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FEEDING INTERRELATIONSHIPS BETWEEN THE SAND SHINER AND THE STRIPED SHINER[1]

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Abstract. Feeding habits of *Notropis stramineus* and *N. chrysocephalus* were investigated in Buffalo Creek, Washington County, PA during September through December, 1977. As an opportunistic feeder, *N. stramineus* consumed large quantities of terrestrial (appx. 40%) and aquatic (appx. 50%) insects during September and October, but shifted almost entirely to insects in the benthic environment (appx. 90%), such as mayfly nymphs (*Caenis* and *Stenonema*) and stonefly nymphs (*Alloperla* and *Isoperla*), in November and December. *N. stramineus* utilized a wide range of prey with the bulk of its diet in the size class 5–8 mm. *N. chrysocephalus* consumed larger aquatic prey (9–12 mm) including crayfish (*Orconectes*), large mayfly nymphs (*Stenonema*), and damselfly naiads (*Argia*) from September through November; however, in December its diet shifted to *Cladophora* and aquatic Chironomidae larvae. Although diet overlap was nearly complete initially (September and October), it diminished as the season progressed. Food habits were unique to each species late in the year, suggesting that as food resources decline the food habits of these two species appear to diverge, minimizing interspecific competition.

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Food habits of fishes have been widely reported as a part of their life histories (Hynes 1970, Eddy and Underhill 1974) or in comparative studies when closely related species were suspected of being in competition with one another for food (Mendelson 1975, Werner and Hall 1976, and Werner 1977). Recently, investigators have compared diets and looked at the topic of food resource partitioning. This topic touches on at least 2 important interactions: predation and competition. Resource sharing, or niche overlap, is a central aspect of competition theory. Ecologists have long been intrigued with the notion that there should be a limit to how similar the food niches of two species can be and still coexist (Pianka 1976).

Notropis life histories, including their food habits, have been widely reported as being similar (Starret 1951, Mendelson 1975, Mathur 1977, and Whittaker 1977). In the present study, we compared the feeding interrelationships between the sand shiner *N. stramineus* (Cope) and the striped shiner *N. chrysocephalus* (Rafinesque) in Buffalo Creek, PA. Specific objectives were to: 1) quantify food availability; 2) determine the prey organisms of each species; 3) calculate the selection for particular food items by forage ratios; 4) examine the distribution of particular prey sizes for each species; and 5) measure the overlap of food habits between the 2 species.

MATERIALS AND METHODS

We collected *Notropis stramineus* and *N. chrysocephalus* the third Saturday of each month during September through December 1977, using 1.2 x 9.1 m straight seine. For food habit analysis, at least 30 specimens of each species were taken during each of the 4 monthly sampling periods; upon capture, fish were iced to prevent regurgitation and later fixed in 10% formalin. Species, total length, date, and location were recorded for each fish. Fish were grouped into arbitrary size categories of 40–49 mm; 50–59 mm; 60–69 mm; 70–84 mm; 85–100 mm; and >115 mm.

Food organisms from the stomach were counted and identified to the generic level when possible. Invertebrate taxa were identified using Usinger (1956) and Hilsenhoff (1975); then frequency of occurrence of detritus, plant

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material (e.g. *Cladophora*), fish eggs, and diatoms was determined.

Concurrent with each fish collection and at the same site, four 1 ft^2 (0.093 m^2) benthic samples of invertebrates were taken with a Surber sampler in order to determine the relative abundance of prey in the environment. Organisms were sorted by hand, identified, counted and measured and sorted into their representative category: 0–4 mm; 5–8 mm; 9–12 mm; 13–16 mm and >16 mm.

The percentage composition of each food organism in both the gut and the environment was determined; then a forage ratio (FR) was calculated as:

(1) $$FR = S/B$$

where S = percentage of prey items of the total of food organisms in the stomach.
B = percentage of the same organism in the environment (as measured by the Surber sampler).

A forage ratio of 1.0 indicated that an organism occurred in the same relative abundance in the digestive tract as in bottom samples; a forage ratio greater than 1.0 indicated a positive selection or greater availability of an organism, and a forage ratio of less than 1.0 indicated that an organism was either less preferable or less available (Ricker 1971).

An index of similarity (modified from Cox 1972) was calculated to determine the similarity (S) between the Surber, sand shiner diet, and striped shiner diet:

(2) $$S = 2W/a+b$$

where, W = sum of the prey species shared by both predator species.
a = sum of prey species taken by predator species a.
b = sum of prey species taken by predator species b.

This measure varied from 0 with no overlap to 1.0 when complete correspondence existed.

The Shannon Weaver Function (SWF), a diversity index which calculates mean diversity, was calculated by the machine formula of Weber (1973) as:

(3) $$D = C/N(N \log_{10} \cdot N - \Sigma n_i \log_{10} \cdot n_i)$$

where C = 3.32198 (converts base $_{10}$log to base 2 log (bits)).
n = total number of individuals in the ith species.
N = total number of individuals.

Standard statistical tests such as the sample mean, standard deviation, student's t-test, arcsine transformation, and analysis of variance (ANOVA) were computed as suggested by Mendenhall (1975) and Zar (1974).

Description of Study Area. Buffalo Creek flows westward from its source in Washington County, Pennsylvania into West Virginia where it eventually drains an area of 298 km^2 into the Ohio River (Kreamer 1976). The topography grades from rolling hills upstream so that agriculture is more prevalent in the upper reaches of Buffalo Creek and its tributaries, whereas the lower and middle reaches are narrow with valleys that are undeveloped and wooded. Much of the study area (Kreamer (1976) site 23) borders on pasture and cropland. Stream flow is moderate to rapid, with regular alteration of riffles and pools. Dense mats of *Cladophora* cover the rapids and become very dense during the late fall and early winter. Pools within the study area were 1.5 m in depth, meandering for stretches up to 1 km with substrate of silted rubble and gravel. Shelter for fish in pools was abundant in brush piles, logs, and cut banks. Sand and striped shiners were most abundant in these pools and beneath bridges, which provide shade.

RESULTS AND DISCUSSION

Total lengths of fish within each species were not statistically different through the sampling period; however, *Notropis chrysocephalus* (mean length: 89±16 mm in September and 96±19 mm in December) was always larger than *N. stramineus* (mean length 56±16 mm in September and 63±11 mm in December). These means were different at the 1% level for each species and for each month studied.

TABLE 1

Mean abundance of selected aquatic invertebrates found in Buffalo Creek, Washington County, PA, Fall 1977.

Organism	Sept.	Oct.	Nov.	Dec.
Chironomidae	342±49*	281±17	247±58	428±31
Stenonema	83±5	99±41	218±53	145±59
Caenis	54±15	137±18	207±14	129±23
Isonychia	0	0	24±15	67±27
Alloperla	0	0	89±19	172±32
Isoperla	0	0	81±28	91±14
Ancyronyx	19±10	30±10	54±23	22±9
Argia	22±9	0	0	0

*mean±SD, 0 indicates that none were found in the Surber samples.

Resource Base. The most abundant aquatic organisms during September were larval Chironomidae, *Stenonema* nymphs, *Ancyronyx* adults, and *Argia* naiads (table 1). From September through October, the mayflies *Caenis* and *Stenonema* continued to increase. In November, the stoneflies *Alloperla* and *Isoperla* appeared in high numbers in leaf packets in the stream benthos. These stoneflies, the mayfly *Isonychia*, and larval Chironomidae increased in December, whereas most other benthic invertebrates declined. Total number of benthic invertebrates increased slightly from September through November, but declined slightly in December. Terrestrial insect activity (such as Chironomidae swarming) was observed (by A.L.G.) to be highest in September and October, with a general decrease through December. This observation concurs with Mendelson's (1975) finding of a decline of terrestrial insects in drift from September to November.

Food Habits. *N. Stramineus* consumed 17 to 22 different species/month of terrestrial and aquatic invertebrates during fall. There was no clear trend in monthly samples of 30 fish in the total number of items consumed (range: from 86 to 114 prey items). The Shannon-Weaver Function showed an increasing trend from 3.63 in September to 3.91 in December. During September, *N. stramineus* fed heavily upon adult Chironomidae (table 2), which were caught in the current and taken by the shiners in drift. Benthic organisms such as *Ancyronyx*, *Caenis*, and *Stenonema* occurred in relatively shallow pool areas of Buffalo Creek. Their presence in the gut of *N. stramineus* indicated it was also feeding on the benthos in September. This trend of increasing consumption of benthic Ephemeroptera continued throughout the season, largely because the mayflies comprised 30% to 38% of the total invertebrate composition. The other major groups of prey taken were larval Chironomidae and the stoneflies, *Alloperla* and *Isoperla*. The major importance of *Alloperla* and *Isoperla*, in regard to selection, was indicated by their November forage ratios, 2.45 and 2.14, respectively (table 2). These species were important in the diet of *N. stramineus*, as indicated by their percent composition during November (30.8%) and December (31.6%) (fig. 1). *N. stramineus* shifted its food habits due to availability of the resource base, thus indicating its opportunistic nature. Overall, *N. stramineus* consumed large quantities of terrestrials (appx. 40%) and aquatic (appx. 50%) insects during September and October. They shifted almost entirely to benthic insects (appx. 90%) in November and December. Feeding habits of *N. stramineus* in late fall reflected increasing benthic feeding

TABLE 2

Principle prey items found in the stomachs of N. stramineus and N. chrysocephalus as indicated by forage ratios (FR) or total individuals (T) taken by 30 fish per month in Buffalo Creek, PA.

Month	*N. stramineus*	FR	T	*N. chrysocephalus*	FR	T
Sept.	*Ancyronyx*	2.76	—	*Ancyronyx*	2.34	—
	Argia	1.33	—	*Argia*	6.21	—
	Adult Chironomidae	—	15	Adult Chironomidae	—	17
				Stenonema	1.64	—
				Caenis	1.37	—
Oct.	*Caenis*	0.80	—	Ceratopogonidae	3.92	—
	Adult Tabanidae	—	12	*Stenonema*	1.02	—
				Ancyronyx	1.30	—
Nov.	*Isonychia*	3.61	—	*Isonychia*	5.44	—
	Baetis	1.24	—	Ceratopogonidae	1.70	—
	Alloperla	2.45	—			
	Isoperla	2.14	—			
	Rheotanytarsus	1.18	—			
	Polypedilum	17.80	—			
	Adult Diptera	—	21			
Dec.	*Alloperla*	1.73	—	*Natarsia*	11.95	—
	Isoperla	1.35	—	*Cryptochironomus*	23.19	—
				Cladophora	—	29

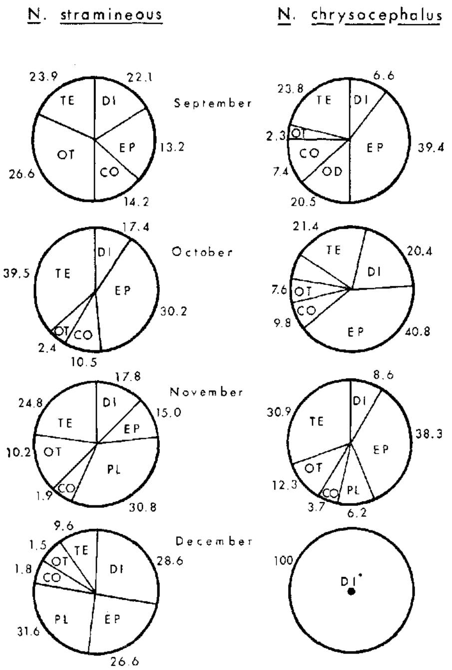

FIGURE 1. Percent composition of the major prey groups found in the diet of *Notropis stramineus* (left) and *N. chrysocephalus* (right). OD = Odontata; EP = Ephemeroptera; DI = Aquatic Diptera; TE = Terrestrials; C = Coleoptera; PL = Plecoptera; and OT = All others.

Note in December the bulk of the diet of *N. chrysocephalus* consists of *Cladophora*.

as indicated by the increasing similarity of its diet to that of the Surber samples (table 3). The subterminal mouth in *N. stramineus* is possibly more adaptive to benthic feeding than the olique mouth of *N. chrysocephalus*.

N. chrysocephalus consumed a wide variety of terrestrial and aquatic invertebrates during fall but its diet shifted dramatically through the season. During September and October, prey diversity remained relatively constant, both in terms of number of species consumed per 30 fish and in Shannon-Weaver Function (3.19 and 3.50, respectively). During November, the number of species consumed (24) and the Shannon-Weaver Function (diversity 4.10) increased greatly. This increase was followed in December by a dramatic decline in number of prey species consumed to 4

TABLE 3

Index of Similarity Values to compare the similarity between the aquatic environment (as measured by the Surber samples) and the diet of the sand shiner, Notropics strainneus, and the striped shiner, N. chrysocephalus.*

Month	Surber vs Sand	Surber vs Striped	Sand vs Striped
Sept.	0.452	0.444	0.615
Oct.	0.385	0.333	0.583
Nov.	0.486	0.615	0.474
Dec.	0.788	0.273	0.235

*Index of Similarity Value calculated from formula $S = 2W/a+b$;

W = sum of prey species shared by both species; a = sum of prey species taken by predator species a; and b = sum of prey species taken by predator species b.

and a Shannon-Weaver Function of 1.14. These results reflected the variability of feeding habits of *N. chrysocephalus*. During September and October, terrestrial Chironomidae, *Caenis* and *Stenonema* were important prey items for *N. chrysocephalus* (table 2). A highly selected prey item for *N. chrysocephalus* in September was the damselfly naiad, *Argia* (FR = 6.21). Although *Argia* was not particularly abundant in the fish's environment, the large size of this particular prey item could produce high energy yields; thus time searching or selecting such large prey could have been profitable in energetic return (Werner 1977). In earlier months, *N. chrysocephalus* appeared to be feeding at various depths of the stream, including surface, midwater, and benthic levels. In December, the diet of the striped shiner shifted to taking large amounts of *Cladophora*, a filamentous algae which bloomed in Buffalo Creek during early winter. Visual observations revealed that *Cladophora* biomass increased greatly in December so that the stomach was distended with it. Its importance to *N. chrysocephalus* is indicated by its high frequency (table 4).

Prey Type and Size Selection. Food habits of *N. stramineus* and *N. chrysocephalus* appeared to be a species phenomenon rather than a size difference within the species. The 2 species con-

TABLE 4

Frequency of occurrence of the major food items in the stomachs of Notropis stramineus and N. Chrysocephalus during the Fall of 1977.

	Notropis stramineus (n=123)				*Notropis chrysocehalus* (n=123)			
Food Category	Sept.	Oct.	Nov.	Dec.	Sept.	Oct.	Nov.	Dec.
Cladophora sp.	0.37	0.40	0.53	0.37	0.57	0.33	0.67	0.97
Detritus	0.03	0.23	0.57	0.57	0.43	0.30	0.77	0.90
Leaves	0.27	—**	—	0.10	0.23	0.13	0.30	0.13
Diatoms	0.03	—	—	—	—	—	—	—
Ephemeroptera	0.32	0.48	0.49	0.57	0.74	0.68	0.57	—
Adult Diptera*	0.52	0.45	0.50	0.23	0.16	0.58	0.43	0.10
Larval Diptera*	0.39	0.36	0.20	0.60	0.45	0.23	0.17	0.47
Coleoptera	0.27	0.42	0.07	0.20	0.29	0.42	0.23	—
All Terrestrials	0.52	0.48	0.50	0.30	0.36	0.55	0.70	0.10
Odonata	0.19	—	—	—	0.45	—	—	—
Plecoptera	—	—	0.47	0.60	—	—	0.13	—
Fish Eggs					0.23	—	—	—

*Primarily Chironomidae.
**Bar indicates none found.

sumed terrestrial insects and aquatic Coleoptera, Diptera, and Ephemeroptera in similar frequencies, but consumed Plecoptera and *Cladophora* in different frequencies ($P<0.01$). Sand and striped shiners consumed animal prey of different size, the striped shiner consuming larger prey than the sand shiner, even in the region of predator size overlap. Overlap was great, especially in the prey size class of 5 to 8 mm. A significant difference between the two species was readily apparent for consumption of prey greater than 16 mm ($P<0.001$). The optimal range for foraging of sand shiners was 5 to 8 mm, and the optimal range for the striped shiner was 9 to 12 mm. *N. chrysocephalus* did take a few smaller prey but took a larger number in size classes 9 to 12 mm, 13 to 16 mm, and >16 mm. This difference might be attributed to its larger mouth. These prey included large terrestrial dipterans, the damselfly *Argia*, and the crayfish *Orconectes*, which were apparently too large for *N. stramineus* to handle.

Diet Overlap. In Buffalo Creek, aquatic insects increased slightly from September through November with a slight decrease in December (table 1), and qualitative observations showed a general decrease in terrestrials from September through December. Temperate stream drift results in a Wisconsin stream (Mendelson 1975) showed a marked decrease of terrestrials from September through November. Our visual observations indicated a similar situation in Buffalo Creek, where the overall supply of available prey dropped and prey composition changed greatly. The index of similarity between the diets of *N. stramineus* and *N. chrysocephalus* decreased throughout the fall (table 3). The higher degree of overlap in September was due to both species preying heavily upon common aquatic invertebrates and terrestrials. The terrestrial food supply appeared to be very abundant at this time, and the high degree of overlap in diet suggested that little competition was occurring between the two species. As the season progressed, terrestrials diminished in supply and diets of the two species shifted to taking more aquatic organisms. Although the feeding niche of *N. stramineus* and *N. chrysocephalus* was very difficult to define in September and October, it became apparent that each species had its own feeding niche in November and December. Once the food supply changed, it appeared that when food competition might have occurred between the species they shifted to a more specialized and defined food niche. When food resources common to both species decreased, the degree of diet overlap also decreased, and each species became more specialized, thereby avoiding interspecific competition.

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