THE OCCURRENCE AND DISTRIBUTION OF LARVAL FISH IN THE CUMBERLAND RIVER

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ABSTRACT

The seasonal distribution of larval fish in the Cumberland River was studied in 1974 and 1975 as part of an environmental monitoring program at the site of the proposed Hartsville Nuclear Power Plant near Dixon Springs, Tennessee. Meter and half-meter diameter nets were used to collect 13,571 larval or young juvenile fish of 13 families during evening hours from April to mid-August. Clupeids, catostomids and Lepomis *sp. dominated the collections during both years. Concentrations of larval fish were significantly ($P \leq 0.05$) higher in the Dixon Creek backwater area than in the river proper. Equations were developed by stepwise multiple regression to predict the seasonal abundance of major taxa and total larval fish populations by water temperature and discharge correlations.*

Concern has been focused recently on the environmental problems associated with electric power stations and other large industries. One particular area of concern is related to withdrawing large quantities of water from a river, lake or estuary for cooling purposes and subsequently withdrawing large numbers of fish eggs and larvae (U.S. Dept. of Commerce, 1973). The degree of mortality involved has been debated, although most agree it is usually high with once-through cooling and near 100 percent for closed-cycle cooling (Hearings . . . , 1974; and Marcy, 1973). Since so little information is available concerning the distribution of larval fish and eggs, as well as species composition and relative abundance, predictions of impacts upon these groups of organisms are nebulous. Studies of these populations are vital to an understanding of the potential impact of a water-using utility or industry on fish populations.

Few studies on the distribution of larval fish taxa are available. Nelson et al. (1968) described an extensive sampling program for monitoring young fishes in Missouri River impoundments. Taber (1969) studied the distribution of larval fishes in an arm of Lake Texoma, Oklahoma. Larval fishes were captured in the limnetic portions of two Wisconsin lakes and the possible reasons for their movements were discussed by Faber (1967). Dovel (1971) reported on an 11-year study in the Chesapeake Bay area and stressed salinity and temperature correlations with larval fish distribution. Mundy (1973) and Walker (1975) have completed larval fish studies on Tennessee River reservoirs.

The objectives of this Cumberland River study were to describe the vertical, horizontal and seasonal distribution patterns of the larval fish populations in the area of the proposed Hartsville Nuclear Power Plant. The following report presents a description of seasonal distribution patterns.

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MATERIALS AND METHODS

Old Hickory Reservoir, a U.S. Army Corps of Engineers impoundment on the Cumberland River, is located in middle Tennessee. All portions are navigable by river traffic. Completed in 1957, this reservoir is 157.1 km long and has a total surface area of 7915 to 9109 ha. The surrounding area is composed of generally low rolling hills with bottom lands along the river and larger streams. The area is underlain by nearly horizontal limestone strata. Mean monthly temperatures range from 4.1 C in January to 25.7 in July. Average annual precipitation is 133.32 cm (Tennessee Valley Authority, 1974).

The continuous river flow is controlled upstream by the Cordell Hull (Cumberland River) and Center Hill (Caney Fork River) dams. The study area is located between Cumberland River Miles (CRM) 284 and 286, approximately 111 km upstream from Old Hickory Dam and near the proposed site of the Hartsville Nuclear Power Plant (Figure 1).

Samples were collected from a transect at CRM 285.5 in 1974 and 1975, and from an additional transect at CRM 284.5 in 1975. The backwater formed by the reservoir and Dixon Creek, a small stream which enters the river at CRM 285, was also sampled during both years. Three backwater stations were sampled in 1974 and one in 1975 (with depths that ranged from one to six meters).

This section of the reservoir was typified by steeply sloping banks and was devoid of rooted aquatic plants. Midchannel depths in summer ranged from approximately eight to ten meters, and river width varied from 110 to 150 meters in the study area. Some shallow areas were found at the mouths of tributaries or adjacent to islands. Riparian woodlands existed along the shores.

Air and water temperatures were taken during each sampling trip (usually weekly) with a mercuric Celsius pocket thermometer. River conditions, such as relative turbidity and amount of floating debris, and weather conditions were also recorded. River discharge data from the Carthage gauging station (24 km upstream) were obtained from the U.S. Geological Survey, Nashville Office.

Larval fish were collected with two sizes of plankton nets similar to those described by Netsch et al. (1971) and Walker (1975). A 1.0 m diameter net was used in 1974, while two 0.5 m diameter nets were used in 1975. All nets were equipped with 0.8 mm delta mesh netting. Flowmeters were mounted in the mouths of the nets to provide water volume estimates.

Samples were collected weekly from 5 April through 15 August in 1974, and from 24 March through 7 August in 1975. The nets were attached near the front of the boat and suspended at the appropriate depth with half-inch rope and an 11.3 kg steel and lead weight. The nets were pushed upstream at low speed. At the completion of each tow (three to five minutes, depending on the amount of debris collecting in the nets) the outboard motor was disengaged and the net(s) retrieved by hand. The retrieval process normally required five to ten seconds.

Replicate tows were made at 0.5 m (surface) and 2.0 on each shoreline (within 15 m of the bank), and at 0.5, 2.0, 6.0 and 10.0 (bottom) m in the midchannel. The deeper midchannel tows at CRM 284.5 were often taken at 4.0 and 8.0 m during the summer due to the decreased river depths associated with low discharge. Vertical tows were made in the Dixon Creek backwater in 1974, but horizontal tows were taken with the half-meter nets at 0.5 and 2.0 m in 1975. Tows were made at night to reduce net avoidance by the larval fish (Noble, 1970; and Scotton et al. 1973). Samples were rinsed into one quart plastic 'freezer' bags, labelled and preserved with formaldehyde (5% solution) in the field.

In the laboratory, larvae were separated, identified, enumerated and measured to the nearest 0.1 mm. All samples were processed by a single individual to reduce sorting efficiency variations.

Larvae were identified to the lowest identifiable taxon utilizing primarily a key (unpublished mimeo) developed by Tennessee Valley Authority biologists in early 1975 for use in the Tennessee River system. Drawings, photographs, and descriptions by Mansueti and Hardy (1967), Nelson (1968), Priegel (1967), Purkett (1961), Siefert (1969), Taber (1969), Wrenn and Grinstead (1971) and Yellayi and Kilambi (1969) were helpful in identification. Common and scientific names used throughout this report are from Bailey (1970).

Terminology developed by Hubbs (1943) was followed in this study: i.e., (1) *prolarvae* were fish which still had a visible yolk-sac; (2) *postlarvae* were fish whose yolk had been absorbed, but which did not yet have a full complement of fin rays; and (3) *juveniles* had fully-developed fin rays and had assumed the shape of the adults, but had not yet attained sexual maturity. All juveniles mentioned in this report were young-of-the-year (i.e., not yet one year old).

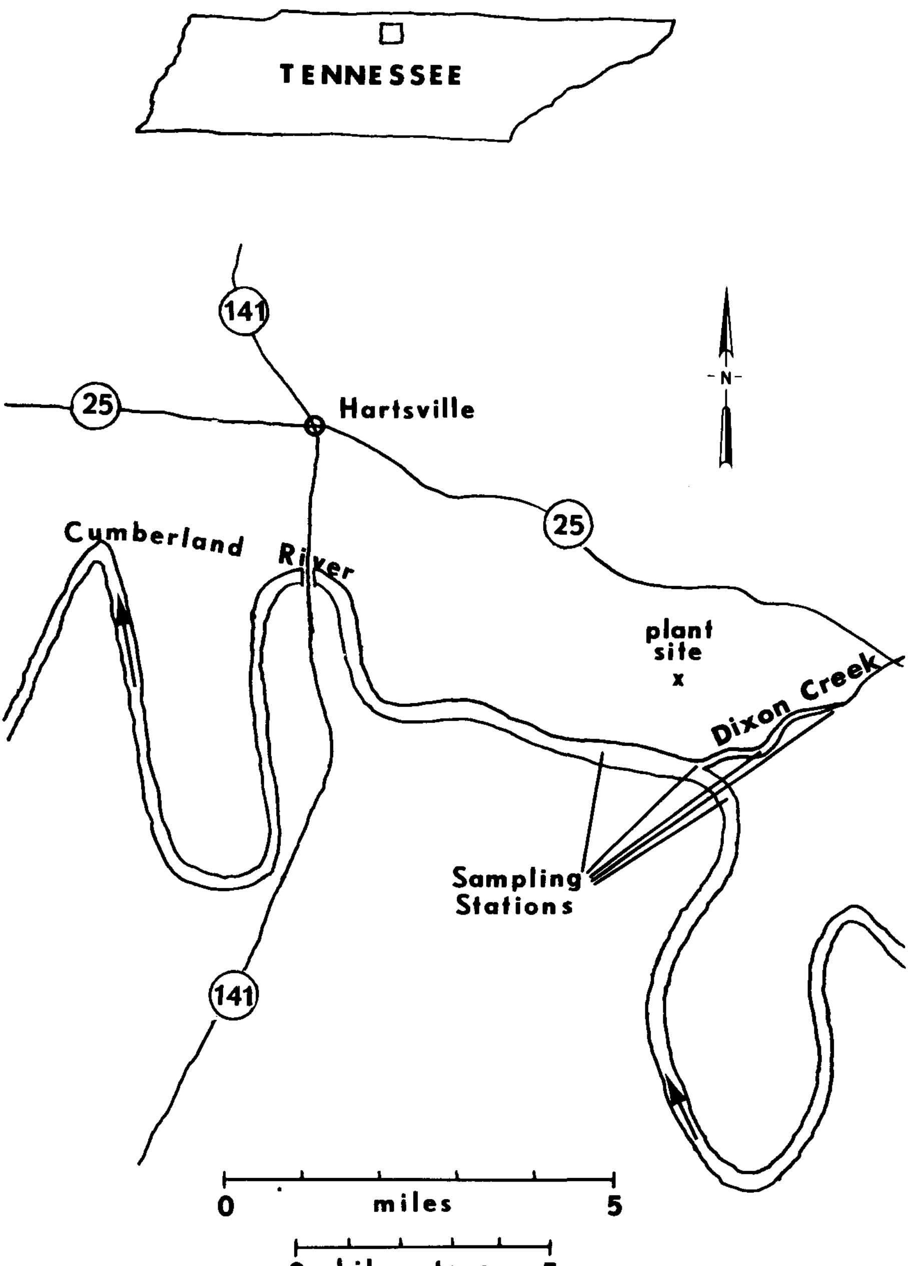

Figure 1. Larval fish sampling stations in the Cumberland River and in the Dixon Creek backwater area near the proposed site of the Hartsville Nuclear Power Plant in north central Tennessee.

Volume of water filtered at each location varied with net size (meter or half-meter diameter) and sampling time (three to five minutes). Larval fish concentrations were expressed as number per ten cubic meters of water sampled, which was then interpreted as abundance or concentration of larval fish. Stepwise multiple regression was used to describe the relationship which existed between larval fish concentrations and water temperature. Concentrations were transformed to log (X+1) since some portions of this data were found to be nonrandom through use of the Chi-squared test.

A Student t-test was used to compare the differences between the means of the creek and river temperatures and between water temperatures during the two years. Model equations were developed for predicting larval fish abundance in the study area, and the results were compared with those from another southeastern mainstream reservoir.

RESULTS

Water temperatures ranged from 9 to 26 C during the study (Figure 2). Water temperatures were significantly ($P \leq 0.05$) lower in 1975 than in 1974 through the first week of May. Thereafter, water temperatures were similar in both years. River temperatures were significantly lower than backwater temperatures during April and May of both years and in July of 1975.

River discharge ranged from 48 to 2353 cms during the study. In general, discharge decreased from April through the end of June, and fluctuated throughout the remainder of the summer.

Twenty-five taxa of larval fish were identified (Table 1). Incomplete larval species descriptions necessitated clumping many closely-related forms. For example, five groupings of the family Clupeidae were established: *Alosa chrysochloris* (prolarval and juvenile skipjack herring), *Dorosoma* sp. (prolarval gizzard and threadfin shad), unidentifiable Clupeidae (postlarval shad and skipjack herring), *Dorosoma cepedianum* (juvenile gizzard shad) and *Dorosoma petenense* (juvenile threadfin shad).

Larval fish were present in the study area from April into August. Larval concentrations were greatest in late June through July (Figure 3). A smaller pulse, consisting mainly of catostomids, occurred in late April and early May. Sampling was terminated in mid-August, when late postlarval and juvenile shad and sunfish dominated the collections. Throughout the summer, concentrations of larval fish were much greater in the creek than in the river.

During 1974 and 1975, a total of 13,571 larval or young juvenile fish were collected (Table 1). Three taxa dominated the collections during both years (Figures 4 and 5). Catostomids were very abundant in 1974, and less so in 1975. *Lepomis* sp. were very abundant in 1975, and less so in 1974. Clupeids were the most abundant taxa during both years, comprising 66.2 and 57.0% of the total numbers in 1974 and 1975, respectively.

Logperch, carp and some other unidentifiable cyprinids were the first taxa to appear in the collections, shortly after the water temperature exceeded 11 C (Figures 6 and 7). This occurred by mid-April in 1974, but not until early May in 1975 due to extremely heavy runoff that spring (Figure 2).

Paddlefish, mooneye and sauger concentrations peaked when the river water temperature reached 15 C. Catostomid abundance was highest slightly later, at 16 C. Larval cyprinids, except carp and emerald shiner, were virtually absent above 20 C.

During midsummer, when water temperatures ranged from 18 to 26 C, *Lepomis* sp., clupeids and freshwater drum larvae were abundant. Concentrations of these taxa peaked in late July, and late-summer collections often contained several juveniles, as well as larvae.

Carp and clupeid larvae were present during most sampling periods. Prolarval clupeids (*Dorosoma* sp.) were much less abundant in 1975 than in 1974, but this decreased abundance was not reflected in the larger postlarval (unidentifiable Clupeidae) and juvenile (*Dorosoma cepedianum* and *D. petenense*) size groups (Table 1).

DISCUSSION

Parameters which are thought to trigger spawning activity include water levels (Hassler, 1970), water temperature (Rawson, 1945) and day length (Snow et al. 1964). June

Table 1. Larval fish collected in the Cumberland River (Old Hickory Reservoir) and in the Dixon Creek backwater in 1974 and 1975.

	1974		1975	
Taxon	*No. Fish*	*% Total No.*	*No. Fish*	*% Total No.*
PETROMYZONTIDAE				
Lampetra lamottei	4	0.1	2	<0.1
POLYODONTIDAE				
Polyodon spathula	6	0.1	43	0.5
LEPISOSTEIDAE				
Lepisosteus sp.	0	0.0	2	<0.1
CLUPEIDAE				
Alosa chrysochloris	0	0.0	2	<0.1
Dorosoma sp.	596	10.7	55	0.7
Unidentifiable Clupeidae	2991	53.8	4270	53.4
Dorosoma cepedianum	54	1.0	95	1.2
Dorosoma petenense	39	0.7	131	1.6
HIODONTIDAE				
Hiodon tergisus	1	<0.1	60	0.8
CYPRINIDAE				
Cyprinus carpio	38	0.7	93	1.2
Notropis atherinoides	5	0.1	36	0.4
Pimephales sp.	0	0.0	13	0.2
Unidentifiable Cyprinidae	23	0.4	12	0.2
CATOSTOMIDAE				
Catostomidae	1311	23.6	438	5.5
ICTALURIDAE				
Ictalurus natalis	0	0.0	1	<0.1
Ictalurus punctatus	0	0.0	2	<0.1
ATHERINIDAE				
Labidesthes sicculus	0	0.0	1	<0.1
PERCICHTHYIDAE				
Morone chrysops	4	0.1	15	0.2
CENTRARCHIDAE				
Lepomis sp.	427	7.7	2567	32.1
Lepomis macrochirus	1	<0.1	4	0.1
Micropterus sp.	0	0.0	5	0.1
Pomoxis sp.	2	<0.1	2	<0.1
PERCIDAE				
Percina caprodes	27	0.5	35	0.4
Stizostedion canadense	2	<0.1	21	0.3
SCIAENIDAE				
Aplodinotus grunniens	25	0.4	90	1.1
TOTALS	5556	99.9	7995	100.0

(1970) found that northern pike resorbed their eggs when water temperature and water levels were lowered during their spawning season.

Many riverine species, especially catostomids, have reproductive requirements of rising or constant water levels over suitable substrates during spawning and incubation periods (Nelson et al. 1968). Benson (1973) stated that any decline in water levels during the fish reproduction period in Missouri River reservoirs will reduce the spawning success of some species. The absence of high flows can eliminate warm floodplain waters upon which some

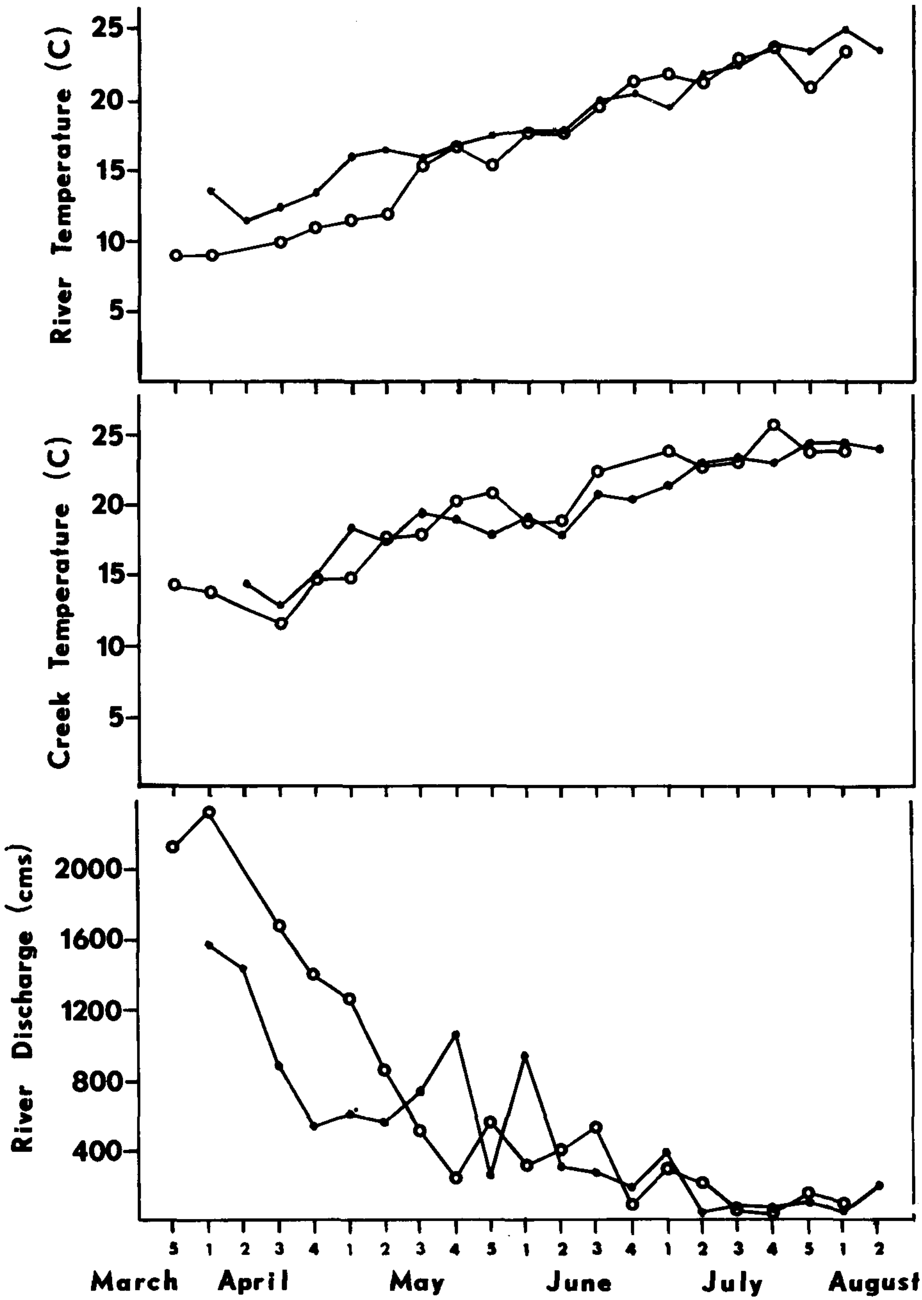

Figure 2. Cumberland River discharges and water temperatures of the river and Dixon Creek during the larval fish sampling seasons in 1974 (closed circles) and 1975 (open circles).

stream species are dependent for spawning, food production and nursery areas (Fraser, 1972).

Fish spawning activities have resulted from adaptations which give the young maximum protection from predators and an adequate food supply (Nikolskii, 1969). Faber (1967) pointed out that variations in spawning time are correlated to seasonal variations of plankton. It follows then that rapid spawning is primarily an adaptation to a short growing season, during which appropriate food for the young is present for only a short period. Prolonged or repeated spawning activities are adaptations to a long growing season for food and to unstable spawning conditions, respectively. Examples of each type of spawning are the sauger for rapid (Nelson, 1968), the carp for prolonged (Jester, 1974) and the bluegill for repeated (Snow et al. 1964).

Water temperature must be within a suitable range for each particular species if their reproduction is to be successful (Snow et al. 1964). Colby and Brooke (1973) developed regression models for predicting hatching times of lake herring at varying water temperatures. They noted a sudden change in temperature may lead to disharmony between hatching date and larval food. Temperature fluctuations have been found to affect survival, growth and number of vertebrae in larval fish (Fonds et al. 1973). A positive relationship between water temperature and growth of young white bass during their first summer was described by Ruelle (1971). Some fish species begin feeding before the yolk is completely absorbed, and thus do not possess a 'critical' period of changeover from yolk to external food sources as do other species (Hoagman, 1973).

Initial larval fish occurrence in the Cumberland River was approximately one month later in 1975 than in 1974 (Figure 3). Heavy rains during March led to flood conditions on the river during much of April 1975 (Figure 2). River water temperatures were suppressed throughout this period due to large releases from upstream reservoirs. While delaying spring spawning somewhat, this extreme flood situation apparently had detrimental effects on only the Catostomidae (Table 1, Figure 4) (Postlarval clupeids were less abundant in the river in 1975, but were more abundant in the creek). Other species, notably paddlefish, mooneye, white bass and sauger, had more successful reproduction through the larval stage in 1975 than in 1974.

Although tributary streams and coves of the Cumberland River warmed up much faster than the river proper, few species capitalized and spawned in both areas. Those taxa whose young were collected in both the river and the creek included carp, emerald shiner *Lepomis* sp., logperch and the clupeids. At some point late in the summer, it appears that the young-of-the-year shad leave the coves and enter the river proper. Rotenone studies conducted in Dixon Creek backwater in 1973 and 1974 indicated that large numbers of shad were present during late August, but that relatively few remained in September (Hess, 1974; 1975). Although they were fairly abundant in the river, freshwater drum larvae were rarely collected in the creek. Apparently adult drum do not spawn there, nor do the larvae congregate in this area.

In general, the results of the present study complement Faber's (1967) observations that the abundance of larvae can be quite variable from year to year, but that some species remain dominant. Dominant taxa in the Cumberland River during both 1974 and 1975 were the clupeids, catostomids and *Lepomis* sp. Though concentrations in the river and creek backwater varied from week to week, two main peaks of abundance did occur both years. The first was the result of catostomid abundance in late spring, and the other the result of large numbers of clupeids and *Lepomis* sp. in mid-summer (Figure 3).

A species-assemblage of nine taxa commenced spawning between 5 April and 2 May (between 11 and 12 C) (Figures 4 through 7). All other taxa (except *Pimephales* sp. which was collected initially at 15.5 C) did not appear until the water temperature had exceeded 17 C. The emerald shiner was the last of the abundant taxa to occur, at 21 C in July. The spawning season of the sauger appears to be exceedingly long in Figure 7, due to the collection of two juveniles in early July. Most sauger larvae were collected in May.

Predictive Model Equations

Since water temperatures and discharge have been documented as affecting reproduction in fishes and since the occurrence of larval fish in the Cumberland River

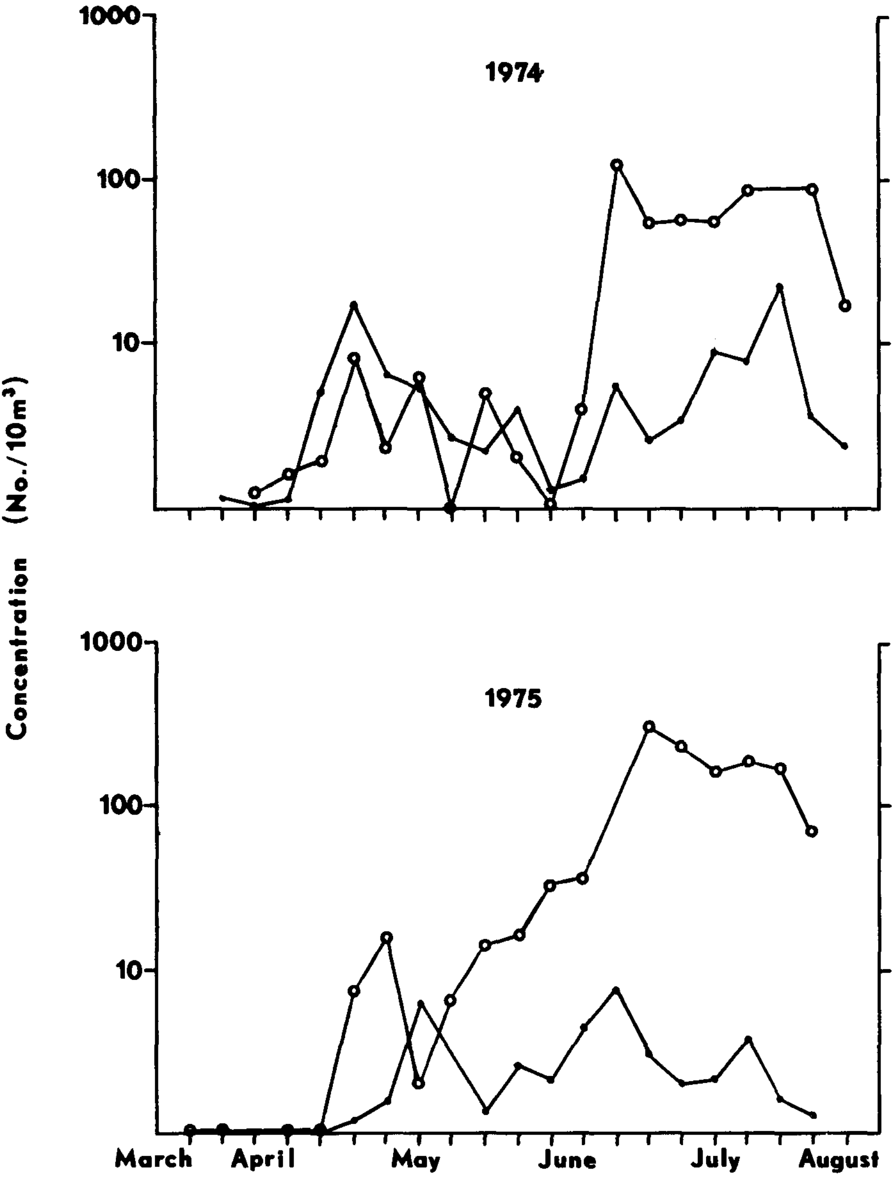

Figure 3. Concentrations of larval fish (weekly means) in the Cumberland River (closed circles) and in the Dixon Creek backwater (open circles) in 1974 and 1975.

appeared to be affected by one or both, model equations based on these two parameters were developed for predicting larval fish concentrations in the Cumberland River and Dixon Creek backwater (Table 2). Correlation coefficients demonstrated that in most cases water temperature, and to a lesser extent discharge, was highly correlated with larval fish abundance (using the stepwise multiple regression method) (Steel and Torrie, 1960). All equations in Table 2 are significant at $P \leqslant 0.05$.

A comparison waa made between the results of the present study and those of Walker's 1973-74 study on the Tennessee River to ascertain the extent to which the Cumberland River equations might accurately describe larval fish populations in other similar mainstream reservoirs in this region. The concentration of larval fish in the Cumberland River was slightly less than that described by Walker (1975) for the Tennessee River, Nickajack Reservoir (Figure 8). Two equations (both significant at $P \leqslant 0.05$) describing the total larval fish population in Nickajack Reservoir were computed using the same regression method. The population estimates for the Cumberland River and the Tennessee River are reasonably similar. Midsummer concentrations range from 1 to 4 larvae per $10m^3$ in the Cumberland and from 3 to 7 larvae per $10m^3$ in the Tennessee. The higher abundance in the Tennessee may be a function of the higher water temperatures, higher nutrient loads or abundant attached aquatic plant life in this river.

It appears that regression models of this type could be helpful in estimating larval fish populations in other similar reservoirs in the Southeast. Further studies are needed to determine 1) to what extent such models may be reliable, and 2) if mainstream reservoirs which have higher water temperatures or additional spawning and egg attachment substrate have higher larval fish production.

Table 2. Equations for prediction of occurrence and abundance of larval fish in the Cumberland River, Dixon Creek and Tennessee River based on water temperature and river discharge.

Total Number	$\log_n(C+1) = -.25205 + 03974T$
Dorosoma sp.	$\log_n(C+1) = -.41436 + .05899T - .00178T^2$
Clupeidae	$\log_n(C+1) = -.44778 + .03964T$
Catostomidae	$\log_n(C+1) = -1.22232 + .18219T - .00559T^2$
Lepomis sp.	$\log_n(C+1) = .46898 - .07255T + .00267T^2$
Aplodinotus grunniens	$\log_n(C+1) = -.08150 + .00608T$
Cumberland River - River Discharge	
Total Number	$\log_n(C+1) = .65720 - .00033D$
Clupeidae	$\log_n(C+1) = .40864 - .00025D$
Lepomis sp.	$\log_n(C+1) = .14105 - .00010D$
Aplodinotus grunniens	$\log_n(C+1) = .04887 - .00004D$
Dixon Creek - Water Temperature	
Total Number	$\log_n(C+1) = 2.55695 + 18679T$
Dorosoma sp.	$\log_n(C+1) = 1.20756 + .14323T - .00384T^2$
Clupeidae	$\log_n(C+1) = 2.67382 + .18155T$
Dorosoma cepedianum	$\log_n(C+1) = -.52920 + .03359T$
Dorosoma petenense	$\log_n(C+1) = -.65449 + .03994T$
Catostomidae	$\log_n(C+1) = -1.52662 + .18120T - .00490T^2$
Lepomis sp.	$\log_n(C+1) = -2.15725 + .13678T$
Dixon Creek - River Discharge	
Total Number	$\log_n(C+1) = 1.73658 - .00101D$
Clupeidae	$\log_n(C+1) = -1.43879 - .00088D$
Dorosoma cepedianum	$\log_n(C+1) = .23674 - .00017D$
Dorosoma petenense	$\log_n(C+1) = .24230 - .00018D$
Lepomis	$\log_n(C+1) = .95552 - .00069D$
Tennessee River - Water Temperature	
Total Number (1)	$\log_n(C+1) = -5.93817 + .63303T - .01468T^2$
Total Number (2)	$\log_n(C+1) = -.04681 + .03603T$

C = Concentration of larval fish (No./$10m^3$ of water)
T = Water Temperature (C)
D = River Discharge (cms)

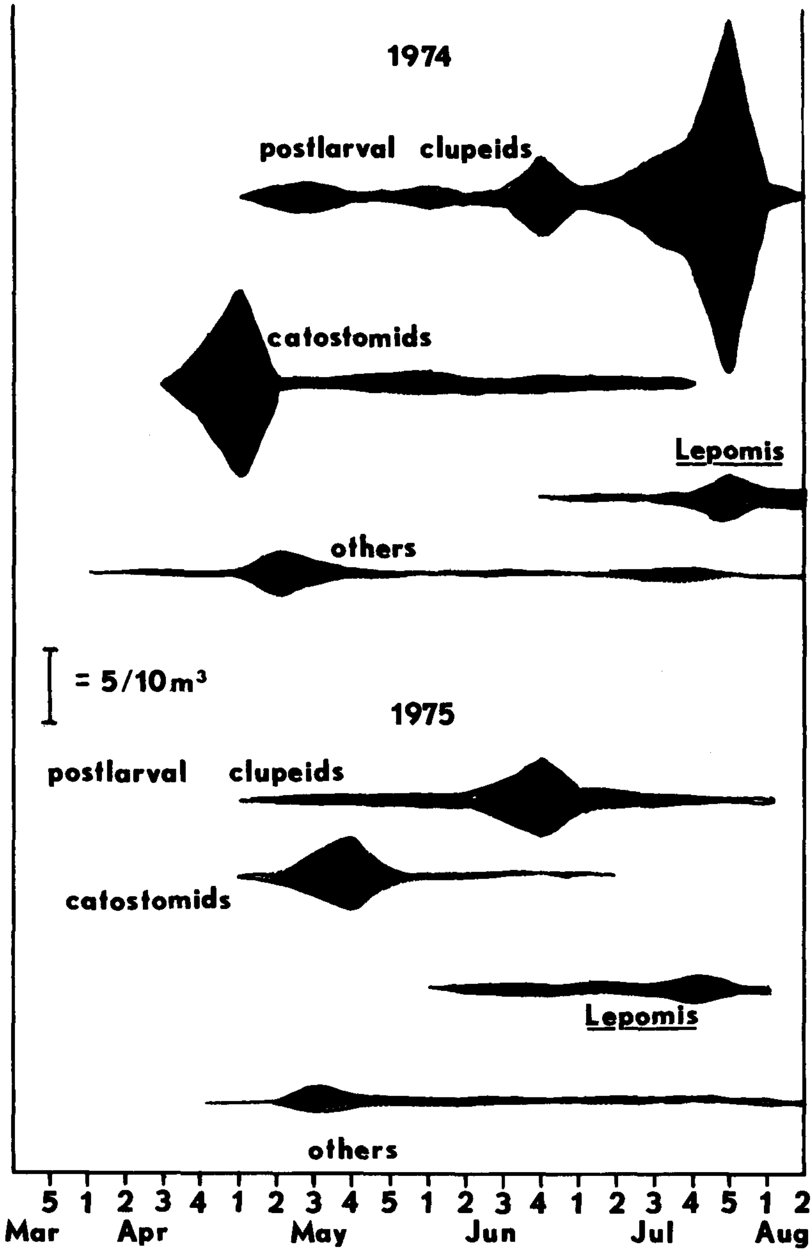

Figure 4. Seasonal distribution of dominant larval fish taxa in the Cumberland River in 1974 and 1975.

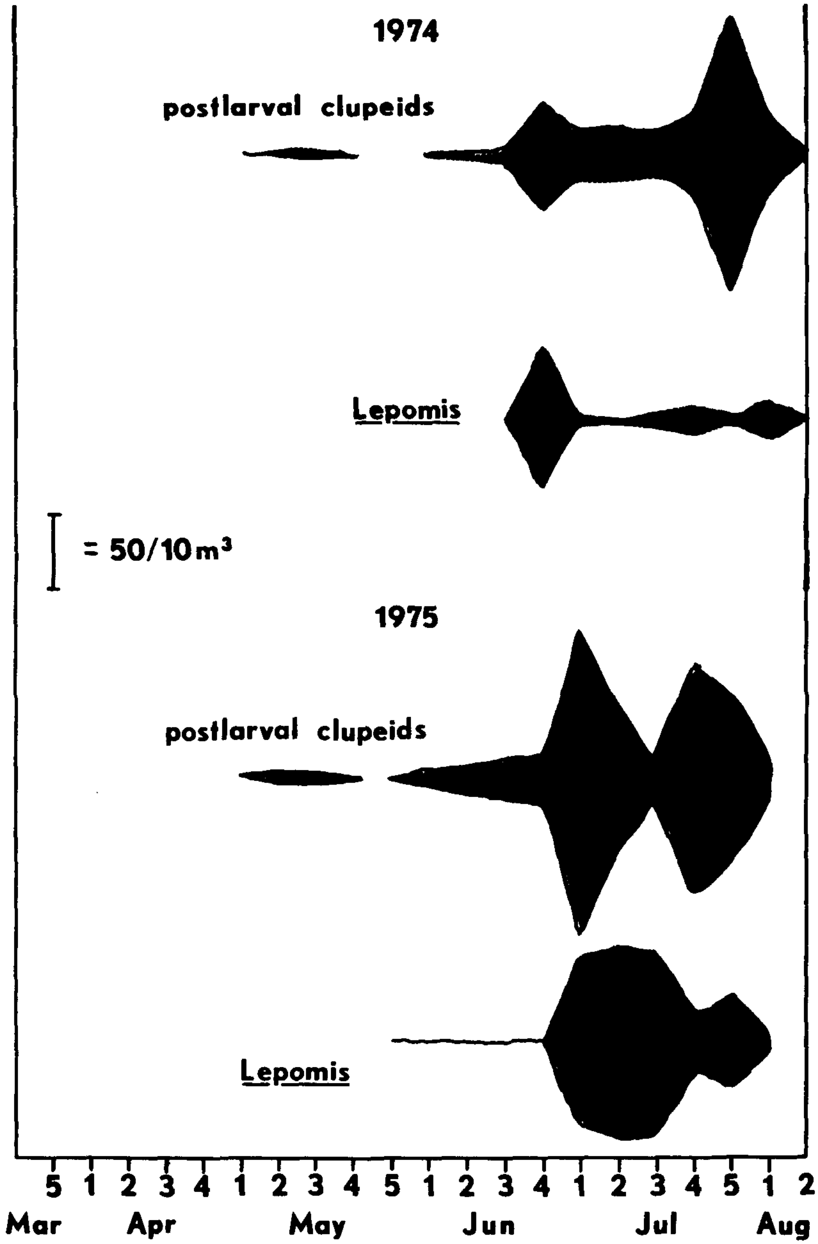

Figure 5. Seasonal distribution of dominant larval fish taxa in the Dixon Creek backwater in 1974 and 1975.

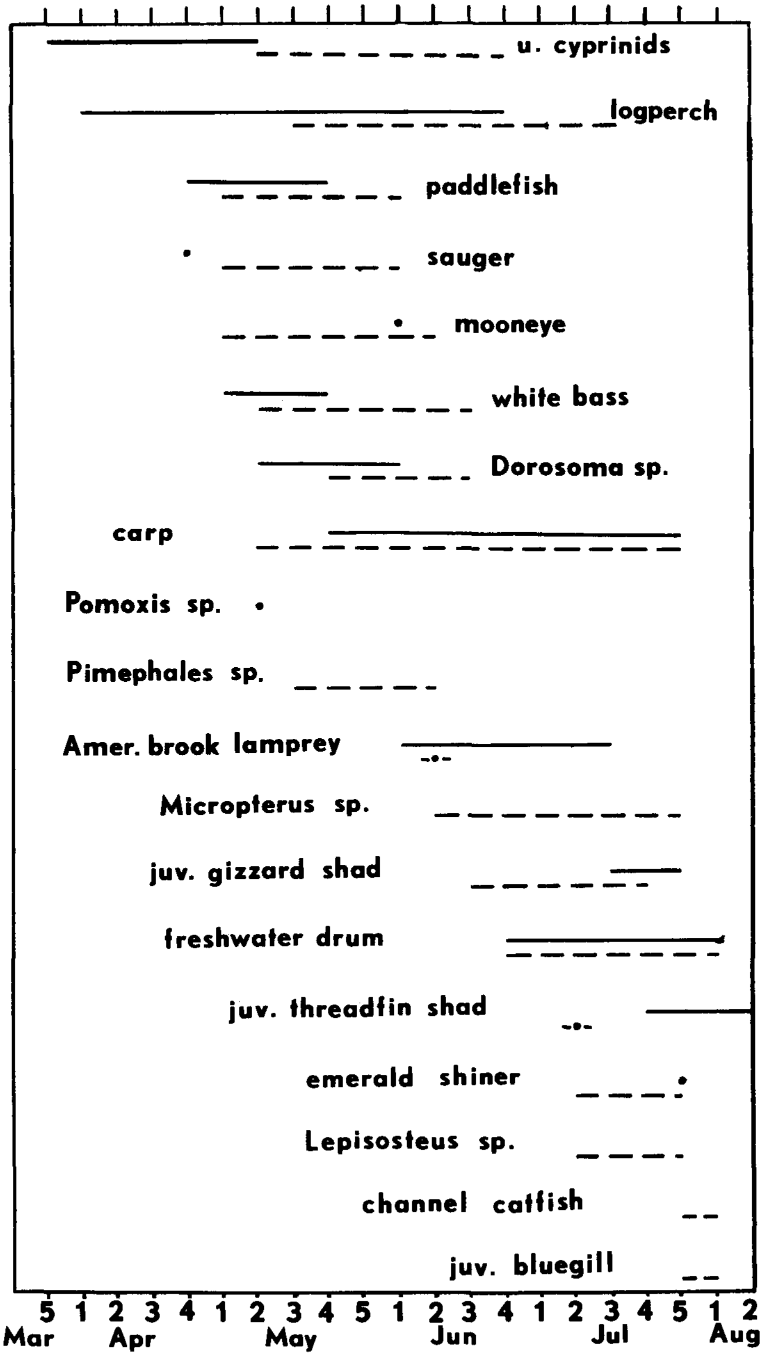

Figure 6. Seasonal occurrence of minor larval fish taxa in the Cumberland River in 1974 (solid lines) and 1975 (broken lines).

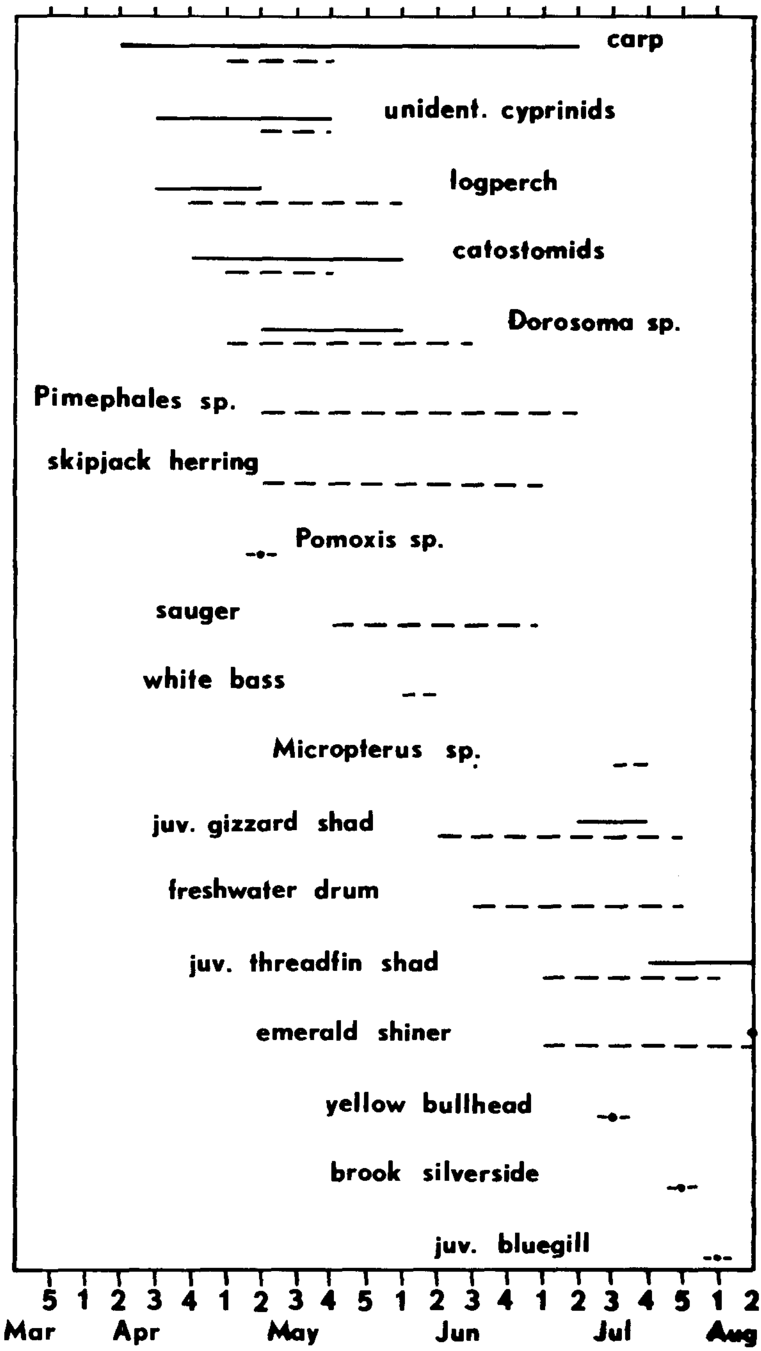

Figure 7. Seasonal occurrence of minor larval fish taxa in the Dixon Creek backwater in 1974 (solid lines) and 1975 (broken lines).

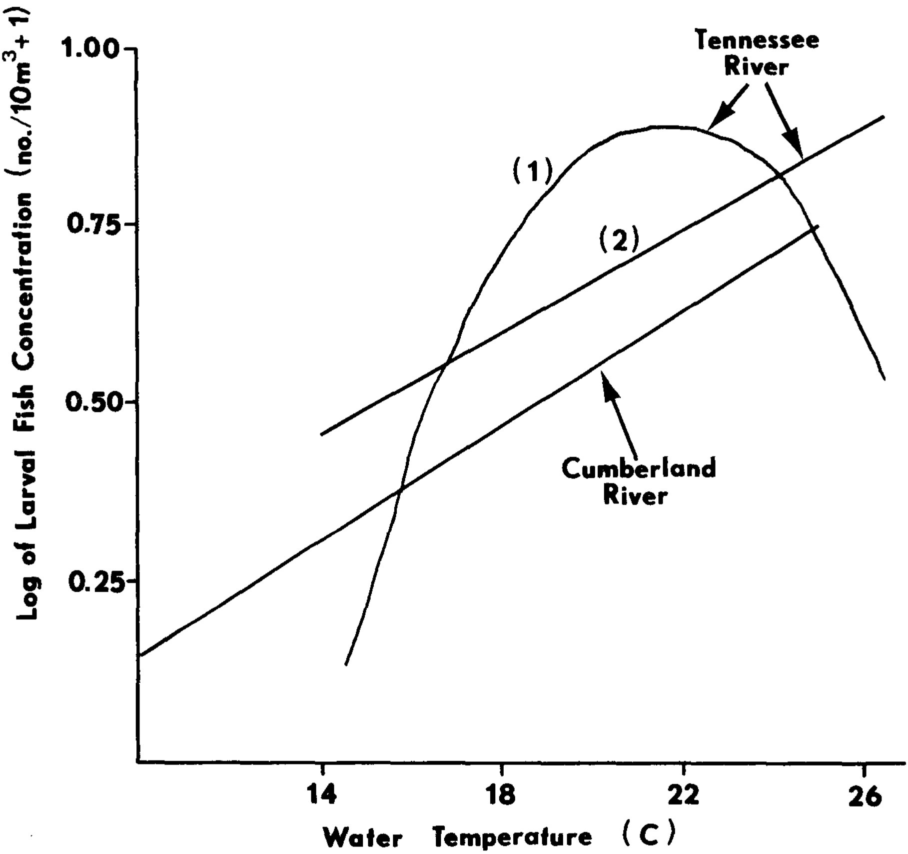

Figure 8. Water temperatures versus larval fish concentration in the Tennessee River (Nickajack Reservoir) in 1973 and 1974 and in the Cumberland River (Old Hickory Reservoir) in 1974 and 1975.

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