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Feeding Ecology and Prey Selection in Larval Sahar (*Tor tor* Ham.) of Trisuli River, Nepal

R.B. KHADKA

Central Department of Zoology
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Abstract

The food and feeding habits of sahar (*Tor tor* Ham.) larvae inhabiting the hill streams of Nepal were investigated. Except for copepods, larval sahar tended to prey on larger zooplankters with increasing zooplankton abundance. Comparison of dietary and prey size frequencies revealed expanding diet breadth with age. Regression analysis for mean intensity of size selection versus mean densities of various prey indicated that the prey species were not differentiated by larval sahar.

Introduction

Reduction in abundance of large zooplankters due to predation by fish in nature was described by Ivlev (1961), Harbacek (1962), Brooks and Dodson (1965) and subsequently verified by Galbraith (1967), Wells (1970), Hutchinson (1971) and Houde and Schakter (1978). These studies were then followed by the proposition of several field and laboratory-based models that predict prey size selection by fish (Ware 1972; Werner 1974; Werner and Hall 1974; Confer and Blades 1975; O'Brien et al. 1976; Bartell 1982; Khadka and Rao 1986). But the information on the food and feeding behavior of early stage sahar (*Tor tor* Ham.) larvae in natural conditions, where mouth size as an overriding constraint for the choice of optimal diet is inadequate. Sahar are abundant in the mountain rivers of Nepal. At maturity individuals may weigh as much as 15 kg. Sahar have not been successfully bred artificially.

The lack of understanding about the feeding behavior of the larvae of sahar in nature is a bottleneck for the development of aquaculture of indigenous riverine species in Nepal. The experiences gained so far on the culture of sahar larvae in captivity showed high larval mortality and reduced growth. The present study is aimed at assessing (1) the types, sizes and the densities of food items available in nature; (2) the types and sizes of food items eaten by sahar larvae at different stages; (3) the relationship of size selection intensity to prey abundances at different stages; and (4) the patterns of the change in the diet of growing sahar larvae as evidenced by total ranges of sizes of prey available to total range of size of prey eaten.

Methods

Study Sites

Two natural breeding sites at Trisuli River were chosen, one at 757 m and another at 500 m mean sea level along the span of river. Local fishermen with considerable experience were employed for the location of spawning sites. The spawning sites selected for the study were shallow river pools with sparse growth of aquatic weeds. Four pairs of brooders in 1987 and three in 1988 were captured and stocked for spawning in a trout hatchery. In both cases spawning took place at the beginning of July. In the natural habitat, eggs were collected in the middle of July 1987 and at the beginning of August 1988. Batches of young larvae with intact yolk reserves were collected on 14 July 1987 and 24 July 1988. Some of these larvae collected from the field were stocked in tanks with running water. Fertilized eggs collected from the field were kept separately.

Field Observations on Prey Selection

Water samples were taken at 0.5 m depth at intervals of 10 days. During the sampling, 30 l of water from different locations and depth were collected and filtered through a plankton sieve (80 µm) concentrated to 500 ml, and immediately preserved in 4% formalin. Chironomid larvae were collected from the bottom using a Peterson Grab sampler (Yadava and Shrestha 1982). As soon as the eggs were hatched, 50 sahar larvae were collected simultaneously with the water samples until the end of September in 1987 and 1988. The size and weight of the larvae collected from the field were determined at each time of sampling and compared with that of known age sahar reared in tanks. Three samples were taken in August and thereafter referred to as August-I, August-II and August-III, respectively. Similarly, three samples were taken in September and designated in the same manner.

The guts of 30 preserved larvae of different stages were isolated and their contents analyzed under a microscope. Initially, the gut contents were sorted into major taxa. At times, partial digestion of food organisms made it difficult to identify the species or genera. Whenever possible confirmation was sought from corresponding species or genera in the plankton collected on the same day; the numbers of different prey items were counted and the body sizes of organisms measured. Partially digested individuals were excluded.

The preserved plankton samples were analyzed by taking 15-20 aliquots to sort out the major zooplankton groups to at least the genus level; their numbers and sizes were recorded using methods described elsewhere (Edmondson 1965). By comparing the prey size frequency in nature with that in larval stomach the indices of prey selectivity were estimated.

A sensitive index, as compared to that of Ivlev (1961) in which prey size selection or avoidances are indicated, called Intensity of Sizes Selection(s) was used in this study to evaluate the degree of size selection (Bartell 1982).

This index is defined as:

$$S = \frac{(L_i - L_w)}{L_R}$$

where:
- S = Intensity of size selection
- L_w = Mean length of prey in water
- L_i = Mean length of ingested prey
- L_R = Size range of prey over stomach and water samples.

The value of S can range from -1 (exclusive selection of the smaller prey) to +1 (exclusive selection of larger prey) with near 0 ($L_i = L_w$) indicating absence of selection.

The values of intensity of size selection (S) for each prey type of 1987 and 1988 samples were pooled, the average data of (S) plotted against mean prey of density and a linear regression analysis performed.

Results

The most common species of zooplankton available during the sampling period were rotifers, such as *Haxarthra, Keratella, Brachionus* and *Polyarthra* species, and among the crustaceans, *Ceriodaphnia, Daphnia, Cypris, Mesocyclops, Heliodaptomus* and *Microthrix* species were mostly dominant. Ephemerid larvae were common and among the coleopteran members of the families Hydroscaphidae, Hydraeridae, Gyrinidae, Hydrophilidae and Dytiscidae were present both in adult and larval forms. Apart from these, the nymphs of *Odonata,* chironomid larvae and other unidentified genera were also present.

The relative abundance of prey in environmental samples and in the guts from July to September 1987 and 1988 were summed for each prey species and the mean values used for calculating relative abundance (Table 1) which showed that the initial plankton samples and stomach contents of larvae were dominated by the rotifers, *Microthrix* and *Ceriodaphnia*. Rotifers, *Ceriodaphnia, Daphnia* and *Mesocyclops* species dominated the August-I zooplankton samples, whereas rotifers (46%) and *Ceriodaphnia* (31%) continued to dominate the larval diet. *Microthrix* (17%), *Ceriodaphnia* (17%) and *Daphnia* species (15%) were available in larval stomachs but rotifers, though abundant in plankton samples were not ingested. Chironomid larvae *Mesocyclops* and *Heliodiaptomus* species were mostly available in early- and midSeptember zooplankton samples but chironomid, coleopteran and ephemerid larvae were found to form the bulk of larval diet. Samples in September-III were dominated by *Heliodiaptomus, Mesocyclops,* ephemerid and chironomid larvae in plankton and stomach samples.

A comparison of prey size frequencies in the plankton and in the diet of sahar larvae sampled at different times indicated that as they grew older larger prey items were ingested progressively (Fig. 1). There was considerable overlap in the ranges of the size of prey species in the plankton with those ingested by sahar larvae (Fig. 3).

The mean size selection intensity value for each sample for each prey type for 1987 and 1988 was obtained. Rotifers were the dominant food item in July samples in newly hatched fish larvae, though larger zooplankton such as *Ceriodaphnia* and *Daphnia* species were also abundant, suggesting a strong selection for smaller prey times. When the larvae were approximately 20 days old, the diet included a variety of prey species of different sizes (rotifers,

Table 1. Relative abundance (%) of prey species in the plankton and larval sahar gut samples (the numbers of prey available in ambient and gut samples for various times for the years 1987 and 1988 were summed and the mean values were used for the calculation of abundances).

Samples	Rotifers	*Ceriodaphnia*	*Daphnia*	*Cypris*	*Coleoptera*	Ephemerid larvae	Chironomid larvae	*Microthrix* sp.	*Heliodiaptomus*	*Mesocyclops*
July:										
Plankton	22	22	13	13	9	9	4	22	0.5	0.5
Gut	51	6	43	-	-	-	-	-	-	-
August-I										
Plankton	11	11	11	9	7	7	7	9	9	11
Gut	46	31	8	6	-	-	4	-	-	0.2
August-II										
Plankton	14	12	10	4	7	4	10	13	10	12
Gut	-	17	15	-	9	-	13	17	9	0.5
August-III										
Plankton	5	7	6	6	12	12	12	9	12	14
Gut	-	33	7	3	14	14	20	3	13	0.5
September-I										
Plankton	3	7	6	6	12	12	13	10	10	12
Gut	-	3	7	3	14	14	17	7	14	0.5
September-II										
Plankton	3	8	5	6	12	12	14	8	14	14
Gut	-	3	3	16	22	16	19	7	19	0.6
September-III										
Plankton	5	5	-	5	7	7	26	-	26	9
Gut	-	16	-	-	5	11	21	-	16	0.6

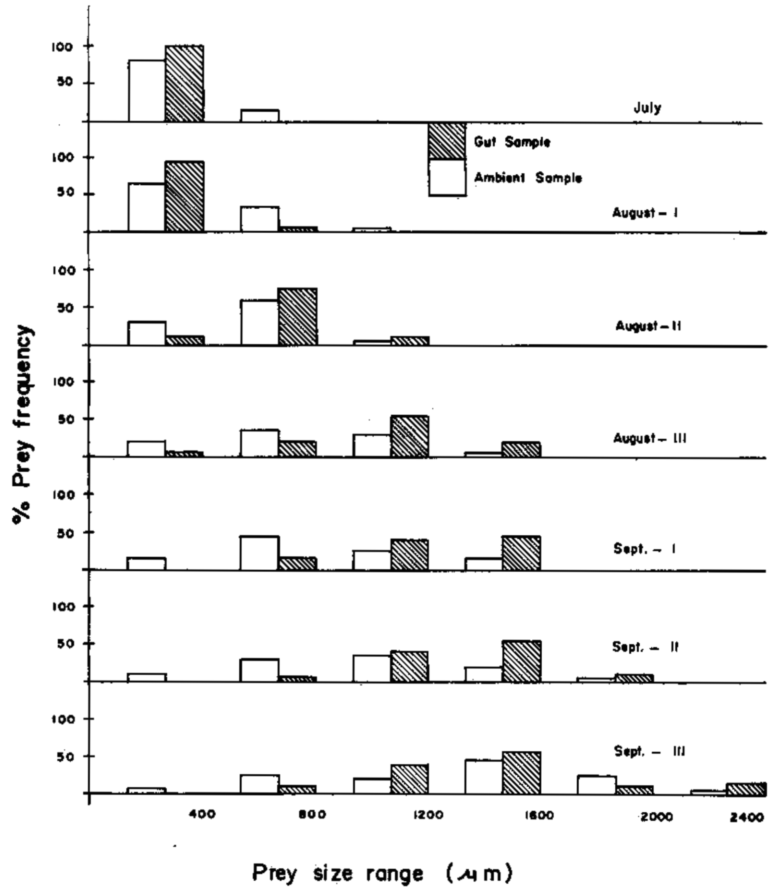

Fig. 1. The relative prey size frequencies of zooplankton sampled at spawning areas in the river and the diet of sahar larvae at different ages. The sample size at each age was 10.

Ceriodaphnia, Daphnia, Cypris, chironomid larvae and a few copepods) and resulted in moderate positive value of the size selection intensity, indicating the selection for larger prey items. August-II samples showed strong positive S values for larger sizes of *Ceriodaphnia, Daphnia* and *Microthrix.*

August-III samples showed a different pattern where coleopterean larvae, which contributed sparsely to the diet earlier, yielded a strong positive value of S, followed by chironomid larvae. This trend of increasing S for larger prey continued up to September-II but the September-III samples showed an increased value only for chironomid larvae.

The calculated values of S tended to increase with increasing prey density. Spearman correlation analysis between S and density of prey species derived from samples of July and August-I were not significant (P > 0.05). The later samples of August and September showed a strong positive correlation between prey density and S (P < 0.05; r = 0.99; n = 20). The regression analysis between S and density of rotifers (r = 0.99, n = 5), *Ceriodaphnia* (r = 0.86, n = 10), *Cypris* (r = 0.79, n = 7), chironomid larvae (r = 0.91, n = 9), and *Microthrix* (r = 0.85, n = 10) were all significant at P < 0.05 but the correlation coefficients for *Heliodiaptomus* and *Mesocyclops* were not significant (Table 2 and Fig. 2). The mean length of ingested prey tended to increase with incrteasing densities of prey species in environmental samples, and the range of prey sizes eaten generally tended to be narrow (Fig. 3).

Table 2. Regression equation and correlation coefficient (r) describing the relation between prey densities (no./l) and size selection intensity (S).[a]

Prey species	Regression and correlation coefficients			Degrees of freedom	Level of significance
	a	b	r	n	P
Rotifers	-0.046	0.27	0.99	5	0.05
Ceriodaphnia	-0.35	1.0	0.80	7	0.05
Daphnia	-0.468	1.20	0.83	13	0.05
Cypris	-0.006	0.40	0.94	10	0.05
Ephemerid larvae	-0.21	0.57	0.84	10	0.05
Chironomid larvae	-0.03	0.488	0.91	7	0.05
Celeopteran larvae	-0.45	0.94	0.72	12	0.05
Heliodiaptomus	-0.28	0.31	0.48	9	N.S.
Mesocyclops	0.042	0.114	0.097	7	N.S.
Microthrix	-1.30	1.80	0.85	10	0.05

[a]Average density data for each prey and corresponding average data for size selective intensity (S) were pooled together for July to September 1987 and July to August 1988 for regression and correlation analysis.

Discussion

Prey size selection by planktivorous fish is one of the most extensively studied aspects of feeding ecology but little attention has been paid to feeding behavior of larval fish in nature. The works of Rosenthal and Hempel (1970) on herring larvae, Braum (1967) on coregonid larvae, Hunter (1972), and of Hunter and Thomas (1974) on anchovy larvae have furnished much insight into the feeding behavior of the early stages of larval fishes.

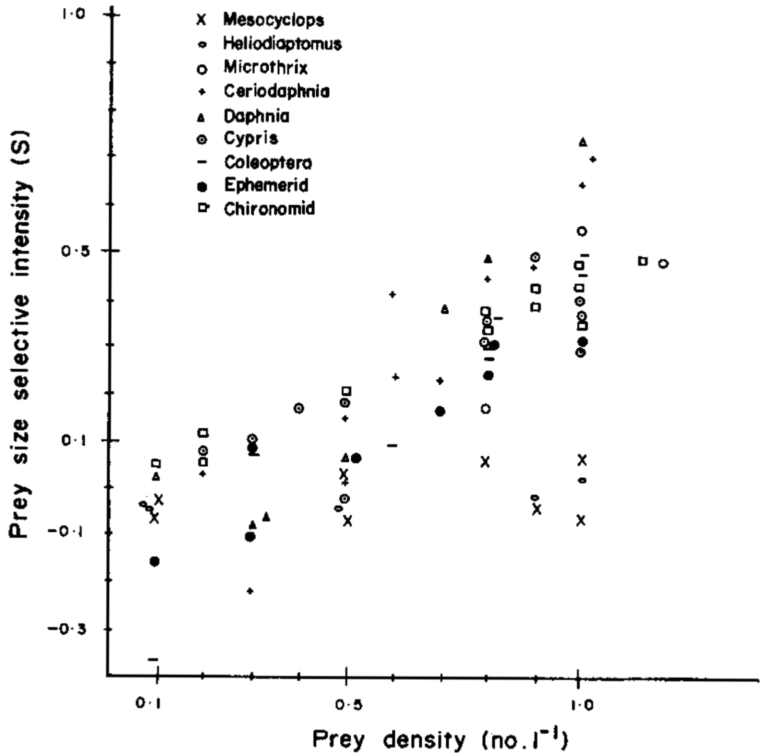

Fig. 2. Relationship between prey density and size selection intensity (S) for various prey.

Eggers (1977) developed a mechanistic model to predict the expected distribution of prey length in fish diets given a frequency distribution of prey lengths available in the water column. The assumption made in this approach is that the estimated distribution of prey lengths in the water column accurately reflects the distribution of prey encountered by feeding fish. But the distribution of available prey under the field condition is difficult to determine because the loss to predation and recruitment of new individuals to the size spectrum occurs continually but at variable rates (Bartell 1982).

Unlike rapids, the pool sections of rivers generally tend to have a higher prey density. In the study area, the availability of rotifers in June and July was found to synchronize with the hatching of sahar eggs and 9-day-old larvae were found to commence feeding on rotifers although yolk reserves were retained up to 11 to 13 days. In addition to rotifers, the early sahar larvae were also found to feed on smaller

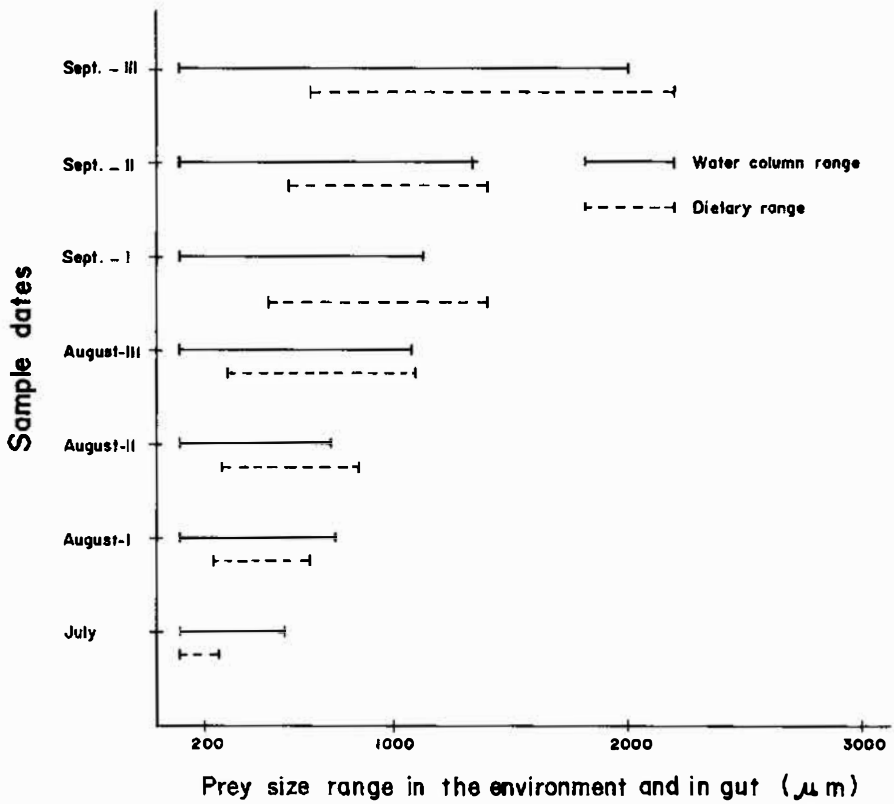

Fig. 3. The total size range of prey available in spawning sites at Trisuli River (solid line) and found in the diet of sahar larvae at different ages (broken line).

sizes of *Daphnia, Ceriodaphnia* and copepod nauplii, until the larvae were about 20 days old. *Ceriodaphnia* ranging from 400 to 800 mm formed the dominant component of the diet in the later stages but *Daphnia* (800-1,200 μm) were also ingested. The predominant food at the age of approximately 1.5 to 2.5 months included the larval chironomids, coleopterans and larger copepods. The mean dietary length distribution of prey species was greater than the mean water column length distribution. It is likely that the shift upward in the size of prey length distribution was due to the greater visibility of larger individuals of prey which resulted in them being encountered by feeding larvae more frequently than reflected in the water column density (Figs. 1 and 3). A similar trend was reported by Carlson (1974) of juvenile sockeye salmon feeding on *Bosmina* in Lake Iliamna.

The clearest trend was the increase in the diet breadth of the fish larvae with increasing age (Fig. 3) but there was also a concomitant increase in the mean prey size of the diet (Fig. 1). The latter trend was true not only for the combined prey size range but with most of the species in the diet. An increase in mean prey size taken with age is related to the increasing mouth size and prey capture ability of sahar larvae.

Comparison of gut contents of larvae of different stages and the prey size ranges in environmental samples indicated an active selection for larger prey (Table 2) - a trend observed nearly universally for all planktivorous fish (Brooks and Dodson 1965; Bartell 1982). The most plausible explanation is that the mouth size at an early age is small and acts as a constraint.

The results presented here do not clarify the total trend of optimal foraging theory in the early stages of sahar larvae in nature. However, it has been shown that there is a significant correlation between prey density and size selection intensity (S) despite the greater variability introduced by complex field conditions. The results of analysis presented here are consistent with models of Confer and Blades (1975), Eggers (1977), O'Brien et al. (1976), Pyke et al. (1977) and Werner and Hall (1974).

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