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Ecological Studies of the Biotic Communities in the Vicinity of the Oak Ridge Gaseous Diffusion Plant

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Environmental Sciences Division

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Abstract: Presents results of biological sampling of the aquatic communities in the vicinity of K-25 from April 1977 to September 1978. Primary focus was on characterizing aquatic environs of Poplar Creek and Clinch River. Includes analytical results for water and sediment.

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PREFACE

An evaluation of the potential environmental impacts resulting from construction and/or operation of large energy production facilities requires a knowledge of the biotic resources that occur near such facilities and, therefore, that could be affected by their operation. This and other information, such as facility design and operation, site description (e.g., geology, hydrology, land/water use), and regional characteristics (e.g., demography, historic and cultural resources) is often presented in a document commonly referred to as an Environmental Report (ER). In most cases, the ER is submitted to the appropriate regulatory agency (if a license or permit is needed) which, in turn, uses this information, and that obtained from outside sources, to prepare an Environmental Impact Statement (EIS). The scope of the information found in ERs is highly variable and dependent upon the type of facility (e.g., new vs existing; demonstration vs commercial) and the regulatory agency responsible for preparing the EIS. The Nuclear Regulatory Commission has published guidelines on the content and format of ERs (and EISs) for nuclear generating facilities, and guidelines for preparing ERs are currently being developed by the Department of Energy (DOE) to cover a variety of energy technologies.

This report on the biotic communities near the Oak Ridge Gaseous Diffusion Plant (ORGDP) differs from most ERs in several respects. First, and most important, no analysis of the impacts of ORGDP operations on biotic resources is included in the report. Unlike most ERs which do address the potential impacts of a proposed project, this report, with the exception of Sections 1.5 and 2.2 which discuss results of studies on the distribution of various contaminants in aquatic and terrestrial biota, respectively, is not intended to be an assessment-oriented document. Instead, the primary purpose of the report is to provide baseline information on the composition, abundance, and distribution of aquatic biota in the vicinity of ORGDP. These data, which are used in the report to characterize the aquatic communities in selected areas of Poplar Creek and the Clinch River (Section 1.6), provided the basis for a later analysis of the impacts of plant operation on the aquatic environment. This analysis was included as part of a comprehensive environment assessment of ORGDP operations.

Other information that is usually included in ERs, such as facility design/operation and nonbiological characteristics of the site and region, also has not been included in this report. However, relevant hydrologic and water quality data, which were either unpublished or not readily available, are included (Sections 1.2 and 1.4, respectively) because the biotic components of a system cannot be adequately described without some knowledge of the abiotic characteristics of that system.

The results obtained from the ORGDP biological sampling program were supplemented, where appropriate, with additional biological data collected from previous surveys of the biota of the lower Clinch River. The most important studies were (1) preoperational biological surveys related to the licensing of the proposed Clinch River Breeder Reactor and the Exxon Nuclear Fuel Recovery and Recycling Center, both of which would have been located near the Clinch River approximately 5 km upstream of ORGDP, and (2) sampling conducted by the Tennessee Valley Authority to assess the environmental impacts of the Kingston Steam Plant located near the mouth of the Clinch River. Extensive efforts were made to compare our results with those obtained from these earlier surveys conducted between 1973 and 1976. These efforts were often unsuccessful because of the difficulties resulting from (1) differences in field sampling methods or laboratory analysis procedures, (2) inadequate information on the actual field and laboratory methods that were used, (3) differences in sampling frequencies, (4) insufficient data (i.e., too few samples), and/or (5) inadequate data (e.g., results presented as relative abundance only).

Finally, the manner in which the large amounts of data collected during the ORGDP survey are summarized and presented in this report differs from that usually found in ERs. Too often, data in these reports are not adequately summarized, and the reader (or EIS author) must sift through voluminous tables that list, for example, the densities of each species collected at a given site on each sampling date. Only minimal effort seems to have been spent examining various aspects of their spatial and temporal distribution (e.g., seasonal succession). Because some of the contributors to this report had participated in previous activities that involved the critical review of ERs and the preparation of Environmental Impact Statements for nuclear power plants, data reduction and summarization procedures were chosen with a knowledge of how the information would eventually be used. For example, much of the detailed information on the abundance and distribution of species at lower trophic levels has been omitted. Instead, data are presented for major taxonomic groups (although important species/genera are identified and discussed, where appropriate). Raw data (individual sample values), however, are presented for both the aquatic and terrestrial studies of contaminant distribution in biota because (1) the concentration of the contaminant in biota is directly related to the degree of impact, and (2) an independent assessment of the results of these studies would likely require data in this form.

In summary, the ultimate goal in modifying the content of this report from that found in many ERs is twofold. First, by attempting to focus on the important aspects of the distribution and abundance of major taxonomic groups, the document should be more useful to the individual(s) responsible for assessing the environmental impacts of the ORGDP. Data on the lower taxonomic groups (genera, species) were examined and included, only where appropriate, in the report. Second, by omitting much of the data that were, in our opinion, not pertinent or necessary for such an assessment, the document should be more readable, and thus of greater value, to those outside the discipline of ecology.

ABSTRACT

LOAR, J. M. (editor). 1981. Ecological studies of the biotic communities in the vicinity of the Oak Ridge Gaseous Diffusion Plant. ORNL/TM-6714. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 328 pp.

Biological sampling of the aquatic communities in the vicinity of the Oak Ridge Gaseous Diffusion Plant (ORGDP) was conducted from April 1977 through September 1978. The primary purpose of this sampling program was to characterize the aquatic environs of Poplar Creek and the Clinch River near the facility, since very little current information was available on the aquatic resources in this area. The information presented in this report provided the basis for a later analysis and evaluation of the environmental impacts of ORGDP operations.

Phytoplankton, zooplankton, periphyton, benthic macroinvertebrates, and fish were collected at sampling sites on Poplar Creek (PCM 11.0, PCM 5.5, and PCM 0.5) and the Clinch River (CRM 15.0, CRM 11.5, and CRM 10.5) both upstream and downstream of known effluent discharge locations. Sampling was conducted from April 1977 through March 1978 at intervals ranging from biweekly (for phytoplankton) to bimonthly (fish) in spring through early fall. Less frequent sampling was conducted during the late fall and winter. Ichthyoplankton were sampled at weekly (February-July) and biweekly (August-September) intervals in 1978 at the same six sites.

Data on the taxonomic composition, abundance, and temporal distribution of each community are presented. These results are compared with the results obtained from several earlier surveys of the flora and fauna in the Clinch River below Melton Hill Dam. Spatial distributions of

communities and/or major taxonomic groups within a community were analyzed statistically using a time-weighted density methodology. In addition, results are presented from studies on the distribution of (1) heavy metals and PCBs in macroinvertebrates and fish and (2) fluoride and nickel in vegetation and small mammals collected in the vicinity of ORGDP. Water quality and sediment data were collected by ORGDP personnel and are also included in this report.

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1. AQUATIC ECOLOGY

1.1 Introduction

To evaluate the environmental impacts due to operation of the Oak Ridge Gaseous Diffusion Plant (ORGDP), baseline information on the aquatic resources in the vicinity of the plant was needed. From April 1977 to September 1978, a comprehensive biological sampling program was conducted to characterize the aquatic communities in the ORGDP study area. The area included sections of Poplar Creek and the Clinch River both upstream and downstream of known effluent discharge locations. Data were obtained on the taxonomic composition as well as the temporal and spatial distribution of phytoplankton, zooplankton, ichthyoplankton, periphyton, benthic macroinvertebrates, and fishes in the study area. Additional information on the concentrations of heavy metals and PCBs in fishes from Poplar Creek and the Clinch River was also collected. The data collected from the ORGDP biological survey provided a basis for an environmental evaluation of the impacts on aquatic resources from ORGDP operations.

1.2 Description of Study Area (J. M. Loar)

The study area consisted of a 7-km reach of the tailwaters of the Clinch River approximately 13 km below Melton Hill Dam, which is located at Clinch River Mile (CRM) 23.1, and an 18-km section of Poplar Creek upstream from the confluence with the Clinch River (CRM 12.0). This area of the Clinch River as well as the lower portion of Poplar Creek is part of upper Watts Bar Reservoir. Sampling stations were located at specific sites within these two regions, both above and below the Oak Ridge Gaseous Diffusion Plant which is situated between Poplar Creek Mile (PCM) 1.5 and 5.0.

The phytoplankton, zooplankton, phytoplankton, periphyton, benthic macroinvertebrate, and fish communities were sampled at three sites on both the Clinch River and Poplar Creek from April 1977 through September 1978 (Fig. 1.2-1). These six sampling locations were chosen because of their relationship (either upstream or downstream) to known effluent discharge sites and their proximity to the permanent water quality monitoring stations operated by ORGDP personnel (Fig. 1.2-2).

Stations CRM 15.0 and PCM 11.0 were located upstream of the ORGDP liquid effluent discharge sites on the Clinch River and Poplar Creek, respectively, and represented control stations. The water quality at these two control stations, however, is influenced, to some extent, by the presence of effluent releases upstream. For example, effluents from Oak Ridge National Laboratory are discharged to White Oak Creek, the mouth of which is located approximately 9 km above station CRM 15.0. Likewise, Poplar Creek above PCM 11.0 receives wastes from extensive strip mining operations in the Cumberland Mountains located in the upper (western) portions of the watershed. Relatively high sulfate levels were found in water samples collected at four sites above PCM 11.0 during the period of 1961-64 (McMaster 1967, Table 11) and at PCM 6.7 during the 1977-78 ORGDP water quality monitoring program. These elevated levels are probably the result of the oxidation and dissolution of iron sulfide minerals exposed during these mining operations (McMaster 1967). The occurrence of coal fragments in the substrates at stations PCM 11.0

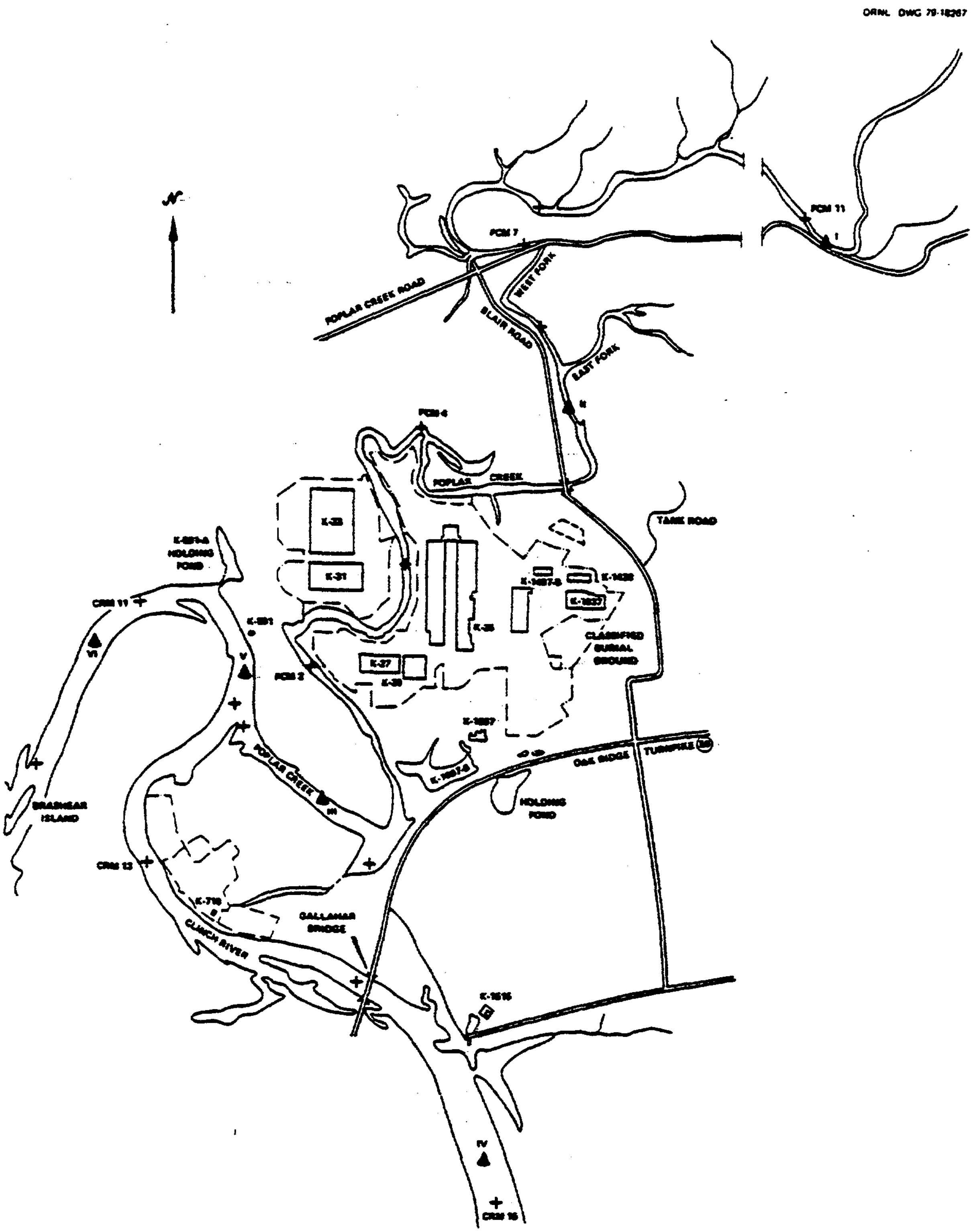

Fig. 1.2-1. Location of the six sites (▲) on Poplar Creek and the Clinch River where biological sampling was conducted during the ORGDP survey, April 1977–September 1978.

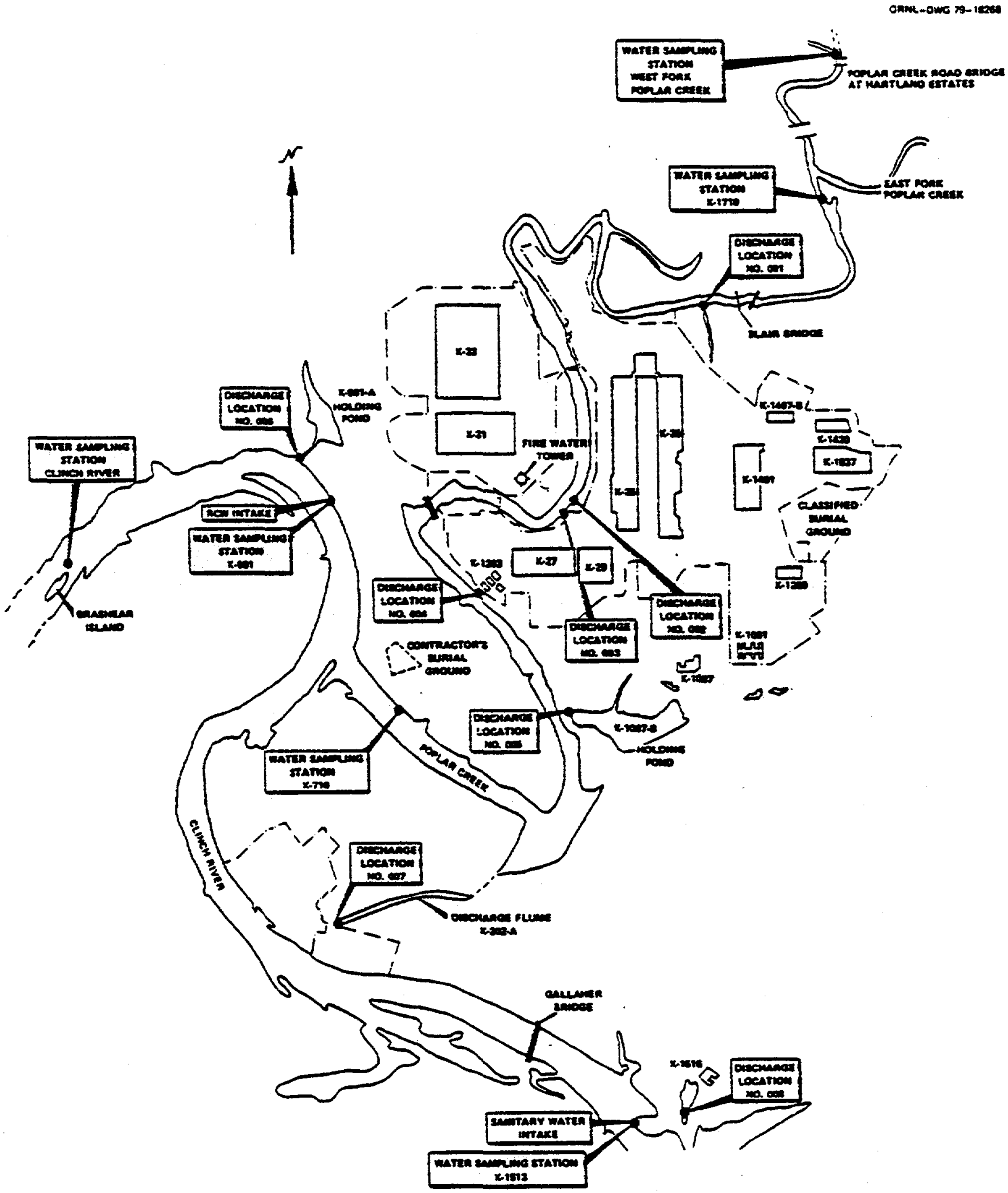

Fig. 1.2.2. Location of the six water quality sampling stations on Poplar Creek and the Clinch River where routine monitoring of 19 parameters is conducted by the Environmental Management Group at ORGDP. The makeup water intake for the recirculating water system (RCW) and the sanitary water intake as well as the eight major effluent discharge sites are also shown. Source: Adapted from: M. J. Ellis (ed.). The Quality Assurance Program for the Environmental and Effluent Sampling Program at ORGDP. Environmental Management Group, Oak Ridge Gaseous Diffusion Plant. July, 1976.

and 5.5 is also indicative of mining activity in the upper regions of the drainage basin.

It is equally important to recognize that water quality in the lower reaches of Poplar Creek is affected not only by releases from the ORGDP facilities but also by releases from the Y-12 plant and the West Oak Ridge Sewage Treatment Plant. The Y-12 facility is located at the headwaters of East Fork Poplar Creek. Liquid wastes are discharged to the creek and also to Bear Creek, a tributary stream which joins the East Fork at Mile Point 1.5. Wastes from the sewage treatment plant are discharged to the East Fork Poplar Creek near Mile Point 8.4. Effluents from these two facilities ultimately enter Poplar Creek at PCM 5.5, just above the biological/water quality sampling site.

More detailed information regarding the Poplar Creek and Clinch River study areas is presented below. Certain descriptive features of these areas such as geology, groundwater hydrology, meteorology, and land use are not discussed in this report. Such information, however, is available from the literature (Boyle 1978, Clinch River Study Steering Committee 1967, Kitchings and Mann 1976, McMaster 1967, Oak Ridge Operations Land-Use Committee 1975, Project Management Corporation 1975, U.S. Nuclear Regulatory Commission 1977).

1.2.1 Poplar Creek

The Poplar Creek drainage basin has an area of 352 km^2 and is located near the western boundary of the DOE Oak Ridge Reservation. Three main tributaries are located in this basin. The headwaters of the main branch (or West Fork) of the creek are located in the Cumberland

Mountains. The creek enters the Reservation north of ORGDP, flows for a distance of 10 km through the plant area, and enters the Clinch River near CRM 12.0. The East Fork Poplar Creek originates from a spring at the Y-12 plant. Streamflow is controlled by New Hope Pond, a 0.2-ha settling pond located 1.6 km below the spring. The creek flows through the Reservation for approximately 7.2 km before joining the West Fork at PCM 5.5. The headwaters of the third stream, Bear Creek, are also located at the Y-12 plant, although numerous small tributaries that originate along the southeast slope of Pine Ridge are located in the upper reaches. The stream flows for a distance of 11.3 km from the Y-12 plant to the confluence with East Fork Poplar Creek (EFPC) at EFPCM 1.5.

Hydrology

Poplar Creek is the largest tributary of the Clinch River between Melton Hill Dam and the northwest boundary of the DOE Oak Ridge Reservation near CRM 10. The average annual discharge of Poplar Creek is approximately an order of magnitude greater than the combined discharges of other tributaries in this 21-km reach of the river (Table 1.2-1). The largest tributary of the lower Clinch River is the Emory River which enters the Clinch at CRM 4.4. The average annual discharge of the Emory River is 45 m^3/s (1590 cfs), or seven times that of Poplar Creek.

Flows in Poplar Creek during the period from April 1977 through September 1978 (Fig. 1.2-3) exhibited seasonal fluctuations that, in general, reflected precipitation and runoff patterns typical of this region of East Tennessee. Maximum precipitation, for example, occurs in

Table 1.2-1. Location, drainage area, and average annual discharge of tributaries to the Clinch River in a 21-km reach below Melton Hill Dam (CRM 23.1). N/A = Information not available. Source: Project Management Corporation (1975), Section 2.5.1.1, unless noted otherwise.

Tributary	Confluence location (CRM)[a]	Drainage area (km^2)	Average annual discharge (m^3/s)[b]
White Oak Creek	20.8	15.5[c]	0.38 (13.5)[c,d]
Raccoon Creek	19.5	1.2[e]	N/A
Ish Creek	19.1	0.9[f]	0.05 (2)[f]
Caney Creek	17.0	21.4	0.40 (14)
Poplar Springs Creek	16.2	7.8	0.14 (5)
Grassy Creek	14.5	5.0	0.08 (3)
Poplar Creek	12.0	352.2	6.45 (228)[g]

[a] CRM = Clinch River Mile, with CRM 0.0 at the confluence with the Tennessee River.

[b] Discharge in cfs (cubic feet per second) in parentheses.

[c] At White Oak Dam (Edgar 1978).

[d] Estimated for the period 1953-55 and 1960-63 (5 water years). Source: U.S. Geological Survey (1963) as cited in Clinch River Study Steering Committee (1967).

[e] Source: Oak Ridge Operations Land-Use Committee (1975).

[f] At 0.56 km above the mouth. Source: McMaster (1967).

[g] Period of record: 1960-1977. Value represents the sum of the average annual discharge of West Fork Poplar Creek (4.98 m^3/s or 176 cfs) and East Fork Poplar Creek (1.47 m^3/s or 52 cfs). Source: U.S. Geological Survey (1978).

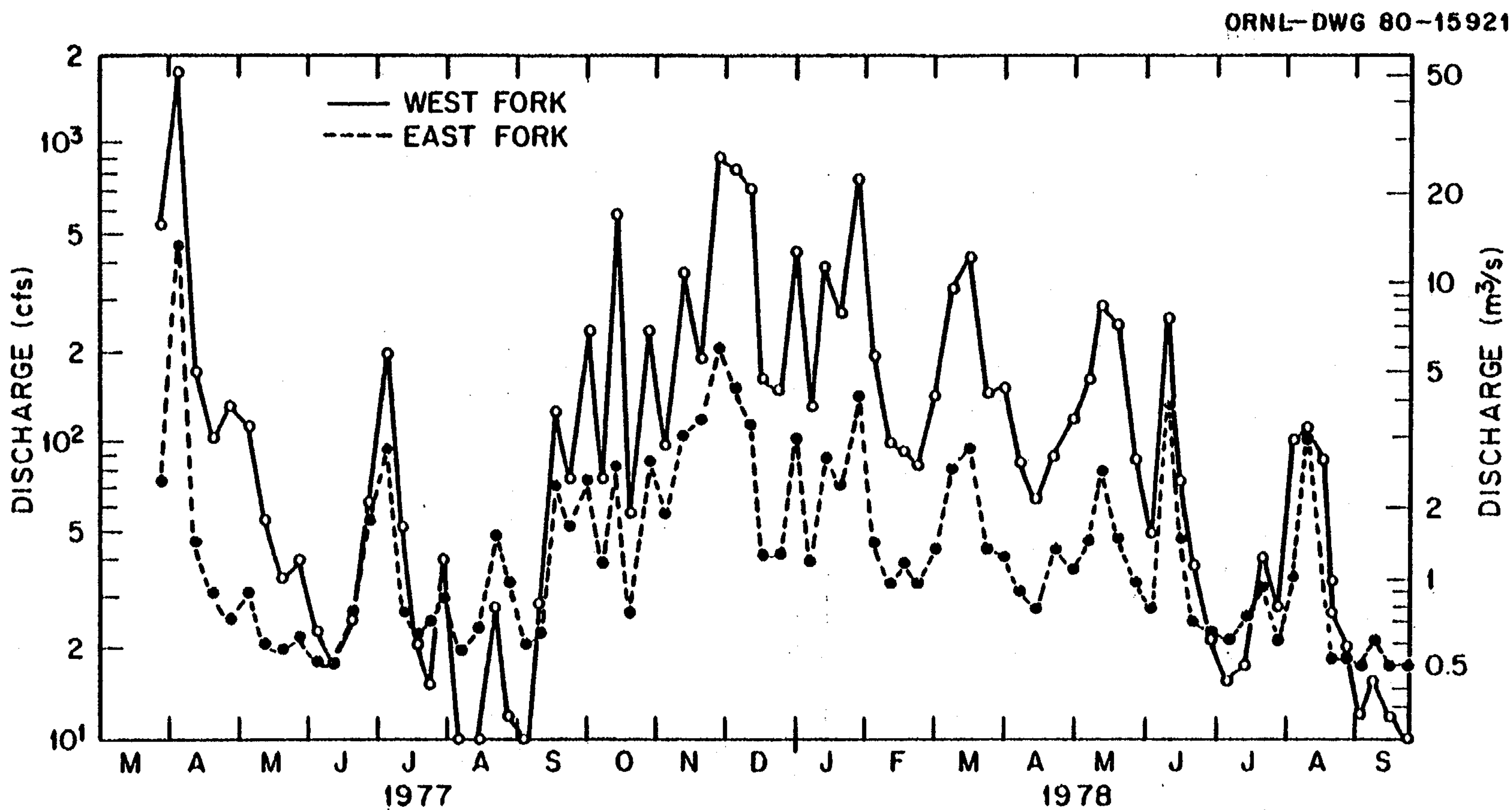

Fig. 1.2-3. Mean weekly discharge of the East Fork and West Fork Poplar Creek between March 27, 1977 and September 30, 1978. Values were calculated using provisional mean daily discharge data recorded at USGS gauging station 03538250 on East Fork Poplar Creek at Mile Point 3.4 and station 03538225 on Poplar Creek at Mile Point 14.0.

winter (December-February) when approximately 31% of the annual precipitation occurs, and the wettest months are February and March (U.S. Nuclear Regulatory Commission 1977, Table 2.3). Likewise, maximum runoff is likely to occur in January, February, or March when rainfall is normally high and maximum soil moisture and groundwater storage occurs (McMaster 1967). As shown in Fig. 1.2-3, the flow in both branches of Poplar Creek was highest during the winter months and lowest in late summer when rainfall is normally low and runoff is minimal.

The flood that occurred in early April 1977, approximately two weeks before the biological sampling program was initiated, was estimated to have a recurrence interval of 2 to 3 years. Measurements taken from the White Oak Creek watershed indicated that 14.7 cm of rain fell during a 41-h period between April 2 and 4, 1977 (Edgar 1978). Personal observations of Poplar Creek made at this time indicated that water levels were approximately 1.5 to 2.5 m above normal at the Blair Road bridge near PCM 4.7 (Fig. 1.2-1) where the high water mark was just below the platform of the bridge. The maximum discharge at the USGS gauging station near PCM 14.0 occurred on April 5 and was estimated to be 323 m^3/s (11,400 cfs). At the USGS station on East Fork Poplar Creek at EFPCM 3.4, a maximum flow of 113 m^3/s (4000 cfs) occurred on April 4 (U.S. Geological Survey 1978).

In addition to the obvious effects caused by heavy rains and high runoff, water levels in Poplar Creek are also influenced by the operation of two Tennessee Valley Authority dams: Melton Hill Dam at CRM 23.1, completed in 1963, and Watts Bar Dam located at Tennessee River Mile (TRM) 529.8 and completed in 1942. Station PCM 11.0 was above the influence of water level fluctuations in Watts Bar Reservoir, but some minor fluctuation (<0.3 m in several hours) was observed at the two downstream stations. Average annual water level fluctuations in Watts Bar Reservoir of approximately 1.8 m have a much more pronounced effect at Station PCM 0.5 where the creek is considerably wider due to extensive shallow regions in the floodplain. The width of the creek near the mouth, for example, is reduced by more than 50% during the winter when reservoir water levels are lowest. Much of the floodplain area is dry, and the flow is restricted primarily to the old creek channel.

Dam operations not only affect the magnitude and frequency of water level fluctuations but also influence both current velocities and flow direction in the lower reaches of Poplar Creek in the vicinity of station PCM 0.5. Upstream and downstream flows of low velocity (probably <15 cm), as well as periods of apparently no net flow, were observed. Although no quantitative measurements of current velocity or direction were taken during the ORGDP survey, results from studies conducted on other tributaries of the lower Clinch River demonstrated the existence of altered flow regimes attributable to dam operation. For example, pronounced upstream flows occur in White Oak Creek (CRM 20.8) when releases from Melton Hill Dam cause a rapid rise in the level of the Clinch River. When dye was added to the discharge through the dam at White Oak Creek Mile 0.6, it ponded in the embayment of the creek when water was discharged at Melton Hill Dam. When no flows occurred at the dam, the dye was released to the river (Clinch River Study Steering Committee 1967). During the Clinch River Breeder Reactor baseline sampling program, net flow into Caney Creek (CRM 17.0) was observed on five of six sampling dates between March and November 1974. Upstream flows in Poplar Springs Creek (CRM 16.2) occurred less frequently, and upstream velocities at both sites generally ranged from 3 to 9 cm/s (Project Management Corporation 1975, Section 2.7.2.3.4). These studies indicate the existence of altered flow patterns in tributaries of the Clinch River below Melton Hill Dam during periods when water is released at the dam. Because Poplar Creek is located 18 km below the dam, the influence of dam operation on water movements in this area would be expected to be less than that in tributaries that are in close proximity to the dam (e.g., White Oak Creek and Caney Creek).

Another unique characteristic of the lower Poplar Creek study area is the presence of a rather marked gradient in water temperature during the summer. Differences of 4 to 5°C were recorded between the surface and bottom waters (average depth of approximately 4 m) in the creek channel near station PCM 0.5. Due to the release of cooler hypolimnetic waters at Norris Dam (CRM 79.8), temperatures at the surface rarely exceed 21°C in the Clinch River just below Melton Hill Dam (U.S. Geological Survey 1978). On the other hand, the maximum surface temperature measured in lower Poplar Creek during the ORGDP survey was 27°C. The density underflows are created when the cooler river water enters Poplar Creek and, due to its higher density, sinks beneath the layer of warmer, less dense water of the creek. This underflow of cooler water extends approximately 1.5 km upstream from the mouth of the creek (M. Mitchell, personal communication).

Although the lower Poplar Creek study area can be described as an embayment of upper Watts Bar Reservoir, it actually exhibits many of the attributes of estuarine systems, including fluctuations in water level (although small), density gradients, and, in particular, the upstream and downstream movement of water. Considering this area, at least on a conceptual basis, to be hydrodynamically similar to an estuary is not a novel (nor inappropriate) approach. A modified tidal estuary analysis was used to predict the dispersion of pulsed releases of radionuclides from White Oak Creek to the Clinch River on the basis that the ebb and flow of water in the creek (due to intermittent discharges from Melton Hill Dam) would be similar to the flow in a tidal estuary. Predictions based on this analysis "agreed very well with observed concentrations of dye tracers" (Clinch River Study Steering Committee 1967). The exchange between the water masses in lower Poplar Creek and the Clinch River is an important consideration when evaluating the similarities between the plankton populations in these two areas and the transport of ichthyoplankton in Poplar Creek (Section 1.6). This topic is discussed in greater detail in Section 1.7.

Habitat characteristics

The changes in stream habitat over the 18-km study section of Poplar Creek are typical of most riverine systems. In the upper reaches, the creek is narrow and swift-flowing over a coarse substratum consisting primarily of medium to large boulders and coal fragments; areas of fine particulate sediments (silt and clay) are limited (Table 1.2-2). The canopy formed by the mixed hardwood riparian vegetation is nearly closed. As the gradient decreases toward the mouth of the creek, velocities are reduced and the deposition of fine particulates

Table 1.2-2. General characteristics of the ORGDP biological sampling sites on Poplar Creek

Station	Stream width (m)	Average depth (m)[a]	Riparian canopy cover (%)	Current velocity	Substrate
PCM 11.0	3–5	1.2	>80	Moderate to swift	Coal fragments, large boulders
PCM 5.5	10–15	3.1	0–40[b]	Moderate	Silt and clay, some coal fragments and sand
PCM 0.5	100–120	4.2	<10	Very slow	Silt, clay

[a]Measurements taken in mid-channel region.

[b]Station included a small section of the creek that traversed a transmission corridor and a section bounded by mixed hardwoods.

occurs. The creek is considerably wider near the mouth due to the impoundment of the Tennessee River at Watts Bar Dam and the resultant flooding of this area.

The riparian vegetation along Poplar Creek consists of numerous hardwood species. Sweet gum and sycamore are common in floodplain and riparian communities found along most major streams within the DOE Oak Ridge Reservation. Other typical dominants include willow, ash, red maple, black walnut, and boxelder (Kitchings and Mann 1976). Habitat for aquatic species, primarily vertebrates, formed by the periodic flooding of riparian vegetation exists in the lower reaches of the creek but is limited in comparison to that which exists along much of the Clinch River.

1.2.2 Clinch River

The Clinch River forms the southern and western boundary of the DOE Oak Ridge Reservation for a distance of approximately 63 km, extending from CRM 49 on Melton Hill Reservoir to CRM 10, approximately 3.2 km downstream from the mouth of Poplar Creek. The headwaters are located in southwestern Virginia, and the river has a drainage area of 11,430 km^2 at its mouth at TRM 567.7. The study area is located in upper Watts Bar Reservoir on a 7-km reach of the Clinch River above and below the confluence with Poplar Creek at CRM 12.0 (Fig. 1.2-1).

Hydrology

Flows in the lower Clinch River are regulated at Melton Hill Dam, a peaking hydroelectric facility located 13 km upstream of the study area. Because of the limited storage capacity in Melton Hill Reservoir, releases at the dam are influenced by the operation of Norris Dam (CRM 79.8), which impounds a large reservoir used for flood control, power generation, and recreation. Both the storage ratio (0.5) and the average annual water level fluctuation (18.3 m) are indicative of the flood control capabilities of Norris Reservoir in comparison to other TVA reservoirs in this area (Table 1.2-3).

Since 1964, the average annual flow of the Clinch River below Melton Hill Dam has been 153 m^3/s (5385 cfs) and has ranged from 85 m^3/s (2944 cfs) in 1966 to 229 m^3/s (8071) in 1974. The maximum daily discharge since final closure of the dam on May 1, 1963, was 990 m^3/s (34,996 cfs) which occurred on January 11, 1974. Maximum flows typically occur during the winter (December-February), and such a pattern was exhibited during the 1977-78 ORGDP survey (Table 1.2-4). However, the maximum daily flow of 869 m^3/s (30,699 cfs) actually occurred on April 5, 1977, following a period of heavy rainfall on April 2 to 4 (see

Table 1.2-3. Comparison of selected parameters among four Tennessee Valley Authority reservoirs whose operation can influence the flow and/or water level of the lower Clinch River in the vicinity of the ORGDP study area. The confluence of the Clinch and Tennessee Rivers is located at Tennessee River Mile 567.7. Source: Jenkins (1967)

	Clinch River		Tennessee River	
Parameter	Norris	Melton Hill	Watts Bar	Fort Loudon
Location, River Mile	79.8	23.1	529.9	602.3
Year of impoundment[a]	1936	1964	1942	1943
Drainage area (km^2)	7,542	8,658	44,833	24,735
Surface area (km^2)[b]	138.4	23.1	156.2	58.9
Surface elevation (m)[c]	310.9	243.8	225.9	247.8
Maximum depth (m)[d]	61.0	21.3	21.3	35.7
Mean depth (m)[d]	18.3	6.4	7.6	7.6
Fluctuation (m)[e]	18.3	3.0	1.8	1.8
Storage ratio[f]	0.65	0.04	0.05	0.04

[a]First year in which significant volume of water was stored.

[b]At average annual pool level.

[c]Elevation above mean sea level of reservoir surface at listed area.

[d]At listed surface area.

[e]Mean annual vertical fluctuation of reservoir surface level.

[f]Ratio of reservoir volume at listed elevation to mean annual discharge.

Section 1.2.1). Flows in the lower Clinch River after 1963 have been similar, on an average annual basis, to those that existed during the period prior to 1963 but after completion of the Norris Dam (1936). Based on measurements taken at a USGS gauging station at the Melton Hill Dam site, the average annual flow during the 28-year period from September 1936 to September 1964 was 130 m^3/s (4591 cfs) (McMaster 1967).

Depending upon the mode of operation of Melton Hill, Watts Bar, and Ft. Loudoun Dams (See Table 1.2-3), flows in the Clinch River can be

Table 1.2-4. Mean monthly discharge, range, and number of days of zero release recorded at Melton Hill Dam during the ORDGP biological sampling program. Discharge in cfs in parentheses. Source: Tennessee Valley Authority, River Management Branch, Knoxville, Tennessee.

	Discharge (m^3/s)		No. days of zero release	Historical mean monthly discharge (m^3/s), 1964-79[b]
	Mean	Range[a]		
1977				
Apr	284 (10,045)	56-869 (1,988-30,699)[c]	1	131 (4,624)
May	156 (5,492)	37-266 (1,300-9,388)	0	110 (3,878)
Jun	149 (5,252)	41-202 (1,442-7,150)	0	133 (4,701)
Jul	148 (5,238)	37-214 (1,308-7,554)	0	138 (4,859)
Aug	125 (4,430)	47-231 (1,671-8,158)	2	165 (5,838)
Sep	105 (3,691)	34-184 (1,217-6,513)	2	136 (4,813)
Oct	93 (3,301)	23-167 (804-5,883)	0	112 (3,962)
Nov	222 (7,824)	39-424 (1,371-14,958)	0	133 (4,711)
Dec	413 (14,581)	175-554 (6,175-19,579)	0	199 (7,016)
1978				
Jan	319 (11,280)	174-531 (6,142-18,754)	0	237 (8,379)
Feb	218 (7,689)	93-318 (3,296-11,237)	0	185 (6,540)
Mar	99 (3,496)	11-288 (392-10,154)	3	153 (5,397)
Apr	108 (3,823)	24-163 (863-5,763)	1	
May	52 (1,820)	17-171 (604-6,050)	3	
Jun	123 (4,341)	40-255 (1,429-9,000)	1	
Jul	149 (5,274)	49-189 (1,725-6,658)	0	
Aug	212 (7,501)	155-285 (5,475-10,054)	0	
Sep	196 (6,928)	97-262 (3,429-9,250)	0	
			Annual	153 (5,385)

[a]Excluding days of zero release.

[b]Values were calculated using data presented in Table 2.5-3 of Project Management Corporation (1975) for 1964-1973 and data received from the Tennessee Valley Authority, River Management Branch, for 1974-79.

[c]Maximum discharge occurred on April 5, 1977.

upstream, downstream, or quiescent (U.S. Nuclear Regulatory Commission 1977). Flows in an upstream direction were neither measured during preoperational studies associated with the Clinch River Breeder Reactor (CRBR) project (Project Management Corporation 1975) nor observed during the ORGDP sampling program. However, such flows, at velocities of approximately 30 cm/s, were postulated to occur in the vicinity of the CRBR site (CRM 14.5 to CRM 18.6) if the turbines at the Melton Hill and Watts Bar dams were abruptly shut down while releases continued at Ft. Loudoun Dam (Project Management Corporation 1975, Section 2.5.1.7). On six dates between March and September 1974, velocity measurements were taken at several depths at each of 13 stations in the vicinity of the proposed CRBR facility. Average surface velocities in the mid-channel region of the river ranged from 30 to 64 cm/s, but ranged from 0 to 85 cm/s at three stations on a transect across the river near CRM 15.0 (Project Management Corporation 1975, Tables 2.7-65 thru 2.7-70). Velocities were highly variable and dependent upon both the location in the river and the magnitude and duration of releases at Melton Hill Dam.

Periods of no directional flow (i.e., periods when the river is quiescent) also occur in the lower Clinch River and usually coincide with periods when power demands are reduced, such as weekends. In 1978, for example, there were 12 days when no water was released at Melton Hill Dam over a 24-h period, and nine of these occurred on weekends (Tennessee Valley Authority 1979). Because power demands also fluctuate on a daily basis, flows in the Clinch River will vary over a 24-h period. Periods of no flow frequently occur during the period from 12 a.m. to 6 a.m. when the demand is lowest (Project Management Corporation 1975, Table 2.7-44).

Although flows in the lower Clinch River are principally regulated by releases at Melton Hill Dam (with influences due to operation of the Norris and Ft. Loudoun dams), water level fluctuations are controlled primarily by the operation of Watts Bar Dam located at Tennessee River Mile (TRM) 529.9, approximately 61 km below the confluence of the Tennessee and Clinch Rivers at TRM 568 (Project Management Corporation 1975, Section 2.5.1.4). The annual fluctuation of Watts Bar Reservoir is 1.8 m with seasonal fluctuations of 0.6 and 0.3 m during the winter and summer, respectively. The winter pool elevation of 224.2 to 224.8 m (735-737 ft) MSL exists from October through mid-April at which time the reservoir level is raised to the summer pool elevation of 225.7 to 226.0 m (740-741 ft) MSL. The Tennessee Valley Authority has followed this plan of normal operation closely since operation of the dam commenced in 1942 (Project Management Corporation 1975, Section 2.5.1.4).

Habitat characteristics

The three sampling sites located in the 7-km study section of the Clinch River (Fig. 1.2-1) have similar physical characteristics. The average river width is approximately 180 to 215 m. Good cover, consisting mostly of submerged tree limbs, tree stumps, and overhanging tree roots and shrubs, exists in numerous areas along both banks of the river, especially during periods of high water in the summer. Sycamore, American elm, and boxelder are common riparian species in the vicinity of station CRM 15.0 (Project Management Corporation 1975, Figure 2.7-7). Very little cover exists along the steep east bank at station CRM 11.5 where the channel of the river passes close to the bank. During the summer, the average depth measured at mid-river was 10.2 m at this station compared to depths of 6.9 and 8.4 m at stations CRM 15.0 and 10.5, respectively.

Measurements of the particle size distribution of the sediments collected at different sites along five transects across the river were made during the CRBR preoperational studies. Because results indicated a high degree of variability in the composition of the sediments, no attempt was made to characterize the type of sediment with respect to station location (Project Management Corporation 1975, Section 2.7.2.3.18). Depositional areas in the Clinch River are restricted to regions outside the channel where scouring occurs, and the substratum is comprised primarily of bedrock. Sand bars are located above station CRM 15.0 and just below station CRM 10.5.

Macrophyte growth was reported to be sparse during both the CRBR survey (Project Management Corporation 1975, Section 2.7.2.4.6) and the preoperational studies that were conducted for the proposed Nuclear Fuel Recovery and Recycling Center (NFRRC) to be located just downstream of the CRBR site (Exxon Nuclear, Inc. 1976, Section 2.7.1.1). Small amounts (strands) of Eurasian water milfoil (*Myriophyllum spicatum*) were observed with the only population occurring in a shallow area above CRM 12.0. During the ORGDP survey, several small beds of *Potamogeton* were observed along the west bank of the river at CRM 15.0 and near the east bank at the transmission line crossing above CRM 15.0. No macrophyte beds were found at the two downstream stations or in Poplar Creek.

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1.3 Methods

1.3.1 Water Quality and Sediment Analyses (J. M. Loar)

Water quality and sediment data were collected by the ORGDP staff. Values for 11 of the 19 chemical parameters that are measured routinely at sampling stations K-1710 (PCM 5.3) and K-716 (PCM 0.3) in Poplar Creek and stations K-1513 (CRM 14.4) and K-901 (CRM 11.6) in the Clinch River (Fig. 1.2-2) represent a 24-h composite. That is, a continuous 24-h sample is taken once each week and an average value for each month is reported. Parameters sampled in this manner include ammonia, arsenic, chemical oxygen demand (COD), cyanide, fluoride, mercury, nitrates, pH, total dissolved and total suspended solids, and sulfates. Monthly values for the remaining eight parameters sampled at these four stations (cadmium, chromium, copper, lead, manganese, nickel, sodium, and zinc) are computed from grab samples taken weekly and composited for monthly analyses. Continuous strip chart monitoring for pH, dissolved oxygen, and specific conductance is also conducted at these four stations, but only data on pH at station K-1710 were available for inclusion in this report. At the upstream station on West Fork Poplar Creek (PCM 6.9) and the downstream station on the Clinch River (CRM 9.8), measurements are made of all 19 parameters listed above (Fig. 1.2-2). The data collected, however, are based on a single 3-liter grab sample taken once each month.

A brief description of the procedures followed in the chemical analyses of these samples is presented in the ORGDP Quality Assurance Program (Ellis 1976). The analytical procedures employed are those recommended by the Environmental Protection Agency (Union Carbide Corporation — Nuclear Division 1978). The analyses are conducted by personnel in the Laboratory Division at the Oak Ridge Gaseous Diffusion Plant.

Sediment sampling is conducted semiannually (July and November) at 18 sites on Poplar Creek and two sites on the Clinch River (Fig. 1.3.1-1). Nonradiological analyses, which are conducted on bulk (i.e., unsieved) samples, include the following parameters: aluminum, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc. The sampler and the procedures used in collecting the sediment cores are described in the ORGDP Quality Assurance Program (Standard Operating Procedures: Silt Sampling) (Ellis 1976). Currently, samples are analyzed by atomic absorption (Union Carbide Corporation — Nuclear Division 1978).

1.3.2 Trace Substances in Fish (J. M. Loar)

Tissue analyses for cadmium, chromium, copper, lead, mercury, nickel, zinc, and PCBs were conducted on fish collected in the spring (April-May) and fall (October-November) of 1977. The majority of the spring fish samples were taken from the routine gill net collections. To obtain an adequate sample of several game fish species (e.g., largemouth bass, bluegill, white crappie), electrofishing was also used and was the primary method of obtaining fish in the fall. In the laboratory, all fish were weighed and measured, and approximately 10 g of axial muscle was taken from the dorsal musculature just above the lateral line. Whole-body analyses were conducted on fish that weighed less than 10 g.

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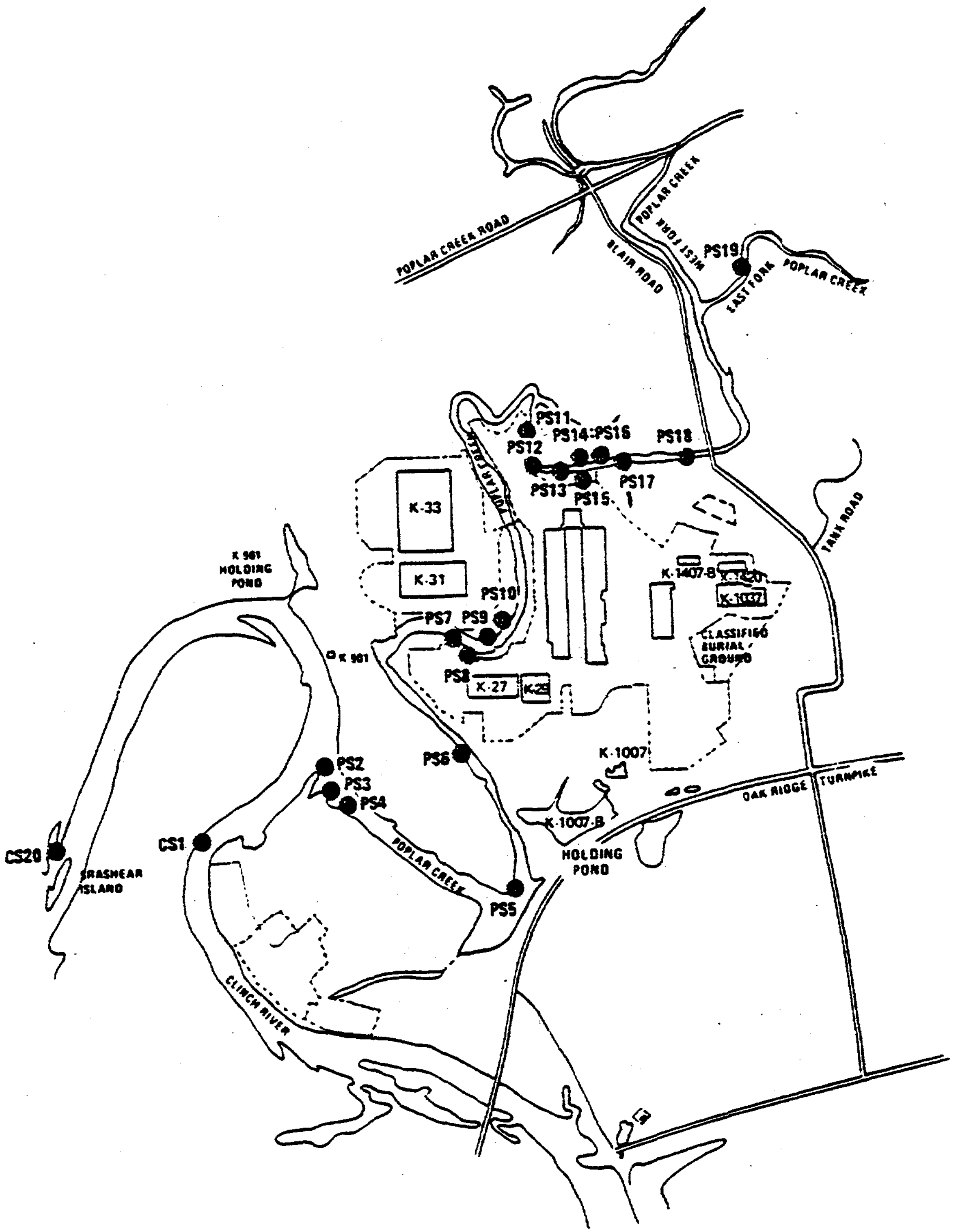

Fig. 1.3.1-1. Location of sampling stations for sediments surveyed in July and November of 1976 and 1977 for nine elements (Al, Cd, Cr, Cu, Pb, Mn, Hg, Ni, and Zn). Source: Union Carbide Corporation — Nuclear Division. Environmental Monitoring Report, United States Energy Research and Development Administration — Oak Ridge Facilities, Calendar Year 1977. Document NO. Y/UB-8 (June 21, 1978), 65 pp.

Tissues were sent to the Y-12 Analytical Laboratory for further processing and analysis. Total mercury concentrations were determined by dissolving a portion of the sample in perchloric acid (Feldman 1974) and analyzing the solution by flameless atomic absorption spectroscopy (Union Carbide Corporation — Nuclear Division 1977). Standard reference materials were used to evaluate the accuracy of the mercury analyses. Another portion of the sample was dissolved in alcoholic tetramethylammonium hydroxide (TMAOH) and analyzed for Cd, Cr, Cu, Ni, Pb, and Zn by graphite furnace atomic absorption, a procedure that was adapted from the literature (Atomic Absorption Newsletter 1974). Matrix interferences were checked using the method of standard addition. To measure the concentration of PCBs in fish tissues, TMAOH solutions from the metals analysis procedure were examined by gas chromatography using an electron capture detector.

Concentrations of six trace metals (Cd, Cr, Cu, Ni, Pb, An) were measured in 5-g samples (gut contents included) of Hexagenia nymphs, a burrowing mayfly found in the sediments of Poplar Creek and the Clinch River. Collections were made in August and September, 1977, at stations PCM 0.5 and 5.5 and station CRM 15.0 (Fig. 1.2-1). After recording the wet weight, the sample was frozen and later sent to the Y-12 Analytical Laboratory for further processing and analysis. Weight loss due to dehydration was noted and the values reported were corrected to reflect this bias (see Section 1.5). The 5-g samples were dissolved in nitric acid and analyzed by graphite furnace atomic absorption spectroscopy. Matrix interferences were checked using the method of standard addition.

1.3.3 Biological Communities (J. M. Loar)

Five biological communities (phytoplankton, periphyton, zooplankton, benthic macroinvertebrate, and fish) were sampled between April 14, 1977, and March 31, 1978. The mid-April startup date for the biological field sampling program was considered too late to ensure the inclusion of eggs and larvae of early-spawning fish species. Consequently, ichthyoplankton sampling was delayed a year and was conducted between February 16 and September 15, 1978. The type of community and the dynamics of the species populations comprising a given community were considered in the initial selection of the methodology and frequency of sampling. Thus, for example, phytoplankton, which exhibit rapid turnover rates during the warmer periods of the year, were sampled at approximately two-week intervals from spring through early fall and at approximately four-week intervals during the winter. Sampling frequencies and the number of samples collected during the ORGDP study are given in Table 1.3.3-1 for each community.

In selecting appropriate field sampling methodologies and laboratory analytical procedures, consideration was given to those techniques which had previously been shown to provide reliable information on both qualitative (e.g., species composition) and quantitative (e.g., population density) parameters (Edmonson and Winberg 1971, U.S. Environmental Protection Agency 1978, Vollenweider 1979, Welch 1948). In addition, the techniques used in other studies conducted in the vicinity of the ORGDP study area were reviewed and evaluated to provide a basis for comparison. The procedures used in the field and laboratory to obtain the data presented in Section 1.6 are discussed below. All

Table 1.3.3-1. Summary of the ORGDP aquatic biological sampling program, April 1977-September 1978

Community	Sampling gear	Approximate sampling frequency	No. of sampling dates	No. of samples collected/ station/date	Total no. samples (all stations)[a]
Phytoplankton	2-liter Kemmerer	Biweekly (April-October; March) Monthly (December-February)	17	2	200
Periphyton	6 plexiglass slides on floating racks	Bimonthly (June, August-November, February, March)	7	5[b]	187
Zooplankton	Clarke-Bumpus with No. 20 mesh (76-μm) net	Monthly (April-March)	12	2	142
Benthic macro-invertebrates	15- × 15- × 15-cm Ponar dredge	Bimonthly (April, June, August-October, December, March)	7	3	126
Fish	Electroshocking	Bimonthly (April, June, July, October, March)	5	1	26
	Stationary experimental gill nets	Bimonthly (April, June,[c] July, October, February)	5	1	26
Ichthyoplankton	0.5-m diameter plankton nets	Weekly (February-July) Biweekly (August-September)	26	2/4[d]	464[e]

[a] Values reflect the actual number of samples collected and analyzed. Where samples were scheduled but not taken due to accidental loss, equipment failure, or fluctuating water conditions, notations have been made on the appropriate tables and/or figures in the text.

[b] Two slides (samples) were used for cell counts; three slides (samples) were used for ash-free dry weight determination.

[c] June collections at the three Poplar Creek stations were actually taken on May 24, 26; the Clinch River stations were sampled on June 2, 1977.

[d] Two samples per station in Poplar Creek; four samples per station in Clinch River (see Section 1.6.6).

[e] Includes diel samples.

six communities were sampled at each of the six sampling sites shown in Fig. 1.2-1.

Phytoplankton

Replicate phytoplankton samples were taken just below the surface at midstream with a 2-liter Kemmerer water sampler. Samples were preserved in Lugol's solution in the field immediately after collection (Vollenweider 1969). In the laboratory, a 2.5-ml whole-water sample was allowed to settle for a minimum of 1.5 h in a Wild plate chamber. Replicate 1-cm transects were counted at a magnification of 200x with a Zeiss inverted microscope. One occurrence of an alga was treated as one counting unit (e.g., one cryptomonad cell, one *Scenedesmus* coenobium, one *Melosira* filament, etc.). Live (unpreserved) samples collected concurrently with the routine scheduled samples were used for identification whenever possible. Identifications, to species whenever possible, were made at magnifications of 200x, 320x or 800x oil immersion using several taxonomic references (Bourrelly 1966, 1968, 1970; Drouet 1968; Drouet and Daily 1956; Forest 1954; Huber-Pestalozzi 1938, 1942, 1950, 1955, 1961; Pascher 1930; Patrick and Reimer 1966, 1975; Prescott 1951; Smith 1950; Tiffany and Britton 1952; Whitford and Schumacker 1969).

Periphyton

Surface-floating samplers, with styrofoam floats and a submerged rack containing six plexiglass slides, were used to collect periphyton. The upper end of the vertically suspended slides was approximately 30 cm below the surface of the water. After an exposure period in the field of approximately two to four weeks, the glass slides were placed in plastic bags and returned to the laboratory. Periphyton analysis consisted of both direct cell counts and gravimetric determination of organic matter (i.e., ash-free dry weight). The periphyton on three of the six slides used for cell counts was removed with a neoprene policeman and distilled water. Two of these "samples" were preserved in Lugol's solution (Vollenweider 1969) and used for enumeration. Cell counts were made with a Sedgewick-Rafter counting chamber, and four fields on each of four replicate transects were counted per sample. The material was allowed to settle for approximately 5 min in an inverted position and was then counted using a Zeiss inverted microscope at a magnification of 200x. As described previously for phytoplankton, one occurrence of an algal type was counted as one algal unit. The third slide, which was not preserved, was used for identification. It was examined using a settling chamber and a Zeiss inverted microscope at magnifications of 200x, 320x, and 800x oil immersion. The same taxonomic references listed above for phytoplankton were used in the periphyton analyses.

The remaining three slides were used in the determination of ash-free dry weight. These were kept frozen until treatment. At this time, the periphyton was scraped off the slide into an aluminum weighing pan with a neoprene policeman and distilled water. Each sample was dried at 105°C for 24 h, weighed, then ashed at 550°C for 4 h and weighed again. The difference between the two weights is the ash-free dry weight or the organic weight of the sample (Vollenweider 1969).

Zooplankton

Replicate zooplankton samples were taken with a Clarke-Bumpus sampler equipped with a No. 20 mesh (76-μm) net. Approximately 3-min horizontal tows were made just below the surface near mid-stream. Immediately after collecting the sample, the zooplankton were narcotized in commercial-grade Neosynephrin and preserved in 5% formalin. In the laboratory, each sample was thoroughly stirred in a beaker from which a 1- or 2-ml aliquot was taken using a Hensen-Stempel pipet. Generally, three subsamples (aliquots) were examined, although as many as five were taken from the earliest samples. If a sample contained very few zooplankton, such as those collected at station PCM 11.0, then the entire sample was examined. The subsample was placed in a Wild dissecting microscope. Cladocerans and copepods were placed in glycerin for identification, while rotifers were identified using a compound microscope. Taxonomic references used to identify organisms included Ahlstrom (1940, 1943); Bartos (1959); Coull (1967a,b); Edmondson (1959); Pennak (1953); U.S. Environmental Protection Agency (1977); and Voight (1956). Although many zooplankters could be identified to species, the majority of the organisms, especially the rotifers, were identified only to genus.

Benthic macroinvertebrates

Benthic macroinvertebrates were sampled with a 15- × 15- × 15-cm hand-operated Ponar dredge. Triplicate grab samples were taken along a transect across the stream/river at each of the six stations. Attempts were made to collect these samples from near the right and left banks and at mid-stream, but the presence of large boulders, bedrock, or occasional strong currents in the river often precluded sampling at precise intervals along the transect. The entire contents of the dredge were placed in a large plastic bag and returned to the laboratory, where the silt and fine detritus were washed through a standard No. 35 mesh (500-μm) screen. The sample was washed from the screen and, whenever possible, organisms were sorted from the debris and substrate while alive. Those samples that could not be immediately processed in this manner were preserved in 70% isopropanol. A number of preserved samples were stained with phloxine B (Mason and Yevich 1967), a technique which was found to facilitate sample processing. The organisms in all the samples were separated from the debris and substrate using white plastic trays and a table-mounted magnifier. Specimens were then preserved in vials containing 70% isopropanol. Permanent slide mounts of chironomids and oligachaetes were prepared for identification purposes. Identifications were made to the lowest taxonomic level, usually genus, using both dissecting and compound microscopes. Several taxonomic references were used to identify the organisms (Beck 1976, Brown 1972, Burch 1972, Cook 1956, Edmondson 1959, Edmunds et al. 1976, Gooch 1967, Hiltunen 1973, Hitchcock 1974, Holsinger 1972, Johannsen 1934, Leonard 1959, Mason 1973, McCafferty 1975, Pennak 1953, Ross 1944, Usinger 1956, Wiggins 1977, Williams 1972). Assistance was also provided by personnel at Tennessee Technological University, the University of Tennessee, and the Tennessee Valley Authority.

Fish

Adult fish were collected by electroshocking and with stationary, experimental (multi-panel) gill nets. The nets were generally set perpendicular to shore at each station for a 24-h period. Because of the narrowness of Poplar Creek, nets were set diagonally at the two upstream stations. Beginning in July, a 48.5- × 1.8-m (150- × 6-ft) net with six 7.6-m (25-ft) panels (1.9-, 2.5-, 3.2-, 3.8-, 5.1-, 7.6-cm bar mesh) was set at each of the three Clinch River sites and two sites on Poplar Creek (PCM 0.5 and 5.5) (Fig. 1.2-1). Since Poplar Creek is relatively narrow in the vicinity of station PCM 11.0, a 22.9- × 1.8-m (75- × 6-ft), 3-panel net with 1.9-, 2.5- and 5.1-cm bar mesh was used at that site. Prior to July, the size of gill nets used at the six stations varied. Both 22.9-m (75-ft) and 38.1-m (125-ft) long nets had to be used interchangeably, since several of the nets set during April were damaged by the heavy debris load in the stream following the heavy rains that occurred during the first week of April.

Fish were electroshocked from a boat using a Smith-Root electrofisher which delivered a pulsed DC current through either one or two boom-mounted electrodes. A Smith-Root-Type IV electrofisher with a single boom was used to electroshock at the shallower upstream stations (PCM 11.0 and PCM 5.5) on Poplar Creek, and a larger boat with two booms and a Smith-Root-Type VI electrofisher was used to sample the other four stations. The right shoreline (facing downstream) was electrofished for a period of approximately 10 min at each of the six stations.

All fish collected in gill nets or by electrofishing were placed in large plastic bags, returned to the laboratory, and frozen until the sample(s) could be processed. Data on total length, weight, sex, and gonadal development were recorded. Identification to species was made using the taxonomic keys of Eddy (1969), Pflieger (1975), Trautman (1957).

Ichthyoplankton

Replicate ichthyoplankton (planktonic fish eggs and larvae) samples were collected at a single, mid-channel location at each of the three Poplar Creek sites and along the left and right shorelines at each of the three Clinch River sites. Two types of nets were used to obtain these samples. Surface collections at all Clinch River stations and at Poplar Creek stations PCM 0.5 and PCM 5.5 were made by towing, against the current, a 2-m long, 0.5-m diameter plankton net approximately 18 m behind a boat. This net had a 0.75-m diameter expanded collar and was composed of 243-μm mesh Nitex. Because of the shallowness of the uppermost Poplar Creek station (PCM 11.0), a 1.3-m-long, 0.5-m-diameter conical net (without the expanded collar), composed of 153-μm mesh Nitex, was used at this location. Stationary net samples at PCM 11.0 were taken by suspending the net in the water and allowing the current to carry drifting organisms into the net. Sample volumes and towing velocities were determined by means of an impeller-type flowmeter (General Oceanics No. 2030) mounted in the center of the mouth of each net. Towed samples were generally taken for 3 to 6 min at velocites of 1 to 2 m/s, resulting in most sample volumes between 50 and 150 m^3. Measured current velocities at PCM 11.0 were normally less than 0.25 m/s, necessitating stationary net sampling times of up to 15 min to obtain adequate sample volumes. Filtered samples were washed down into a screened collecting bucket at the cod end of the net. Samples were field-preserved in 5% formalin solution for later identification and enumeration.

In the laboratory, samples were poured into black enamel pans, and ichthyoplankton were separated from detritus and zooplankton with the aid of an illuminated magnifying lense. In most cases the entire sample was sorted, but high densities of eggs or larvae in 21 samples (4% of the total) necessitated subsampling with a Folsom Plankton Splitter. Total length measurements were made for all larvae in selected samples (day-night comparisons) by means of a grid attached to the base of the microscope. The taxonomic references used to identify ichthyoplankton included Connor (1978); Gerlach (1973); Hogue and Buchanan (1977); Hogue et al. (1976); Lippson and Moran (1974); May and Gasaway (1967); Nelson (1968); Wrenn and Grinstead (1971).

1.3.4 Statistical Analyses (K. D. Kumar)

The primary purpose of the statistical analyses used in Section 1.6 was to compare the phytoplankton, zooplankton, ichthyoplankton, and benthic macroinvertebrate densities among the various sampling stations. The variance model most often used to compare stations is:

$$Y = \mu_o + \text{(date effect)} + \text{(station effect)} + \text{(station-date interaction)}.$$

The effects are assumed to be fixed. In a balanced design this assumption leads to the comparison of annual or seasonal mean densities of the stations. This methodology, however, ignores the sampling frequency. When sampling biota, one often is sampling from a nonstationary stochastic process. Consequently, the period of sampling and the sampling interval play an important role in the "confidence" one has in the data. A data base consisting of quarterly samples, for example, would clearly contain less information than one where sampling was conducted at weekly intervals. The point is that the statistic used to summarize data at a given station must reflect both the sampling frequency and the number of replicates collected on a given sampling date. For the ORGDP aquatic survey, a Time-Weighted Density (TWD) parameter that takes into account sampling frequency was computed.

A TWD is a time-weighted annual (or seasonal) density (numbers per unit area or volume) given by

$$TWD = \sum_{j=1}^{N} w_j d_j \ , \qquad (1)$$

where w_j = weighting factor for sampling day j, which is a function of the sampling interval,

and d_j = average density on sampling day j.

A simple form of TWD is obtained by using the trapezoidal rule of integration, namely

$$TWD = \sum_{j=1}^{N-1} \frac{(t_{j+1}-t_j)}{} \left[\frac{(d_j+d_{j+1})}{2}\right] \ , \qquad (2)$$

where t_j = j^{th} sampling day.

The trapezoidal rule of integration is equivalent to assuming an average density [given by the term in the second parenthesis of Eq. (2)] over the time interval $t_{j+1} - t_j$. This weighted mean density seems more appropriate than the simple arithmetic mean and has been used in the station comparisons presented in Section 1.6.

The variance of TWD is given by

$$V(\mathrm{TWD}) = \left[\left(\frac{t_2-t_1}{2}\right)^2 \frac{1}{n_1} + \sum_{j=2}^{N-1} 2\left(\frac{t_{j+1}-t_{j-1}}{2}\right)^2 \frac{1}{n_j} + \left(\frac{t_N-t_{N-1}}{2}\right)^2 \frac{1}{n_N}\right]\sigma^2 , \tag{3}$$

where $\frac{\sigma^2}{n_j}$ = variance of d_j, the average density on day j,

and n_j = number of replicates on day j.

The variance is an increasing function of the sampling interval. If the sampling interval is a constant (Δ), then Eq. (3) reduces to

$$V(\mathrm{TWD}) = \frac{\Delta^2}{4}\left[\frac{1}{n_1} + \sum_{j=2}^{N-1}\left(\frac{2}{n_j}\right) + \frac{1}{n_N}\right]\sigma^2 . \tag{4}$$

As the sampling interval (Δ) increases, the variance increases, indicating less confidence in the TWD. The "penalty function" for very large sampling intervals is that the confidence region increases linearly as a function of Δ.

Estimation of σ^2

In Eq. (3), the variance of average sample density d_j is given as $\frac{\sigma^2}{n_j}$. It is assumed that the variance does not change over time. To use Eqs. (2) and (3), one needs an estimate of σ^2, which is easily obtained as follows:

Suppose that $a_1, a_2, \ldots a_r$ are the r days on which replicate samples are collected. Then the estimate of σ^2 (s^2) is given by

$$s^2 = \frac{1}{\left(\sum_{j=1}^{r} n_{a_j}\right) - r} \sum_{j=1}^{r} \left(d_{a_j} - \bar{d}_{a_j}\right)^2 , \tag{5}$$

where $\bar{d}_{a_j}$ = average density on day a_j,

and n_{a_j} = number of replicates on day a_j.

The degrees of freedom associated with s^2 is $\left(\sum_{j=1}^{r} n_{a_j}\right) - r$.

As discussed above, the variance (σ^2) is estimated from the replicates. It is well known that the sample variance of σ^2 is not robust in the presence of outliers, and hence it is necessary to identify outliers. The number of replicates was usually two on a given day. Referring to Eq. (5), the "residuals" on each of the sampling days, on which the replicates were taken, were obtained as

$$r_{a_{ij}} = d_{a_{ij}} - \bar{d}_{a_i} .$$

The residuals are then plotted on normal probability graphs to identify outliers by visual inspection of the plots. Additionally, the Kolmogorov-Smirnov statistic was computed. If the assumption of normality was rejected, then one suspects either departure from distributional assumptions or the presence of outliers, or both. Since on most days the number of replicates was two, the residuals will tend to look normal (due to symmetry about zero) unless outliers are present. Hence, after removing the "outlier," the goodness-of-fit statistic should indicate normality of the remaining observations. The variance was computed using the data on those days when no outliers were found.

Comparison of stations

The comparison of the stations is accomplished in a straightforward manner. If the TWD at station k and ℓ are $(TWD)_k$ and $(TWD)_\ell$ and the respective variances are V_k^2 and V_ℓ^2, then the comparison is carried out as follows:

(1) If $V_k^2 = V_\ell^2$, then a simple two-sample Student's-t test is used.

(2) If $V_k^2 \neq V_\ell^2$, then the Cochran's approximation to the Behrens-Fisher problem is used (Cochran 1964).

The test statistic d is given by

$$d = \frac{(TWD)_k - (TWD)_\ell}{\sqrt{V_k^2 + V_\ell^2}} .$$

The approximate significance level d is given by

$$\hat{d} = \frac{V_k^2 t_k + V_\ell^2 t_\ell}{V_k^2 + V_\ell^2} , \tag{7}$$

where t_k, t_ℓ = significance levels of Student's t for the appropriate degrees of freedom and the desired probability level.

Some comments on the length of the season

The ORGDP sampling program was conducted over an entire year, with greater frequency during the period of high biological productivity (April-October). With the possible exception of benthic macroinvertebrates, densities are very low during the winter months. Ichthyoplankton densities in winter are at or near zero. Consequently, in analyzing some of the individual ichthyoplankton taxa, the season was truncated to exclude those months when the taxa under study were observed to be absent from all the stations. The purpose of this exclusion was to obtain a simple stratification of the year into spawning and nonspawning seasons. The inclusion of the data from the nonspawning season will tend to increase the variance of TWD without increasing the value of TWD as can be readily seen from Eqs. (2) and (3). Since the purpose of the study was to examine the aquatic system in the vicinity of the ORGDP during the season of interest, the nonspawning season was excluded from the analysis.

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1.4 Results and Discussion of Water Quality

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Nineteen water quality parameters are routinely sampled by ORGDP personnel at three stations on Poplar Creek and at the sites on the Clinch River (Fig. 1.2-2). Monthly concentrations of each parameter for the period April 1977 to March 1978 were obtained from the ORGDP Environmental Management Group (M. Mitchell, unpublished data) and were used to calculate the mean annual values presented in Table 1.4-1. These data are compared below with the results obtained from two earlier water quality surveys conducted in 1974-75 (Clinch River Breeder Reactor survey) and 1975-76 (Exxon Nuclear Fuel Recovery and Recycling Center survey).

1.4.1 Clinch River Breeder Reactor (CRBR) Survey

In March 1974, a comprehensive preoperational environmental sampling program was initiated in the vicinity of the proposed site of the Clinch River Breeder Reactor (Project Management Corporation 1975). Water quality samples were taken at various locations within a 5-km region of the Clinch River (Fig. 1.4-1). This area of the river is just upstream of the ORGDP sanitary water intake (CRM 14.4) where ORGDP water quality sampling station K-1513 is located. In March and September 1974, measurements were made of 34 parameters, including various pesticides and organic compounds, at transect 4, station 3 (Project Management Corporation 1975, Table 2.7-35). Eleven of these parameters (As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn, cyanide, and fluoride) were sampled in the ORGDP water

Table 1.4-1. Mean annual concentration (mg/liter) and range (in parentheses) of 19 water quality parameters at six stations on Poplar Creek and the Clinch River (see Fig. 1.2-2). Mean values were calculated from monthly data collected from April 1977 to March 1978. Since less than (<) signs were ignored in these computations, the means are biased and somewhat conservative. An annual mean was reported as 'less than' some table value if more than one-half of the monthly concentrations reported for a parameter were below the detection limit (given in parentheses below the parameter). N/A = no data available.

Parameter	West Fork Poplar Creek (PCM 6.9)[a]	K-1710 (PCM 5.3)[a]	K-1513 (PCM 0.3)[a]	K-1513 (CRM 14.4)[b]	K-901 (CRM 11.6)[b]	Clinch River (CRM 9.8)[b]
Ammonia (NH_3) (0.01,0.2)[c]	<0.10 (<0.01–0.21)	0.13 (<0.01–0.24)	0.14 (<0.01–0.38)	<0.10 (<0.01–0.2)	0.10 (<0.01–<0.2)	<0.10 (<0.01–0.23)
Arsenic (0.01)	<0.01 (<0.01–0.02)	<0.01 (<0.01–0.03)	<0.01 (<0.01–0.02)	<0.01 (<0.01–0.03)	<0.01 (<0.01–0.02)	<0.01 (<0.01–0.03)
Cadmium (0.005)	<0.005 (all <0.005)	<0.005 (<0.005–0.006)	<0.005 (all <0.005)	<0.005 (all <0.005)	<0.005 (all <0.005)	<0.005 (<0.005–0.007)
Chromium, total (0.005)	0.006 (<0.005–0.01)	0.007 (<0.005–0.016)	0.014 (0.008–0.022)	0.007 (<0.005–0.015)	0.007 (<0.005–0.015)	0.005 (<0.005–0.008)
COD (2,5)[d]	8 (<5–13)	7 (<5–14)	10 (<5–14)	5 (<5–10)	6 (<2–13)	5 (<2–10)
Copper (0.005)	0.014 (<0.005–0.048)	0.017 (<0.005–0.059)	0.016 (<0.005–0.08)	0.026 (<0.005–0.029)	0.013 (<0.005–0.06)	0.014 (<0.005–0.073)
Cyanide (0.0005,0.002)[e]	0.0025 (<0.0005–0.013)	0.0021 (0.0006–0.005)	0.0022 (<0.0005–0.005)	0.0016 (<0.0005–0.003)	<0.0019 (<0.0005–0.005)	0.0021 (0.0007–0.005)
Fluoride (0.1)	<0.10 (<0.1–0.13)	0.23 (<0.1–0.44)	0.22 (<0.1–0.4)	<0.11 (<0.1–0.17)	<0.1 (<0.1–0.1)	<0.11 (<0.1–0.2)
Lead (0.005,0.01)[f]	<0.010 (<0.005–0.02)	0.034 (0.006–0.3)	<0.010 (<0.005–0.019)	<0.009 (<0.005–0.014)	<0.010[g] (<0.005–0.02)	<0.010 (<0.005–0.02)
Manganese (0.005)	0.158 (0.019–0.311)	0.080 (0.025–0.198)	0.122 (0.04–0.173)	0.035 (<0.005–0.3)	0.036 (0.01–0.048)	0.063 (0.007–0.28)
Mercury (0.001)	<0.001 (<0.001–0.002)	<0.001 (<0.001–0.001)	<0.001 (<0.001–0.001)	<0.001 (all <0.001)	<0.001 (<0.001–0.001)	<0.001 (<0.001–0.003)
Nickel (0.005)	0.020 (<0.005–0.112)	0.019 (<0.005–0.08)	0.015 (0.002–0.031)	0.011 (<0.005–0.026)	0.013 (<0.005–0.027)	0.009 (<0.005–0.018)
Nitrates (NO_3^-) (0.01)	2.13 (0.04–3.54)	2.68 (0.28–6.20)	3.82 (<0.01–5.49)	2.99 (1.72–4.25)	4.32 (1.45–14.7)	2.54 (0.35–4.96)
pH	N/A	7.0 (6.0–8.3)	7.4 (7.0–8.2)	7.8 (7.1–8.1)	7.4 (6.9–7.8)	N/A
Sodium	4.17 (2.5–5.79)	5.07 (3.02–7.81)	5.89 (1.8–9.64)	3.12 (2.5–3.88)	3.34 (2.68–4.00)	3.19 (1.95–4.2)
Sulfates	43 (25–53)	34 (21–50)	34 (15–45)	23 (14–40)	27 (15–50)	24 (13–45)
Total dissolved solids	189 (40–330)	195 (114–294)	179 (98–244)	160 (118–278)	168[h] (114–202)	159 (90–218)
Total suspended solids (5)	26 (<5–67)	20 (<5–74)	21 (<5–43)	11 (<5–32)	19[h] (<5–74)	16 (<5–34)
Zinc	0.017 (0.005–0.053)	0.025 (0.008–0.051)	0.028 (0.009–0.059)	0.050 (0.016–0.133)	0.020 (0.006–0.05)	0.017 (0.005–0.05)

[a] PCM = Poplar Creek Mile, beginning at the confluence with the Clinch River (PCM = 0) and proceeding upstream.

[b] CRM = Clinch River Mile, beginning at the confluence with the Tennessee River (CRM = 0) and proceeding upstream.

[c] Detection limit was 0.01 mg/liter for April-September, and March samples and 0.2 mg/liter for October-February samples.

[d] Detection limit was 2 mg/liter for April-September samples and 5 mg/liter for October-March samples.

[e] Detection limit was 0.0005 mg/liter for April-September and March samples and 0.002 mg/liter for October-February samples.

[f] Detection limit was 0.005 mg/liter for June, November, and January samples and 0.01 mg/liter for the other nine samples.

[g] n = 11; no value given for May.

[h] n = 1; no value given for August.

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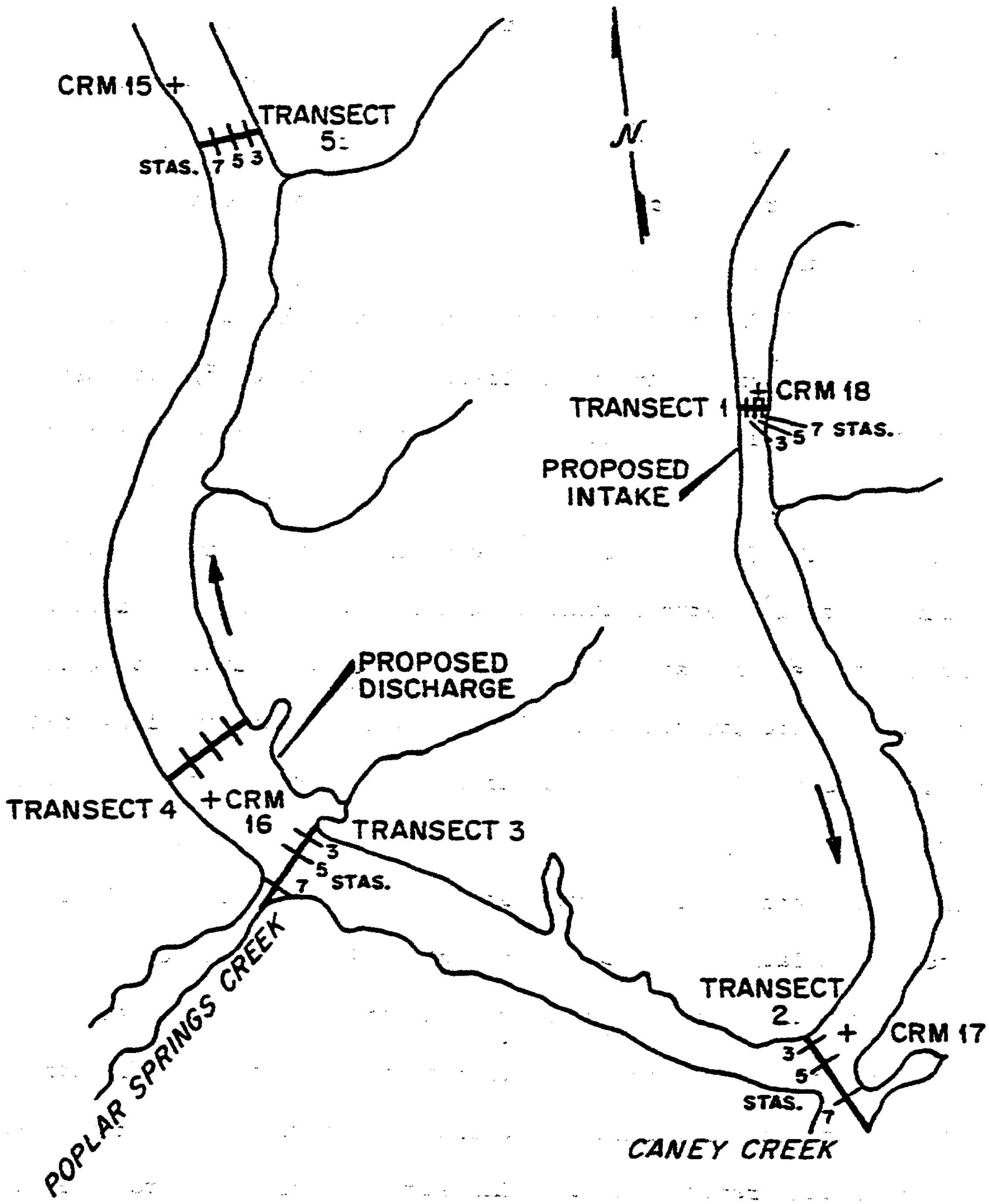

Fig. 1.4-1. Water quality and sediment sampling stations surveyed in 1974-1975 as part of the preoperational baseline monitoring program for the Clinch River Breeder Reactor Project. Source: Project Management Corporation (1975), Fig. 6.1-4.

quality monitoring program. The concentrations reported for March and September 1977 at station K-1513 (Table 1.4-1) are generally in close agreement with values obtained in 1974. The only exception was zinc for which the concentration reported in September at station K-1513 was approximately an order of magnitude higher than the concentration found in the same month in 1974.

An additional 23 parameters were sampled monthly (except during February, October, and December) at Transect 1 (Station 5), Transect 4 (Station 3), and Transect 5 (Station 5) (Project Management Corporation 1975, Tables 2.7-31 and 2.7-32). Seven of these 23 parameters (COD, NO_3-N, NH_3-N, TDS, TSS, Na^+, and $SO_4^=$) were also sampled in the ORGDP monitoring program. Between-transect differences in the mean annual concentration (n=9) of each of these seven parameters appeared negligible. When these data are compared with the mean annual concentrations (n=12) reported at station K-1513, the differences also appear to be insignificant, with the exception of nitrates and ammonia.

These parameters were reported as nitrogen (NO_3-N and NH_3-N) in the CRBR study (see Table 1.4-2) but as nitrates (NO_3) and ammonia (NH_3) in the ORGDP survey. After correcting for differences in the method of expression, nitrate nitrogen concentrations at station K-1513 were found to be consistently higher, by a factor of approximately five, than the concentrations reported in the CRBR survey. Ammonia nitrogen levels at station K-1513, on the other hand, were lower than the values reported at the CRBR stations. A comparison of levels measured during the same months in the different years revealed that the concentration of NH_3-N was approximately an order of magnitude lower at the station K-1513 from

Table 1.4-2. Phosphorus and nitrogen concentrations (mg/liter) measured at three sites on the Clinch River upstream of the ORGDP sanitary water intake, March 1974–April 1975.

Parameter	Transect-station[a]	Sampling date								
		March 26	May 29	June 27	July 22	August 26	September 24	November 19	January 16	April 14
Phosphorus										
Ortho PO_4-P	1-5	0.120	<0.003	0.003	0.020	<0.003	<0.003	<0.003	<0.003	0.080
	4-3	0.060	<0.003	0.003	0.017	<0.003	<0.003	<0.003	<0.003	0 030
	5-5	0.100	<0.003	<0.003	0.020	<0.003	<0.003	<0.003	<0.003	0.010
Total PO_4-P	1-5	0.130	<0.003	0.020	0.023	0.020	<0.003	0.004	0.050	0.120
	4-3	0.130	<0.003	0.008	0.027	0.010	<0.003	0.004	0.030	0.230
	5-5	0.120	<0.003	0.007	0.020	0.020	<0.003	0.003	0.050	0.350
Nitrogen										
NO_2-N	1-5	0.068	0.009	0.009	0.001	<0.001	0.002	<0.001	<0.001	0.003
	4-3	0.062	0.008	0.010	0.002	<0.001	<0.001	<0.001	<0.001	0.003
	5-5	0.065	0.007	0.009	0.002	<0.001	<0.001	<0.001	<0.001	0.003
NO_3-N	1-5	0.4	0.5	0.3	<0.1	<0.1	0.4	0.1	<0.1	<0.1
	4-3	0.5	0.5	0.3	<0.1	<0.1	0.4	0.1	0.4	<0.1
	5-5	0.4	0.5	0.4	0.1	<0.1	0.3	0.1	<0.1	<0.1
NH_3-N	1-5	1.00	0.22	0.05	0.58	0.10	0.17	0.18	0.33	<0.02
	4-3	0.93	0.17	0.04	0.52	0.18	0.19	0.19	0.30	<0.02
	5-5	0.90	0.18	0.09	0.59	0.12	0.18	0.18	0.30	<0.02

[a]Transect and station locations are shown on Fig. 1.4-1.

Source: Project Management Corporation (1975), Table 2.7-31.

March through August after which time the values obtained during the two years were generally similar. These differences in NO_3-N and NH_3-N levels between stations in relative close proximity to one another probably cannot be attributed to natural variability. Moreover, neither of these nitrogen compounds is a constituent in the effluent that is released to the Clinch River in the general vicinity of station K-1513 (M. Mitchell, pers. comm.). Differences in analytical methods might account for some of this discrepancy. Nitrate and ammonia samples collected during the ORGDP monitoring program were analyzed using the cadmium reduction and distillation methods respectively (Ellis 1976). Standard methods (American Public Health Association 1971) were used in the CRBR water quality survey (see Project Management Corporation 1975, Table 6.1-2), but it is not known which of the several methods listed was the one actually used. The different values reported for the ORGDP and CRBR surveys might also be due to differences in sample handling (e.g., filtration, preservation, storage), blank corrections, and/or reference standards.

Nitrite, nitrate, and ammonia nitrogen concentrations were all highest in March with secondary peaks occurring in July and January. Levels the following spring (April), however, were substantially lower. No seasonal trends were observed at the three ORGDP sampling stations located downriver, but elevated nitrate levels did occur at station K-901, especially during the winter and spring. This station is located approximately 700 m below the mouth of Poplar Creek and 30 m above the point of discharge from the K-901-A holding pond.

The ORGDP monitoring program was designed for continuous strip chart monitoring of pH, dissolved oxygen, and specific conductance at stations K-1710 and K-716 on Poplar Creek and stations K-1513 and K-901 on the Clinch River (M. Mitchell, pers. comm.). However, continuous monitoring data were only available for pH at station K-1710. At the other three stations, pH was measured from monthly grab samples. Although no recent data on specific conductance and dissolved oxygen levels in Poplar Creek or the Clinch River are currently available, both of these parameters as well as pH were measured during the CRBR preoperational monitoring program. Measurements of specific conductance and pH were recorded at the surface, mid-depth, and bottom of the water column at 15 stations (three stations along each of the five transects; see Fig. 1.4-1) on seven dates between March 1974 and April 1975. Dissolved oxygen (DO) was also measured at these stations each month (except October, December, and February). The DO measurements were taken at 1-m depth intervals from surface to bottom. Average annual values for pH varied from 7.8 to 8.0 between the five transects, and minimum and maximum values were 6.5 and 8.3, respectively (Project Management Corporation 1975, Table 2.7-33). The pH recorded at CRM 14.4 (station K-1513) during the ORGDP survey ranged from 7.1 to 8.1 ($\overline{x}$ = 7.8, n = 12) while that recorded at CRM 15.1 (transect 5) during the CRBR survey ranged from 6.7 to 8.2 ($\overline{x}$ = 7.8, n = 7). Specific conductance exhibited little variability between transects, the annual average ranging from 208 to 212 µmhos/cm. Minimum values occurred in July and ranged from 120 to 170 µmhos/cm between the five transects, and maximum values (245-260 µmhos/cm) were recorded in September (Project Management Corporation 1975, Table 2.7-30).

This region of the Clinch River is generally well oxygenated throughout most of the year. The average concentration of dissolved oxygen (DO) at any given transect was greater than 6.0 mg/liter on every sampling date except August when minimum levels of 5.6 mg/liter (62.2% saturation) were found. Maximum DO levels (11.2 mg/liter and 100.9% saturation) occurred in March (Project Management Corporation 1975, Table 2.7-34). Although the concentrations of dissolved oxygen decreased with increasing depth, the differences were generally less than 0.3 mg/liter. An interesting exception to this pattern was exhibited in July at all three stations along transects 1 and 2 where the DO levels at the bottom were, on the average, approximately 0.6 mg/liter higher than at the surface (Project Management Corporation 1975, Table 2.7-68). The absence of any stratification in dissolved oxygen suggests that surface and bottom waters are well mixed in this region of the Clinch River. This interpretation is also consistent with the vertical temperature profiles observed during the CRBR survey. Temperatures between the surface and bottom usually varied by less than 0.5°C. A maximum difference of 1°C occurred during periods of zero release at Melton Hill Dam that had begun the previous evening.

Another important nutrient in aquatic systems (in addition to nitrogen) is phosphorus. Concentrations of total phosphate and orthophosphate, both expressed as phosphorus (PO_4-P), fluctuated seasonally in rather well-defined patterns in that region of the Clinch River upstream of the ORGDP sanitary water intake (Table 1.4-2). Peaks in both parameters occurred in the spring with a secondary peak evident in midsummer. Very little variability in the levels of phosphorus was evident among the three sampling sites.

Data are also available on several other parameters that were not included in the routine ORGDP nonradiological monitoring program. Those of greatest importance in characterizing the water quality in this region of the river are included in Table 1.4-3 and summarized below. Data on other parameters (e.g., pesticides, bacteria, etc.) are presented in Project Management Corporation (1975) Tables 2.7-31, 2.7-32, 2.7-35, and 2.7-40.

Alkalinity and hardness were lowest in March and highest in September at all three sampling stations (Project Management Corporation 1975, Section 2.7.2.3.10 and Table 2.7-31). A general increase in both parameters was observed from March through September followed by a gradual decline from November through April 1975. Calculations of hardness based on divalent ion concentrations (American Public Health Association 1976, Sawyer and McCarty 1967) indicate that the hardness of the Clinch River is principally due to the presence of Ca^{++}. Many of the streams entering the Clinch River, such as Caney Creek, Ish Creek, and White Oak Creek (see Table 1.2-1), derive their base flow from dolomite, $CaMg(CO_3)_2$, and, consequently, exhibit elevated concentrations of Mg^{++}, Ca^{++}, and HCO_3^-. Because water in a stream can be assumed to be in contact with soil and bedrock for a longer time during periods of low as compared to high base flow, an inverse relationship often exists between streamflow and dissolved solids content (McMaster 1967). Such a relationship, which may also reflect a dilution effect, probably accounts for the seasonality associated with alkalinity and hardness levels in the Clinch River.

Table 1.4-3. Mean, minimum, and maximum concentrations (mg/liter) of seven parameters measured at three stations in the Clinch River upstream of the ORGDP sanitary water intake, March 1974-April 1975

Parameter	Transect 1-station 5[a]			Transect 4-station 3[a]			Transect 5-station 5[a]		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Total alkalinity (as $CaCO_3$)	96	76	114	98	76	116	93	76	106
Hardness (as $CaCO_3$)	112	96	136	115	88	138	111	82	136
Calcium[b]				33.5	24.0	43.0			
Magnesium[b]				7.8	7.0	8.5			
Iron (total)[b]				0.38	0.08	0.68			
Chloride	5.0	2.6	13.0	4.7	2.0	11.0	4.6	1.0	10.0
Potassium	1.4	1.1	1.7	1.4	1.1	1.9	1.3	1.1	1.6
BOD	2.1	0.3	6.0	1.8	0.9	3.0	2.2	<1.0	3.4
Total organic carbon	4.0	1.0	10.0	4.5	1.0	9.0	3.2	1.0	6.0

[a]Transect and station locations are shown in Fig. 1.4-1.

[b]Samples were only taken in March and September 1974 at Transect 4, station 3.

Source: Project Management Corporation (1975), Tables 2.7-32 and 2.7-35.

For other parameters, temporal patterns were not as well defined. For example, biochemical oxygen demand (BOD) was less than 3.5 mg/liter on every sampling date at every station with the exception of transect 1 on July 22, 1974, when a level of 6.0 mg/liter was recorded. Peaks in total organic carbon (TOC) were exhibited in March and late summer (August/September) while the minimum concentration of 1.0 mg/liter was found in April at all three stations. Chloride levels fluctuated from 2.0 to 5.0 mg/liter during 1974, reaching maximum levels (10.0-13.0 mg/liter) in January and April 1975. Potassium levels in the Clinch River also exhibited seasonal maxima during the winter and early spring.

1.4.2 Exxon Nuclear Fuel Recovery and Recycling Center (NFRRC) Survey

After termination of the CRBR survey in April 1975, another one-year survey was initiated the following month to provide preoperational baseline data necessary to assess the potential environmental impacts of the Exxon Nuclear Fuel Recovery and Recyling Center (Exxon Nuclear Company, Inc. 1976). The proposed site of this facility is located just upstream of the ORGDP sanitary water intake on the Clinch River (CRM 14.4). Thirty-six water quality parameters were measured at the surface, mid-depth, and bottom of the water column at three stations located near the east shore of the Clinch River (CRM 12, CRM 14.5, CRM 15). Additional measurements of these parameters were taken at mid-depth at two stations located near the middle and west shore of the Clinch River at station CRM 15. Differences in concentration between the three sampling depths were minor for most of the parameters measured (Exxon Nuclear Company, Inc. 1976, Table 2.5-3).

Levels of total nickel, however, were highest near the bottom, and differences in concentration between the surface and bottom ranged from 10 to 21 μg/liter. Differences in the levels of total zinc at the surface and bottom ranged from 16 to 26 μg/liter, but no consistent relationship between concentration and depth was exhibited. Likewise, between-station comparisons indicated that levels of most of the parameters measured were similar at stations CRM 12, 14.5, and 15. Specific conductance was slightly higher at the two downstream stations, while the concentration of nickel at these two stations was approximately 10 μg/liter higher than the levels observed at CRM 15.0 (Exxon Nuclear Company, Inc. 1976, Table 2.5-3).

The results obtained from the NFRRC preoperational monitoring program were compared with those of the ORGDP and CRBR surveys. Mean annual concentrations for 14 of 36 parameters measured during NFRRC (Table 1.4-4) were, in general, similar to the values reported at station K-1513 (CRM 14.4) during the ORGDP study (Table 1.4-1). Levels of total dissolved solids and total suspended solids were slightly lower than the levels found in 1974-75 during the CRBR survey and in 1977-78 during the ORGDP survey. The concentration of nickel at all five NFRRC stations was considerably higher than that found during the CRBR (<10 μg/liter at CRM 15.9) and the ORGDP survey ($\bar{x}$ = 11 μg/liter; range = <5-26 μg/liter at CRM 14.4).

An additional eighteen parameters that, with the exception of ammonia, are not routinely sampled in the ORGDP water quality monitoring program were measured during the NFRRC survey (Table 1.4-5). Levels of dissolved oxygen, organic carbon, orthophosphorus, and nitrite + nitrate

Table 1.4-4. Mean annual concentrations and standard deviations of 13 water quality parameters that were measured in the Clinch River during the Exxon Nuclear Fuel Recovery and Recycling Center preoperational survey and are routinely monitored by the ORGDP staff. Tabular values are based on mid-depth samples taken from May 1975 through April 1976.

Parameter	Sampling site (CRM)				
	12	14.5	15-L[a]	15-M[a]	15-R[a]
Dissolved solids (mg/liter)	127 ± 18	120 ± 42	131 ± 22	127 ± 14	135 ± 25
Suspended solids (mg/liter)	9.1 ± 3.6	7.2 ± 3.6	6.8 ± 4.0	7.4 ± 3.2	6.4 ± 4.0
COD (mg/liter)	5.7 ± 2.5	6.6 ± 2.2	6.3 ± 3.0	6.3 ± 2.2	7.0 ± 3.2
Fluoride (mg/liter)	0.09 ± 0.05	0.10 ± 0.07	0.14 ± 0.08	0.12 ± 0.09	0.07 ± 0.05
Sulfate (mg/liter)	14.3 ± 3.3	15.3 ± 3.8	14.6 ± 3.6	15.0 ± 3.6	14.2 ± 3.4
Sodium (mg/liter)	2.7 ± 0.6	2.6 ± 0.6	2.5 ± 0.6	2.6 ± 0.5	2.6 ± 0.5
Cadmium (μg/liter)	1.1 ± 0.3	1.1 ± 0.3	1.4 ± 0.5	1.3 ± 0.5	1.1 ± 0.3
Chromium (μg/liter)	5.6 ± 1.0	5.8 ± 1.7	5.2 ± 0.4	5.2 ± 0.6	5.1 ± 0.3
Copper (μg/liter)	34 ± 32	30 ± 29	33 ± 40	33 ± 38	29 ± 35
Lead (μg/liter)	11.4 ± 3.0	10.8 ± 1.9	10.3 ± 0.6	13.3 ± 5.1	11.6 ± 3.6
Manganese, total (μg/liter)	54 ± 28	54 ± 26	52 ± 22	51 ± 21	45 ± 20
Manganese, dissolved (μg/liter)	17 ± 8	15 ± 6	18 ± 8	17 ± 11	18 ± 8
Nickel (μg/liter)	72 ± 30	76 ± 40	63 ± 22	65 ± 28	68 ± 34
Zinc (μg/liter)	61 ± 45	48 ± 40	56 ± 53	55 ± 43	44 ± 42

[a]Stations were located at 25% of river width measured from left bank facing upstream (15-L), 50% of river width (15-M), and 75% of river width (15-R).

Source: Exxon Nuclear Company, Inc. (1976), Table 2.5-3.

nitrogen reported during the NFRRC study were somewhat higher than the levels found the previous year during the CRBR survey (see Table 1.4-2). Biochemical oxygen demand and ammonia nitrogen, on the other hand, were generally lower at the NFRRC sites compared with the CRBR sites located upstream. The mean annual concentrations reported for ammonia nitrogen were similar to those obtained during the ORGDP sampling program but were almost an order of magnitude lower than those found during the CRBR study. On the other hand, nitrate levels measured in 1977-78 at station K-1513 exceeded the levels reported in both 1974-75 at CRM 15.1 and in

Table 1.4-5. Mean annual concentrations (mg/liter) and standard deviations of 18 water quality parameters that were measured in the Clinch River during the Exxon Nuclear Fuel Recovery and Recycling Center preoperational survey and are not routinely monitored by the ORGDP staff.[a] Tabular values are based on mid-depth samples taken from May 1975 through April 1976.

Parameter	Sampling site (CRM)				
	12	14.5	15-L[b]	15-M[b]	15-R[b]
Conductance[c]	209 ± 29.1	207 ± 31.0	201 ± 35.6	199 ± 37.5	199 ± 37.5
Dissolved oxygen	8.9 ± 1.8	9.1 ± 2.2	9.1 ± 2.3	9.1 ± 2.3	9.1 ± 2.3
BOD	1.1 ± 0.2	1.1 ± 0.2	1.0 ± 0.1	1.1 ± 0.2	1.1 ± 0.2
Organic carbon	14.8 ± 9.0	15.9 ± 9.2	16.2 ± 10.3	15.1 ± 9.1	12.1 ± 7.3
pH	7.9 ± 0.6	7.9 ± 0.5	7.8 ± 0.6	7.7 ± 0.6	7.8 ± 0.5
Alkalinity	95 ± 8.8	95 ± 6.0	96 ± 5.9	95 ± 6.3	94 ± 7.4
Chloride	3.0 ± 0.5	2.9 ± 0.3	2.9 ± 0.5	2.9 ± 0.6	3.1 ± 0.7
Organic nitrogen	0.29 ± 0.29	0.28 ± 0.31	0.28 ± 0.27	0.30 ± 0.22	0.24 ± 0.13
NH_3-N	0.05 ± 0.04	0.04 ± 0.05	0.05 ± 0.04	0.07 ± 0.10	0.04 ± 0.05
NO_2 + NO_3-N	0.34 ± 0.12	0.32 ± 0.12	0.34 ± 0.12	0.36 ± 0.13	0.33 ± 0.17
PO_4-P (total)	0.07 ± 0.03	0.06 ± 0.04	0.08 ± 0.05	0.06 ± 0.04	0.07 ± 0.05
PO_4-P (dissolved)	0.04 ± 0.04	0.03 ± 0.04	0.04 ± 0.02	0.04 ± 0.04	0.03 ± 0.03
Calcium	36 ± 15	36 ± 16	35 ± 15	36 ± 16	36 ± 15
Magnesium	6.8 ± 1.1	6.9 ± 1.2	6.9 ± 1.2	6.9 ± 1.1	6.9 ± 1.1
Potassium	1.2 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.4
Iron (total)[d]	377 ± 120	338 ± 215	348 ± 161	336 ± 122	277 ± 111
Iron (dissolved)[d]	103 ± 41	121 ± 54	174 ± 127	131 ± 71	120 ± 64
Silica (dissolved)	3.0 ± 2.3	2.3 ± 2.0	2.4 ± 1.7	2.8 ± 1.8	2.4 ± 1.3

[a]Except NH_3.

[b]Stations were located at 25% of river width measured from leftbank facing upstream (15-L), 50% of river width (15-M), and 75% of river width (15-R).

[c]Values expressed as μmhos at 25°C.

[d]Values expressed as μg/liter.

Source: Exxon Nuclear Company, Inc. (1976), Table 2.5-3.

1975-76 at CRM 14.5 and 15 (latter values include both nitrite and nitrate nitrogen). As discussed previously, the reasons for the elevated nitrate levels in 1977-78 are not known.

1.4.3 Other Water Quality Studies

An additional but limited water quality sampling program was conducted in 1974-1975 in the vicinity of ORGDP (B. G. Blaylock, unpublished data). Twenty-seven parameters were measured at stations on Poplar Creek above and below ORGDP and on the Clinch River at CRM 11.0, approximately 600 m below the point of discharge from the K-901-A holding pond to the river. No in-depth comparison of these data with those collected in the CRBR and NFRRC preoperational surveys or during the ORGDP monitoring program is possible due to both the limited scope of the 1974-75 survey and the location of the sampling stations (Table 1.4-6). A few statements, however, seem appropriate.

In the Clinch River, total chromium levels in 1977 were one to three orders of magnitude lower than levels measured during the winter of 1974-75, but it should be noted that the 1977 station used for comparison was 2 km below the 1974 sampling site. Two of the three samples taken in the Clinch River (CRM 11.0) in 1974-75 exceeded 1.0 mg/liter total dissolved chromium (maximum suspended chromium concentration was 0.39 mg/liter), while the maximum concentration reported for the same months in 1977-78 was 0.077 mg/liter. Similarly, sulfate levels exceeded 100 mg/liter in two of the three samples taken in 1974-75 ($\bar{x}$ = 101; range 17-165) but never exceeded 45 mg/liter during the entire 1977-78 study. Values reported for the remaining parameters sampled in

Table 1.4-6. Parameters measured during a water quality survey conducted from September 1974 through March 1975 at sites on Poplar Creek and the Clinch River. S,O,D,J,M = months sampled.

Parameter	Station PC-1[a]					Station PC-2[b]					Station CR-3[c]				
	S	O	D	J	M	S	O	D	J	M	S	O	D	J	M
Temperature	X			X	X		X		X	X			X	X	X
Turbidity				X	X				X	X					X
TSS	X			X	X		X		X	X			X	X	X
TDS					X				X	X			X	X	X
DO	X			X	X		X		X	X			X	X	X
pH	X			X	X		X		X	X			X	X	X
Alkalinity				X					X				X	X	
Hardness				X	X		X		X	X			X	X	X
Al[d]	X			X	X		X			X					X
Cd[d]	X			X			X		X				X	X	
Cr[d]	X				X		X		X	X			X	X	X
Cu[d]	X			X			X		X	X			X	X	X
Mn[d]	X			X					X	X			X	X	
Pb[d]	X			X					X				X	X	
Zn[d]	X			X											
Hg				X	X				X	X			X	X	X
NO_3				X					X				X	X	X
PO_4				X					X				X	X	X
SO_4				X					X				X	X	X
B				X	X				X	X			X	X	X
Ba				X	X				X	X			X	X	X
Ca				X	X				X	X			X	X	X
K				X	X				X	X			X	X	X
Mg				X	X				X	X			X	X	X
Na				X	X				X	X			X	X	X
Ni				X	X				X	X			X	X	X
Si				X	X				X	X			X	X	X

[a] Located 50 m above confluence with East Fork Poplar Creek.

[b] Located 100 m above the mouth of the creek.

[c] Located at CRM 11.0

[d] Measurements of both the dissolved and suspended (retained by 0.8-μm Millipore filter) fractions were taken.

Source: B. G. Blaylock, unpublished data.

1974-75 were generally all within the range found during the 1977-78 ORGDP monitoring program.

In Poplar Creek, water quality samples were taken near the mouth during both the 1974-75 and the ORGDP surveys, and parameter values reported during the two surveys were similar. Several other parameters not included in the 1977-78 ORGDP monitoring program were also sampled in this area as part of the 1974-75 survey (B. G. Blaylock, unpublished data). In three months of sampling, for example, hardness varied from 65 to 112 mg/liter ($\bar{x}$ = 84.0 mg/liter; n = 3) and dissolved oxygen ranged from 4.4 mg/liter in October to 11.0 mg/liter in March ($\bar{x}$ = 8.5 mg/liter; n = 3). Although detailed comparisons could not be made between station PC-1 at PCM 5.6 (Table 1.4-6) and the West Fork station at PCM 6.9 (Table 1.4-1), the concentrations found at station PCM 5.6 generally fell within the range reported for the upstream station. However, levels of zinc (dissolved) were 0.06 and 0.08 mg/liter at station PCM 5.6 in September 1974 and January 1975, respectively, while the average concentration reported at PCM 6.9 in 1977-78 was 0.017 mg/liter (Table 1.4-1). Twenty-three of the 27 parameters included in the 1974-75 survey at station PC-1 were sampled on only one or two dates. Of the four parameters measured on three occasions (September, January, and March), those of greatest interest were dissolved oxygen ($\bar{x}$ = 8.7) mg/liter; range 6.7-10.0 mg/liter) and pH ($\bar{x}$ = 7.34; range = 7.00-7.72).

The concentration of polychlorinated biphenyls (PCBs) in water was measured in a study of PCBs in surface waters and sediments in the vicinity of the three Oak Ridge facilities (Mitchell 1978a,b). Samples were taken from New Hope Pond at Y-12, East Fork Poplar Creek, White Oak

Creek, and Melton Hill Reservoir, both near the dam and in Scarboro embayment, in addition to Poplar Creek and the Clinch River. Although the majority of the sampling effort focused on sediment analysis, some water samples were examined. Samples taken from Poplar Creek at Blair Bridge (PCM 4.7) and 1.6 km below discharge location 5 (Fig. 1.2-2) had PCB concentrations that were less than 0.0005 µg/liter. The same values were reported for samples collected at the ORGDP sanitary water intake, at a site 1.6 km below the outfall of the K-901-A holding pond, and at two locations described only as "above (and below) Poplar Creek" (Mitchell 1978a).

1.4.4 Trace Elements in Sediments

Routine analysis of sediments for various elements (Al, Cd, Cr, Cu, Pb, Mn, Hg, Ni, and Zn) is also conducted by the ORGDP staff on a semiannual basis (July and November). Currently, sediment cores are taken at 18 sites on Poplar Creek and two sites on the Clinch River above and below the mouth of Poplar Creek (Fig. 1.3.1-1). The nonradiological sediment monitoring program was initiated in 1974 when eight stations were sampled for iron, nickel, zinc, mercury, lead, and cadmium. The following year the program was expanded to 102 sampling sites and was reduced to 19 stations in 1976. An additional station in the Clinch River near Brashear Island (CRM 9.8) was included in the 1977 monitoring program. Results obtained from 1975-77 are presented in Table 1.4-7.

Data collected during the first year of sampling (1974) have not been included in this report because of the limited scope of the program and the lack of sufficient information on sampling locations. In general, however, the 1974 sediment concentrations of nickel, zinc, mercury, and cadmium at the seven stations located on Poplar Creek were within the range reported in later surveys. Levels of lead in the upper sediment layers were ⩾250 ppm at six of the seven stations. Values of this magnitude were also found in 1975 but apparently decreased markedly in 1976 and 1977. It should also be noted that samples were taken at various depths below the surface of the substrate during the initial survey in 1974. Concentrations in the top 6 to 11 cm were greater than or equal to the concentrations found in deeper layers in the majority of the cores taken.

In any given year, the concentration of mercury in the sediments of Poplar Creek exhibited the greatest variability between sampling sites of any of the elements. For example, the range in concentrations found between the 20 sampling sites varied by more than three orders of magnitude, and, with the exception of July 1976, was always greater than two orders of magnitude. Of the remaining elements, only the levels of nickel and copper consistently differed by more than an order of magnitude between stations. Values in Table 1.4-7 represent the concentrations in bulk sediment samples and have not been normalized for differences in particle size. Because 80 to 90% of sediment mercury (and many of the other elements as well) is associated with the clay-silt size fraction (<63μm), the inclusion of larger particles will have a significant influence on the measured concentrations in bulk samples.

Using the data collected in 1975 and 1976 on mercury in Poplar Creek sediments between PCM 0 AND PCM 5.2 (Union Carbide Corporation —

Table 1.4-7. Concentrations (ug/g, dr
from various sites in Poplar Creek a
1 = July 1975; 2 = July 1976; 3

Sampling site[a]	Aluminum					Cadmium					Chromium					Copper					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1
1	NS	24	40	4.8	2.4	NS	<5	<5	<5	<5	NS	92	38	38	50	NS	15	25	13	40	NS
2	25	26	33	4.3	4.1	<0.1	<5	<5	<5	<5	20	115	65	68	65	20	59	30	37	116	20
3	40	34	76	4.5	4.2	3	<5	10	<5	<5	170	80	110	62	60	90	23	87	16	39	250
4	70	8	76	4.7	2.4	<0.1	<5	<5	<5	<5	180	140	90	77	150	80	53	104	17	57	300
5	55	27	30	5.0	1.6	<0.1	<5	<5	<5	<5	110	200	200	17	57	100	67	62	5	20	40
6	70	10	47	4.6	1.9	<0.1	<5	<5	<5	<5	130	320	83	160	266	120	78	20	35	70	400
7	22	9	40	5.2	2.1	<0.1	<5	10	<5	<5	60	150	215	42	60	30	66	76	10	30	10
8	80	22	50	4.3	4.1	<0.1	<5	<5	<5	<5	90	125	100	31	73	150	34	355	7	42	100
9	36	18	NS	4.1	2.2	<0.1	<5	NS	<5	<5	90	70	NS	43	143	50	16	NS	10	95	30
10	66	8	88	3.7	2.1	2	<5	10	<5	<5	240	42	180	57	75	70	25	75	11	38	200
11	94	52	55	4.2	1.5	1	<5	<5	<5	<5	130	185	125	45	50	70	90	81	11	30	35
12	40	38	46	4.5	1.4	<0.1	<5	<5	<5	<5	90	61	65	19	30	70	40	49	27	14	15
13	72	31	36	4.8	2.7	<0.1	<5	<5	<5	<5	100	80	70	41	69	60	120	150	8	37	15
14[c]		7	61	4.5	3.1		<5	<5	<5	<5		100	100	110	49		45	175	72	23	
15	51	6	60	5.0	4.1	<0.1	<5	10	<5	<5	50	45	300	56	88	30	32	175	12	46	10
16[c]		9	48	4.7	5.8		<5	<5	<5	<5		410	140	270	537		200	153	180	162	
17	58	8	48	4.6	5.3	1	<5	<5	<5	<5	570	330	160	56	196	280	430	250	46	186	50
18	48	11	35	5.7	4.2	1	<5	10	<5	<5	60	65	45	66	88	50	30	26	28	53	40
19	59	8	2.59	5.3	3.8	<0.1	<5	<5	<5	<5	50	75	60	63	184	200	48	50	31	80	60
20	NS	NS	NS	6.0	3.0	NS	NS	NS	<5	<5	NS	NS	NS	48	126	NS	NS	NS	8	23	NS

[a]Sampling sites for 1976 and 1977 are shown in Fig. 1.3.1-1. Samples in 1975 were collected at 102 sites from the mouth of Poplar Creek (PCM 0) upstream to West Fork Poplar Creek above the confluence with East Fork Poplar Creek. Only the results from those 1975 samples taken in immediate vicinity of the 1976-1977 sites are presented. In those cases where several samples from 1975 were taken near one of the 1976-1977 sites, the maximum concentration is presented.

[b]Values presented in columns 1, 2, and 3 are × 10^3; values in columns 4 and 5 are % Al.

[c]No sampling station in the 1975 survey was in the immediate vicinity of this site.

Source: M. Mitchell, unpublished data.

t) of nine elements in bulk sediment samples collected
the Clinch River in 1975-1977. Sampling dates are:
ovember 1976; 4 = July 1977; 5 = November 1977.
= not sampled.

Lead			Manganese					Mercury					Nickel					Zinc				
3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
10	22	90	NS	540	2100	230	2290	NS	<1	<0.1	<0.2	0.35	NS	50	600	27	38	NS	70	80	28	120
20	21	90	260	500	410	130	352	<0.1	2	2	43.0	10.26	30	120	660	320	76	30	75	80	250	124
140	24	100	680	775	315	170	380	10	2	20	10.0	18.81	140	70	730	48	51	160	200	175	54	124
20	21	80	700	700	515	130	587	5	2	2	12.0	12.48	1200	90	490	42	67	160	165	145	40	148
45	21	80	2130	870	680	20	550	<0.1	5	10	1.3	1.40	50	150	648	78	31	70	200	220	8	120
30	26	80	380	630	300	120	394	3	10	2	39.0	38.0	100	250	580	70	120	100	250	200	62	160
45	26	75	300	500	480	270	871	5	10	125	3.4	<0.2	60	100	500	43	40	70	160	223	25	200
35	23	46	1090	660	500	50	435	1	<0.2	0.5	<0.2	3.05	700	120	320	35	78	130	110	145	100	106
NS	25	70	1200	495	NS	160	454	5	10	NS	0.56	21.5	200	65	NS	39	164	100	85	NS	26	200
35	25	70	650	875	1000	440	441	30	10	10	<0.2	5.24	400	70	600	43	66	200	80	200	21	134
75	24	90	940	730	678	100	265	1	5	20	0.84	8.4	120	155	445	43	61	180	200	180	27	114
30	23	90	530	1000	1070	20	150	10	1	<0.1	5.7	<0.2	500	65	365	30	30	200	82	105	5	95
33	25	42	740	835	500	80	177	0.5	5	<0.1	<0.2	6.54	90	90	500	38	274	150	175	100	20	89
40	29	30		970	700	250	308		1	100	307.0	<0.2		100	170	170	69		130	170	9	68
35	26	48	1400	1085	550	150	351	0.1	1	2	<0.2	7.80	70	57	145	43	334	60	60	182	22	104
25	33	73		700	600	270	533		1	2	21.0	1.65		175	325	680	224		180	163	120	130
20	29	66	450	590	780	210	432	10	5	2	8.2	11.0	1000	1500	623	46	892	250	410	225	43	186
35	27	44	430	1000	528	760	614	5	1	1	32.0	8.97	70	75	70	56	322	50	100	85	78	106
20	27	51	1230	1300	615	70	374	0.1	10	20	62.0	21.9	150	85	50	70	226	80	130	115	37	96
NS	28	47	NS	NS	NS	180	632	NS	NS	NS	0.3	0.40	NS	NS	NS	36	73	NS	NS	NS	14	75

Nuclear Division 1977a, 1978), an analysis of the frequency distribution of mercury concentrations in these samples indicated that, in these two years, they did not follow a normal or log-normal distribution. Thus, any comparisons between sampling stations and dates must be based on transformed data (J. W. Elwood, pers. comm.). This precaution should also be noted with regard to the data on mercury levels collected in 1977, since the distribution of these concentrations in both July and November also appears to be skewed. An examination of the data on mercury concentrations in the sediments of Poplar Creek collected in 1977 with that collected in the preceding two years suggests that different analytical procedures may have been employed. For example, the lowest reported concentration of mercury in the sediment samples collected in 1977 was less than 0.2 μg/g (see Table 1.4-7), which is the detection limit for mercury analyzed by flameless atomic absorption (Union Carbide Corporation — Nuclear Division 1977b). Additional information (J. W. Elwood, pers. comm.) indicates that samples collected in 1977 were analyzed for mercury by atomic absorption, whereas an emission spectrograph, which has substantially lower precision, was used to analyze samples collected in 1975 and 1976.

Finally, an analysis of mercury levels in that section of Poplar Creek extending from the mouth (Station PS 2) upstream to East Fork Poplar Creek (PS 19) indicates that more than 80% of the sediment samples taken from this area in 1976 and 1977 had mercury concentrations greater than 1.0 μg/g dry wt ($\overline{X}$ = 81.7%; range 66.7% in July 1977 to 94.4% in July 1976) and more than one-third of the samples had levels greater than 10.0 μg/g dry wt ($\overline{X}$ = 38.0%; range = 27.8% in July 1976 to 44.4% in

July 1977). Mercury values as high as 300 μg/g dry wt were recorded near PCM 1.5 and PCM 1.6 in July 1975 and near PCM 4.5 in July 1977.

Additional data on heavy metal levels in sediments from surface waters in the vicinity of ORGDP were collected in two studies conducted in 1974-75. During the CRBR preoperational survey, composite samples of sediment were taken from three stations along each five transects located in a 4.8-km section of the Clinch River (Fig. 1.4-1). Samples were analyzed for 16 heavy metals and phosphate in March 1974 (Project Management Corporation 1975, Table 2.7-37). Forty-two parameters, including polychlorinated biphenyls and five insecticides, were measured in samples taken in a similar manner at transects 1, 4, and 5 in April of the following year (Project Management Corporation 1975, Table 2.7-38). Levels of cadmium, copper, lead, manganese, mercury, and zinc measured at these stations were similar to the levels found in samples collected at station PS-1 (CRM 12.5) during the ORGDP survey in 1976 and 1977 (Table 1.4-8). Three elements (Al, Cr, and Ni), however, exhibited higher concentrations in the sediments from station PS-1 than were found in the sediments near the proposed site of the Clinch River Breeder Reactor (CRM 15.1 to 17.9). For example, the maximum chromium concentration reported in the CRBR survey was 30 μg/g at transect 2 (CRM 17.0), whereas the minimum concentration found during the routine ORGDP sediment sampling program at PS-1 (CRM 12.5) was 38 μg/g dry wt.

Sediments from Poplar Creek and the Clinch River were analyzed for 25 parameters during a 1974-75 study (B. G. Blaylock, unpublished data). The two samples taken at station CR-3 (CRM 11.0) in December and January had mercury levels that were two orders of magnitude higher than the

Table 1.4-8. Mean concentrations (μg/g, dry wt) (range in parentheses) of nine elements in sediment samples[a] collected during three surveys at various stations in the Clinch River in the vicinity of ORGDP. The number of samples (n) collected were as follows: CRBR survey, n = 5 (March) and n = 3 (April); ORGDP survey, n = 4 (Station PS-1) and n = 2 (Station PS-20); 1974-75 survey (n = 2). N/A = data not available in μg/g. NS = not sampled.

	CRBR survey[b]		ORGDP survey[c]		1974-75 survey[d]
Element	March 1974 (CRM 17.9-15.1)	April 1975 (CRM 17.9-15.1)	PS-1 (CRM 12.5)	PS-20 (CRM 9.8)	CR-3 (CRM 11.0)
Al	6240 (3,900-10,000)	>10,000 (all samples)	32,000[e] (24,000-40,000)	N/A	N/A
Cd	<2 (all samples)	<0.5 (all samples)	<5 (all samples)	<5 (all samples)	<2 (<2-2)
Cr	16 (5-30)	20 (all samples)	55 (38-92)	87 (48-126)	21 (10-32)
Cu	18 (15-25)	11 (7-15)	23 (13-40)	16 (8-23)	34 (14-54)
Pb	<15 (all samples)	26 (22-31)	36 (10-90)	38 (28-47)	22 (20-24)
Mn	1900 (700-2900)	400 (all samples)	1290 (230-2290)	406 (180-632)	N/A
Hg	<100 (all samples)	0.04 (0.02-0.08)	<0.4 (<0.1-0.5)	0.35 (0.3-0.4)	34.6 (17.3-51.9)
Ni	7 (5-10)	40 (all samples)	179 (27-600)	55 (36-73)	N/A
Zn	46 (30-60)	33 (30-40)	75 (28-120)	45 (14-75)	NS

[a]Tabular values based on bulk (unsieved) samples in ORGDP study. Samples sieved through 0.635-cm (0.25-in) mesh and No. 30 (520 μm) mesh screens in the CRBR and the 1974-75 studies, respectively.

[b]Source: Project Management Corporation (1975), Tables 2.7-37 and 2.7-38.

[c]Source: See Table 1.4-7.

[d]Source: B. G. Blaylock, unpublished data.

[e]Based on analysis of only two samples from 1976. Values in 1977 were reported as %, by weight.

levels reported in two samples collected during the ORGDP survey at a site approximately 2 km downstream (Table 1.4-8). A comparison of total chromium concentrations at the same two stations, however, indicated a trend in the opposite direction. Chromium levels in the two samples collected at CRM 11.0 were below the levels found in two samples from station PS-20 (CRM 9.8). Elwood et al. (1980) reported an average concentration of 44 ± 30 μg/g, dry weight (±2 SD) for total chromium on the less than 53-μm-size fraction of surface (0-5 cm) sediments from an uncontaminated embayment of Melton Hill Reservoir at CRM 33.

Sediment data were also collected at Poplar Creek stations PC-1 (PCM 5.6) and PC-2 (PCM 0.1) in January and March 1975. Total chromium concentrations reported at station PC-1 were lower ($\overline{X}$ = 26; n = 2) than those reported in sampling conducted from 1975 to 1977 in the same general region of the creek (stations PS-2, PS-3, and PS-4). Concentrations of other elements found in the sediments at station PC-1 were generally within the range reported in the ORGDP survey.

1.4.5 PCBs in Sediments

Polychlorinated biphenyls (PCBs) were sampled in 1974 at six locations in Poplar Creek from the mouth upstream to discharge location 1 (see Fig. 1.2-2). The mean concentration in these samples was 11 μg/g with a range from 6 to 15 μg/g (Mitchell 1978b). Concentrations of 24 and 25 μg/g were found in the K-901-A lagoon and the K-1407-C sludge lagoon, respectively, while much lower PCB levels were reported from the K-1007-B holding pond (0.4 μg/g) and the K-1001-B holding pond (<0.1 μg/g). Six other samples taken from the mouth of Poplar Creek to above Blair

Bridge had substantially lower concentrations ($\overline{X}$ = 0.4 μg/g; range = <0.1 - 1.5 μg/g) (Mitchell 1978a). With the possible exception of the sample from the mouth of the creek, these latter samples were not collected in the immediate vicinity of the 1974 sampling sites. Finally, sediment samples collected at stations PC-1 and PC-2 in January 1975 had PCB concentrations of 0.1 and 0.4 μg/g, respectively (B. G. Blaylock, unpublished data). No information is available on the type of PCBs (e.g., Arochlor 1254, Arochlor 1016) that were found in the sediments analyzed in these various studies.

Levels of PCBs in sediments from the Clinch River were substantially lower than those found in Poplar Creek. Three samples collected near Grubb Island (CRM 18.4) in 1974 all had PCB concentrations that were less than 0.1 μg/g (Mitchell 1978b). Samples were also collected in April 1975 at three sites just below Grubb Island, and the concentrations of PCBs were: 0.00064 μg/g at CRM 17.9, 0.016 μg/g at CRM 15.9 (mean of two analyses), and 0.00028 μg/g at CRM 15.1 (Project Management Corporation 1975, Table 2.7-39). Two samples taken in the Clinch River near CRM 11.0 had elevated levels of PCBs. These samples, which were collected in December 1974 and January 1975, had PCB concentrations of 0.1 and 1.6 μg/g, respectively (B. G. Blaylock, unpublished data).

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1.5 Results and Discussion of Trace Substances in Fish

J. M. Loar, J. W. Huckabee, and J. A. Solomon

With the exception of mercury, polychlorinated biphenyls (PCBs), and possibly nickel, the levels of trace substances found in the tissues of 357 fish (16 species) collected from Poplar Creek (Tables 1.5-1 thru 1.5-3) and the Clinch River (Tables 1.5-4 thru 1.5-6) in the spring and fall of 1977 were generally within the ranges that have been reported in freshwater fishes from relatively uncontaminated environments (Table 1.5-7). In all the tissues analyzed for PCBs, these compounds were detected in measurable quantities. Since they do not occur naturally, any amount of PCBs in fish should be regarded as contamination.

1.5.1 Mercury

The concentration of total mercury in muscle tissue was equal to or exceeded 0.5 μg/g, wet weight, in 16% and 15% of the game fish (species in the families Centrarchidae, Ictaluridae, Percichthyidae and Percidae) collected from Poplar Creek and the Clinch River, respectively. Concentrations in excess of 1.0 μg/g, the action level for mercury in fish recently recommended by the U.S. Food and Drug Administration (FDA) [Fed. Regist. 44(14):3990-3993, January 19, 1979] were found in 2% and 1% of the game fish from these two areas, respectively. Migratory species, such as the white bass and gizzard shad, were less contaminated with mercury than many of the resident species (e.g., largemouth bass, bluegill, channel catfish). An exception to this trend was observed in sauger, a migratory species that was collected in the Clinch River near

Table 1.5-1. Mean concentration of metals and PCBs (μg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species (n ⩾ 3 individuals) collected from Poplar Creek at Station PCM 11.0 in April 1977. Values for all samples analyzed are given in Appendix A-1.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
White bass	0.17 (0.01)	0.21 (0.02)	0.008 (0.001)	5.0 (0.5)	0.6 (0.1)	0.09 (0.02)	0.5 (0)	0.4 (0.1)
Gizzard shad	0.04 (0.002)	0.13 (0.02)	0.007 (0.001)	4.0 (0.3)	0.8 (0.1)	0.16 (0.07)	0.6 (0.1)	0.3 (0.05)
Bluegill	0.10 (0.03)	0.09 (0.01)	0.023 (0.004)	8.0 (1.4)	0.5 (0.1)	0.29 (0.11)	0.6 (0.2)	0.3 (0.1)

Table 1.5-2. Mean concentration of metals and PCBs (μg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species (n ⩾ 3 individuals) collected from Poplar Creek at Station PCM 5.5 in spring (April-May) and fall (November) 1977. Values for all samples analyzed are given in Appendix A-2. N/A = No analysis performed.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
Spring								
White bass	0.19 (0.03)	0.06 (0.01)	0.008 (0.001)	4.0 (0.4)	0.5 (0.04)	0.05 (0.01)	2.0 (0.5)	1.0 (0.2)
Gizzard shad	0.04 (0.003)	0.10 (0.01)	0.008 (0.0004)	4.0 (0.2)	0.7 (0.04)	0.07 (0.02)	0.7 (0.1)	0.7 (0.2)
Bluegill	0.17 (0.06)	0.12 (0.04)	0.022 (0.006)	7.0 (1.2)	0.34 (0.03)	a	1.1 (0.1)	b
<u>Lepomis</u>	0.29 (0.06)	0.13 (0.03)	0.022 (0.007)	8.0 (1.2)	0.3 (0.04)	b	0.9 (0.1)	N/A
Channel catfish	0.52 (0.09)	0.11 (0.05)	0.008 (0.002)	5.0 (0.3)	0.4 (0.1)	0.08 (0.05)	1.0 (0.5)	4.6 (2.4)
Fall								
<u>Lepomis</u>	0.43 (0.10)	0.10 (0.03)	0.013 (0.002)	6.0 (0.5)	0.3 (0.02)	0.02 (0)	0.6 (0.02)	0.2 (0)
White crappie	0.66 (0.10)	c	0.014 (0.001)	5.0 (0.6)	0.3 (0)	0.02 (0)	b	0.4 (0.2)

[a]All values were <0.02 μg/g.

[b]Only one value was above the detection limits of 0.02, 0.5, and 0.1 μg/g for Cr, Ni, and PCB, respectively.

[c]All values were <0.05 μg/g.

Table 1.5-3. Mean concentration of metals and PCBs (µg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species (n ≥ 3 individuals) collected from Poplar Creek at Station PCM 0.5 in spring (April-May) and fall (November) 1977. Values for all samples analyzed are given in Appendix A-3.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
Spring								
White bass	0.17 (0.04)	0.11 (0.04)	0.010 (0.0005)	6.0 (0.8)	0.6 (0.1)	0.09 (0.04)	1.6 (0.2)	2.0 (0.8)
Gizzard shad	0.05 (0.01)	0.08 (0.01)	0.008 (0.001)	4.0 (0.5)	1.0 (0.1)	0.05 (0.01)	2.5 (0.2)	0.4 (0.05)
Bluegill	0.19 (0.03)	0.07 (0.01)	0.025 (0.005)	10.0 (1.5)	0.37 (0.04)	0.15 (0.08)	0.8 (0.1)	0.4 (0.1)
White crappie	0.08 (0.01)	a	0.008 (0.005)	6.0 (0.4)	0.26 (0.02)	0.04 (0.01)	a	0.5 (0.2)
Channel catfish	0.24 (0.03)	0.13 (0.02)	0.008 (0.001)	5.0 (0.6)	0.6 (0.1)	0.36 (0.18)	1.8 (0.6)	2.3 (0.9)
Largemouth bass	0.20 (0.04)	b	0.017 (0.003)	9.0 (1.6)	0.5 (0.1)	0.23 (0.13)	a	0.4 (0.1)
Longnose gar	0.66 (0.15)	0.33 (0.12)	0.048 (0.016)	7.0 (1.3)	0.6 (0.1)	0.28 (0.11)	0.5 (0)	3.2 (1.8)
Striped bass	0.14 (0.04)	0.15 (0.03)	0.007 (0.002)	5.0 (1.2)	0.4 (0.1)	0.03 (0.01)	1.1 (0.4)	c
Fall								
White bass	0.16 (0.07)	0.12 (0.02)	0.009 (0.002)	5.0 (0.7)	0.5 (0.2)	0.06 (0.04)	d	0.2 (0.05)
Largemouth bass	0.71 (0.09)	0.12 (0.02)	0.013 (0.001)	5.0 (1.0)	0.3 (0)	e	d	0.3 (0.1)
Lepomis	0.62 (0.07)	0.12 (0.01)	0.013 (0.001)	8.0 (0.6)	0.11 (0.01)	0.05 (0.02)	a	c

[a] Only one value was above the detection limits of 0.05 and 0.5 µg/g for Pb and Ni, respectively.

[b] All values were <0.05 µg/g.

[c] One sample analyzed.

[d] All values were <0.5 µg/g.

[e] All values were <0.02 µg/g.

Table 1.5-4. Mean concentration of metals and PCBs (μg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species ($n \geq 3$ individuals) collected from the Clinch River at Station CRM 15.0 in April and November 1977. Values for all samples analyzed are given in Appendix A-4. N/A = No analysis performed.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
Spring								
Gizzard shad	0.07 (0.01)	0.05 (0.002)	0.008 (0.001)	2.0 (0.1)	0.6 (0.1)	0.36 (0.08)	a	0.5 (0.2)
Fall								
White bass	0.04 (0.005)	0.12 (0.01)	0.016 (0.003)	8.0 (0.5)	0.3 (0.1)	b	a	0.3 (0.2)
<u>Lepomis</u>	0.53 (0.11)	0.08 (0.01)	0.009 (0.001)	12.0 (0.4)	0.3 (0.01)	b	0.6 (0.03)	N/A
Largemouth bass	0.24 (0.05)	0.19 (0.03)	0.026 (0.004)	6.0 (0.4)	0.1 (0)	a	c	d

[a]Only one value was above the detection limits of 0.02 and 0.5 μg/g for Cr and Ni, respectively.

[b]All values were <0.02 μg/g.

[c]All values were <0.5 μg/g.

[d]One sample analyzed.

Table 1.5-5. Mean concentration of metals and PCBs (μg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species ($n \geq 3$ individuals) collected from the Clinch River at Station CRM 11.5 in April 1977. Values for all samples analyzed are given in Appendix A-5.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
Gizzard shad	0.06 (0.01)	0.14 (0.02)	0.016 (0.006)	5.0 (0.7)	0.6 (0.1)	0.08 (0.02)	0.7 (0.2)	0.4 (0.1)
<u>Lepomis</u>	0.49 (0.14)	0.30 (0.02)	0.014 (0.001)	11.0 (1.4)	0.4 (0.03)	0.04 (0.005)	a	b

[a]All values were <0.5 μg/g.

[b]One sample analyzed.

Table 1.5-6. Mean concentration of metals and PCBs (μg/g wet wt ± 1 S.E. in parentheses) in axial muscle of selected fish species ($n \geq 3$ individuals) collected from the Clinch River at Station CRM 10.5 in spring (April) and fall (October-November) 1977. Values for all samples analyzed are given in Appendix A-6. N/A = No analysis performed.

	Hg	Pb	Cd	Zn	Cu	Cr	Ni	PCB
Spring								
Gizzard shad	0.04 (0.002)	0.10 (0.01)	0.007 (0.001)	4.0 (0.4)	0.7 (0.04)	0.16 (0.06)	a	0.2 (0.04)
Largemouth bass	0.08 (0.04)	a	0.006 (0.0005)	10.0 (1.3)	0.5 (0.1)	0.26 (0.16)	0.8 (0.2)	0.4 (0.2)
Fall								
White bass	0.06 (0.004)	0.14 (0.02)	0.014 (0.002)	4.0 (0.4)	0.5 (0.04)	0.07 (0.02)	a	0.3 (0.1)
Striped bass	0.08 (0.02)	0.20 (0.04)	0.007 (0.001)	6.0 (0.2)	0.4 (0.02)	0.05 (0.01)	0.6 (0.1)	b
Largemouth bass	0.32 (0.07)	0.07 (0.01)	0.017 (0.002)	3.0 (0.4)	0.5 (0.1)	0.10 (0.03)	a	a
Lepomis	0.16 (0.03)	0.09 (0.01)	0.008 (0.0005)	10.0 (0)	0.4 (0)	a	0.8 (0.1)	0.2 (0.2)
Sauger	0.48 (0.09)	0.11 (0.02)	0.014 (0.007)	4.0 (1.0)	0.3 (0.1)	0.05 (0.03)	a	0.1 (0)

[a]Only one value was above the detection limits of 0.05, 0.02, and 0.5 and 0.1 μg/g for Pb, Cr, Ni, and PCB, respectively.

[b]All values were below the detection limit of 0.1 μg/g.

CRM 10.5 (Appendix A-6). Although the mean total mercury concentration was 0.44 μg/g, wet wt (range = 0.29-0.72 μg/g; n = 5), a larger sample would be necessary to confirm the extent of elevated levels in this species. High levels were also found in the two species of gar that inhabit the lower reaches of Poplar Creek (Appendices A-2 and A-3). Although differences between the two stations (PCM 5.5 and 0.5) could

Table 1.5-7. Mean trace element concentrations (μg/g, wet wt) in selected fish species collected from relatively uncontaminated[a] lakes and streams in North America. Range in parentheses.

	Skinface Pond South Carolina[b]		Cayuga Lake New York[c]	Moose Lake Manitoba[d]	Wintergreen Lake Illinois[e]		Great Smoky Mtns National Park[f]
Element	Largemouth bass	Bluegill	Lake trout	Northern pike	Largemouth bass	Hybrid sunfish	Rainbow trout
Cd			0.0041 (0.0021-0.0063)	<0.05	0.036 (0.020-0.048)	0.039 (0.026-0.051)	
Cr			0.016 (0.002-0.090)	<0.035			
Cu	0.22 (0.09-0.50)	0.12 (0.07-0.22)	0.022 (0.015-0.036)	0.70			
Hg				0.11	0.468 (0.189-0.899)	0.255 (0.136-0.382)	0.036[g] (0.003-0.177)
Ni			0.014 (0.007-0.023)	<0.2			
Pb	0.1[h] (<0.1-0.4)	0.3[h] (<0.1-1.1)	0.011 (0.004-0.022)	<0.5	0.301 (0.170-0.445)	0.198 (0.030-0.414)	
Zn	2.5 (1.4-4.9)	6.3 (2.5-9.7)	0.210 (0.035-0.048)	19			

[a] Some industrial and domestic wastes are discharged to Cayuga Lake near Ithaca; Wintergreen Lake is eutrophic.

[b] Wiener and Giesy (1979). Wet wt of fish ranged from 51.3 to 1191.8g and 97.7 to 351.2g for largemouth bass and bluegill, respectively.

[c] Tong et al. (1974). Composite sample of three decapitated and eviscerated fish was analyzed for each of 12 age classes.

[d] Uthe and Bligh (1971). Composite sample consisting of at least 2268g (5 lbs) or three fish (decapitated and eviscerated) was analyzed for each element.

[e] Mathis and Kevern (1975). Largemouth bass used in Hg analysis ranged from 400 to 2400g (no additional size/age data reported).

[f] Huckabee et al. (1974). No size/age data reported.

[g] Value based on both axial and whole body determinations.

[h] Whole body concentration. Wet wt of fish ranged from 0.34 to 69.36g and 0.03 to 20.58g for largemouth bass and bluegill, respectively.

not be analyzed statistically due to the small sample size, the mean concentration (both species and stations combined) was 0.56 μg/g (range = 0.30-0.98 μg/g; n = 8).

The highest mercury concentration (2.14 μg/g wet wt) in all the fish collected was found in a 240-g largemouth bass from station PCM 5.5. Both largemouth bass and white crappie from this station had significantly higher levels of mercury ($P < 0.05$) than did individuals collected in the vicinity of station PCM 0.5 (Table 1.5-8). In addition, concentrations of mercury in _Lepomis_ from both PCM 5.5 and 0.5 were higher than those observed in bluegill from the upstream (control) station in Poplar Creek. However, only the difference between stations PCM 11.0 and 5.5 was statistically significant ($P < 0.05$). The differences in total mercury concentration in _Lepomis_ from stations PCM 5.5 and 0.5 were not significant for either the spring or fall collections.

Elevated levels of mercury ($\overline{x}$ = 0.53 μg/g wet wt) were found in _Lepomis_ collected in the Clinch River at CRM 15.0 (Table 1.5-4). These levels were significantly higher than those found in _Lepomis_ from CRM 10.5 ($P < 0.05$) but were not significantly different ($P > 0.05$) from the levels observed in the individuals collected at the two lower stations on Poplar Creek (Table 1.5-8). Concentrations of mercury in largemouth bass from the three river sites, on the other hand, were not significantly different, but the levels in the bass from stations CRM 15.0 and 10.5 were significantly lower than those found at PCM 0.5. The elevated levels of mercury found in _Lepomis_ collected from the Clinch River approximately 4.8 km above the mouth of Poplar Creek (CRM 12.0) could be attributed to (1) movement of individuals between the creek and the

Table 1.5-8. Comparisons of mean concentration of total Hg in axial muscle (μg/g, wet wt) of fishes collected from various sites in Poplar Creek and the Clinch River. An analysis of variance was performed on each species/season group, and a Duncan's multiple range test was used to sort the means and identify significant differences among stations. Means with the same letter in their superscripts are not significantly different ($\alpha = .05$). Sample size (n) in parentheses. N/A = no analysis; $n < 2$.

	Poplar Creek (PCM)			Clinch River (CRM)		
Species/season	11.0	5.5	0.5	15.0	11.5	10.5
Gizzard shad spring	$0.04(15)^{a,b}$	$0.04(15)^{a,b}$	$0.05(26)^{a,b}$	$0.07(8)^{b}$	$0.06(15)^{b}$	$0.04(17)^{a}$
White bass spring	$0.17(15)^{a}$	$0.19(17)^{a}$	$0.17(9)^{a}$	N/A	N/A	N/A
fall	N/A	N/A	$0.16(4)^{a}$	$0.04(4)^{b}$	$0.13(2)^{a,b}$	$0.06(13)^{b}$
*Lepomis** spring	$0.08(10)^{a}$	$0.23(14)^{b}$	$0.20(15)^{a,b}$	N/A	$0.49(4)^{c}$	$0.20(4)^{a,b}$
fall	N/A	$0.43(8)^{a,b}$	$0.62(11)^{a}$	$0.50(15)^{a}$	$0.31(4)^{a,b}$	$0.16(11)^{b}$
Largemouth bass spring	N/A	$1.90(2)^{a}$	$0.20(10)^{b}$	N/A	N/A	$0.08(3)^{b}$
fall	N/A	N/A	$0.71(3)^{a}$	$0.24(5)^{b}$	$0.44(2)^{a,b}$	$0.32(7)^{b}$
White crappie spring	N/A	$0.28(2)^{a}$	$0.08(12)^{b}$	N/A	N/A	N/A
Channel catfish spring	N/A	$0.52(3)^{a}$	$0.24(9)^{b}$	N/A	N/A	N/A

*Includes bluegill and redbreast sunfish river and/or (2) other sources of mercury to the Clinch River in addition to Poplar Creek. Hildebrand et al. (1980) also reported elevated levels of mercury (i.e., above 0.5 μg/g wet wt) in several fish collected more than 5 km above an old chloralkali plant on the North Fork Holston River in southwestern Virginia.

Several species exhibited higher total mercury concentrations in the fall compared with spring. For example, at station PCM 0.5 Lepomis (probably bluegill) collected in the fall had 0.62 μg/g ± 0.07 (1 S.E.) mercury in muscle tissue compared with 0.19 ± 0.03 μg/g in bluegill collected in spring (Table 1.5-3). Largemouth bass from the same fall collection had 0.71 μg/g ± 0.09 but had only 0.20 μg/g ± 0.04 mercury in muscle tissue in the spring, a 72% increase in five months. Largemouth bass from station CRM 10.5 also showed a large percent increase from the spring to fall (75%), as did Lepomis at PCM 5.5 (33%) (Tables 1.5-6 and 1.5-2, respectively). An analysis of variance indicated that the spring-fall difference in mercury concentrations was highly significant ($P < .0001$) (Table 1.5-9). These results imply that either different populations of fish were sampled in the spring and fall or the fish collected in the fall had been exposed to higher mercury levels than had the fish collected in the spring; i.e., these populations, at least in the spring, were not at equilibrium.

Numerous investigators have reported significant positive correlations between total mercury concentration in fish and size or age (see review by Huckabee et al., 1979, Table 12.2). The existence of such a relationship could bias an analysis of between-station (or between-season) differences in total mercury concentrations if the size range

Table 1.5-9. Results of an analysis of variance to detect seasonal differences in the concentration of total Hg in fish muscle tissue. Species-station combination was used as a blocking factor.

Source of variation	df	SS	MS	F	Pr > F
Season[a]	1	1.995	1.995	60.67	<0.0001
Species-station[b]	4	0.489	0.122	3.71	0.0084
Error	71	2.334	0.033		
Corrected total	76	4.810			

[a]Seasons were spring and fall.

[b]Species-station data used in this analysis were: Lepomis, stations PCM 5.5 and 0.5; largemouth bass, stations PCM 0.5 and CRM 10.5; and white crappie, station PCM 0.5.

(or age) of the fish from the different stations (or seasons) was not comparable. Consequently, a correlation analysis between fish body weight and total mercury concentration was performed for the more abundant species collected from Poplar Creek and the Clinch River. Significant positive correlations ($P < 0.05$) were found in only two of the fifteen groups (i.e., species/station/season data sets) examined (Table 1.5-10).

If weight adequately reflected age which, in turn, reflected the duration of exposure, then all of the groups could intuitively have been expected to exhibit a significant positive correlation (Hildebrand et al. 1980). The absence of such a relationship has been attributed to (1) inadequate range of sizes/ages in the sample, (2) differences in individual growth patterns, and/or (3) differences in exposure histories (Huckabee et al. 1979). Most of the fish included in the analyses

Table 1.5-10. Results of correlation analysis between body weight and concentration of total Hg in axial muscle for selected fish species in Poplar Creek and the Clinch River near ORGDP.

Species	Station(s)	Season[a]	n	r	P[b]
Gizzard shad	PCM 11.0, 5.5, 0.5	S	55	−0.13	0.21
	CRM 15.0, 11.5, 10.5	S	40	−0.08	0.64
White bass	PCM 11.0, 5.5, 0.5	S	41	0.02	0.89
	PCM 0.5, CRM 15.0, 11.5, 10.5	F	23	0.31	0.15
Lepomis[c]	PCM 11.0	S	10	0.86	0.002
	PCM 5.5	S	14	0.24	0.40
		F	8	0.50	0.23
	PCM 0.5	S	15	0.33	0.23
		F	11	−0.50	0.12
	CRM 15.0	F	15	−0.06	0.84
	CRM 10.5	F	10	0.41	0.24
Largemouth bass	PCM 0.5	S	10	−0.01	0.98
	CRM 10.5	F	7	0.27	0.58
White crappie	PCM 0.5	S	12	0.09	0.77
Channel catfish	PCM 0.5	S	9	0.70	0.03

[a]S = Spring; F = Fall.

[b]P = probability of observing a higher correlation coefficient (r) given that the true correlation coefficient (ρ) = 0. If $n < 10$, then Fisher's transformation (Edwards 1976) was used to calculate the significance level.

[c]Includes bluegill.

presented in Table 1.5-10 were small and, in many cases, an adequate size range was not included. This observation is important when evaluating the relatively low percentage of game fish with total mercury levels that exceeded 1.0 µg/g wet wt. In addition, it is likely that exposure history could have varied among the individuals in a given group. Since there are no barriers to prevent movement between stations and because the distribution of mercury in the sediments of Poplar Creek is not uniform (Table 1.4-7), fish can be exposed to varying levels of contamination at different stages in their life history.

Mercury concentrations in the sediments of Poplar Creek between stations PCM 5.5 and 0.5 are very high in certain areas (Table 1.4-7). This distinctly nonuniform distribution of mercury in lower Poplar Creek indicates that large releases did occur in the past, since weathering and transport processes tend to distribute any mercury, either natural or anthropogenic, homogeneously downstream (Nelson et al. 1977, Turner and Lindberg 1978). It is probable that Poplar Creek was contaminated with mercury by a local but unknown source at some time in the past few to several years and that the mercury still remaining will gradually decline as it is moved downstream. Inevitably, however, some of this mercury will enter the aquatic food chain (Gillespie 1971, Kudo 1976). Thus, the fish in both Poplar Creek and the Clinch River in the vicinity of the confluence with Poplar Creek are continuously or episodically exposed to levels of mercury that, in some cases, produce concentrations in their muscle tissue that exceed the FDA action level.

Numerous investigations have shown that all fish older than 2-3 years have 80% or more of their total mercury present as the methylated form (MeHg) (Bache et al. 1971, Huckabee et al. 1974, Kamps et al. 1972). Although MeHg was not measured directly, the assumption was made that this relationship is true for the fish inhabiting Poplar Creek and the Clinch River. In addition, the elimination rate of MeHg by fish is long, usually exceeding a biological half-life of 200-300 days. Continuous or frequent exposure of fish to MeHg, therefore, will result in an increase in the tissue concentration of MeHg with age (Huckabee et al. 1975, McKim et al. 1976, Ruohtula and Miettihen 1975). Consequently, it would seem that the resident fish populations in Poplar Creek and the Clinch River near the mouth of the creek are contaminated with MeHg and will remain so for at least several months and possibly years.

1.5.2 PCBs

Most of the fish analyzed for polychlorinated biphenyls (PCBs) had concentrations well below the FDA temporary tolerance level of 5 μg/g [Fed. Regist. 38(129):18096-18104, July 6, 1973].* However, PCB levels near the FDA limit were characteristic of the channel catfish and gars (two species) collected from Poplar Creek (Appendices A-2 and A-3). Two of the nine catfish had PCB levels that exceeded 5 μg/g (7.0 and 6.0 μg/g at stations PCM 5.5 and 0.5, respectively). Although the mean concentration at station PCM 5.5 was twice that found in the catfish

*The FDA recently issued a final regulation reducing tolerances for PCBs in several classes of foods [Fed. Regist. 44(127):38330-38340, June 29, 1979]. Although the tolerance level for PCBs in fish and shellfish was lowered from 5 ppm to 2 ppm, the effective date of this provision of the regulation was stayed, pending resolution of the issues raised in an objection and request for formal hearings submitted by the National Fisheries Institute [Fed. Regist. 44(195):57389, October 5, 1979]. Because no objections and hearing requests were received on other provisions of the regulation (revised tolerances for PCBs in milk, dairy products, poultry, and eggs), these provisions went into effect, as scheduled, on August 28, 1979.

collected from PCM 0.5, the difference was not statistically significant ($P > 0.05$; ANOVA and Duncan's multiple range test). In addition, a longnose gar collected near PCM 0.5 had a PCB concentration of 8.5 µg/g. These results, and those obtained in an earlier survey of PCB levels in sediments (Section 1.4), indicate a PCB source in Poplar Creek, especially for the channel catfish and gars.

Polychlorinated biphenyls (PCBs) are very rapidly accumulated by fish from both ambient water and food and are preferentially stored in lipids (as is MeHg). Concentration factors of 10^4 and 10^5 (level in tissues vs that of water or food) have been reported for PCBs in fish (Nebeker 1975). Depuration rates of PCBs by fish are slow; an 18% loss of tissue PCBs after 60 days has been reported for fathead minnows (DeFoe et al. 1978). Although tissue levels of 5-10 µg/g PCBs apparently have a limited effect on fish, other organisms can be much more sensitive. For example, mink fed fish contaminated with 5 µg/g PCBs had 100% reproductive failure, and a concentration of 1 µg/g PCBs in their food was reported to be the "no effect" level of mink (Ringer et al. 1972).

1.5.3 Nickel

Elevated levels of nickel were found in the tissues of several species collected at stations PCM 5.5 (Table 1.5-2) and PCM 0.5 (Table 1.5-3). The mean concentrations in gizzard shad, white bass, and channel catfish were generally at least an order of magnitude above the levels reported in fish from relatively uncontaminated lakes (Table 1.5-7). Concentrations in other species (e.g., longnose and spotted gar, largemouth bass) were at or below the detection limit (0.5 µg/g wet wt).

Because of the relatively low toxicity of nickel to humans, little information is available on its accumulation by aquatic biota (Phillips and Russo 1978). Freshwater fishes collected from 11 lakes and rivers in New York had nickel concentrations ranging from 0.03 to 3.8 μg/g, wet wt; mean concentrations in smallmouth bass and walleye were 0.51 μg/g (range: 0.16-1.2 μg/g; n = 10) and 0.60 μg/g (0.12-3.8 μg/g; n = 14), respectively (Tong et al. 1972). In the Illinois River near Peoria, nickel concentrations in the muscle of eight fishes ranged from 0.02 to 0.52 μg/g, wet wt with the highest levels occurring in gizzard shad ($\bar{x}$ = 0.28 μg/g; range = 0.06-0.52 μg/g; n = 13) (Mathis and Cummings 1973). Levels exceeding 7.0 μg/g have been found in muscle tissue of some marine fishes collected off the northeast coast of England, an area heavily polluted by coal wastes (Wright 1976). In general, the levels found in fish collected from lower Poplar Creek fall within the ranges reported in fish collected from waters that are contaminated by industrial and/or domestic wastes.

1.5.4 Heavy Metal Concentrations in Benthic Macroinvertebrates

Burrowing mayflies (*Hexagenia*) were collected at two stations in Poplar Creek (PCM 5.5 and 0.5) and one site in the Clinch River (CRM 15.0) in August and September 1977, and tissue analyses for six heavy metals were conducted (Table 1.5-11). Because the samples dehydrated before analysis (losing 78% of their initial weight), the measurements of heavy metal concentrations were biased 78% too high. Consequently, the concentrations reported in Table 1.5-11 have been reduced by the dehydration factor (0.78) and the results should be regarded as semi-quantitative.

Table 1.5-11. Semi-quantitative concentrations (μg/g wet wt) of selected trace elements in Hexgenia nymphs collected from Poplar Creek (Stations PCM 5.5 and 0.5) and the Clinch River (Station CRM 15.0) in late summer 1977. Values are shown for each of the 5-g samples taken at each station.

Station	Cd	Cr	Cu	Ni	Pb	Zn
PCM 5.5						
1	0.09	0.48	1.31	0.75	0.68	8.5
2	0.03	0.47	0.99	0.72	0.40	5.8
3	0.18	0.54	1.50	0.93	0.75	8.6
$\overline{X}$	0.10	0.50	1.27	0.80	0.61	7.6
PCM 0.5						
1	0.30	1.73	1.34	1.09	0.54	8.9
2	0.31	1.97	1.37	1.30	0.78	9.1
3	0.33	1.70	0.92	1.07	0.57	9.9
$\overline{X}$	0.34	1.80	1.21	1.15	0.63	9.3
CRM 15.0						
1	0.10	0.43	0.88	0.41	0.79	7.5
2	0.07	0.42	0.91	0.27	0.82	5.6
3	0.06	0.28	0.83	0.09	0.49	6.0
$\overline{X}$	0.08	0.38	0.87	0.26	0.70	6.4

An analysis of variance was performed on the data presented in Table 1.5-11, and a Duncan's multiple range test was used to compare the means and reveal significant differences among stations. Results indicated that the concentration of heavy metals in Hexagenia collected at station PCM 0.5 was significantly greater ($P < 0.05$) than the levels observed at stations PCM 5.5 and CRM 15.0. The heavy metal concentrations in mayflies from the latter two sites was not significantly different ($P > 0.05$).

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1.6 Results and Discussion of Biological Communities

1.6.1 Phytoplankton (J. A. Solomon)

With few exceptions, the phytoplankton of riverine systems are generally of less importance from the point of view of ecosystem function than are the phytoplankton populations of natural lakes. Because lotic environments, especially the tailwater regions below dams, are characterized by flow regimes that can exhibit considerable temporal variability, phytoplankton populations can be viewed as transient, rarely reaching the densities found in most lentic systems, including many reservoirs. Whereas production is primarily autochthonous and phytoplankton are the significant primary producers in these latter systems, production in lotic systems is primarily dependent on allochthonous inputs. Consequently, phytoplankton occupy a less significant position with regard to the trophic dynamics of riverine ecosystems.

While recognizing the less significant role of phytoplankton in lotic vs lentic ecosystems, the rationale for inclusion of this community in the ORGDP biological survey was based on another criterion that takes into account the purpose of the survey. Phytoplankton have relatively high turnover rates and may be among the first components of aquatic systems to respond to environmental perturbations (e.g., altered thermal and nutrient regimes). Because the purpose of the biological sampling program was to provide a basis for evaluating the environmental impacts of ORGDP operations, information on the temporal and spatial distribution of phytoplankton was required.

Review of previous studies

The phytoplankton communities in the lower Clinch River have been described in several studies designed to assess the impact of existing and developmental technologies on community composition and population dynamics (Table 1.6.1-1 and 1.6.1-2). The first survey was conducted during the summer of 1956, seven years before the completion of the Melton Hill Dam at CRM 23.1 (Lackey 1957). Qualitative sampling of the river from the mouth of White Oak Creek (CRM 20.8) downstream to the confluence with the Tennessee River (CRM 0.0) resulted in the identification of 253 species of phytoplankton, 44% of which were green algae (Chlorophyta). The river below Gallaher Bridge (CRM 14.0) was described as "plankton-rich," whereas the stretch of the river from Norris Dam (CRM 79.8) to White Oak Creek was described as "almost barren of plankton" due to the discharge of colder hypolimnetic waters from Norris Lake (Lackey 1957). The quiet and warmer water in upper Watts Bar Lake and the "seeding" of the river by water from White Oak Lake were the explanations given for the "plankton-rich" character of the lower reaches of the river.

As part of an overall assessment of the impacts on the aquatic ecosystem due to operation of the Kingston Steam Plant, phytoplankton sampling was conducted monthly from June through October 1973 (Brooks 1978). Maximum and minimum surface densities at sampling sites near CRM 1.4, 2.1, and 2.6 were 2916 cells/ml (August) and 444 cells/ml (June), respectively. Chrysophytes (yellow-green and yellow-brown algae and diatoms), especially the diatoms *Melosira* and *Synedra*, were abundant

Table 1.6.1-1. Comparison of the sampling designs employed in four quantitative surveys of the phytoplankton communities in the lower Clinch River. Locations of the ORGDP sampling stations are shown in Fig. 1.2-1.

	Survey			
	TVA	CRBR	NFRRC	ORGDP
Sampling period	June-October 1973	March 1974-April 1975	May 1975-April 1976	April 1977-March 1978
Sampling sites (CRM)	1.4 2.1 2.6	17.9 15.9 15.1	12.0 14.4 15.0 (east shore) 15.0 (west shore)	10.5 11.5 15.0
Sampling frequency	Monthly	Monthly[a]	Monthly	Biweekly[b]
Sample collection Location in water column[c]	CRM 1.4 (S,1,3,5)[d] CRM 2.1 (S,1,3,5)[d] CRM 2.6 (S,1,3)	S	S,2,5	S
Replicate samples taken	No	Yes	Yes	Yes
Number of samples taken per sampling date	11[e]	6	24	6
No. of sampling dates	5	9	12	17
Total no. of samples collected	53	54	288	102

[a]Months sampled were: 1974: March, May, June, July, August, September, November; 1975: January, April.

[b]Months sampled (no. of trips/month in parentheses) were: 1977: April (1), May (2), June (2), July (1), August (2), September (1), October (2), December (1); 1978: January (1), February (1), March (3).

[c]S = surface; numbers indicate depth of the sample in meters.

[d]5-m sample not taken in September and October.

[e]Ten samples taken in September and October.

Table 1.6.1-2. Summary of results from previous phytoplankton studies on the lower Clinch River

Study	Dates	Location	Total cells/ml Minimum	Total cells/ml Maximum	Dominant taxa
Lackey (Lackey 1957)	Summer 1956	CRM 0.0-20.8			
TVA (Brooks 1978)	June-Oct. 1973	CRM 1.4-2.6	444 (June)	2,916 (August)	[a]Early: Chrysophyta (Melosira) Mid: Chrysophyta (Melosira) Chlorophyta (Scenedesmus) Late: Chrysophyta (Melosira) Cyanophyta (Phorinidium) Chlorophyta (Scenedesmus)
CRBR (Project Management Corporation 1975)	March 1974-April 1975	CRM 15.0-18.0	190 (April)	2,940 (July)	Early: Chrysophyta (Melosira) Mid: Cyanophyta (Oscillatoria) Chrysophyta (Dinobryon) Late: Chrysophyta (Melosira, Dinobryon)
NFRRC (Exxon Nuclear Co., Inc. 1976)	May 1975-April 1976	CRM 12.0-15.0	179 (March)	10,371 (July)	Early: Chrysophyta (Melosira, Dinobryon) Chlorophyta (Ankistrodesmus) Mid: Chrysophyta (Melosira) Late: Cyanophyta (Merismopedia, Oscillatoria) Chrysophyta (Melosira)

[a]Early: start of growing season (April) to mid-June; Mid: mid-June through July; Late: August to end of growing season (October).

throughout the summer, comprising more than 70% of the cell numbers in June. The percent abundance of this group declined during the summer and was followed by increased densities of Scenedesmus, a green algae, during midsummer and a peak in blue-green algae (Cyanophyta) in late summer. The latter group comprised approximately 30 to 40% of the phytoplankton numbers in September, due primarily to the presence of Phormidium.

In March 1974, a one-year preoperational aquatic sampling program was initiated near the proposed site of the Clinch River Breeder Reactor (Project Management Corporation 1975). Samples were collected 0.25 m below the surface at three stations between CRM 18.0 and 15.0 on nine sampling dates between March 1974 and April 1975, including monthly samples from May through September (Table 1.6.1-1). Phytoplankton abundance in this region of the Clinch River ranged from 190 cells/ml in April to 2940 cells/ml in July. Total phytoplankton densities were not appreciably different between stations on a given sampling date (Project Management Corporation 1975, Section 2.7.2.4.3).

Except for June and July when blue-green algae comprised 40 to 75% of the phytoplankton numbers, Chrysophyta (mostly diatoms) composed the greatest percentage of the population (Project Management Corporation 1975, Table 2.7-45). The most abundant diatom from March through July was Melosira ambigua, which reached a maximum density of 395 cells/ml in late May (Project Management Corporation 1975, Table 2.7-47). Other chrysophytes which were abundant in August and September were Melosira herzogii (maximum density of 210 cells/ml), Dinobryon sociale (406 cells/ml) in August, and Dinobryon divergens (311 cells/ml) in September.

The densities of Chlorophyta were generally low in the spring, increased to a peak in August and September (primarily Chlorella spp.), and declined thereafter.

The dominance of chrysophytes throughout most of the year was also observed during a one-year preoperational study (Exxon Nuclear Company, Inc. 1976) designed to characterize the aquatic communities near the proposed site of the Exxon Fuel Recovery and Recycling Center (Table 1.6.1-2). From May 1975 through April 1976, monthly phytoplankton samples were collected from three depths in the Clinch River at each of four stations: CRM 12.0 (near the mouth of Poplar Creek), CRM 14.4, and CRM 15.0 near both the east and west shores (Table 1.6.1-1). At all four sampling sites, the most abundant of the Chrysophyta was the diatom Melosira spp., although blooms of Dinobryon spp., especially Dinobryon sertularia, were found at CRM 12.0 and 14.4 in May. The dominance of the chrysophytes was interrupted at CRM 14.4 in September due to an increase in the density of blue-green algae and at CRM 15.0 (east) in May due to an increase in the Chlorophyta. This increase was due to a bloom of Ankistrodesmus falcatus (4000 cells/ml) which was also observed at CRM 12.0 in May.

As was seen during 1974 in the CRBR survey, total phytoplankton densities in 1975 usually reached a peak in midsummer (Exxon Nuclear Company, Inc. 1976, Section 2.7.1.1). The highest density of phytoplankton (10,371 cells/ml) was found during July at CRM 14.4 while the lowest density (179 cells/ml in March) also occurred at this site. In-depth comparisons of the data on phytoplankton species composition and abundance in this region of the river (CRM 12.0 to 15.0) with the data collected in the present study cannot be made. Because only data on relative abundance (%) of the various algal groups at each site were presented, quantitative comparisons are not possible.

In summary, the three surveys conducted in 1973-76 (Tables 1.6.1-1 and 1.6.1-2) revealed a dominance by chrysophytes throughout the growing season (April through October). Chlorophyta may become abundant in early summer, while Cyanophyta usually reach a peak in late summer and fall. No appreciable growth of phytoplankton occurs during the winter (generally November through March in this region of the country).

Seasonal distribution

Results obtained in the present study indicate that the phytoplankton populations in the Clinch River and the lower reaches of Poplar Creek followed a seasonal abundance pattern common throughout North America (Reid 1961) and previously observed in Tennessee (Taylor 1971). These populations exhibited two major growth pulses; the first occurred in late spring and was followed by a second peak in late summer and early fall (Figs. 1.6.1-1 and 1.6.1-2). Although the magnitude and composition of these peaks varied according to sampling location, some general trends were observed.

Late spring peak

Maximum densities in late spring occurred at station PCM 0.5 (see Fig. 1.2-1) near the mouth of Poplar Creek (8470 units/ml) and at the Clinch River site (CRM 11.5) located just below the mouth of the creek

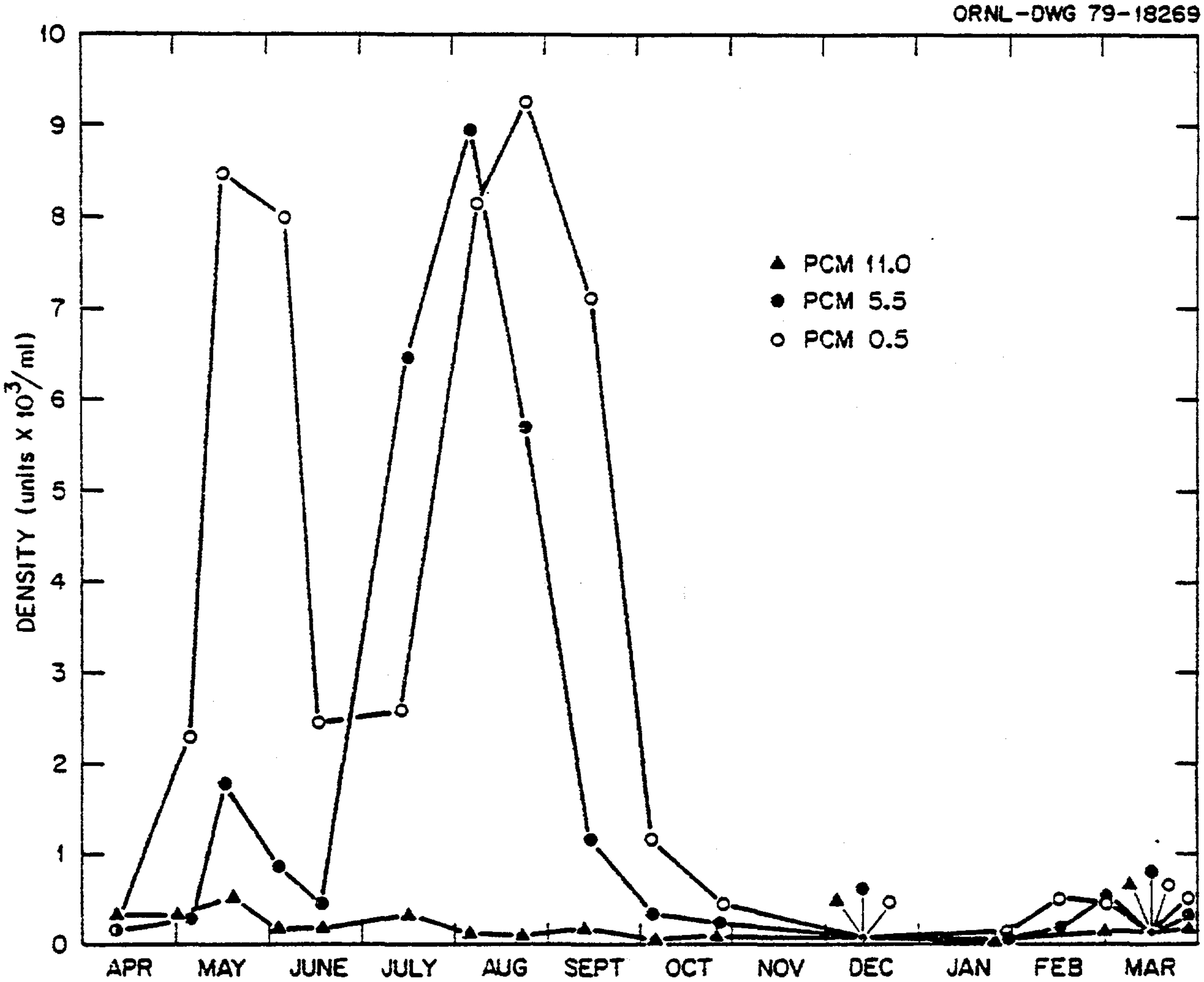

Fig. 1.6.1-1. Temporal fluctuations in total phytoplankton density (units/ml) at the three ORGDP sampling sites on Poplar Creek, April 1977 — March 1978. For filamentous species, 1 filament = 1 unit.

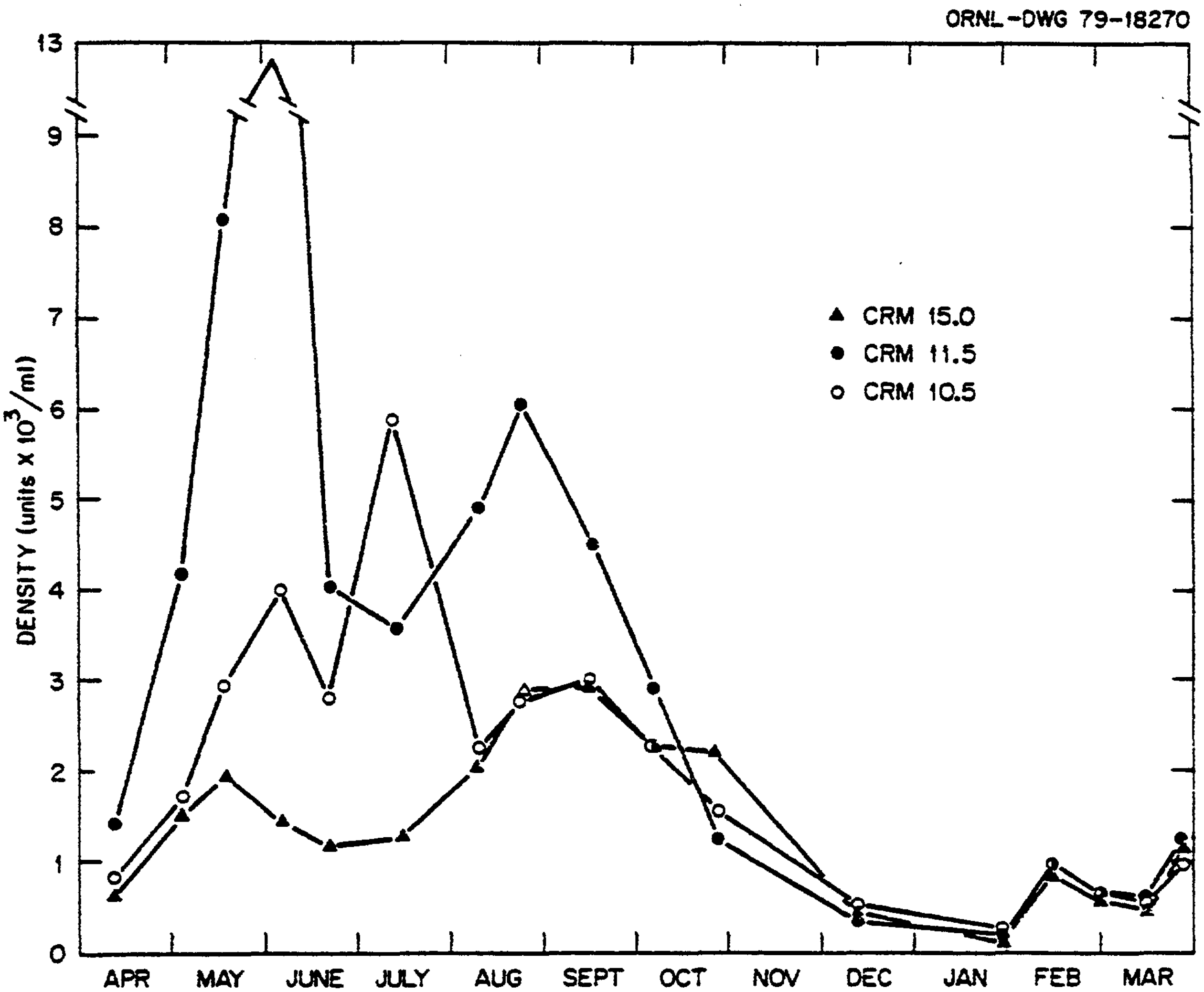

Fig. 1.6.1-2. Temporal fluctuations in total phytoplankton density (units/ml) at the three ORGDP sampling sites on the Clinch River, April 1977 — March 1978. For filamentous species, 1 filament = 1 unit.

(12,840 units/ml). More than 50% of the cells comprising the spring pulse at these stations consisted of a unicellular flagellated green alga, Carteria sp. (Figs. 1.6.1-3 and 1.6.1-4). Other species abundant at this time were Cyclotella sp., a diatom (Chrysophyta:Bacillariophyceae), and Cryptomonas acuta, a unicellular flagellated crytomonad (Cryptophyta). Similar species composition but lower cell densities (3999 units/ml) were found at station CRM 10.5 (Fig. 1.6.1-5).

The phytoplankton communities at the other ORGDP sampling sites also exhibited a peak in abundance in late spring, but the composition of the peak varied. At station CRM 15.0 located approximately 4.8 km above the mouth of Poplar Creek, diatoms and green algae were essentially absent (Fig. 1.6.1-6). Approximately 75% of the spring phytoplankton community consisted of the cryptomonad, Cryptomonas acuta (50%), and an unidentified flagellate (25%). The maximum density observed at CRM 15.0 at this time of the year was only 1964 units/ml. Similar results were found at a sampling site (PCM 5.5) on Poplar Creek where the density of the spring peak was 1788 units/ml and consisted primarily of an unidentified flagellate (probably colorless) (Fig. 1.6.1-7). Colorless flagellates are heterotrophs usually found in organically-rich environments.

Poplar Creek at station PCM 11.0 is quite narrow (approximately 3-5 m wide) and flows swiftly beneath a canopy of riparian vegetation that shades much of the creek. Under such circumstances, the phytoplankton community is generally poorly developed (Reid 1961), as was the case at this site. The maximum density of 528 units/ml occurred in May and consisted mostly of benthic diatoms. Because of the atypical composition and abundance of the phytoplankton, this station has been omitted from much of the discussion that follows.

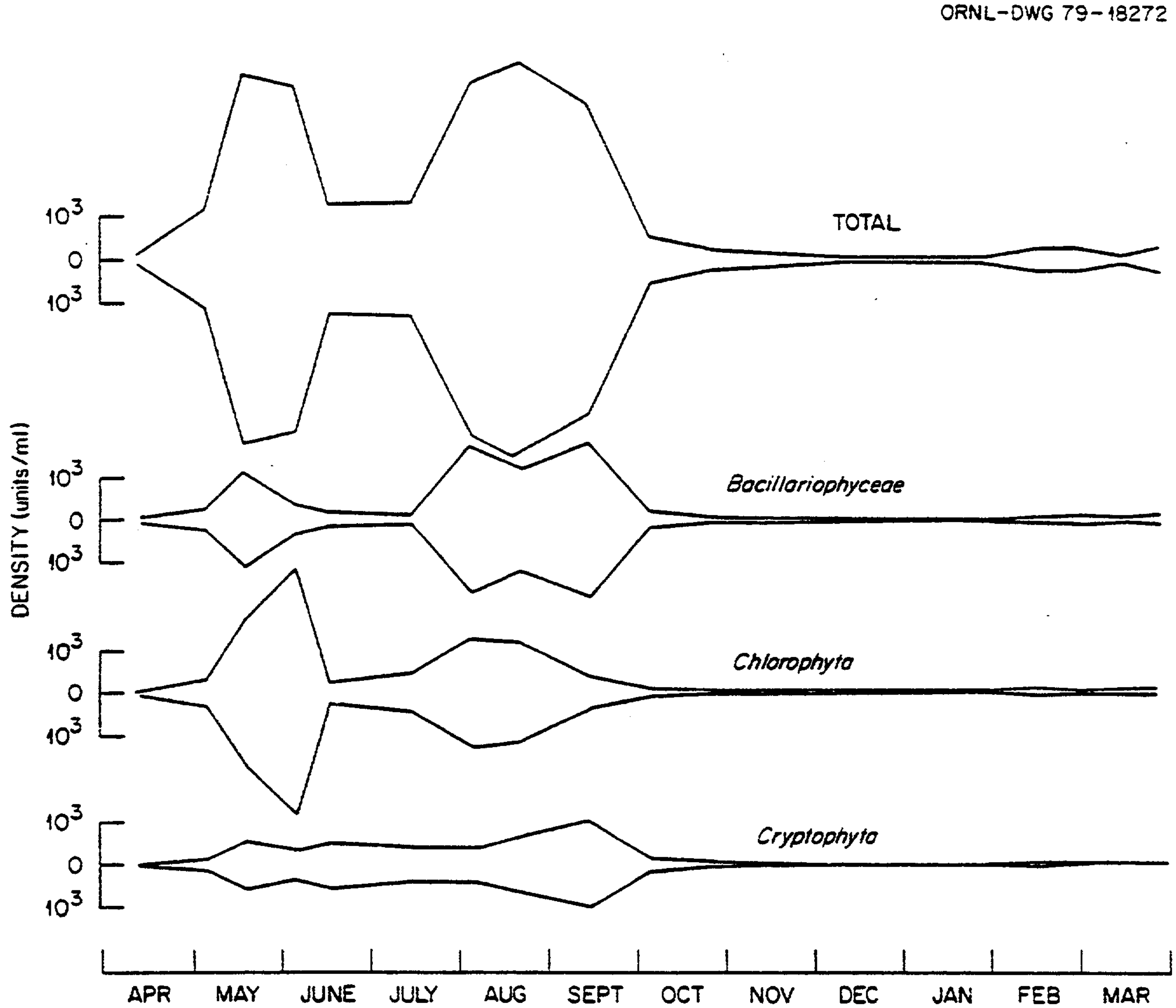

Fig. 1.6.1-3. Temporal distribution and abundance of the three major algal groups comprising the phytoplankton community near the mouth of Poplar Creek (PCM 0.5), April 1977 — March 1978.

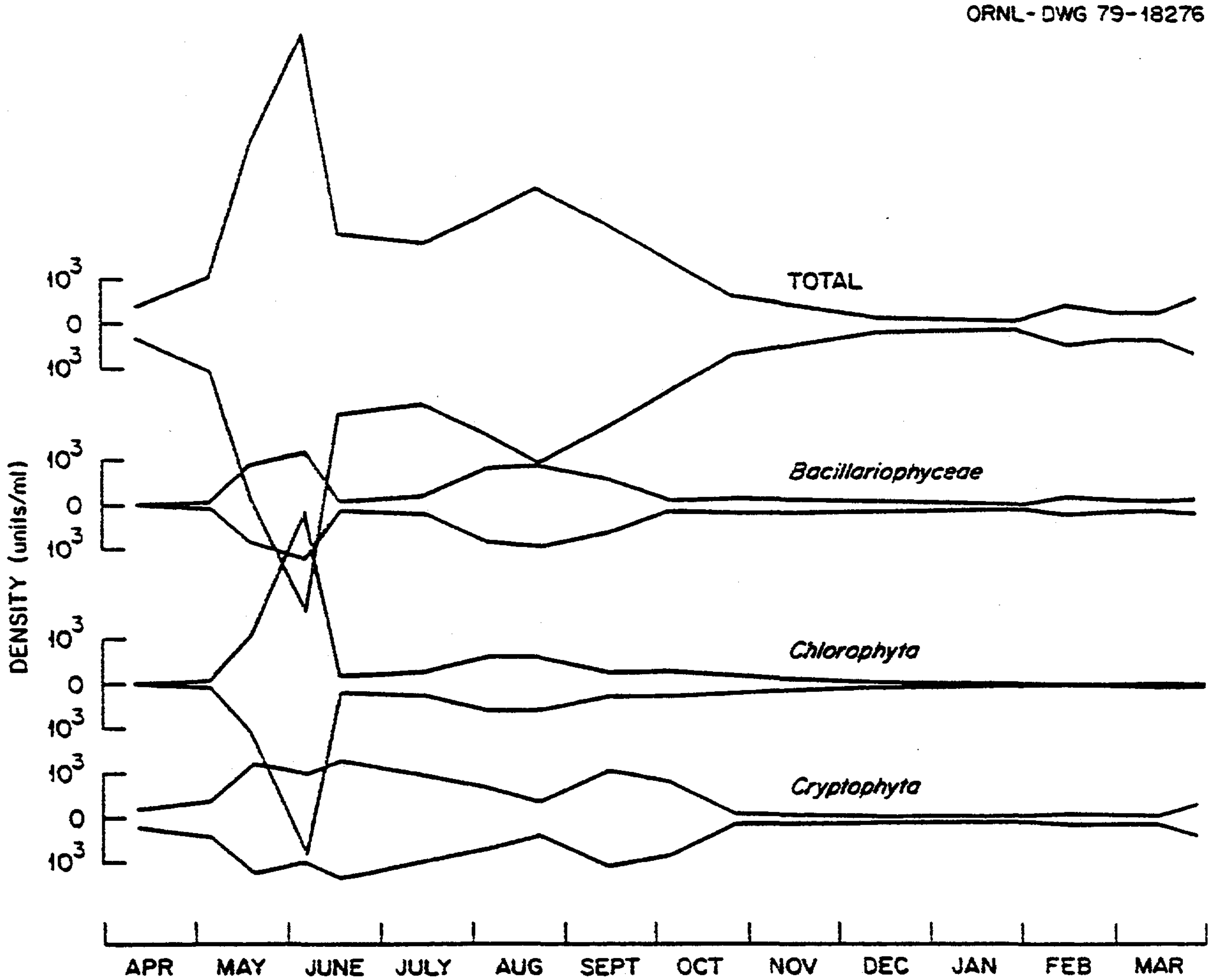

Fig. 1.6.1-4. Temporal distribution and abundance of the three major algal groups comprising the phytoplankton community in the Clinch River just below the mouth of Poplar Creek (CRM 11.5), April 1977 — March 1978.

ORNL-DWG 79-18273

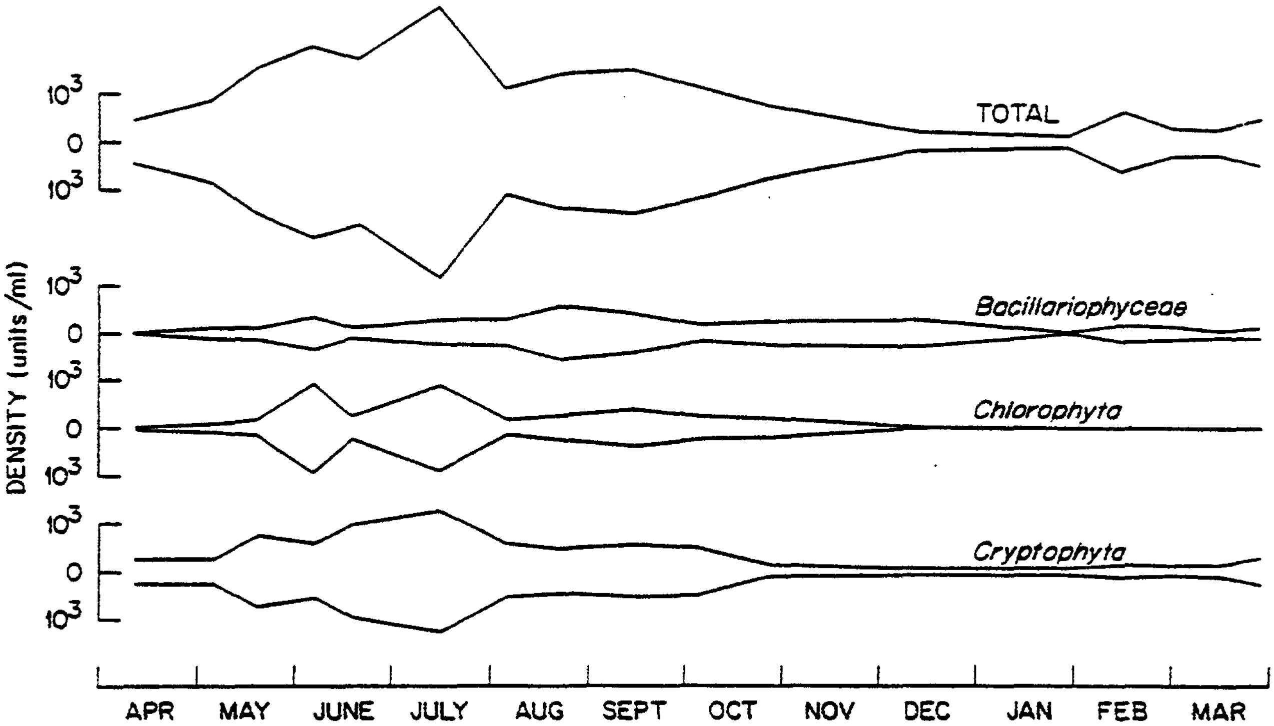

Fig. 1.6.1-5. Temporal distribution and abundance of the three major algal groups comprising the phytoplankton community at the downstream station on the Clinch River (CRM 10.5), April 1977 — March 1978.

ORNL-DWG 79-18274

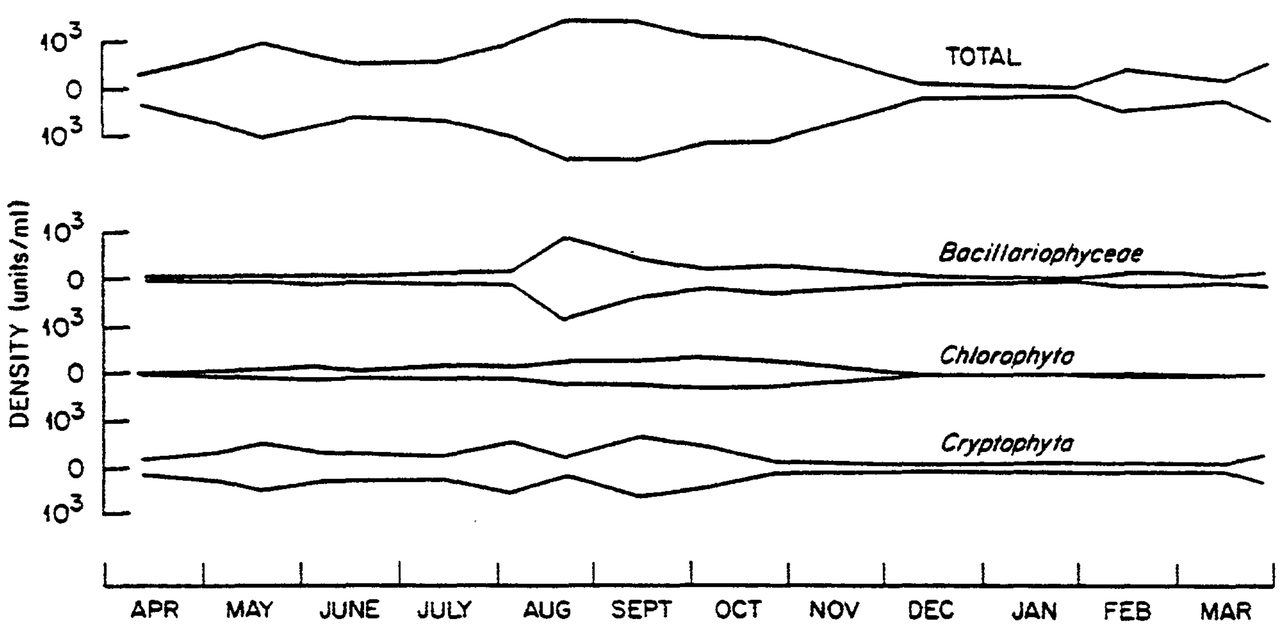

Fig. 1.6.1-6. Temporal distribution and abundance of the three major algal groups comprising the phytoplankton community at the upstream station on the Clinch River (CRM 15.0), April 1977 — March 1978.

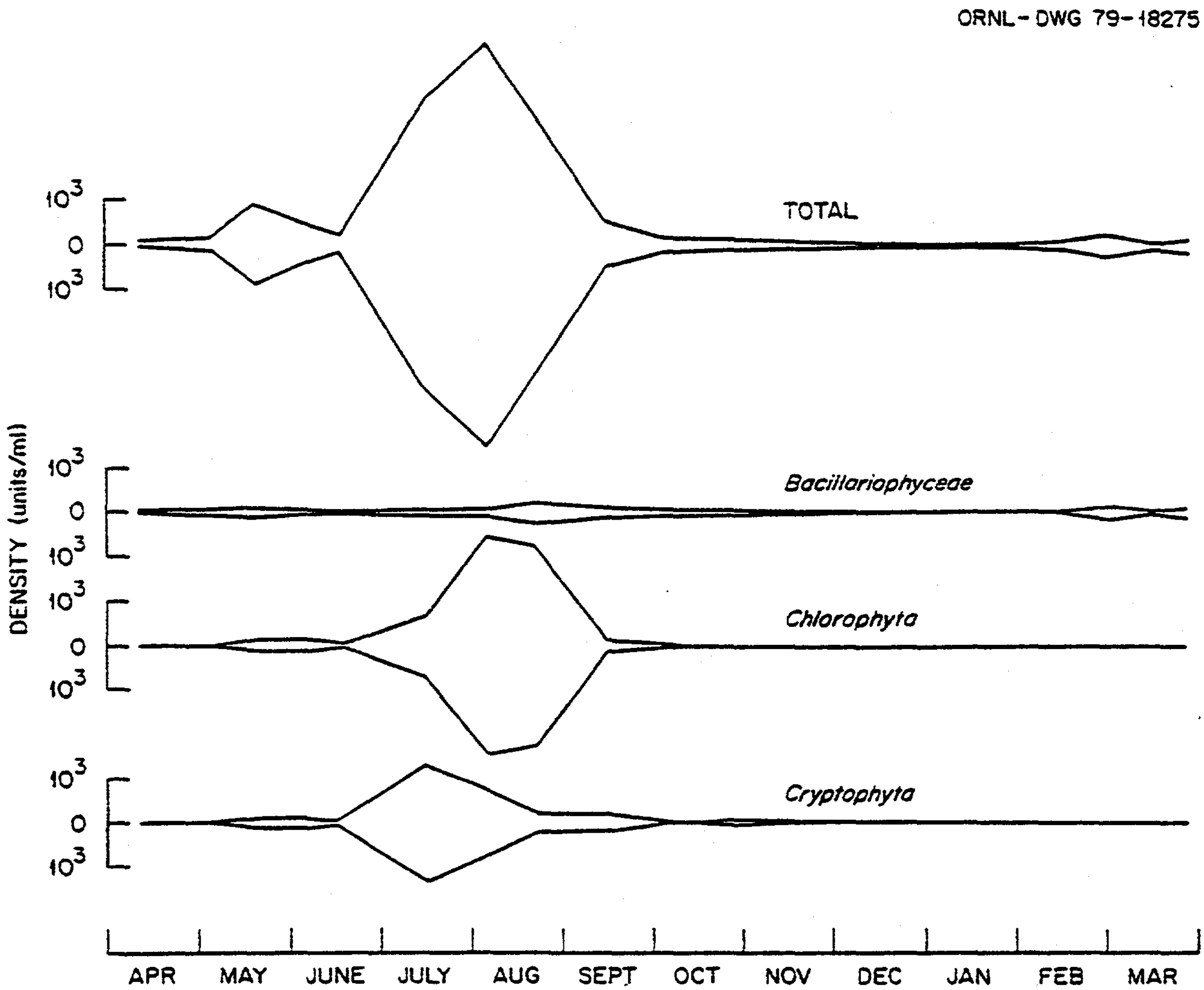

Fig. 1.6.1-7. Temporal distribution and abundance of the three major algal groups comprising the phytoplankton community in Poplar Creek just below the confluence of the East Fork and West Fork Poplar Creek (Station PCM 5.5), April 1977 — March 1978.

Late summer peak

The second or late summer pulse in phytoplankton growth was of longer duration (approximately two or three months) than the spring pulse (Figs. 1.6.1-1 and 1.6.1-2). Cryptomonads were abundant at all stations, contributing between 1000 and 2500 cells/ml. Maximum total densities occurred during August at stations PCM 5.5 (8990 units/ml) and PCM 0.5 (9220 units/ml), when the green algae, Scenedesmus spp., comprised 77 and 44% of the population, respectively (Figs. 1.6.1-3 and 1.6.1-5). Distinct diatom pulses were observed in August at stations PCM 0.5 and CRM 11.5 (primarily Cyclotella spp.) and at stations CRM 15.0 and 10.5 (Synedra delicatissima). From early August through early October, total densities at stations CRM 15.0 and 10.5 were approximately the same (almost 3000 units/ml) but were less than one-half the peak density observed at station PCM 11.5 in late August (6020 units/ml). The higher cell density at CRM 11.5 in August was due in part to the filamentous blue-green, Schizothrix sp. (previously classified as Oscillatoria sp.), which contributed 2000 filaments/ml (Fig. 1.6.1-8).

Since a Schizothrix filament consisted of 5 to 10 cells, this "bloom" would represent a cell density of approximately 10 to 20,000 cells/ml. Appreciable growth of blue-greens is not unusual in mid to late summer. For example, a cyanophyte density of 2178 cells/ml was reported in one of the two replicates samples collected at CRM 17.9 in July 1974 (Project Management Corporation 1975, Table 2.7-88).*

*These data were included in the original version of the Environmental Report but had been eliminated from a later version submitted as Ammendment VI, April 1976.

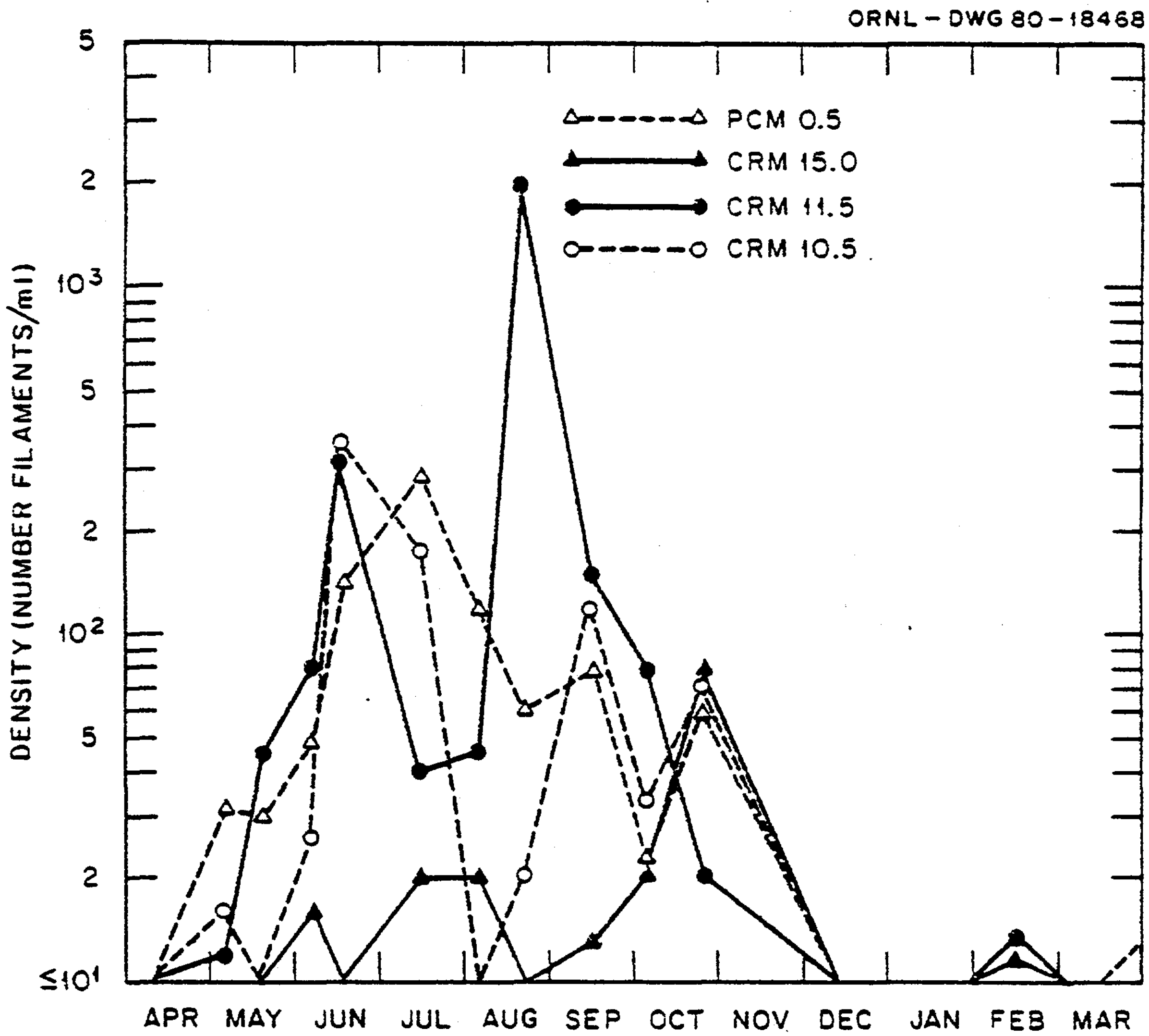

Fig. 1.6.1-8. Temporal distribution and abundance of blue-green algae (Cyanophyta) at four ORGDP sampling sites, April 1977 — March 1978.

The bloom that occurred during the ORGDP survey, however, appears to be considerably larger than those found in prior surveys of the lower Clinch River. Smaller blue-green peaks (2-4,000 units/ml) were noted at CRM 10.5 and 11.5 in mid-June and at PCM 0.5 in July (Fig. 1.6.1-8).

Although peaks in phytoplankton abundance were observed in late spring and late summer at all sampling sites, the period of maximum growth at the downstream station (CRM 10.5) actually occurred in mid-July (Fig. 1.6.1-2). Densities of almost 6000 units/ml were found at this time of year, with cryptomonads comprising more than 40% of phytoplankton numbers. Besides cryptomonads, the mid-July peak at CRM 10.5 consisted of green alga, *Ankistrodesmus falcatus*, which reached a density 1800 cells/ml.

Differences in seasonal distribution and taxonomic composition among surveys

The structure of the phytoplankton community (i.e., species composition and abundance) in the lower Clinch River, as characterized by the sampling conducted during the ORGDP survey, differed in two important aspects from that described in the 1973-76 studies. First, two growth pulses or peaks in phytoplankton abundance, one in late spring and the other in early fall, were observed in the ORGDP survey, whereas a single peak in midsummer was found in the previous surveys. This observed difference in phytoplankton population dynamics was probably the result of the different sampling frequencies employed (Table 1.6.1-1). That is, the previous studies all employed a sampling design that consisted of monthly sampling from late spring (May/June) through early fall

(September/October) (Table 1.6.1-1). With the exception of a single sampling trip in June and September, phytoplankton sampling frequencies in the ORGDP survey were biweekly between May and October. Because of the high turnover rates of most phytoplankton species, blooms can occur within relatively short periods of time. Thus, by reducing the interval between sampling periods, the probability of detecting these blooms is increased.

Second, differences in the relative importance of cryptophytes and diatoms were found between the present survey and those conducted previously. Earlier studies indicated that Chrysophyta was the most abundant component of the phytoplankton community throughout most of the year. Diatoms, especially Melosira spp., were generally abundant through a single growing season (May/June through October), while blooms of assorted green algae, blue-green algae, and other chrysophytes, such as Dinobryon spp., also occurred for shorter periods. In the present study, the Crytophyta exhibited considerable spatial and temporal constancy with diatoms, greens, and blue-greens blooming sporadically within two growing seasons.

No Cryptophyta were identified in either the 1973 TVA study (Brooks 1978) or the 1974-75 CRBR survey (Project Management Corporation 1975, Table 2.7-49), and only a single species, Cryptomonas sp., was reported from the 1975-76 NFRRC survey (Exxon Nuclear Company, Inc. 1976, Table 2.7-2). In sharp contrast to these findings, eight species of Cryptophyta were reported from the lower Clinch River prior to construction of the Melton Hill Dam (Lackey 1957), and nine species were identified in the ORGDP survey (Appendix B-1). The apparent absence or incidental occurrence of cryptomonads in the 1973-75 studies was probably due to the use of formalin as the preservative (Brooks 1978; Project Management Corporation 1975, Section 6.1.1.2); the method of sample preservation was not identified in the 1975-76 study (Exxon Nuclear Company, Inc., Table 6.1-5). Formalin is known to produce significant distortion of delicate organisms, particularly cryptomonads (Lackey 1938; Vollenweider 1969). Because identifications were made on live material in the 1956 study (Lackey 1957) and on samples that had been preserved in Lugol's solution in the ORGDP survey (Section 1.3.3), these fragile forms were not lost.

Differences in counting procedures could also account for the variation in the abundance of chrysophytes between the present study and the other three surveys. The dominant chrysophytes in the ORGDP survey were the diatoms Cyclotella and Synedra, whereas the diatom Melosira and the flagellate Dinobryon, both of which are colonial forms, were the most abundant chrysophytes in earlier studies. The procedure used in the CRBR study (and presumably the other two studies as well) was to count each cell of a colonial form as one individual. In the present study, one filament (or other colonial unit) was counted as one unit (Section 1.3.3). Consequently, if a single Dinobryon colony consisted of 20 cells, the apparent abundance of Dinobryon in the present study must be multiplied by a factor of 20.

After taking these procedural differences into account (i.e., eliminating the cryptomonads and multiplying the number of Melosira filaments by 7.5, the average number of cells per filament), the phytoplankton commmunities observed in the 1974-75 and 1977-78 surveys at station CRM 15.0 are remarkably similar with respect to the relative composition of major taxa. Applying the same procedure to the 1973 TVA study, however, did not indicate similarity; rather, the phytoplankton population densities in the vicinity of the Kingston Steam Plant were considerably lower than those found near the mouth of Poplar Creek (stations PCM 0.5 and CRM 11.5). During the TVA survey, for example, the highest density of phytoplankton in surface samples occurred in August (2916 cells/ml). Excluding the cryptomonad component, densities of more than 7000 units/ml were found at station PCM 0.5 in May and August, while densities of 11,000 units/ml and 5300 units/ml were observed at station CRM 11.5 during June and August, respectively (Figs. 1.6.1-1 and 1.6.1-2). Peak phytoplankton densities at CRM 15.0 (1600 units/ml) and CRM 10.5 (3200 units/ml), on the other hand, are very similar to those observed near the Kingston Steam Plant (Fig. 1.6.1-2). Insufficient quantitative data were available for any comparisons to be made between the present study and the NFRRC survey (see Exxon Nuclear Company, Inc. 1976, Section 2.7.1.1).

<u>Spatial distribution</u>

To compare differences in the abundance of phytoplankton (all taxa combined) among the six sampling sites, time-weighted densities (TWD) (Section 1.3.4) were computed (Table 1.6.1-3). A significant increase ($P < 0.01$) in phytoplankton TWD occurred in a downstream direction in Poplar Creek (Table 1.6.1-4). Slower velocities, higher water temperatures, and greater light penetration due to a reduction in the canopy formed by riparian vegetation are all factors that could have

Table 1.6.1-3. Time-weighted densities (TWD) of phytoplankton (all taxa combined) at the six ORGDP sampling sites. Tabular values are expressed as days x numbers/ml (see Section 1.3.4).

Poplar Creek (PCM)			Clinch River (CRM)		
11.0	5.5	0.5	15.0	11.5	10.5
1341.5	2098.0	2348.4	2433.4	2569.8	2529.6

Table 1.6.1-4. Pairwise comparisons of time-weighted densities (TWD) of phytoplankton (all taxa combined) between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01[b]	<0.01	<0.01	<0.01	<0.01
PCM 5.5			<0.01	<0.01	<0.01	<0.01
PCM 0.5				<0.01+(c)	<0.01+	<0.01+
CRM 15.0					<0.01+	<0.01+
CRM 11.5						0.12+
CRM 10.5						

[a] Sampling sites are shown in Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = Standard two-sample Student's t-tests were used. If no superscripts, then Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

contributed to this pattern. The total phytoplankton TWD at each of the Clinch River sites was also significantly higher ($P < 0.01$) than the TWD at each of the Poplar Creek sites. Continual recruitment of phytoplankton to the Clinch River from White Oak Lake and Melton Hill Lake (via releases from Melton Hill Dam) are, in part, the reason for the higher river densities.

Phytoplankton TWD at each of the sites in the Clinch River below the mouth of Poplar Creek (stations CRM 11.5 and 10.5) were significantly higher ($P < 0.01$) than the density at the upstream or control station CRM 15.0, but no significant difference ($P < 0.05$) was found between the two downstream sites (Table 1.6.1-4). Warmer water temperatures in Poplar Creek during the summer may have had some influence on the differences in abundance observed between the three river sites. From temperature data taken concurrently with the phytoplankton samples, maximum surface water temperatures reached 27°C at PCM 0.5, whereas maximum temperatures recorded at CRM 15.0, 11.5, and 10.5 were 20°, 23° and 21°C, respectively. The release of cooler hypolimnetic water at Melton Hill Dam accounts for the relatively stable water temperatures that were recorded at station CRM 15.0 between mid-June and early October (1977: range = 19-20°C, $n = 7$; 1978: range = 17-20°C, $n = 11$). Temperature differences of 3 to 5°C between the upstream site at CRM 15.0 and station CRM 11.5 located just below the mouth of Poplar Creek were common during the summer of 1977. Differences of this magnitude were also recorded in July and August 1978 during the ichthyoplankton sampling program. Data from both years showed that temperatures were, on the average, only 1 to 2°C higher at station CRM 11.5 compared to CRM 10.5, a pattern consistent with the results of the statistical analysis which showed that the total phytoplankton TWDs between the two downstream sites were not significantly different.

Summary

The higher temperatures in the creek during the summer months may have enhanced phytoplankton productivity at the two lower Poplar Creek sites and those in the Clinch River just below the mouth of the creek. The composition and abundance of phytoplankton at PCM 0.5 and CRM 11.5 were generally very similar. Although the densities were somewhat lower at station CRM 10.5 during the late spring and early fall, the composition of the phytoplankton community at this downstream site was similar to that found at stations CRM 11.5 and PCM 0.5. The phytoplankton community at the upstream site (CRM 15.0) was typical of the communities encountered in previous studies conducted in this region of the river (after accounting for differences in sampling frequency and methodology).

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1.6.2 Periphyton (J. A. Solomon and J. M. Loar)

Periphyton consists of both heterotrophic and autotrophic organisms that are attached to vegetation or other surfaces (e.g., sediment, rocks) at or projecting from the bottom of streams, rivers, or lakes. The communities are often sampled using artificial substrates (e.g., glass slides) which are colonized primarily by benthic algae. Quantitative estimates of periphyton growth can be made during or after the colonization period.

Although the periphyton communities in many aquatic systems play an important role in energy flow viz-a-viz their contribution to primary production, they are also important as indicators of environmental perturbations. Unlike planktonic organisms that can be considered transients in lotic systems, periphyton are spatially stable. Although some sloughing of cells occurs, the community essentially is confined to one location or a single glass slide. Consequently, they play an important role as "integrators" of physical and chemical changes that may occur over extended periods of time (i.e., during the colonization period). Due to the high turnover rates of algal cells, the community dynamics of periphyton represent a good indicator of water quality changes (Szluha 1974), since their growth (or productivity) is influenced by these changes (Tillery and Haushild 1975).

Review of previous studies

In previous studies conducted in the Tennessee area between 1968 and 1975, periphyton exhibited a successional pattern consisting of diatom-dominated communities during the winter and spring and a shift toward dominance by green and blue-green algae in summer and early fall (Project Management Corporation 1975, Section 2.7.2.4.4). Such a pattern was observed in a 1973 study conducted by the Tennessee Valley Authority (TVA) on the lower Clinch River in the vicinity of the Kingston Steam Plant (Brooks 1978) and in the 1974-75 preoperational aquatic survey conducted between CRM 18.0 and 15.0 near the proposed Clinch River Breeder Reactor (CRBR) site (Project Management Corporation 1975). Diatoms dominated the total cell counts for the eight months (September 1975 through April 1976) when periphyton were sampled as part of the preoperational aquatic sampling program near the proposed site of the Exxon Nuclear Fuel Recovery and Recycling Center (NFRRC) at CRM 14.4 (Exxon Nuclear Company, Inc. 1976). The NFRRC Environmental Report provided no quantitative data on the composition and abundance of the periphyton communities (e.g., see Exxon Nuclear Company, Inc. 1976, Table 2.7-34).

It is difficult to compare the results of the studies mentioned above with those obtained in the present survey. Different (or presumably different) counting procedures were used in the earlier surveys, and the problems encountered because of these differences are the same as those described for phytoplankton (Section 1.6.1). Although this problem is unique only to numerical abundance and not biomass, data on the latter were not reported in the NFRRC Survey and only five values (i.e., mean of all stations on five dates) were reported in the CRBR survey (Project Management Corporation 1975, Table 2.7-70). Sampling periods and exposure times also varied among the different surveys. No samples were collected during the summer in the NFRRC study (Exxon Nuclear Company, Inc. 1976, Section 2.7.1.4). The length of the colonization period (i.e., the exposure or incubation time) was reported as three to four weeks and 30 days in the CRBR and NFRRC surveys, respectively. It is likely, however, that some variation in the exposure time could have occurred. Since the specific number of days for each sampling period was not given, differences in exposure times among the various surveys are difficult to evaluate. Finally, it is reasonable to assume that different types of artificial samplers were used and that these samplers may have been deployed in different ways (e.g., at different depths below the surface).

Seasonal distribution

The successional patterns observed in earlier studies were also exhibited in the ORGDP survey. With the exception of station PCM 11.0 (Fig. 1.2-1) where the February periphyton community was dominated by a microflagellate, the communities present during the winter (November and February) consisted primarily of diatoms, which comprised 87 to 99% of the periphyton numbers during this period (Fig. 1.6.2-1). The decrease in the relative abundance of diatoms in October and March was common at all sites and was generally due to an increase in density of cryptophytes and/or unidentified flagellates. No consistent pattern in the time of occurrence of maximum diatom densities was found, but minimum densities at PCM 0.5 and the three river sites all occurred in February when periphyton abundance in the creek exceeded that in the river.

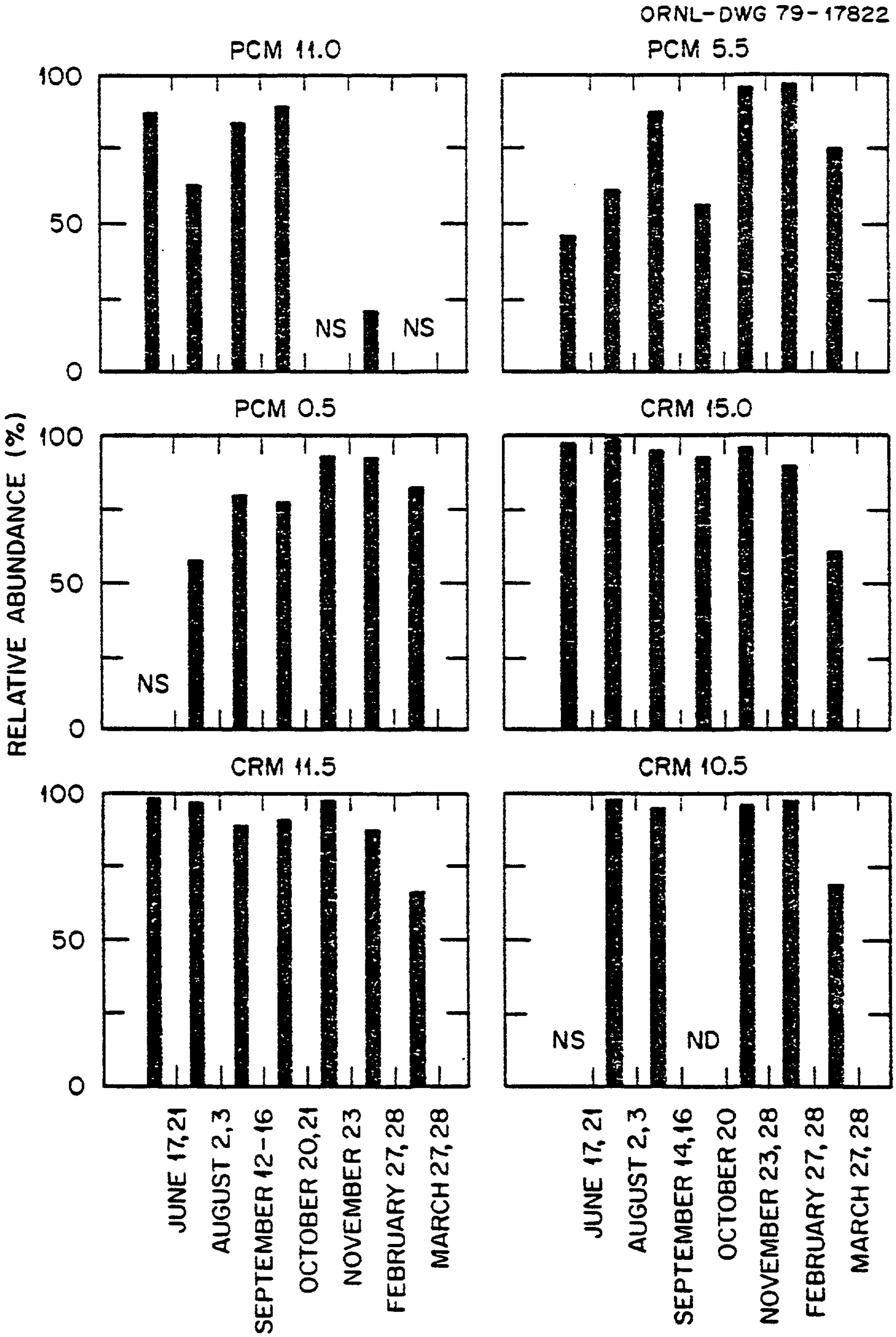

Fig. 1.6.2-1. Relative abundance of diatoms in the periphyton communities at the six ORGDP sampling sites, June 1977–March 1978. Periphyton slides were collected and returned to the laboratory on the dates listed. NS = no samples taken; sampler lost due to fluctuating water levels. ND = no data collected on cell densities due to fungal growth.

The expected growth of filamentous green and blue-green algae during late summer and early fall (August-October) was also observed. In the Clinch River, peak densities of nonfilamentous green algae coincided with the peaks in density of filamentous greens in September and October (Fig. 1.6.2-2). No consistent temporal patterns in green algal abundance were found among the three Poplar Creek sampling sites (Fig. 1.6.2-3).

Despite the increase in abundance of green and blue-green algae in late summer and early fall, the non-diatom component of the Clinch River periphyton communities never constituted more than 10% of the total cell counts during the summer growth period. With the exception of station PCM 0.5 during the fall and winter, diatom densities in Poplar Creek were considerably lower than those observed in the Clinch River (Table 1.6.2-1). Consequently, relatively small fluctuations in the abundance of non-diatom species resulted in rather dramatic changes in community composition. Non-diatoms in Poplar Creek, for example, comprised from 11 to 54% of the total cell counts between June and October (Fig. 1.6.2-1).

The green algal population in Poplar Creek, especially at PCM 0.5, had an important unicellular component. Periphyton samplers collected from the field in early August after a three-week colonization period had an average density of 41,818 cells/cm^2, primarily Scenedesmus and Ankistrodesmus. A second peak of 90,233 cells/cm^2 occurred during October, with Carteria one of the more abundant genera. These relatively high densities of unicellular greens at PCM 0.5 were not observed at the other stations and, in part, accounted for the reduction in the relative abundance of diatoms during these periods.

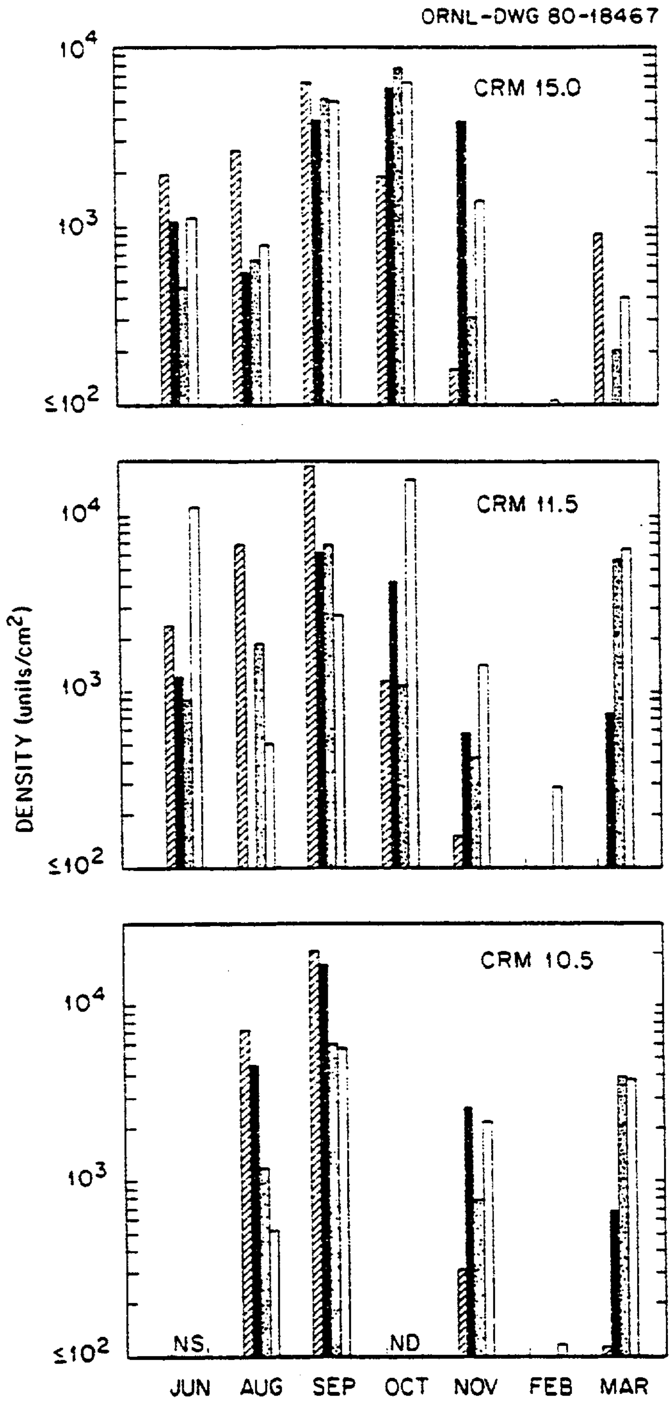

Fig. 1.6.2-2. Densities (number of units/cm^2) of the non-diatom components of the periphyton communities at the three ORGDP sampling sites on the Clinch River, June 1977–March 1978. Periphyton slides were collected and returned to the laboratory on the dates listed. No. of units = no. of filaments (for filamentous species) or no. of cells (for nonfilamentous species). NS = no samples taken; sampler lost due to fluctuating water levels. ND = no data collected on cell densities due to fungal growth. ■ = filmentous greens; ▤ = nonfilamentous greens; ▨ = blue-greens; □ = others (includes all groups except the Bacillariophyceae, Chlorophyta, and Cyanophyta).

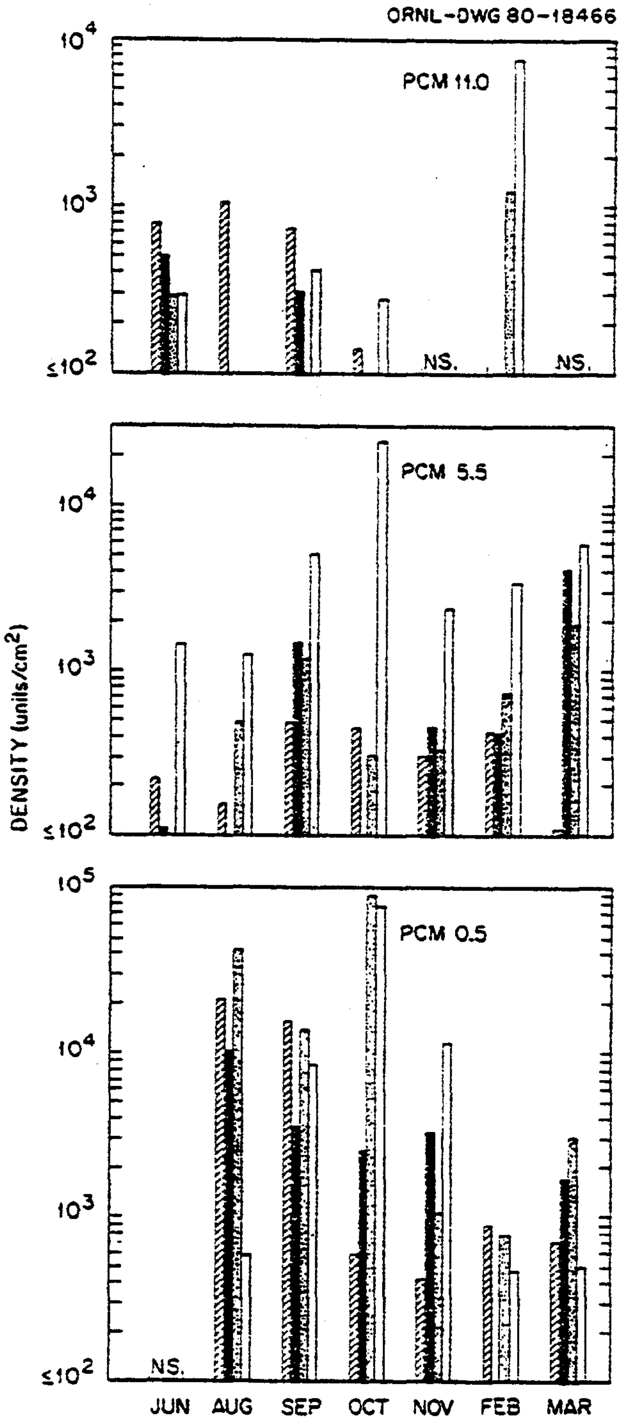

Fig. 1.6.2-3. Densities (number of units/cm^2) of the non-diatom components of the periphyton communities at the three ORGDP sampling sites on Poplar Creek, June 1977-March 1978. Periphyton slides were collected and returned to the laboratory on the dates listed. No. of units = no. of filaments (for filamentous species) or no. of cells (for nonfilamentous species). NS = no samples taken; sampler lost due to fluctuating water levels. ■ = filamentous greens; ▩ = nonfilamentous greens; ▨ = blue-greens; □ = others (includes all groups except the Bacillariophyceae, Chlorophyta, and Cyanophyta).

Table 1.6.2-1. Diatom densities (units/cm^2) on plexiglass slides at the six ORGDP sampling sites, June 1977–March 1978. Dates represent the last day of the colonization/incubation period (duration, in days, in parentheses).

	Poplar Creek (PCM)			Clinch River (CRM)		
Date	11.0	5.5	0.5	15.0	11.5	10.5
June 17, 21 (14, 15)	13,828	1,529	*a*	210,415	969,347	*a*
August 1-3 (19-21)	1,926	2,881	96,890	422,535	415,306	648,859
September 12, 14-16 (21-24)	12,780	56,190	159,980	368,730	304,000	969,010
October 20, 21 (14-17)	3,453	32,866	601,500	277,250	219,606	*b*
November 23, 28 (20, 25[c])	*a*	77,460	230,925	129,650	180,750	170,486
February 27, 28 (19, 20, 27, 29)[d]	2,369	141,375	29,441	929	3,979	4,021
March 27, 28 (12)	*a*	34,758	27,503	2,315	25,875	18,610
MEAN	6,871	49,580	191,040	201,689	302,695	362,197

[a]Sampler lost due to fluctuating water levels.

[b]Samples lost due to fungal growth.

[c]For station PCM 5.5 only.

[d]Length of incubation period was 19 d at PCM 0.5; 20 d (PCM 11.0); 27 d (PCM 5.5); and 29 d (all river stations).

The abundance of greens at the two upstream sites on Poplar Creek was generally low throughout the study. Peaks of 1248 and 6088 units/cm^2 occurred at stations PCM 11.0 in February and PCM 5.5 in March, respectively (Fig. 1.6.2-3). Maximum densities of greens in the Clinch River were considerably higher and, like station PCM 0.5, the peaks occurred in September and October. The maximum density of green algae in the Clinch River (17,024 filaments + 6055 cells/cm^2) was found at station CRM 10.5 in September (Fig. 1.6.2-2).

Maximum densities of blue-green algae occurred in August and September. Abundance was highest at station PCM 0.5, and densities in the Clinch River greatly exceeded those in upper Poplar Creek. The blue-green algal population at station CRM 15.0, however, was consistently low throughout the study (Fig. 1.6.2-2). The maximum density of 6281 filaments/cm^2 occurred in September at the same time that maximum densities of 19,692 and 20,228 filaments/cm^2 were observed at stations CRM 11.5 and 10.5, respectively. In Poplar Creek, blue-green abundance at the two upper sites never exceeded 1086 filaments/cm^2, but densities of 21,196 and 15,488 filaments/cm^2 were found at PCM 0.5 in August and September, respectively (Fig. 1.6.2-3). The peak densities of blue-greens in the periphyton and phytoplankton samples from this site occurred at approximately the same time (see Fig. 1.6.1-8). The periphyton sampling program confirmed not only the low densities of blue-greens at station CRM 15.0 but also the relatively high densities found at stations PCM 0.5, CRM 11.5, and CRM 10.5 during the phytoplankton study.

A comparison of periphyton community composition at the Clinch River sites with that found at the two upper creek sites indicates the existence of two distinct periphyton assemblages. The community that exists near the mouth of the creek (PCM 0.5), however, exhibits characteristics typical of both the Clinch River and upper Poplar Creek communities. For example, from August to November, diatom abundance at station PCM 0.5 was higher than that in Poplar Creek and approached and sometimes exceeded that observed in the river (Table 1.6.2-1). A similar pattern was found with the blue-green algae (Figs. 1.6.2-2 and 1.6.2-3). The magnitude of the seasonal shifts in the relative abundance of diatoms at PCM 0.5 was less than that observed in the creek sites but greater than that found in the Clinch River where diatoms comprised at least 90% of the periphyton cell counts during all sampling periods except March.

Finally, the high densities of nonfilmentous greens that occurred in August and October were only characteristic of the periphyton community at station PCM 0.5. Populations of greens at the other five sites were considerably smaller. The high degree of similarity in the composition of the phytoplankton communities at stations PCM 0.5 and CRM 11.5 (Section 1.6.1) was not exhibited by the periphyton communities.

Spatial distribution

Cell counts

Based, in part, on differences in the hydrodynamic properties and habitat characteristics of the two major bodies (Section 1.2), it was not surprising to find rather dramatic differences in periphyton abundance in Poplar Creek and the Clinch River. Densities in Poplar Creek at stations PCM 11.0 and 5.5 were considerably lower than those found in the Clinch River. Densities at station PCM 0.5, on the other hand, were generally more similar to the densities in the river than to the densities at the upstream stations. The maximum abundance of 772,390 units/cm^2 that occurred in October at station PCM 0.5 was exceeded only by the density in June at station CRM 11.5. Like the Clinch River populations, the periphyton populations in Poplar Creek fluctuated throughout the year with peak densities occurring in different months at the three sampling sites (Table 1.6.2-2).

Except for reduced growth during the winter months, periphyton densities in the Clinch River exhibited no consistent temporal pattern; periods of peak abundance at the three sites did not coincide (Table 1.6.2-2). Populations at station CRM 15.0 remained moderately high throughout the summer and fall (June-November). Except for the very high initial density of 985,580 units/cm^2, the densities 3.6 km downstream (CRM 11.5) were similar to those at the upstream site during this period. The temporal distribution of periphyton abundance during the summer and fall at station CRM 10.5 is uncertain, since no data were available for June and October. In August and September, cell densities at this site were higher than those observed at the two sites upriver. During the remainder of the sampling program, however, densities were, with a single exception, similar at all three river sites. The low periphyton abundance at station CRM 15.0 during the winter is difficult to explain; phytoplankton densities were very similar at all three river sites throughout the winter and early spring (Fig. 1.6.1-2). Interestingly, phytoplankton abundance at the river sites was approximately double that at the Poplar Creek sites in February and March (Fig. 1.6.1-1),

Table 1.6.2-2. Total periphyton densities (units/cm^2) on plexiglass slides at the six ORGDP sampling sites, June 1977-March 1978. Dates represent the last day of the colonization/incubation period (duration, in days, in parentheses).

	Poplar Creek (PCM)			Clinch River (CRM)		
Date	11.0	5.5	0.5	15.0	11.5	10.5
June 17, 21 (14, 15)	15,756	3,294	*a*	214,980	985,580	*a*
August 1-3 (19-21)	3,013	4,769	170,540	427,245	424,864	662,249
September 12, 14-16 (21-24)	15,290	64,364	201,070	389,165	340,000	1,018,054
October 20, 21 (14-17)	3,873	57,964	772,390	299,215	242,792	*b*
November 23, 28 (20, 25[c])	*a*	80,942	247,145	135,300	183,400	176,552
February 27, 28 (19, 20, 27, 29)[d]	11,302	146,385	31,661	1,032	4,568	4,135
March 27, 28 (12)	*a*	45,836	33,451	3,838	39,220	27,094
MEAN	9,847	57,651	242,710	210,111	317,203	377,617

[a] Sampler lost due to fluctuating water levels.

[b] Samples lost due to fungal growth.

[c] For station PCM 5.5 only.

[d] Length of incubation period was 19 d at PCM 0.5; 20 d (PCM 11.0); 27 d (PCM 5.5); and 29 d (all river stations).

whereas periphyton abundance (cell density) in the two areas exhibited just the opposite pattern.

Biomass

Contrary to the results obtained from direct cell counts, periphyton biomass in the winter (February and March) was very similar at the three river sites (Table 1.6.2-3). The differences that did occur were confined to other times of the year when abundance was higher (June-November). During this latter period, biomass was generally higher at station CRM 11.5 than at station CRM 15.0, in contrast to the similarity in cell density noted previously. The differences in periphyton biomass between the two sites cannot be explained on the basis of a greater number of filamentous forms at the downstream site. Rather, the higher biomass at CRM 11.5 may simply be indicative of the presence of more nonalgal organic matter.

Any detailed comparison between station CRM 10.5 and the other sites is difficult due to the contamination of both the September and October samples by fungi. Although algal counts rose from August to September, biomass declined, and many fungal hyphae were noted in the September samples. Biomass decreased again in October, and it was noted that the samples preserved in Lugol's solution contained only a large mass of fungal mycelium that had not been present at the time of preservation. It is possible, and somewhat speculative, that considerable algal biomass may have occurred at CRM 10.5 in October. If that happened, then it is possible that the amount of Lugol's solution added to the sample was not sufficient to prevent the growth of the fungus.

Table 1.6.2-3. Periphyton biomass (ash-free dry wt, mg/m^2) on plexiglass slides at the six ORGDP sampling sites, June 1977-March 1978. Dates represent the last day of the colonization/incubation period (duration, in days, in parentheses).

	Poplar Creek (PCM)			Clinch River (CRM)		
Date	11.0	5.5	0.5	15.0	11.5	10.5
June 17, 21 (14, 15)	407	781	*a*	1,309	2,533	*a*
August 1-3 (19-21)	612	587	5,828	3,330	4,790	6,666
September 12, 14-16 (21-24)	729	1,579	2,651	3,221	5,668	3,995
October 20, 21 (14-17)	471	1,765	2,243	2,192	1,683	1,624
November 23,28 (20, 25[b])	*a*	1,208	2,400	4,969	5,070	3,177
February 27, 28 (19, 20, 27, 29)[c]	544	1,614	551	317	385	786
March 27, 28	*a*	833	472	382	445	277
MEAN	553	1,195	2,358	2,246	2,939	2,754

[a]Sampler lost due to fluctuating water levels.

[b]For station PCM 5.5 only.

[c]Length of incubation period was 19 d at station PCM 0.5; 20 d (PCM 11.0); 27 d (PCM 5.5); 29 d (all river stations).

Although the fungus grew in the sample from September (which contained a relatively large amount of algae), the entire sample was not destroyed. The critical question, and one which cannot be answered, is whether the fungal growth occurred because of the presence of high algal biomass. Changes in water quality could also have occurred, resulting in an enhancement of the growth of the algae, the fungus, or both.

In Poplar Creek, periphyton biomass also fluctuated throughout the year at a given site, and the pattern observed was not consistent among the three sites. The month of peak biomass varied between sites. Maximum biomass at station PCM 0.5 occurred in August (5828 mg/m^2) and was the second highest value recorded at any site during the entire study. The peak was due primarily to the presence of filamentous green and blue-green algae (Fig. 1.6.2-3).

With few exceptions, both periphyton density and biomass increased in a downstream direction in Poplar Creek. Relatively low densities and biomass were found throughout the study at PCM 11.0. From August through November, densities and biomass were lower at station PCM 5.5 than at PCM 0.5, but the trend was reversed in February and March. During these months, periphyton cell densities and biomass at PCM 5.5 (and to a lesser extent at PCM 11.0) were the highest of any site, including those in the Clinch River. The increase in periphyton abundance from station PCM 11.0 downstream to station PCM 0.5 was not surprising. A reduction in the canopy of riparian vegetation increases light availability, and the lower current velocities in the downstream reaches of the creek (Table 1.2-2) enable algal communities to become permanently established. The greater abundance of periphyton in upper

Poplar Creek (station PCM 5.5) during February and March is difficult to explain without concurrent data on several physical parameters (e.g., turbidity, water temperature and quality, light intensity).

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1.6.3 Zooplankton (J. M. Loar and F. A. Burkhart)

A review of the plankton studies conducted on the large rivers throughout the world has shown that the species composition and abundance of zooplankton communities in rivers differ substantially from those occurring in lakes or nonflowing environments (Hynes 1970). The former are generally dominated by rotifers, most of which are truly planktonic (e.g., *Keratella*, *Synchaeta*, *Polyarthra*, *Asplanchna*, *Brachionus*). Although crustaceans are an important component of lacustrine communities, they are rarely abundant in the open-water of rivers and consist primarily of the genera *Cyclops* and *Bosmina*.

In both riverine and lacustrine ecosystems, zooplankton can represent an important pathway in the flow of energy from producers (e.g., phytoplankton) to consumers (e.g., fishes). They constitute a significant food resource of the early life history stages of most fish species (e.g., Carlander 1969, 1977; Cramer and Marzolf 1970; Siefert 1972). Young fish larvae have specific food requirements and are vulnerable to starvation (Siefert 1972). Consequently, an environmental perturbation that adversely affected the abundance and availability of the food resource could significantly affect the population utilizing that resource. Zooplankton are also the primary food of some species during all stages of development, from larva to adult. For example, threadfin shad, a forage species and prey for many of the game species (e.g., largemouth bass, sauger) in Watts Bar Reservoir, has been reported to feed mainly on zooplankton (Carlander 1969). An analysis of the stomach contents of threadfin shad (size/age not given) collected during the CRBR survey indicated that the cladocerans, *Bosmina longirostris* and *Leptodora* *kindtii*, and the rotifer, *Keratella* sp., were the most abundant organisms in the diet (Project Management Corporation 1975, Section 2.7.2.4.9). Because zooplankton occupy an important intermediate position in the trophic structure of aquatic ecosystems, information was obtained on their abundance and distribution in the vicinity of ORGDP.

Review and comparison of results from previous studies

Direct comparisons of our results with those obtained in prior surveys are difficult due to differences in sampling methodology. In previous zooplankton surveys of the lower Clinch River, vertical tows were taken using a No. 20-mesh plankton net, whereas in the ORGDP study, a Clarke-Bumpus sampler was towed at the surface. The mesh of the nets and the sampling frequencies, however, were similar in all surveys, including the present one. Sampling procedures other than vertical towing were also employed during various stages of the CRBR preoperational survey in order to examine the vertical stratification of zooplankton (Project Management Corporation 1975). As a result, an evaluation of the effect of surface versus vertical tows on estimates of zooplankton abundance in the Clinch River can be performed. Such an evaluation is necessary if comparisons between the various surveys are to be meaningful.

Comparison of surface vs vertical tows

Zooplankton stratification was examined in the CRBR survey by collecting 2-min pump samples at the surface, mid-depth, and bottom of the water column from March through July 1974 (Project Management Corporation 1975). Analysis of the samples collected in June and July indicated that the distribution of zooplankton was stratified, with generally higher densities recorded near the surface than at the mid-depth and bottom stations (Project Management Corporation 1975, Table 2.7-53). Surface densities in June were generally twice those at the deeper stations, due primarily to the presence of the cladoceran, Bosmina longirostris. In July, densities at mid-depth only slightly exceeded those at the bottom in July, but surface densities were an order of magnitude greater. Species contributing to the high abundance at the surface were primarily the rotifers Asplanchna priodonta, Conochilus unicornis, Polyarthra spp., and Synchaeta sp. (Project Management Corporation 1975, Section 2.7.2.4.3). Unlike the samples collected in March and May, the summer samples were taken following extended periods (approximately 6-12 h) of zero release at Melton Hill Dam (Project Management Corporation 1975, Section 2.7.2.4.3 and Table 2.7-44).

Because of the stratification observed in July, surface towing was initiated in September, and from then until April of the following year, surface and vertical tows were taken concurrently (Project Management Corporation 1975). Estimates of zooplankton density obtained with these two sampling procedures are given in Table 1.6.3-1. The consistently higher densities of zooplankton in the surface tows at all three sampling sites in September and November were due to the high abundance of rotifers, especially Keratella and Polyarthra (Project Management Corporation 1975, Section 2.7.2.4.3). These results were similar to

Table 1.6.3-1. Comparison of total zooplankton densities (no./liter) obtained in vertical (V) and surface (S) tows with a No. 20 mesh, 0.5-m plankton net at three sampling sites on the Clinch River in 1974-75. Q = discharge in m^3/s (cfs in parentheses) at Melton Hill Dam during the period of sampling.

		CRM 17.9		CRM 15.9		CRM 15.1	
Sampling date	Q[a]	V[b]	S[c]	V	S	V	S
September 26	161 (5,680)	20.82	67.12	29.62	35.36	8.40	38.07
November 19	227 (8,000)	7.94	22.46	8.88	16.49	7.20	15.79
January 16	0[d]	39.10	14.51	23.21	9.04	19.82	9.02
April 14	540 (19,060)	4.97	6.62	4.78	5.85	6.38	5.68
MEAN		18.21	27.68	16.62	16.68	10.45	17.14

[a]Source: Project Management Corporation (1975), Table 2.7-44.
[b]Source: Project Management Corporation (1975), Table 2.7-52.
[c]Source: Project Management Corporation (1975), Table 2.7-54.
[d]No release 4 h prior to and during the period of sampling.

those obtained from stratified (i.e., at discrete depths) pump sampling in July as discussed above.

Stratification was also apparent in January, but densities in the vertical tows were approximately twice those in the surface tows (Table 1.6.3-1). Although copepod and cladoceran densities were consistently higher in the vertical tows on three of the four sampling dates, including January, the apparent concentration of rotifers in the deeper water (as suggested by their higher density in the vertical vs surface tows) contrasted with the pattern found at other times of the year (Table 1.6.3-2). The distribution of zooplankton (particularly rotifers) may be influenced by the presumably warmer water in the deeper regions of the river during periods of zero release at Melton Hill Dam in the winter. Finally, no evidence for the stratification of

Table 1.6.3-2. Comparison of the densities (no./liter) of crustacean and noncrustacean zooplankters taken in vertical (V) and surface (S) tows with a No. 20 mesh, 0.5-m plankton net on four sampling dates in 1974-75. Values represent the mean densities of samples collected at CRM 17.9, 15.9, and 15.1.

	Sampling date							
	September 26		November 19		January 16		April 14	
	V	S	V	S	V	S	V	S
Crustacea								
Cladocera	3.27	1.13	1.30	0.90	1.67	0.37	2.48	2.64
Copepoda	3.82	2.83	0.45	0.37	2.30	1.14	1.81	2.05
Total	7.09	3.96	1.75	1.27	3.97	1.51	4.29	4.69
Rotifera	12.57	42.89	6.28	16.99	21.74	9.38	1.15	1.42
Total zooplankton	19.66	46.85	8.03	18.26	25.71	10.89	5.43	6.10

Source: Project Management Corporation (1975), Table 2.7-56.

zooplankton was found in April. High river flows in the spring likely result in relatively complete mixing of the water column, and the high current velocities prevent the establishment of well-defined vertical distribution patterns.

Results from the CRBR gear/flow comparison study suggest that estimates of zooplankton abundance in the Clinch River can be influenced not only by the method of towing or the type of gear employed but also by the discharge regime at Melton Hill Dam relative to the time when sampling was conducted. Extended periods of zero release before and during the sampling period, for example, may affect the distribution of zooplankton in the water column. Under these quiescent conditions, an opportunity exists for species to occupy discrete areas, thereby resulting in a nonuniform distribution between the surface and bottom.

Many lacustrine zooplankton species exhibit well-defined diurnal vertical migration patterns (e.g., see review by Hutchinson 1957). Finally, the variability in densities between years is a phenomenon associated with natural zooplankton population dynamics. The abundance of given species may differ dramatically between successive years (Hutchinson 1957), so fluctuations in total zooplankton densities from one year to the next would not be surprising. In summary, any one or all of these factors (sampling methodology, discharge regime, natural variability) may account for the differences in zooplankton abundance observed during the four surveys conducted on the Clinch River between 1973 and 1978 and discussed below.

TVA survey

Three sites located near the mouth of the Clinch River were sampled by the TVA in 1973 (Brooks 1978). Zooplankton samples were collected at CRM 1.4, 2.1, and 2.6 at approximately four-week intervals from mid-June through early October. Maxima occurred in mid-July and mid-September at all three sites. In July, densities ranged from 244.2 organisms/liter at CRM 2.6 to 394.8 organisms/liter at CRM 1.4. Dominant species at this time were the rotifers *Polyarthra* and *Filinia*. Maximum densities of these two genera were 142.7 and 47.5 organisms/liter at CRM 1.4 and CRM 2.1, respectively. Like the ORGDP survey, rotifers dominated the zooplankton community during most of the year. In June and September, for example, their relative abundance exceeded 95%. Cladoceran and copepod densities also reached a peak in July. The most abundant species were *Diaphanosoma leuchtenbergianum* (maximum of 27.6 organisms/

liter at CRM 1.4) and Bosmina longirostris (21.5 organisms/liter at CRM 2.6). Nauplii comprised the majority of the copepod population at this time and throughout the study.

A smaller peak in zooplankton density occurred in mid-September and was comprised primarily of rotifers, particularly Asplanchna. At this time, total densities ranged from 66.3 to 130.0 organisms/liter at stations CRM 2.6 and 1.4, respectively. The cladoceran population exhibited a fall maximum in early October with Bosmina longirostris (9.6 organisms/liter at CRM 1.4) the dominant species.

Zooplankton densities at these sites exceeded those observed during the ORGDP survey. The greatest similarity between the two surveys was observed at station CRM 15.0 (Fig. 1.2-1). At this site and those located near the mouth of the river, peak zooplankton densities occurred in mid-July and the most abundant species was Polyarthra. Peak densities at stations CRM 11.5 and 10.5 occurred in early June where the dominant genera were the rotifers Brachionus spp. and Keratella, respectively. Crustacean abundance at station CRM 15.0 reached maxima in mid-July and early October, as was observed in the TVA study, but the densities were considerably higher in the latter.

Although Bosmina longirostris was found to be abundant in both studies, Diaphanosoma leuchtenbergianum was infrequently collected in the present study. Instead, Sida crystallina, a member of the same family as Diaphanosoma (Sididae), reached a density of 9.2 organisms/ liter and comprised 85% of the cladoceran population during the peak in mid-July at station CRM 10.5. Though abundant at five of the six ORGDP sites, S. crystallina was collected in relatively low numbers in the

1973 TVA study (Brooks 1978) and was not reported in either the CRBR or NFRRC surveys (Project Management Corporation 1975; Exxon Nuclear Company, Inc. 1976). The discrepancy is difficult to explain, but may reflect a shift in species abundance due either to fluctuations in physicochemical (abiotic) properties or changes in biotic parameters such as competition and predation. These shifts in the dominance of the two zooplankton could be mediated through changes in the algal food supply, since both species are filter-feeders (Hutchinson 1957). A possible error in species identification was also considered, but the two species are not difficult to separate taxonomically.

CRBR survey

Sampling frequencies for zooplankton were identical to those for phytoplankton; samples were collected on nine dates between March 1974 and April 1975 and were taken monthly from May through September. Except for the absence of *S. crystallina* and the relatively high abundance of *D. leuchtenbergianum* (Project Management Corporation 1975, Tables 2.7-55 and 2.7-56), the results obtained during the 1974-75 CRBR survey were similar to those obtained in the ORGDP study. Rotifers were the most abundant and diverse group of zooplankton. At all three sampling sites (CRM 17.9, 15.9, 15.0), highest densities occurred in late May, with secondary peaks observed in late August and mid-January at each site. Maximum densities ranged from 113.9 to 206.6 organisms/liter in May at stations CRM 15.0 and 15.9, respectively. Minimum densities were found in late March and ranged from 2.7 organisms/liter at CRM 15.0 to

5.3 organisms/liter at CRM 17.9 (Project Management Corporation 1975, Table 2.7-52).

Composition of the May peak consisted primarily of rotifers (96%), with Conochilus unicornis (average density of 69.4 organisms/liter) and Asplanchna priodonta (27.1 organisms/liter) the most abundant species (Project Management Corporation 1975, Table 2.7-55). Densities of Keratella spp. and Polyarthra spp. were 13.3 and 18.4 organisms/liter, respectively. The peak in later summer (63.6 organisms/liter) was also dominated by rotifers (97%), and species composition and relative abundance were similar to the earlier peak. However, a greater portion of the peak in August was composed of Brachionus spp., especially B. budapestinensis and B. calyciflorus, which reached an average density of 11.8 organisms/liter. Densities of Brachionus spp. in May were less than 1 organism/liter at a time when total zooplankton densities averaged 146.2 organisms/liter. The peak in January (25.7 organisms/liter from vertical tows) was dominated by Synchaeta spp. (20.1 organisms/liter) (Project Management Corporation 1975, Table 2.7-56)

Crustaceans were a numerically significant component of the community only in the spring when total zooplankton abundance was low. Peak abundance in vertical tows of both cladocerans and copepods occurred in late May (average density of 6.3 organisms/liter) and mid-September (7.1 organisms/liter). Dominant species were Bosmina longirostris in May (4.3 organisms/liter) and Daphnia retrocurva, Diaphanosoma leuchtenbergianum, and B. longirostris in September. Immature stages (nauplii) constituted the majority of the copepod population, which, except for January, was generally lower than the population of cladocerans. The small peak in the winter was due to an increase in the abundance of nauplii from 0.4 to 2.0 organisms/liter in November and January, respectively.

NFRRC survey

Zooplankton samples were collected monthly at four stations located between CRM 12.0 (at the mouth of Poplar Creek) and CRM 15.0 during the 1975-76 NFRRC survey (Exxon Nuclear Company, Inc. 1976). Total densities at each station exceeded those found in all other studies, including the present one. Maximum densities at the four sites ranged from 644 organisms/liter in April at CRM 15.0 (near east shore) to 1241 organisms/liter in May at CRM 14.4. Densities exceeded 1000 organisms/liter at CRM 12.0 and 15.0 (near west shore) in May and July, respectively. Minimum densities, on the other hand, occurred in January and ranged from 12 to 20 organisms/liter (Exxon Nuclear Company, Inc. 1976, Table 2.7-9).

In general, the most abundant species from May through November were the rotifers Keratella sp. and Polyarthra dolichoptera. As was observed in the present study and those discussed previously, the relative abundance of rotifers was considerably lower during the winter than in the summer. In January, rotifer density declined and the most abundant species collected at all four sites was Bosmina longirostris (Exxon Nuclear Company, Inc. 1976, Table 2.7-8). Thereafter, rotifer abundance increased, with Asplanchna amphora and Synchaeta sp. the dominant species. Zooplankton densities in Grassy Creek were not reported, but the dominant species found in samples collected between May and

October of 1975 from the Grassy Creek embayment was Keratella sp. (Exxon Nuclear Company, Inc. 1976, Table 2.7-25). No data on the densities of individual species from either Grassy Creek or the Clinch River were presented.

Seasonal distribution

Temporal fluctuations in total zooplankton abundance during the ORGDP study exhibited rather well-defined patterns at both the Poplar Creek and Clinch River sampling sites (Figs. 1.6.3-1 and 1.6.3-2, respectively). With the exception of station PCM 5.5, maxima occurred in early summer and fall. At station PCM 0.5 near the mouth of Poplar Creek, the peak density of 92.5 organisms/liter occurred in early June, with a second, considerably smaller, peak in September (9.3 organisms/liter) (Fig. 1.6.3-1). Maxima also occurred at this time at stations CRM 11.5 and 10.5 which were located approximately 0.8 and 2.4 km, respectively, below the mouth of the creek (Fig. 1.6.3-2). The second peak, however, occurred in early October and, at station CRM 11.5, was somewhat lower than the peak in late spring. At station CRM 10.5, the fall zooplankton population level exceeded that of the spring. The populations at the upstream station on the Clinch River, where water temperatures were generally lower than at the downstream sites, reached a maximum in mid-July. A similar temporal lag in both the summer and fall maxima were characteristic of the zooplankton at station PCM 5.5 where peaks occurred in mid-July and December.

Rotifers were the dominant group comprising the zooplankton community in the Clinch River (Fig. 1.6.3-3). The Rotifera were abundant during

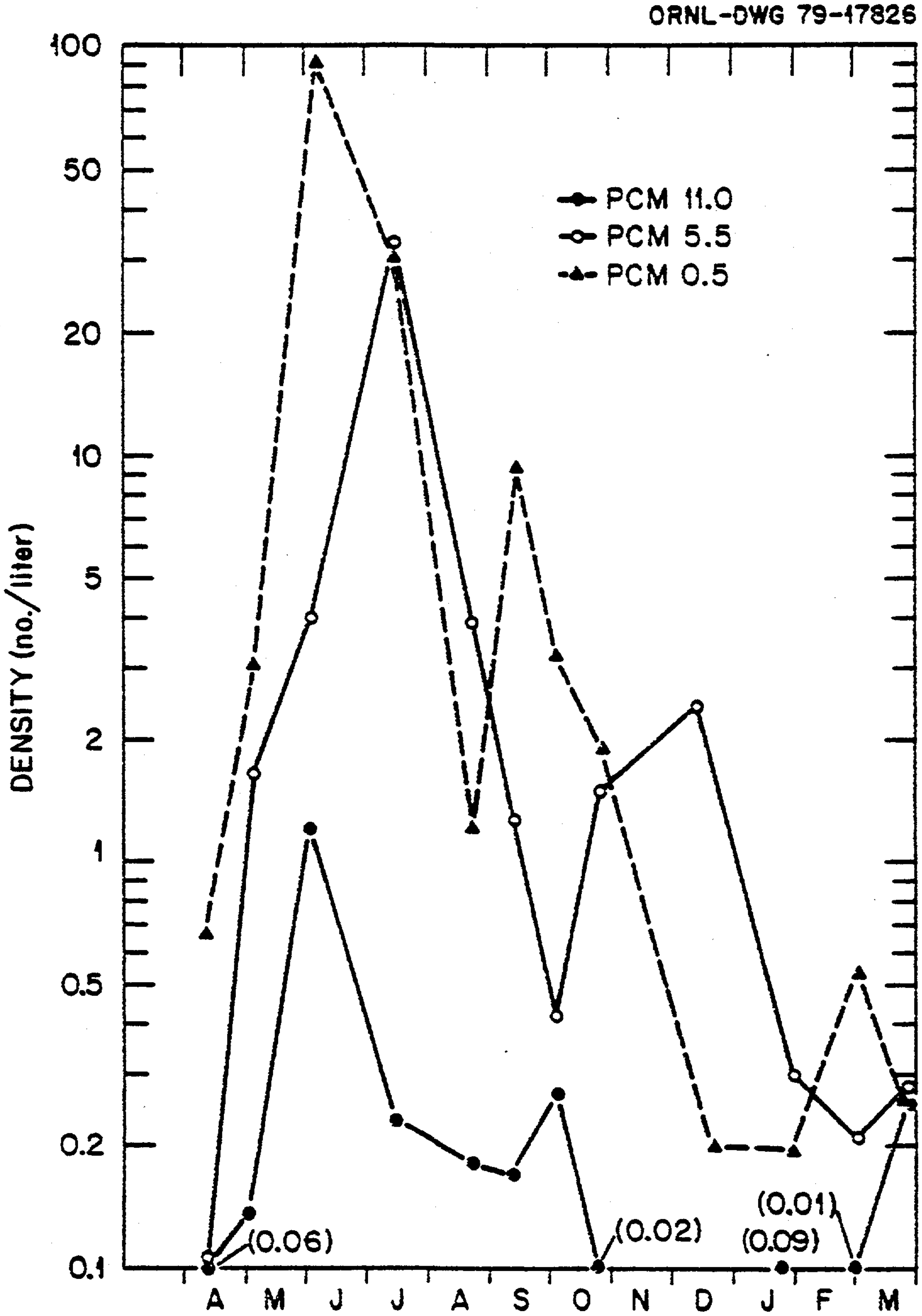

Fig. 1.6.3-1. Temporal fluctuations in total zooplankton densities (no./liter) at the three ORGDP sampling sites on Poplar Creek, April 1977-March 1978.

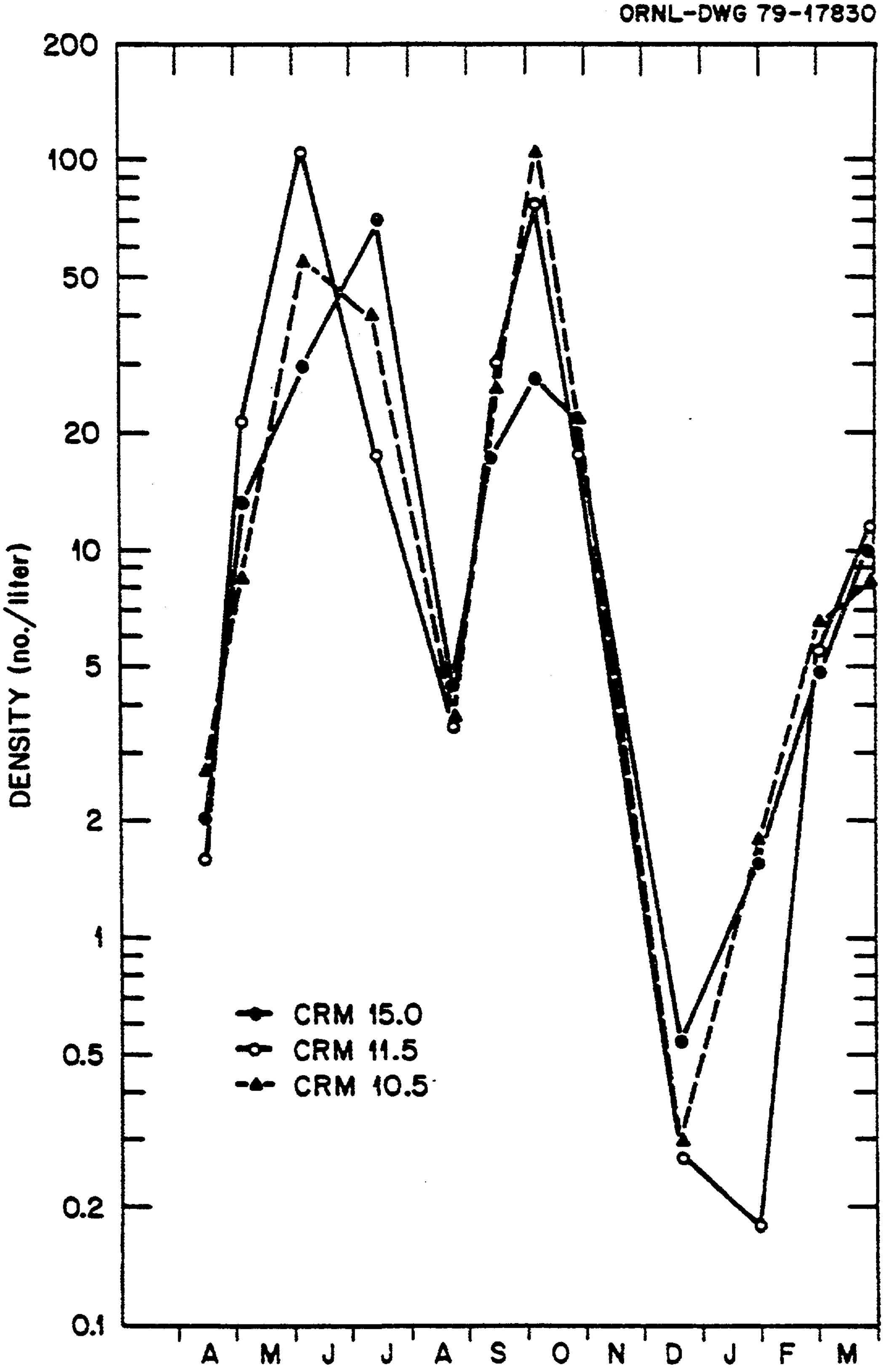

Fig. 1.6.3-2. Temporal fluctuations in total zooplankton densities (no./liter) at the three ORGDP sampling sites on the Clinch River, April 1977-March 1978.

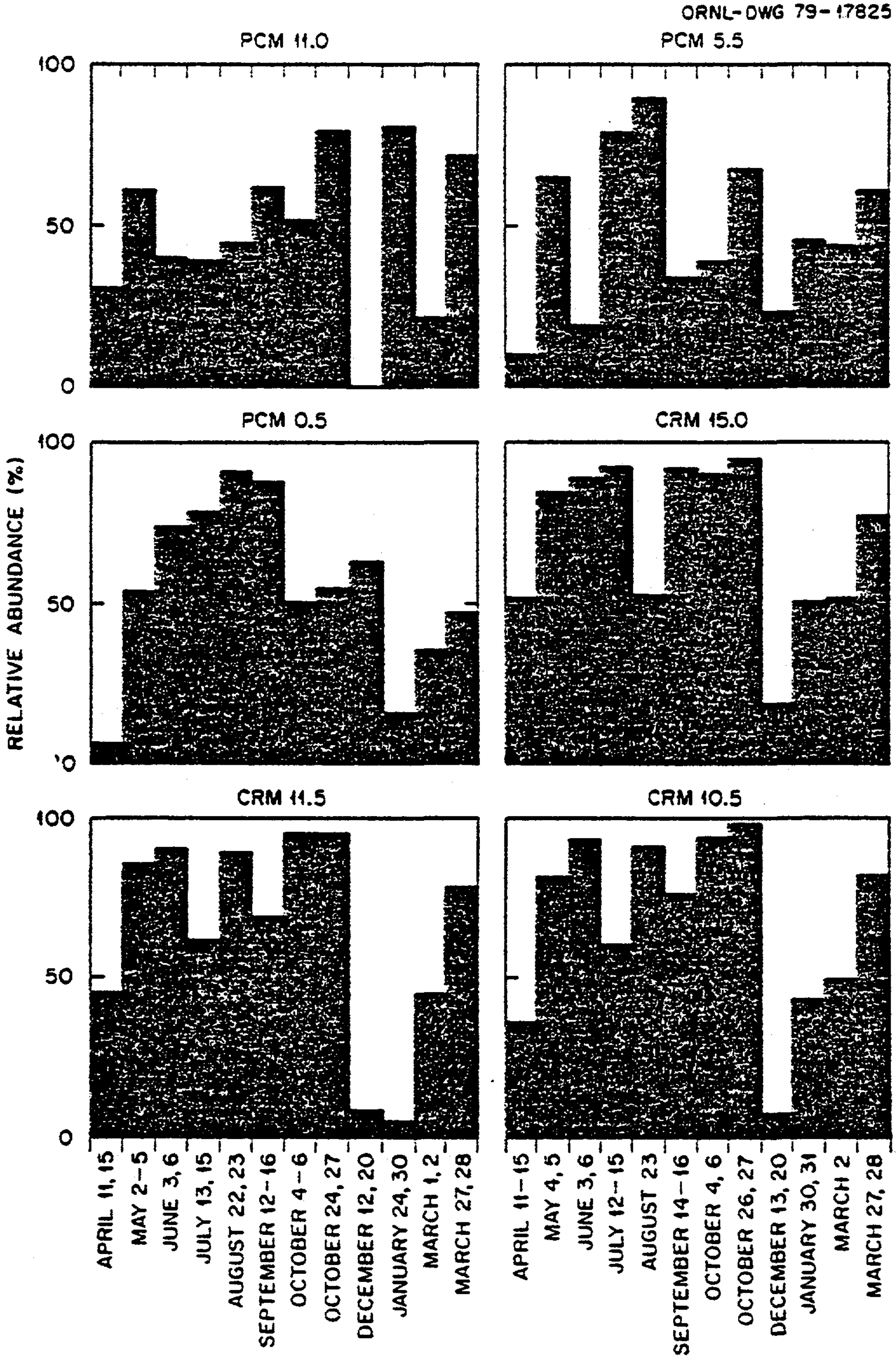

Fig. 1.6.3-3. Relative abundance of rotifers in the zooplankton samples collected at the six ORGDP sampling sites, April 1977–March 1978.

the warmer seasons of the year, but comprised less than 50% of the zooplankton numbers during the winter months (December through early March). Because the other major group of zooplankton, the Crustacea (cladocerans and copepods), were abundant periodically during the summer (Fig. 1.6.3-4), the relative abundance of rotifers fluctuated accordingly. From early May through late October rotifers generally constituted more than 85% of the zooplankton.

In contrast to the Clinch River communities, the zooplankton communities encountered in Poplar Creek were not dominated to the same extent by rotifers. The average relative abundance of rotifers at stations PCM 11.0 and 5.5 was 48% compared with the three river sites where the relative abundance ranged from 62% (CRM 11.5) to 71% (CRM 15.0). The zooplankton community at station PCM 0.5 near the mouth of Poplar Creek exhibited seasonal shifts in the relative abundance of rotifers that were intermediate between the patterns found at the upstream sites on Poplar Creek and those observed in the Clinch River (Fig. 1.6.3-3). The average relative abundance of this group, for example, was 55%, falling midway between the values for the two nearest sampling stations (PCM 5.5 and CRM 11.5).

With the exception of the peak periods of abundance in early and late summer, the Copepoda, primarily immature stages (nauplii), were generally more abundant than the Cladocera in both the Clinch River (Fig. 1.6.3-4) and Poplar Creek (Fig. 1.6.3-5). In the winter (December and January), cladoceran densities were slightly higher than copepod densities. Like the rotifers, however, neither of these crustacean groups was very abundant during these colder periods of the year. In

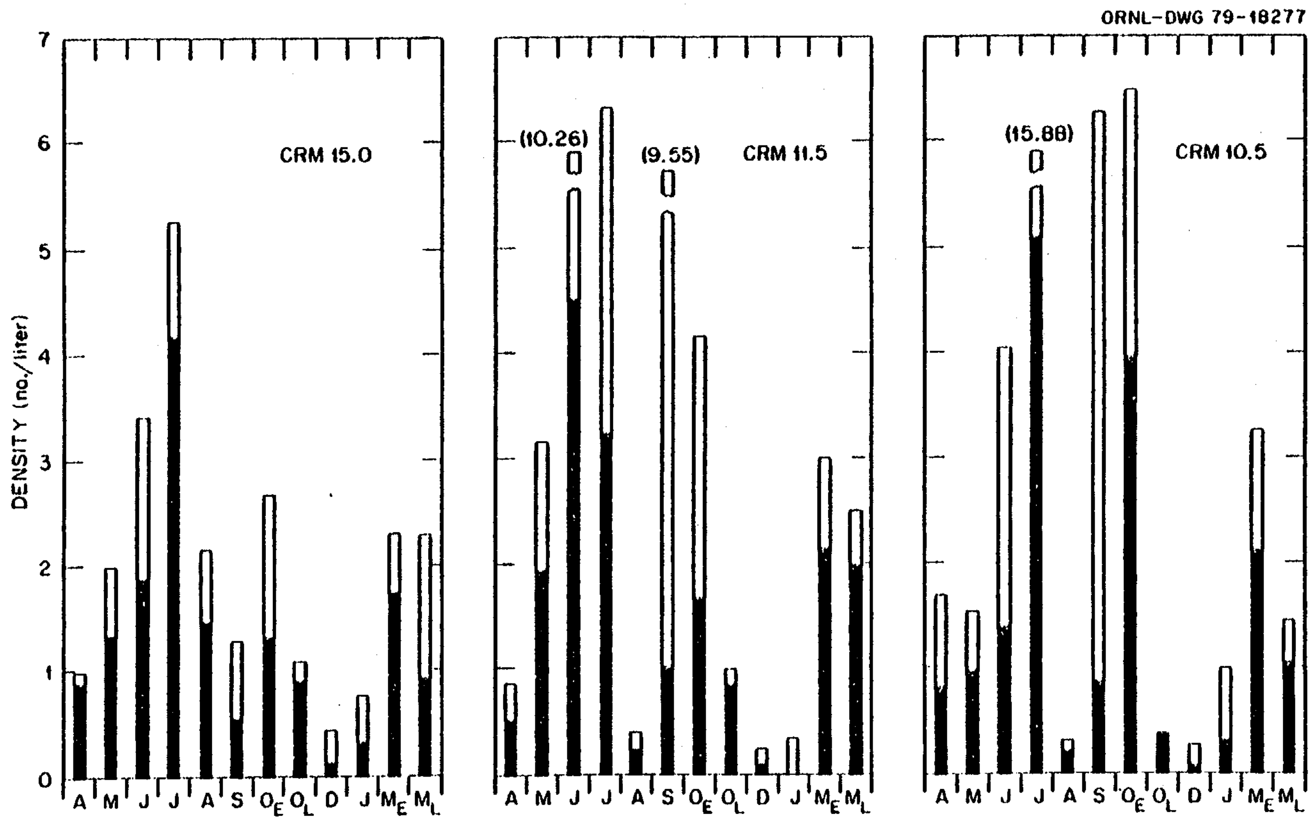

Fig. 1.6.3-4. Densities (no./liter) of copepods (■) and cladocerans (□) at the three ORGDP sampling sites on the Clinch River. O_E/M_E = early October/March; O_L/M_L = late October/March.

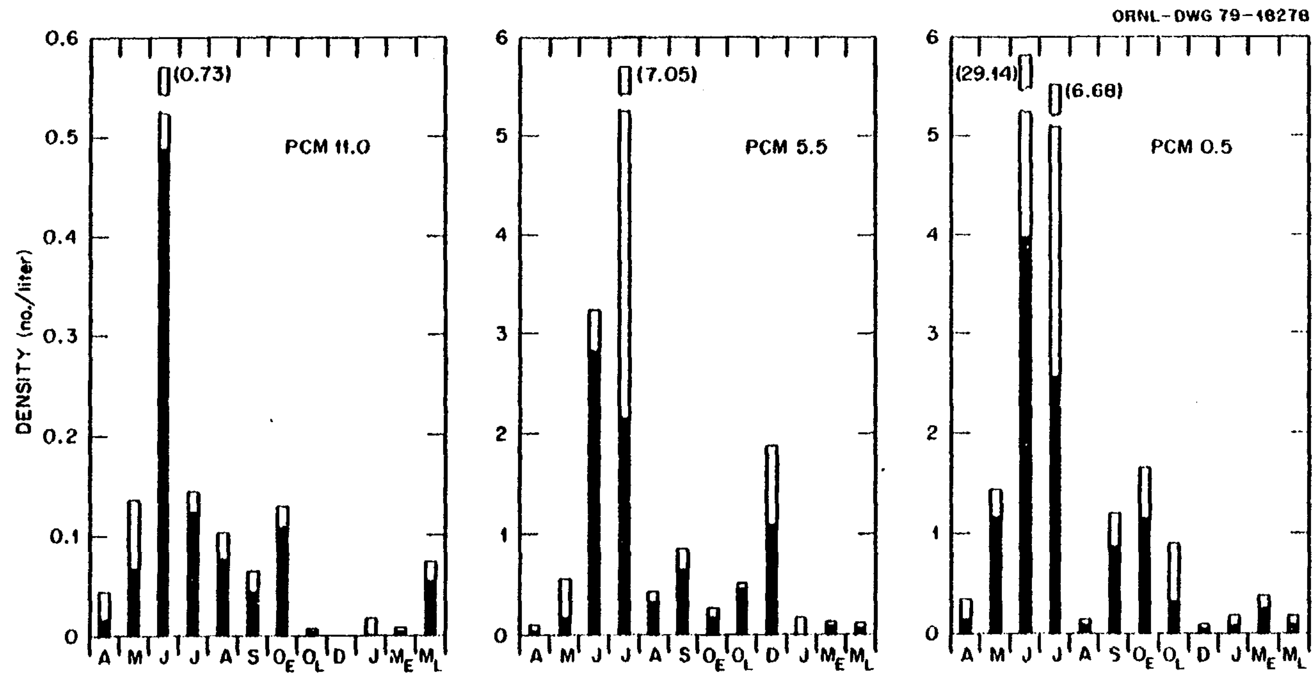

Fig. 1.6.3-5. Densities (no./liter) of copepods (■) and cladocerans (□) at the three ORGDP sampling sites on Poplar Creek, April 1977–March 1978. O_e/M_E = early October/March; O_L/M_L = late October/March.

temperate lakes the general pattern of seasonal succession is comparable between these two groups and, for the most part, the Cladocera have a life history which, in its superficial characters, resembles that of the Rotifera Monogononta (Hutchinson 1957). There are perennial and seasonal species in both groups and differences in their life histories account for the fluctuations in relative abundance that occur in various seasons.

Spatial distribution

Time-weighted densities (TWD) (see Section 1.3.4) were computed for total zooplankton (all taxa combined) and each of the three major taxonomic groups (Rotifera, Copepoda, Cladocera) (Table 1.6.3-3). Total zooplankton TWDs at each of the three Poplar Creek sites were significantly lower ($P < 0.01$) than the TWDs at the three Clinch River sites (Table 1.6.3-4). Although no significant differences were found among the three river sites ($P > 0.20$), the TWDs of total zooplankton at the Poplar Creek sampling sites were significantly different from one another ($P < 0.01$). Identical results were obtained from statistical analyses of rotifer TWDs (Table 1.6.3-5). Because of the high proportion of rotifers in the zooplankton samples (Fig. 1.6.3-3), the differences in total zooplankton TWDs are probably due to differences in rotifer abundance.

The swift-flowing nature of Poplar Creek at station PCM 11.0 and the absence of any backwater areas where zooplankton populations can develop continuously and be recruited, via displacement, to the populations in the creek preclude the establishment of any significant

Table 1.6.3-3. Time-weighted densities (TWD) of zooplankton at the six ORGDP sampling sites. Tabular values are expressed as days × numbers/liter (see Section 1.3.4).

Sampling site	Total (all taxa combined)	Rotifera	Copepoda	Cladocera
PCM 11.0	66.9	35.5	27.3	13.2
PCM 5.5	393.4	278.2	166.0	132.4
PCM 0.5	508.3	422.6	173.8	210.5
CRM 15.0	792.2	712.2	261.8	166.3
CRM 11.5	785.7	701.6	262.7	278.6
CRM 10.5	821.8	730.4	244.6	276.2

Table 1.6.3-4. Pairwise comparisons of time-weighted densities (TWD) of zooplankton (all taxa combined) between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01[b]	<0.01	<0.01	<0.01	<0.01
PCM 5.5			<0.01+[c]	<0.01+	<0.01+	<0.01+
PCM 0.5				<0.01+	<0.01+	<0.01+
CRM 15.0					0.85+	0.39+
CRM 11.5						0.20+
CRM 10.5						

[a] Sampling sites are shown in Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = Standard two-sample Student's t-tests were used. If no superscript, then Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

Table 1.6.3-5. Pairwise comparisons of time-weighted densities (TWD) of Rotifera between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01[b]	<0.01	<0.01	<0.01	<0.01
PCM 5.5			<0.01+[(c)]	<0.01+	<0.01+	<0.01+
PCM 0.5				<0.01+	<0.01+	<0.01+
CRM 15.0					0.76+	0.60+
CRM 11.5						0.37+
CRM 10.5						

[a]Sampling sites are shown in Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = Standard two-sample Student's t-tests were used. If no superscript, then Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

zooplankton community at this site. On the other hand, lower current velocities, higher phytoplankton densities (and, consequently, potentially greater food resources for filter-feeding zooplankton), and recruitment from East Fork Poplar Creek and several holding ponds in the vicinity of ORGDP enhance the production of zooplankton in lower Poplar Creek. Indeed, a consistent (and statistically significant) increase in the TWDs of rotifers, copepods, and cladocerans was observed from PCM 11.0 downstream to PCM 0.5 (Tables 1.6.3-5 through 1.6.3-7). Only the difference in copepod TWDs at stations PCM 5.5 and 0.5 was not statistically significant at the 0.05 level (Table 1.6.3-6).

In contrast to the pattern exhibited in Poplar Creek, TWDs of the three major gorups of zooplankton were, in general, not significantly different among the three Clinch River sites (Tables 1.6.3-5 through 7). The only exception was the significantly lower ($P < 0.01$) cladoceran

Table 1.6.3-6. Pairwise comparisons of time-weighted densities (TWD) of Copepoda between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01[b]	<0.01	<0.01	<0.01	<0.01
PCM 5.5			0.78+[c]	<0.01+	<0.01+	<0.01+
PCM 0.5				<0.01+	<0.01+	<0.01+
CRM 15.0					0.97+	0.44+
CRM 11.5						0.45+
CRM 10.5						

[a]Sampling sites are shown in Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = Standard two-sample Student's t-tests were used. If no superscript, then Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

Table 1.6.3-7. Pairwise comparisons of time-weighted densities (TWD) of Cladocera between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01[b]	<0.01	<0.01	<0.01	<0.01
PCM 5.5			0.05	0.14+[c]	<0.01	<0.01+
PCM 0.5				>0.10	0.09+	0.08+
CRM 15.0					<0.01+	<0.01+
CRM 11.5						0.94+
CRM 10.5						

[a]Sampling sites are shown in Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = Standard two-sample Student's t-tests were used. If no superscript, then Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

densities at CRM 15.0 compared with the two downstream stations (Table 1.6.3-7). Cladoceran densities at PCM 0.5 also exhibited an interesting contrast to the densities observed in the river. Unlike the TWDs of rotifers and copepods, the cladoceran TWD at PCM 0.5 was not significantly different from that found at the three river sites. The presence of relatively high densities of cladocerans, especially the small *Bosmina longirostris*, occurred at a station (PCM 0.5) where high ichthyoplankton densities were found the following year (see Section 1.6.6). The occurrence of relatively large numbers of small cladocerans in lower Poplar Creek could constitute an important food resource for early post-yolk-sac fish larvae. However, in the absence of additional concurrent sampling of zooplankton and ichthyoplankton, apparent spatial and temporal correlations between the two communities may be spurious.

Some aspects of zooplankton population dynamics

The occurrence and composition of the maxima at station PCM 0.5 near the mouth of Poplar Creek and station CRM 11.5 just below the mouth of the creek were similar, and can be distinguished on this basis from the populations at CRM 15.0. At stations PCM 0.5 and CRM 11.5, total zooplankton densities increased from May to a maximum in early June, due primarily to increases in the rotifers *Brachionus* spp. and *Keratella*. During this period densities of *Brachionus* spp. increased from 0.6 to 29.0 organisms/liter at PCM 0.5 and from 1.1 to 42.7 organisms/liter at CRM 11.5. (The increase at station CRM 10.5 was due primarily to an increase in *Keratella*, although the abundance of *Brachionus* spp. and

Polyarthra also increased. At the upriver site (CRM 15.0), Brachionus spp. densities actually decreased from May to June. The increase in total zooplankton density observed at this time was due to Keratella and Polyarthra, and the continued rise in zooplankton density at CRM 15.0 to a peak in mid-July was due to a fivefold increase in the density of Polyarthra.

The presence of a secondary peak in zooplankton abundance in early October at the Clinch River sites can also be attributed to a rise in rotifer abundance, especially Keratella, Asplanchna, and Synchaeta. Although Brachionus spp. densities also increased, the rise in overall abundance was due to a general increase among these three genera. At station PCM 0.5, however, Brachionus spp. increased from 0.2 to 4.4 organisms/liter from mid-August to mid-September, and this rise accounted for the presence of a secondary peak in zooplankton abundance (Fig. 1.6.3-1). In the winter and early spring, the rotifer communities at this site and those in the Clinch River consisted primarily of Synchaeta and Keratella. In late March and April, co-dominants (Synchaeta and Asplanchna) characterized the communities at the four sites.

Although the dynamics of the zooplankton population in the Clinch River and lower Poplar Creek can be examined and, in part, understood on the basis of fluctuations in the abundance of a few rotifer genera, the crustacean component of the communities is no less important. Temporal fluctuations in copepod abundance in Poplar Creek exhibited maxima in June and early October and minima in mid-summer (August) and during the winter and spring (Fig. 1.6.3-5). Similar trends were observed at station PCM 11.5, but spring densities were considerably greater (Fig.

1.6.3-4). Maxima at the upstream and downstream stations on the Clinch River occurred in mid-July. The fall minimum occurred in September at CRM 15.0 and in August at the two downstream sites. Although a secondary peak in copepod abundance occurred in early October at all six sites, the peak (89% nauplii) that occurred at CRM 10.5 was relatively high (Fig. 1.6.3-4). Throughout the study, the majority of the copepods were nauplii at all sites. Spring copepod densities were similar at the three river sites and, at this time of the year, exceeded the cladoceran densities.

With the exception of station CRM 15.0 where copepods generally outnumbered cladocerans throughout most of the year, cladocerans were, numerically, the most important group of crustaceans during the early summer and fall maxima. Maximum cladoceran densities (20.2 organisms/liter) occurred in early June at station PCM 0.5 near the mouth of Poplar Creek (Fig. 1.6.3-5). Similar but smaller peaks were also observed at this time at stations CRM 11.5 and 10.5 (5.7 and 2.7 organisms/liter, respectively). With the exception of station CRM 11.5, the dominant species comprising this peak was the small (0.5-1.0 mm) *Bosmina longirostris* (Edmondson 1959), which, like most cladocerans, is a filter-feeder (Hutchinson 1957). The low densities of *B. longirostris* at station CRM 11.5 seem, in part, correlated with the higher density of *Leptodora kindtii*, a raptorial cladoceran (Table 1.6.3-8). The presence of this predator has been shown to coincide with the loss of younger stages of *Daphnia galesta mendotae*, and it has been suggested that this species may play a significant role in regulating the seasonal occurrence of other species (Hutchinson 1957).

Table 1.6.3-8. Densities (no./liter) and percent abundance (in parentheses) of the dominant cladocerans during the summer and fall maxima at four ORGDP sites on the Clinch River and lower Poplar Creek. Tabular values represent the mean of two replicates. NC = none collected.

	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
June 3-6				
Bosmina longirostris	11.60 (57.5)	1.06 (69.3)	0.30 (5.2)	1.64 (61.9)
Sida crystallina	5.14 (25.5)	0.13 (8.5)	3.92 (68.3)	0.23 (8.7)
Leptodora kindtii	0.23 (1.1)	0.07 (4.6)	0.96 (16.7)	0.07 (2.6)
Cladocerans (total)	20.18	1.53	5.74	2.65
July 12-15				
Bosmina longirostris	0.04 (1.0)	NC	0.10 (3.3)	0.18 (1.7)
Sida crystallina	3.89 (94.4)	0.85 (80.2)	1.96 (64.1)	9.20 (85.4)
Leptodora kindtii	0.19 (4.6)	0.21 (19.8)	0.79 (25.8)	0.42 (3.9)
Cladocerans (total)	4.12	1.06	3.06	10.77
October 4-6				
Bosmina longirostris	0.19 (37.3)	1.24 (91.9)	1.63 (65.7)	2.33 (92.5)
Sida crystallina	0.22 (43.1)	0.04 (3.0)	0.41 (16.5)	NC
Leptodora kindtii	NC	NC	NC	NC
Cladocerans (total)	0.51	1.35	2.48	2.52

Another abundant cladoceran in early June is Sida crystallina, a large (3-4 mm) filter-feeder (Edmondson 1959), but its density does not appear to be well correlated with the densities of other species. Densities of S. crystallina reached a second peak in September at stations CRM 11.5 (7.7 organisms/liter) and CRM 10.5 (4.5 organisms/liter) where it comprised 90 and 83% of the cladocerans at those sites, respectively. From September to October, the density of S. crystallina declined while the abundance of B. longirostris increased slightly. The absence of L. kindtii in the fall is consistent with the observation that this species is monacmic, usually with a maximum in the summer (Hutchison 1957). Both the low densities of cladocerans following the early summer maxima and the absence of a secondary peak in the fall at station PCM 0.5 may be related to relatively heavy grazing by larval and juvenile fishes. In 1978, maximum densities of ichthyoplankton occurred in May and June at this site (Fig. 1.6.6-5). It has been postulated that variation in predation by fishes could produce an effect on species such as _Daphnia_ (i.e., the occurrence of summer minima) similar to that observed with _L. kindtii_ (Hutchinson 1957).

In addition to predation and competition between species, the seasonal succession of zooplankton and the occurrence of maxima can be associated with fluctuations in the composition and abundance of food resources (e.g., phytoplankton). Coincident with the increase in zooplankton to a maximum in early June at stations PCM 0.5 and CRM 11.5 was an increase in green algae. Maximum densities of greens occurred in early June at station PCM 0.5 (5600 units/ml), CRM 11.5 (7600 units/ml) and CRM 10.5 (1850 units/ml). Densities at this time were less than 500 units/ml at stations PCM 5.5 and CRM 15.0. This bloom in green algae was due primarily to the unicellular flagellates, _Carteria_ and _Chlamydomonas_. A second peak of the same magnitude occurred at station CRM 10.5 in mid-July and may, in part, account for the delayed decline in zooplankton there. For example, zooplankton densities at CRM 11.5 and PCM 0.5 fell following the peak in early June, but the decrease at station CRM 10.5 did not occur until after mid-July (Fig. 1.6.3-2).

Because cryptomonads are a significant component of the nannoplankton in lakes and the total planktonic rotifer population has been shown to follow that of the nannoplankton (Hutchinson 1957), it is possible that the rise in the rotifer populations in the summer is causally linked to the population dynamics of cryptophytes in the study area. For example, at station PCM 5.5, the Cryptophyta reached a maximum density of 2600 cells/ml in mid-July. Densities during other times of the year were generally less than 400 cells/ml. This peak coincided with a substantial increase in the rotifer *Conochilus* from early to mid-July of 0.1 to 16.1 organisms/liter. A species identified from the study area, *Conochilus unicornis*, has been found to ingest food that is less than 10 μm in diameter. This indirect evidence suggests that fluctuations in the abundance of some rotifer species could occur in response to changes in the availability of food resources.

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1.6.4 Benthic Macroinvertebrates (A. M. Sasson)

Current ecological theory maintains that environment-benthic macroinvertebrate interactions produce different community structures which reflect the quality of a given habitat (Cairns 1974, Wilhm and Dorris 1968). Thus, a meaningful approach to the assessment of the quality of a water body may be achieved through the evaluation of its benthic communities. Such an assessment may be considerably more informative than a method which relies solely on physical and chemical analyses. The complex interactions of many variables may affect the populations in ways that could not be predicted from data on individual water quality parameters alone; synergistic effects, such as those related to combinations of temperature, pH and ammonia, may be of greater magnitude than individual stresses (U.S. Environmental Protection Agency 1976). The habitat preferences, relatively long life spans, and low motility of benthic macroinvertebrates subject them to effects from all substances in the aquatic environment.

Man's creation of reservoir systems has been one of the major influences on the structure of benthic macroinvertebrate communities, including those near ORGDP. Reservoirs in the Tennessee Valley have altered benthic communities through such processes as siltation, water-level fluctuations, current deprivation, retention of organics, loss of fish-host associations and the introduction of exotic species (Baxter 1977, Chutter 1969, Isom 1971). The impoundment of the lower Clinch River by the construction of Watts Bar Reservoir on the Tennessee River and Melton Hill Reservoir on the Clinch River has undoubtedly been a major factor influencing the structure of the macroinvertebrate communities currently found in the vicinity of ORGDP.

Review of previous studies

The combination of reservoir influences and many other factors has produced distinct macroinvertebrate communities in the vicinity of ORGDP. Recent studies of the lower Clinch River in Watts Bar Reservoir have described low to moderately diverse benthic communities. Twenty-three taxa were collected between CRM 1.4 and 3.9 during a study conducted in 1973 by the Tennessee Valley Authority (Brooks 1978). A 1974-75 preoperational aquatic survey conducted between CRM 15.0 and 18.0 in the vicinity of the proposed site of the Clinch River Breeder Reactor resulted in the collection of 82 taxa (Project Management Corporation 1975). Additional sampling was performed the following year as part of the preoperational aquatic survey for the Exxon Nuclear Fuel Recovery and Recycling Center (Exxon Nuclear Co., Inc. 1976). Collections made from May 1975 through April 1976 between CRM 12.0 and 15.0 yielded 107 taxa.

The benthic macroinvertebrate communities in the vicinity of ORGDP were sampled on seven dates between April 1977 and March 1978. In comparison to the results of the above surveys, 43 taxa were collected from the three sites in the Clinch River between CRM 10.5 and 15.0, whereas 54 taxa were collected from three sites in Poplar Creek (see Fig. 1.2-1 for locations of the six sampling stations). A total of 67 taxa were identified from the entire study area. Differences in the number of taxa collected in these four studies may be attributed to variations in sampling frequency, methodology, and sites.

Temporal and spatial patterns in density

Temporal patterns in benthic macroinvertebrate density were observed during the sampling period. In general, densities in the study area increased from April through September but declined to relatively low levels in October (Table 1.6.4-1). In Poplar Creek, the highest density (1997 organisms/m^2) occurred in June at PCM 11.0, while the lowest density (72 organisms/m^2) was found in December at PCM 5.5. The magnitude of the difference between maximum and minimum densities in the Clinch River was similar to that found in the creek. Densities ranged from 1293 organisms/m^2 at station CRM 11.5 in September to 29 organisms/m^2 at CRM 10.5 in March.

High densities in the summer can be attributed to increases in the chironomid populations, while the peak densities observed in late summer (September) were the result of growth and maturation of oligochaetes and mollusks, primarily Corbicula manilensis. Benthic densities observed at station CRM 15.0 were consistently higher than the densities found during the 1974-75 CRBR survey (Project Management Corporation 1975, Table 2.7-73), but were lower than those observed in the NFRRC survey conducted in the same region of the Clinch River in 1975-76 (Exxon Nuclear Company, Inc. 1976, Table 2.7-12).

The spatial distribution of benthic macroinvertebrates in the study area was examined by statistical comparisons of the time-weighted densities (TWD) (see Section 1.3.4) of various groups (see Table 1.6.4-2)

Table 1.6.4-1. Densities of benthic macroinvertebrates (no. of organisms/m^2) at the six ORGDP sampling sites,[a] April 1977 — March 1978

	Poplar Creek Mile (PCM)			Clinch River Mile (CRM)		
	11.0	5.5	0.5	15.0	11.5	10.5
April 1977	115	402	848	216	259	316
June	1997	503	790	1049	1063	374
August	1537	632	919	575	948	632
September	1192	1121	1365	1121	1293	704
October	302	560	388	201	445	345
December	604	72	733	876	977	488
March 1978	244	201	632	1192	603	29
MEAN	856	499	811	747	798	412

[a]Sampling sites are shown in Fig. 1.2-1.

Table 1.6.4-2. Time-weighted densities (TWD) of benthic macroinvertebrates at the six ORGDP sampling sites. Tabular values are expressed as days × numbers/m^2 (see Section 1.3.4).

Sampling site	Total (all taxa combined)	Chironomidae	Oligochaeta	*Corbicula manilensis*
PCM 11.0	1261	694	615	400
PCM 5.5	921	587	520	13
PCM 0.5	1377	707	706	34
CRM 15.0	1176	507	613	501
CRM 11.5	1332	541	851	281
CRM 10.5	892	206	494	349

at the six sampling sites. Between-station comparisons of TWDs (all taxa combined) indicated that the density of benthic macroinvertebrates at station PCM 5.5 was significantly lower than the density at PCM 11.0 ($P \leq 0.03$) and PCM 0.5 ($P \leq 0.01$). In the Clinch River, the density at CRM 10.5 was not significantly different from the density at the control station, CRM 15.0 ($P > 0.10$), but was lower than that observed just upstream ($P < 0.01$) (Table 1.6.4-3). The low density of organisms at CRM 10.5 was due primarily to a paucity of chironomid larvae. Results of statistical comparisons of the density of chironomids between the three river sites were similar to those for total organisms (Table 1.6.4-4). The other co-dominant of the benthic macroinvertebrate communities near ORGDP is the Oligochaeta, and the spatial distribution was similar to that described for the Chironomidae (Table 1.6.4-5). Neither the oligochaete or chironomid densities differed significantly among the three Poplar Creek sites.

Taxonomic composition

Four phyla were collected from the six stations that defined the ORGDP study area. Representatives of the phyla Arthropoda and Annelida comprised 47 and 38%, respectively, of the total number of organisms collected from April 1977 to March 1978. The remainder of the benthic macroinvertebrates collected in the study area belonged to the phyla Mollusca (15%) and Nematoda (<1%). Oligochaetes (Annelida) were the dominant taxa, numerically, at the Clinch River sites (45% of the benthos), while dipterans constituted 26% of the organisms collected (Table 1.6.4-6). An opposite pattern was found in Poplar Creek with

Table 1.6.4-3. Pairwise comparisons of time-weighted densities (TWD) of benthic macroinvertebrates (all taxa combined) between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		0.03^{+}[b,c]	0.40^{+}	0.67^{+}	0.66^{+}	0.02^{+}
PCM 5.5			<0.01^{+}	>0.10	0.01^{+}	0.83^{+}
PCM 0.5				>0.10	0.75^{+}	<0.01^{+}
CRM 15.0					0.44^{+}	>0.10
CRM 11.5						<0.01^{+}
CRM 10.5						

[a]Sampling sites are shown on Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

Table 1.6.4-4. Pairwise comparisons of time-weighted densities (TWD) of Chironomidae between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		0.46^{+}[b,c]	>0.10	0.36^{+}	0.31^{+}	<0.01^{+}
PCM 5.5			0.22^{+}	>0.10	0.71^{+}	<0.01^{+}
PCM 0.5				>0.10	>0.10	0.01
CRM 15.0					>0.10	0.14^{+}
CRM 11.5						0.02^{+}
CRM 10.5						

[a]Sampling sites are shown on Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

Table 1.6.4-5. Pairwise comparisons of time-weighted densities (TWD) of Oligochaeta between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		$0.44^{+(b,c)}$	0.48^{+}	0.99^{+}	0.14^{+}	0.39^{+}
PCM 5.5			0.11^{+}	>0.10	0.03^{+}	0.84^{+}
PCM 0.5				>0.10	0.33^{+}	0.11^{+}
CRM 15.0					0.19^{+}	0.48^{+}
CRM 11.5						0.03^{+}
CRM 10.5						

[a]Sampling sites are shown on Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

dipterans and oligochaetes representing 50 and 31% of the benthic fauna, respectively. Pronounced differences in relative abundance were found between some sampling sites. For example, dipterans, primarily members of the family Chironomidae, comprised nearly 56% of the benthos at station PCM 5.5 but only 17% of the benthos at station CRM 10.5. If *Corbicula* are not considered, these differences are much more pronounced.

In the Clinch River, dipteran larvae, primarily those in the family Chironomidae (aquatic midges), attained peak densities in July, while in Poplar Creek densities remained relatively high through September. This family was the most diverse in the study area, with 22 genera represented. (Appendix C). The most common genera were *Procladius* (9% of all organisms collected), *Polypedilum* (6%), *Cryptochironomus* (4%), and *Tribelos* (3%). At two of the three Poplar Creek sites (PCM 5.5 and

Table 1.6.4-6. Relative abundance (%) of benthic macroinvertebrates at the six ORGDP sampling sites.[a] Values were calculated from samples collected on seven sampling dates between April 1977 and March 1978.

Taxon	Poplar Creek Mile (PCM)			Clinch River Mile (CRM)		
	11.0	5.5	0.5	15.0	11.5	10.5
DIPTERA (total)	46.6	56.4	46.7	33.3	26.8	17.3
Chironomidae	43.3	54.4	31.2	32.5	22.3	16.3
Ceratopogonidae	2.6	0.4	2.8	0.5	2.4	
Chaoborus punctipennis		1.2	12.7	0.3	2.1	1.0
Others	0.7	0.4				
OLIGOCHAETA (total)	26.4	32.5	34.8	38.7	51.3	44.6
Tubificidae	25.4	31.3	34.2	37.3	50.5	43.6
Others	1.0	1.2	0.6	1.4	0.8	1.0
PELECYPODA (total)	20.6	3.7	4.1	26.5	9.4	29.7
Corbicula manilensis	20.1	0.4	0.5	26.2	8.8	28.7
Others	0.5	3.3	3.6	0.3	0.6	1.0
EPHEMEROPTERA (total)	1.7	3.3	13.2	0.6	8.7	6.4
Hexagenia limbata		3.3	13.2	0.3	8.7	6.4
Others	1.7			0.3		
COLEOPTERA (total)	2.2	2.5	0.3		0.8	0.5
Dubiraphia	2.2	2.5	0.3		0.5	0.5
Others					0.3	
TRICOPTERA	0.2	0.4		0.6	0.3	1.0
AMPHIPODA					1.5	
OTHERS[b]	2.3	1.2	0.9	0.3	1.2	0.5

[a]Sampling sites are shown in Fig. 1.2-1.

[b]Includes the following orders: Gastropoda, Hydracarina, Isopoda, Megaloptera, Nematoda, Odonata.

0.5), Procladius was the most abundant taxon collected, comprising 39 and 15% of the individuals collected at these two stations, respectively. Chironomid larvae belonging to many genera are common in the diet of bottom-feeding fishes, such as carp and smallmouth buffalo, in the Clinch River (Project Management Corporation 1975, Section 2.7.2.4.9).

Typical communities of chironomids usually contain species of many functional groups, and a lake or stream may yield more than 100 species (Coffman 1978, Cummins 1973). The environmental requirements of many species have been used as a basis for selecting these species as "indicators" of water quality (Beck 1977, Paine and Gaufin 1956, Weber 1973). To improve the applicability of such a system, however, several investigators have recognized the need for more definitive and detailed ecological and taxonomic studies (Oliver 1971, Resh and Unzicker 1975), since two species of the same genus may have significantly different tolerance limits for a particular parameter.

Larvae of the dipteran Chaoborus punctipennis (Culicidae) were especially abundant at PCM 0.5. This species normally occupies lentic habitats but may be found in stream reaches of reduced current. Chaoborus is a common component of the diet of white bass and skipjack herring in this region of the river (Project Management Corporation 1975).

Another common order of arthropods found near ORGDP was the Ephemeroptera (mayflies). Hexagenia limbata, the most abundant ephemeropteran, was most numerous near the mouth of Poplar Creek (PCM 0.5) and in the Clinch River (CRM 11.5) just below the mouth of the creek. This species accounted for approximately 5% of the benthic macroinvertebrates collected during the study and was relatively common at all sampling sites except PCM 11.0. Species of this genus prefer fine adhesive substrates and usually do not inhabit sand or gravel bottoms (Edmunds et al. 1976, Eriksen 1964, Lyman 1943). This habitat requirement may explain its absence in the samples collected at station PCM 11.0 where the substrate consisted primarily of large boulders, gravel, and coal fragments. These species often flourish in reservoir systems (Swanson 1967), and commonly provide a source of food for fishes such as white bass, skipjack herring, freshwater drum, and catfish (Project Management Corporation 1975, Klaassen and Marzolf 1971). Hexagenia was especially abundant at PCM 0.5 and may constitute a large portion of the fish diet in lower Poplar Creek.

Representatives of the order Oligochaeta (aquatic earthworms), primarily species of the family Tubificidae, were common at all six sampling sites throughout the year. Tubificids were the most numerous taxonomic group at PCM 0.5 and all three Clinch River stations (Appendix C). A widely distributed introduced species, Branchiura sowerbyi, was especially abundant at the two upstream stations on Poplar Creek (PCM 5.5 and 11.0) and in the Clinch River at station CRM 11.5. Sexually immature tubificids and species of the genus Limnodrilus were also abundant at all sampling stations. The Limnodrilus species identified in the present study have been described as the most tolerant to organic pollution of the species in this genus (Aston 1973). L. hoffmeisteri has been described as being very adaptable to varied environmental conditions, and distinctly different habitat preferences among congeners have not been recognized (Kennedy 1965, 1966).

Six members of the phylum Mollusca were identified from the ORGDP study area, including Corbicula manilensis (Asiatic clam), Sphaerium, Anodonta, Ferrissia, Physa, and Gyraulus. Recent studies of the lower Clinch River have identified a total of 19 mollusk species, 12 of which belong to the family Unionidae (Brooks 1978, Project Management Corporation 1975, Exxon Nuclear Company, Inc. 1976, Van der Schalie and Burch 1961). As a whole, the Clinch River system supports an abundant mollusk fauna, including about 60 species of freshwater mussels. The existence of these species currently represents the greatest diversity of surviving mussels in the Southern Appalachian-Cumberland Plateau region of the southeastern United States (Stansberry 1973). The construction of reservoirs in the Tennessee Valley, however, appears to be limiting the distribution of many species of the families Unionidae and Sphaeridae (Isom 1969). Although several endangered species inhabit the Clinch River system (U.S. Department of Interior 1976, Stansberry 1973), none have recently been recorded from the lower region of the river (Project Management Corporation 1975, Table 2.7-71; Exxon Nuclear Co., Inc. 1976, Table 2.7-10*). No species listed as threatened or endangered by the State of Tennessee (Tennessee Wildlife Resources Commission 1975) or the U.S. Department of Interior (1980) was collected in the ORGDP survey.

*The species list in Table 2.7-10 includes a taxon identified as 'cf. Fusconaia sp.'. Two species belonging to this genus (F. cuneolus and F. edgariana) are listed as endangered (Tennessee Wildlife Resources Commission 1975, U.S. Department of Interior 1980).

The Pelecypoda were most abundant in the late summer and early fall with peak densities occurring in September. Clam densities in the study area declined to very low levels in winter and early spring, possibly due to winter mortality and loss to predators. One species, the Asiatic clam Corbicula manilensis, which comprised more than 90% of all clams collected, was the most abundant organism in the ORGDP study area. Numerically, it was the dominant organism throughout most of the year in the samples collected at the upstream station on Poplar Creek (PCM 11.0) and at all three Clinch River sites. However, the time-weighted densities of C. manilensis at both PCM 5.5 and 0.5 were approximately an order of magnitude lower than the densities in the Clinch River or upper Poplar Creek (Table 1.6.4-2), a difference that was significant at the 0.02 level (Table 1.6.4-7).

Table 1.6.4-7. Pairwise comparisons of time-weighted densities (TWD) of Corbicula manilensis between the six ORGDP sampling sites

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0	CRM 11.5	CRM 10.5
PCM 11.0		<0.01+[(b,c)]	<0.01+	0.35+	0.24+	0.53+
PCM 5.5			0.76+	<0.01+	0.02+	<0.01+
PCM 0.5				<0.01+	0.02+	<0.01+
CRM 15.0					0.07+	>0.10
CRM 11.5						0.46+
CRM 10.5						

[a]Sampling sites are shown on Fig. 1.2-1.

[b]Critical probability values of two-sided tests for equality of time-weighted densities.

[c]+ = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

The Asiatic clam is a species introduced from the Orient and was reported to have been distributed over much of the Tennessee Valley region as early as 1959 (Sinclair and Isom 1963, Sinclair and Ingram 1961). By 1963, the species had established itself in the upper Tennessee River (Sinclair 1963). The species was not found in samples collected from the Clinch river at CRM 15 in 1961 (Van der Schalie and Burch 1961), but has obviously proliferated widely in the area since that time and has recently been found in great abundance in the lower portions of the river between CRM 18.0 and 1.4 (Brooks 1978, Exxon Nuclear Company, Inc. 1976, Project Management Corporation 1975). In terms of both numbers and biomass, *Corbicula manilensis* dominated the benthic fauna in this region of the river. The rapid dispersion and establishment of the Asiatic clam is due both to its adaptability to environmental conditions and the magnitude and intensity of its spawning. The species has been very successful in many Tennessee Valley impoundments and is widely recognized as a problem at water intake structures (Sinclair 1964). Juvenile and adult *C. manilensis* often serve as food for catfishes, sunfishes, freshwater drum, and various mammals that feed along the shoreline of creeks and rivers (Sinclair and Isom 1963). They have been reported to be quite common in the diet of carp and smallmouth buffalo in the Clinch River (Project Management Corporation 1975). The Asiatic clam has undoubtedly assumed an ecological role similar to that formerly held by the many mollusks displaced by impoundments.

Measures of community structure

The number of taxa provides a simple, practical, and objective measure of species richness, a component of community structure (Peet 1974). The highest number of taxa (41) was found at the upstream station on Poplar Creek (PCM 11.0), while the lowest number (25) was collected in the Clinch River at CRM 10.5 (Table 1.6.4-8). In general, variability in the total number of taxa collected at the six ORGDP sampling sites could be attributed to the number of chironomid genera found at a given site. For example, 18 of the 22 genera in the family Chironomidae collected in the present survey were present at PCM 11.0, but only seven general were found at CRM 10.5 (Appendix C).

The Shannon index of diversity (H') provides another measure of community structure which takes into account not only the number of species in the community (species richness) but also the abundance and distribution of individuals among species (equitability). Diversity is computed according to the following formula (Shannon and Weaver 1949):

$$H' = -\sum_{i} \frac{n_i}{N} \log_e \frac{n_i}{N}$$

where n_i is the number of individuals of taxon i and N is the total number of individuals in a sample. Higher diversity values are considered to be characteristic of mature communities occupying habitats of a favorable and/or varied nature (Zand 1976).

Species diversity at the ORGDP sites varied between sampling dates but was generally low at most stations (Table 1.6.4-8). In Poplar Creek, values of H' ranged from 0.44 to 2.06 at PCM 11.0, while H' at

Table 1.6.4-8. Species diversity (H') and total number of benthic macroinvertebrate taxa (T) found at the six ORGDP sampling sites.[a] Monthly diversity values represent the mean of three samples collected at each site; total H' was calculated by pooling all samples (21) collected at a given site

		Poplar Creek mile (PCM)			Clinch River mile (CRM)		
		11.0	5.5	0.5	15.0	11.5	10.5
April 1977	(H')	0.44	1.33	1.76	0.75	1.73	1.35
	(T)	4	16	14	4	12	10
June	(H')	2.06	1.48	1.81	0.67	1.65	0.45
	(T)	27	11	15	10	13	7
August	(H')	1.61	0.85	1.93	1.47	1.40	1.27
	(T)	18	7	13	11	14	12
September	(H')	1.69	1.33	1.65	1.15	1.55	0.74
	(T)	16	15	12	16	13	7
October	(H')	1.12	1.76	1.42	0.82	0.89	1.00
	(T)	5	16	12	7	7	7
December	(H')	1.21	1.05	1.77	1.08	1.32	0.59
	(T)	8	3	17	11	10	5
March 1978	(H')	0.77	1.64	1.67	1.30	1.97	0.69
	(T)	5	9	13	15	16	2
Total	(H')	2.72	2.52	2.69	2.46	2.56	2.10
	(T)	41	38	31	32	36	25

[a]Sampling sites are shown in Fig. 1.2-1.

the Clinch River sites ranged from 0.46 (CRM 10.5) to 1.96 (CRM 11.5). An H' value greater than 1.80 may be considered to represent a community in a "clean or recovering stream" (Godfrey 1978, Wilhm 1970). Low substrate diversity in the Clinch River has been suggested as a possible explanation for the absence of highly diverse communities in the stream both above and below Melton Hill Dam (Dahlman et al. 1977). A similar explanation might be applied to the lower reach of Poplar Creek. During the ORGDP survey, diversity tended to remain relatively high throughout the year at stations PCM 0.5 and CRM 11.5. Obvious differences in diversity between adjacent stations were not consistently evident throughout the year, although values at CRM 11.5 did show some tendency to be higher than those at CRM 10.5.

Statistical comparisons of diversity between sampling sites were not made. Small sample size and high variability among samples collected at a given site may have obscured some differences between sites. Comparisons with previous studies on the Clinch River were not possible due to the lack of information on the categorization of taxa in the computation of diversity values (e.g., the classification of groups of immature tubificids). In addition, these studies did not specify the logarithm base used ($\log_e$, $\log_{10}$, $\log_2$) in the computation of H'.

Organism-substrate relationships

Organism-substrate relationships are an important factor influencing the density, diversity, and distribution of benthic macroinvertebrates. Because current velocity largely determines substrate size and composition, it also indirectly controls benthic community structure. The relationship between benthic macroinvertebrate distribution and the nature of the substrate may be either direct or indirect, with substrate particle size being a major determinant (Hynes 1970, Rabeni and Minshall 1977).

In many streams, a more diverse substrate (in terms of the size range of the particles) may be created in an erosional environment. Such a habitat may in turn support a more diverse fauna than a depositional environment (Minshall and Minshall 1977). Reservoir systems such as the Clinch River present a major contrast to the free-flowing upper reaches of Poplar Creek. Channel areas are frequently scoured in the

Clinch River while nearby areas may undergo substantial deposition. The depositional nature of the Clinch River near its mouth might be used to explain the low diversity of the benthic fauna in this region (Brooks 1978).

Qualitative analysis of the substrate found in the ORGDP Ponar grab samples suggests that the Poplar Creek sites, in general, had coarser substrates (gravel and sand with some clay) than the Clinch River sites. Samples collected at station PCM 11.0 frequently contained gravel and coal fragments, the latter being much less prominent in samples collected at the downstream Poplar Creek sites. The substrate at the Clinch River sites, on the other hand, consisted primarily of silt, clay, and detritus, although gravel was found in samples collected at station CRM 10.5 during the summer. It should be noted that sampling at these sites was limited to those regions of the river that, for the most part, were outside the channel area where scouring occurs due to periodically high current velocities. No grab samples could be taken from the surface of the exposed bedrock in these channel regions of the river.

While no quantitative comparisons of the substrates at ORGDP study sites were made, results from the NFRRC survey indicated that the substrate near CRM 12.0 and 15.0 was similar. More than 70% of the substrate at these two stations consisted of fine sand or smaller particles (Exxon Nuclear Company, Inc. 1976, Table 2.7-13). In studies conducted during the CRBR preoperational aquatic survey, the benthic community in the Clinch River from CRM 18.0 downstream to CRM 15.0 was found to be related to the type of substratum present. For example, Limnodrilus (Oligochaeta:Tubificidae) was abundant in substrates consisting of fine sand. In relatively coarse substrates, the clam *Corbicula manilensis* (Pelecypoda:Corbiculidae) exhibited the highest densities, while chironomid larvae were common in both gravel and fine sand (Project Management Corporation 1975).

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1.6.5 Fishes (J. M. Loar)

Another important component of aquatic ecosystems is the vertebrate fauna, primarily fishes. Fish communities are comprised of species that represent several trophic levels, from primary to tertiary consumers or top carnivores. Many important sport fishes, for example, are at or near the end of food chains that ultimately lead to man. Because some toxic substances can become concentrated in biota at higher trophic levels, a process commonly referred to as bioaccumulation, these toxicants could accumulate in those species that constitute a significant resource for man. In addition, fishes are dependent upon organisms in lower tropic levels for food, so the well-being of local fish populations is often used as an index to water quality (Greenson et al. 1977).

Field sampling by gill netting and electroshocking was conducted from April 1977 to March 1978. The purpose of this survey was to provide information on the species composition, relative abundance, and distribution of the fish populations in the vicinity of ORGDP.

Review of previous studies

Since 1960, at least 10 fishery surveys have been conducted in various regions of the Clinch River, including Melton Hill and Watts Bar Reservoirs. Initial studies were performed in 1960-62 prior to the completion of Melton Hill Dam (CRM 23.1), and provide the only known source of information on pre-impoundment fish populations inhabiting the Clinch River above the dam site (Fitz 1968). Numerous post-impoundment surveys followed these initial efforts. Thus, the data collected in these various sampling programs provide both a historical perspective as well as a detailed description of the fish populations currently inhabiting this region of the river.

In order to summarize the data in the most meaningful yet concise manner, results of these surveys have been reduced to an expression of relative abundance for three major categories: game, rough, and forage fishes. The species comprising each of the three categories were similar among the various surveys. The families Centrarchidae, Percichthyidae, and Percidae (yellow perch, sauger, walleye only) were considered game species; the families Catostomidae, Hiodontidae, Ictaluridae, Sciaenidae, Polyodontidae, Lepisosteidae, Clupeidae (skipjack herring only), and Cyprinidae (carp only) were considered rough species; and species in the families Atherinidae, Cottidae, Poecillidae, Cyprinidae, and Clupeidae were categorized as forage species.

This method of data reduction and summarization was chosen for several reasons. First, these categories generally parallel the major trophic levels found in the community. For example, the most abundant forage species are threadfin shad and gizzard shad, both of which are primarily planktivores. Many of the rough fishes are bottom-feeders that could be classified as either omnivores or detritivores, while game fishes are carnivores, many of which (e.g., white bass, sauger, largemouth bass, white crappie), as adults, feed primarily on fish. Second, in some surveys, the results were only presented on the basis of these three categories. Third, because of differences in the way in which a given type of sampling gear was deployed (e.g., gill nets set perpendicular vs parallel to the shoreline) as well as the variability in sampling frequency, sampling sites, and collection dates, comparisons of species abundance between surveys that employed the same gear are difficult, if not impossible, for all but only the most common species. Crandall et al. (1978) compared the composition and abundance of fishes taken by gill-netting and cove rotenone sampling and found the dominance of major species was reflected in both types of collections. In addition, direct comparisons of the results obtained with different gear types are not possible due to the selectivity of the gear for various kinds of fishes. Electrofishing is less effective in collecting bottom-feeding species, such as catfishes, than is gill-netting, since the fish, when stunned by the electric field, usually remain near the bottom and are not collected. Gill-netting, on the other hand, has been shown to be ineffective in collecting centrarchids (Crandall et al. 1978). Also, due to their selectivity, gill nets cannot be used for comparing the true relative abundance between species (Fitz 1968). A major difficulty encountered with cove rotenone sampling is that schooling and pelagic species may not be present in proportion to their actual abundance at the time of sampling (Crandall et al. 1978), a problem that could largely be overcome by increasing the number of coves that are sampled.

Because of gear selectivity, results obtained with a variety of sampling gears will provide the most reliable estimates of species composition and relative abundance. Gill nets in combination with cove rotenone sampling have been shown to provide good estimates of the relative order of abundance of major fish species in reservoirs (Crandall et al. 1978), and similar satisfactory results have been obtained from gill-net and electroshocking collections (Bennett and

Brown 1969). Gill-netting was the most common method used in previous surveys of the Clinch River fisheries, but electroshocking and cove rotenone sampling were also employed, either alone or in combination with gill-netting. If the results from these previous surveys are combined with the information obtained during the present fish sampling program, a more accurate characterization of the fish community in the vicinity of ORGDP can be obtained.

Comparison of pre- and post-impoundment surveys

Historically, the fish community inhabiting the lower Clinch River was probably dominated primarily by gizzard shad and various rough fishes (Fitz 1968). After completion of the Melton Hill Dam (gates were closed on May 1, 1963), the relative abundance of rough fish in the 70-km-long impoundment created by the dam declined, whereas the proportion of game fish increased (Table 1.6.5-1). The average rough fish:game fish ratio (R/G) based on catch-per-unit-effort (number of fish collected per gill-net day) was 30.5 and 8.2 in pre- and post-impoundment gill-net surveys, respectively. The R/G ratios were calculated from data collected on similar dates at the same stations in 1960-61 and 1963-64 (Fitz 1968). An estimate of R/G based on a 1974 cove rotenone survey in Melton Hill Reservoir was 1.6, but in two other local reservoirs the R/G ratio was <1; i.e., the relative abundance of game fishes exceeded that of rough fishes (Table 1.6.5-2). Rotenone sampling of 10 coves in Watts Bar and Norris Reservoirs resulted in average R/G ratios of 0.23 and 0.07, respectively.

Table 1.6.5-1. Relative abundance (%), based on number collected, of game, rough, and forage fishes found in surveys conducted by TVA before and after completion of the Melton Hill Dam at CRM 23.1. Percent of the total fish collected that were threadfin shad is given in parentheses
Source: Fitz (1968)

Sampling date(s)[a]	No. of sampling stations	Location (CRM)	Method of sampling	Relative abundance (%)		
				Game	Rough	Forage
Pre-impoundment						
11 (1960)	4	23.1-62.5	Gill nets	5	82	13 (0.8)
1,2,6,10,12 (1961)						
6 (1962)						
N/A[b]	1	~61.0	Cove rotenone	2	25	74 (0)
Post-impoundment						
11 (1963)	4	23.1-62.5	Gill nets	14	77	9 (0.6)
2,5,8,10 (1964)						
10 (1964)	2	23.8, 40.0	Cove rotenone	3	1	96 (78.3)

[a] Numbers refer to months (1 = January ... 12 = December).

[b] Specific dates not given; sampling probably conducted in 1961 or 1962.

Table 1.6.5-2. Relative abundance (%), based on number collected, of game, rough, and forage fishes in cove rotenone surveys conducted by TVA in Melton Hill (TVA 1976a), Watts Bar (TVA 1976b), and Norris Reservoirs (TVA 1976c). Percent of the total fish collected that were threadfin shad is given in parentheses.

Sampling date(s)	No. of coves sampled	Location	Relative abundance (%)		
			Game	Rough	Forage
Melton Hill Reservoir (1974)					
June 25-26	1	CRM 23.8	20	11	69
June 18-July 12	6	CRM 23.8-40.0	11	19	70 (4.3)
Watts Bar Reservoir (1973)					
July 24	1	CRM 4.9	31	15	54
July 24-August 16	10[a]	TRM 533.0-575.6[b]	22	5	73 (55.7)
Norris Reservoir (1975)					
September 2-October 1	10	CRM 80.1-116.3 PRM 1.3-26.2[c]	16	1	83 (51.5)

[a]Includes station CRM 4.9.

[b]TRM = Tennessee River Mile; TRM 0.0 is located at the mouth of river.

[c]PRM = Powell River Mile; PRM 0.0 is located at the confluence with the Clinch River.

In both the Watts Bar and Norris surveys, the majority of the reservoir fish population consisted of threadfin shad, a forage species. In Melton Hill Reservoir, however, gizzard shad comprised 56.7% of the total number of fish collected in rotenone sampling of six coves (Tennessee Valley Authority 1976a). Because the earlier sampling in Melton Hill (mid-June to mid-July) may have been conducted prior to the period of peak abundance of young-of-the-year threadfin shad, the observed dominance of gizzard shad in the reservoir may be misleading. Young-of-the-year threadfin shad were the dominant age class in both Watts Bar (99.8% of the threadfin shad collected) and Norris Reservoirs (95.3%), but comprised only 35.9% of the threadfin shad population in Melton Hill Reservoir (Tennessee Valley Authority 1976a,b,c). In this regard, the very low relative abundance of threadfin shad (<1%) in the pre- and post-impoundment gill-net surveys (Table 1.6.5-1) may have been due to the use of 2.5-to 7.6-cm bar mesh nets (Fitz 1968). Mesh sizes smaller than 2.5 cm may be more effective in collecting small species such as threadfin shad that are noted for their extensive movements in reservoirs (Crandall et al. 1978).

Significant shifts in relative abundance before and after dam operation included an increase from 0.1 to 7.8% in the relative abundance of white bass collected by gill-netting. Considerable seasonal movements of white bass from Watts Bar Reservoir upstream to the Melton Hill tailwaters and the lock into the reservoir was expected (Fitz 1968). Changes in the relative abundance of rough fishes also occurred, the most notable of which was the absence of mooneye in the post-impoundment samples. This species was the most abundant fish taken during the pre-impoundment survey, comprising 28.1% of the catch. Although the relative abundance of most rough species declined after impoundment, a few species increased dramatically. For example, the relative abundance of carp rose from 1.4 to 26.4%. In the 1974 cove rotenone survey, this species comprised almost 12% of the total number of fish that were collected. Likewise, the relative abundance of skipjack herring collected by gill-netting increased from 1.7 to 29.5%. This species was not collected in the pre-impoundment rotenone sampling of a cove near CRM 61.0 and was very rare in the post-impoundment rotenone collections (relative abundance was <0.05% in the 1974 survey) (Tennessee Valley Authority 1976a).

Comparison of ORGDP survey with other post-impoundment surveys

Even though no quantitative pre-impoundment sampling was conducted below Melton Hill Dam and only limited qualitative data are available (Clinch River Study Steering Committee 1967, Table 6.1), it seems reasonable to assume that, prior to completion of the dam, the fish populations in this region of the river were similar to those found above CRM 23.1 (Fitz 1968). Following completion of the dam in May 1963, the relative abundance of rough fishes below the dam probably decreased. Results from cove rotenone surveys indicate that these fishes currently constitute a lower proportion of the total fish population below the dam than above it (Table 1.6.5-2). Comparisons of the results obtained from gill-net surveys in 1964 (Table 1.6.5-1) and 1973-78 (Table 1.6.5-3) also support this conclusion. Rough:game fish ratios calculated from gill-net and electroshocking collections were greater than 1 in the vicinity

Table 1.6.5-3. Relative abundance (%), based on number collected, of game, rough, and forage fishes found in five surveys conducted on the Clinch River in the vicinity of ORGDP between 1973 and 1978. Percent of the total fish collected that were threadfin shad is given in parentheses.

Survey	Sampling dates[a]	No. of sampling stations	Location (CRM)	Relative abundance (%)		
				Game	Rough	Forage
Electroshocking only						
TVA[b]	2,5,8 (1973)	3	15.7-17.9	1	5	94 (0.0)
CRBR[c]	5-9,11,12 (1974) 1 (1975)	10	15.1-17.9	21	14	64 (15.7)
1974-75[d]	7-12 (1974) 1-3 (1975)	1	11.0-11.5	46	19	35 (2.0)
ORGDP	4,6,7,10 (1977) 3 (1978)	3	10.5-15.0	81	5	14 (1.1)
Gill nets only						
TVA[b]	2,5,8 (1973)	3	15.7-17.9	28	66	6 (0.0)
CRBR[c]	3,5-9,11 (1974) 1 (1975)	10	15.1-17.9	9	30	61 (58.3)
ORGDP	4,6,7,10 (1977) 2 (1978)	3	10.5-15.0	25	28	47 (5.1)
Electroshocking and gill nets						
TVA[b]	2,5,8 (1973)	3	15.7-17.9	7	19	74 (0.0)
CRBR[c]	3,5-9,11,12 (1974) 1 (1975)	10	15.1-17.9	16	21	63 (33.8)

Table 1.6.5-3 (continued)

Survey	Sampling dates[a]	No. of sampling stations	Location (CRM)	Relative abundance (%)		
				Game	Rough	Forage
Electroshocking and gill nets (continued)						
NFRRC[e]	N/A (1975-76)[f]	4	12.0-15.0	19	15	66 (42.2)
ORGDP	4,6,7,10 (1977) 2,3 (1978)	3	10.5-15.0	58	14	28 (2.8)

[a] Numbers refer to months (1 = January ... 12 = December).

[b] Source: Project Management Corporation (1975), Tables 2.7-95 and 2.7-96.

[c] Source: Project Management Corporation (1975), Tables 2.7-88, 2.7-90 through 2.7-93.

[d] Source: B. G. Blaylock, unpublished data.

[e] Source: Exxon Nuclear Co. Inc. (1976), Table 2.7-15.

[f] Specific sampling dates not reported; sampling period extended from May 1975 through April 1976.

of the proposed site of the Clinch River Breeder Reactor in both 1973 and 1974 but were less than 1 in other surveys conducted just downstream (Table 1.6.5-3). The relative abundance of game fish was generally highest in the electroshocking collections, especially those made during the 1974-75 and ORGDP surveys downstream. Gill-net and electroshocking data collected during the preoperational survey for the Exxon Nuclear Fuel Recovery and Recycling Center were not reported separately (Exxon Nuclear Company, Inc. 1976).

Trends in the relative abundance of forage fish are difficult to interpret but are undoubtedly related not only to differences in sampling dates (or seasons) and gear type, including different mesh gill nets as discussed previously, but also to the population dynamics and distribution of the principal forage species, the threadfin shad, in upper Watts Bar Reservoir. Of the 871 fish collected at six stations during the ORGDP survey, only 12 (1.4%) were threadfin shad, yet this species comprised 33.8 and 42.2% of the total fish collected by similar types of gear during the 1974-75 CRBR and the 1975-76 NFRRC surveys, respectively (Table 1.6.5-3). It was also the most abundant species (relative abundance = 51.6%) found during the 1974-75 sampling program in Poplar Creek (Table 1.6.5-4).

Infrequent sampling and shifts in the spatial distribution of the species may account for the absence of threadfin shad in the TVA survey conducted between CRM 15.7 and 17.9 in 1973 and their relatively high abundance in small coves in Watts Bar Reservoir the same year (Table 1.6.5-3). During the 1974-75 survey (B. G. Blaylock, unpublished data), this species was also rarely encountered in routine electroshocking

Table 1.6.5-4. Relative abundance (%), based on number collected, of game, rough, and forage fishes found in various surveys conducted on Poplar and Grassy Creeks in the vicinity of ORGDP between 1974 and 1978. Percent of the total fish collected that were threadfin shad is given in parentheses. The ORGDP sampling sites are shown in Fig. 1.2-1.

Survey	Sampling dates[a]	Sampling site (PCM)	Relative abundance (%)		
			Game	Rough	Forage
Electroshocking only					
1974-75[b]	7-12 (1974) 1,2 (1975)	0.5	20	17	63 (51.6)
		6.0	49	37	14 (0.0)
ORGDP	4,6,7,10 (1977) 3 (1978)	0.5	69	12	19 (0.0)
	4,6,10 (1977) 3 (1978)	5.5	54	15	31 (0.0)
	4,6,7 (1977)	11.0	37	32	31 (0.0)
Gill nets only					
ORGDP	4,5,7,10 (1977) 2 (1978)	0.5	16	32	52 (1.2)
		5.5	22	15	63 (0.7)
	5,7,9 (1977) 2 (1978)	11.0	13	40	47 (0.0)
Electroshocking and gill nets					
NFRRC[c]	N/A (1975-76)[d]	GCM 0.4[e]	30	8	62 (28.3)
	N/A (1975-76)[d]	GCM 1.0[e]	10	1	89 (0.0)
	N/A (1975-76)[d]	GCM 2.2[e]	0	0	100[f]

Table 1.6.5-4 (continued)

Survey	Sampling dates[a]	Sampling site (PCM)	Relative abundance (%)		
			Game	Rough	Forage
Electroshocking and gill nets (continued)					
ORGDP	4-7,10 (1977) 2,3 (1978)	0.5	32	26	42 (0.8)
		5.5	32	15	53 (0.5)
	4-7,9 (1977) 2 (1978)	11.0	33	33	33 (0.0)

[a]Numbers refer to months (1 = January ... 12 = December).

[b]Source: B. G. Blaylock, unpublished data.

[c]Source: Exxon Nuclear Co., Inc. (1976), Table 2.7-31.

[d]Specific sampling dates not reported; sampling period extended from May 1975 through April 1976 (GCM 0.4) and from October 1975 to April 1976 (GCM 1.0 and 2.2).

[e]GCM = Grassy Creek Mile; GCM 0.0 is located at the confluence with the Clinch River (CRM 14.4).

[f]Only species collected were the blacknose dace (34%) and the creek chub (66%).

in the river but was abundant in the samples collected in Poplar Creek. Their low abundance in 1977-78, however, may be related to the unusually cold winters in 1976-77 and 1977-78. Low temperatures are known to stress the species and may be a major source of mortality (Griffith 1978, Parsons and Kimsey 1954). Extensive attempts to collect individuals in upper Watts Bar Reservoir during the late winter and spring of 1978 were generally unsuccessful (R. McLean, personal communication). Thus, their low abundance in 1977-78 gill-net and electroshocking collections taken in the vicinity of ORGDP may actually reflect their low abundance in the reservoir.

The low abundance of forage fishes in the ORGDP samples taken from the Clinch River affected the relative abundance of the other two categories. Hayne et al. (1967) pointed out that the relative abundance of a species may be underestimated either because it is less abundant in the sample or because other species are more abundant; each value depends upon all other values. Since this same observation can be applied to the relative abundance of groups of species, the high relative abundance of game fishes found during the ORGDP survey can, in part, be accounted for by the relatively low abundance of forage fishes, especially the threadfin shad.

Similarly, the differences between the relative abundance of game fish collected by electrofishing at station PCM 0.5 (Fig. 1.2-1) during the 1974-75 and the 1977-78 surveys can be explained on the basis of differences in the abundance of threadfin shad (Table 1.6.5-4). At station PCM 5.5, the results obtained in the two surveys were similar. The only forage species collected by electrofishing at this site in both surveys was the gizzard shad, a species that migrates up Poplar Creek to spawn in the spring (Fig. 1.6.5-1). However, the lower relative abundance of gizzard shad in the earlier survey can best be attributed to an absence of sampling during the upstream migration in the spring. Although some individuals may reside for extended periods of time in the creek, the majority of the population moves down the creek to the reservoir after spawning has occurred (Fig. 1.6.5-1).

Differences between the Grassy Creek and Poplar Creek fish populations are largely a function of the size of the two creeks. The former is a small stream, approximately 4 km long with a drainage area of about 4.9 km^2 (Exxon Nuclear Company, Inc. 1976, Section 2.7.1.2). It originates from a series of hardwater springs with alternating pool and riffle habitats. The high relative abundance of species such as the blacknose dace and creek chub reflect the rather distinct character of this stream compared with Poplar Creek (Section 1.2.1 and Table 1.6.5-4).

Species composition and relative abundance

The most abundant species collected from Poplar Creek were gizzard shad and white bass (Table 1.6.5-5), and most of these were ripening adults that had moved into the creek to spawn in the spring. Although gizzard shad were also abundant in the river during this period, fewer individuals were collected at the river than at the creek stations (Fig. 1.6.5-1). White bass, on the other hand, were rarely encountered at the river sites in April and May but were found in October (Fig. 1.6.5-1). The twelve individuals collected at station CRM 11.5 ranged in total length from 16.3 to 21.1 cm ($\bar{x}$ = 18.7 cm). Similarly,

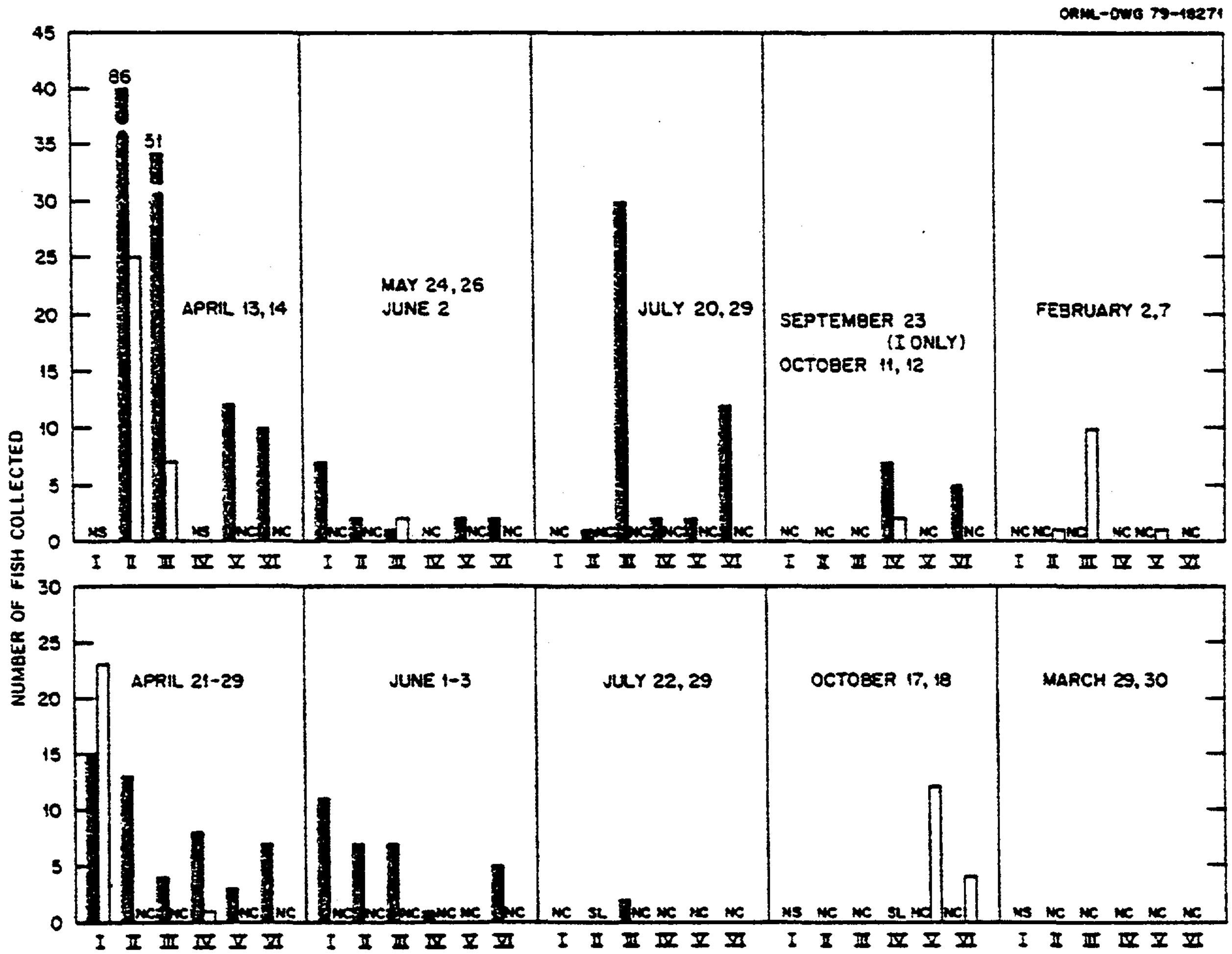


Fig. 1.6.5-1. Numbers of gizzard shad (■) and white bass (□) collected in gill nets (top) and by electroshocking (bottom) at the six ORGDP sampling sites, April 1977-March 1978. Sampling sites were: I (PCM 11.0); II (PCM 5.5); III (PCM 0.5); IV (CRM 15.0); V (CRM 11.5); VI (CRM 10.5); NS = not sampled; NC = no fish collected; SL = sample lost.

Table 1.6.5-5. Total number of fish collected by gill-netting (G) and electroshocking (S) at the three ORGDP sampling sites on Poplar Creek, April 1977-March 1978. Number of collection periods given in parentheses.

	PCM 11.0		PCM 5.5		PCM 0.5	
Family/species	G(4)	S(3)	G(5)	S(4)	G(5)	S(5)
Catostomidae						
Smallmouth buffalo		7	3	2	1	5
Black buffalo				2		
River carpsucker				1		1
Silver redhorse	2	17	2	2	2	1
Spotted sucker			1		2	
Total	2	24	6	7	5	7
Centrarchidae						
Largemouth bass		2		4		14
Spotted bass			1			
White crappie		2		10	1	17
Bluegill	1	3	1	9	1	19
Redbreast sunfish		1				
Orange-spotted sunfish				2		
Warmouth				1		
Lepomis sp.				8		
Total	1	8	2	34	2	50
Clupeidae						
Gizzard shad	7	26	89	20	82	13
Threadfin shad			1		2	
Skipjack herring	4				11	
Total	11	26	90	20	95	13
Cyprinidae						
Carp			4	3		2
Notropis sp.					3	
Unidentified						1
Total			4	3	3	3
Hiodontidae						
Mooneye					1	
Ictaluridae						
Channel catfish			4		12	

Table 1.6.5-5 (continued)

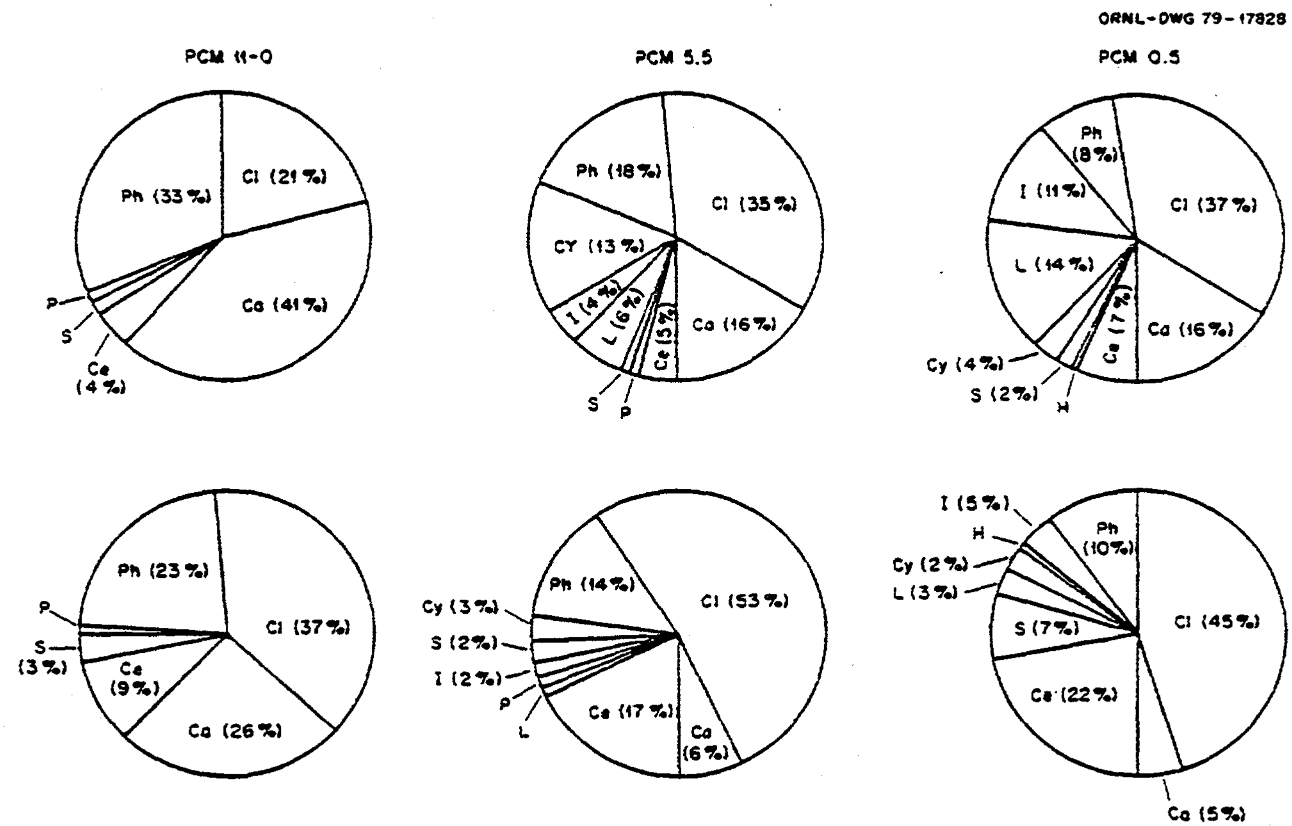
Family/species	PCM 11.0 G(4)	PCM 11.0 S(3)	PCM 5.5 G(5)	PCM 5.5 S(4)	PCM 0.5 G(5)	PCM 0.5 S(5)
Lepisosteidae						
Spotted gar			1		2	
Longnose gar			1		5	
Total			2		7	
Percichthyidae						
White bass		23	26		19	
Yellow bass			1	1	1	
Striped bass					4	
Total		23	27	1	24	
Percidae						
Sauger	1		2			
Sciaenidae						
Freshwater drum		3	5		17	
Total fish collected	15	84	142	65	166	73

individuals collected at station CRM 10.5 in October and at station PCM 0.5 in February ranged from 17.4 to 19.1 cm ($\bar{x}$ = 18.2 cm, n = 4) and from 16.2 to 21.2 cm ($\bar{x}$ = 19.3 cm, n = 10), respectively. Based on a review by Ruelle (1971) of white bass growth in other reservoirs, the individuals collected in October and February during the ORGDP survey were probably age I+ fish (Ruelle 1971). Although these yearlings are present in the study area in the fall and winter, none were collected in Poplar Creek in April.

Because of the relatively high numbers of adult white bass and gizzard shad collected in Poplar Creek in the spring, the families to which these two species belong (Percichthyidae and Clupeidae, respectively) dominated the community on a biomass basis (Fig. 1.6.5-2). These families accounted for more than 50% of the fish biomass at the two upstream stations and 45% of the biomass at PCM 0.5. At all three stations, however, rough fish was the dominant group based on biomass, due primarily to the presence of adult silver redhorse and smallmouth buffalo at stations PCM 11.0 and 5.5 and the longnose gar, channel catfish, and shipjack herring at PCM 0.5.

Rough fish in the Clinch River comprised a smaller proportion of total fish biomass than was found in Poplar Creek (Fig. 1.6.5-3). Although the relative abundance of clupeids was similar in the two areas, catostomids were a significant component at only the downstream station (Table 1.6.5-6). At all three of the river sites, the families Centrarchidae (especially bluegill and largemouth bass) and Percidae (sauger) constituted a greater proportion of the biomass than was found at any of the sites on Poplar Creek. As a result, game fish was the dominant group, based on weight, at stations CRM 15.0 and 11.5, comprising 44 and 48% of the biomass, respectively. Forage fish was the dominant group at station CRM 10.5 with game fish comprising only 22% of the biomass.

The differences observed in the relative abundance of species between Poplar Creek and the Clinch River were the result of seasonal shifts in the distribution of various species as well as the nature and range of habitats found in these two areas. Difficulties in sampling some areas (e.g., setting gill nets in the river channel) may also have biased the results obtained from the Clinch River. For example, the proportion of rough fish, which are especially susceptible to gill-



KEY:
Ca = *Catostomidae*
Ce = *Centrarchidae*
Cl = *Clupeidae*
Cy = *Cyprinidae*
H = *Hiodontidae*
I = *Ictaluridae*
L = *Lepisostidae*
Ph = *Percichthyidae*
P = *Percidae*
S = *Scianidae*

Fig. 1.6.5-2. Relative abundance (%) of fishes based on weight (top) and numbers (bottom) at the three ORGDP sampling sites on Poplar Creek, April 1977-March 1978. Samples obtained by gill-netting and electroshocking were combined in the computation of relative abundance. Where no percentage is given for a particular family, the relative abundance was ≤1%.

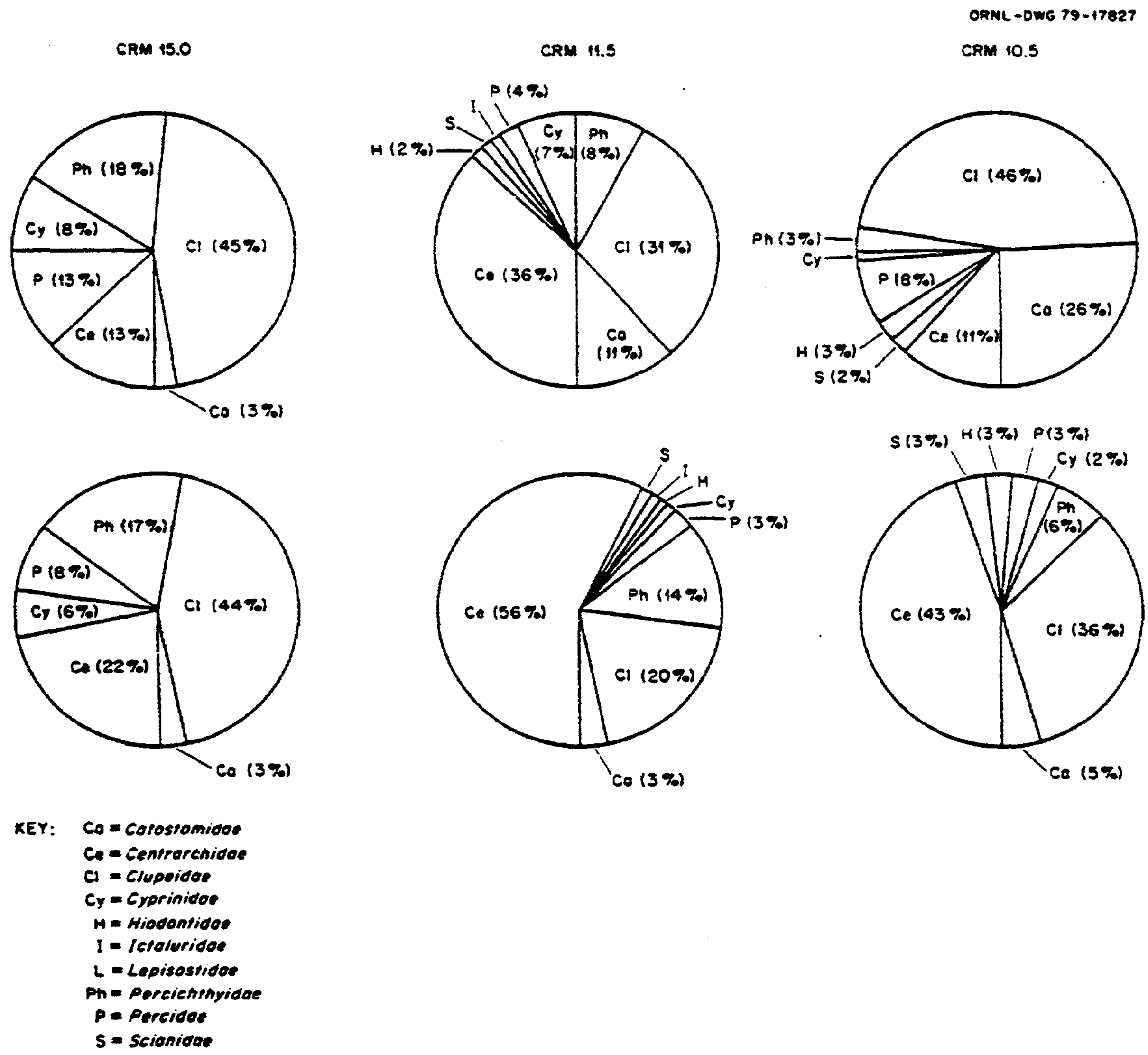


Fig. 1.6.5-3. Relative abundance (%) of fishes based on weight (top) and numbers (bottom) at the three ORGDP sampling sites on the Clinch River, April 1977-March 1978. Samples obtained by gill-netting and electroshocking were combined in the computation of relative abundance. Where no percentage is given for a particular family, the relative abundance was ≤1%.

Table 1.6.5-6. Total number of fish collected by gill-netting (G) and electroshocking (S) at the three ORGDP sampling sites on the Clinch River, April 1977-March 1978. Number of collection periods given in parentheses.

	CRM 15.0		CRM 11.5		CRM 10.5	
Family/species	G(4)	S(4)	G(5)	S(5)	G(5)	S(5)
Catostomidae						
River carpsucker					1	2
Silver redhorse	1			2	2	
Black redhorse				1		1
Spotted sucker					2	
Northern hogsucker	1					
Total	2			3	5	3
Centrarchidae						
Largemouth bass		6		14	1	10
Spotted bass				1		1
White crappie		1				
Bluegill	1	6		30	3	37
Redbreast sunfish				3		8
Warmouth						4
Rock bass				3		
Lepomis sp.				7		5
Total	1	13		58	4	65
Clupeidae						
Gizzard shad	9	9	16	3	29	12
Threadfin shad	7					2
Skipjack herring	3		2		14	
Total	19	9	18	3	43	14
Cyprinidae						
Carp		1		1		1
Common shiner	3					
Unidentified						1
Total	3	1		1		2
Hiodontidae						
Mooneye			1		4	
Ictaluridae						
Channel catfish			1			

Table 1.6.5-6 (continued)

Family/species	CRM 15.0 G(4)	CRM 15.0 S(4)	CRM 11.5 G(5)	CRM 11.5 S(5)	CRM 10.5 G(5)	CRM 10.5 S(5)
Percichthyidae						
White bass	2	1	1	12		4
Yellow bass	8		1			
Striped bass					5	
Total	10	1	2	12	5	4
Percidae						
Sauger	4	1	3		5	
Sciaenidae						
Freshwater drum			1		5	
Total fish collected	39	25	26	77	71	88

netting, may have been underestimated. Since game fishes, especially centrarchids, are not effectively sampled with this gear, estimates of their relative abundance would be indirectly affected and may have been overestimated. The apparent low abundance of the principal forage species, the threadfin shad, following the winter of 1977-78 also contributed to the atypical patterns in relative abundance observed during the ORGDP survey. In general, however, the results obtained during the present study, when combined with the data collected in previous fishery surveys, provide a reasonably accurate, reliable description of the fish community in the lower Clinch River. Finally, no species listed as threatened or endangered by the State of Tennessee (Tennessee Wildlife Resources Commission 1975) or the U.S. Department of Interior (1980) was collected in the 1974-75 CRBR and the 1975-76 NFRRC surveys (Project Mangement Corporation 1975, Table 2.7-87 and Exxon Nuclear Co., Inc. 1976, Table 2.7-14, respectively) or the ORGDP survey.

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1.6.6 Ichthyoplankton (G. F. Cada and J. M. Loar)

Planktonic fish eggs and larvae (ichthyoplankton) have been the subject of a considerable amount of research effort in recent years. These early life history stages are particularly sensitive to natural or man-induced environmental perturbations and, due to limited swimming capabilities, are often unable to avoid them. Because natural mortality among ichthyoplankton is normally very high, it is recognized that year-class strength in fish populations is generally formed during the first year of life. Consequently, knowledge of the production and distribution of ichthyoplankton in a water body is crucial to an understanding of the dynamics of the fish populations under investigation.

A field survey of the ichthyoplankton in Poplar Creek and the Clinch River near ORGDP was conducted during 1978. This study was designed to provide information on the species composition and abundance of ichthyoplankton in this area, as well as their seasonal, spatial, and diel distribution.

Review of previous studies

Ichthyoplankton were sampled at five stations between CRM 15 and 18 as part of the Clinch River Breeder Reactor preoperational environmental monitoring program (Project Management Corporation 1975). Biweekly bottom samples were taken from March 28 through August 29, 1974, by means of both submersible pumps and stationary 0.5 m-diameter, 1-mm mesh plankton nets. Collections at each station were made at a single location in the channel, close to the left shore (facing upstream). In

(CRM 2.8) between March 26 and July 30, 1975 (Tennessee Valley Authority 1976a). Night samples were taken by means of pumping, push-netting, vertical netting, and horizontal netting. All samples were filtered through 0.79-mm-mesh nets and were analyzed for species composition and relative abundance. Similar surveys were taken in 1975 in the vicinity of the Bull Run Steam Plant (Tennessee Valley Authority 1976b) at CRM 48.0 and the Watts Bar Steam Plant (Tennessee River Mile 529.2) which draws water from Watts Bar Reservoir (Tennessee Valley Authority 1976c).

The results of these three surveys were similar in terms of species composition and seasonal distribution. Clupeid larvae were the most abundant ichthyoplankters near all three plants, comprising approximately 94, 74, and 97% respectively, of the total numbers in the collections. Centrarchids and cyprinids were also relatively abundant. Ichthyoplankton were first collected on April 9 near the Kingston Plant, on April 16 near Bull Run, and on May 5, 1975, at the Watts Bar Steam Plant. Highest seasonal densities of larvae were found during late May-early June in all three studies, due primarily to large numbers of clupeid larvae (Tennessee Valley Authority 1976a,b,c).

Seasonal distribution

A total of 4198 fish eggs and 38,443 larvae were collected during the ORGDP ichthyoplankton sampling program in 1978 (Table 1.6.6-1). Clupeids (Clupeidae, Dorosoma, Alosa) were the most abundant larvae in the samples, accounting for 92.9% of the total number. Of the remaining taxa, Morone larvae were also relatively common. Five families (Catostomidae, Centrarchidae, Cyprinidae, Percidae, and Sciaenidae) made

Table 1.6.6-1. Total numbers of eggs and larvae collected in the 1978 ORGDP ichthyoplankton survey, all samples combined

Category	Life stage[a]	Number collected	Percent of total
Clupeidae	ysl, pysl	23,275	54.5
Dorosoma	ysl	12,443	29.2
Morone	ysl, pysl	2,222	5.2
Ictiobinae	ysl	237	0.6
Pomoxis	ysl, pysl	96	0.2
Lepomis	ysl, pysl	81	0.2
Cyprinidae	ysl, pysl	34	0.1
Cyprinus carpio	ysl, pysl	27	0.1
Alosa	ysl	11	<0.1
Catostomidae	ysl	8	<0.1
Percidae	ysl, pysl	6	<0.1
Stizostedion	ysl	5	<0.1
Aplodinotus grunneiens	ysl, pysl	2	<0.1
Notemigonus crysoleucas	ysl	2	<0.1
Micropterus	ysl	1	<0.1
Minytrema melanops	pysl	1	<0.1
Unidentified eggs		4,198	9.8
Unidentified larvae	ysl	3	<0.1
		42,652	

[a]ysl = yolk-sac larvae; pysl = post-yolk-sac larvae.

addition, mid-depth tows were used to sample ichthyoplankton in Poplar Springs Creek and Caney Creek on five dates.

Probably due to small sample volumes, only one egg was collected by pumping (Project Management Corporation 1975, Section 2.7.2.4.8). A total of 296 eggs were collected in the Clinch River drift nets, the majority (275) appearing on May 16 and June 2, 1974 (Project Management Corporation 1975, Tables 2.7-97 and 2.7-98). Mean annual egg densities were similar between the five Clinch River stations (range: 0.11 to 0.20 eggs/m^3). A single percid larva was collected in the Clinch River on March 28, and 13 clupeid larvae were found in the Poplar Springs Creek and Caney Creek tows on June 25 and 26 (Project Management Corporation 1975, Table 2.7-99).

Larval fishes were collected in the Clinch River near ORGDP from May through September 1975 by means of towed, 0.5-m nets (Exxon Nuclear Company, Inc. 1976). A total of 2328 larvae were found in the 135 tows. No eggs were recorded. Clupeid larvae, which were collected throughout this study period, were the most abundant of the 10 taxa reported. They represented 89.7% of the total number of larvae collected, while white crappie larvae accounted for 9.1% of the total number. Four of the 10 taxa were represented by single individuals (Exxon Nuclear Company, Inc. 1976, Table 2.7-17). No discussion of station differences or seasonal patterns in ichthyoplankton distribution was provided in this report.

Recent, more intensive surveys of ichthyoplankton in the vicinity of ORGDP have been conducted as part of entrainment impact assessments for operating steam electric generating stations. For example, biweekly ichthyoplankton collections were made near the Kingston Steam Plant up the remainder of the identifiable larvae collected in the Clinch River and Poplar Creek.

Figure 1.6.6-1 shows the times of appearance of the most common ichthyoplankters and a plot of seasonal changes in water temperature at station PCM 0.5 (see Fig. 1.2-1). Sampling was begun in mid-February, and the first eggs were collected on March 28 at a water temperature of 8.3°C. Greater egg densities in a single sample (97.8 eggs/m^3) were found on May 1 at a temperature of 12.8°C and occurred during a time when white bass (Morone chrysops) were observed spawning in Poplar Creek. A second, smaller peak in egg densities was noted in mid-June (Fig. 1.6.6-2). No eggs were collected after July 28, 1978.

Morone yolk-sac larvae (ysl) first appeared in the samples on April 3 at a water temperature of 15.5°C. Observed densities peaked in mid-April at a mean of 2.65/m^3 and again in late May at 1.96/m^3 (Fig. 1.6.6-3). Highest densities of Morone post-yolk-sac larvae (pysl) were also noted in mid-April. Their appearance in the ichthyoplankton samples between April and June was sporadic but always followed peaks in abundance of yolk-sac larvae.

Dorosoma ysl and Clupeidae pysl were first collected on April 10, 1978. Both ysl and pysl were found in relatively high numbers in Poplar Creek through July, and pysl appeared in the samples at all three Poplar Creek stations until the end of August (Figs. 1.6.6-4 and 1.6.6-5). Greatest numbers of Dorosoma ysl in Poplar Creek (Fig. 1.6.6-4 followed egg density peaks at PCM 11.0 in early April, early May, and early to mid-June (Fig. 1.6.6-2). Clupeidae pysl, which were found in relatively high densities in the lower portions of Poplar Creek (PCM 5.5 and 0.5),

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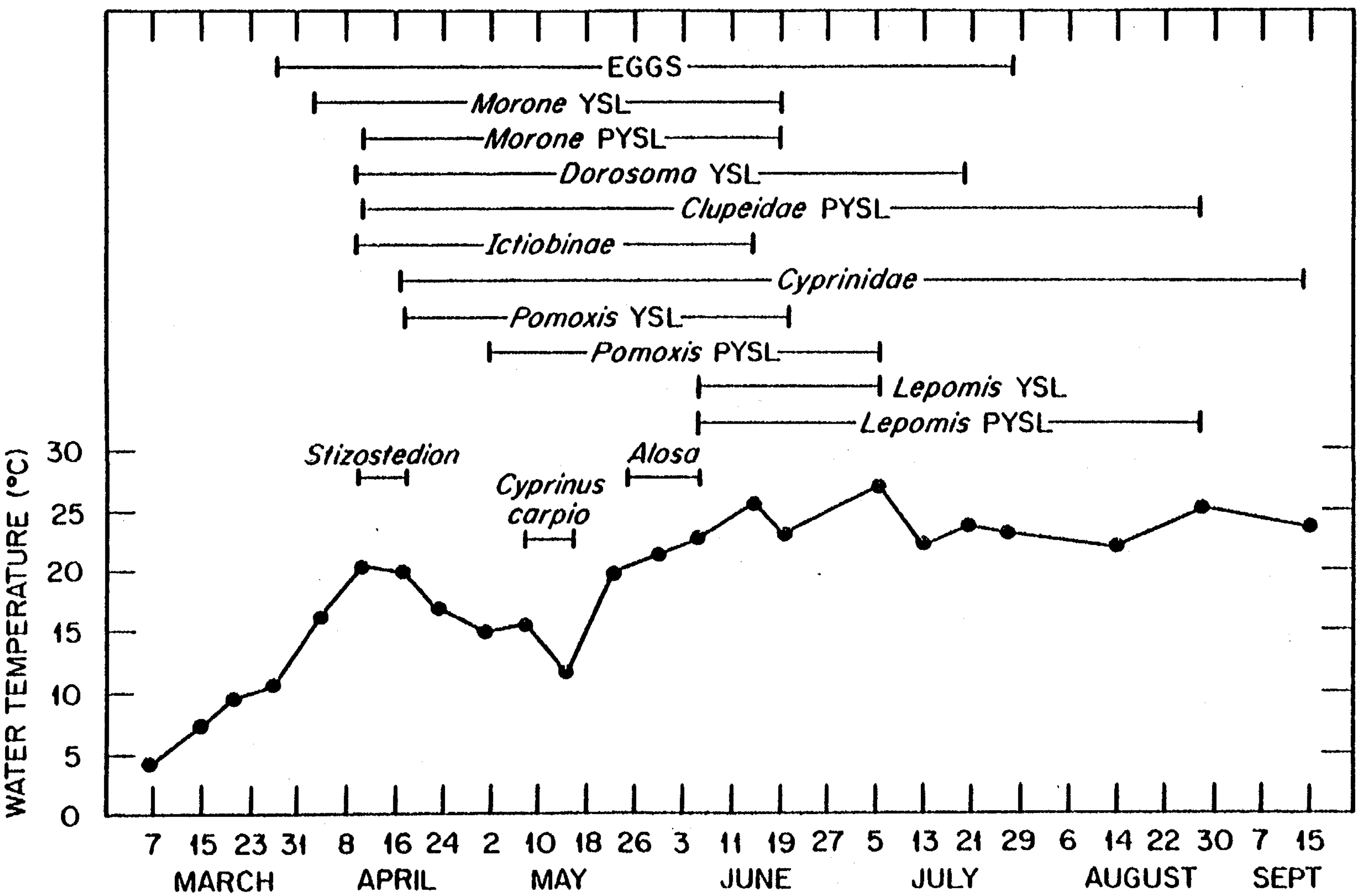

Fig. 1.6.6-1. Surface water temperatures at PCM 0.5 and dates of appearance of the most abundant ichthyoplankton taxa in the Clinch River and Poplar Creek samples.

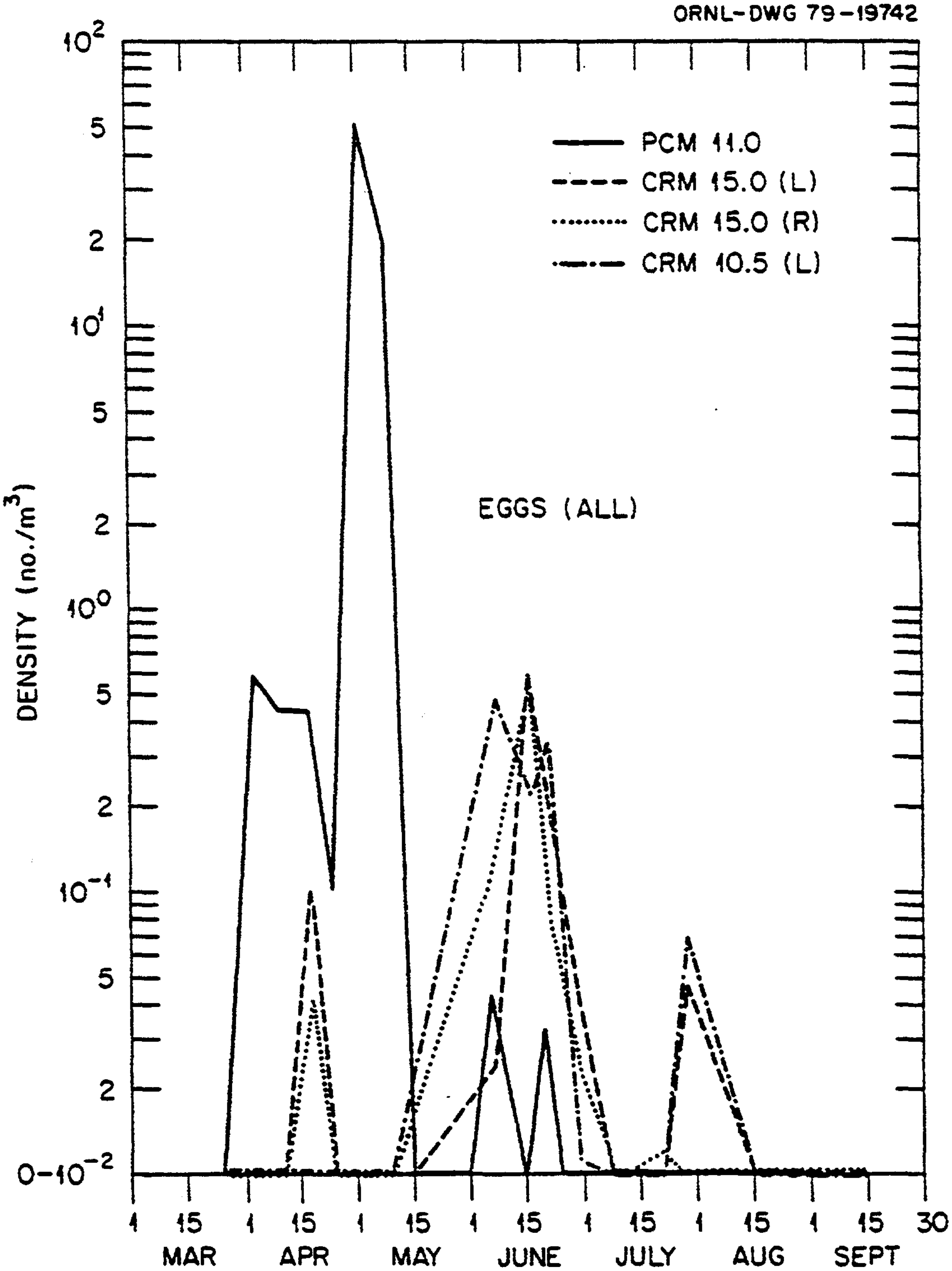

Fig. 1.6.6-2. Seasonal distribution of fish eggs at four sampling stations in Poplar Creek and the Clinch River, 1978.

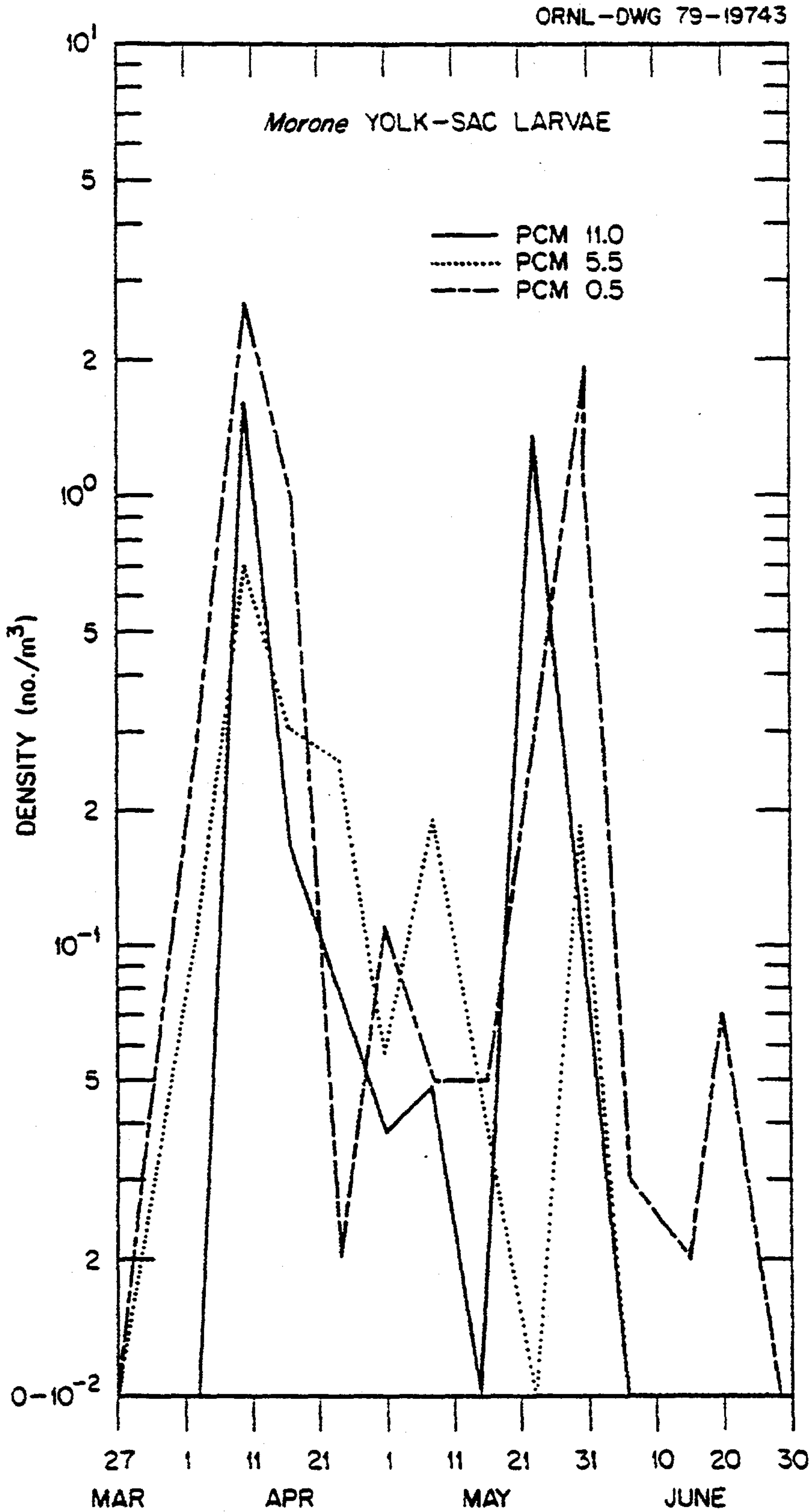

Fig. 1.6.6-3. Seasonal distribution of Morone yolk-sac larvae at the three Poplar Creek sampling stations, 1978.

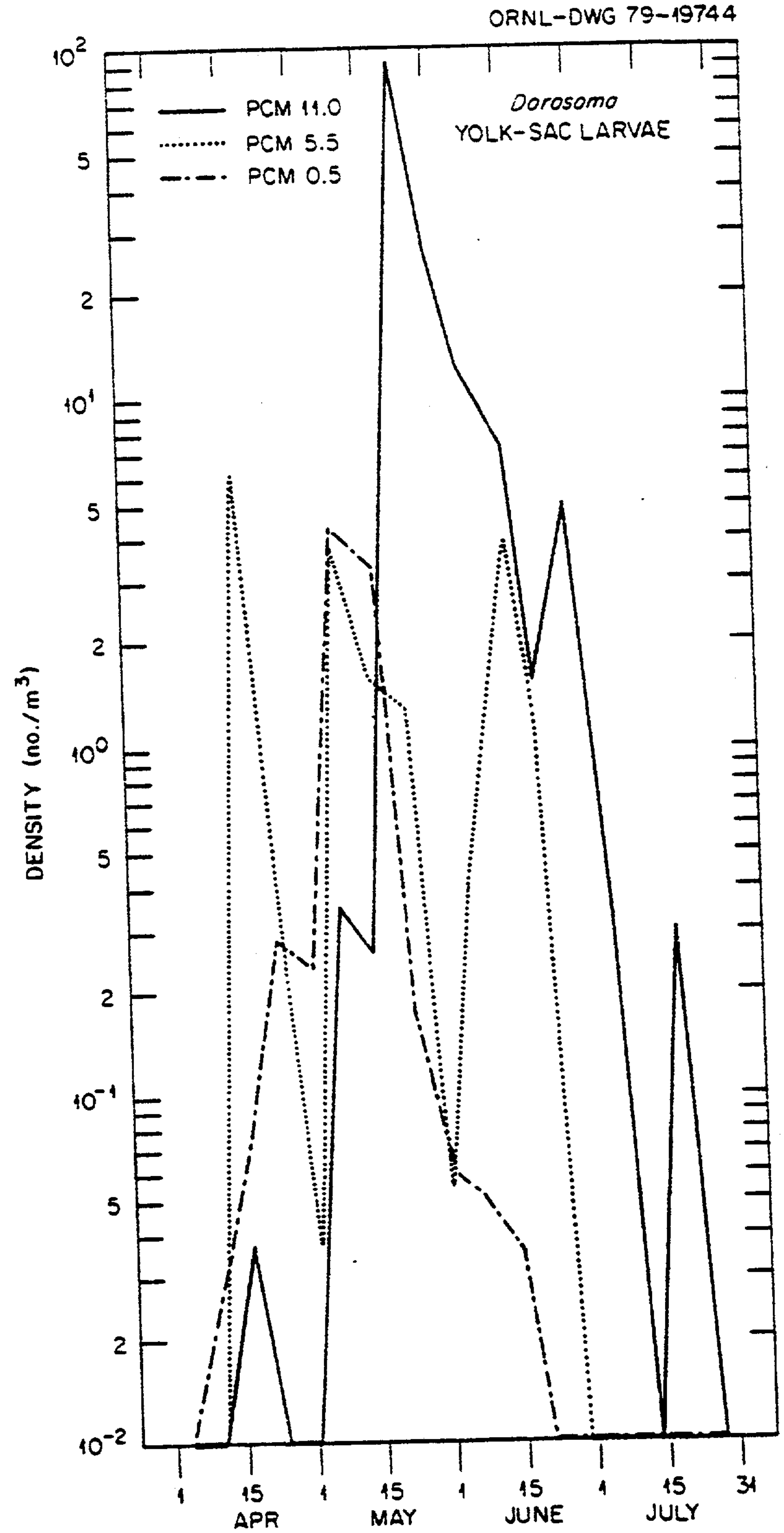

Fig. 1.6.6-4. Seasonal distribution of Dorosoma yolk-sac larvae at the three Poplar Creek sampling stations, 1978.

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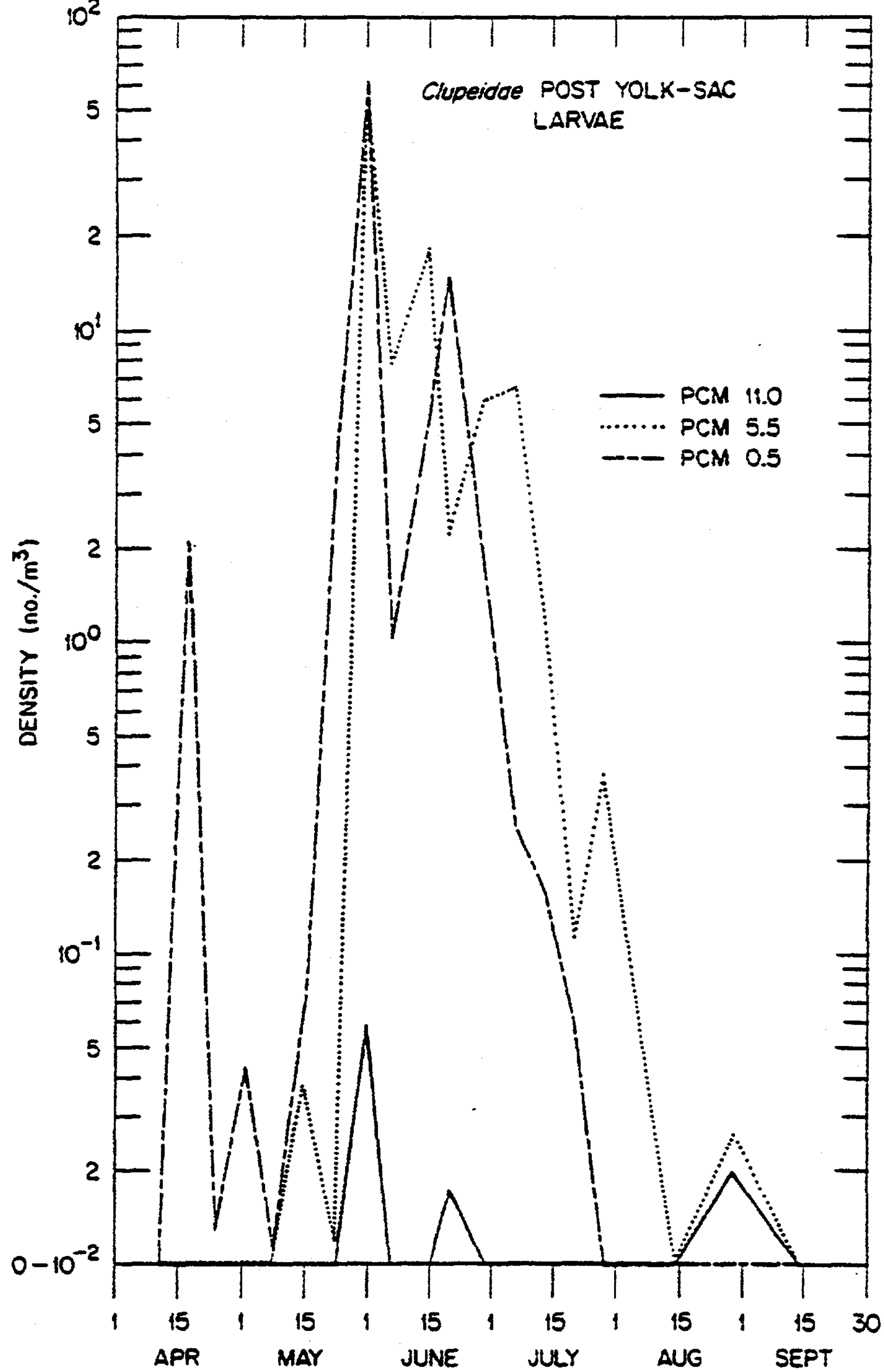

Fig. 1.6.6-5. Seasonal distribution of Clupeidae post-yolk-sac larvae at the three Poplar Creek sampling stations, 1978.

mirrored the peaks of Dorosoma ysl that were noted further upstream (PCM 11.0).

Other taxa (Table 1.6.6-1) were collected in small numbers, and seasonal trends in their distribution were difficult to discern. Ictiobinae yolk-sac larvae were collected in large numbers (up to $4.57/m^3$) on May 23, 1978, at Station PCM 11.0, but occurred in low densities (less than $0.10/m^3$) in the remainder of the samples. Both Pomoxis and Lepomis larvae (ysl and pysl combined) were found in uniformly low densities (generally less than $0.10/m^3$) throughout their appearance in the drift. With the exception of three larvae collected at PCM 0.5, all carp were found in the Clinch River. A lack of ichthyoplankton samples from the Clinch River between May 10 and June 5, caused by loss of the collecting net (Sect. 1.3.3.6), may have prevented the detection of the entire period of appearance of this species in the ichthyoplankton. Based on the weekly Poplar Creek samples, the times of appearance of other taxa depicted in Fig. 1.6.6-1 were not affected by the lack of Clinch River collections during this time.

Spatial distribution

Time-weighted densities (TWD) (Section 1.3.4) of fish eggs were compared among the three Poplar Creek and six Clinch River sampling stations (Fig. 1.6.6-6; Table 1.6.6-2). The highest egg TWD was found at Station PCM 11.0, and this value was significantly greater ($P \leq 0.01$) than the densities at any of the other stations. The time-weighted densities of eggs at stations PCM 5.5 and 0.5, on the other hand, were lower than at most of the Clinch River stations. In view of the likelihood

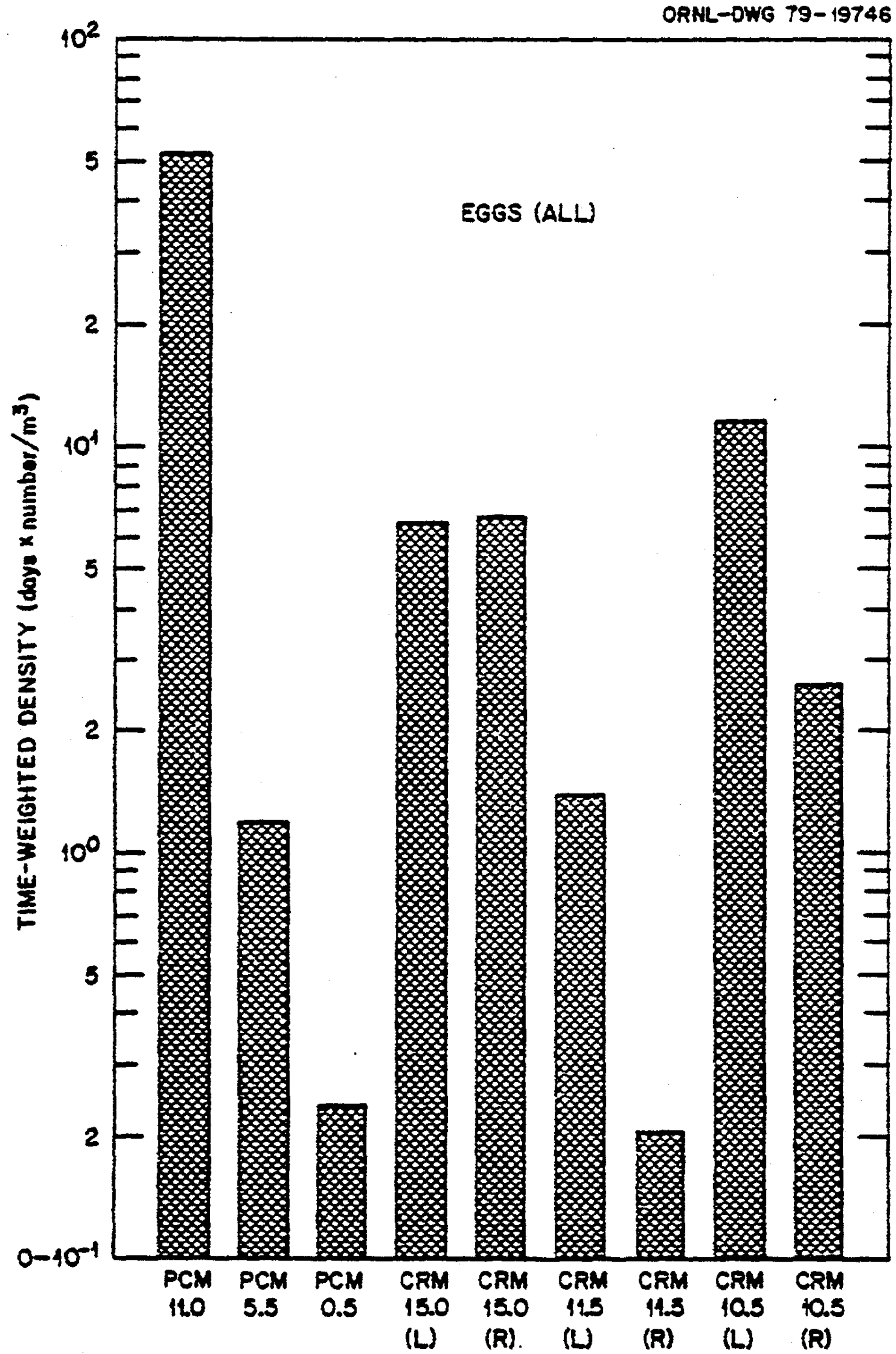

Fig. 1.6.6-6. Time-weighted densities (TWD) of fish eggs (all species combined) at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-2. Pairwise comparisons of time-weighted densities of fish eggs between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		<0.01[b]	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01
PCM 5.5			0.60+[c]	<0.01+	0.01	>0.10	>0.10	<0.01+	>0.10
PCM 0.5				<0.01+	<0.01+	0.21	>0.10	0.01	0.01+
CRM 15.0 (L)					0.90+	<0.01+	0.01	0.10	0.01
CRM 15.0 (R)						<0.01+	<0.01	0.10	<0.01+
CRM 11.5 (L)							>0.10	0.01	0.14+
CRM 11.5 (R)								0.01	0.01
CRM 10.5 (L)									0.01
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

that some of the planktonic eggs produced at PCM 11.0 are subsequently carried downstream and sampled at PCM 5.5 and 0.5, this significant difference in TWDs between stations indicates that egg production per unit sampling volume is relatively low in the lower regions of Poplar Creek and that much of the egg deposition occurs at a considerable distance upstream of its confluence with the Clinch River.

Egg TWDs in the Clinch River were highest at stations CRM 10.5 (L), 15.0 (R), and 15.0 (L) (Fig. 1.6.6-6). Differences between the right and left sides of the river at stations CRM 15.0 and 11.5 were not significant, but CRM 10.5 (L) had a significantly greater ($P = 0.10$) time-weighted density than CRM 10.5 (R) (Table 1.6.6-2).

Yolk-sac larvae (all species combined) were found in highest time-weighted densities at the three Poplar Creek stations (Fig. 1.6.6-7). The time-weighted density of yolk-sac larvae at PCM 11.0 was significantly greater ($P < 0.01$) than that of any other station (Table 1.6.6-3). TWDs at stations PCM 5.5 and 0.5 were not significantly different from each other ($P > 0.10$), but were greater than the values at the Clinch River stations.

Greater densities of yolk-sac larvae in the Clinch River occurred at stations CRM 11.5 and 10.5, downstream from the mouth of Poplar Creek. The TWDs at these stations were significantly greater ($P \leq 0.05$) than at station CRM 15.0, probably as a result of the contribution of yolk-sac larvae from Poplar Creek to the Clinch River. Differences in yolk-sac larvae TWDs between the two sides of the river at a given station were not statistically significant ($P \geq 0.10$).

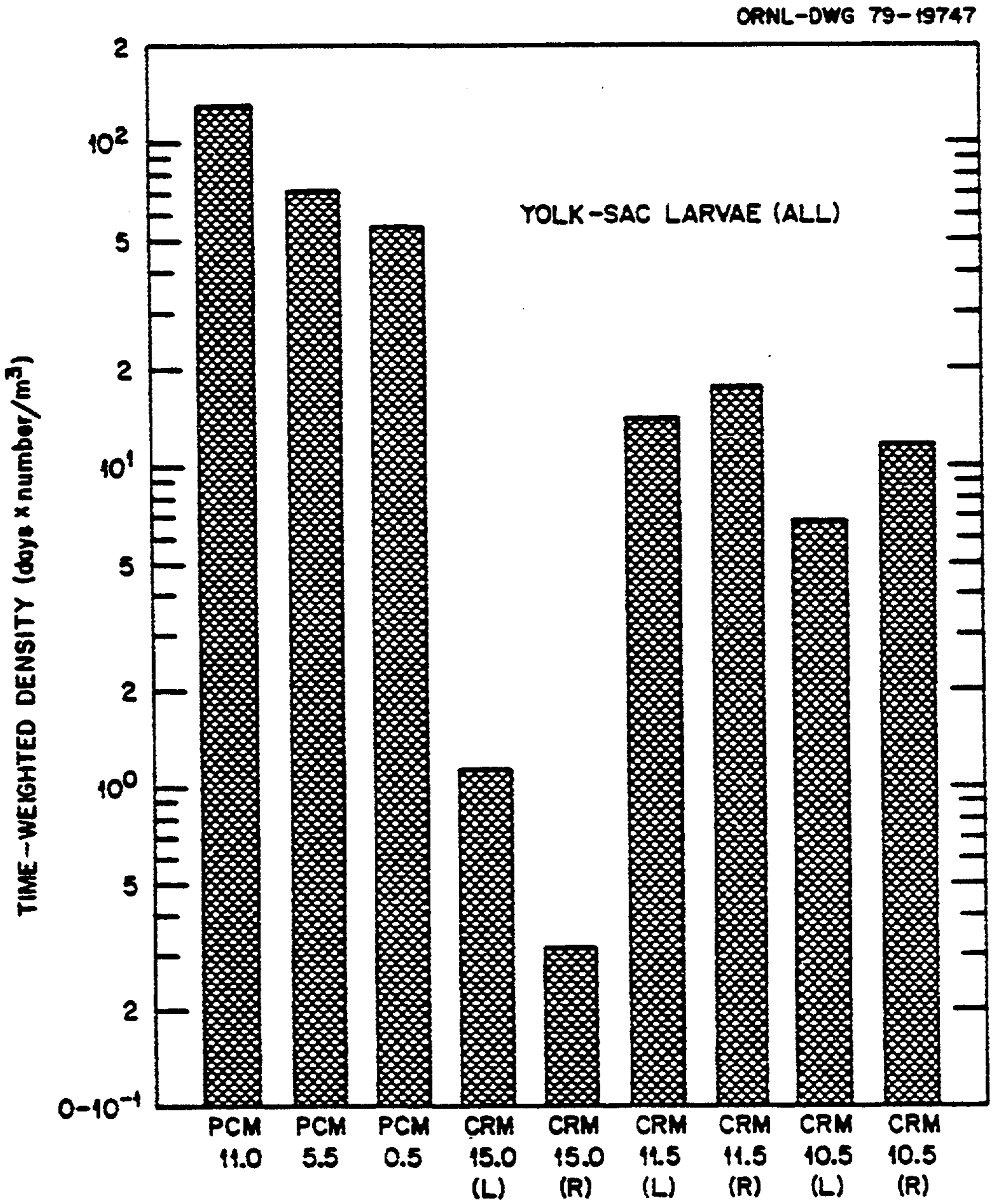

Fig. 1.6.6-7. Time-weighted densities (TWD) of yolk-sac larvae (all species combined) at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-3. Pairwise comparisons of time-weighted densities of yolk-sac larvae (all species combined) between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		<0.01[b]	<0.01^{+}[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01^{+}
PCM 5.5			0.10	<0.01	0.01	<0.01	<0.01	<0.01	<0.01^{+}
PCM 0.5				<0.01	<0.01	<0.01	<0.01	<0.01^{+}	<0.01^{+}
CRM 15.0 (L)					0.45^{+}	<0.01^{+}	<0.01^{+}	0.02^{+}	0.05
CRM 15.0 (R)						<0.01^{+}	<0.01^{+}	0.01^{+}	0.05
CRM 11.5 (L)							0.10	0.01	>0.10
CRM 11.5 (R)								<0.01^{+}	>0.10
CRM 10.5 (L)									>0.10
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

Time-weighted densities of post-yolk-sac larvae (all species combined) were significantly greater ($P < 0.01$) in the lower portions of Poplar Creek (PCM 5.5 and 0.5) than at the remaining stations (Fig. 1.6.6-8). In contrast to the pattern of distribution noted for eggs and yolk-sac larvae, PCM 11.0 had the lowest post-yolk-sac larvae TWD of all of the sampling stations. Highest TWDs among the Clinch River stations were generally found downstream of Poplar Creek. As with yolk-sac larvae, there were no statistically significant differences in TWDs of post-yolk-sac larvae between the two sides of the Clinch River at these downstream sampling stations (Table 1.6.6-4).

Statistical analyses were conducted on the time-weighted densities for the most abundant taxa collected in the ichthyoplankton sampling program (i.e., Morone ysl, Dorosoma ysl, and Clupeidae pysl). The TWD of Morone ysl at PCM 0.5 was significantly greater ($P < 0.01$) than that of any other station, and all three Poplar Creek Stations had significantly greater ($P \leq 0.05$) time-weighted densities of this taxa than did any of the Clinch River sites (Fig. 1.6.6-9). Differences in Morone TWD between the left and right sides of the Clinch River at a given station were not statistically significant ($P > 0.10$) (Table 1.6.6-5).

Dorosoma ysl had the highest TWD values in Poplar Creek (Fig. 1.6.6-10). Time-weighted densities of this taxa showed significant decreases ($P < 0.01$) from the upper to the lower Poplar Creek stations, and TWDs at all Clinch River stations were significantly lower ($P \leq 0.01$) than those in the tributary creek (Table 1.6.6-6). The virtual absence of Dorosoma ysl from CRM 15.0 and decreasing TWDs between CRM 11.5 and 10.5 indicate that much of the production of

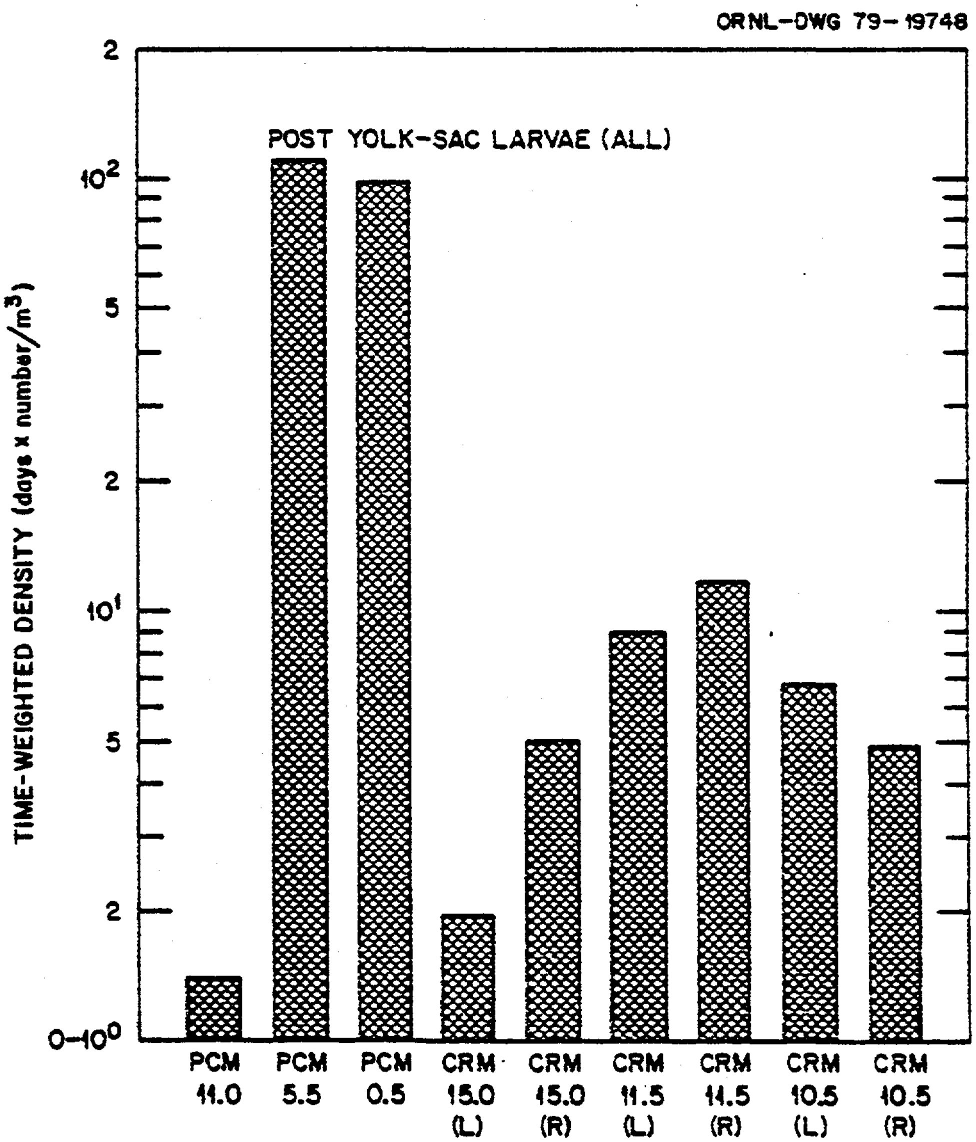

Fig. 1.6.6-8. Time-weighted densities (TWD) of post-yolk-sac larvae (all species combined) at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-4. Pairwise comparisons of time-weighted densities of post-yolk-sac larvae (all species combined) between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		<0.01[b]	<0.01	>0.10	0.10	0.01+[c]	<0.01+	0.04+	0.14+
PCM 5.5			>0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PCM 0.5				<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CRM 15.0 (L)					<0.01+	0.01	<0.01	0.05	>0.10
CRM 15.0 (R)						0.10	0.01	>0.10	>0.10
CRM 11.5 (L)							0.36+	0.41+	0.16+
CRM 11.5 (R)								0.06+	0.01+
CRM 10.5 (L)									0.47+
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

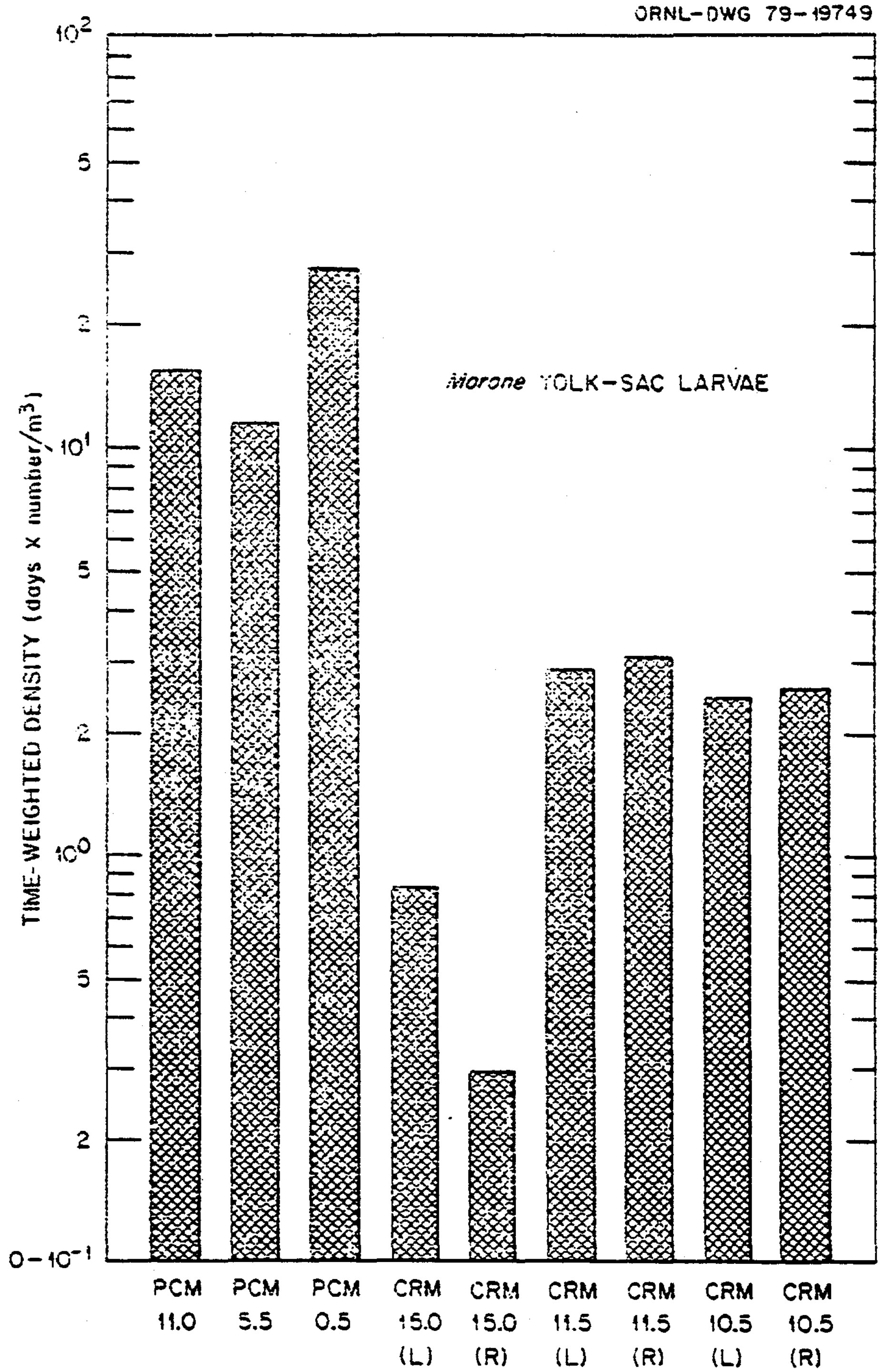

Fig. 1.6.6-9. Time-weighted densities (TWD) of Morone yolk-sac larvae at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-5. Pairwise comparisons of time-weighted densities of *Morone* yolk-sac larvae between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		>0.10[b]	0.01	0.02	0.05	0.05	0.05	0.05	0.03^{+}[c]
PCM 5.5			<0.01^{+}	0.01	0.01	<0.01^{+}	0.01	<0.01^{+}	<0.01^{+}
PCM 0.5				<0.01	<0.01	<0.01^{+}	<0.01	<0.01^{+}	<0.01^{+}
CRM 15.0 (L)					0.40^{+}	>0.10	<0.01^{+}	>0.10	>0.10
CRM 15.0 (R)						>0.10	<0.01^{+}	>0.10	>0.10
CRM 11.5 (L)							>0.10	0.86^{+}	0.93^{+}
CRM 11.5 (R)								>0.10	>0.10
CRM 10.5 (L)									0.95^{+}
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

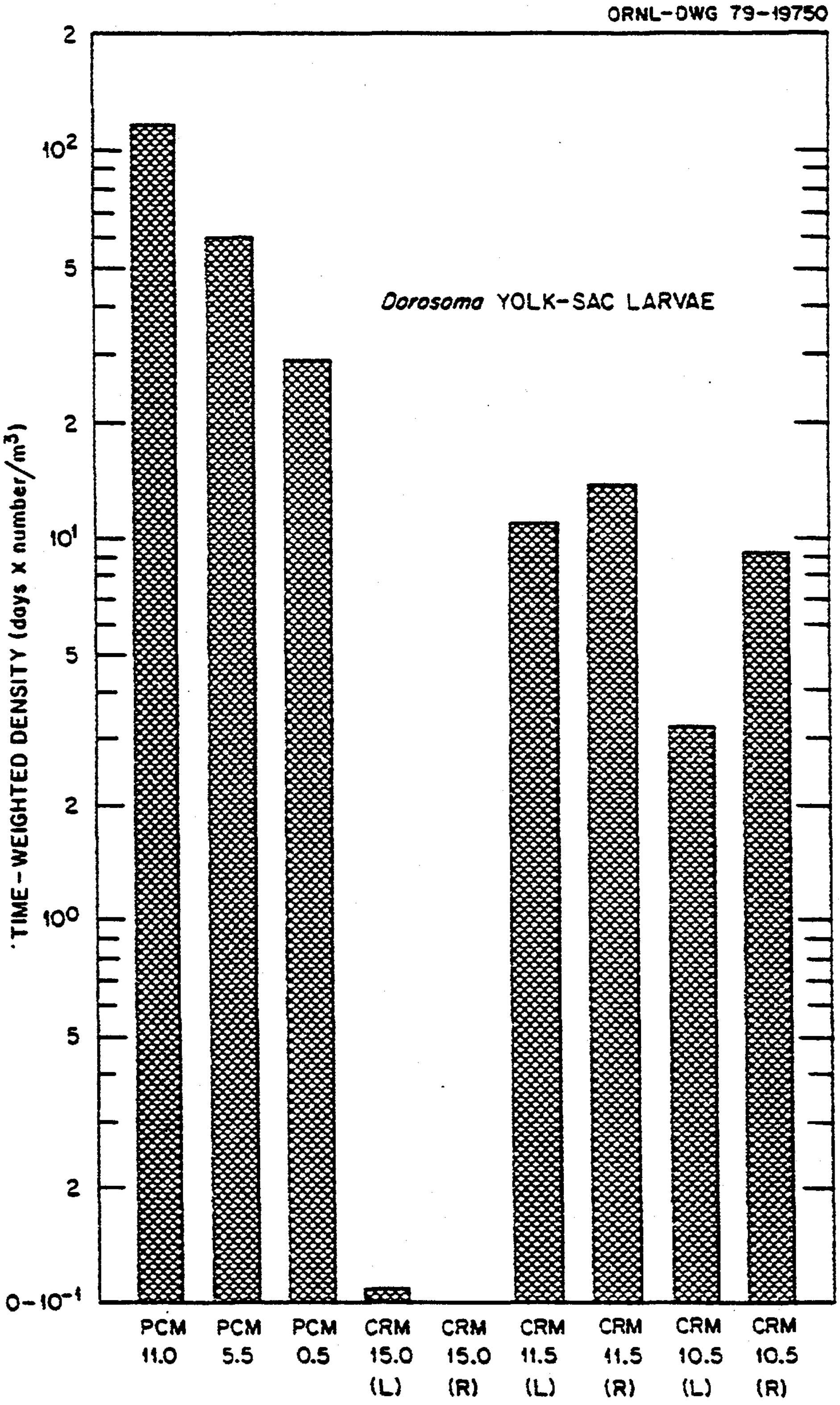

Fig. 1.6.6-10. Time-weighted densities (TWD) of Dorosoma yolk-sac larvae at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-6. Pairwise comparisons of time-weighted densities of Dorosoma yolk-sac larvae between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		$<0.01^{+(b,c)}$	$<0.01^{+}$	$<0.01^{+}$	*d*	<0.01	$<0.01^{+}$	<0.01	$<0.01^{+}$
PCM 5.5			$<0.01^{+}$	$<0.01^{+}$		<0.01	$<0.01^{+}$	<0.01	$<0.01^{+}$
PCM 0.5				$<0.01^{+}$		0.01	$<0.01^{+}$	0.01	<0.01
CRM 15.0 (L)						$<0.01^{+}$	$<0.01^{+}$	0.06^{+}	0.07^{+}
CRM 15.0 (R)									
CRM 11.5 (L)							>0.10	0.01	>0.10
CRM 11.5 (R)								0.05	0.27^{+}
CRM 10.5 (L)									>0.10
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

[d] No Dorosoma yolk-sac larvae were collected at station CRM 15.0 (R).

Dorosoma ysl occurs in Poplar Creek. Some of these yolk-sac larvae are subsequently transported into the Clinch River and are collected downstream from the mouth of the creek.

Figure 1.6.6-11 displays the time-weighted densities of Clupeidae post-yolk-sac larvae. Relative to the Clinch River stations, high TWDs were found in the lower portions of Poplar Creek. However, the time-weighted density for this taxa was lowest at station PCM 11.0, implying that many of the clupeid yolk-sac larvae found at this station (e.g., *Dorosoma* ysl in Fig. 1.6.6-10) do not remain there long enough to develop into the post-yolk-sac stage. This transport of developing clupeid ysl downstream from PCM 11.0 is further shown by a comparison of Figs. 1.6.6-4 and 1.6.6-5, in which a peak in *Dorosoma* ysl at PCM 11.0 on May 23 is followed on May 30 by a peak of Clupeidae pysl at PCM 5.5 and 0.5.

Most of the Clupeidae pysl TWDs of the various Clinch River stations were not significantly different, and in no case was the difference between right and left sides of the river at a given station significant ($P > 0.10$) (Table 1.6.6-7).

Diel distribution

Diel variations in the rate and composition of the ichthyoplankton drift were also examined during 1978. Recurring temporal patterns in drift rates over a 24-h period have been demonstrated for many benthic invertebrates (see review by Adamus and Gaufin 1976). Clifford (1972) observed a pronounced diel drift pattern in the fry of white suckers. Marcy (1973) found fish larvae in greatest densities near the bottom of

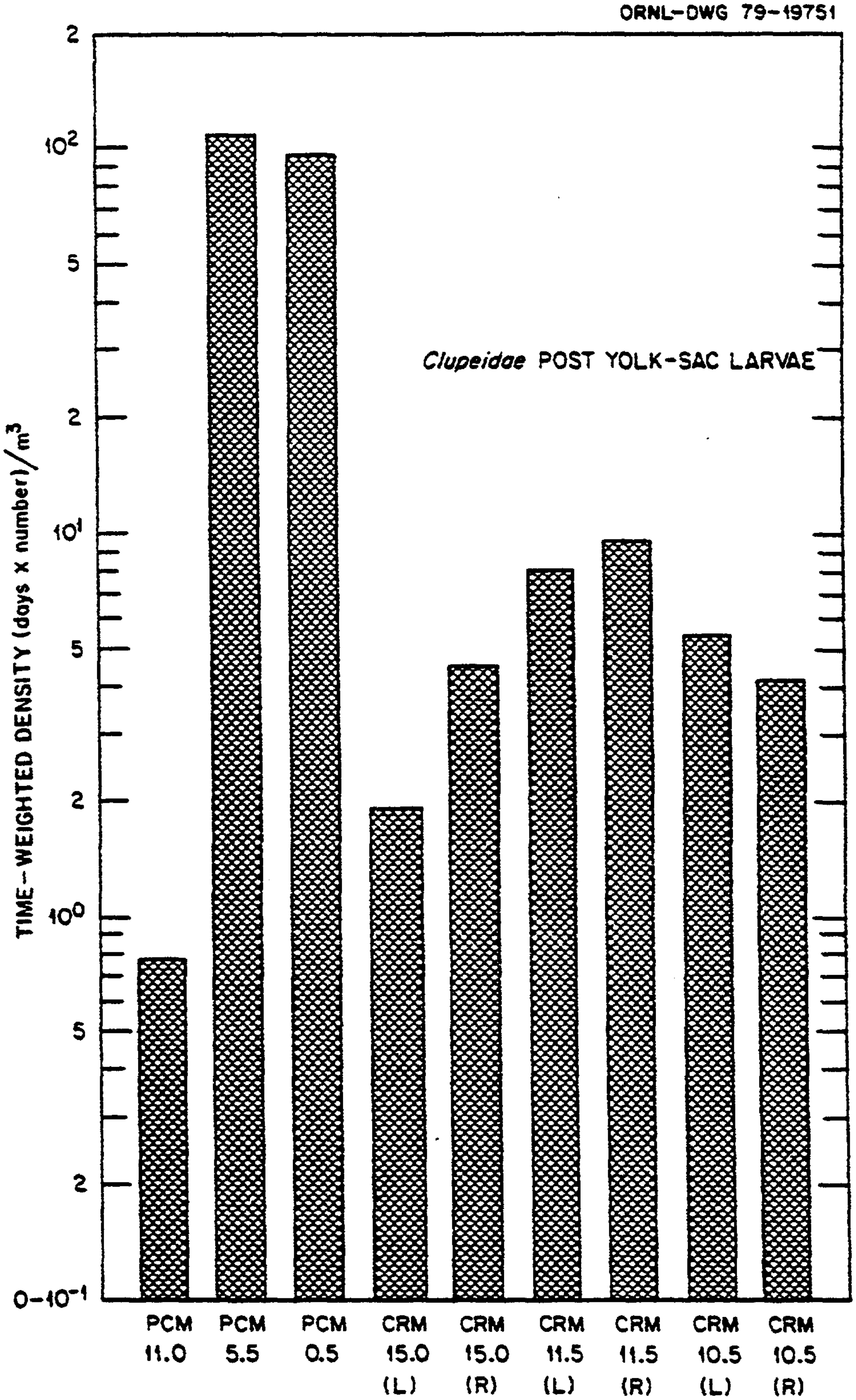

Fig. 1.6.6-11. Time-weighted densities (TWD) of Clupeidae post-yolk-sac larvae at the Poplar Creek and Clinch River ichthyoplankton sampling stations, 1978.

Table 1.6.6-7. Pairwise comparisons of time-weighted densities of Clupeidae post-yolk-sac larvae between ichthyoplankton sampling stations

	PCM[a] 11.0	PCM 5.5	PCM 0.5	CRM 15.0 (L)	CRM 15.0 (R)	CRM 11.5 (L)	CRM 11.5 (R)	CRM 10.5 (L)	CRM 10.5 (R)
PCM 11.0		<0.01[b]	<0.01+[c]	0.46+	>0.10	0.02+	<0.01+	0.07+	0.06+
PCM 5.5			>0.10	<0.01	<0.01+	<0.01	<0.01	<0.01	<0.01
PCM 0.5				<0.01	<0.01+	<0.01	<0.01	<0.01	<0.01
CRM 15.0 (L)					>0.10	0.05	<0.01+	>0.10	0.11+
CRM 15.0 (R)						>0.10	>0.10	>0.10	>0.10
CRM 11.5 (L)							>0.10	0.37+	>0.10
CRM 11.5 (R)								0.07+	<0.01+
CRM 10.5 (L)									>0.10
CRM 10.5 (R)									

[a] Sampling stations are shown on Fig. 1.2-1.

[b] Critical probability values of two-sided tests for equality of time-weighted densities.

[c] + = standard two-sample Student's t-tests were used. If no superscript, Cochran's approximation to the Behrens-Fisher problem was used (see Section 1.3.4).

the Connecticut River during the day and between midwater and the surface at night. Knowledge of diel changes in drift rates and/or spatial distribution of fish larvae, therefore, is important when describing the dynamics of ichthyoplankton in a river system.

In addition, diel sampling is useful for gaining insight into the extent of sampling gear avoidance by motile organisms. For example, visual avoidance is a common occurrence when sampling zooplankton in surface waters during daylight hours (Clutter and Anraku 1968), and can result in underestimates of true organism densities. Large fish larvae are more capable of avoiding a plankton net than are small larvae, and this may be reflected not only in decreased daytime densities but also in smaller mean lengths in daytime samples as compared to nighttime samples.

In view of these considerations, diel ichthyoplankton sampling was conducted on five dates (May 16, May 23, June 6, June 15, July 6) at station PCM 0.5 and on three dates (June 6, June 15, July 6) at CRM 11.5 (L) in 1978. Triplicate daytime samples were collected in the usual manner (Section 1.3.3.6) between 1015 and 1440 hours on each date. Comparable triplicate nighttime samples were taken on the following evening between 2320 and 0200 hours. Fish larvae in these samples were subsequently identified, enumerated, and measured (total length).

Because the presence or absence of daylight was the variable of interest, attempts were made to keep all other factors constant between the day and night samples. However, the difficulty of replicating precise boat speeds (generally ranging between 1.5 and 2.1 m/s) resulted in differences in towing velocities between the day and night collections of up to 0.5 m/s. Of the eight day-night comparisons, nighttime towing velocities were significantly greater than daytime towing velocities in three (Student's t-test, $\alpha = 0.05$); daytime velocities were significantly greater in two cases; and in the remaining three cases the differences were not statistically significant.

Ichthyoplankton taxa that were collected in sufficient numbers for statistical comparisons include Clupeidae pysl, Dorosoma ysl, Morone ysl, Lepomis, and Cyprinus carpio. Two-way analyses of variance (blocked on date) were performed to detect diel differences in the mean densities (log-transformed data) and mean lengths of these taxa. Nighttime densities were significantly greater for C. carpio at PCM 0.5 ($P < 0.05$). Density differences in the seven remaining day-night comparisons were not statistically significant ($P > 0.05$).

While density differences between day and night samples were frequently not significant, the differences in mean total lengths were significant in all of the six possible comparisons (Table 1.6.6-8). Mean total lengths of Clupeidae pysl and Lepomis were significantly greater ($P < 0.01$) in the nighttime samples at both stations. On the other hand, mean total lengths of Morone ysl and Dorosoma ysl at PCM 0.5 were significantly smaller ($P < 0.01$) in the nighttime samples. Because of the small numbers in the samples, comparisons of mean total lengths were not possible for C. carpio at PCM 0.5 and Dorosoma ysl at CRM 11.5 (L).

The results of the diel ichthyoplankton sampling program demonstrate the importance of examining characteristics of the fish larvae other than their densities in the water. Day-night density comparisons

Table 1.6.6-8. Comparisons of mean densities and mean total lengths of ichthyoplankton collected in diel sampling, 1978

Station[a]	Species	Number of individuals	Mean density (no./m^3)		Critical probability[b]	Mean total length (mm)		Critical probability[b]
			Day	Night		Day	Night	
PCM 0.5	Clupeidae pysl	5699	2.81	2.55	0.79	6.4	9.7	<0.01
	Dorosoma ysl	1140	0.69	0.85	0.26	4.4	4.0	0.02
	Morone ysl	103	0.07	0.03	0.09	3.9	3.6	<0.01
	Cyprinus carpio	122	0.00	0.12	0.01		6.9	
	Lepomis	23	0.01	0.01	0.13	6.5	14.1	<0.01
CRM 11.5 (L)	Clupeidae pysl	437	0.18	0.43	0.28	10.5	13.1	<0.01
	Dorosoma ysl	2	0.002	0.002	0.97	5.0	4.5	
	Lepomis	14	0.002	0.01	0.09	6.3	14.4	<0.01

[a]Sampling stations are shown on Fig. 1.2-1.

[b]Critical probability value at which one would reject the null hypothesis of equal densities (mean lengths) between day and night.

showed only one significant difference, whereas diel differences in mean total lengths of the larvae were statistically significant in all cases. The biological significance of these differences, however, is difficult to ascertain in some cases. The greater mean total lengths and densities of Clupeidae pysl and Lepomis in the nighttime samples reflect a trend that would be expected based solely on the assumption of visual avoidance of the sampler by these larger larvae. It is possible, then, that the diel pattern exhibited by these taxa is simply an artifact of biased daytime sampling. On the other hand, yolk-sac larvae (Dorosoma and Morone) had smaller mean total lengths in the night samples, a phenomenon that cannot be explained by net avoidance or extrusion. Sampling efficiency is probably relatively high for these small larvae, and it is likely that the day-night differences observed in this study for yolk-sac larvae are due to some actual diel change in distribution or drift rates. Additional field studies would be necessary to determine the precise reason for these observations. Additional analyses of the diel distribution of ichthyoplankton in Poplar Creek are presented in Cada et al. (1980).

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1.7 SYNTHESIS

(J. M. Loar and G. F. Lada)

The intensive sampling conducted from April 1977 through September 1978 provided information needed to characterize aquatic communities in the vicinity of the Oak Ridge Gaseous Diffusion Plant (ORGDP). Data on community composition, abundance, and distribution are an important prerequisite to an evaluation of the impacts of ORGDP operations. While these data are useful in describing aquatic resources in Poplar Creek and the lower Clinch River, they provide limited insight into how the individual components (species populations) interact functionally to produce the assemblages of species (communities) found in these areas. Species interactions, such as competition and predation, are likely to be important processes in the persistence of biological communities in both space and time. Unfortunately, these processes are very difficult to examine in constantly fluctuating natural environments (compared to the controlled conditions of a laboratory). Without experimental data collected from both the laboratory and field, few inferences can be drawn concerning significant biotic processes that regulate the structure of aquatic communities described in this study.

Abiotic factors are also important determinants of species abundance and distribution, and they are examined further in this section. Available information on some of the physical characteristics of lower Poplar Creek and the Clinch River was integrated with results of the biological survey to develop several hypotheses related to plankton communities. While gaps exist in our knowledge of individual populations that comprise these communities, the intent of this section is to synthesize a framework for examining interrelationships among these various components of the system. The framework described in this section is, to a great extent, speculative because specific studies of the functional interrelationships of the biological communities with their environment were beyond the scope of this project.

The Clinch River near ORGDP is influenced by releases from several hydroelectric dams built and operated by the Tennessee Valley Authority. River flows in this region are regulated mainly by releases at Melton Hill Dam located approximately 17.8 km above the confluence with Poplar Creek. Because the facility is operated to provide power during periods of peak demand, flows can vary considerably over a 24-h period; in fact, periods of no net downstream flow can occur for several hours at a time. Water levels in the lower Clinch River are primarily influenced by operation of Watts Bar Dam located on the Tennessee River, and daily water-level fluctuations are generally less than 0.5 m from late spring to early fall (May-September). Finally, the subsurface withdrawal of cool hypolimnetic water at Norris Dam, located 91 km upstream from Melton Hill Dam, is responsible for the relatively low water temperatures that exist in the lower Clinch River during the summer (summer maximum rarely exceeds 21°C).

The presence of these dams also influences the hydrologic regime found in lower Poplar Creek below ORGDP. Flows in this region can be upstream, downstream, or quiescent, but current velocities are usually low (<15 cm/s during non-storm periods). Also, a marked gradient in temperature of 4 to 6°C between the surface and bottom water occurs during the summer. This gradient is created when the cooler river water enters Poplar Creek and, due to its greater density, sinks beneath the layer of warmer, less dense water of the creek. Water-level fluctuations in the lower creek are similar in magnitude and frequency to those that occur in the river. These observations suggest that lower Poplar Creek, from a hydrologic standpoint, is similar to an estuary, with the density-layering caused by temperature rather than salinity. This analogy not only helps explain results obtained from the plankton sampling during the ORGDP survey but also leads to hypotheses related to aspects of the early life history of reservoir fishes that utilize Poplar Creek as a spawning area.

The existence of upstream and downstream dams results in a complex hydrologic regime that undoubtedly influences the distribution of planktonic species in the study area. The exchange of water masses between the river and the creek probably accounts for the similarity between lower Poplar Creek and the Clinch River in both composition and abundance of phytoplankton and zooplankton. Also, from April to October, surface waters in the creek are warmer than the river. Mixing of the two water masses below their confluence is evidenced by the fact that temperatures at the two river sites below the mouth of the creek were generally higher than the surface water temperatures at the upstream Clinch River station (see Fig. 1.2-1). Similarly, phytoplankton densities at each of the downstream sites were significantly higher ($P < 0.01$) than the density at station CRM 15.0, located approximately 5 km above the mouth of Poplar Creek (Section 1.6.1). These data suggest that lower Poplar Creek can be viewed as an embayment of the Clinch River where reduced water velocities and recruitment of plankton from the river (during net upstream flow in the lower creek) provide for the establishment of plankton communities that are similar in both composition and abundance to those found in the river. This conception, however, may be too simplistic. In our opinion, the unique hydrologic regime created by the presence of both upstream and downstream dams could have important biological consequences which can best be understood by examining some aspects of the ichthyoplankton community found in this area.

Results obtained from weekly sampling of ichthyoplankton in the Clinch River and Poplar Creek suggest that the latter area is an important spawning site for several fish species. Although the identity of the larvae is uncertain, based on (1) the large numbers of sexually mature individuals collected in upper Poplar Creek in April of the preceding year, and (2) known spawning areas (i.e., primary spawning habitats are located in tributary streams), it is likely that the majority of the ichthyoplankton identified as _Morone_ and _Dorosoma_ were white bass and gizzard shad, respectively. The importance of Poplar Creek as a spawning area for shad is illustrated by _Dorosoma_ yolk-sac larval densities, which approached 100 organisms/m^3 at station PCM 11.0, while densities of post-yolk-sac larvae exceeded 50 organisms/m^3 at stations PCM 5.5 and 0.5. Peak clupeid densities in Poplar Creek exceed, by almost an order of magnitude, the densities reported in other studies conducted on reservoirs in the Southeast.

In addition to the importance of Poplar Creek as a spawning area, its unique hydrologic regime near the mouth of the creek probably influences the transport (and possibly the fate) of larvae that drift downstream from spawning sites located in the upper reaches of the creek. This general hypothesis, which is based on our conception of this area as analogous to an estuary, has several interesting implications. If, for example, downstream transport rates are reduced due to hydraulics associated with the presence of upstream and downstream dams, then larvae may reside in this area for an extended period of time. If this residency occurs at a time when zooplankton abundance is at or near the initial peak in late spring, then potentially abundant food resources will be available to early post-yolk-sac larvae that are beginning to utilize exogenous sources of food. The coincidence of high early post-larval densities and an abundant food resource (zooplankton) may be enhanced by the existence of a flow regime similar to that found in estuaries. The increase in water retention time (due to reduced current velocities) could result in a more rapid warming of the surface waters, and both factors (increased residency time and elevated temperatures) may allow the zooplankton populations to increase earlier and more rapidly in this area than in the river. The availability of an abundant food supply at a time when larvae first begin to feed exogenously (the so-called "critical period") may an important factor influencing survival (reproductive success).

In summary, the complex hydrology that exists in lower Poplar Creek and the Clinch River may be an important factor affecting the spatial and temporal distribution of plankton communities. The initial conception of lower Poplar Creek as merely an embayment of or a tributary to the Clinch River is too simplistic and fails to adequately consider the significance of the hydraulic regime created by the operation of

Melton Hill and Watts Bar Dams. Admittedly, many gaps exist in our knowledge of the significance of this regime in influencing species interrelationships. Tailwater tributary streams, such as Poplar Creek, that are located on the upper reaches of a reservoir and thus are influenced by both the upstream and downstream dams are relatively unexplored environments, especially with regard to their significance to the early life history stages of fishes. Understanding how important species interactions (competition, predation) have been modified by the establishment of these environments represents an even greater challenge.

2. TERRESTRIAL ECOLOGY

2.1 Introduction

Various aspects of the terrestrial ecology of the DOE-Oak Ridge Reservation have been investigated over the past 20 years and, as a result, considerable information has been obtained on the flora and fauna of the area (e.g., see Johnson 1964, Olson et al. 1966, Grigal and Goldstein 1971, Anderson et al. 1977, Mann and Bierner 1975, Bradburn 1977, Dahlman et al. 1977, Johnson et al. 1978). Data on the occurrence of threatened and endangered species as well as the distribution of plant communities (and the fauna associated with them) within the DOE Oak Ridge Reservation have been summarized by Kitchings and Mann (1976). Because this baseline descriptive information was already available, a systematic characterization of the terrestrial biota (similar to that conducted for aquatic biota) in the vicinity of the Oak Ridge Gaseous Diffusion Plant (ORGDP) was not performed. However, operation of the ORGDP facilities results in atmospheric releases of fluoride and nickel, and little is known of their accumulation in wild mammal populations. Consequently, a study of the distribution of these substances in terrestrial plant and animal species was included as part of the ORGDP biological sampling program.

2.2 Distribution of Fluoride and Nickel in Plant and Animal Communities in the Vicinity of ORGDP

J. T. Kitchings and J. D. Story

2.2.1 Introduction

In small amounts, fluoride is considered to be an essential nutrient in the development of dental and skeletal tissue in animals. High concentrations, however, have been documented to cause etching of dental surfaces (fluorsis) and osteoporosis (NAS 1971). Grazing animals can accumulate hazardous concentrations from forage crops even though the levels are not hazardous to the plants themselves. While this has been reported to occur in domesticated animals, there are few studies which have documented a similar occurrence among wild animals. Nickel, on the other hand, is usually accumulated in animals by direct inhalation and virtually no data exist on the transfer of nickel compounds from producers to consumers in natural ecosystems.

Gaseous effluents containing fluorides are released by a number of different operations (fluorine plant, hydrogen fluoride tank farm, and the diffusion purge cascade) at the Oak Ridge Gaseous Diffusion Plant, while the release of nickel is confined to the general area of the barrier facility. The purpose of our present investigation was to document the distribution of nickel and fluorides in vegetation and small mammal species around ORGDP. The study was conducted prior to the operation of the purge cascade scrubber system in 1977, so the results reflect pre-scrubber system releases.

2.2.2 Materials and Methods

Vegetation

The vegetation around ORGDP is variable, ranging from fescue fields to mature hardwood stands. Plantations of white pine, loblolly pine, and Virginia pine are also found in the immediate vicinity. The study area is criss-crossed with power lines and roads providing early to mid-successional vegetation which results in abundant populations of small mammals.

The distribution of sampling transects is illustrated in Fig. 2.2-1. Transects were established to correspond with the prevalent wind directions which are generally southwest to northeast. Samples were collected at random from plot centers within a 10-m radius circle (314 m^2) around each point. To facilitate sample collection, measurements along each transect were started at the personnel exclusion fence surrounding the plant. The first point was located 200 m from the fence with subsequent points at 500, 1000, and 2000 m. There were 26 sites in all, and vegetation samples from each point were collected once during a period spanning the middle of May to the first week in June of 1977. Honeysuckle, cedar, pine, grass, and litter were collected, when available, from each site.

The cost of sample analysis prohibited a large number of individual vegetation samples, so all experimental values are for a single sample, pooled from a number of samples taken from each plot. Samples were brought to the laboratory, washed, dried at 100°C for 48 h, then ground in a Wiley Mill through a 40-μm-mesh screen, with cedar being

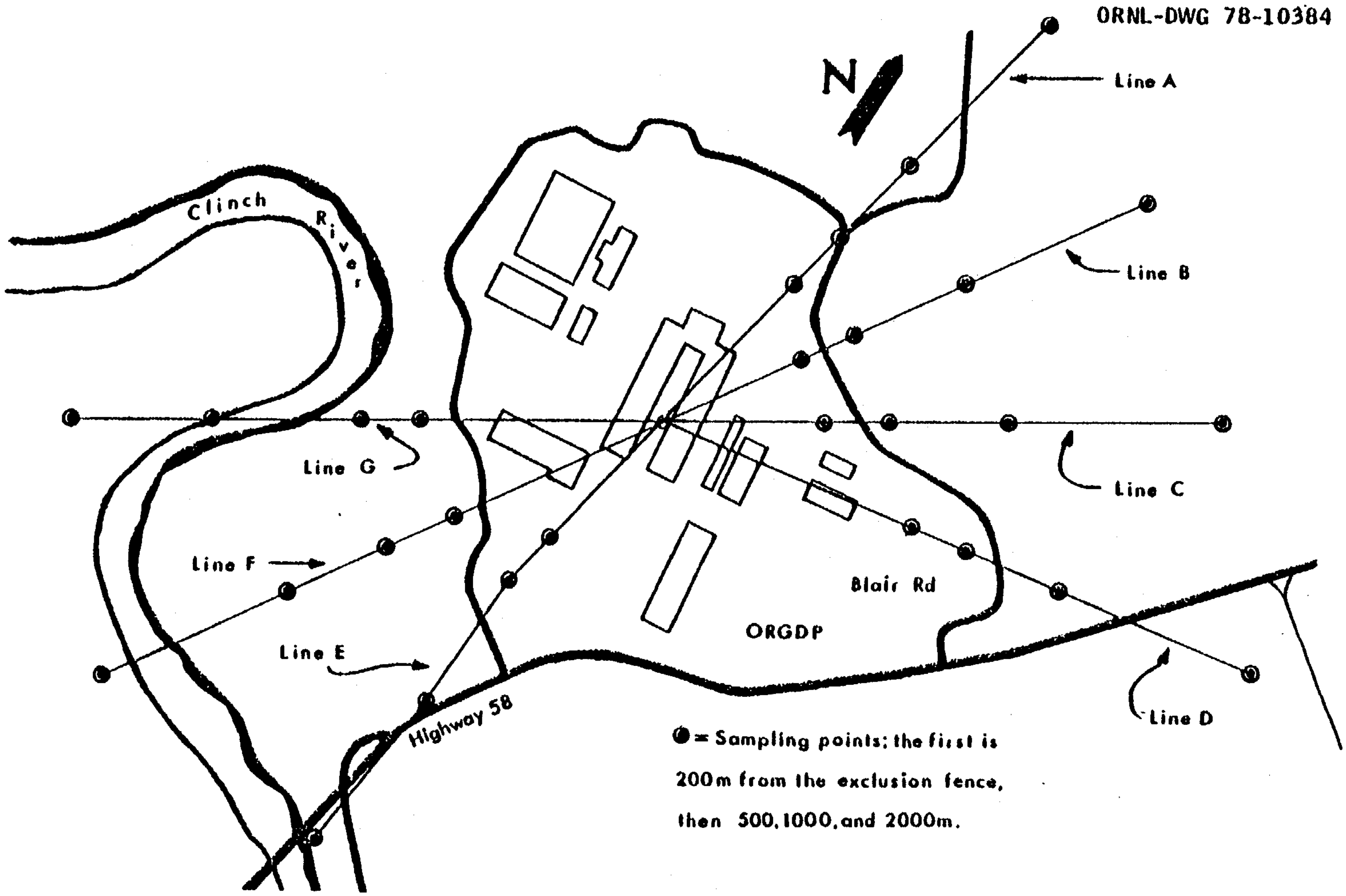

Fig. 2.2-1. Locations of transects and sampling sites where vegetation and small mammals were collected during the ORGDP survey.

ground through a 20-μm-mesh screen. A subsample was taken from the ground material and analyzed by a method described by Galloway et al. (1975). All results are expressed as $\mu gF^{-}/g$, dry wt.

Control samples were collected at random from within a 10-m radius around each of five points located approximately 4.3 km due east of the ORGDP area. These samples were considered to be removed from any known source of F contamination. In fact, they were less than the 10 ppm that Marier and Rose (1971) considered as "normal" for vegetation.

Mammals

Small mammals were trapped during the two periods: May 1-14, 1977, and August 1-14, 1977. Ten Sherman live-traps (8 × 8 × 30.5 cm) were placed at each of the sampling sites. Each trap was baited with sunflower seeds, with the bait being replenished as necessary. Animals were transferred from the traps to kill jars containing cotton soaked with ether. Each animal was marked as to location, date, and species. Samples were frozen until the various tissues could be removed. The femurs were subsequently removed for fluoride analysis and the lungs were taken to be analyzed for nickel. Because the mass of the lungs is generally small, samples from the same species at the same location were lumped to achieve a more precise measurement of the amount of nickel present. The excised tissues were ashed overnight at 550°C. The methodology for elemental determination (specific-ion electrode) was similar to that used for the vegetation.

2.2.3 Results and Discussion

Fluoride distribution

The potential for vegetation damage around ORGDP was identified by utilizing a Gaussian plume dispersion model (AIRDOS) to predict the distribution of hydrogen fluoride (HF) released during routine operations. Dispersion coefficients were calculated for rooftop emissions only (effective stack height of 20 m) to approximate hydrogen fluoride released from sources lower than the steam plant stacks. Additional estimates were made for steam plant stacks using an effective stack height of 100 m. Using literature values as a guide, a dispersion rose, based on areas where potential effects might occur, was constructed (Fig. 2.2-2). An air concentration value of 0.2 $\mu g/m^3$ was arbitrarily chosen as the level above which some damage to sensitive plants might occur. This conservative value was selected to ensure that all areas of potentially high levels could be identified. In actuality, for exposure periods of 1 d, the threshold for foliar marking is usually 3 to 4 $\mu g/m^3$ for susceptible species and for periods of 30 d or longer, exposure to 0.5 $\mu g/m^3$ is a more realistic threshold for susceptible species (NAS 1971).

The results of the dispersion calculations indicated that sectors 1, 8, and 16 would be the most likely candidates for elevated fluoride concentration and subsequent damage resulting from the fluoride releases, providing sensitive species are present. The area encompassed by these sectors does, in fact, have the highest concentrations as determined by actual air monitoring (Union Carbide Corporation, Nuclear Division

ORNL-DWG 81-4613

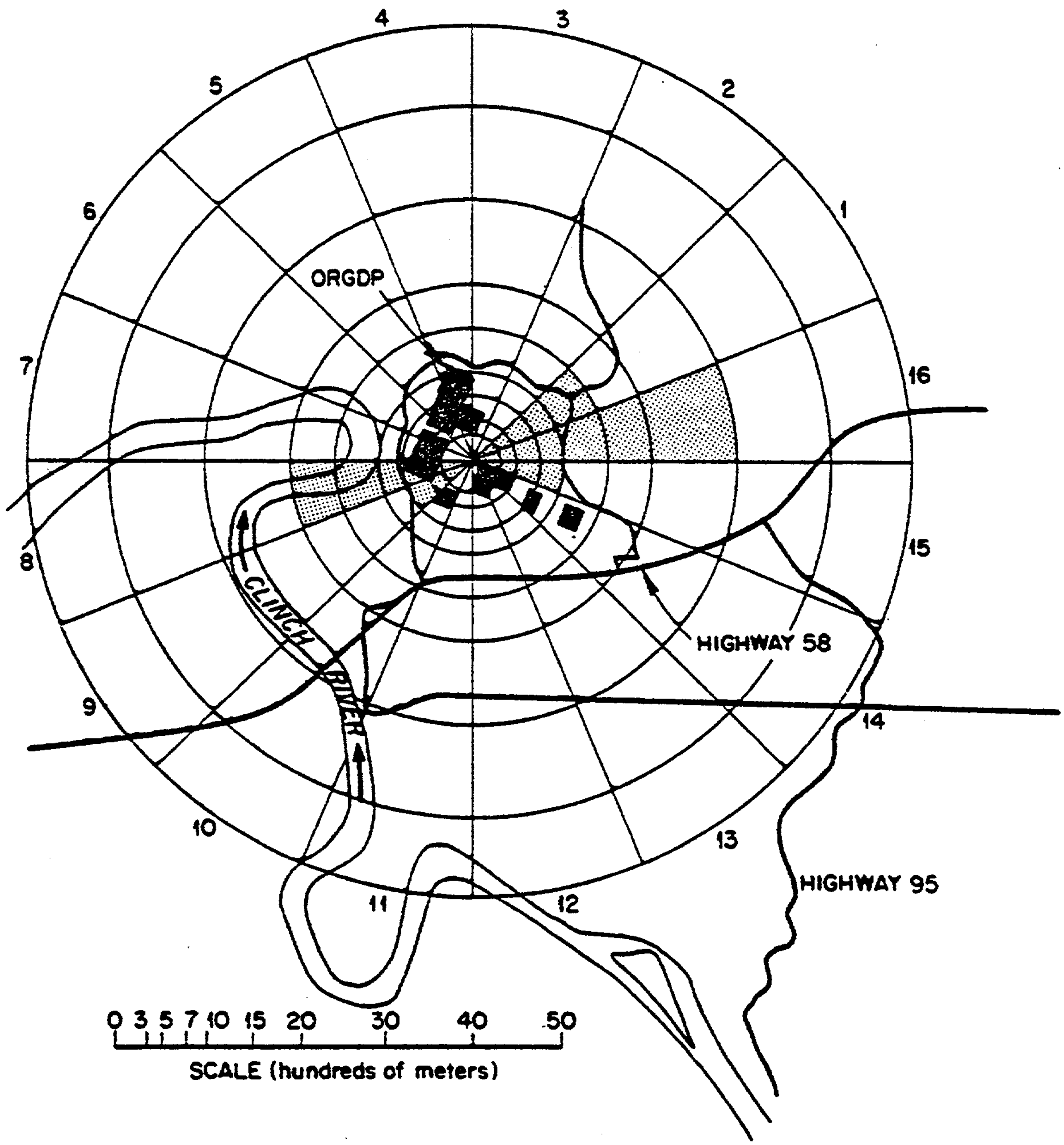

Fig. 2.2-2. Dispersion rose showing areas of potential effects from atmospheric concentrations of total fluorides that are >0.2 μg/m^3.

1978). Verification of the model led to systematic sampling of vegetation and small mammals within these and adjacent sectors. Transect A (Fig. 2.2-1) is the midline for sector 1 (Fig. 2.2-2). Likewise, transect B is the midline for sector 16, C for 15, D for 14, E for 10, F for 9, and G for 8.

Honeysuckle, grass, and litter samples were taken according to their potential usage by small mammal species as food or nesting material. Pine and cedar samples were collected as indicators of fluoride accumulation from UF_6 technologies and subsequent potential for plant damage.

Concentrations of fluorides for the control area and each sampling site are shown in Table 2.2-1. Only at 1000 m and beyond did levels approach control values. Samples taken from transects C and G had the highest values obtained in the study. Even at 1000 m on transect C (plot C-3), concentrations were approximately five times those of the control area, and the concentration of fluorides in litter collected at C-3 exceeded 100 μg/g.

Samples of loblolly pine taken at sites C-1 and C-2 were suspected to have damage from some air pollutant since needle tips were dead and had a brown or red tip indicative of air pollutant damage. While the 22.6- and 24.1-μg/g values did not seem extremely high, a subsequent sampling of damaged needles showed that the concentration of fluoride in the tips of the needles exceeded 50 μg/g in one case and 80 μg/g in another (Table 2.2-2), both of which are above the concentration known to produce damage in susceptible vegetation. Assuming that white pine and Virginia pine would have the same approximate sensitivity to pollutants, we would expect damage to these species in the 200-m area of

Table 2.2-1. Fluoride concentration (μg/g, dry wt) in vegetation in the vicinity of ORGDP. Control values are mean ±1 standard error. Samples size for controls is in parentheses. All experimental values are for a single sample, pooled from a number of samples taken from each plot.

Transect-plot no.	Honeysuckle	Cedar	Pine	Grass (fescue)	Litter
Control	3.8 ± 0.7 (5)	6.9 (2)	5.4 ± 2.2 (3)	4.4 ± 1.0 (4)	8.2 ± 1.2 (5)
A-1	10.2	13.0		10.8	
2	11.5	16.8		10.0	9.4
3	4.1	6.7			7.8
4	3.7		9.6		7.9
B-1	16.6	14.3		11.1	
2	13.0	17.8		23.5	
3	11.5		12.6	6.4	6.3
4	6.2	6.6		3.4	10.1
C-1	36.3	48.3	22.6	6.8	39.6
2	22.5		24.1	20.0	
3	19.3	30.4	26.2		105.0
4	29.6		2.4		5.5
D-1	18.4		21.0	32.0	24.3
2	8.4		6.9		13.6
3	8.5	9.9	9.5	4.4	30.1
4	2.0	7.1			7.7
E-1					
2				6.2	10.0
3	4.3		1.9	3.5	4.5
4	3.0		2.1	2.1	11.1
F-1	26.2		19.5	9.0	20.8
2	14.4		7.3	2.8	15.2
3	27.7	27.2		11.7	16.0
4	4.2		4.4	6.4	4.4

Table 2.2-1 (continued)

Transect-plot no.	Honeysuckle	Cedar	Pine	Grass (fescue)	Litter
G-1	57.8		47.0	11.9	12.0
2	15.5	16.5	21.7		10.3
3	24.3	14.2		14.8	8.2
4				3.8	8.1

Table 2.2-2. Fluoride concentration (μg/g, dry wt) in loblolly pine. Source: F. G. Taylor, unpublished data

	Tip	Base	Whole needle	Tip/base
Control 1	6.7	1.6	4.1	4.2
Control 2	3.4	1.5	1.7	2.3
Damage 1	81.0	5.8	26.1	14.0
Damage 2	54.9	9.2	25.0	10.0

transects C, D, F, and G. Only in C and G would the damage extend beyond 500 m.

The elevated fluoride levels found in honeysuckle collected from transects B, C, D, F, and G could contribute to the F body burden of those species feeding on it. The high concentrations found in several litter samples were probably a result of particulate deposition from sources other than UF_6 related processes, since no effort was made to remove particulate debris from the litter samples. Fly ash and/or resuspension of soil particles could account for the high concentration found. The use of this material for nest building by small mammals could also add to the F exposure to these species.

No evidence of foliar "burn" was noted in eastern red cedar which, on transect C, had a higher concentration than the pines. Weinstein (1977) classified cedars as a tolerant species susceptible only to levels above 200 μg/g.

Data on fluoride concentrations found in seven small mammal species are presented in Table 2.2-3. The white-footed mouse (*Peromyscus leucopus*) and pine vole (*Microtus pinetorum*) were the two most abundant species (total of 108 and 88 individuals, respectively) at most of the sites. Less common species included the golden mouse (*Ochrotomys*

Table 2.2-3. Fluoride concentrations (μg/g, dry wt) in seven small mammal species trapped in the vicinity of ORGDP. Values are mean ±1 standard error. Sample size is in parentheses. NC = no individuals collected. NA = no analysis performed.

Transect-plot no.	*Peromyscus leucopus*	*Microtus pinetorum*	*Ochrotomys nuttalli*	*Tamias striatus*	*Blarina brevicauda*	*Glaucomys volans*	*Sigmodon hispidus*
Control	489.6 ± 27.8 (34)	469.2 ± 74.6 (6)	514.5 ± 57.4 (15)	213 (2)	1345.8 ± 99.6 (8)	NC	NC
A-1	618.0 ± 67.8 (8)	886.0 (1)	736.3 ± 66.4 (3)	497 (1)	1473.0 (1)	NC	NC
2	750.5 ± 57.6 (4)	1050.75 ± 48.2 (16)	NC	812 (1)	2474.3 ± 436.4 (4)	NC	NC
3	639.0 (2)	716.7 ± 63.5 (3)	703.0 ± 90.6 (7)	NC	1889.5 (2)	NC	NC
4	735.5 ± 105.0 (6)	NC	NC	NC	1422.0 (1)	NC	NC
B-1	1235.0 ± 81.2 (5)	1298.5 ± 96.0 (6)	1217.8 ± 98.0 (4)	NC	2262.0 ± 178.4 (6)	NC	NC
2	610.0 ± 47.2 (7)	NC	518.0 ± 120.5 (3)	636 (1)	786.7 ± 392.3 (3)	NC	NC
3	257.4 ± 34.9 (19)	460.4 ± 50.9 (7)	NA	NC	1041.3 ± 187.9 (3)	NC	NC
4	535.2 ± 64.7 (5)	753.0 (1)	759.8 ± 50.0 (8)	NC	NA	NC	NC
C-1	613.6 ± 73.6 (16)	NC	NC	NC	2049.5 (2)	NC	NC
2	1233.4 ± 130.6 (9)	NC	NC	NC	NC	NC	NC
3	505.0 ± 82.0 (5)	1209.0 (1)	NC	NC	NC	NC	NC
4	358.5 (2)	497.0 ± 113.6 (4)	551.0 (1)	NC	1445.0 ± 210.1 (9)	NC	NC
D-1	708.3 ± 115.7 (3)	NC	NC	NC	NC	1157 (1)	NC
2	539.5 (2)	NC	532.0 (1)	NC	NC	NC	NC
3	994.0 ± 132.5 (7)	NC	NC	NC	NC	NC	NC
4	NC	NC	477.5 (2)	NC	NC	NC	NC
E-1	NC	NC	NC	NC	NC	NC	NC
2	NC	341.4 ± 60.3 (5)	NC	NC	1540.0 (1)	NC	328.3 ± 58.7 (6)
3	798.0 (2)	620.0 ± 28.2 (42)	NC	NC	NC	NC	159.0 (2)
4	599.3 ± 82.1 (10)	517.8 ± 45.3 (16)	656.0 (1)	NC	1390.6 ± 68.5 (7)	NC	NC
F-1	815.1 ± 125.4 (8)	959.6 ± 122.8 (12)	NC	NC	2019.0 ± 196.8 (8)	NC	NC
2	487.0 ± 45.3 (7)	NC	NC	NC	NC	NC	NC
3	1038.7 ± 36.7 (3)	NC	NC	230.0 (1)	248.0 (2)	NC	NC
4	530.0 ± 54.8 (3)	530.8 ± 37.9 (25)	NC	NC	1317.6 ± 256.2 (8)	NC	NC
G-1	776.8 ± 85.7 (5)	1032.0 ± 80.5 (15)	NC	NC	1653.2 ± 401.2 (5)	NC	NC
2	1114.0 (1)	906.2 ± 101.6 (6)	NC	NC	1647.0 (1)	NC	NC
3	616.7 ± 26.4 (3)	NC	738.3 ± 223.4 (3)	NC	NC	NC	NC
4	426.8 ± 44.4 (4)	641.3 ± 68.5 (6)	561.0 (1)	NC	NC	NC	NC

nuttali), 25 captures, and the short-haired shrew, *Blarina brevicauda*, 14 captures. Chipmunks (*Tamias striatus*), flying squirrels (*Glaucomys volans*), and cottom rats (*Sigmodon hispidus*) were collected at only a few sites (5, 1, and 3 individuals, respectively).

Mean concentrations of fluoride in species from the control area ranged from 213 to 1345 µg/g. However, values were similar for those species that are principally granivores and/or herbivores (*Peromyscus*, *Ochrotomys*, and *Microtus*), ranging from 491 ± 107 to 676 ± 56 µg/g. The short-tailed shrew, an insectivore, had a significantly higher concentration than the other four species collected from the control area. Shupe and Sharma (1976) reported F concentrations in rock squirrels (*Spermophilus variegatus*) and pack rats (*Neotoma cinerea*) inhabiting the Intermountain Region that ranged from 100 to 1850 µg/g. The concentration of F in the species reported here falls within the range reported by Shupe and Sharma and is, to our knowledge, the first such data available for small mammal species in the Southeast. We found no lesions on either teeth or femurs taken from any of the animals.

There does not appear to be any real relationship between fluoride concentration in small mammal tissues and distance from the exclusion fence. In general, all species exhibited the same trend, with the individuals from the experimental sites having higher concentrations than those from the control site. At site B-1, for example, *Peromyscus*, *Microtus*, and *Ochrotomys* all had fluoride levels that were above 1200 µg/g and significantly higher ($P < 0.01$) than those found in individuals collected from the control area.

No correlations were found between the concentration of F in the femur of small mammals and the concentration of F in honeysuckle, grass, or litter. In fact, those areas where the concentration of fluoride in mammals was significantly different from that of the control appeared to be more or less randomly located. It is probable that an important component of the species' diet was not sampled, thereby making it difficult to compare F concentrations in vegetation and small mammals. The high levels found in shrews, for example, might be related to the fluoride levels in insects, which were not sampled.

Nickel distribution

Nickel concentrations in vegetation in the vicinity of ORGDP are shown in Table 2.2-4. The highest values were found in the areas traversed by transects C and D. Very high concentrations of Ni were evident in all samples collected at the C-1, C-2, D-1, D-2, and D-3 locations. Natural vegetation is reported to have nickel concentrations ranging from 0.5 to 5.0 ppm (NAS 1975). These values are for unwashed samples and may represent particulate material adhering to the surface of the vegetation. Even though excessive levels of nickel can cause chlorosis (NAS 1975), we found no evidence of this in the cedar or pine at transects C and D. The Ni concentrations in controls collected from the same area as the fluoride controls were higher than would be expected from the literature (NAS 1975), so it is possible that Ni pollution is somewhat more extensive than we had initially thought.

As with the fluoride data, there appears to be no correlation between the concentration of Ni in vegetation and that found in the lung

Table 2.2-4. Nickel concentration (μg/g, dry wt) in vegetation in the vicinity of ORGDP. Control values are mean ± 1 standard error. Sample size for controls is in parentheses. All experimental values are for a single sample, pooled from a number of samples taken from each plot.

Transect-plot no.	Honeysuckle	Cedar	Pine	Grass	Litter
Control	11.1 ± 2.4 (5)	2.0 (2)	8.3 ± 0.7 (3)	14.5 ± 1.2 (4)	11.2 ± 4.7 (5)
A-1	8.2	24.7		5.6	
2	8.5	17.2		5.6	30.6
3	12.8	19.7			26.5
4	9.0		8.7		22.8
B-1	18.4	27.3		11.9	
2	9.9	16.1		5.4	
3	10.4		18.8	15.1	14.7
4	10.4	22.2		15.2	29.4
C-1	252.0	335.0	70.7	21.7	741.0
2	81.7		68.1	77.4	
3	47.2	81.6	32.3		160.8
4	26.7		10.8		38.1
D-1	275.0	671.0		102.0	727.0
2	227.2		84.8		970.0
3	110.6	148.0	72.8	19.8	436.9
4	14.7	32.3			44.0
E-1					
2				18.8	74.8
3	5.6		9.5	5.3	35.1
4	3.7		9.2	2.3	40.0
F-1	55.1		20.4	18.1	181.0
2	15.5		16.5	22.0	126.3
3	41.7	68.0		15.7	102.4
4	17.7		7.0	13.1	19.6

Table 2.2-4 (continued)

Transect-plot no.	Honeysuckle	Cedar	Pine	Grass	Litter
G-1	23.3		17.6	15.1	68.2
2	24.7	42.0	16.3		97.6
3	25.7	54.0		21.6	126.9
4				30.4	32.4

tissue of small mammals. No reference to concentrations of Ni in wild mammals was found, but laboratory studies have indicated that Ni absorption from the G-I tract occurs only when the exposure dose is very large (>1000 μg/g). Consequently, we used the lung as the indicator tissue since any nickel inhaled by the animals would readily accumulate there (Sunderman 1973). Because analytical procedure required a sample larger than the lungs from a single animal, the lung tissues from the same species at the same sampling site were pooled for analysis.

The concentrations of nickel found in the lungs of several small mammal species collected near ORGDP are listed in Table 2.2-5. In contrast to the variation in fluoride levels found between species, nickel concentrations were approximately the same in the four species collected from the control area. In addition, no area appeared to be a "hot" spot in terms of increased concentrations in the lungs of small mammals inhabiting the area around ORGDP.

2.2.4 Conclusions

Based on the data we have collected, two primary observations can be made:

1. The levels of F and Ni released from ORGDP are of such a magnitude that damage to sensitive vegetation in the area could occur. This damage would be principally in the southwest-northeast sectors (C, D, F, and G), which are in the track of the prevaling winds, but should not extend beyond 500 m from the ORGDP exclusion fence.

Table 2.2-5. Nickel concentrations (µg/g, dry wt) in six small mammal species trapped in the vicinity of ORGDP. Control values are means with sample size in parentheses. All experimental values are for a single sample, pooled from a number of samples (individuals) collected from each plot. NC = no individuals collected. NA = no analysis performed.

Transect-plot no.	*Peromyscus leucopus*	*Microtus pinetorum*	*Ochrotomys nuttalli*	*Tamias striatus*	*Blarina brevicauda*	*Sigmodon hispidus*
Control	0.63 (4)[a]	<1.0 (1)	0.8 (2)[a]	<1.0 (1)	NA	NC
A-1	<1.0	<1.0	<1.0	NA	NA	NC
2	0.4	0.9	NC	0.6	0.6	NC
3	0.5	0.3	0.5	NC	0.5	NC
4	<1.0	NC	NC	NC	NA	NC
B-1	0.45	0.56	0.62	NC	NA	NC
2	0.41	NC	1.2[a,b]	0.82	0.41	NC
3	0.45[b]	NA	0.7	NC	NA	NC
4	0.5	NA	NA	NC	<1.0	NC
C-1	0.41	NC	NC	NC	NA	NC
2	0.42	NC	NC	NC	NC	NC
3	<0.5	NA	NC	NC	NC	NC
4	<0.7	0.67	NA	NC	0.74	NC
D-1	0.58	NC	NC	NC	NC	NC
2	0.54	NC	NA	NC	NC	NC
3	0.25	NC	NC	NC	NC	NC
4	NC	NC	<0.4	NC	NC	NC
E-1	NC	NC	NC	NC	NC	NC
2	NC	0.3	NC	NC	NA	0.3
3	0.5	1.0[b]	NC	NC	NC	NA
4	<1.0	<1.0	NA	NC	NA	NC
F-1	1.1	0.6	NC	NC	0.7	NC
2	0.36	NC	NC	NC	NC	NC
3	<1.0	NC	NC	<1.0	NA	NC
4	NA	0.47	NC	NC	<0.6	NC
G-1	0.28	0.18[b]	NC	NC	NA	NC
2	<0.6	0.23	NC	NC	NA	NC
3	NA	NC	<0.3	NC	NC	NC
4	<0.8	0.26	NA	NC	NC	NC

[a] Less than signs ignored in computation of mean.

[b] Mean of two samples.

2. There is no indication that the small mammal species inhabiting this same area will suffer any damage from the levels of F and Ni being released. No lesions resulting from excessive fluoride concentrations were noted, even though some levels in the bone were above 3000 μg/g. The concentrations of Ni found in the lung tissues did not appear to differ from the levels observed in animals collected from the control area.

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APPENDICES

APPENDIX A

Appendix A-1. Concentration of metals and PCBs (μg/g wet wt) in muscle tissue of fish collected from Poplar Creek (Station PCM 11.0) in April 1977.

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
White bass										
1	365.9	32.5	0.16	0.09	0.005	5.0	0.5	0.07	<0.5	0.2
2	511.9	35.5	0.21	0.14	0.006	9.0	1.3	<0.02	0.5	0.5
3	470.6	35.0	0.16	0.29	<0.005	3.0	0.5	0.04	0.5	0.4
4	578.1	37.5	0.13	0.24	0.008	4.0	0.5	0.11	<0.5	<0.1
5	355.6	32.3	0.14	0.31	0.005	4.0	0.5	0.04	<0.5	0.2
6	411.2	34.4	0.14	0.34	0.005	4.0	0.9	0.02	<0.5	0.2
7	332.4	31.0	0.16	0.32	<0.005	2.0	0.3	<0.02	<0.5	0.2
8	280.8	30.0	0.10	0.32	<0.005	3.0	0.4	<0.02	<0.5	0.2
9	436.0	34.4	0.18	0.28	0.010	4.0	0.6	<0.02	<0.5	1.0
10	385.2	33.1	0.18	0.23	0.011	4.0	0.6	0.12	0.5	0.3
11	577.0	37.1	0.20	0.21	0.013	6.0	0.6	0.25	0.5	0.2
12	660.9	40.4	0.21	0.09	<0.005	5.0	0.7	0.18	<0.5	0.3
13	344.0	31.3	0.16	0.11	0.011	4.0	0.5	0.02	<0.5	0.3
14	259.4	28.5	0.21	0.11	<0.005	5.0	0.8	0.02	<0.5	0.6
15	185.0	25.2	0.18	0.11	0.005	9.0	0.6	0.09	<0.5	0.3
$\bar{x}$			0.17	0.21	0.008	5.0	0.6	0.09	0.5	0.4
(1 S.E.)			(0.01)	(0.02)	(0.001)	(0.5)	(0.1)	(0.02)	(0)	(0.1)
Bluegill										
1	73.6	15.0	0.32	0.08	0.018	10.0	0.7	0.63	0.5	<0.1
2	60.9	14.5	0.12	0.09	0.008	11.0	0.6	0.19	0.4	0.2
3	43.3	13.4	0.09	<0.05	0.028	10.0	0.8	0.47	0.7	0.4
4	12.3	9.0	0.04	<0.05	0.028	4.0	0.3	0.03	1.5	<0.1
5	4.0	7.2	0.04							
6	17.3	9.9	0.08	<0.05	0.031	6.0	0.3	0.11	0.6	<0.1
7	2.7	6.3	0.04							
8	2.8	6.1	0.03							
$\bar{x}$			0.10	0.09	0.023	8.0	0.5	0.29	0.6	0.3
(1 S.E.)			(0.03)	(0.01)	(0.004)	(1.4)	(0.1)	(0.11)	(0.2)	(0.1)

Appendix A-1 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Gizzard shad										
1	208.0	29.6	0.05	0.14	0.007	7.0	1.4	0.04	<0.5	0.6
2	184.1	27.5	0.05	0.20	<0.005	4.0	0.5	<0.02	<0.5	0.4
3	188.7	28.9	0.03	0.12	<0.005	4.0	1.3	<0.02	0.5	0.4
4	164.7	27.5	0.05	0.09	<0.005	6.0	0.7	<0.02	<0.5	0.2
5	215.0	29.5	0.04	0.12	<0.005	4.0	0.7	<0.02	<0.5	0.4
6	185.8	28.0	0.04	0.20	<0.005	4.0	0.1	0.02	0.5	0.4
7	174.8	28.0	0.03	0.13	<0.005	4.0	0.1	0.05	<0.5	0.2
8	177.5	27.7	0.03	<0.05	0.006	2.0	0.7	0.17	1.0	<0.1
9	178.9	28.2	0.04	0.11	0.006	4.0	0.8	0.09	<0.5	<0.1
10	230.1	29.6	0.03	0.05	0.006	3.0	0.6	0.10	0.5	<0.1
11	191.2	27.5	0.04	<0.05	0.006	5.0	1.0	0.08	<0.5	0.4
12	163.8	27.2	0.04	<0.05	0.013	3.0	0.7	0.12	<0.5	0.1
13	201.0	28.9	0.03	<0.05	0.006	4.0	0.8	0.80	<0.5	<0.1
14	180.1	28.5	0.05	<0.05	0.005	4.0	0.7	0.13	<0.5	<0.1
15	220.0	29.5	0.04	<0.05	0.008	3.0	1.6	0.16	<0.5	<0.1
$\bar{x}$			0.04	0.13	0.007	4.0	0.8	0.16	0.6	0.3
(1 S.E.)			(0.002)	(0.02)	(0.001)	(0.3)	(0.1)	(0.07)	(0.1)	(0.05)
Largemouth bass										
1	221.5	28.3	0.20	0.09	<0.005	5.0	0.4	0.49	<0.5	1.0
<u>Lepomis</u>										
1	15.2	9.5	0.02	<0.05	0.028	7.0	0.38	0.04	1.2	<0.1
2	11.5	8.7	0.06	<0.05	0.021	4.0	0.27	<0.02	1.8	<0.1
$\bar{x}$			0.04		0.024	6.0	0.32		1.5	
(1 S.E.)			(0.02)		(0.004)	(1.5)	(0.06)		(0.3)	

Appendix A-1 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Spotted bass										
1	2.5	6.6	0.02							
2	7.5	9.5	0.30							
$\bar{x}$			0.16							
(1 S.E.)			(0.14)							
Freshwater drum										
1	144.0	25.0	0.15	0.25	0.012	6.0	0.2	<0.02	<0.5	
Channel catfish										
1	39.2	18.5	0.04							

[a] Less than (<) values were ignored in computing the mean and standard error.

Appendix A-2. Concentration of metals and PCBs (µg/g wet wt) in muscle tissue of fish collected from Poplar Creek (Station PCM 5.5) in the spring (April-May) and fall (November) 1977.

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
White bass (spring)										
1	222.8	26.5	0.13	<0.05	0.008	6.0	0.4	<0.02	<0.5	<0.1
2	244.3	27.5	0.16	<0.05	0.008	6.0	0.4	0.03	<0.5	0.6
3	228.4	30.0	0.16	<0.05	0.010	4.0	0.5	<0.02	<0.5	<0.1
4	634.3	38.5	0.25	<0.05	0.008	4.0	0.4	<0.02	<0.5	<0.1
5	567.6	36.8	0.22	<0.05	0.008	4.0	0.6	0.02	0.5	<0.1
6	582.1	35.8	0.17	<0.05	0.007	5.0	0.5	0.02	<0.5	1.4
7	522.0	36.0	0.13	<0.05		4.0	0.4	<0.02	<0.5	<0.1
8	444.2	54.0	0.59	<0.05		4.0	0.4	<0.02	<0.5	<0.1
9	460.0	34.5	0.13	<0.05		7.0	0.4	0.04	0.5	0.6
10	649.8	40.0	0.16	<0.05	0.010	4.0	0.4	<0.02	0.5	1.3
11	533.0	35.0	0.24	<0.05	0.008	2.0	0.3	<0.02	<0.5	1.6
12	492.5	35.0	0.13	<0.05	0.006	4.0	0.4	0.02	<0.5	0.4
13	551.7	36.5	0.14	<0.05	0.006	4.0	0.3	0.02	<0.5	1.0
14	559.1	37.8	0.17	<0.05	<0.005	7.0	0.4	0.12	3.0	<0.1
15	636.6	39.5	0.20	0.09	0.005	2.0	0.8	0.11	3.5	<0.1
16	557.0	37.5	0.17	0.05	<0.005	3.0	0.8	0.05	2.5	<0.1
17	482.8	34.0	0.13	0.05	<0.005	4.0	0.5	0.05	2.5	<0.1
$\bar{x}$			0.19	0.06	0.008	4.0	0.5	0.05	2.0	1.0
(1 S.E.)			(0.03)	(0.01)	(0.001)	(0.4)	(0.04)	(0.01)	(0.5)	(0.2)
Largemouth bass (spring)										
1	239.8	26.8	2.14	0.21	0.014	9.0	0.3	0.06	<0.5	
2	138.6	22.0	1.67	0.29	0.016	8.0	0.3	0.07	<0.5	
$\bar{x}$			1.90	0.25	0.015	8.0	0.3	0.06		
(1 S.E.)			(0.24)	(0.04)	(0.001)	(0.5)	(0)	(0.005)		

Appendix A-2 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
White crappie (spring)										
1	169.3	24.4	0.19	0.10	0.006	5.0	0.2	<0.02	0.6	
2	51.7	16.9	0.37	<0.05	0.022	5.0	0.2	<0.02	1.3	
$\bar{x}$			0.28		0.014	5.0	0.2		1.0	
(1 S.E.)			(0.09)		(0.008)	(0)	(0)		(0.4)	
White crappie (fall)										
1	134.4	23.0	0.72	<0.05	0.014	3.0	0.3	0.02	<0.5	
2	141.2	22.7	0.29	<0.05	0.015	5.0	0.3	0.02	<0.5	0.2
3	17.0	12.1	0.79	<0.05	0.012	4.0	0.3	<0.02	<0.5	
4	16.5	12.6	0.69							
5	18.0	12.6	0.81	<0.05	0.014	6.0	0.3	0.02	0.7	0.6
$\bar{x}$			0.66		0.014	5.0	0.3	0.02		0.4
(1 S.E.)			(0.10)		(0.001)	(0.6)	(0)	(0)		(0.2)
Bluegill (spring)										
1	72.6	15.0	0.38	0.08	0.024	4.0	0.38	<0.02	<0.5	<0.1
2	24.2	11.1	0.17	<0.05	0.031	6.0	0.27	<0.02	0.9	0.4
3	10.7	8.9	0.15	<0.05	0.028	10.0	0.42	<0.02	1.2	<0.1
4	4.0	6.7	0.04							
5	4.0	6.8	0.33							
6	2.3	6.1	0.05							
7	100.0	16.3	0.09	0.17	0.005	7.0	0.3	<0.02	1.3	
$\bar{x}$			0.17	0.12	0.022	7.0	0.34		1.1	
(1 S.E.)			(0.06)	(0.04)	(0.006)	(1.2)	(0.03)		(0.1)	

Appendix A-2 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Lepomis (spring)										
1	39.7	12.7	0.32	0.10	0.012	6.0	0.2	<0.02	0.9	
2	61.0	14.4	0.32	0.12	0.008	7.0	0.2	<0.02	0.7	
3	37.5	12.5	0.27	0.10	0.023	7.0	0.4	<0.02	0.9	
4	30.5	11.7	0.44	0.07	0.050	8.0	0.2	<0.02	1.1	
5	19.0	10.1	0.51	0.25	0.018	13.0	0.3	0.03	<0.5	
6	4.3	6.5	0.09							
7	3.3	6.0	0.06							
$\bar{x}$			0.29	0.13	0.022	8.0	0.3		0.9	
(1 S.E.)			(0.06)	(0.03)	(0.007)	(1.2)	(0.04)		(0.1)	
Lepomis (fall)										
1	80.1	16.2	0.98	<0.05	0.015	9.0	0.3	0.02	0.6	
2	93.8	17.0	0.37	<0.05	0.010	5.0	0.3	0.02	0.6	0.2
3	89.4	16.6	0.56	<0.05	0.011	5.0	0.3	<0.02	0.5	
4	53.2	14.0	0.33	0.07	0.006	4.0	0.3	<0.02	0.6	
5	39.0	13.4	0.11	0.08	0.027	7.0	0.4	<0.02	0.5	
6	26.7	11.6	0.40	0.16	0.011	6.0	0.3	<0.02	<0.5	0.2
7	25.7	11.3	0.52	<0.05	0.011	6.0	0.2	<0.02	<0.5	
8	20.0	10.7	0.17	<0.05	0.016	6.0	0.4	0.02	0.5	
$\bar{x}$			0.43	0.10	0.013	6.0	0.3	0.02	0.6	0.2
(1 S.E.)			(0.10)	(0.03)	(0.002)	(0.5)	(0.02)	(0)	(0.02)	(0)

Appendix A-2 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Gizzard shad (spring)										
1	401.5	34.0	0.04	0.13	0.011	4.0	0.8	0.10	1.0	0.9
2	385.9	35.0	0.04	0.13	0.009	4.0	0.6	0.02	1.0	<0.1
3	460.4	34.5	0.03	0.07	0.008	2.0	0.6	<0.02	0.5	<0.1
4	426.1	36.0	0.04	0.09	0.008	4.0	0.7	0.05	0.5	<0.1
5	359.4	33.0	0.04	0.08	0.008	4.0	0.9	0.20	0.5	<0.1
6	289.4	31.5	0.05	<0.05	0.005	4.0	0.9	0.09	1.0	
7	362.3	33.0	0.03	0.11	0.009	4.0	0.7	0.10	0.5	
8	321.4	33.5	0.04	0.15	0.006	3.0	0.7	0.09	1.0	<0.1
9	155.2	26.3	0.03	0.06	0.006	4.0	0.8	0.02	0.5	<0.1
10	252.8	29.6	0.03	<0.05	0.007	4.0	0.6	0.03	0.5	<0.1
11	245.2	30.3	0.05	0.05	<0.005	4.0	0.8	0.05	1.0	<0.1
12	205.5	29.2	0.05	<0.05	0.006	3.0	0.8	0.03	0.5	<0.1
13	179.6	27.6	0.05	<0.05	0.008	4.0	0.4	<0.02	<0.5	<0.1
14	255.8	30.5	0.04	<0.05	0.010	6.0	0.5	<0.02	<0.5	<0.1
15	181.9	26.4	0.08	<0.05	0.008	4.0	0.8	<0.02	0.5	0.5
$\bar{x}$			0.04	0.10	0.008	4.0	0.7	0.07	0.7	0.7
(1 S.E.)			(0.003)	(0.01)	(0.0004)	(0.2)	(0.04)	(0.02)	(0.1)	(0.2)
Channel catfish (spring)										
1	908.0	46.0	0.34	0.06	0.012	6.0	0.4	0.12	0.5	7.0
2	1180.4	50.0	0.61	0.06	0.008	5.0	0.5	0.03	<0.5	2.2
3[b]	690.0	45.0	0.61	0.21	0.005	5.0	0.3	<0.02	1.5	—
$\bar{x}$			0.52	0.11	0.008	5.0	0.4	0.08	1.0	4.6
(1 S.E.)			(0.09)	(0.05)	(0.002)	(0.3)	(0.1)	(0.05)	(0.5)	(2.4)

Appendix A-2 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Freshwater drum (spring)										
1	488.6	35.0	0.18	0.06	0.012	4.0	0.4	0.18	0.5	2.0
2	207.1	26.5	0.16	<0.05	0.008	3.0	0.5	0.03	<0.5	0.6
$\bar{x}$			0.16		0.010	4.0	0.4	0.10		1.3
(1 S.E.)			(0.005)		(0.002)	(0.5)	(0.05)	(0.08)		(0.7)
Longnose gar (spring)										
1	2383.5	37.0	0.62	<0.05	0.015	4.0	0.7	0.02	<0.5	3.7
Spotted gar (spring)										
1	1589.0	70.0	0.37	0.06	0.021	5.0	0.5	0.04	<0.5	2.6

[a] Less than (<) values were ignored in computing the mean and standard error.

[b] Collected on May 26, 1977; all other fish in spring collection were taken on April 13 and 25, 1977.

Appendix A-3. Concentration of metals and PCBs (μg/g wet wt) in muscle tissue of fish collected from Poplar Creek (Station PCM 0.5) in the spring (April-May) and fall (November) 1977.

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
White bass (spring)										
1	465.3	34.0	0.12	0.05	<0.005	4.0	0.8	0.08	3.0	<0.1
2	234.0	28.0	0.11	<0.05	<0.005	5.0	0.5	0.05	2.0	<0.1
3	419.6	31.0	0.09	0.13	0.011	6.0	0.6	<0.02	2.0	<0.1
4	415.8	35.0	0.23	<0.05	0.016	7.0	0.6	<0.02	1.5	<0.1
5	647.6	28.2	0.17	0.11	0.007	3.0	0.7	<0.02	2.0	1.0
6	540.0	35.0	0.18	0.12	0.008	6.0	0.6	0.1	0.5	3.5
7	487.0	34.5	0.17	<0.05	0.013	5.0	1.0	0.2	1.5	1.5
8[b]	58.6	17.2	0.42	0.09	0.010	11.0	0.4	<0.02	1.0	
9[b]	63.6	18.3	0.06	0.17	0.006	6.0	0.4	0.04	0.8	
$\bar{x}$			0.17	0.11	0.010	6.0	0.6	0.09	1.6	2.0
(1 S.E.)			(0.04)	(0.04)	(0.001)	(0.8)	(0.1)	(0.04)	(0.2)	(0.8)
White bass (fall)										
1	111.3	21.3	0.30	<0.05	0.004	7.0	0.3	<0.02	<0.5	
2	121.3	21.5	0.04	<0.05	0.009	4.0	0.8	0.11	<0.5	0.2
3	82.7	19.5	0.27	0.14	0.010	4.0	0.8	0.02	<0.5	
4	53.0	16.8	0.05	0.09	0.012	5.0	0.2	<0.02	<0.5	0.1
$\bar{x}$			0.16	0.12	0.009	5.0	0.5	0.06		0.2
(1 S.E.)			(0.07)	(0.02)	(0.002)	(0.7)	(0.2)	(0.04)		(0.05)

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Striped bass (spring)										
1	359.8	33.4	0.08	<0.05	<0.005	3.0	0.5	0.02	2.0	0.1
2[b]	73.2	19.5	0.12	0.12	0.005	7.0	0.3	0.04	0.7	
3[b]	69.0	18.8	0.21	0.18	0.009	6.0	0.3	<0.02	0.7	
$\bar{x}$			0.14	0.15	0.007	5.0	0.4	0.03	1.1	
(1 S.E.)			(0.04)	(0.03)	(0.002)	(1.2)	(0.1)	(0.01)	(0.4)	
Largemouth bass (spring)										
1	127.2	21.8	0.25	<0.05	0.016	9.0	0.8	0.03	<0.5	0.4
2	28.6	14.9	0.04	<0.05	0.014	10.0	0.7	0.12	<0.5	<0.1
3	108.0	20.4	0.26	<0.05	0.009	9.0	0.6	0.02	<0.5	0.4
4	36.7	14.7	0.23	<0.05	0.011	9.0	0.7	0.46	<0.5	0.9
5	19.9	12.7	0.51	<0.05	0.037	19.0	0.6	1.08	1.3	0.6
6	156.1	22.5	0.15	<0.05	0.016	6.0	0.32	0.04	<0.5	0.1
7	126.7	21.2	0.19	<0.05	0.017	6.0	0.28	0.06	<0.5	0.2
8	110.5	20.7	0.13	<0.05	0.013	5.0	0.23	0.03	<0.5	0.3
9	15.1	12.4	0.05							
10	11.8	11.0	0.14							
$\bar{x}$			0.20		0.017	9.0	0.5	0.23		0.4
(1 S.E.)			(0.04)		(0.003)	(1.6)	(0.1)	(0.13)		(0.1)

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Largemouth bass (fall)										
1	18.1	11.6	0.87	0.15	0.014	4.0	0.3	<0.02	<0.5	0.4
2	13.3	10.8	0.55							
3	103.9	19.2	0.71	0.10	0.012	6.0	0.3	<0.02	<0.5	0.2
$\bar{x}$			0.71	0.12	0.013	5.0	0.3			0.3
(1 S.E.)			(0.09)	(0.02)	(0.001)	(1.0)	(0)			(0.1)
Silver red-horse (spring)										
1	865.5	43.0	0.16	0.14	0.008	8.0	0.9	0.02	1.0	
2	629.6	36.5	0.15	<0.05	<0.005	1.0	0.8	0.04	1.0	
$\bar{x}$			0.16			4.0	0.8	0.03	1.0	
(1 S.E.)			(0.005)			(3.5)	(0.05)	(0.01)	(0)	
Spotted sucker (spring)										
1	702.6	42.0	0.09	0.11	<0.005	4.0	0.9	0.02	1.0	
2	115.0	22.1	0.07	0.18	<0.005	6.0	0.6	0.02	0.5	0.1
$\bar{x}$			0.08	0.14		5.0	0.8	0.02	0.8	
(1 S.E.)			(0.01)	(0.04)		(1.0)	(0.2)	(0)	(0.2)	

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Bluegill (spring)										
1	112.4	17.7	0.32	<0.05	0.026	9.0	0.4	0.56	1.0	0.1
2	65.5	15.2	0.33	<0.05	0.012	12.0	0.4	0.05	<0.5	0.2
3	41.2	13.4	0.39	0.10	0.080	16.0	0.4	1.01	0.5	0.8
4	18.3	10.2	0.16	0.05	0.013	20.0	0.7	0.02	1.3	0.5
5	15.0	10.0	0.20	<0.05	0.015	18.0	0.6	0.02	0.9	0.4
6	25.2	11.8	0.15	<0.05	0.023	5.0	0.34	0.04	<0.5	<0.1
7			0.07	<0.05	0.023	6.0	0.31	0.02	0.8	<0.1
8	22.3	11.5	0.14	<0.05	0.028	7.0	0.25	0.02	0.7	0.3
9	21.9	11.2	0.16	0.08	0.028	4.0	0.41	0.02	0.7	<0.1
10	132.5	19.5	0.20	0.05	0.019	3.0	0.23	0.02	<0.5	0.7
11	29.8	13.3	0.32	<0.05	0.026	8.0	0.14	0.04	0.6	0.3
12	19.6	11.0	0.10	<0.05	0.021	8.0	0.29	0.08	1.1	0.3
13	5.8	7.5	0.11							
14	80.3	15.8	0.15	<0.05	0.016	7.0	0.31	0.02	<0.5	<0.1
15	3.0	6.2	0.10							
$\bar{x}$			0.19	0.07	0.025	10.0	0.37	0.15	0.8	0.4
(1 S.E.)			(0.03)	(0.01)	(0.005)	(1.5)	(0.04)	(0.08)	(0.1)	(0.1)
<u>Lepomis</u> (spring)										
1	77.9	16.7	0.10	<0.05	0.020	6.0	0.23	0.02	<0.5	<0.1
<u>Lepomis</u> (fall)										
1	122.1	18.0	0.29	0.20	0.013	5.0	0.1	0.13	<0.5	
2	77.5	16.1	0.43	0.13	0.011	7.0	0.1	<0.02	<0.5	
3	51.5	14.2	0.43	0.11	0.018	8.0	0.2	0.03	<0.5	
4	60.6	16.1	1.10	0.11	0.015	9.0	0.1	<0.02	<0.5	

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Lepomis (fall) (continued)										
5	49.4	13.8	0.77	0.11	0.015	10.0	0.1	<0.02	<0.5	
6	48.7	14.3	0.38	0.10	0.008	6.0	0.1	0.02	<0.5	1.1
7	53.5	14.9	0.52	0.09	0.010	8.0	<0.1	0.02	0.6	
8	57.0	15.4	0.65	0.10	0.011	10.0	0.1	0.03	<0.5	
9	48.5	14.2	0.70	0.17	0.018	8.0	<0.1	<0.02	<0.5	
10	2.2	5.5	0.78							
11	1.7	4.9	0.76							
$\bar{x}$ (1 S.E.)			0.62 (0.07)	0.12 (0.01)	0.013 (0.001)	8.0 (0.6)	0.11 (0.01)	0.05 (0.02)		
White crappie (spring)										
1	95.6	20.1	0.08	<0.05	0.012	4.0	0.25	0.02	<0.5	0.2
2	182.0	24.0	0.08	<0.05	0.012	5.0	0.21	0.03	<0.5	<0.1
3	110.3	20.8	0.09	<0.05	0.012	6.0	0.19	0.06	<0.5	0.8
4	105.7	20.5	0.05	<0.05	0.005	6.0	0.27	<0.02	<0.5	<0.1
5	87.0	20.0	0.12	<0.05	0.005	6.0	0.27	<0.02	<0.5	1.2
6	73.6	19.1	0.06	<0.05	0.007	8.0	0.23	<0.02	<0.5	<0.1
7	67.4	18.3	0.06	<0.05	<0.005	4.0	0.25	<0.02	<0.5	<0.1
8	55.0	17.2	0.11	<0.05	0.006	7.0	0.26	<0.02	<0.5	0.2
9	53.9	18.0	0.04	<0.05	<0.005	6.0	0.23	<0.02	<0.5	0.1
10	56.8	17.2	0.07	<0.05	<0.005	8.0	0.39	<0.02	<0.5	0.4
11	38.3	16.2	0.04	<0.05						
12	60.6	17.5	0.14	0.27	0.005	6.0	0.3	<0.02	0.7	
$\bar{x}$ (1 S.E.)			0.08 (0.01)		0.008 (0.001)	6.0 (0.4)	0.26 (0.02)	0.04 (0.01)		0.5 (0.2)

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
White crappie (fall)										
1	300.2	26.9	0.13	0.07	0.012	5.0	0.4	<0.02	0.5	
Gizzard shad (spring)										
1	192.1	27.9	0.02	<0.05	<0.005	1.0	0.6	0.19	2.0	0.3
2	204.3	28.5	0.04	<0.05	0.007	2.0	0.6	0.04	1.5	0.2
3	238.0	30.0	0.06	0.08	0.008	3.0	1.6	0.06	6.0	<0.1
4	257.2	29.0	0.10	0.06	<0.005	2.0	1.3	0.07	3.0	0.5
5	191.5	28.0	0.09	0.05	<0.005	4.0	1.3	0.03	3.5	0.5
6	255.6	30.0	0.05	0.06	<0.005	2.0	1.1	0.09	2.5	0.4
7	300.9	31.3	0.03	0.05	<0.005	2.0	0.8	0.11	2.0	0.3
8	187.1	27.2	0.03	0.05	0.005	3.0	0.5	<0.02	2.1	0.1
9	270.0	29.6	0.03	<0.05	<0.005	1.0	0.6	0.07	2.0	0.2
10	290.7	30.4	0.03	<0.05	<0.005	2.0	0.6	<0.02	2.5	0.4
11	468.7	34.6	0.03	<0.05	<0.005	1.0	0.6	<0.02	2.5	0.2
12	266.1	29.0	0.04	<0.05	0.005	4.0	0.5	0.05	3.5	0.4
13	288.3	31.4	0.05	0.05	<0.005	2.0	0.5	0.03	3.0	0.4
14	342.2	32.8	0.03	0.11	<0.005	4.0	0.6	0.03	<0.5	0.4
15	184.5	26.8	0.03	0.10	<0.005	6.0	0.5	0.03	<0.5	0.4
16	46.5	17.0	0.21	0.11	0.005	10.0	1.9	0.03	<0.5	0.1
17	52.4	17.6	0.04	0.12	0.005	8.0	2.0	0.02	<0.5	0.4
18	427.8	34.5	0.03	0.10	0.008	5.0	1.0	0.02	1.5	
19	216.6	29.0	0.05	<0.05	<0.005	4.0	0.9	0.02	2.0	
20	375.0	34.0	0.06	0.07	<0.005	6.0	0.8	<0.02	2.5	
21	354.4	33.0	0.03	0.08	<0.005	6.0	1.0	0.02	2.0	
22	356.0	33.0	0.02	<0.05	0.012	2.0	0.3	<0.02	2.0	<0.1
23	440.5	35.5	0.05	<0.05	0.009	4.0	1.2	<0.02	2.0	1.0
24	432.4	36.5	0.04	<0.05	0.011	2.0	1.2	<0.02	<0.5	<0.1

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Gizzard shad (spring) (continued)										
25	191.2	28.0	0.02	<0.05	0.011	8.0	2.7	<0.02	2.5	<0.1
26	308.6	30.5	0.04	0.17	0.009	3.0	1.6	<0.02	<0.5	0.5
$\bar{x}$			0.05	0.08	0.008	4.0	1.0	0.05	2.5	0.4
(1 S.E.)			(0.01)	(0.01)	(0.001)	(0.5)	(0.1)	(0.01)	(0.2)	(0.05)
Channel cat-fish (spring)										
1	1280.0	49.5	0.29	0.09	0.006	6.0	0.3	<0.02	1.1	
2	2724.0	61.0	0.44	0.14	<0.005	6.0	0.6	0.12	0.5	1.3
3	178.9	27.6	0.08	0.11	<0.005	8.0	0.4	0.10	0.5	<0.1
4	311.0	33.5	0.23	<0.05	<0.005	3.0	0.4	0.11	4.0	0.4
5	224.7	30.0	0.27	0.06	0.006	2.0	0.5	0.04	5.0	0.4
6	324.0	36.0	0.13	0.14	0.005	6.0	1.4	1.1	1.0	2.0
7	285.5	34.0	0.20	0.21	0.009	6.0	0.7	>1.6	<0.5	3.5
8	1429.0	51.0	0.24	0.15	0.009	5.0	1.2	0.7	1.0	6.0
9	56.0	20.5	0.31	0.12	0.012	5.0	0.3	<0.02	0.9	
$\bar{x}$			0.24	0.13	0.008	5.0	0.6	0.36	1.8	2.3
(1 S.E.)			(0.03)	(0.02)	(0.001)	(0.6)	(0.1)	(0.18)	(0.6)	(0.9)
Longnose gar (spring)										
1	794.5	71.6	0.32	0.69	0.050	10.0	0.7	0.24	0.5	0.6
2	3405.0	106.7	0.86	0.17	<0.005	9.0	0.5	0.12	<0.5	2.6
3	2156.5	92.7	0.50	0.31	0.075	5.0	0.4	0.18	<0.5	1.3
4	1702.5	90.2	0.98	0.15	0.020	5.0	0.8	0.60	0.5	8.5
$\bar{x}$			0.66	0.33	0.048	7.0	0.6	0.28	0.5	3.2
(1 [illegible].)			(0.15)	(0.1[illegible]	(0.016)	(1.3)	(0.1)	(0.11)	(0)	([illegible])

Appendix A-3 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu[a]	Cr[a]	Ni[a]	PCB[a]
Spotted gar (spring)										
1	794.5	58.7	0.52	0.42	0.010	4.0	0.6	0.18	0.5	0.8
2	1248.5	65.5	0.30	0.34	0.012	4.0	0.6	0.02	0.5	1.1
$\bar{x}$			0.41	0.38	0.011	4.0	0.6	0.10	0.5	1.0
(1 S.E.)			(0.11)	(0.04)	(0.001)	(0)	(0)	(0.08)	(0)	(0.2)

[a]Less than (<) values are ignored in computing the mean and standard error.

[b]Collected on May 26, 1977; all other fish in spring collection were taken on April 13 and 25, 1977.

Appendix A-4. Concentration of metals and PCBs (μg/g wet wt) in muscle tissue of fish collected from the Clinch River (Station CRM 15.0) in the spring (April) and fall (November) 1977.

	Weight (g)	Length (cm)	Hg[a]	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Gizzard shad (spring)										
1	249.5	30.5	0.06	0.06	<0.005	2.0	0.5	0.44	<0.5	<0.1
2	277.5	30.6	0.06	<0.05	0.009	2.0	0.7	0.14	<0.5	0.2
3	235.6	29.7	0.07	0.05	<0.005	2.0	0.4	0.24	0.5	<0.1
4	242.8	29.5	0.10	0.05	0.011	2.0	1.2	0.26	<0.5	0.9
5	189.5	28.0	0.10	<0.05	0.009	3.0	0.7	0.80	<0.5	0.6
6	236.4	29.5	0.05	<0.05	<0.005	2.0	0.6	0.14	<0.5	<0.1
7	202.5	27.7	0.05	<0.05	0.006	2.0	0.5	0.50	<0.5	0.2
8	249.5	29.6	0.04	<0.05	0.005	2.0	0.5	0.38	<0.5	<0.1
$\bar{x}$			0.07	0.05	0.008	2.0	0.6	0.36		0.5
(1 S.E.)			(0.01)	(0.002)	(0.001)	(0.1)	(0.1)	(0.08)		(0.2)
Lepomis (fall)										
1	141.2	20.4	0.86	0.06	0.006	13.0	0.2	<0.02	<0.5	0.1
2	110.7	18.8	0.36	0.10	0.008	12.0	0.2	<0.02	0.6	
3	70.1	15.7	0.14	<0.05	0.011	11.0	0.2	<0.02	0.6	
4	32.5	12.0	0.02	<0.05	0.010	10.0	0.3	<0.02	0.7	
5	21.4	10.6	<0.02	0.06	0.006	10.0	0.3	<0.02	0.5	<0.1
6	34.4	12.7	0.12	0.09	0.006	13.0	0.3	<0.02	0.5	
7	8.3	8.3	0.57							
8	17.8	10.5	0.12	<0.05	0.009	13.0	0.3	<0.02	0.5	
9	15.2	9.6	0.31	<0.05	0.009	11.0	0.3	<0.02	0.5	
10	12.8	9.9	0.49	0.09	0.010	12.0	0.3	<0.02	0.5	
11	14.3	9.1	1.51	0.08	0.013	13.0	0.3	<0.02	<0.5	
12	9.8	8.3	0.50	0.06	<0.005	10.0	0.3	<0.02	<0.5	

Appendix A-4 (continued)

	Weight (g)	Length (cm)	Hg[a]	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Lepomis (fall) (continued)										
13	8.9	8.2	0.75							
14	9.2	8.5	0.97							
15	6.7	7.9	0.71							
$\bar{x}$			0.53	0.08	0.009	12.0	0.3		0.6	
(1 S.E.)			(0.11)	(0.01)	(0.001)	(0.4)	(0.01)		(0.03)	
White bass (fall)										
1	56.2	17.5	0.03	0.12	0.022	9.0	0.5	<0.02	<0.5	
2	66.9	18.0	0.03	0.12	0.017	7.0	0.1	<0.02	<0.5	
3	77.2	18.9	0.05	0.13	0.019	7.0	0.1	<0.02	<0.5	0.5
4	55.9	16.8	0.04	0.09	0.006	7.0	0.3	<0.02	0.5	0.1
$\bar{x}$			0.04	0.12	0.016	8.0	0.3			0.3
(1 S.E.)			(0.005)	(0.01)	(0.003)	(0.5)	(0.1)			(0.2)
Largemouth bass (fall)										
1	155.2	22.8	0.29	0.17	<0.005	6.0	0.1	<0.02	<0.5	
2	166.6	23.0	0.07	0.16	0.034	5.0	0.1	<0.02	<0.5	
3	67.8	17.9	0.17	0.15	0.016	6.0	0.1	<0.02	<0.5	
4	74.3	18.3	0.32	0.32	0.024	7.0	0.1	0.11	<0.5	
5	48.0	16.4	0.37	0.13	0.031	7.0	0.1	<0.02	<0.5	<0.1
$\bar{x}$			0.24	0.19	0.026	6.0	0.1			
(1 S.E.)			(0.05)	(0.03)	(0.004)	(0.4)	(0)			

Appendix A-4 (continued)

	Weight (g)	Length (cm)	Hg[a]	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Sauger (spring)										
1	660.2	44.6	0.29	0.05	<0.005	2.0	0.3	0.23	<0.5	<0.1

[a]Less than (<) values were ignored in computing the mean and standard error.

Appendix A-5. Concentration of metals and PCBs (μg/g wet wt) in muscle tissue of fish collected from the Clinch River (Station CRM 11.5) in the spring (April) and fall (November) 1977.

	Weight (g)	Length (cm)	Hg	Pb	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Gizzard shad (spring)										
1	233.9	30.3	0.09	0.21	0.014	9.0	0.3	0.04	<0.5	
2	171.4	27.3	0.09	0.38	0.033	11.0	1.6	0.03	<0.5	
3	301.5	30.2	0.13	0.36	0.014	6.0	0.5	0.04	<0.5	
4	209.3	28.8	0.04	0.05	0.006	4.0	0.7	0.03	0.5	0.4
5	191.3	28.3	0.04	0.09	<0.005	3.0	0.6	0.33	1.0	0.2
6	188.8	27.3	0.03	0.15	<0.005	2.0	0.8	<0.02	0.5	0.2
7	212.2	28.3	0.07	0.10	0.008	8.0	0.5	0.06	<0.5	0.3
8	249.6	30.0	0.04	0.12	<0.005	3.0	0.4	0.05	<0.5	<0.1
9	184.5	28.0	0.05	0.09	<0.005	3.0	0.4	0.09	<0.5	<0.1
10	236.4	28.7	0.04	0.09	<0.005	3.0	0.5	0.08	<0.5	<0.1
11	241.5	29.4	0.04	0.07	0.060	4.0	1.0	0.02	<0.5	<0.1
12	268.4	29.5	0.04	0.11	0.005	4.0	0.4	0.03	<0.5	<0.1
13	230.0	31.0	0.03	0.14	0.010	5.0	0.4	0.10	<0.5	<0.1
14	182.7	26.4	0.09	0.12	0.007	4.0	0.5	0.14	<0.5	0.6
15	211.4	29.0	0.04	0.06	0.005	4.0	0.5	0.12	<0.5	0.4
$\bar{x}$			0.06	0.14	0.016	5.0	0.6	0.08	0.7	0.4
(1 S.E.)			(0.01)	(0.02)	(0.006)	(0.7)	(0.1)	(0.02)	(0.2)	(0.1)
White bass (fall)										
1	52.3	17.6	0.18	0.09	<0.005	8.0	0.4	<0.02	0.6	0.1
2	61.3	18.0	0.08	0.10	0.005	7.0	0.4	<0.02	0.6	<0.1
$\bar{x}$			0.13	0.10		8.0	0.4		0.6	
(1 S.E.)			(0.05)	(0.005)		(0.5)	(0)		(0)	

Appendix A-5 (continued)

	Weight (g)	Length (cm)	Hg	Pb	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Largemouth bass (fall)										
1	532.7	32.5	0.47	0.10	0.007	6.0	0.3	<0.02	<0.5	0.1
2	123.6	21.6	0.40	0.09	0.005	6.0	0.3	<0.02	0.8	0.1
$\bar{x}$			0.44	0.10	0.006	6.0	0.3			0.1
(1 S.E.)			(0.04)	(0.005)	(0.001)	(0)	(0)			(0)
Rock bass (spring)										
1	63.8	15.1	0.33	0.36	0.015	8.0	0.3	0.03	<0.5	
White crappie (fall)										
1	64.3	18.4	0.33	0.10	0.006	8.0	0.3	<0.02	<0.5	
Lepomis (spring)										
1	132.7	19.6	0.51	0.33	0.016	12.0	0.3	0.03	<0.5	0.1
2	95.0	17.6	0.45	0.25	0.015	9.0	0.3	0.05	<0.5	
3	65.8	15.1	0.84	0.25	0.013	8.0	0.4	0.03	<0.5	
4	44.3	13.6	0.15	0.30	0.014	14.0	0.4	0.03	<0.5	
$\bar{x}$			0.49	0.30	0.014	11.0	0.4	0.04		
(1 S.E.)			(0.14)	(0.02)	(0.001)	(1.4)	(0.03)	(0.005)		

Appendix A-5 (continued)

	Weight (g)	Length (cm)	Hg	Pb	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Lepomis (fall)										
1	110.0	19.3	0.65	0.10	0.008	10.0	0.2	0.05	1.2	0.1
2	2.3	5.2	0.08							
$\bar{x}$			0.36							
(1 S.E.)			(0.28)							
Redbreast sunfish (fall)										
1	107.5	18.2	0.32	0.12	<0.005	4.0	0.6	0.02	0.6	0.1
2	95.3	17.4	0.19	0.09	0.006	9.0	0.3	0.04	0.6	
$\bar{x}$			0.26	0.10		6.0	0.4	0.03	0.6	
(1 S.E.)			(0.06)	(0.02)		(2.5)	(0.2)	(0.01)	(0)	

[a]Less than (<) values were ignored in computing the mean and standard error.

Appendix A-6. Concentration of metals and PCBs (μg/g wet wt) in muscle tissue of fish collected from the Clinch River (Station CRM 10.5) in the spring (April) and fall (October-November) 1977.

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
White bass (fall)										
1	74.0	18.3	0.05	0.09	0.006	8.0	0.6	0.11	<0.5	
2	64.7	17.5	0.08	0.06	<0.005	7.0	0.4	<0.02	<0.5	
3	61.6	17.5	0.04	0.18	0.023	4.0	0.7	0.03	<0.5	
4	70.0	18.5	0.05	0.18	0.013	3.0	0.4	0.03	<0.5	
5	96.0	20.8	0.04	0.20	0.018	4.0	0.7	0.05	<0.5	0.4
6	77.4	19.4	0.04	0.22	0.019	4.0	0.6	0.04	1.6	
7	59.2	17.6	0.04	0.10	0.011	4.0	0.4	0.05	<0.5	
8	68.1	18.3	0.05	0.13	0.010	4.0	0.3	0.27	<0.5	
9	59.2	17.0	0.05	0.21	0.011	4.0	0.4	0.03	<0.5	
10	58.8	18.0	0.07	0.09	0.014	5.0	0.4	0.02	<0.5	
11	69.8	17.7	0.06	0.10	0.016	4.0	0.5	0.03	<0.5	0.2
12	51.2	16.6	0.06	0.15	0.009	4.0	0.5	0.06	<0.5	
13	36.6	15.1	0.08	0.08	0.021	2.0	0.6	0.15	<0.5	
$\bar{x}$			0.06	0.14	0.014	4.0	0.5	0.07		0.3
(1 S.E.)			(0.004)	(0.02)	(0.002)	(0.4)	(0.04)	(0.02)		(0.1)
Striped bass (fall)										
1[b]	111.2	20.0	0.16	0.23	0.006	6.0	0.4	<0.02	<0.5	<0.1
2[b]	123.9	21.2	0.07	0.30	0.007	6.0	0.3	0.06	0.6	<0.1
3[b]	67.3	17.3	0.05	0.24	0.009	6.0	0.3	0.04	0.6	
4[b]	63.5	18.1	0.06	0.10	<0.005	7.0	0.4	<0.02	0.8	
5[b]	72.0	18.0	0.04	0.12	<0.005	7.0	0.4	<0.02	0.5	
$\bar{x}$			0.08	0.20	0.007	6.0	0.4	0.05	0.6	
(1 S.E.)			(0.02)	(0.04)	(0.001)	(0.2)	(0.02)	(0.01)	(0.1)	

Appendix A-6 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Largemouth bass (spring)										
1	47.0	17.1	0.04	<0.05	0.007	13.0	0.7	0.42	0.9	0.2
2	39.7	15.5	0.15	<0.05	0.005	9.0	0.5	0.09	0.6	0.6
3	97.5	20.8	0.04	0.25	0.006	9.0	0.3	<0.02	<0.5	
$\bar{x}$			0.08		0.006	10.0	0.5	0.26	0.8	0.4
(1 S.E.)			(0.04)		(0.0005)	(1.3)	(0.1)	(0.16)	(0.2)	(0.2)
Largemouth bass (fall)										
1	4.4	7.5	0.16							
2	8.9	9.0	0.34							
3	47.3	16.3	0.45	0.09	0.021	4.0	0.5	0.05	<0.5	0.2
4	23.3	12.3	0.19	0.05	0.021	3.0	0.6	0.09	0.5	
5	331.5	28.4	0.23	0.09	0.018	2.0	0.3	0.16	<0.5	
6	946.8	39.4	0.25	0.06	0.009	2.0	0.3	0.02	<0.5	<0.1
7	624.9	33.6	0.65	0.07	0.014	2.0	0.6	0.17	<0.5	
$\bar{x}$			0.32	0.07	0.017	3.0	0.5	0.10		
(1 S.E.)			(0.07)	(0.01)	(0.002)	(0.4)	(0.1)	(0.03)		
Bluegill (spring)										
1	29.8	12.5	0.30	0.26	0.007	12.0	0.2	<0.02	0.5	
2	33.1	12.5	0.15	0.27	0.007	13.0	0.3	0.03	0.5	
$\bar{x}$			0.22	0.26	0.007	12.0	0 2		0.5	
(1 S.E.)			(0.08)	(0.005)	(0)	(0.5)	(0.05)		(0)	

Appendix A-6 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Redbreast sunfish (fall)										
1	125.2	18.4	0.20	0.11	0.007	9.0	0.3	0.03	0.6	
Lepomis (spring)										
1	61.9	15.7	0.05	0.26	0.007	10.0	0.2	<0.02	<0.5	
2	76.8	16.2	0.28	0.31	0.008	10.0	0.3	<0.02	0.7	
$\bar{x}$ (1 S.E.)			0.16 (0.12)	0.28 (0.02)	0.008 (0.001)	10.0 (0)	0.2 (0.05)			
Lepomis (fall)										
1	9.0	8.7	0.37							
2	7.6	8.0	0.20							
3	7.5	8.3	0.10							
4	3.3	6.4	0.11							
5	7.4	8.1	0.04							
6	10.6	9.0	0.19							
7	19.5	10.7	0.13	0.08	0.008	10.0	0.4	0.10	0.9	0.1
8	40.0	13.7	0.27	0.10	0.007	10.0	0.4	<0.02	0.7	0.4
9	6.7	7.9	0.12							
10	6.7	8.2	0.07							
$\bar{x}$			0.16 (0.03)	0.09 (0.01)	0.008 (0.0005)	10.0 (0)	0.4 (0)		0.8 (0.1)	0.2 (0.2)
Silver redhorse (spring)										
1	702.8	41.5	0.38	0[illegible]	<0.005	3.0	0.7	0.05	0.5	[illegible].1

Appendix A-6 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Sauger (fall)										
1[b]	303.3	33.9	0.29	0.09	0.005	6.0	0.2	0.12	<0.5	0.1
2[b]	529.4	38.2	0.51	0.10	<0.005	4.0	0.2	<0.02	0.9	0.1
3	1118.0	48.4	0.72	0.17	0.027	2.0	0.6	0.02	<0.5	
4	820.0	45.0	0.39	0.09	0.010	2.0	0.3	0.02	<0.5	
$\bar{x}$			0.48	0.11	0.014	4.0	0.3	0.05		0.1
(1 S.E.)			(0.09)	(0.02)	(0.007)	(1.0)	(0.1)	(0.03)		(0)
Spotted sucker (spring)										
1	746.7	44.0	0.08	0.19	<0.005	8.0	0.5	0.06	1.0	0.2
Gizzard shad (spring)										
1	283.2	30.0	0.03	<0.05	0.013	2.0	0.7	0.18	<0.5	<0.1
2	137.3	24.7	0.02	0.11	0.007	2.0	0.8	0.12	<0.5	<0.1
3	297.6	31.0	0.05	0.07	0.006	2.0	0.8	0.60	<0.5	<0.1
4	245.5	29.5	0.04	<0.05	0.010	6.0	1.0	0.03	<0.5	0.5
5	217.7	28.2	0.03	0.06	0.008	5.0	0.6	0.02	<0.5	0.1
6	211.6	29.2	0.02	<0.05	0.006	6.0	0.5	0.04	<0.5	<0.1
7	314.3	31.7	0.03	<0.05	0.006	5.0	0.8	0.92	<0.5	<0.1
8	354.5	32.0	0.04	0.23	<0.005	3.0	0.6	<0.02	<0.5	0.1
9	640.1	29.1	0.03	0.12	0.008	4.0	0.8	0.06	<0.5	0.2
10	174.8	27.0	0.04	0.10	<0.005	4.0	0.7	0.04	<0.5	0.2
11	194.7	29.0	0.04	0.07	<0.005	3.0	0.6	0.09	<0.5	0.2
12	141.4	24.2	0.05	<0.05	0.007	3.0	0.6	0.07	<0.5	0.3
13	228.1	29.2	0.04	0.09	0.007	5.0	0.4	0.07	<0.5	0.2

Appendix A-6 (continued)

	Weight (g)	Length (cm)	Hg	Pb[a]	Cd[a]	Zn	Cu	Cr[a]	Ni[a]	PCB[a]
Gizzard shad (spring) (continued)										
14	190.0	27.0	0.04	0.09	0.003	6.0	0.5	0.04	<0.5	0.4
15	228.8	30.0	0.03	0.08	0.008	7.0	0.5	0.02	0.5	<0.1
16	190.3	28.0	0.04	0.10	<0.005	6.0	0.4	0.05	<0.5	0.2
17	182.9	27.5	0.05	0.07	<0.005	4.0	0.7	0.17	<0.5	0.2
$\bar{x}$			0.04	0.10	0.007	4.0	0.7	0.16		0.2
(1 S.E.)			(0.002)	(0.01)	(0.001)	(0.4)	(0.04)	(0.06)		(0.04)

[a] Less than (<) values were ignored in computing the means and standard error.

[b] Collected on October 10-11, 1977; all other fish in fall collection were taken on November 17, 1977.

APPENDIX B

Appendix B-1. Phytoplankton taxa collected during the ORGDP sampling program, April 1977-March 1978. For each of three locations (Clinch River, mouth of Poplar Creek, and upper Poplar Creek), an 'X' denotes the presence of the taxon in at least one of the samples from that area.

Taxon	Clinch River	Poplar Creek	
		PCM 0.5	PCM 11.0, 5.5
Chlorophyta			
Actinastrum hantschii	X	X	X
Ankistrodesmus falcatus	X	X	X
Asterococcus superbus	X		
Binuclearia sp.	X	X	X
Botryococcus braunii	X		
Carteria sp.		X	X
Chlamydomonas spp.	X	X	X
Chlorella sp.	X	X	X
Chlorogonium elongatum	X	X	X
Chodatella longiseta	X	X	X
C. quadriseta	X		
Closterium gracile		X	
C. venus	X		X
Coelastrum cambricum	X		
C. spaericum	X	X	
Cosmarium sp.			X
Crucigenia crucifera	X		
C. fenestrata	X	X	
C. quadrata	X	X	X
C. rectangularis	X	X	
Dictyosphaerium pulchellum	X	X	X
Dimorphococcus lunatus		X	
Elakatothrix gelatinosa	X		
Franceia droescheri	X	X	X
Gloecystis gigas		X	
Golenkinia paucispina	X		
G. radiata	X		

Appendix B-1 (continued)

Taxon	Clinch River	Poplar Creek	
		PCM 0.5	PCM 11.0, 5.5
Gonium pectorale		X	X
Kirschneriella okesa	X	X	
Micractinium pusillum		X	X
Mougeotia spp.	X		
Oocystis sp.	X		X
Pandorina morum	X	X	
Pediastrum biradiatum		X	
P. boryanum	X		
P. duplex var. duplex	X	X	
P. duplex var. gracilimum	X		
P. simplex	X		
P. simplex var. duodenarium	X		
Pedinopera granulosa	X		X
Phacotus angustus		X	X
P. lenticularis	X		
Planktosphaeria gelatinosa	X	X	X
Platymonas elliptica	X	X	X
Pyraminonas inconstans	X	X	X
Scenedesmus sp.	X	X	X
S. abundans	X	X	X
S. armatus			X
S. bijuga	X	X	X
S. bijuga var. alternans	X		
S. denticulatus	X	X	
S. dimorphus	X	X	X
S. longus var. naegelii	X		
S. obliquus	X		X
S. opoliensis	X	X	X
S. quadricauda	X	X	X
Scherffelia phacus		X	X

Appendix B-1 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Schroederia setigera		X	X
Selenastrum sp.	X	X	X
S. westii	X	X	
Spermatazoopsis exultans		X	X
Staurastrum sp.			X
Tetraedron minimum	X	X	X
Tetrastrum sp.	X	X	
T. heterocanthum	X	X	
T. heterocanthum fo. *elegans*	X		
T. staurogeniaeforme		X	
Treubaria triappendiculata	X	X	X
Ulotherix spp.			X
Westella botryoides	X	X	
Wislouchiella planctonica	X	X	
Chrysophyta			
Bacillariophyceae (diatoms)			
Asterionella formosa	X		
Attheya zachariasi	X		
Cymbella spp.	X		X
Cyclotella sp.	X	X	X
C. chaetoceros	X		
Fragillaria crotonensis	X		X
Gomphonema spp.	X	X	X
Gyrosigma sp.			X
Melosira arenaria		X	
M. granulata var. *angustissima*	X	X	X
M. granulata var. *granulata*	X	X	
M. varians	X	X	X
Navicula spp.	X	X	X

Appendix B-1 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Nitzschia spp.	X	X	X
N. clausii	X		
N. holsatica	X	X	X
Pinnularia sp.	X	X	X
Rhizosolenia longiseta	X	X	X
Stephanodiscus sp.	X	X	X
Surirella sp.	X	X	X
Synedra sp.	X		
S. delicatissima	X	X	X
Tabellaria	X		
Others			
Chromulina sp.	X		X
Chrysamoeba radians	X	X	X
Chrysococcus sp.	X	X	X
Cyclonexis annularis	X	X	X
Dinobryon sp.	X	X	X
D. divergens	X	X	X
Lagynion ampullaceum	X		X
Mallomonas spp.	X	X	X
Ochromonas sp.	X	X	
Rhipidodendron sp.	X		X
Synura uvella	X		X
Cryptophyta			
Chilomonas sp.	X	X	X
Chroomonas acuta	X	X	X
Cryptomonas spp.	X	X	X
C. erosa var. *reflexa*	X	X	X
C. marssoni	X	X	X

Appendix B-1 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
C. ovata	X	X	
Rhodomonas sp.	X	X	X
R. lacustris	X	X	X
R. minuta var. *nannoplanctica*	X		
R. ovalis	X	X	X
Cyanophyta			
Agmenellum sp.	X	X	X
Anabaena sp.	X	X	X
Coccochloris peniocystis	X	X	
Oscillatoria spp.	X	X	X
Schizothrix spp.	X	X	X
Euglenophyta			
Euglena spp.	X	X	X
E. acus		X	
E. deses	X		
E. gracilis	X		
Lepocynclis sp.	X	X	X
L. glabra fo. *minor*		X	
L. ovum	X	X	
Phacus sp.	X	X	
Strombomonas sp.	X	X	X
Trachelomonas spp.	X	X	X
Pyrrophyta			
Ceratium hirundinella fo. *brachyceras*	X	X	
Glenodinium sp.	X		
Gymnodinium helveticum	X	X	
Peridinium spp.	X		X
P. inconspicum	X		

Appendix B-2. Zooplankton taxa collected during the ORGDP survey, April 1977-March 1978. For each of three locations (Clinch River, mouth of Poplar Creek, and upper Poplar Creek), an 'X' denotes the presence of the taxon in at least one of the samples from that area.

Taxon	Clinch River	Poplar Creek	
		PCM 0.5	PCM 11.0, 5.5
Arthropoda			
Crustacea			
Cladocera			
Alona sp.		X	X
Bosmina longirostris	X	X	X
Ceriodaphnia quadrangula		X	
Chydorus sphaericus	X	X	X
Daphnia spp.	X	X	X
Leptodora kindtii	X	X	
Macrothrix laticornis		X	
Pleuroxus denticulatus		X	X
Scapholebris kingi	X	X	X
Sida crystallina	X	X	X
Copepoda			
Cyclops bicuspidatus thomasi	*a*	*a*	X
Diaphanosoma sp.	*a*	*a*	X
Diaptomus pallidus	*a*	X	X
Ergasilus sp.	X	X	X
Cyclopoid copepodid	X	X	X
Calanoid copepodid	X	X	X
Nauplii	X	X	X
Rotifera			
Bdelloidea			
Harbrotrocha	X	X	
Mniobia	X	X	X
Rotaria (?)	X	X	

Appendix B-2 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Monogononta			
Asplanchna	X	X	X
Brachionus angularis	X	X	X
B. bidentata	X	X	X
B. budapestinensis	X	X	X
B. calyciflorus	X	X	X
B. caudatus	X	X	X
B. havanaensis	X	X	X
B. quadridentata	X	X	X
Cephalodella	X	X	X
Collotheca	X	X	
Collurella			X
Conochiloides	X	X	X
Conochilus	X	X	X
Epiphanes			X
Euclanis	X	X	X
Filinia	X	X	
Gastropus		X	X
Hexartha	X	X	X
Kellicottia	X	X	X
Keratella	X	X	X
Lecane	X	X	X
Macrochaetus	X		X
Monostyla sp.	X	X	X
Platyias patulus	X	X	X
P. quadricornis		X	X
Ploesoma	X	X	X
Polyarthra	X	X	X
Pompholyx		X	
Synchaeta	X	X	X

Appendix B-2 (continued)

Taxon	Clinch River	Poplar Creek	
		PCM 0.5	PCM 11.0, 5.5
Testudinella	X	X	X
Trichocerca	X	X	X
Trichotria		X	X

[a]Presence highly probable but not confirmed from taxonomic observations. Identification of Calanoida and Cyclopoida to species was discontinued after initial examinations of samples from stations PCM 11.0 and 5.5.

Appendix B-3. Benthic macroinvertebrate taxa collected during the ORGDP sampling program, April 1977-March 1978. For each of three locations (Clinch River, mouth of Poplar Creek, and upper Poplar Creek), an 'X' denotes the presence of the taxon in at least one of the samples from that area.

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Annelida			
Oligochaeta			
Enchytraeidae			X
Lumbriculidae	X	X	X
Naididae			
Nais sp.	X		X
N. communis	X		
Pristina		X	
Slavina	X		
Stylaria fossularis			X
Tubificidae			
Aulodrilus americanus	X	X	
A. limnobius	X		X
A. pigueti	X	X	X
A. pluriseta	X	X	X
Branchiura sowerbyi	X	X	X
Limnodrilus sp.	X	X	X
L. cervix	X	X	X
L. hoffmeisteri	X	X	X
L. udekemianus	X		
Peloscolex freyi	X		
Tubifex	X		X
Arthropoda			
Arachnoidea			
Hydracarina		X	X
Crustacea			
Amphipoda			
Gammaridae			
Crangonyx	X		

Appendix B-3 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Isopoda			
Asellidae			
Asellus			X
Insecta			
Coleoptera			
Dytiscidae			
Copelatus	X		
Elmidae			
Dubiraphia	X	X	X
Diptera			
Ceratopogonidae			
Bezzia	X	X	
Palpomyia	X	X	X
Chaoboridae			
Chaoborus punctipennis	X	X	X
Chironomidae			
Ablabesmyia	X		X
Chironomus	X	X	X
Coelotanypus		X	X
Conchapelopia	X		X
Cryptochironomus	X	X	X
Dicrotendipes	X		X
Endochironomus			X
Eukiefferiella			X
Larsia	X	X	X
Microtendipes			X
Orthocladius	X		X
Paracladopelma	X	X	X
Paralauterborniella			X
Paratendipes	X		X

Appendix B-3 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Parorthocladius			X
Phaenopsectra			X
Polypedilum	X	X	X
Procladius	X	X	X
Rheotanytarsus			X
Stenochironomus			X
Tanytarsus	X		X
Tribelos		X	X
Empididae			X
Tabanidae			
Chrysops sp.			X
Ephemeroptera			
Caenidae			
Caenis	X		X
Ephemeridae			
Hexagenia limbata	X	X	X
Heptageniidae			
Stenonema			X
Megaloptera			
Sialidae			
Sialis	X	X	X
Odonata			
Gomphidae			
Progomphus	X		
Libellulidae			
Perithemis			X
Plecoptera			
Perlodidae			
Isogenus			X

Appendix B-3 (continued)

Taxon	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Tricoptera			
Hydroptilidae			
Agraylea	X		
Leptoceridae			
Oecetis	X		X
Psychomyiidae			
Polycentropus	X		
Mollusca			
Gastropoda			
Ancylidae			
Ferrissia rivularis	X		
Physidae			
Physa	X		X
Planorbidae			
Gyraulus			X
Pelecypoda			
Corbiculidae			
Corbicula manilensis	X	X	X
Sphaeriidae			
Sphaerium		X	
Unionidae			
Anodonta	X		
Nematoda	X	X	

Appendix B-4. Fish species collected during the ORGDP sampling program, April 1977-March 1978. For each of three locations (Clinch River, mouth of Poplar Creek, and upper Poplar Creek), an 'X' denotes the presence of the taxon in at least one of the samples from that area.

Family/species	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Catostomidae			
Carpiodes carpio (River carpsucker)	X	X	X
Hypentelium nigricans (Northern hog sucker)	X		
Ictiobus bubalus (Smallmouth buffalo)		X	X
I. niger (Black buffalo)			X
Minytrema melanops (Spotted sucker)	X	X	X
Moxostoma anisurum (Silver redhorse)	X	X	X
M. duquesnei (Black redhorse)	X		
Centrarchidae			
Ambloplites rupestris (Rock bass)	X		
Lepomis auritus (Redbreast sunfish)	X		X
L. gulosus (Warmouth)	X		X
L. humilis (Orangespotted sunfish)			X
L. macrochirus (Bluegill)	X	X	X
Micropterus punctulatus (Spotted bass)	X		X
M. salmoides (Largemouth bass)	X	X	X
Pomoxis annularis (White crappie)	X	X	X
Clupeidae			
Alosa chrysochloris (Skipjack herring)	X	X	X
Dorosoma cepedianum (Gizzard shad)	X	X	X
D. petenense (Threadfin shad)	X	X	X
Cyprinidae			
Cyprinus carpio (Carp)	X	X	X
Notropis sp.		X	
N. cornutus (Common shiner)	X		
Hiodontidae			
Hiodon tergisus (Mooneye)	X	X	

Appendix B-4 (continued)

Family/species	Clinch River	Poplar Creek PCM 0.5	Poplar Creek PCM 11.0, 5.5
Ictaluridae			
Ictalurus punctatus (Channel catfish)	X	X	X
Lepisosteidae			
Lepisosteus oculatus (Spotted gar)		X	X
L. osseus (Longnose gar)		X	X
Percichthyidae			
Morone chrysops (White bass)	X	X	X
M. mississippiensis (Yellow bass)	X	X	X
M. saxatilis (Striped bass)	X	X	
Percidae			
Stizostedion canadense (Sauger)	X	X	X
Sciaenidae			
Aplodinotus grunniens (Freshwater drum)	X	X	X

Appendix B-5. Ichthyoplankton taxa collected during the ORGDP sampling program, April 1977-March 1978. For each of three locations (Clinch River, mouth of Poplar Creek, and upper Poplar Creek), an 'X' denotes the presence of the taxon in at least one of the samples from that area.

		Poplar Creek	
Taxon	Clinch River	PCM 0.5	PCM 11.0, 5.5
Catostomidae	X	X	X
Ictiobinae	X	X	X
Minytrema melanops			X
Centrarchidae			
Lepomis	X	X	X
Micropterus			X
Pomoxis		X	X
Clupeidae	X	X	X
Alosa	X		X
Dorosoma	X	X	X
Cyprinidae	X	X	X
Cyprinus carpio	X	X	
Notemigonus crysoleucas[a]	X		X
Percichthyidae			
Morone	X	X	X
Percidae			X
Stizostedion	X		X
Sciaenidae			
Aplodinotus grunniens	X		

[a]Common name is golden shiner. Common names of other species/genera are given in Appendix B-4.

APPENDIX C

Appendix C. Relative abundance (%) of benthic macroinvertebrate taxa at the six ORGDP sampling sites, April 1977–March 1978.

Taxon	Poplar Creek (PCM) 11.0	Poplar Creek (PCM) 5.5	Poplar Creek (PCM) 0.5	Clinch River (CRM) 15.0	Clinch River (CRM) 11.5	Clinch River (CRM) 10.5
Annelida						
Oligochaeta						
Enchytraeidae	0.2					
Lumbriculidae	0.7		0.3	1.1	1.1	0.5
Naididae						
Nais sp.		0.4		0.3		
N. communis					0.3	
Pristina			0.3			
Slavina						0.5
Stylaria fossularis		0.8				
Tubificidae						
Aulodrilus americanus			1.3	0.8		
A. limnobius	0.2			0.3		
A. pigueti		2.1	2.8	0.3	0.3	0.5
A. pluriseta		0.8	0.3	0.3	0.5	0.5
Branchiura sowerbyi	5.3	4.1	4.8	2.5	8.7	2.0
Limnodrilus sp.	0.7	0.8	0.3	0.5	0.8	
L. cervix	1.7	2.5	5.3	0.5	6.2	2.5
L. hoffmeisteri	1.9	2.1	2.5	0.3	0.3	
L. udekemianus					0.3	
Peloscolex freyi						0.5
Tubifex		0.4				2.0
Immature tubificids						
WCS[a]		4.5	3.3	4.7	2.1	2.5
WOCS[b]	15.6	14.0	13.9	27.2	31.4	33.3
Arthropoda						
Arachnoidea						
Hydracarina	0.2		0.3			
Crustacea						
Asellus	0.7					
Crangonyx					1.5	

Appendix C (continued)

Taxon	Poplar Creek (PCM)			Clinch River (CRM)		
	11.0	5.5	0.5	15.0	11.5	10.5
Coleoptera						
Copelatus					0.3	
Dubiraphia	2.2	2.5	0.3		0.5	0.5
Diptera						
Ceratopogonidae						
Bezzia			0.3		0.3	
Palpomyia	2.6	0.4	2.5	0.5	2.1	
Chaoboridae						
Chaoborus punctipennis		1.2	12.7	0.3	2.1	1.0
Chironomidae						
Ablabesmyia	4.8	0.4			0.3	0.5
Chironomus	0.7	0.4	3.0	3.3		0.5
Coelotanypus		0.4	0.3			
Conchapelopia	0.7	0.8		0.3		
Cryptochironomus	2.2	1.6	5.5	4.7	5.1	3.5
Dicrotendipes		1.2		8.8	0.8	0.5
Endochironomus	0.2					
Eukiefferiella	0.2					
Larsia	0.5		0.5		0.3	
Microtendipes	0.2					
Orthocladius		0.4		0.3	0.5	
Paracladopelma	1.2	0.4	0.8	2.5	4.6	3.5
Paralauterborniella	0.7					
Paratendipes	0.2			1.1		
Parorthocladius		0.4				
Phaenopsectra	2.4	0.4				
Polypedilum	12.2	2.1	1.5	4.1	5.7	6.0
Procladius	1.4	38.7	15.2	2.5	2.6	1.0
Rheotanytarsus	0.5					
Stenochironomus	0.2					
Tanytarsus	0.2	0.4		3.0		

Appendix C (continued)

Taxon	Poplar Creek (PCM) 11.0	5.5	0.5	Clinch River (CRM) 15.0	11.5	10.5
Tribelos	13.7	1.2	0.3			
Unidentified Chironominae		2.5		1.9	0.3	
Unidentified Orthocladiinae					0.8	
Unidentified Tanypodinae		2.9	4.3		1.8	1.0
Empididae	0.2					
Tabanidae						
Chrysops sp.	0.2					
Unidentified Diptera	0.7	0.4				
Ephemeroptera						
Caenis	1.2			0.3		
Hexagenia limbata		3.3	13.2	0.3	8.7	6.5
Stenonema	0.5					
Megaloptera						
Sialis	0.7		0.3		0.3	
Odonata						
Perithemis		0.4				
Progomphus					0.3	
Plecoptera						
Isogenus		0.4				
Unidentified	0.2					
Tricoptera						
Agraylea				0.5		
Oecetis	0.2	0.4				0.5
Polycentropus					0.3	
Unidentified				0.3		
Mollusca						
Gastropoda						
Ferrissia rivularis						0.5
Gyraulus		0.4				
Physa	0.5				0.3	

Appendix C (continued)

Taxon	Poplar Creek (PCM) 11.0	Poplar Creek (PCM) 5.5	Poplar Creek (PCM) 0.5	Clinch River (CRM) 15.0	Clinch River (CRM) 11.5	Clinch River (CRM) 10.5
Pelecypoda						
Anodonta					0.3	0.5
Corbicula manilensis	20.1	0.4	0.5	26.1	9.3	29.4
Sphaerium			0.3			
Unidentified	0.5	3.3	3.3	0.3		
Nematoda			0.3	0.3	0.3	

[a]WCS = With capilliform setae in dorsal bundles (*Peloscolex*, *Tubifex*); WOCS = Without capilliform setae in dorsal bundles (*Monopylephorus*, *Limnodrilus*) (Pennak 1953).

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