Cey. J. Sci. (Bio. Sci.) Vol. 23, No. 1, 1994

FOOD AND FEEDING BIOLOGY OF THE ENDEMIC CARPLETS *Barbus cumingi* AND *B. nigrofasciatus* (OSTEICHTHYES, CYPRINIDAE) OF SRI LANKA

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ABSTRACT

The food and feeding biology of *B. cumingi* and *B. nigrofasciatus* were studied in a small stream of the upper reaches of the river Mahaweli. Both species are herbivorous substratum feeders and their diets consist mainly of diatoms and detritus. Diatoms were the most abundant food item (50.1%) in the diet of *B. nigrofasciatus* but both diatoms (36.8%) and detritus (38.4%) were common in the diet of *B. cumingi*. Both species appear to avoid blue-green algae.

The relative abundance of detritus and diatoms in the diet of both species varied from month to month and the importance of diatoms generally increased and that of detritus decreased with the increase of body size.

The "intestinal" contents of *B. cumingi* contained a larger amount of diatoms in comparison to that of "stomach" contents, whereas in *B. nigrofasciatus* the amount of diatoms was low in the intestine.

The relative gut length (RGL) of *B. cumingi varied* from 0.96 to 2.64 while that of *B. nigrofasciatus* varied from 0.89 to 2.54. These ranges agree well with the reported RGL ranges for other herbivorous cyprinids. The RGL increased with increase in body size in both species as has been observed in other cyprinids.

INTRODUCTION

Cyprinidae is one of the most common families of freshwater fishes in the tropics, and is the most common in Sri Lanka. About 70 indigenous fish species inhabit the freshwaters of the island of which 33 species are cyprinids which include 16 endemic species. Most of these are small carplets growing to not more than 10 cm in total length. The 19 endemic freshwater fish species presently recognized in the island are mostly confined to the headwaters and upper reaches of major rivers in the wet zone, and at least nine of these appear to be vulnerable or threatened (IUCN, 1988). *B. cumingi* Günther and *B. nigrofasciatus* Günther are two such vulnerable species. These two species often occur together in the head-streams of the rivers.

The feeding biology of the indigenous cyprinids of the island has been previously studied by De Silva *et al.* (1977), De Silva & Kortmulder (1977), De Silva *et al.* (1980), Schiemer & Hofer (1983), Schut *et al.* (1984) and De Silva *et al.* (1985).

The present study deals with the feeding biology of *B. cumingi* and *B. nigrofasciatus* in a small stream of the river Mahaweli at its upper reaches in the central part of the island.

MATERIALS AND METHODS

Habitat

The study was carried out in a perennial stream, called "Kahawaturu oya", in Ambagamuwa village, situated at 7° 1'N, 80° 29'E. This montane stream, which is about 10 km long, starts from Rambukpitiya hill range at an elevation of about 1200 m and joins the river Mahaweli at an elevation of 585 m. The stream passes mostly over sandy and muddy substratum with occasional rocky patches. The submerged stones and the substratum were covered with algae and other aufwuchs and sometimes there were floating masses of green algae.

Sampling

Monthly samples were obtained during the period of September 1986 to November 1987 from five sites, selected randomly along a stretch of about 100 m near the mouth of the stream. A monthly sample contained 25-50 individuals of each species. Samples of fish were collected between 0700 and 1100 hrs using a cast net with a diameter of about 4 m and stretched mesh size of 10 mm and were immediately injected with formol calcium into the body cavity and preserved in 5% formalin. At the time of each sampling, the temperature, pH, conductivity and concentration of dissolved oxygen of water were measured using calibrated portable electronic meters. The speed of water flow was estimated by noting the time taken by a floating cork to travel a specified distance along the middle of the stream. Monthly mean depth of water was calculated by measuring the depth at 1 m intervals along a line transect at each site. The rainfall data were obtained from the Meteorological Station at Blackwater Tea Estate, which is situated at the same elevation about 2 km away from the sampling site.

Analyses

The total and standard lengths of each fish were measured to the nearest 1 mm. Fish were divided into three size classes by total length, viz., <31, 31-45, and >45 mm. Gut of each fish was completely removed, uncoiled and the length was measured to the nearest 1 mm.

The ratio of the length of gut to total length was calculated in each individual and the mean for each 5 mm length class of all monthly samples was taken as the relative gut length (RGL) corresponding to that total length. The percentage fullness of the anterior enlarged portion of the gut ("stomach") of each specimen was estimated by eye and assigned a value from 0 to 4 in the following manner: 0=<5% full; 1=5%-25% full; 2=25%-50% full; 3=50%-75% full; 4=75%-100% full. The mean value of the monthly sample was taken as the monthly index of the fullness of gut.

The contents of the gut of randomly-chosen five specimens of each size class from each monthly collection were carefully removed, pooled and suspended in 10 ml of water. The contents of "stomach" and "intestine" (the narrow posterior part of the gut) were analyzed separately. Samples were further diluted if necessary. Five 1 ml samples of the suspension were studied in a Sedgewick Rafter Cell under a stereo-microscope. The relative abundance of each food item was estimated by counting the number of each item present in 50 squares along the diagonals of the counting grid.

The degree to which a particular food item was selected or avoided from the food source by each species was estimated using the food selection index of Ivlev (1961) as modified by Jacobs (1974). This index (D) can be given as D=(r-p)+(r+p-2rp), where r and p are respectively the relative abundance of the food item in the diet and in the habitat. Ivlev's index was determined for diatoms, detritus, green algae and blue-green algae. The abundance of animal matter and macrophyte remains in the stomach contents were too low (Fig. 2) for a meaningful Ivlev index to be obtained.

RESULTS

Temperature, pH, conductivity and dissolved oxygen concentration of the water in the stream varied from 19.0-26.5 °C, 6.2-7.1, 26-58 μS^{23} and 7.8-9.8 mg l^{-1}, respectively. Water flow and mean depth varied from 4.0-14.4 cm sec^{1} and 45-140 cm. Monthly rainfall varied from 30-1189 mm. The flow is usually moderate (5-15 cm sec^{-1}) except during heavy rains.

Both species are substratum feeders. Juveniles as well as adults of both species were observed feeding together on the bottom aufwuchs layer, but *B. cumingi* was observed more often in shallower waters. No aggressive behaviour was observed during feeding. Both species were found to feed up to a depth of about 1.5 m, with smaller individuals usually feeding in shallower waters.

There is no distinct demarcation between the stomach and the intestine in either species. The enlarged anterior part of the gut gradually tapers into the intestine. The posterior part of the gut is narrow and coiled. The maximum lengths of gut observed for *B. cumingi* and *B. nigrofasciatus* were, respectively, 135 mm in a female of 64 mm total length and 133 mm in a male of 61 mm total length. Approximate ratio between the stomach and intestine is 1:10 in both species.

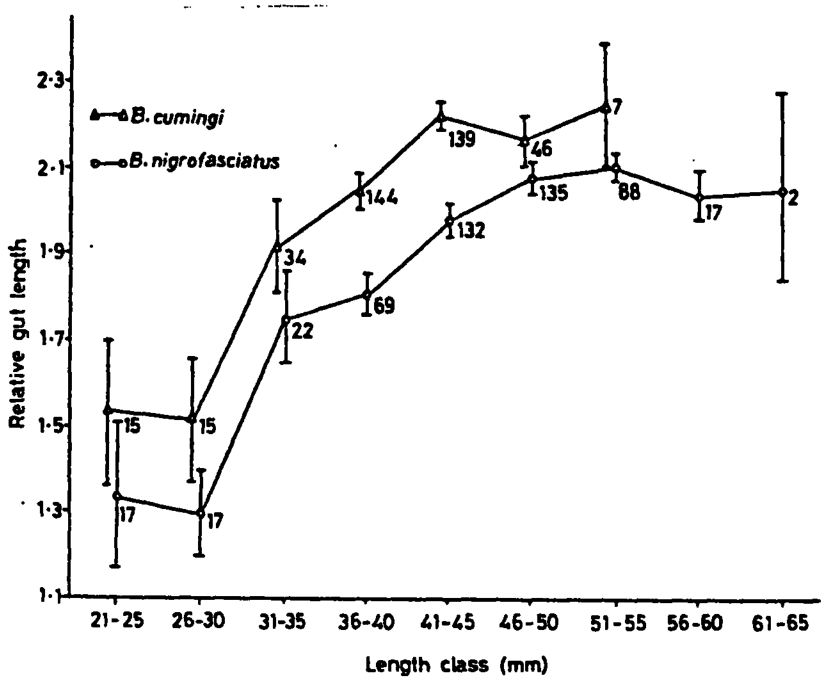

Fig. 1. The relationship between the relative gut length (mean±95% CL of each 5 mm size classes) and total length of *B. cumingi* and *B. nigrofasciatus*.

The relationship between the relative gut length (RGL) (i.e. the ratio between the gut length and the total length) and the total length ranged from 0.96 to 2.64 in *B. cumingi* and 0.89 to 2.54 in *B. nigrofasciatus*. The RGL increases with increase in length in the total length range of 25-50 mm in both species and then remains almost constant (Fig. 1).

Both species are herbivorous. Diatoms were the most important food item in *B. nigrofasciatus* while detritus was second in importance. In *B. cumingi*, detritus and diatoms were of almost equal importance (Fig. 2). There was an appreciable amount of sand which must have been inadvertently ingested while feeding on the substratum. Green algae (including desmids) and blue-green algae play only a minor role in both species. Green and blue-green algae, animal matter such as eggs of other aquatic organisms, and higher plant matter amounted to less than 7% in *B. cumingi* and to less than 5% in *B. nigrofasciatus*. Higher plant matter, which was the least important food item, consisted of a few fragments of aquatic weeds.

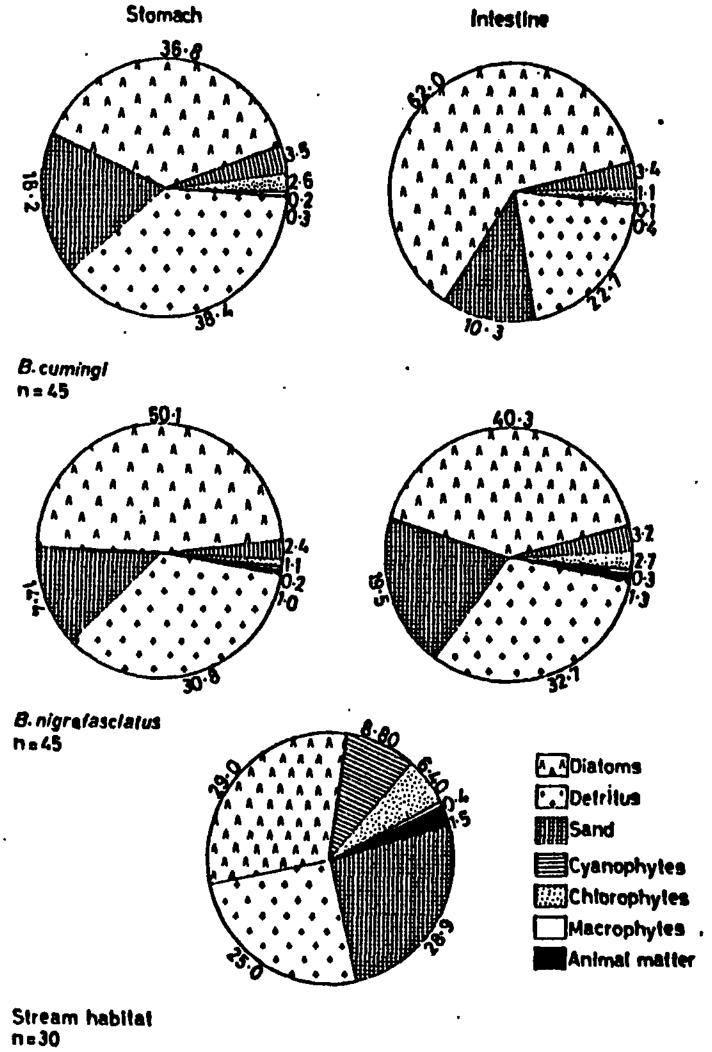

Fig. 2. Relative abundance of food items in the stream and in the "stomach" and "intestinal" contents of *B. cumingi* and *B. nigrofasciatus*.

56 genera of lower plants (including blue-green algae and diatoms) were found in the diet of *B. cumingi* while 54 genera were found in that of *B. nigrofasciatus*. Among diatom species found in the diet, *Navicula* sp. (73%) and *Pinnularia* sp. (21%) were predominant in *B. cumingi* while *Navicula* sp. (38%), *Gomphonema* sp. (33%) and *Pinnularia* sp. (23%) were predominant in *B. nigrofasciatus* (Table 1).

Table 1. Relative abundance of individual genera in the diatom component of the diet of different size classes of *B. cumingi* and *B. nigrofasciatus*.

	B. cumingi Size Group			*B. nigrofasciatus* Size Group		
Diatom genus	<31	31-45	>45	<31	31-45	>45
Achnanthes		0.01				
Amphora	2.17	0.58	1.22	2.59	2.52	0.02
Asterionella	0.08	0.05	0.01	0.44	0.02	0.01
Cocconeis	0.16				0.01	
Cymbella	1.99	3.91	1.34	0.55	0.85	0.31
Epithemia		0.01	0.01		0.01	
Fragilaria	0.77	0.01	0.22	4.96	0.13	0.13
Gomphonema	0.08	1.95	0.51	32.90	22.57	44.26
Gyrosigma	0.16	0.01	0.03	0.81	0.03	0.01
Melosira	0.05		0.01		0.01	
Navicula	73.24	65.89	75.80	33.58	47.84	33.13
Nitzschia	0.02	0.02	0.12		0.09	0.04
Pinnularia	20.53	22.92	19.67	22.32	24.86	21.53
Surirella		0.01	0.01		0.01	0.01
Synedra	0.19	0.35	0.34	0.52	0.44	0.13
Tabellaria	0.56	0.28	0.71	1.33	0.61	0.42

The relative abundance of diatoms and detritus, which formed about 75% in *B. cumingi* and 81% in *B. nigrofasciatus*, changed somewhat during different months, although the abundance of the two items together remained almost constant throughout the year (Fig. 3). There appears to be some increase of the relative abundance of detritus and sand during and immediately after the rainy period of September-October but the relative abundance of both items decreased during the rainy months of June and August. During the latter period the water speed remained high (Fig. 3).

In general, the importance of diatoms increased and that of detritus as well as blue-green and green algae decreased with increase in body size of fish (Fig. 4).

In *B. cumingi* "intestinal" contents in comparison to "stomach" contents had a higher percentage of digested diatoms and a lower percentage of detritus. On the other hand, in *B. nigrofasciatus*, the percentage of diatoms was lower and that of detritus was slightly higher in the "intestine" in comparison to those in the "stomach" (Fig. 2).

Monthly variation of the fullness of "stomach" of the two species is shown in Fig. 5. In general, the fullness of "stomach" of *B. nigrofasciatus* was higher during the rainy months of September and

October than during the drier months. During the period of May-August (including the rainy months of June and August) the water flow was high and the relative abundance of detritus was low in the diet of both species. Among the size classes examined, there were no distinct differences in the pattern of monthly changes of the fullness of the gut in either species.

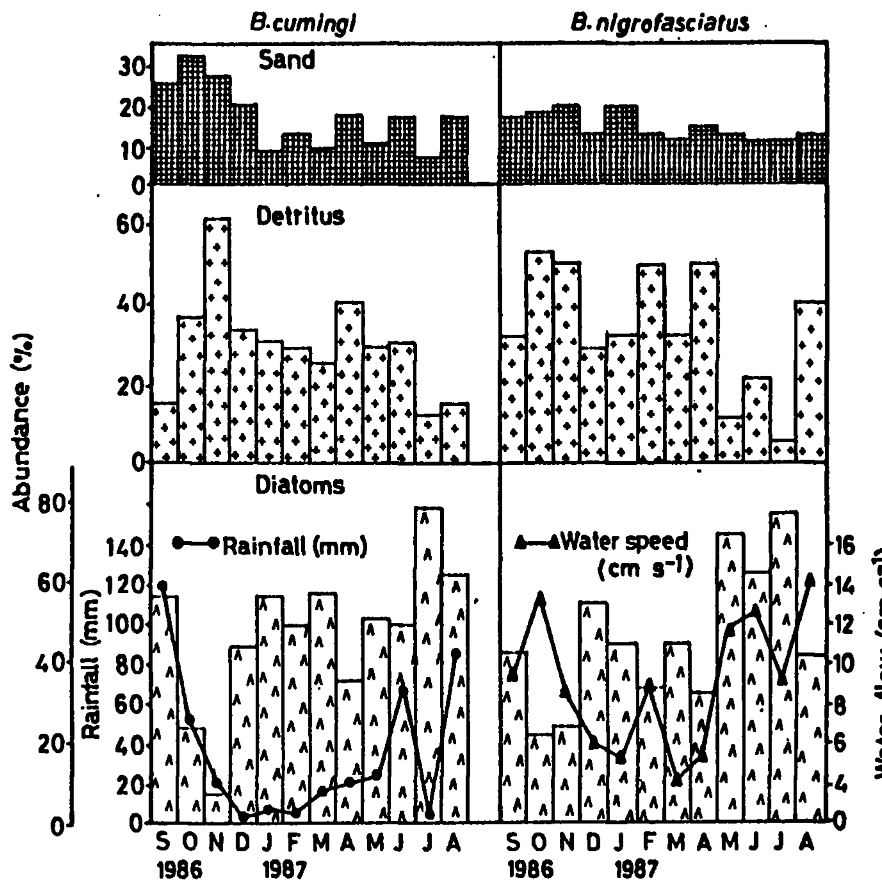

Fig. 3. Monthly changes in the relative abundance of diatoms, detritus and sand in the stomach contents of *B. cumingi* and *B. nigrofasciatus*.

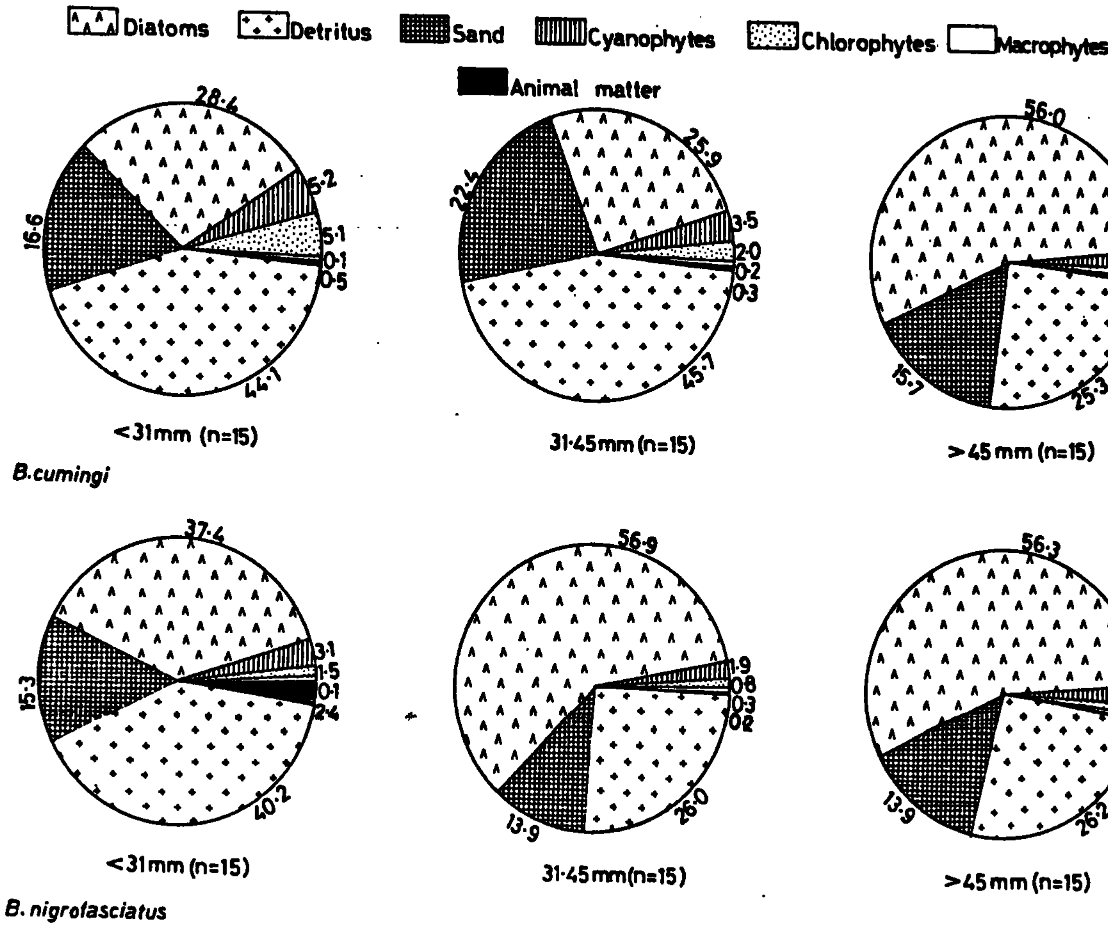

Fig. 4. Relative abundance of food items in different size classes of *B. cumingi* and *B. nigrofasciatus*.

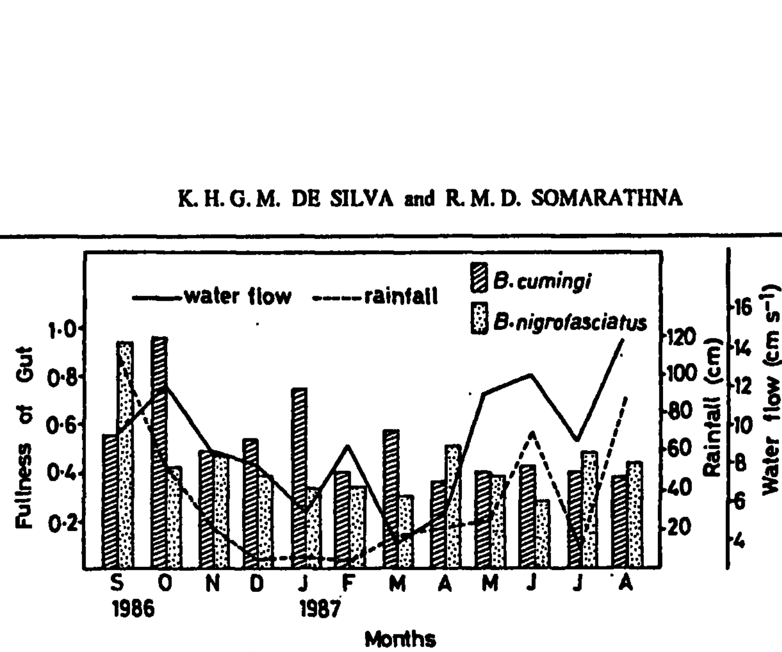

Fig. 5. Monthly changes in the fullness of "stomach" of *B. cumingi* and *B. nigrofasciatus*.

DISCUSSION

Cyprinids are generally herbivorous or omnivorous in their food habits. The relative importance of different food items differs in different species, even among those species that live together in the same habitat. This would obviously reduce the intensity of competition for the same food item and would play an important part in niche segregation. For instance, De Silva *et al.* (1980) showed that, among the co-habiting *Barbus amphibius*, *B. dorsalis*, *Danio aequipinnatus* and *Rasbora daniconius*, the latter three species are omnivorous. *B. amphibius* was found to feed almost exclusively on plant material (but see Kumar *et al.*, 1986). Crustaceans were as important as insects in the diet of *D. aequipinnatus* but played only a minor role in the diet of *R. daniconius; B. dorsalis* was found to feed on plants, crustaceans and insects, but insects were not as important as crustaceans. Higher plant material was of lesser importance for *D. aequipinnatus* and *R. daniconius* than for *B. amphibius* and *B. dorsalis*. Desmids were of lesser importance to *D. aequipinnatus* and *R. daniconius* but were of major importance to *B. amphibius* and *B. dorsalis*. De Silva, Kortmulder & Wijeyaratne (1977) found that the co-occurring *B. bimaculatus* and *B. titteya* are both algal-detritus feeders but that the former species feeds mainly on green algae whereas the latter species feeds mainly on detritus. Diatoms and blue-green algae are not of much importance to either species. Kumar *et al.*, (1986) showed that the co-occurring *B. amphibius* and *B. filamentosus* are omnivorous in southern India, but the former species feeds mainly on detritus whereas the latter species feeds mainly on filamentous algae and higher plants.

Although both *B. cumingi* and *B. nigrofasciatus* were found to feed mainly on diatoms in the present study, De Silva & Kortmulder (1977) found that *B. cumingi* in the headwaters of the river Gin in the southern part of Sri Lanka feeds mainly on green algae including desmids, whereas *B. nigrofasciatus* in the same streams feeds mainly on diatoms. Such differences may be due to different relative abundance of these food items in the different habitats investigated. In the present study, diatoms were found to be abundant in the habitat but green algae including desmids were not very common (Fig. 2); the relative abundance of diatoms and green algae in the habitat studied by De Silva & Kortmulder (1977) is not known. The two species in the river Gin are reported as occupying non-overlapping habitats, *B. cumingi* below the flood water level and *B. nigrofasciatus* above the flood water level (Schut *et al.*, 1984), but both species were found below the flood level in the stream studied in the present work.

The monthly variation of the relative abundance of different food items in the diet of the two species may be due to changes in the stream water caused by the rainfall. During the rainy season, the increased turbidity of water could decrease the light penetration thus affecting the growth of aufwuchs. The sudden increase of water flow may also wash away a part of the bottom aufwuchs layer on which the two species feed. The increased detritus content in the diet observed during and immediately after the rainy period of September and October could be due to higher amounts of allochthonous material brought into the habitat during this period. However, during the period of June to August, the increased water flow may have carried away such material thus causing detritus to be relatively scarce. Kumar *et al.* (1986) observed that, in *B. amphibius* and *B. filamentosus* in southern India, the detritus component in the diet increases markedly during the peak of the rains.

In general, cyprinid species appear to feed during daylight hours. *Amblypharyngodon melettinus, B. chola, B. dorsalis, B. filamentaosus, B. sarana* and *R. daniconius* have been reported as daytime feeders (Wijegoonawardana, 1990). Kumar & John (1985) showed that *R. daniconius* is a visual feeder and needs sufficient daylight for feeding. *B. cumingi* and *B. nigrofasciatus* in the river Gin also feed during daylight hours (Kortmulder *et al.*, 1978) as has been observed in the present study. However, in contrast to the observations of Wijegoonawardana, 1990) in the southern part of Sri Lanka, Schiemer & Hofer (1983) report that, in Parakrama Samudra reservoir in the eastern part of the country, the fullness of stomach of *B. chola* remained more or less constant throughout the 24-hour cycle and that the stomach contents of *B. dorsalis* increased from sunset to midnight and remained high until sunrise.

Both *B. cumingi* and *B. nigrofasciatus* were found to depend more on diatoms and less on detritus as they grew (Fig. 4). Change of food habits with increase in size has been reported for many cyprinid species. Thus, with increase in size, *B. dorsalis* and *B. amphibius*, change their diet from one of predominantly crustaceans to one of predominantly higher plants (De Silva *et al.*, 1980); *Acrossocheilus hexagonolepis* and *Tor khudree* change their dietary emphasis from animal matter to plant matter (Dasgupta, 1988; P. K. de Silva, personal communication), *B. filamentosus* depends more on filamentous algae, macrophytes and detritus and less on protozoans, diatoms and desmids (Kumar *et al.*, 1986). Such a change of food habit with growth will reduce the interspecific competition for food. At least in some species, such changes may result simply from larger fish being able to consume more of the larger food items such as filamentous algae, macrophytes and detritus (Kumar *et al.*, 1986).

The Ivlev's index (Table 2) emphasizes the differences observed in the dietary and food source compositions (Figs. 2 and 4). All size classes of both species were found to show some avoidance of green algae and blue-green algae (Table 2). *B. cumingi* showed a higher selection of detritus whereas *B. nigrofasciatus* showed a higher selection of diatoms.

Table 2. Modified Ivlev index with respect to different food items in the diet of *B. cumingi* and *B. nigrofasciatus*.

Food item	*B. cumingi*				*B. nigrofasciatus*			
	Size Class							
	all classes	<31	31-35	>45	all classes	<31	31-45	>45
Diatoms	0.09	-0.14	-0.16	0.49	0.28	0.07	0.50	0.47
Cyanophyta	-0.52	-0.36	-0.50	-0.75	-0.66	-0.58	-0.73	-0.70
Chlorophyta	-0.49	-0.20	-0.58	-0.80	-0.77	-0.69	-0.83	-0.79
Detritus	0.24	0.35	0.45	-0.12	0.09	0.25	-0.14	-0.11

In both species, the avoidance of blue-green algae appears to increase with the increase in body size (Table 2). In general, larger size classes of both species showed a better selection of diatoms and a poor selection of detritus.

In teleosts, it has been shown that the length of gut is very much related to the food habit (Kapoor, Smith & Verighina, 1975). The relative gut lengths (RGL) and the food habits of various cyprinid species are given in Table 3. In general, the omnivores that depend predominantly on an animal diet have a RGL of 0.6-1.0 while those that depend more on vegetable matter have a RGL of 1.0-3.5; herbivores have a RGL of >4.0. The carnivorous *Channa gachua* (Family Channidae) has a RGL of <0.5. The observed RGLs of 1.27-2.42 of *B. cumingi* and 1.15-2.12 of *B. nigrofasciatus* in the present study indicate an omnivorous habit.

Table 3. Food habits and relative gut length (RGL) of some cyprinids. Major food items of each species are indicated within parenthesis. Data for the carnivorous *Channa gachua* (Family Channidae) are given for comparison. (C-carnivorous; H-herbivorous; O-omnivorous).

Species	TL (mm)	Food habit	RGL	Source
Channa gachua	45-130	C (insects and larvae)	0.34-0.51	1
Barbus titteya	15-40	O (detritus, animal matter)	0.60-0.70	2
Danio aequipinnatus	25-80	O (dipteran larvae)	0.65-0.70	3
Rasbora daniconius	40-80	O (dipteran Larvae)	0.75-0.85	4
	30-115		0.65-0.80	3
B. dorsalis	60-90	O (crustaceans, insects,	1.10-1.60	4
	60-170	detritus)	1.30-1.40	3
B. nigrofasciatus	20-65	O (detritus, diatoms)	1.15-2.12	5
B. cumingi	20-55	O (detritus, diatoms)	1.27-2.42	5
B. filamentosus	40-120	O (filamentous algae, macrophytes)	1.30-1.90	4
B. chola	40-110	O (insect larvae)	1.30-2.10	4
B. amphibius	70-100	O (zooplankton, detritus)	1.50-1.70	3
B. bimaculatus	15-50	O (green algae, detritus)	1.50-1.70	2
B. sarana	70-210	O (insect larvae, gastropods, fallen leaves)	1.50-2.00	4
Tor khudree	50-580	O (detritus, fallen leaves; insect larvae)	1.78-2.55	6
Acrossocheilus hexagonolepis	40-450	O (algae, macrophytes, animal matter)	1.87-3.14	7
Amblypharyngodon melettinus	30-70	H (phytoplankton)	4.00-5.50	5
Garra ceylonensis	58-200	H (diatoms, green algae)	3.77-6.79	6
Labeo dussumieri	85-270	H (phytoplankton)	15.20-18.60	1

Source: 1-K. H. G. M. DE SILVA (unpublished data); 2-DE SILVA *et al.*, 1977; 3-DE SILVA *et al.*, 1980; 4-WIJEGOONAWARDANA, 1990; 5-Present study; 6-P. K. DE SILVA (unpublished data); 7-DASGUPTA, 1988.

The RGL has been shown to be related to the body length in several cyprinid species. An increase in RGL with body length was observed in *Acrossocheilus hexagonolepis* (Dasgupta, 1988), *B. bimaculatus* (De Silva *et al.*, 1977), *B. amphibius* and *B. dorsalis* (De Silva *et al.*, 1980), *Amblypharyngodon melettinus*, *B. chaola*, *B. dorsalis* and *B. filamentosus* (Wijegoonawardana, 1990), *Garra ceylonensis* and *Tor khudree* (P. K. de Silva, personal communication). The RGL appears to decrease with increase in body length in *R. daniconius* (Wijegoonawardana, 1990), and it does not seem to change much with increase in body length in *B. sarana* (Wijegoonawardana, 1990), *B. titteya* (De Silva et al., 1977) and *D. aequipinnatus* (De Silva et al., 1980). The change of RGL in *B. amphibius*, *B. filamentosus*, *Acrossocheilus hexagonolepis* and *Tor khudree* has been shown to accompany a change of food habit with more emphasis on plant matter in higher size groups (De Silva *et al.*, 1980; Dasgupta, 1988; P. K. de Silva, personal communication). The increase in the RGL in *B. cumingi* and *B. nigrofasciatus* is consistent with the observation that both species, with increase in size, feed more on diatoms and less on detritus.

Other fish species, which were commonly present together with *B. cumingi* and *B. nigrofasciatus* in the habitat studied were *B. dorsalis*, *Danio aequipinnatus*, *Garra ceylonensis*, *Rasbora daniconius* and the juveniles of *Tor khudree*. *D. aequipinatus* and *R. daniconius* are omnivorous and mostly stayed in the column. *G. ceylonensis* fed mainly on diatoms and was sometimes found feeding together with *B. cumingi* and *B. nigrofasciatus*, but, *G. ceylonensis* usually fed attached to stones in deeper waters and faster flow areas of the stream. Thus, its microhabitat appears to be rather separated from that of the other two species. Diatoms do not form a major component in the diet of juvenile *T. khudree*. *B. dorsalis* feeds on benthos and macrophytes (Schiemer & Hofer, 1983).

The similarity of the food habits of the presently studied two species living in the same habitat could be an apparent contradiction to the hypothesis of competitive exclusion of Gause (1934). Similar observations on two fish species or more utilizing the same food source in the same habitat have been made by several authors (Hartley, 1948; Fryer, 1959; De Silva, 1973; De Silva *et al.*, 1980). It may be that, as has been observed in the present study, even if two species feed on the same food items their relative dependence on different food items is different so that the competition for the same food item is reduced. It may also be that the respective population sizes of different species involved in the assemblage are kept in control by factors other than the limitations of food source as, for instance, the sudden increase of the water speed and flooding may cause marked reduction of the population size. In such an instance, food source may not become critically limited for the competitive exclusion principle to operate.

ACKNOWLEDGEMENTS

We are very grateful to Prof. H. H. Costa of Dept. of Zoology, University of Kelaniya, for his critical reading of the manuscript and his very helpful suggestions. We also wish to thank Mr T. S. B. Alagoda of Department of Zoology, University of Peradeniya for preparing the figures.

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