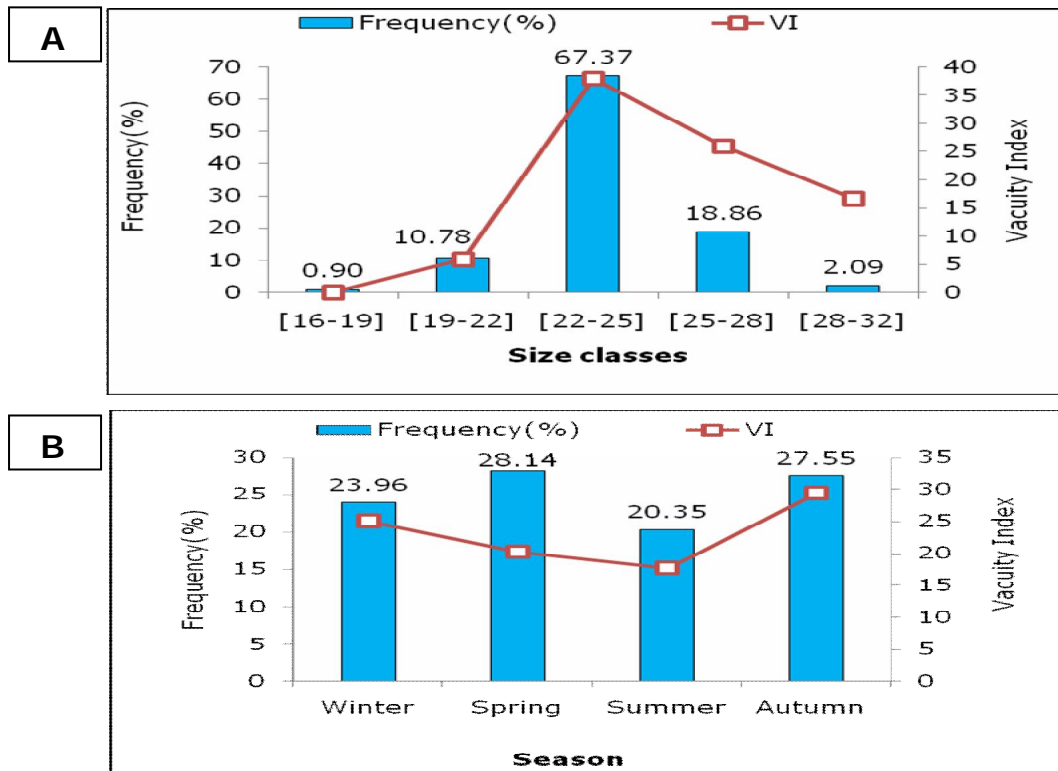


Figure 3. Vacuity index percentage and frequency distribution: (A) by size-classes, (B) by season.

Diet composition. Table 1 presents the different categories of prey identified in the stomach contents of *C. carassius*. 10558 prey items were founds corresponding to 10 major groups. These major groups were: algae, diatoms, rotifers, copepods, cladocerans, ostracods, dipterans, bivalves, nematodes and fish. The results indicate that algae was the most often prey consumed by *C. carassius* in Beni Haroun Dam (F = 60.85%), followed by cladocerans (F = 39.92%), copepods (F = 20.93%) and rotifers (F = 20.54%). The lowest percentage of occurrence was for bivalves (F = 0.77%). In term of number and weight, the cladocerans were the most prey consumed (N = 31.39%, W = 37.91%), followed by algae (N = 26.77%, W=19.25%), rotifers (N = 18.03%, W = 7.72%). The classification of prey by the calculation of the relative importance index shows that algae (IRI = 28.21%) and cladocerans (IRI = 27.87%) were the most important prey in the diet of *C. carassius*.

Table 1

Diet composition of *C. carassius* in Beni Haroun Dam expressed as: F% - frequency of occurrence; N% - Numerical abundance; W% - weight percentage; IRI% - index of relative importance

Food item	Food index				
	F %	N %	W %	IRI %	
Phytoplankton	Algae	60.85	26.77	19.25	28.21
	Diatoms (total)	22.86	4.63	13.18	4.10
	<i>Pinnularia</i> sp.	18.21	2.98	7.82	1.98
	<i>Cyclotella</i> sp.	4.65	1.65	5.35	0.32
Zooplankton	Rotifera (total)	20.54	18.03	7.72	5.32
	<i>Keratella</i> sp.	17.82	7.14	2.88	1.79
	<i>Brachionus</i> sp.	2.32	6.08	2.71	0.20
	<i>Philodina</i> sp.	0.38	4.81	2.12	0.02
	Copepoda (total)	20.93	3.72	2.04	1.21
	<i>Cyclops</i> sp.	20.93	3.72	2.04	1.21
	Cladocera (total)	39.92	31.39	37.91	27.87
	<i>Daphnia</i> sp.	18.60	16.29	14.94	5.85
	<i>Bosmina</i> sp.	14.72	11.01	12.76	3.52
	<i>Chydorus</i> sp.	6.58	4.09	10.20	0.94
	Ostracoda	12.79	4.01	1.35	0.69
Insecta	Diptera (total)	18.60	4.01	3.19	1.34
	<i>Chironomus</i> sp.	17.82	2.95	2.15	0.91
	<i>Chaoborus</i> sp.	0.77	1.06	1.04	0.016
Mollusca	Bivalvia	0.77	0.44	2.12	0.019
Nematoda		12.40	12.40	12.40	1.30
Fish		8.91	8.91	8.91	0.37
Unidentified		31.78	31.78	31.78	5.26

Comparison of diet according to size classes

Comparison of IRI. ANOVA analysis showed significant interaction effects in diet among size classes (ANOVA, F = 13.14, p < 0.001), whereas, the preferential diet of the [16-19] size-class was algae (IRI = 100%), this prey being considered as important for [19-22] size-class algae, followed by rotifers especially: *Keratella* sp. (IRI = 19.35%) and *Brachionus* sp. (IRI = 16.80%). For the larger size classes, algae and cladocerans were important prey: [22-25]: algae (IRI = 51.43%), *Daphnia* sp. (IRI = 12.73%); [25-28]: algae (IRI = 47.75%), *Daphnia* sp. (IRI = 23.96%); [28 -32]: algae (IRI = 29.55%), *Daphnia* sp. (IRI = 28.59%) (Figure 4).

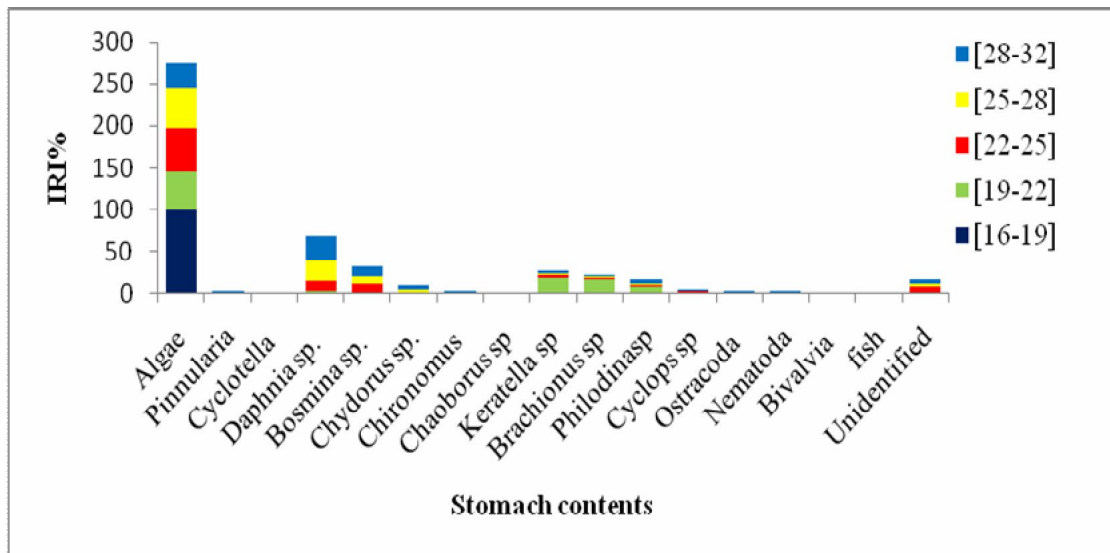


Figure 4. Variation of *C. carassius* IRI% in relation to size classes.

Comparison of occurrence. The use of principal component analysis (PCA) as a preliminary and exploratory descriptive approach led to investigate the existence of possible similarities of frequency of occurrence between size classes (Figures 5, 6). The first two major components (F1 and F2) contain 80.77% of total variability (58.54% and 22.23%) respectively, showing a significant difference of the feeding between size classes (ANOVA, $F = 9.17$, $p < 0.0001$); the diet of [16-19] size class was strongly influenced by algae. Rotifers, especially *Keratella* sp. and *Brachionus* sp. for [19-22] size class; cladocerans (*Daphnia* sp. and *Bosmina* sp.), dipterans (*Chironomus* sp.), copepods (*Cyclops* sp.) for the [22-25] and [25-28] size classes, and fish for the [28-32] size class.

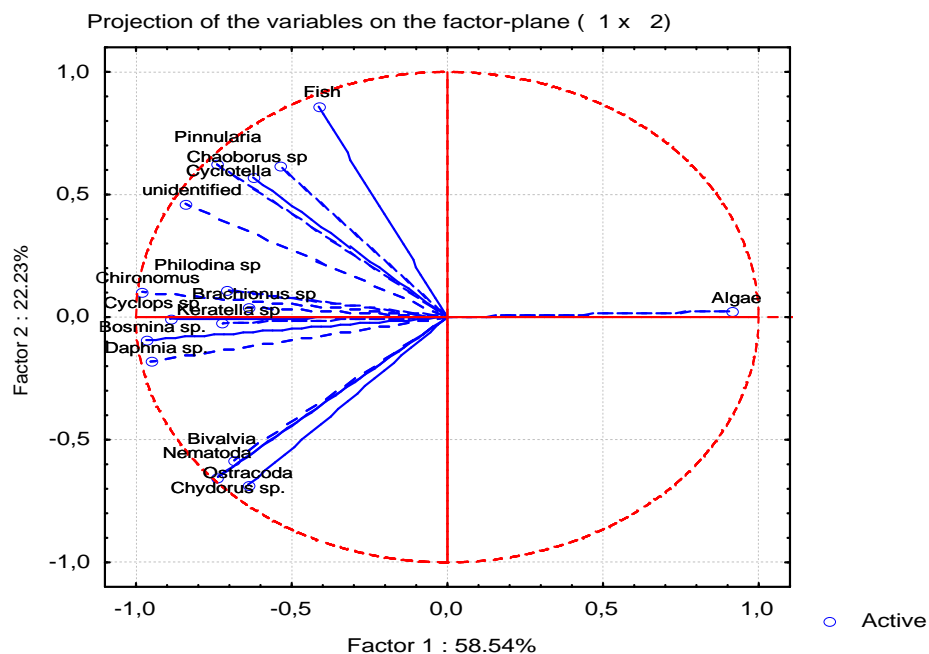


Figure 5. Correlation circle of frequency of occurrence of prey items with the first two principal axes.

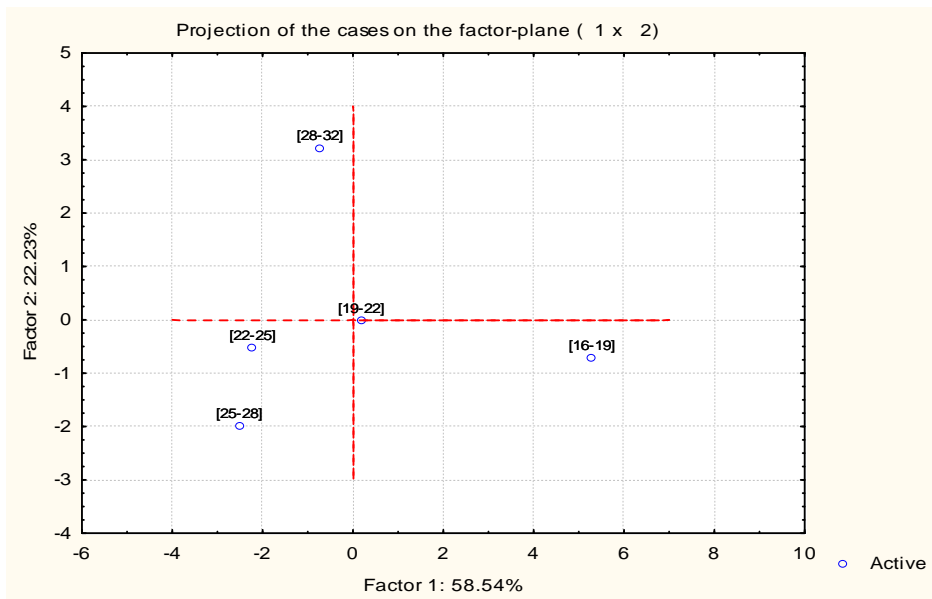


Figure 6. Projection of size classes on the first two principal axes.

Comparison of diet according to season

Comparison of IRI. By season, the diet of *C. carassius* based on the percentage of IRI was statistically significant (ANOVA, $F = 9.95$, $p < 0.001$). In winter and spring, algae was the prey mainly often consumed by *C. carassius* (IRI = 76.94%, and 84.12% respectively) (Figure7). However, the importance of algae declined during summer and autumn (IRI = 36.52%, and 23.50% respectively). *Daphnia* sp. was the most important prey in the diet in summer (IRI = 35.79%), in autumn rotifers, especially *Keratella* sp. and *Brachionus* sp., were also important prey in the diet (IRI = 12.01%, and 12.53% respectively).

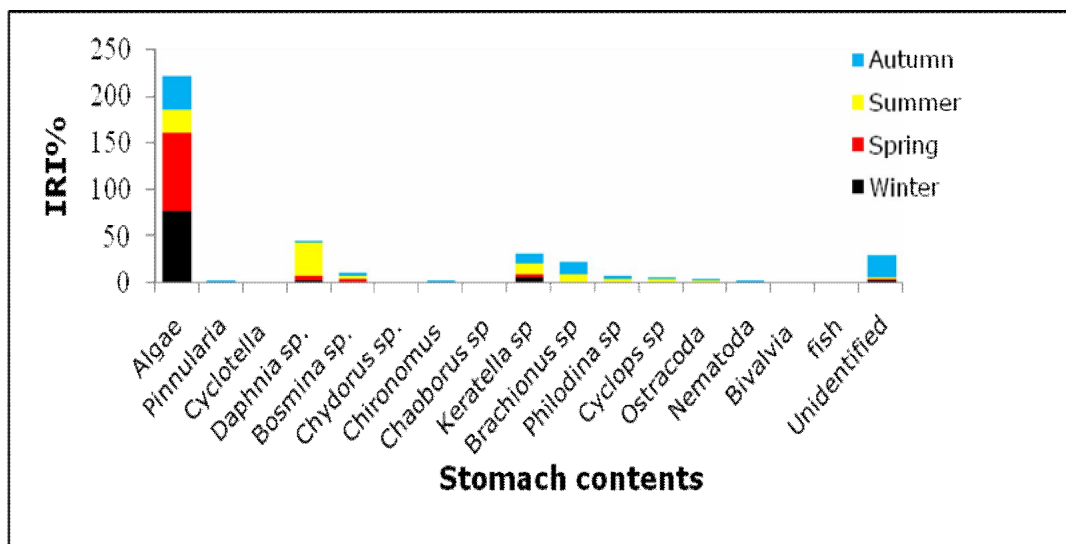


Figure 7. Variation of IRI% in relation to seasons.

Comparison of occurrence. By season the first two major components (F1 and F2) contain 80.54% of total variability (44.95% and 35.59 %) respectively, and showed a seasonal variation in the diet of *C. carassius* (ANOVA, $F = 61.95$, $p < 0.0001$). The contribution of algae was the highest in winter and spring occurring in 70.86% and 89.87% respectively. However, the contribution of zooplanktons (*Brachionus* sp., *Keratella* sp., *Cyclops* sp., and *Daphnia* sp.) and Dipterans (*Chironomus* sp.) increased during autumn (42.60%, 43.34%, 12.38%, 18.43%, and 20.74% respectively) and summer (70.09%, 65.47%,

31.96%, 40.63%, and 20.74% respectively) showing a diversified food spectrum in this period.

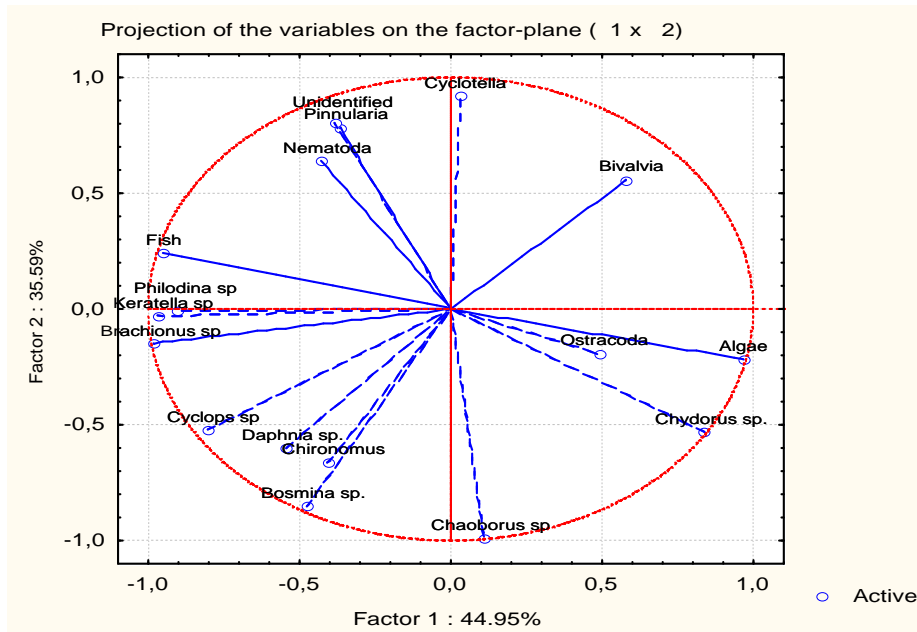


Figure 8. Correlation circle of frequency of occurrence of prey items with the first two principal axes.

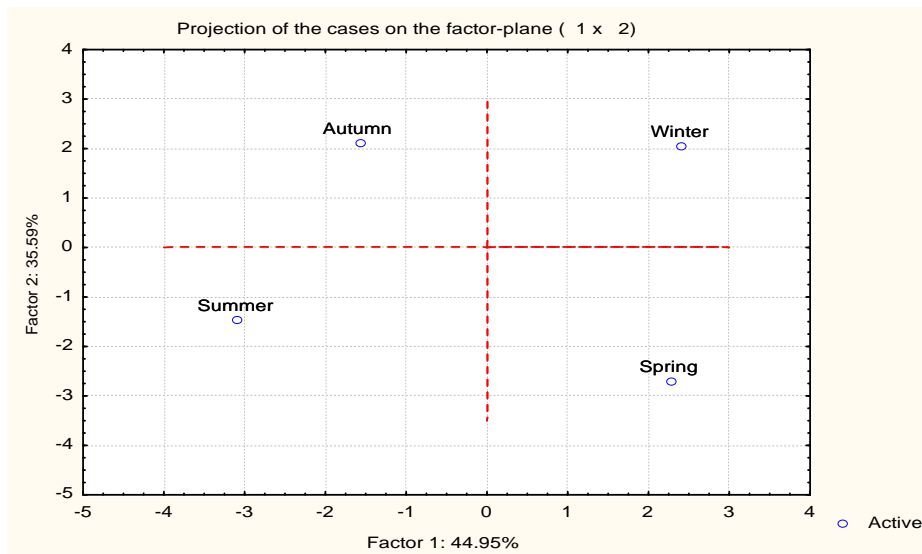


Figure 9. Projection of season on the first two principal axes.

Feeding strategy. Analysis of feeding strategy based on the Amundsen's method, established the importance of algae as the main food item in the diet of *C. carassius*, located in the upper right corner of the graph. Majority of the specimens had been feeding on this prey item. Whereas, most preys located in the lower part present a generalist feeding strategy of this species, and include preys had the lowest frequency of occurrence and prey-specific abundance, considered as unimportant prey, being consumed by few specimens or included occasionally in the diets (Figure 10).

Diet breadth index calculated ($H = 2.39$) indicates a moderately wide spectrum of prey species in the diet of *C. carassius* in the Beni Haroun Dam.

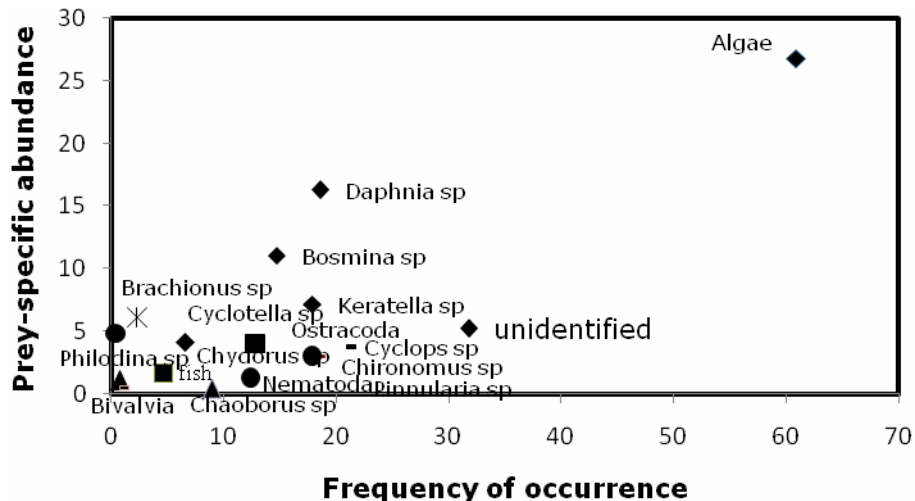


Figure 10. Feeding strategy diagram of *C. carassius* in the Beni Haroun Dam according to Amundsen et al (1996) methods.

Discussion. The dietary habits of fish, based on stomach analyses, is widely used in fish ecology as an important method to investigate trophic relationships in aquatic communities (Fagbenro et al 2000). In the present work, we studied the feeding strategy and diet composition of *C. carassius* in Beni Haroun Dam.

The feeding intensity varies significantly according to season. The highest percentage of vacuity observed in autumn to winter, whereas it is low during summer, which corresponds to high feeding activity in this period. These results agree with Penttinen & Holopainen (1992) who reported that the high frequency of empty guts are found from late autumn to spring. Both the high frequency of empty guts and low enzymatic activity, from late autumn to spring indicate that the main period of active feeding is restricted to the summer. Prejs (1973) reported that summer presents the peak in feeding intensity of *C. carassius* in Lake Warniak. It is generally known that feeding activity of Cyprinids decreases with decreasing of the water temperature (Penttinen & Holopainen 1992).

Accordingly to the previous works, the present study confirmed that the vacuity changed significantly with size classes, the small fish present the lowest vacuity rate, indicating a high level of food activity, which decreases with age. However, in our study the number of large fish was low, these may be the reason of the low percentage of vacuity for the large size classes. The same results were recorded by Reyes-Marchant et al (1992) for another species of cyprinids, *Barbus callensis*. This is probably due to that adults can develop selectivity in the choice of food (Khalaf 1985; Benabid 1990).

Feeding intensity and frequency are directly correlated with meal size and digestion time (Fänge & Grove 1979; Grove & Crawford 1980). Therefore, larger specimens exhibited a lower feeding frequency than the younger ones. A similar tendency has been reported for many fish species (Smith & Page 1969; Martin 1970; Kislialioglu & Gibson 1976; Werner 1979; Robb & Hislop 1980) and it is related to the energetic cost of obtaining their food, as the metabolic activity decreases with the age or size (Davies & Warren 1971; Webb 1978; Brett & Groves 1979; Macpherson & Duarte 1991).

The results of the present study showed that *C. carassius* is omnivorous in its diet in Beni Haroun Dam, and consumed a wide range of food items including algae, diatoms, rotifers, copepods, cladocerans, dipterans, bivalves, ostracods, nematodes and fish. Ciepielewski (1985) classified this species as a benthophagous with a preference for molluscs and chironomid larvae. Uspenskaja (1953) and Prejs (1973) reported that zooplankton may form a substantial part of the diet of *C. carassius*, with the addition of algae and macrophytes. Phytoplanktons were the most important prey in the diet (Holopainen et al 1997). Among five lakes studied by Uspenskaja (1953), molluscs dominated the diet of *C. carassius* in three lakes, chironomid larvae in one lake, and cladocerans dominated in the final lake.

In our study the contribution of algae to the *C. carassius* diet was higher in terms of W%, F% and IRI%, while the cladocerans were dominating the diet by number. These food categories were followed by copepods, rotifers and dipterans. Other studies had revealed the greater importance of algae over cladocerans in the diet of *C. carassius* (Uspenskaja 1953; Szlauer 1971; Andersson et al 1978; Penttinen & Holopainen 1992; Paszkowski et al 1996). In general, cladocerans are more abundant in carp (*Cyprinus carpio*) diet as they are larger and show a lower escape velocity compared to copepods (Drenner et al 1978; Lu et al 2002). The importance of different prey taxa varies from lake to lake and individuals from a single lake can contain a wide range of kinds and sizes of foods, including benthic insects, molluscs, cladocerans, macrophytes, algae, and detritus (Uspenskaja 1953; Prejs 1973; Andersson et al 1978).

Algae are the most dominant prey in small size classes followed by rotifers. Sibbing et al (1986) and Dulić et al (2011) reported a large portion of rotifers in the diet of small fish, which decreased in the diet of large fish. Their low proportion in gut samples of large fish could also be explained by rapid degradation in the fish gut or due to their low abundance in the environment (compared to crustacean density) (Sutela & Huusko 1997). In cyprinids, the most significant change in diet of juveniles and adults was the shift from phytoplankton and rotifers to crustaceans and chironomid larvae (Adzhimudarov 1972; Hammer 1985; Mark et al 1987, 1989). The large *C. carassius* fed on cladocerans (*Daphnia* sp. and *Bosmina* sp.), Dipterans (*Chironomus* sp.), copepods (*Cyclops* sp.) and fish. Penttinen & Holopainen (1992) studied the diet of *C. carassius* across the size, and no strong ontogenetic diet shift was observed, but the dominance of food items gradually changed from planktonic microcrustaceans to benthic cladocerans and chironomids.

In the present study, the diet composition of *C. carassius* showed some seasonal variations both in frequency of occurrence and index of relative importance. Seasonality in the feeding activity of *C. carassius* showed that algae are the preferential prey in winter and spring, while in summer and autumn the diet was very diversified, consisting mainly in cladocerans (*Daphnia* sp.), Copepods (*Cyclops* sp.), rotifers (*Brachionus* sp. and *Keratella* sp.) and dipterans (*Chironomus* sp.). These results were confirmed by Prejs (1973). The reason for the higher variety of food items could be associated to the period of spawning. Holopainen et al (1997) reported that June-July is the period of growth and reproduction in *C. carassius*, whereas in August-September reserves are built up. In summer, *C. carassius* show the common cyprinid feeding mode, with high plasticity in prey selection (Uspenskaja 1953; Prejs 1973). Coulatti & Remes Lenicov (2001) and Adámek et al (2003) reported that chironomid larvae become a preferred food item in early summer for cyprinids.

A low proportion of benthic insects in cyprinid diets could be associated with over exploitation of benthic macro-invertebrate production because of the strong feeding pressure of dense fish populations inhabiting the tributary site. The potential for competitive exclusion by any particular prey species may decrease due to different prey preferences of coexisting generalist species (Shurin & Allen 2001). Therefore, generalist feeding patterns may explain the coexistence of different species (Sanchez-Hernandez et al 2011).

High diversity of prey suggests that the trophic niche of *C. carassius* is wide, feeding on variety of available prey. However, some studies related the moderate value of Shannon-Wiener index with the invasive species (Britton et al 2007; Weber & Brown 2009). Such a generalist and omnivore foraging behaviour is frequently observed in highly variable environments, such as the Mediterranean ones, where food resources are not predictably available and fish take advantage of whatever food is accessible (Pusey et al 2010).

Conclusions. The results of the present study have clearly shown that the most important food categories of *C. carassius* in Beni Haroun Dam were phytoplankton, zooplankton, and insects. Foods of minor importance were bivalves, nematodes, fish, and ostracodes. The gut content analysis suggested that *C. carassius* is an omnivorous fish in its feeding habits. The fish also showed changes in its feeding habits according to season

and size. Among the major food items, algae was largely consumed during winter and spring, while in summer and autumn *C. carassius* fed on cladocerans, rotifers and dipterans. The difference in diet between small and large fish was the shift from phytoplankton and rotifers to cladocerans and dipterans. *C. carassius* exhibited a generalist feeding strategy with a moderately wide spectrum of diet.

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