Food Habits of Rainbow Trout in a Tennessee Tailwater

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Abstract: Food habits of rainbow trout were studied at 3 locations for 1 year on the Center Hill Dam tailwater in central Tennessee. Staple food items consisted of isopods (*Lirceus* sp.) and chironomids. Seasonal food items from Center Hill Reservoir (threadfin shad and *Daphnia* sp.) were highly utilized and contributed nearly 60% to the total volume of food items taken. Occurrence of algae in rainbow trout stomachs was common and appeared to be related to seasonal forage base. Condition of rainbow trout did not significantly change with season, but was usually significantly higher closer to the dam.

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The Center Hill Dam tailwater supports an extensive rainbow trout (*Oncorhynchus mykiss*) put-and-take fishery. This portion of the Caney Fork River annually receives about 70,000 catchable rainbow trout. Smaller numbers of brown trout (*Salmo trutta*) are stocked periodically.

Stream-dwelling rainbow trout are predominantly insectivorous on either aquatic or terrestrial organisms, depending on seasonal and environmental variables (Kennedy 1967, Jenkins et al. 1970, Tippets and Moyle 1978, Golus and Jakubowics 1982). However, due to hydroelectric turbine discharges and resulting drastic changes in downstream water levels, much of the Center Hill Dam tailwater has depauperate populations of aquatic invertebrates. The diversity of the benthic macroinvertebrate community in the Caney Fork River is apparently related to distance downstream from Center Hill Dam. Benthic communities are severely reduced near the dam, but a greater degree of diversity and stabilization develops further

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downstream (Mullican et al. 1967, Abbott 1974, Odenkirk 1987). However, even at downstream sampling sites, Abbott (1974) and Odenkirk (1987) found benthic macroinvertebrate populations indicative of a stressed community.

The objective of our study was to determine and compare food habits and indices of rainbow trout fitness from different sections of the Center Hill Dam tailwater.

Methods

The study area was below the U.S. Army Corps of Engineers' Center Hill Dam on the Caney Fork River. A hypolimnetic discharge results in coldwater releases throughout the year. The Caney Fork River had a typical warmwater and coolwater fishery prior to impoundment. Trout were first stocked in the early 1950s.

Center Hill Reservoir is a tributary impoundment constructed primarily for flood control and hydroelectric power generation purposes. Consequently, discharge and resulting flow in the tailwater are dependent on regional power demands and rainfall in the watershed. Average flows during peaking power generations are 96, 201, and 303 m^3/s, depending on whether 1, 2, or 3 turbines are used. Tailrace water level fluctuations may exceed 3 m, and reductions of 63% in stream substrate can occur during periods of no generation. Minimum flow in the tailwater is maintained by a 0.6 m^3/s seepage from the reservoir. The only major tributary to the tailwater is Smith Fork Creek, which is located about 16 km below the dam.

For sampling purposes, the 43-km tailwater was divided into 3 relatively equal sections. Sampling stations were established on the first upstream kilometer of each section and were designated as Stations I, II, and III, beginning at the upper section.

Rainbow trout were collected monthly from Station I between October 1985 and October 1986, excluding December, and from Station II between January and October 1986, excluding February. Fish sampling at Station III began in January 1986 but was terminated in April due to low catch rates (electrofishing CPUE averaged 0.2 rainbow trout/hour). Fish were captured at night using a portable electrofishing unit with a hand-held probe from a 4-m aluminum johnboat. Between 5 and 10 rainbow trout were collected on each sampling date for stomach content analysis. Tippets and Moyle (1978) found that the contents of 7 stomachs represented an adequate sample of the taxa consumed by rainbow trout. Immediately following capture, rainbow trout were measured for total length, weighed, and given an identification tag. Stomachs were then removed from the fish and preserved in 10% formalin with their tags. In the laboratory, stomach contents were identified, enumerated, and volumetrically measured. Invertebrates were identified to genus (where practical) using keys by Pennak (1978) and Merritt and Cummins (1978). Volumetric measurements to the nearest 0.1 ml were made in a graduated cylinder (Hyslop 1980).

Because of the small sample size (N = 11) of rainbow trout captured at Station III, analysis of food habit data was restricted to Stations I (112 fish) and II (77 fish).

Condition coefficients, K, of rainbow trout captured at different locations and during different seasons were calculated using a Fulton-type condition factor (Anderson and Gutreuter 1983). Data were not divided into similar-sized categories for calculating K, as isometric growth was exhibited. The calculated slope of the length-weight regression line was never significantly different from 3.00 ($P < 0.05$).

Multivariate analyses of variance (MANOVA) were used to compare condition factors, and Tukey's procedure (Steel and Torrie 1980) was applied to determine which factors differed significantly. Null hypotheses were rejected if $P < 0.05$. General linear models procedures (SAS Inst. 1982) were used when appropriate.

Results

Food Habits of Rainbow Trout

The mean size of rainbow trout sampled was 257 mm total length. Minimum and maximum total lengths were 200 and 520 mm.

Station I.—Daphnia sp. were consumed in the greatest quantity, composing nearly 62% of the total food items taken by rainbow trout throughout the study period, but were present only from July to September (Table 1). Only 2 other food groups made numerically substantial contributions to trout diet at this station, isopods (*Lirceus* sp.; 18.7% of total number) and chironomids (17% of total number). Abundance of *Lirceus* sp. and chironomids in the gut fluctuated throughout the year. Gastropods supplemented trout diet during winter months, whereas terrestrial organisms were taken in relatively large numbers in November, March, and June. Algae and detritus were found in 50% of the fish examined.

Threadfin shad (*Dorosoma petenense*) composed only 1% of the total number of food items but >70% of the total volume (Table 2). Threadfin shad were present in the diet during November 1985 and from February to May 1986. Mean standard length of threadfin shad consumed by rainbow trout was 44 mm (SD = 8.7). A significant difference existed between mean total length of rainbow trout that fed on shad (320 mm, SD = 60) and those that did not (280 mm, SD = 58).

The only other fish species found in rainbow trout stomachs was the banded sculpin (*Cottus carolinae*). Three banded sculpin (mean standard length = 71 mm, SD = 16) were found in a 410-mm rainbow trout captured in July.

Lirceus sp. made up the only other large volumetric portion of the rainbow trout diet, composing 8.6% of the total volume. Terrestrial organisms, including members of the families Formicidae, Cicadidae, Gryllidae and Araneidae, composed only 2.2% of the total volume of food items consumed.

Volume of stomach contents per fish was highest in winter ($\bar{x}$ = 10.80 ml) and lowest in fall ($\bar{x}$ = 0.82 ml). Average volume of algae and detritus in the gut was greatest in summer (0.80 ml) and least in fall (0.12 ml; Table 3). Algae and detritus composed 29% of the total volume of stomach contents in summer and 15% in fall.

Station II.—Lirceus sp. were consumed in the greatest quantity (66.3%) at this station (Table 4). Chironomids (12.5%) and terrestrial organisms (10.1%) were also important dietary components. *Lirceus* sp. were utilized to the greatest extent in

Table 1. Major food organisms consumed by rainbow trout at Station I on the Center Hill Dam Tailwater.

			Percent of total number of food organisms consumed monthly (1985–1986)											
Organism	Total *N*	% of total *N*	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Daphnia sp.	16,045	61.9									96.5	87.3	76.6	
Lirceus sp.	4,846	18.7	88.1	24.1	86.7	5.1	8.3	96.7	80.0	62.8	0.5	5.0	5.5	39.0
Chironomidae	4,414	17.0	9.2	53.0	11.7	82.0	83.3	3.2	16.9	33.6	2.6	6.9	16.8	60.0
D. petenense	251	1.0		1.0		12.7	5.2	0.1	0.1					
Others[a]	344	1.4	2.7	21.9	1.6	0.2	3.2		3.0	3.6	0.4	0.8	1.1	1.0

[a]Available from the authors.

Table 2. Volume (ml) of major food organisms consumed by rainbow trout at Station I on the Center Hill Dam Tailwater.

			Total volume (ml) of food organisms for all fish examined (1985–1986)											
Organism	Total volume	% of total volume	Oct	Nov	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
D. petenense	284.7	71.7		7.9		188.7	87.7	0.1	0.3					
Lirceus sp.	34.3	8.6	3.7	1.2	8.9	0.4	1.4	6.4	4.5	4.9	0.6	1.0	0.2	0.9
Chironomidae	13.6	3.4	0.1	0.9	0.5	3.1	4.8	0.1	0.4	0.7	1.0	0.6	0.6	0.7
Daphnia sp.	5.0	1.3									3.7	1.1	0.2	
Others[a]	59.3	15.0	0.6	7.8	0.7		1.4		3.8	1.2	23.3	14.6	5.8	

[a]Available from the authors.

Table 3. Average volume and number of food items consumed by rainbow trout at Station I on the Center Hill Dam Tailwater.

	Seasonal means per fish			
	Winter	Spring	Summer	Fall
N Organisms	137	136	640	61
Volume (ml)				
Aquatic invertebrates	0.74	0.77	1.91	0.43
Threadfin shad	9.83	3.06		0.13
Terrestrial food items	0.01	0.09	0.05	0.14
Algae/detritus	0.22	0.76	0.80	0.12
Total mean volume	10.80	4.68	2.76	0.82

Table 4. Major food organisms consumed by rainbow trout at Station II on the Center Hill Dam Tailwater.

Organism	Total *N*	% of total *N*	Percent of total number of food organisms consumed monthly (1986)								
			Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Lirceus sp.	7,490	66.3	99.0	72.2	19.7	2.8	12.7	6.2	5.2	62.8	80.5
Chironomidae	1,414	12.5	0.1	17.4	9.7	38.3	26.8	65.1	69.4	21.4	3.1
Terrestrial	1,143	10.1		1.0	3.4	19.8	47.9	16.6	11.8	0.9	1.0
D. petenense	20	0.2	0.4								
Others[a]	1,236	10.9	0.5	9.4	67.2	39.1	12.6	12.1	13.6	14.9	15.4

[a]Available from the authors.

Table 5. Volume (ml) of major food organisms consumed by rainbow trout at Station II on the Center Hill Dam Tailwater.

Organism	Total volume	% of total volume	Total volume (ml) of food organisms for all fish examined (1986)								
			Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
D. petenense	82.2	42.1	82.2								
Lirceus sp.	39.6	20.3	26.0	2.6	1.0	0.1	1.8	0.1	0.2	1.4	6.4
Terrestrial	32.1	16.4		0.5	2.8	2.6	16.9	1.2	7.1	0.5	0.4
Chironomidae	5.4	2.8		0.4	0.4	1.0	1.5	0.2	1.4	0.2	0.2
Others[a]	36.0	18.4	0.7	1.1	4.1	1.2	0.8	18.7	2.1	5.1	2.3

[a]Available from the authors.

winter and to a lesser degree during summer and fall. Numerical abundance of terrestrial organisms and chironomid larvae was low in winter, increased through spring, peaked during summer, and receded during fall.

Lirceus sp. composed 20.3% of total volume, and terrestrial organisms 16.4% (Table 5). Volume of terrestrial organisms consumed fluctuated greatly on a monthly basis.

Threadfin shad were only found in rainbow trout stomachs during January. They composed only 0.2% of total items consumed but represented the greatest volume of food (42.1%) in the annual diet. Diptera larvae (other than Chrironomidae), gastropods, and *Gammarus* sp. supplemented rainbow trout diet at this station.

Volume of aquatic food items (total minus algae) was highest in winter (21.52 ml), dropped sharply in spring, continued to decrease through summer, and reached a low of 0.77 ml in fall (Table 6). Terrestrial items composed from 0% (winter) to 27% (summer) of the total volume of items consumed. Relative percentage of algae taken was lowest during winter, rose steadily throughout the year and peaked in fall, composing 58% of total fall stomach volume, or an average of 1.12 ml per fish.

Condition of Rainbow Trout

Rainbow trout captured during spring at Station I had the highest condition of all trout sampled (1.21), and winter fish from Station II had the lowest (1.00). There were no significant differences in condition between seasons at each station, but there were significant within-season, between-station differences in condition of rainbow trout in every season except summer. Rainbow trout captured from Station I had a significantly higher condition factor during winter and spring seasons, whereas Station II fish had a significantly higher condition factor during fall.

Discussion

Previous investigators have documented that the macroinvertebrate populations of the Center Hill Dam tailwater are characteristic of most benthic communities in southeastern tailwaters below tributary storage impoundments. Drastic water level fluctuations create an environment that is unsuitable for many macroinvertebrate taxa. The diet of rainbow trout at Station I was composed mainly of *Lirceus* sp., Chironomidae, *Daphnia* sp., and threadfin shad. Chironomids and *Lirceus* sp. were staple food items, as they were consumed throughout the year and were endemic to the tailwater. Occurrence of threadfin shad and *Daphnia* sp. in rainbow trout diet was seasonal and probably related to discharge and water temperature in Center Hill

Table 6. Average volume and number of food items consumed by rainbow trout at Station II on the Center Hill Dam Tailwater.

	Seasonal means per fish			
	Winter	Spring	Summer	Fall
N Organisms	1,112	63	103	87
Volume (ml)				
Aquatic invertebrates	7.96	2.48	1.54	0.77
Threadfin shad	13.56			
Terrestrial food items		0.19	1.05	0.05
Algae/detritus	0.16	1.11	1.3	1.12
Total mean volume	21.68	3.78	3.89	1.94

Reservoir. Periodically, large quantities of threadfin shad were observed exiting the turbines into the stilling basin from November through April. Griffith and Tomljanovich (1975) found that the greatest threadfin shad impingement in TVA reservoirs occurred during the colder winter and spring months. Furthermore, McDonough and Hackney (1979) stated that threadfin shad >50 mm usually became impinged, while fish below this size were likely to pass through the screens. Parsons (1955) reported that dead and dying threadfin shad provided rainbow trout in the Center Hill Dam tailwater with an almost inexhaustible food supply from September through March. When threadfin shad were present in the stilling basin, virtually every rainbow trout >300 mm sampled was gorged with them to the extent that the stomach membrane was stretched to transparency. Growth of rainbow trout sampled from the upstream site was highest in spring, following the presence of threadfin shad (Kanehl 1988). All of the threadfin shad observed in the upper portion of the tailwater in this study were dead or dying. Threadfin shad were observed floating and scattered along the river bands up to 3 km below Center Hill Dam and were found in stomachs from rainbow trout 12 km below the dam (Station II).

An apparently viable population of threadfin shad was observed in the lower portion of the Caney Fork River and was probably resident to the Cumberland River, moving into the lower Caney Fork River when water temperatures increased. No live threadfin shad were ever observed in the Caney Fork River >6 km above the confluence with the Cumberland River. Limited findings indicated that rainbow trout residing in the lower section of the Caney Fork River utilized the Cumberland River threadfin shad population as a forage base.

Daphnia sp. were drawn through the penstocks and consumed by rainbow trout in large quantities from July through September at Station I, apparently replacing chironomids and *Lirceus* sp. as the preferred food item. In fall, when *Daphnia* sp. declined in the reservoir, chironomids and *Lirceus* sp. again became the major food items for trout below the dam.

Algae and detritus were very common in rainbow trout stomachs. Consumption of algae is thought to be a behavioral pattern in response to an insufficient forage base and may be a characteristic behavior of rainbow trout residing in tailwater environments (Parsons 1955, Pfitzer 1962, Tippets and Moyle 1978). When forage decreased, rainbow trout ingested large amounts of filamentous algae. Consumption of algae was lowest in winter, when rainbow trout utilized threadfin shad, and highest during months when invertebrates and forage fish were least common.

Significant differences in condition factors may be attributable to a greater concentration of threadfin shad at the upstream station during winter and spring and an increase in terrestrial food items during summer at the lower station.

Conclusions

Chironomids and isopods (*Lirceus* sp.) were the most utilized macroinvertebrate food items numerically, contributing between 35% and 80% (Stations I and II, respectively) of the total number of items consumed by rainbow trout. However, food materials from Center Hill Reservoir (threadfin shad and *Daphnia* sp.) were important seasonal food items, contributing between 72% and 42% (Stations I and II) of the total volume of items consumed by rainbow trout annually.

Rainbow trout seemed to display a behavioral adaptation to a decreasing forage base by ingesting large amounts of filamentous algae. Trout were probably able to utilize large quantities of small invertebrates (predominately chironomids) living within the algal mats.

Condition of rainbow trout did not significantly change with season but was usually significantly greater in fish taken from the upper portion of the river, probably as a result of the utilization of reservoir-based food items.

Fishery managers should consider the apparently substantial role of food items originating from Center Hill Reservoir when contemplating salmonid tailwater stocking densities and locations. Faunal changes within the reservoir could adversely affect the rainbow trout population in the tailwater by eliminating a major food source in the upper portion of the tailwater.

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