FOOD OF LARVAL YELLOW PERCH IN A SOUTH CAROLINA RESERVOIR RECEIVING HEATED EFFLUENT

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Abstract: Food of larval yellow perch (*Perca flavescens*) from Keowee Reservoir, South Carolina was determined before (1973) and after (1976) power production began a 2,580-MW nuclear power plant. Mean water temperatures at 1 m increased 2-3 C throughout the reservoir by 1976. The diet of larvae examined consisted exclusively of zooplankton. Cyclopoid copepods, *Diaptomus mississippiensis* and *Diaphanosoma brachyurum* were the principal organisms eaten in all areas even though other organism were sometimes more abundant. The operation of the plant reduced zooplankton abundance in the discharge cove while the amount of zooplankton consumed by larval yellow perch increased.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 35:592-597

Effects of a heated effluent from a nuclear power plant on reproduction, growth and standing crop of yellow perch have been studied in Keowee Reservoir, South Carolina (Clugston et al. 1978). After the plant began discharging heated water, catches of young-of-the-year yellow perch declined in all areas of the reservoir, especially near the heated discharge, from 23.0 to 0.3 per trawl haul (Ruelle et al. 1977). Because water temperatures never reached lethal levels, possible causes for declining larval numbers include: trends related to reservoir aging, increased predation, temperature changes (sufficient to alter reproductive or other behavorial patterns), and flushing and diluting effects of larval-free condenser cooling water discharged from the plant. This study was designed to determine food selection and food availability before and after the discharge of heated water and whether these contributed to the reduction in abundance of larval yellow perch in Keowee Reservoir.

Keowee Reservoir was constructed by Duke Power Company primarily to supply cooling water for the 2,580-MW Oconee Nuclear Station. This warm monomictic reservoir reached full pool evlevation of 243.8 m above mean sea level in April 1971, and has a surface area of 7,435 ha, a mean depth of 15.8 m (maximum 45.7 m), and a storage volume of 11.79×10^8 m^3. Condenser cooling water for the nuclear station flows beneath a skimmer wall (a concrete barrier across the intake canal) at a depth of 19.8 to 27.4 m and is discharged approximately 10 C above the intake temperature. The reservoir generally begins to stratify thermally in late March or early April and remains stratified until turnover in late September or October. Surface temperatures are usually highest in July and August, when they range from 27 C to 32 C. Water temperatures are usually isothermal from November through February (Duke Power Company 1976).

The 1st of the plant's 3 units began commercial operation in July 1973, the 2nd in September 1974 and the 3rd in December 1974. Power production averaged 1.3% of rated capacity during the period of larval fish sampling in 1973 (13 Mar -4 Jun) and 35.7% during the sampling period in 1976 (16 Mar - 11 May).

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METHODS

Two stations in Keowee Reservoir were sampled: one (the control) in the south impoundment, 11 km south of the power plant; and one near the discharge cove of the nuclear plant. Larval yellow perch (6-18 mm total length) and zooplankton were collected simultaneously. Larval yellow perch were collected weekly from March to June with a frame trawl (1.3-m^2 aluminum frame, 6.1-m long, 0.8-mm mesh nylon net) towed at a depth of 1 m during daylight (Ruelle et al. 1977) and zooplankton were collected with a No. 20 Wisconsin net (0.076 mm) mounted in the opening of the frame trawl. All samples were preserved in 10% formalin and zooplankton samples were counted by the technique of Cowell (1967). Water temperature was measured weekly at 1 m in each area with a temperature-oxygen meter. Total length of each fish was measured to the nearest 0.1 mm with an ocular micrometer. The entire digestive tract was excised and food organisms identified and counted. Computations of mean numbers of organisms per stomach and percent occurrence included only stomachs containing food.

Selection of available food by larvae was determined by using the quantitative index of electivity:

$$E = \frac{r_i - P_i}{r_i + P_i}$$

where E = electivity, r_i = percent composition of zooplankter i in the digestive tract and P_i = percent composition of zooplankter i in the zooplankton sample (Ivlev 1961). E values range from −1 (complete avoidance of prey item) to +1 (complete selection of prey item).

Larval yellow perch were divided into 3 length groups (6.0 – 9.9, 10.0 – 13.9 and 14.0 – 18.0 mm) to determine the effect of fish size on food selection. Since sample size was small and sampling distribution unknown, the Mann-Whitney nonparametric test (Conover 1971) was used to test differences in average number of food organisms consumed by perch for each length group between areas by year. If no area differences were found, samples were combined and differences tested between years. Results of statistical analysis were considered significant when $P \leq 0.05$.

RESULTS

Water Temperatures

Water temperatures at a depth of 1 m were not significantly different at control and discharge areas throughout the sampling period in 1973 but were significantly higher at the discharge area during 1976. Mean water temperatures during 1976 were 16.0 C at the control area and 17.4 C at the discharge area as compared with 15.1 C and 15.0 C in 1973. In general, 1976 water temperatures were about 2 C higher than in 1973, even though air temperatures were lower in 1976 than in 1973 (Kish 1974, 1977) — suggesting that the operation of Oconee Nuclear Station substantially affected reservoir water temperatures.

Zooplankton Abundance

Eighteen species of copepods and cladocerans — 13 planktonic and 5 littoral or benthic — were collected from Keowee Reservoir. Total densities were generally less than 3 organisms/l. *Diaptomus* and cyclopoids (including nauplii) were the most abundant copepods while *Diaphanosoma, Holopedium amazonicum, Daphnia* spp. and *Bosmina* spp. were the most abundant cladocerans. The three major types of organisms eaten (cyclopoid copepods, *Diaptomus* and *Diaphanosoma*) made up less than 40% of the total zooplankton standing crop. Copepod nauplii made up the largest proportion (42% to 63%) of the numbers of zooplankters in both areas and both years, but were seldom eaten. Total standing crop of zooplankton at all areas was 2.7/l during 1973 and 1.9/l during 1976 — a 42% decrease. During 1976, only *Bosmina* spp. and cyclopoid copods increased in concentration over 1973 densities. All other zooplankton species remained near the same or decreased in concentration, especially in the discharge cove.

Food Selection

A total of 237 larvae was examined. Larvae (still with yolk sac) began feeding at a length of about 6.2 mm; the yolk sac was completely absorbed in fish longer than 7.2 mm. Stomachs were empty in 14% of the perch examined in 1973 and in 10% in 1976. Of the empty stomachs, 94% in 1973 and 89% in 1976 were from fish 6.0 to 7.9 mm long. Larval yellow perch fed exclusively on zooplankton, of which 86% to 98% were cyclopoid copepods (primarily *Mesocyclops edax*, 54%, and *Cyclops vernalis*, 24%), the calanoid copepod *Diaptomus mississippiensis*, and the cladoceran *Diaphanosoma brachyurum* (Table 1). Other zooplankters eaten in small quantities (<0.5/digestive tract) on various dates were *Holopedium amazonicum, Daphnia* spp. and *Bosmina* spp. Copepod nauplii were uncommon (<0.1/digestive tract) even in small (<8.0 mm) fish.

The number of cyclopoid copepods, *Diaphanosoma, Diaptomus* and total zooplankters eaten did not differ significantly ($P \leq 0.05$) between control and discharge areas in 1973 and 1976. Therefore, comparisons were made between years with areas combined. The number of *Diaptomus* eaten was not significantly different between years within any length group. During 1976, significantly more *Diaphanosoma* and total zooplankton were eaten by fish in the 6.0 - 9.9-mm length group. In the 10.0 - 13.9-mm length group significantly more cyclopoid copepods, *Diaphanosoma,* and total zooplankton were eaten in 1976 than 1973. However, only the number of cyclopoid copepods eaten by fish showed a significant difference between years in the largest length group (14.0 - 18.0 mm).

Fish in the 6.0 - 9.9-mm length group contained an average of 3.4 zooplankters per stomach in 1973 and 5.1 in 1976. As the fish grew, the mean number of zooplankters in the diet increased, reaching a maximum of 14.9 in 1973 and 18.9 in 1976 for fish in the 14.0 - 18.0-mm length group. In 1976 the total number of zooplankters per stomach in all length groups increased 19% over 1973. More than 1½ times as many cyclopoid copepods and over 70% more *Diaphanosoma* were eaten in 1976 than 1973.

Changes in electivity indices (E) occurred between length groups for the 3 major prey types eaten — cyclopoid copepods, the calanoid copepod *Diaptomus,*

Table 1. Mean number and percent occurrence (in parentheses) of the 3 most common food items and total food items found in the digestive tracts of 3 length groups of yellow perch captured from Keowee Reservoir, South Carolina, during March through mid-June, 1973 and 1976.

	Mean food items per digestive tract					
	6.0 - 9.9 mm Total length		10.0 - 13.9 mm Total length		14.0 - 18.0 mm Total length	
Food item	1973	1976	1973	1976	1973	1976
Copepods						
Cyclopoids	0.7	1.2	0.1	1.2	0.7	3.7
	(45)	(51)	(14)	(62)	(37)	(67)
Diaptomus mississippiensis	1.7	1.3	3.9	2.9	7.7	5.6
	(66)	(60)	(95)	(77)	(87)	(73)
Cladocerans						
Diaphanosoma brachyurum	0.7	1.9	1.8	4.4	5.5	9.3
	(33)	(60)	(52)	(85)	(93)	(93)
Total	3.4	5.1	6.2	8.7	14.9	18.9
Number of fish examined	67	65	21	39	30	15

and the cladoceran *Diaphanosoma*. Cyclopoid copepods were positively selected at all areas during both years by fish <10 mm, but were not selected during 1973 by perch >10 mm at either sampling area. In 1976, all length groups selected cyclopoid copepods. During 1973, all sizes of perch at both areas exhibited a preference for *Diaptomus;* however, during 1976 larval perch rejected or showed little preference for *Diaptomus* in the control area, but positively selected it in the discharge area. Preference for *Diaphanosoma* increased with an increase in fish size in all areas and years. Fish rejected nauplii at both areas and in both years. Although *Bosmina* spp., *Daphnia* spp. and *Holopedium* were present in the zooplankton community in concentrations equal to or greater than cyclopoid copepods, they were rarely eaten.

DISCUSSION

Food of larval yellow perch in Keowee Reservoir was different from that reported in studies of northern non-cooling lakes and reservoirs. Galbraith (1967) while studying 2 Michigan lakes found that yellow perch utilized *Daphnia* exclusively even though there were other zooplankton species present. Wong and Ward (1972), in West Blue Lake, Manitoba, found that yellow perch fed heavily on *Daphnia* and less frequently on *Cyclops* and *Diaptomus.* Bulkley et al. (1976) and Clady (1977) found *Bosmina* to be an important food item for larval yellow perch from lakes in Iowa and New York, respectively. Although *Daphina* spp. and *Bosmina* spp. were rarely eaten in Keowee Reservoir, they were present in the zooplankton community in concentrations equal to or greater than those of cyclopoid copepods or *Diaphanosoma.* As the perch grew, they selected larger, more abundant zooplankters, exhibiting a particularly high selectivity for *Diaphanosoma.* Even though copepod nauplii (the smallest zooplankters) made up the largest proportion of the standing crop of zooplankton, they were seldom eaten. This is in contrast to what Siefert (1972) found in his study of larval yellow perch from two Minnesota lakes where copepod nauplii were the dominant food at initiation of feeding and remained a common food item for all sizes of fish examined.

A basic change in larval feeding intensity occurred over the length of our study. The average number of cyclopoid copepods and *Diaphanosoma* eaten increased substantially from 1973 to 1976 even though their abundance in the reservoir decreased. A possible explanation for this change in feeding intensity could be the increased reservoir-wide water temperatures resulting in increased fish metabolic activity and their need to consume more food in order to grow and maintain themselves. Although increased water temperatures were in the 2 - 3 C range, they may have been sufficiently large to impact yellow perch in Keowee Reservoir, which lies on the southern range of this species distribution.

The decreased abundance of zooplankton in the discharge area resulted from Oconee Nuclear Station's use of a skimmer wall which limits the intake of cooling water to depths below 20 meters. Hudson and Nichols (1978) found that selective withdrawal of water from depths below 20 meters with low zooplankton densities, coupled with possible latent zooplankton mortality, created an area of low standing crop in the discharge area from mid-October through June. This mode of operation resulted in a dilution of zooplankton in most of the outfall area during a period when larval yellow perch were present.

This study has shown that the food habits of yellow perch has changed considerably between 1973 and 1976. Whether these changes could be related to the general decline of yellow perch in Keowee Reservoir due to increased power production by Oconee Nuclear Station is questionable. However, it seems plausible that these changes, along with increased water temperatures, increased competition for the available food source and other trends related to reservoir aging, may have contributed to the overall reduction of yellow perch.

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