Food And Feeding Of Fish In Hartwell Reservoir Tailwater, Georgia-South Carolina[1]

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Abstract: Food of silver redhorse (*Moxostoma anisurum*), redbreast sunfish (*Lepomis auritus*), green sunfish (*L. cyanellus*), and bluegills (*L. macrochirus*) was examined to determine whether or not these fish in the Hartwell Reservoir tailwater (Savannah River, Georgia-South Carolina) ate organisms entrained from the reservoir or displaced from the tailwater during water releases associated with the production of hydropower. These fish fed primarily on aquatic insects, crayfish, and terrestrial organisms originating from the tailwater. Major periods of feeding occurred during nongeneration.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildlife Agencies 39:185–193

Discharges of large volumes of water from reservoirs built for flood control and generation of hydropower can result in the downstream transport of reservoir fish, plankton, and aquatic insects (Hudson and Cowell 1966, Benson and Cowell 1968, Walburg 1971, Matter et al. 1983). These discharges also scour tailwater substrates and can temporarily increase drift rates for autochthonously produced macroinvertebrates (Armitage 1977, Brooker and Hemsworth 1978, Matter et al. 1983). Downstream transport of reservoir and tailwater biota during hydropower discharge may be a valuable source of food for fish in tailwaters.

Walburg et al. (1971) indicated that fish in the tailwater of Lewis and Clark Lake ate organisms discharged from the reservoir, but Matter et al. (1983) doubted that fish below large, peaking hydropower reservoirs (e.g., Hartwell Reservoir)

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could effectively use this food source. Instead, they believed that velocities reached during hydropower generation might interfere with fish feeding behavior and limit the degree to which fish are able to use these displaced organisms. Our objective was to determine whether or not fish in the tailwater of Hartwell Reservoir ate organisms entrained from the reservoir or displaced from the tailwater during hydropower generation.

We thank Don Field and Jorgen Skjeveland for assistance in the field and laboratory. This study was funded by the Environmental and Water Quality Operational Studies Program sponsored by the Office, Chief of Engineers, U.S. Army, under EWQOS Task IIB.

Methods

The tailwater of Hartwell Reservoir is that section of the Savannah River between Georgia and South Carolina extending about 20 km downstream from Hartwell Dam. During generation of peaking hydropower (264 megawatts) at Hartwell Dam, water is released from Hartwell Reservoir (22,652 ha) through inlets located at a centerline depth of 30 m when this reservoir is at full pool (201 m above mean sea level). Flows in the tailwater range from 3 to 11 m^3/sec during nongeneration, but increase up to 665 m^3/sec during generation. The maximum velocity is about 1.8 m/sec during generation. A description of Hartwell Reservoir and additional information on the tailwater and hydropower operations at Hartwell Dam are given in Dudley and Golden (1974), Matter et al. (1983), and Barwick and Oliver (1982).

Redbreast sunfish (*Lepomis auritus*), green sunfish (*L. cyanellus*), bluegills (*L. macrochirus*), and silver redhorse (*Moxostoma anisurum*) are the dominant species of fish inhabitating this tailwater (Barwick and Oliver 1982) and were selected for study. Redbreast sunfish, green sunfish, and bluegills were collected on July 20 and 21, 1982, and each of these sunfishes plus silver redhorse were collected on September 1 and 2, 1982, from an area of the tailwater about 12 km below Hartwell Dam. Because fish could not be obtained during flows associated with hydropower generation, we collected them by electrofishing, using methods described by Barwick and Oliver (1982), either during the day (0900-1530 hours) before flows increased in the river due to generation or at night (2400-0530 hours) beginning about 1-2 hours after flows began to subside.

We measured all fish collected (TL in mm) and removed their stomachs (stomach and first half of the gut in silver redhorse). Stomach contents were grouped by species and preserved with 10% formalin, as described by Borgeson (1963). Weights (g) of fish collected in July were estimated from length-weight regressions obtained from data collected from Hartwell Reservoir tailwater in 1979-80 (Barwick and Oliver 1982); fish collected in September were weighed before their stomachs were removed.

Feeding periodicity and digestion rates of fish in the tailwater were unknown when the study began, so we preserved some stomach contents almost immediately after collection to facilitate identification of prey. To eliminate bias induced by digestion in pregeneration and postgeneration comparisons of feeding, we collected about 10 fish of each species prior to generation and held them in a fiberglass tank (232 x 60 x 45 cm) supplied with river water filtered through a 0.750-mm mesh net, and pumped continuously at a rate of about 10 liters/min. These fish were held until additional fish could be collected after hydropower generation; then stomach contents of fish in the tank and those collected during postgeneration were preserved separately by species. Feeding periodicity was estimated using a method similar to that of Keast and Welsh (1968), in which relative weights (dry weight of the stomach contents divided by wet weight of fish in the sample x 10,000) were calculated and compared for each period.

Stomach contents were generally examined entirely, however, some were subsampled. When subsampling, the large but less-numerous organisms were removed, and the remaining items were suspended in 400 ml of water and divided with a Folsom Splitter.[4] At least 25% of each sample was processed and the appropriate factor was applied to extrapolate their percentage to total numbers and weights of all items eaten. All organisms were identified to family (unless such identification was prevented by digestion) and some were identified to species. Dry weights (g) were obtained for major groups of organisms by drying them to a constant weight at 60° C. Dry weights of trichopteran larvae and gastropods included the weight of their cases and shells, when present.

Results and Discussion

Aquatic insects (primarily dipterans, ephemeropterans, and trichopterans), decapods, and organisms of terrestrial origin (primarily insects) composed most of the food (by weight) eaten by all 4 species of fish (Table 1). Trichopteran larvae of the genus *Hydroptila* appeared to be the most important prey for silver redhorse and made up the greatest weight of identifiable prey. Terrestrial organisms, *Asellus* sp., *Hyalella* sp., and dipterans also were important in the diet of this fish. Dipterans (primarily larvae and pupae of the chironomid genera *Cricotopus* and *Orthocladius*) contributed only 1% of the total stomach contents by weight, but they were numerically more abundant than trichopterans (Table 2). Inclusion of the weight of trichopteran cases (which have little or no nutritional value) may overstate the importance of these organisms to the diet of silver redhorse. Meyer (1962) found that silver redhorse from the Des Moines River, Iowa, ate immature chironomids more frequently than trichopterans.

The sunfishes from Hartwell Reservoir tailwater had diets similar to that reported for these fish from many natural streams (Minckley 1963, Davis 1972, Benke et al. 1979, Coomer et al. 1979, Mancini et al. 1979). All 3 species ate similar weights of ephemeropterans (nymphs and adults of the genera *Ephemerella* and *Pseudocloeon*) and terrestrial organisms. Dipterans (larvae and pupae of the chironomid genera *Chironomus, Cricotopus,* and *Orthocladius*) predominated by

[4]Reference to trade names does not imply government endorsement of commercial products.

Table 1. Dry weights (g) of various groups of organisms eaten by fish collected from Hartwell Reservoir tailwater in July and September (data combined), 1982. The number of stomachs examined and the range in total length (mm) of fish are in parentheses.

Organisms	Silver redhorse[a]		Redbreast sunfish		Green sunfish		Bluegill	
	(*N* = 30; 313–500)	Percent of total food	(*N* = 48; 81–194)	Percent of total food	(*N* = 78; 86–184)	Percent of total food	(*N* = 61; 63–205)	Percent of total food
Cladocera and Copepoda[b]	0.0100	0.1	.0002	T[c]	0.0016	T	0.0052	0.1
Asellus sp. and *Hyalella* sp.	0.1208	1.2	.0400	0.9	0.0957	1.1	0.0936	2.0
Decapoda (crayfish)			.2490	5.4	3.5760	41.7	0.0026	0.1
Diptera	0.1088	1.0	1.4072	30.5	0.4496	5.2	0.4019	8.8
Ephemeroptera	0.0536	0.5	1.0757	23.3	1.4798	17.3	0.6600	14.4
Trichoptera	1.1872	11.3	.2649	5.7	0.5515	6.4	0.9256	20.2
Miscellaneous aquatic insects[d]			.0107	0.2	0.0468	0.6	0.0159	0.4
Terrestrials[e]	0.1892	1.8	.3426	7.4	0.7996	9.3	0.5066	11.0
Periphyton	0.0324	0.3	.0503	1.1	0.0233	0.3	0.0199	0.4
Miscellaneous[f]	0.0736	0.7	.0521	1.1	0.0655	0.8	0.0577	1.3
Unidentified	8.7108	83.1	1.1294	24.4	1.4853	17.3	1.8948	41.3
Total	10.4864		4.6221		8.5747		4.5838	

[a]Silver redhorse were collected only in September
[b]Primarily *Moina brachiata* and *Mesocyclops edax*
[c]T = trace (<0.05)
[d]Megaloptera, Odonata, and Plecoptera
[e]Mostly terrestrial insects, but terrestrial earthworms (Oligochaeta), semi-terrestrial Lumbriculidae, and Arachnida (spiders) are included
[f]Ostracoda, Hydracarina, and Gastropoda (Physidae)

Table 2. Numbers of the organisms most frequently eaten by fish in Hartwell Reservoir tailwater in July and September (data combined) 1982.

Organisms	Silver redhorse[a]	Redbreast sunfish	Green sunfish	Bluegill
Cladocera and Copepoda[b]	1,652	33	118	369
Asellus sp. and *Hyalella* sp.	1,528	176	528	593
Decapoda (crayfish)		2	10	2
Diptera				
Chironomidae				
Larvae	3,612	455	159	367
Pupae	1,556	274	228	279
Adults	264	17	131	167
Simuliidae				
Larvae	48	51	36	145
Pupae	20			
Adults	112			
Tipulidae				
Larvae	44	44	17	22
Pupae		1	1	
Adults		5	11	13
Others[c]				
Larvae	56	5	4	14
Pupae	152[d]	1	2	1
Adults	104[d]	2	167[e]	94[e]
Ephemeroptera				
Nymphs	532	524	694	721
Adults	56	669	1,387	428
Trichoptera				
Larvae	1,280	260	590	1,013
Adults	176	26	179	165
Terrestrials[f]	184	93	300	287

[a]Silver redhorse were collected only in September
[b]Primarily *Moina brachiata* and *Mesocyclops edax*
[c]Culicidae, Chaoboridae, Ceratopogonidae, Stratiomyidea, Dolichopodidae, Ephydridae, and unidentified dipterans
[d]Primarily Ceratopogonidae
[e]Primarily *Chaoborus* sp.
[f]Mostly terrestrial insects, but includes terrestrial earthworms (Oligochaeta), semi-terrestrial Lumbriculidae, and Arachnida (spiders)

weight in redbreast sunfish, decapods in green sunfish, and trichopterans (primarily larvae of the genus *Hydroptila*) in bluegills (Table 1). Numerically, ephemeropterans were most important in redbreast sunfish and green sunfish, while trichopterans were most important in bluegills (Table 2).

Even though hydropower generation at Hartwell Dam increased abundance of invertebrates in the tailwater (Matter et al. 1983), the silver redhorse was the only species of the 4 studied that appeared to feed extensively during generation. Postgeneration stomach samples for this fish contained more aquatic insects, terrestrial organisms, and unidentified material than did pregeneration samples (Table 3). In addition, the silver redhorse was the only fish that ate considerable numbers of the copepod *Mesocyclops edax* (Table 2), a species common in reservoirs. However, feeding on drift during periods of generation would appear atypical for a fish with an inferior mouth.

Table 3. Relative weights (dry weight of the organisms in grams divided by total wet weight of fish in grams × 10,000) of various groups of organisms eaten by fish collected from the Hartwell Reservoir tailwater during pregeneration and postgeneration periods in July and September 1982. The numbers of stomachs examined are in parentheses.

	Silver redhorse[a]		Redbreast sunfish				Green sunfish				Bluegill			
	September		July		September		July		September		July		September	
Organisms	Pre-generation (10)	Post-generation (10)	Pre-generation (10)	Post-generation (10)	Pre-generation (6)	Post-generation (4)	Pre-generation (15)	Post-generation (15)	Pre-generation (10)	Post-generation (10)	Pre-generation (10)	Post-generation (11)	Pre-generation (10)	Post-generation (10)
Cladocera and Copepoda	T[b]	T	T				0.2	T		T	T		T	T
Asellus sp. and *Hyalella* sp.	T	0.1	0.1	T	0.1	0.1	0.3	0.1	0.1	0.2	0.1	0.1	0.2	0.2
Decapoda (crayfish)						7.8	21.9	18.8	0.1	2.5	T			
Aquatic insects[c]	0.1	1.3	13.3	11.6	2.1	4.0	11.0	9.4	3.2	2.5	3.9	4.0	3.4	3.1
Terrestrials[d]	T	0.3	3.1	0.9	0.2	T	5.5	3.9	0.1	0.2	0.2	3.8	0.3	0.4
Periphyton	T	T				0.8	0.3							0.1
Miscellaneous[e]	T	T	0.4	0.2	T	0.7	0.8	T	T	T	T	0.3	0.1	T
Unidentified	0.9	7.9	4.0	7.2	1.6	1.4	3.8	8.9	1.9	4.7	3.1	6.7	3.1	5.7

[a]Silver redhorse were collected only in September
[b]T = trace (<0.05)
[c]Diptera, Ephemeroptera, Megaloptera, Odonata, Plecoptera, and Trichoptera
[d]Mostly terrestrial insects, but terrestrial earthworms (Oligochaeta), semi-terrestrial Lumbriculidae, and Arachnida (spiders) were included
[e]Ostracoda, Hydracarina, and Gastropoda (Physidae)

Additional evidence questioning the validity of the feeding periodicity data for silver redhorse arose when we compared the *Mesocyclops* eaten in the tailwater with that found in reservoirs. The form eaten by the silver redhorse was smaller than that normally found in reservoirs, and the posterior edges of the urosomes were sculptured which is in contrast to the smooth edges of the reservoir form. Thus, the *Mesocyclops edax* eaten by silver redhorse in the Hartwell Reservoir tailwater may be indigenous to the tailwater along with the cladoceran *Moina brachiata,* which also was frequently eaten. The inferior mouth of the silver redhorse, absence of *Moina* from plankton and benthic samples collected from this tailwater over several years (P. L. Hudson and S. J. Nichols, unpubl. data), and the presence of the atypical *Mesocyclops* probably suggests benthic feeding by this fish in isolated or specialized habitats during nongeneration. The observed increase in the stomach contents from pregeneration to postgeneration may have resulted from an artifact of sampling.

Although relative weights of food eaten by each species of sunfish in the tailwater before and after generation were more variable than that observed for silver redhorse (Table 3), it appears that most of the aquatic insects and terrestrial organisms found in their stomachs were eaten prior to generation. Increased feeding activity during pregeneration was generally indicated by higher weights of these organisms in pregeneration samples when compared to postgeneration samples. In addition, there was a general increase in the weight of unidentified material found in the stomachs of these fish from pregeneration to postgeneration periods, suggesting that food intake during generation was limited while digestion had reduced some of the previously eaten items to an unidentified state. However, this was not the case for all organisms eaten.

Weights of decapods consumed by redbreast sunfish and green sunfish were at times higher in postgeneration samples than in pregeneration samples (Table 3). Observations in the tailwater and general observations by Hobbs (1981) indicated that crayfish move from beneath rocks at night and are probably more susceptible to predation by fish at this time than they are during daylight. Active night feeding on crayfish by redbreast sunfish and green sunfish after hydropower generation may explain the increased abundance of crayfish in postgeneration samples in September, since it is unlikely that many crayfish were being swept downstream during generation. Maude and Williams (1983) reported that *Cambarus bartoni* (the predominant crayfish in Hartwell Reservoir tailwater) is especially adapted for life in flowing water; its superior streamlining helps to prevent it from drifting in strong currents.

Even though bluegills ate considerable quantities of aquatic insects and terrestrial organisms during pregeneration, the relative weights of these organisms in their stomachs did not decline from pregeneration to postgeneration as observed for redbreast sunfish and green sunfish. Relative weights for aquatic insects and terrestrial organisms were generally similar in pregeneration and postgeneration samples. However, bluegill stomachs collected in July contained many more terrestrial organisms during postgeneration than during pregeneration. This and the similar weights for aquatic insects and terrestrial organisms (September only) in both pregeneration and postgeneration samples may have resulted because bluegills were primarily collected from backwaters where limited feeding during generation may have been possible.

As determined from the foods eaten by fish in this study, predation during periods of nongeneration on organisms entrapped and concentrated by flows associated with hydropower generation appeared to be the major mode of feeding for fish in the Hartwell Reservoir tailwater. These fish ate considerable numbers of chironomids (pupae and adults), ephemeropterans (adults), and trichopterans (larvae and adults) which originated from the tailwater. Concentrations of these organisms were often observed in the surface film behind obstructions such as rocks and logs after generation, where they were readily available as food for fish. Flows during generation apparently drowned many of these insects while emerging and concentrated them in these areas. In addition to aquatic insects, terrestrial organisms were similarly concentrated. These organisms were thought attracted to the unflooded area of the tailwater during periods of nongeneration where they were also drowned and concentrated by flows during generation. The presence of aquatic insects and terrestrial organisms in silver redhorse suggests that the concentration of these organisms was not totally a surface phenomenon, but that this material was also concentrated behind submerged objects.

Thus, our data apparently supports the suspicions of Matter et al. (1983) who questioned the ability of fish in the Hartwell Reservoir tailwater to eat displaced reservoir biota extensively during periods of generation. This was apparently true for the 4 species of fish studied during the time of our sampling. However, consumption of tailwater biota was related to daily flow regimes associated with peaking hydropower operations.

Literature Cited

Armitage, P. D. 1977. Invertebrate drift in the regulated River Tees, and an unregulated tributary Maize Beck, below Cow Green Dam. Freshwater Biol. 7:167–183.

Barwick, D. H. and J. L. Oliver. 1982. Fish distribution and abundance below a southeastern hydropower dam. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:135–145.

Benke, A. C., D. M. Gillespie, and F. K. Parish. 1979. Biological basis for assessing impacts of channel modification: invertebrate production, drift, and fish feeding in a southeastern blackwater river. Ga. Inst. Tech., Completion Rep. OWRT Proj. B-105-GA, Atlanta. 187pp.

Benson, N. G. and B. C. Cowell. 1968. The environment and plankton density in Missouri River reservoirs. Pages 358–373 *in* Reservoir fishery resources symposium. Reservoir Comm., Southern Div. Am. Fish. Soc., Bethesda, Md.

Borgeson, D. P. 1963. A rapid method for food-habits studies. Trans. Am. Fish. Soc. 92:434–435.

Brooker, M. P. and R. J. Hemsworth. 1978. The effect of the release of an artificial discharge of water on invertebrate drift in the R. Wye, Wales. Hydrobiologia 59:155–163.

Coomer, C. E., Jr., D. R. Holder, and C. D. Swanson. 1979. A comparison of the diets of redbreast sunfish and spotted sucker in a coastal plain stream. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31:587–596.

Davis, J. R. 1972. The spawning behavior, fecundity rates, and food habits of the redbreast sunfish in southeastern North Carolina. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:556–560.

Dudley, R. G. and R. T. Golden. 1974. Effect of a hypolimnion discharge on growth of bluegill (*Lepomis macrochirus*) in the Savannah River, Georgia. Univ. of Ga., Final Rep. USDI/OWRR Proj. B-057-GA, Athens. 28pp.

Hobbs, H. H., Jr. 1981. The crayfishes of Georgia. Smithsonian Contrib. to Zool., No. 318. Smithsonian Inst. Press, Washington, D.C. 549pp.

Hudson, P. L. and B. C. Cowell. 1966. Distribution and abundance of phytoplankton and rotifers in a main stem Missouri River reservoir. Proc. S.D. Acad. Sci. 45:84–106.

Keast, A. and L. Welsh. 1968. Daily feeding periodicities, food uptake rates, and dietary changes with hour of day in some lake fishes. J. Fish. Res. Board Can. 25:1133–1144.

Mancini, E. R., M. Busdosh, and B. D. Steele. 1979. Utilization of autochthonous macroinvertebrate drift by a pool fish community in a woodland stream. Hydrobiologia 62:249–256.

Matter, W. J., P. L. Hudson, and G. E. Saul. 1983. Invertebrate drift and particulate organic material transport in the Savannah River below Lake Hartwell during peak power generation cycle. Pages 357–370 *in* T. D. Fontaine III and S. M. Bartell, eds. Dynamics of lotic ecosystems. Ann Arbor Sci., Ann Arbor, Mich.

Maude, S. H. and D. D. Williams. 1983. Behavior of crayfish in water currents: hydrodynamics of eight species with reference to their distribution patterns in southern Ontario. Can. J. Fish. Aquat. Sci. 40:68–77.

Meyer, W. H. 1962. Life history of three species of redhorse (*Moxostoma*) in the Des Moines River, Iowa. Trans. Am. Fish. Soc. 91:412–419.

Minckley, W. L. 1963. The ecology of a spring stream Doe Run, Meade County, Kentucky. Wild. Soc. Monogr. 11. 124pp.

Walburg, C. H. 1971. Loss of young fish in reservoir discharge and year-class survival, Lewis and Clark Lake, Missouri River. Pages 441–448 *in* G. E. Hall, ed. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Pub. 8.

———, G. L. Kaiser, and P. L. Hudson. 1971. Lewis and Clark tailwater biota and some relations of the tailwater and reservoir fish populations. Pages 449–467 *in* G. E. Hall, ed. Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Pub. 8.