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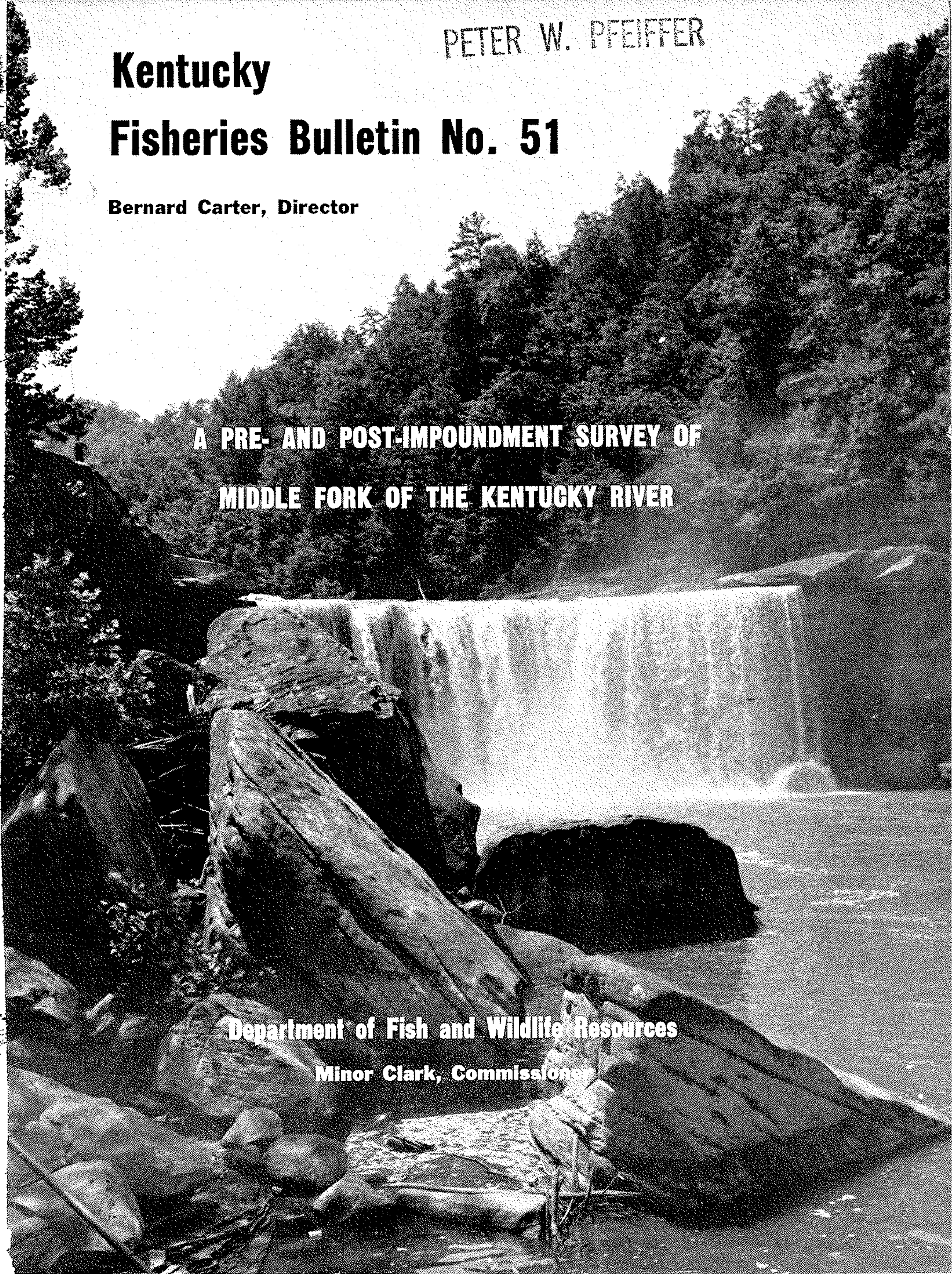

A PRE- AND POST-IMPOUNDMENT SURVEY OF MIDDLE FORK OF THE KENTUCKY RIVER

Department of Fish and Wildlife Resources
Minor Clark, Commissioner

A PRE- AND POST-IMPOUNDMENT SURVEY OF MIDDLE FORK OF THE KENTUCKY RIVER

By

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INTRODUCTION

The Kentucky River Basin is the largest that lies entirely within the confines of Kentucky and it traverses the state from southeast to northwest (Fig. 1, inset). The drainage basin incloses 6,968 square miles, or approximately 17 percent of the state's area (U. S. Department of the Interior, 1958). The river is formed essentially by the convergence of three major streams, North Fork, Middle Fork, and South Fork, which originate in the mountains of southeastern Kentucky in the Eastern Coalfield physiographic region. Middle Fork flows due north and empties into the principal headwater tributary, North Fork, about 4 miles upstream from the town of Beattyville. The South Fork joins the North Fork at Beattyville, and at their confluence the Kentucky River is formed. From this point, the river courses northwestward for 255 miles, ultimately discharging into the Ohio River at Carrollton, Kentucky.

A reservoir was authorized for the Middle Fork of the Kentucky River by the Flood Control Act of 1938, and construction of a dam about 0.5 mile upstream from the village of Buckhorn, Kentucky began in September 1956. Subsequent to the inception of this project, the Kentucky Department of Fish and Wildlife Resources initiated pre-impoundment investigations of the fishery resources and water quality of the Middle Fork drainage. Pre-impoundment data collected during the summers from 1957 through 1960 were compared to those collected during the first three years of impoundment, 1961 through 1963, to disclose the various changes resulting from the transition. The studies were designed to measure and evaluate changes in water quality, the kinds, abundance and distribution of fishes, fish biomass, population structure, fishing intensity, creel composition, and fishing success following impoundment.

MIDDLE FORK OF THE KENTUCKY RIVER

Hydrology

Middle Fork is the smallest of the three major headwater streams and drains 559 square miles (U. S. Department of the Interior, 1957). The source of Middle Fork is in Harlan County on the northwest-facing slope of Pine Mountain. After leaving Harlan County, the stream flows northward through Leslie and Perry Counties where the ensuing investigations were centered. Middle Fork has a cuneiform drainage basin and, as is usual in areas of such rugged relief, the drainage pattern is typically dendritic (Fig. 1).

In addition to the main stem, the headwaters of Middle Fork include two principal tributaries, Beech Fork and Greasy Creek. Above their confluence, Greasy Creek is considerably larger than the parent stream and normally has a greater discharge. Some of the fluvial dynamics of these streams, above their points of junction, are outlined in Table 1. Near river mile 63.0, Cutshin Creek joins the parent stream and is the last major tributary upstream from the dam site, mile 43.3.

The source of Middle Fork is about 1,800 feet above mean sea level (msl) and the gradient is very steep in the headwaters; the rate of slope exceeds 100 feet per mile between elevations 1,400 and 1,600 feet (Fig. 2). Greasy Creek originates 2,000 feet above msl, and the declivity in its upper reaches is greater than in Middle Fork (Table 2). Greasy Creek is 8.5 miles longer than Middle Fork.

Figure 1. Middle Fork drainage showing tributaries mentioned in text. Inset shows the location of the study area in reference to the Kentucky River.

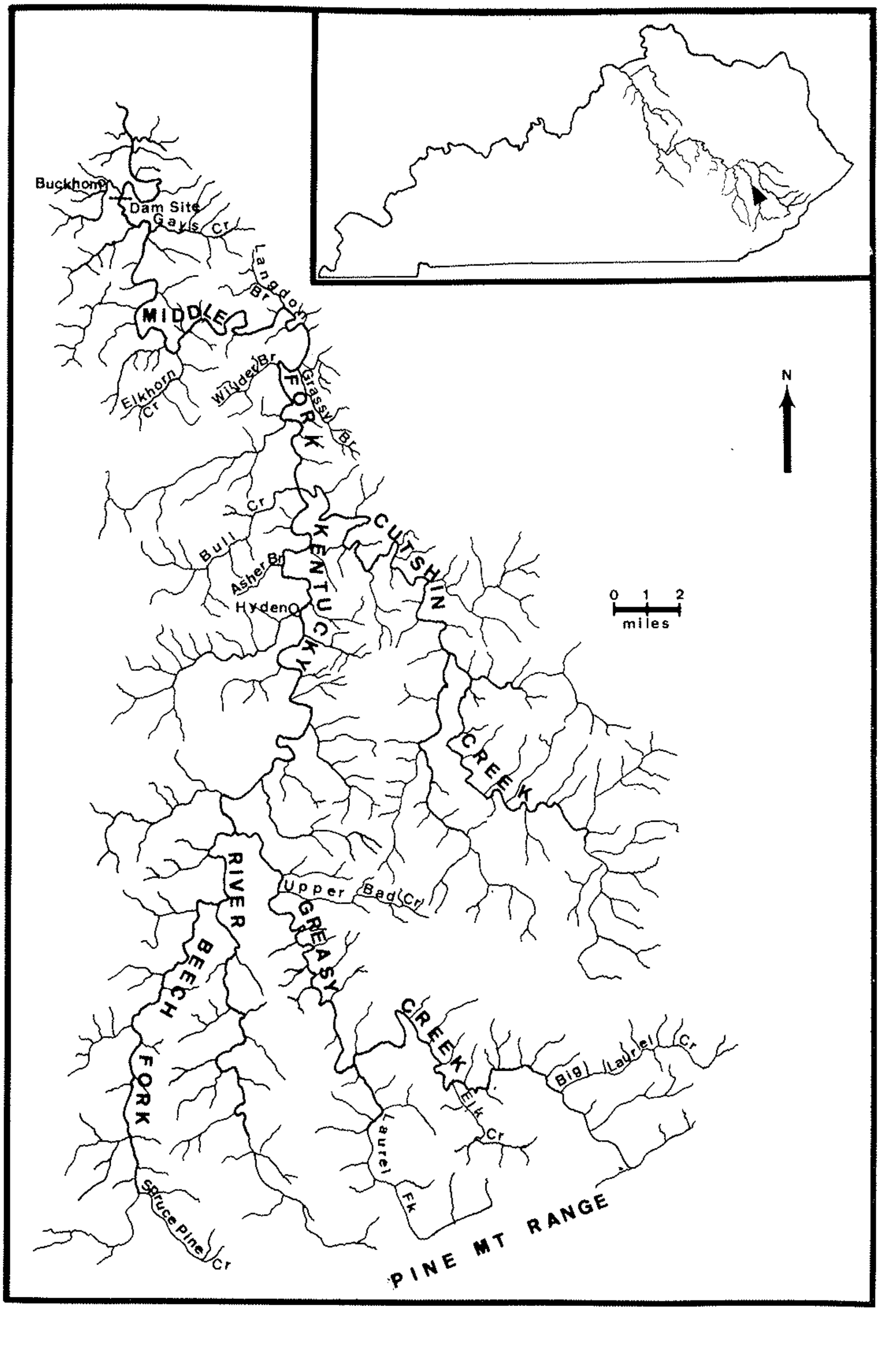


Figure 2. Longitudinal profile of Middle Fork above Buckhorn Dam, showing stream orders and various pool stages of the reservoir.

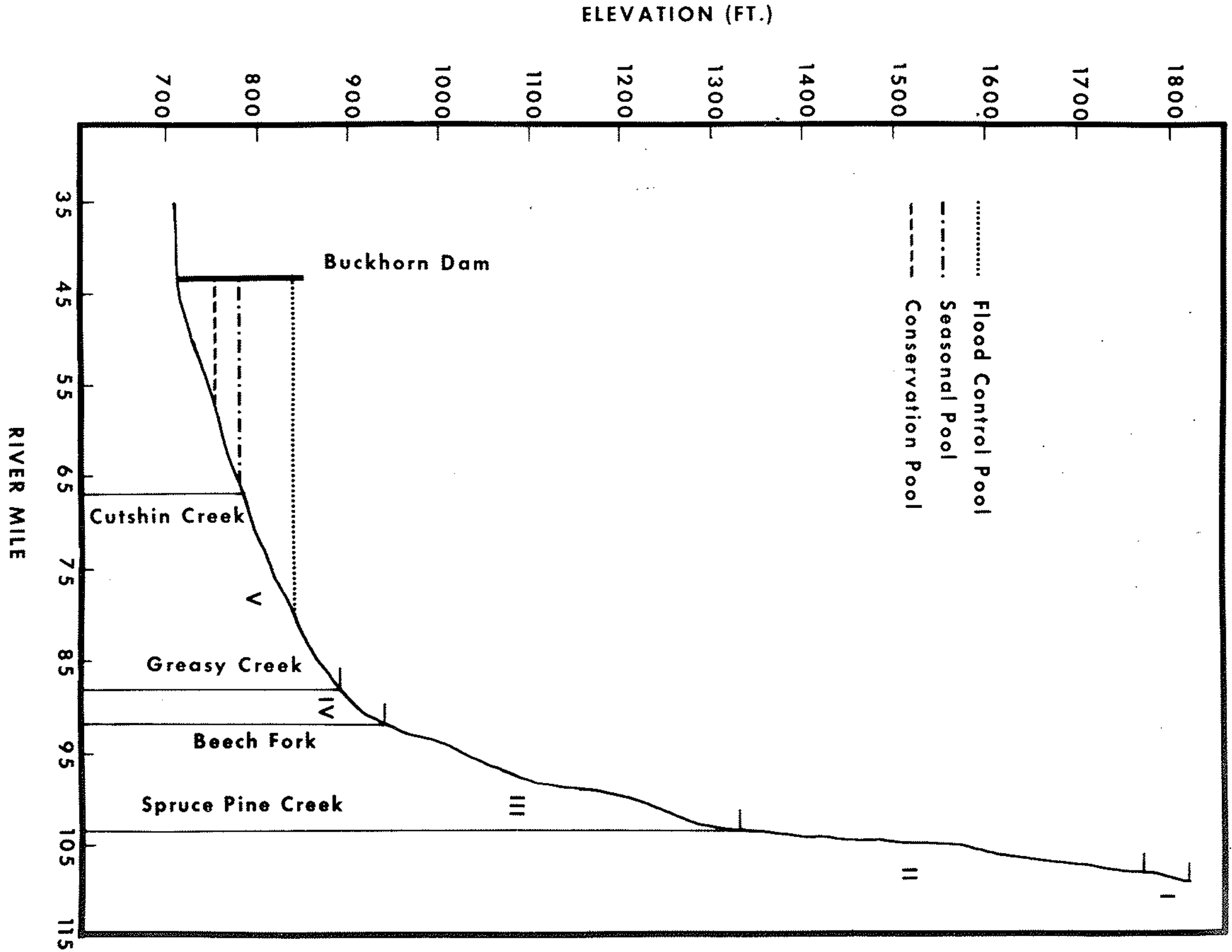


Table 1. *Discharge measurements from the major headwater streams of Middle Fork (After Kirkpatrick, Price, Jr., and Madison, 1963).*

Stream	Drainage area (sq.mi.)	1958 Date	1958 Disch. (cfs)	1958 Disch. per sq.mi. (cfs)	1959 Date	1959 Disch. (cfs)	1959 Disch. per sq. mi (cfs)	1960 Date	1960 Disch. (cfs)	1960 Disch. per sq. mi. (cfs)
Beech Fork	33.9	10-1	14.60	.4307	7-31	0.62	.0183	8-1	2.29	.0676
(near mouth)		10-30	1.17	.0345	10-8	0.57	.0168	9-23	2.96	.0873
Middle Fork (above Beech Fork)	70.6	10-3	11.00	.1558	7-31	1.75	.0248	8-1	5.32	.0754
		10-30	1.95	.0276	10-8	0.88	.0125	9-23	6.92	.0980
Greasy Creek	95.0	10-1	6.40	.0674	7-30	5.73	.0603	8-1	16.50	.1737
(near mouth)		10-30	2.68	.0282	10-8	1.51	.0159	9-23	11.20	.1179

Table 2. *Some morphometric features of Middle Fork and Greasy Creek*

Stream	Length (miles)	Change in elevation (feet)	Gradient (ft./mi.)
Middle Fork (from source to 9 miles below dam site)	1.99	170	85.4
	1.50	200	133.3
	4.70	200	42.6
	5.85	200	34.2
	22.10	200	9.1
	24.60	80	3.3
	21.50	40	1.9
Greasy Creek (from source on Big Laurel Creek to 2 miles above mouth)	0.60	80	133.3
	2.90	200	69.0
	1.90	200	105.3
	4.05	200	49.4
	12.90	200	15.5
	4.65	80	17.2

Geology

In Harlan and Leslie Counties, Middle Fork drains mostly from the Breathitt Formation. The Breathitt Formation, as defined by Kirkpatrick, Price, Jr., and Madison (1963), includes all Pennsylvanian strata between the underlying Lee Formation and overlying Conemaugh Formation and consists of variable sequences of shale, sandstone, and coal grading from about 480 feet thick in northeastern Kentucky to about 2,500 feet in the south. The outcrop area covers most of the Eastern Coalfield region. A small portion of Greasy Creek, which has its source on the northwest face of Pine Mountain, drains limestone rocks of Mississippian and Devonian origin.

The Middle Fork watershed is maturely dissected and the relief is characterized by deep narrow valleys, steep slopes, and long narrow ridges. As the stream valley gradually broadens, alluvial terraces are more conspicuous. The alluvium consists of clayey and sandy material reflecting the character of the shales and sandstones from which it was derived. The alluviated valley, or floodplain, becomes evident at the Perry County boundary and the amount of fill increases as the valley widens downstream.

Chemical Features

The water quality of Middle Fork was only spot sampled before impoundment; therefore, to make the data more comprehensive, the results have been incorporated with findings of the Kentucky Geological Survey (Kirkpatrick, *et al.*, 1963) and are presented in Table 3. Waters of the Middle Fork drainage are soft and circumneutral, the pH ranging from 6.6 to 7.7. On only two occasions did total alkalinity (bicarbonate) exceed 50 ppm. The lowest alkalinities were recorded from Greasy Creek during June of 1958 and 1959, and were 4.4 and 8.0 ppm, respectively. Total dissolved solids ranged from 27 to 67 ppm. In general, lower concentrations of bicarbonates and total dissolved solids occurred during the colder months and higher concentrations during the warmer months.

Table 3. *Chemical quality of surface waters of the Middle Fork basin as determined by spot sampling, 1957-1959.*

Location	Date	Temp. (°F.)	Total alkalinity (ppm)	pH	Dissolved solids (ppm)
Beech Fk. at mouth	1-30-58		13.0	6.9	35
Greasy Cr. at Elk Cr.	6-4-57	77	4.4	7.5	
	6-10-58	75	8.0		
Greasy Cr. at mouth	8-11-57		48.0	7.5	67
	1-30-58		12.0	6.6	28
Middle Fk. at Hyden	8-11-57		52.0	7.6	72
	1-30-58		12.0	6.9	27
	9-30-58		43.0	7.0	63
	3-25-59		15.0	6.9	38
Middle Fk. at Bull Cr.	6-7-57	79	30.0	7.6	
Middle Fk. at Langdon Br.	9-24-58		63.0		
Middle Fk. at Gays Cr.	6-5-57	79	30.0	7.7	

Description of Study Areas

The Middle Fork drainage was divided into three sections for study purposes; one in the headwaters, one in the proposed reservoir area, and one downstream from the dam site. In preference to the other headwater streams, Greasy Creek was selected for study because of its larger size and the reputedly greater amount of fishing. All of the sampling areas on Greasy Creek were confined to the section extending from Upper Bad Creek upstream to the mouth of Laurel Fork. This stream segment was designated as Section I (Fig. 1). The average gradient in Section I was 17.4 feet per mile.

Section II, located on Middle Fork, conformed to the stream segment that would be impounded by the seasonal pool of the reservoir. This section extended from near the mouth of Gays Creek upstream to the vicinity of Grassy Branch. The average gradient in this section was 3.3 feet per mile.

Section III was established downstream from the dam site to determine conditions in the impending tailwater area. Sampling in this section was limited to the segment extending from the dam site to five miles downstream. The average gradient in this section (measured downstream from Gays Creek) was 1.9 feet per mile.

Massive boulders occurred frequently throughout the stream but were most abundant in Section I where a floodplain was virtually nonexistent. In the downstream sections, the distribution of boulders was confined to areas where the stream was bordered by precipitous bluffs.

In Greasy Creek, the substrate consisted of bedrock where the current was of sufficient velocity to sweep the bottom clean. Large to medium-sized boulders formed riffles in the upper parts of Section I, while small boulders and rubble made up riffles in the lower part. Pool bottoms were covered with moderate deposits of sandy silt, and in eddies and areas where tributaries discharged, there were deep and extensive accumulations of sand.

In the two sections on Middle Fork, the riffles were composed chiefly of rubble and pebbles. The pools were considerably wider and longer than in Section I, and proportionately more silted. Many of the riffles in the lower section were choked with water willow, *Justicia americana* (L.) Vahl, and the flow of water was greatly constricted. Water willow was the only emergent aquatic vegetation noted. Submergent forms of vegetation were not examined.

Forest vegetation of the surrounding region was essentially the same from Greasy Creek to Section III. Beech, *Fagus grandifolia* Ehrh., was the predominant forest tree and was most commonly associated with a variety of oaks, *Quercus* spp.; hickories, *Carya* spp.; and sugar maple, *Acer saccharum* Marsh. Dense stands of yellow poplar, *Liriodendron tulipifera* L., occurred on hillsides that had been cut-over and occasional specimens were interspersed among the forest dominants. Shortleaf pine, *Pinus echinata* Mill., and scrub pine, *P. virginiana* Mill., occurred at higher elevations along sandstone outcroppings and on steep rocky slopes. The principal understory trees were dogwood, *Cornus florida* L.; redbud, *Cercis canadensis* L.; sourwood, *Oxydendron arboreum* (L.) DC.; mulberry, *Morus rubra* L.; American hornbeam, *Carpinus caroliniana* Walt.; mountain ash, *Sorbus americana* (Marsh.) DC.; and ericaceous plants which formed impenetrable tangles locally called "slicks".

Riparian vegetation along Greasy Creek mainly consisted of hemlock, *Tsuga canadensis* (L.) Carr.; eastern white pine, *Pinus strobus* L.; beech; umbrella magnolia, *Magnolia tripetala* L.; American holly, *Ilex opaca* Ait.; rosebay, *Rhododendron maximum* L.; and mountain laurel, *Kalmia latifolia* L.

Along Sections II and III, the narrow floodplain was cleared for agricultural purposes, and only a fringe of trees remained adjacent to the banks. Species predominant along Greasy Creek yielded to forms better adapted to alluvial fill, except in areas where bluffs and outcroppings bordered the stream. The chief species along the banks were river birch, *Betula nigra* L.; black willow, *Salix nigra* Marsh.; sycamore, *Platanus occidentalis* L.; boxelder, *Acer negundo* L.; American elm, *Ulmus americana* L.; and silver maple, *Acer saccharinum* L.

BUCKHORN RESERVOIR

Construction of a flood-control dam across Middle Fork was begun by the Corps of Engineers, U. S. Army, in September, 1956 and completed in September, 1960. The dam is located at river mile 43.3, about 0.5 mile upstream from the village of Buckhorn in Perry County. The coordinates at this point are roughly 37° 20' N. and 83° 28' W., and the base of the dam is 715 feet above msl. Much of the hydrological and project data cited herein are those reported by the U. S. Department of the Interior (1957).

Hydrology

Buckhorn Dam, a rock-fill embankment with an earthern core, is 1,020 feet long by 162 feet high and is 830 feet wide at the base. The water outlet, a reinforced concrete conduit 14 feet in diameter, is installed in the base of the dam, and the inlet is inverted to elevation 724 feet above msl. The flow of water through the conduit is regulated by three service gates, each 5.5 feet wide by 11.0 feet high. The gates are operated from a concrete control tower, 176 feet high. The spillway is an open-cut saddle, 150 feet wide by 1,860 feet long, with four vertical lift gates, each 33 feet wide by 23 feet high. The elevation at the top of the gates is 843 feet above msl.

The various pool levels of Buckhorn Reservoir are shown in Fig. 2. Conservation-pool elevation is 757 feet above msl., and at this elevation the reservoir is 555 surface acres, 13.2 miles long, and has a volume of 10,300 acre-feet. Seasonal pool is at elevation 782 feet above msl., and at this level the surface area is 1,230 acres, the length is 21.2 miles and the volume is 32,000 acre-feet. Flood-control pool is at elevation 840 feet above msl., and at this stage, the reservoir is 34.0 miles long, 3,610 surface acres, and the storage capacity is 157,700 acre-feet. The total drainage area upstream from the dam is 408 square miles.

The water level in the reservoir is regulated concordantly for flood control, fisheries, and recreation. By the seasonal storage of water during non-flood threat periods, management of fisheries in the reservoir is expedited and a continuous discharge below the dam is made possible. Seasonal-pool elevation is attained as rapidly as possible after April 1. Drawdown begins on or about September 1, and conservation-pool elevation is reached by November 30. Regulation of minimum flow for the maintenance of downstream fisheries from April through August provides for a continuous release of 50 cfs. Minimum flow is regulated by two 24-inch bypass conduits with intakes at elevation 743.5 feet above msl. These conduits have a combined discharge capacity of 140 cfs. and are used for the regulation of downstream flow, except during winter drawdown and periods when stored flood waters are released.

Water Quality Studies

Physico-chemical analyses of the water quality in Buckhorn Reservoir were conducted monthly from April 1963 through March 1964. Three water sampling areas were established on the reservoir : Area 1, at the head of the reservoir near Wilder Branch; Area II, nine miles up-lake from the dam near Elkhorn Creek; and Area III, 1,000 feet up-lake from the dam. A fourth area (Area IV) was established in the tailwater, 1,000 feet downstream from the dam (Fig. 3). Data were obtained from Areas II, III, and IV every month except August, but water levels dictated sampling regularity at Area I. During periods of low water, stream conditions prevailed in the upper end of the reservoir and Area I was inaccessible.

Physical Characteristics

Water temperatures were recorded electrometrically from surface to bottom, at five-foot intervals, in the mid channel of the reservoir. Temperatures in the tailwater were measured with a mercury-bulb thermometer. All temperatures were recorded in degrees Fahrenheit.

Water temperature - Based on the annual temperature cycle during 1963-1964, Buckhorn Reservoir is best described as a dimictic lake, (Reid 1961). Surface temperatures near 39.2° F (4° C) became established in December at Area III (Figures 4 - 5). An ice cover was present at Area II and inverse stratification occurred with 39.2° water extending from one foot beneath the ice to within three feet of the bottom. The temperature near the bottom warmed to 40°, presumably caused by the liberation of heat from profundal sediments (Hutchinson, 1957). Heat is stored in the bottom deposits during the warmer months and slowly liberated at the mud-water interface when the temperature decreases. The density of this water is increased by the simultaneous diffusion of solutes (Fig. 5). At Area III, where the ice had melted from the open waters, the bottom temperature was nearly 3° warmer than at the surface.

Figure 3. Water quality and fish population study areas in Buckhorn Reservoir and tailrace.

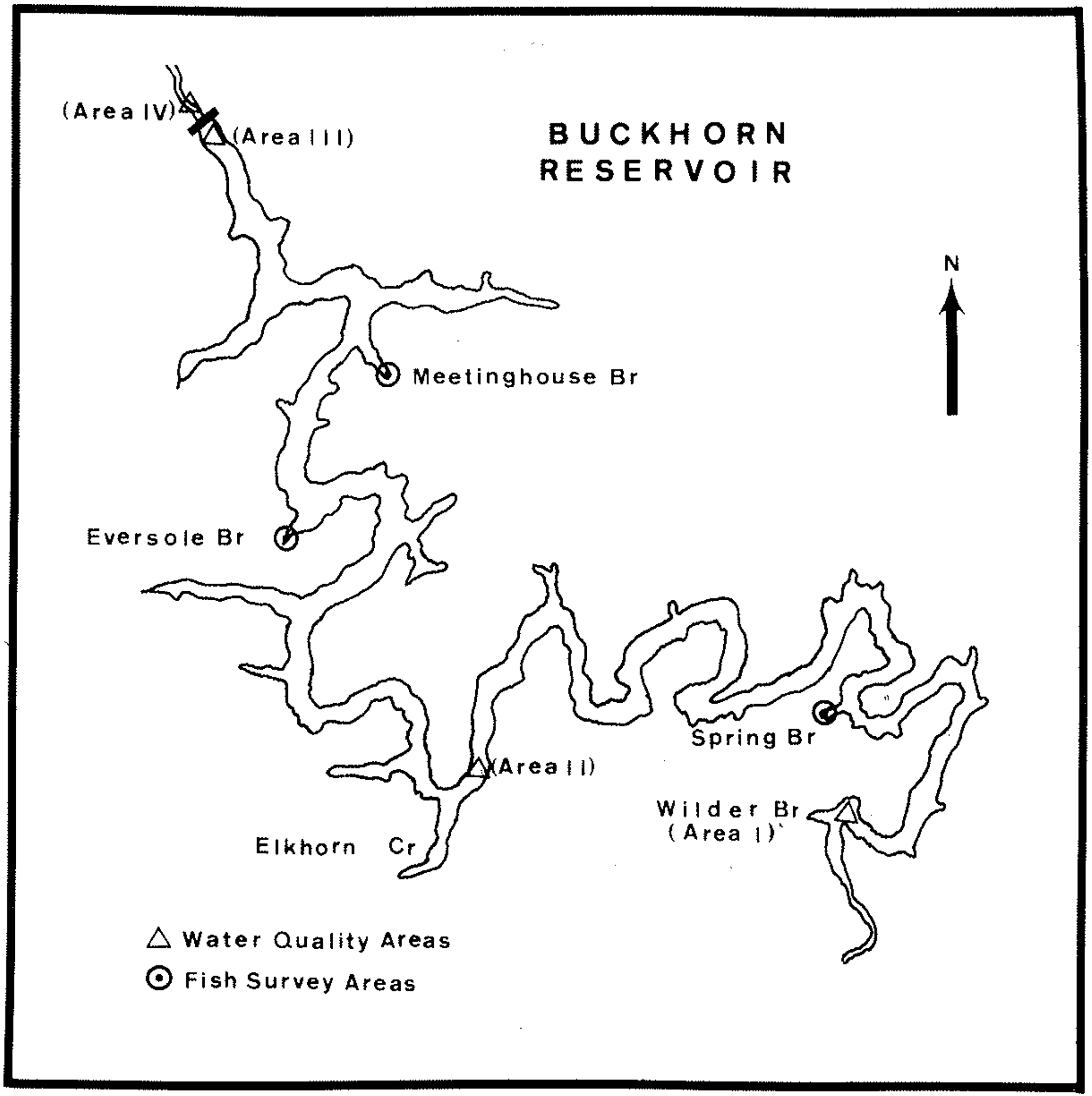


Figure 4. Annual temperature cycle in Buckhorn Reservoir (Area II, left, Area III, right) from April 1963 to March 1964.

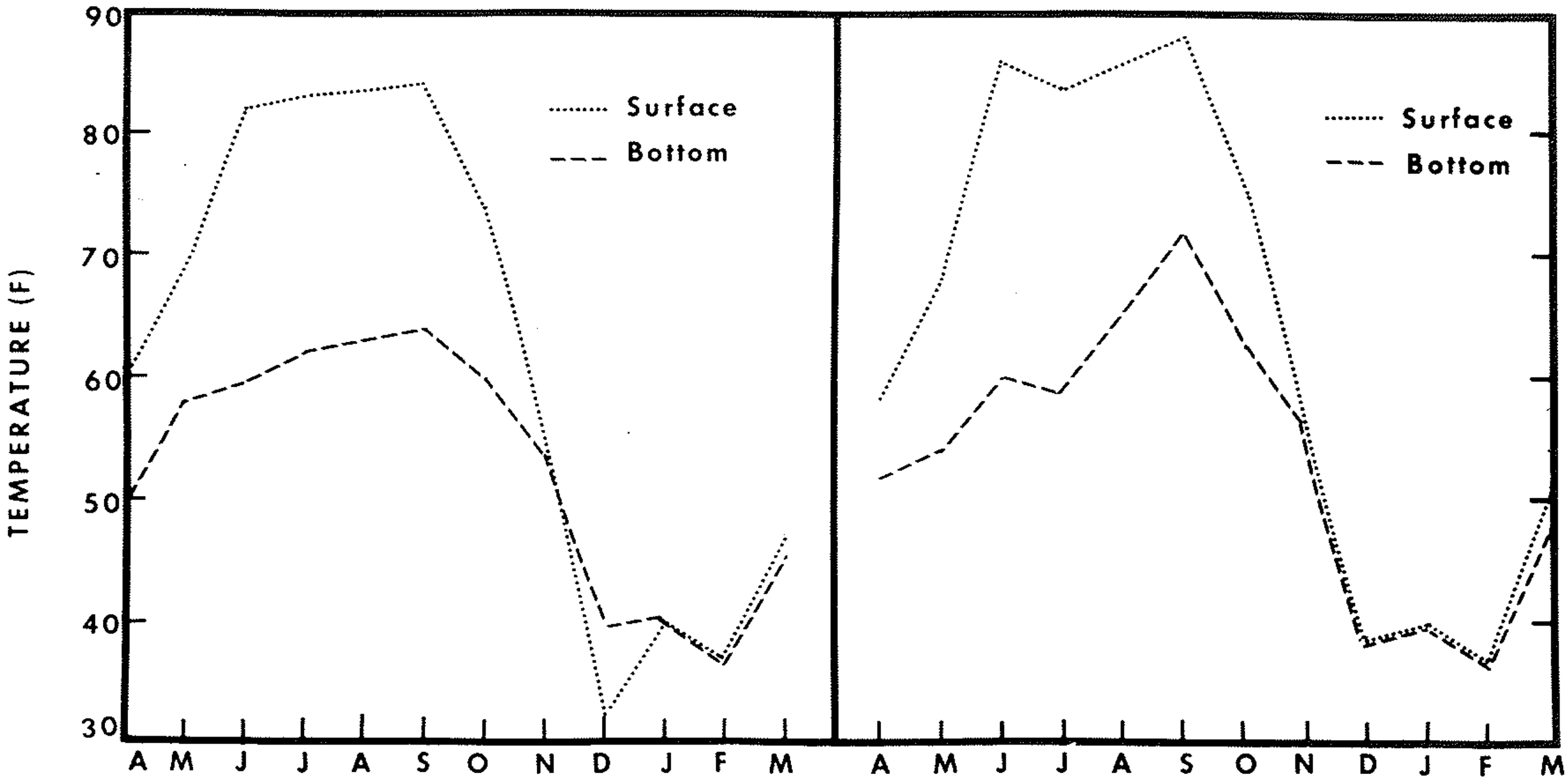
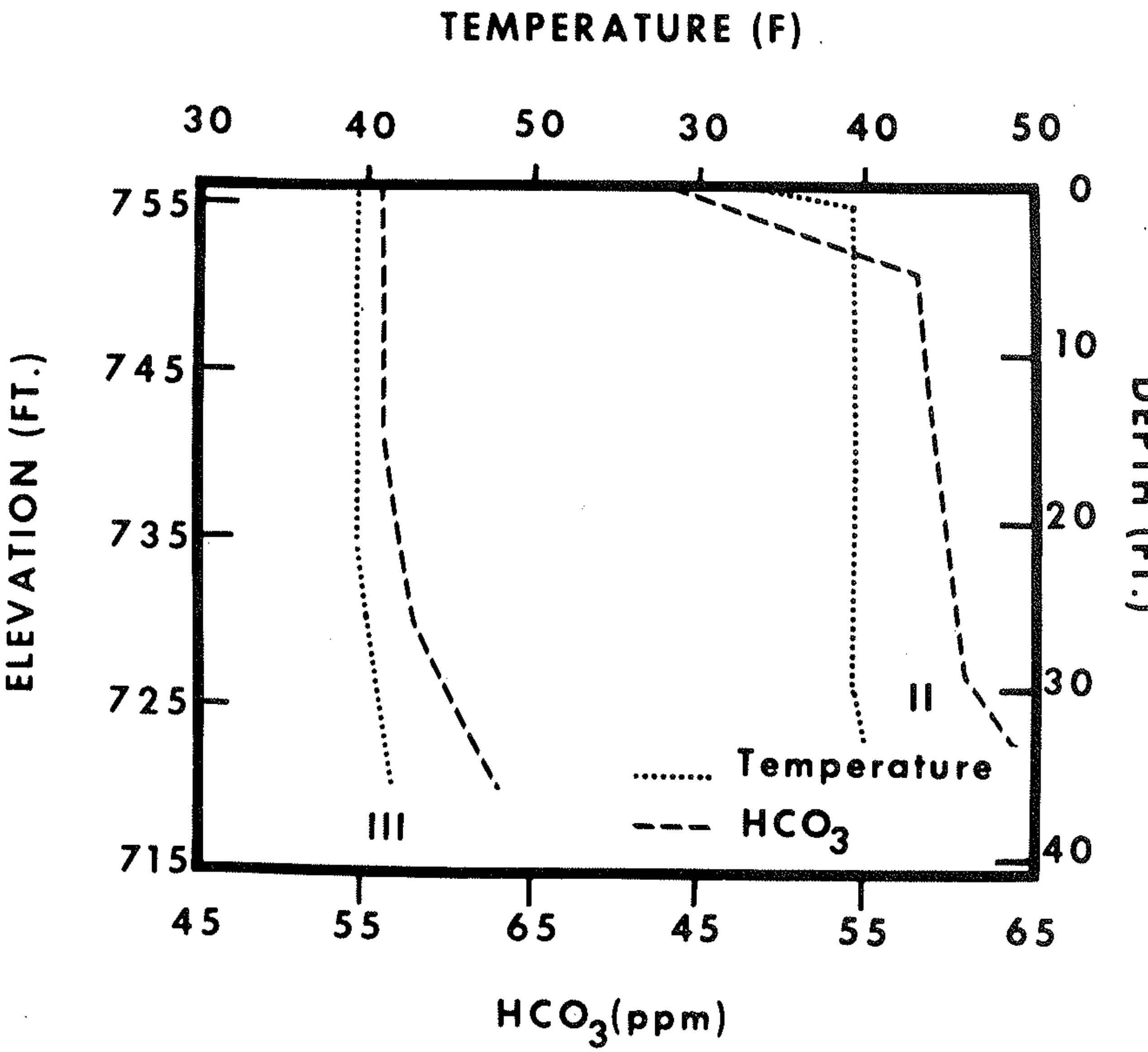


Figure 5. Mid-channel temperature and alkalinity profiles in Buckhorn Reservoir on December 16, 1963. Inverse stratification is depicted at Area II.

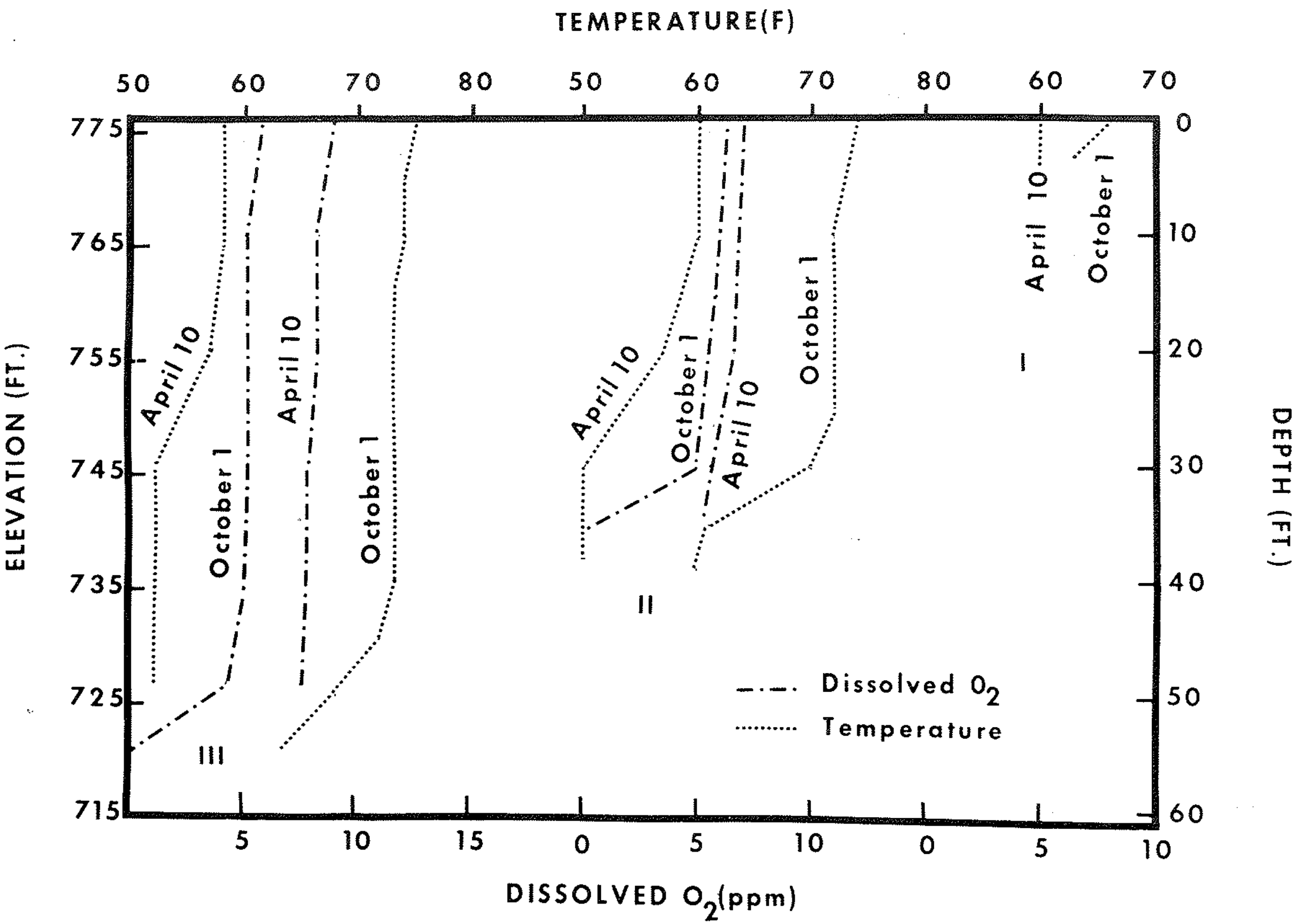


The ice cover had melted completely when the reservoir was visited on January 27, 1964, and the waters were isothermal at 40° F. These conditions persisted through February. By late March, spring circulation was in progress, and the surface waters had warmed to 47° and 50° at Areas II and III, respectively, and the bottom temperatures were only 1° to 2° cooler.

Typical thermal stratification rarely occurred in Buckhorn Reservoir during the summer of 1963. The reservoir is an open system — Middle Fork continually discharges into the upper end, and numerous tributaries flow into the impoundment; waters are constantly released from near the bottom of the reservoir through gates in the dam, and the water level is subjected to drastic seasonal fluctuations. Ellis (1950) descriptively termed such an impoundment a "half lake", and remarked on the instability of limnological conditions in the "adclaustral region" (the region in proximity to the dam and extending several miles up-lake) of such reservoirs. Fish (1961) reported physico-chemical aberrations in John H. Kerr Reservoir, Virginia, and warned against sampling in the adclaustral zone when only a single profile was possible for determining stratification patterns. In Buckhorn Reservoir stratification patterns were often disrupted during the summer of 1963, and this was attributed to a combination of stream inflow and interactions within the "adclaustral region".

Despite a very contracted temperature gradient (Fig. 4), thermal stratification was well-defined on April 10 (Fig. 6). At Area II the thermocline extended from a depth of 20 to 29 feet, and somewhat weakened at Area III where a minimal decrease of 5° occurred between 20 and 30 feet. The entire thermal gradient from surface to bottom amounted to only 6° at Area III and 10° at Area II. Isothermal conditions existed at Area I because of inflow. By May 21 remnants of the initial thermocline occurred

Figure 6. Vertical temperature and dissolved oxygen profiles in Buckhorn Reservoir on October 1, 1963 and April 10, 1964.



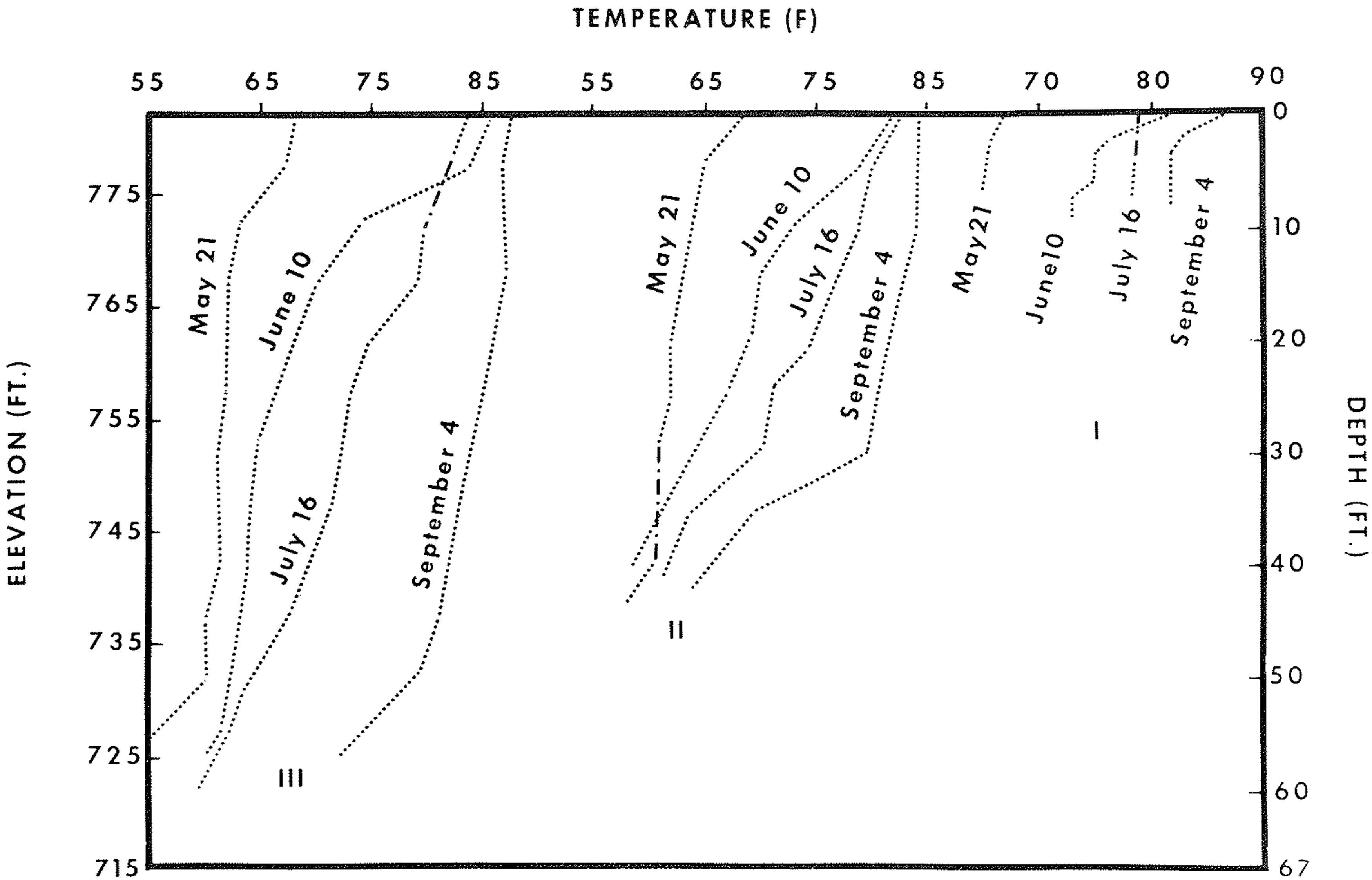
near the bottom of the reservoir and a secondary thermocline had developed, extending from the surface to a depth of 5 feet at Area II and from 5 to 10 feet at Area III (Fig. 7). At Area I, where the depth was only 7 feet, diminutive stratification occurred and a thermocline extended from the surface to 2 feet.

On June 10 thermal gradients attained the annual maximal differential of 23° at Area II and 26° at Area III (Fig. 4). A typical stratification pattern existed at Area III, and the thermocline extended from 5 to 15 feet. At Area II a thermocline extended from the surface to 15 feet, while the initial thermocline increased in extent.

Rainfall during July made waters very turbid at the head of the reservoir. Stream waters, cooled by the rains, flowed under the less dense water in the reservoir and a profound temperature change (8°) occurred in the upper 4 feet at Area I (Fig. 7). At Area II the lowermost thermocline became more pronounced and extended from a depth of 20 feet to the bottom, while a secondary thermocline was still discernable in the upper 5 feet of the water column. The persistence of a thermocline at the surface is ascribable to protection from the winds by the surrounding terrain. At Area III the thermocline extended essentially from the surface to the bottom but was more intensified between 15 and 25 feet and from 45 feet to the bottom.

In September and October the waters became progressively homeothermous to within about 10 feet of the bottom. From this level the temperature decreased abruptly to the bottom (Figures 6 - 7). By November 12, the surface temperatures decreased to 55° at Area II and 57° at Area III (Fig. 4) and the waters were nearly isothermous.

Figure 7. Vertical temperature profiles in Buckhorn Reservoir during the summer of 1963.



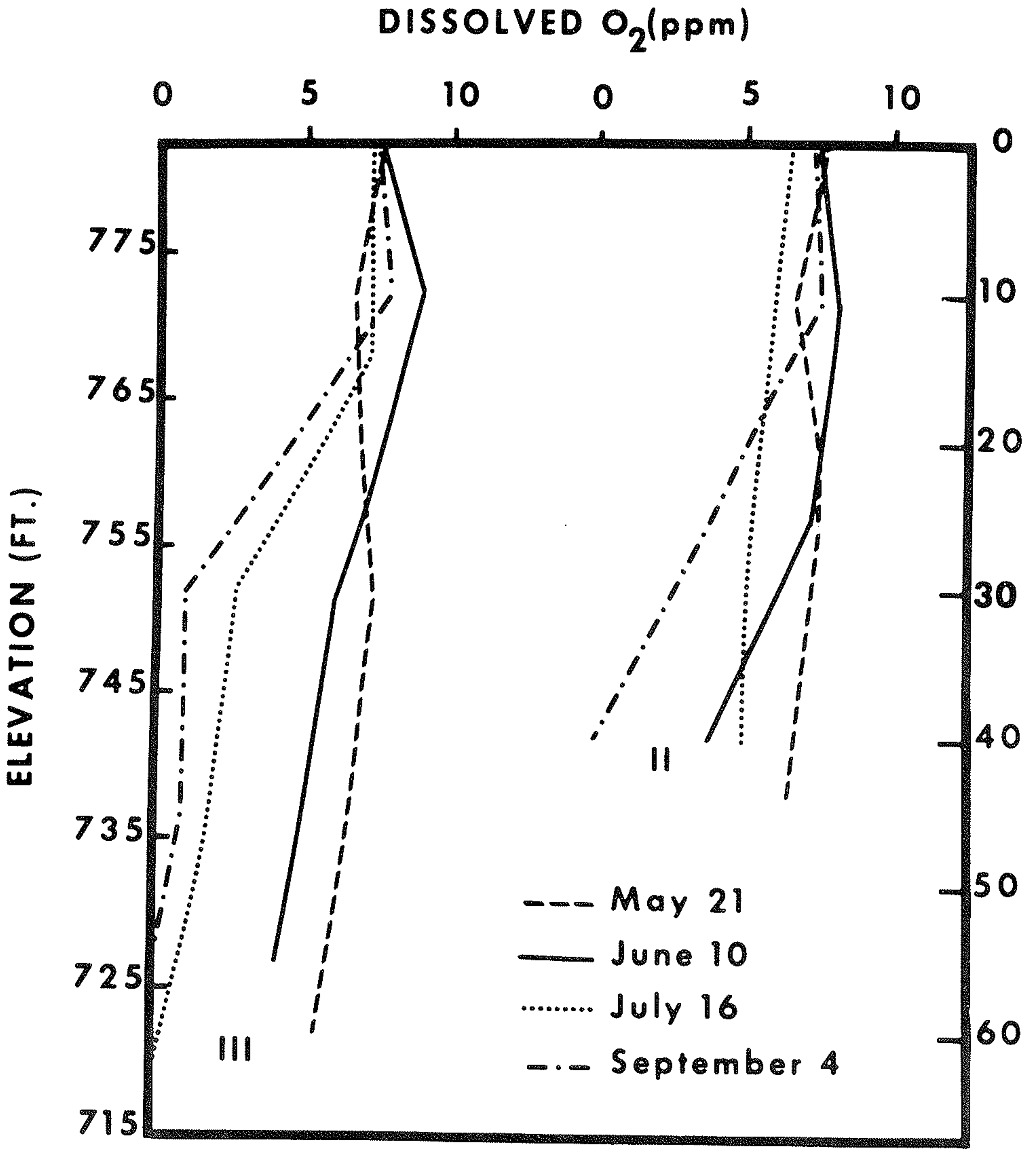
Chemical Characteristics

Water samples were collected in the mid-channel of the reservoir from surface to bottom at 10-foot depth intervals with a Kemmerer water bottle. Frequently, samples were collected from additional depths in order to determine the demarcation of various strata. Concentrations of dissolved oxygen were determined by the unmodified Winkler method (Ellis, Westfall, and Ellis, 1948). Alkalinity in Buckhorn Reservoir was due exclusively to bicarbonates and was measured by using methyl orange xylene-cyanol as an indicator and titrating with 0.02 N sulfuric acid. The results were expressed as ppm $CaCO_3$. Free carbon dioxide was calculated from pH and total alkalinity data employing procedures outlined by the American Public Health Association (1946). Hydrogen-ion concentration was measured electrometrically.

Dissolved Oxygen - Although the temperature pattern in the reservoir was rather erratic, eutrophic zonation was more concisely defined by dissolved oxygen distribution. Despite the evanescence of a typical hypolimnion, summer stagnation occurred and first became evident during July at Area III and probably developed at Area II by August. Anaerobic water at lower levels persisted at both areas into October, while holomictic conditions prevailed at the head of the reservoir throughout the summer because of inflow. The lowest concentration of dissolved oxygen recorded at Area I was 6.6 ppm.

Dissolved oxygen began to diminish in the deeper waters during June (Fig. 8); concentrations ranged from 7.6 ppm at the surface to 4.1 ppm at the bottom in Area III, and from 7.4 to 3.5 ppm in Area II. By mid-July a typical clinograde distribution pattern developed at Area III, but at Area II oxygen concentrations were nearly homogeneous because of intensified inflow from recent rains. By September anoxic conditions were

Figure 8. Mid-channel dissolved oxygen profiles in Buckhorn Reservoir during the summer of 1963.



established in the lower waters at Area II, and at Area III the clinograde distribution pattern was maintained. In June and September, increases in dissolved oxygen content were noted in the euphotic zone, probably marking the summer trophogenic layer.

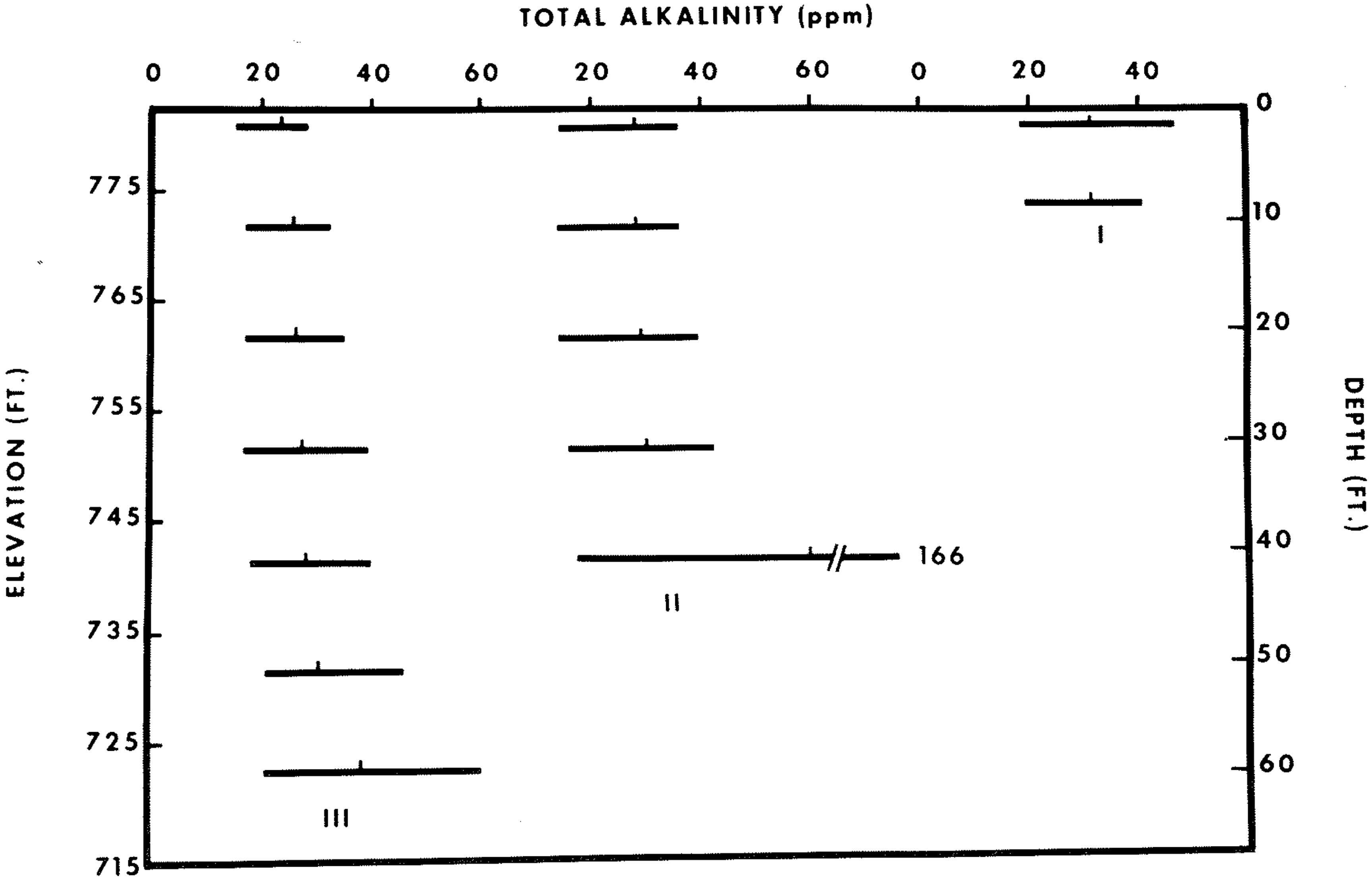
Dissolved oxygen concentrations paralleled temperature profiles at Areas II and III on October 1 (Fig. 6), and distribution was nearly uniform from the surface to about 10 feet above bottom. From this point down, anaerobic conditions rapidly transpired. By November 12, autumnal circulation distributed the dissolved oxygen rather evenly from surface to bottom, and concentrations ranged from 7.9 to 7.8 ppm at Area II and from 8.0 to 7.8 ppm at Area III.

Beneath the ice cover in December, 10.5 ppm dissolved oxygen were measured. Maximal values were noted in February, 13.2 ppm at the surface in Area II and 12.0 ppm at the surface in Area III.

Total Alkalinity - Total alkalinities reached their annual minima in January, February, and March, and concentrations were nearly homogeneous from surface to bottom throughout the reservoir. The minimal surface value recorded during this period was 11 ppm on January 27 at Area III, while the maximum surface value of 16 ppm was recorded on January 27 and March 24 at Area II. Concentrations at the bottom were 1 ppm higher in all three instances. Alkalinities increased in April as temperatures warmed and the reservoir commenced filling to seasonal-pool level. On April 10 surface values reached 34, 30, and 20 ppm at Areas I, II, and III, respectively.

Total alkalinity concentrations decreased successively down-lake throughout May - September when the water level was stable (Fig. 9). Concomitant with this decrease, alkalinity increased with depth

Figure 9. Vertical alkalinity profiles (ranges and means) in Buckhorn Reservoir during seasonal-pool stage, May - September 1963.



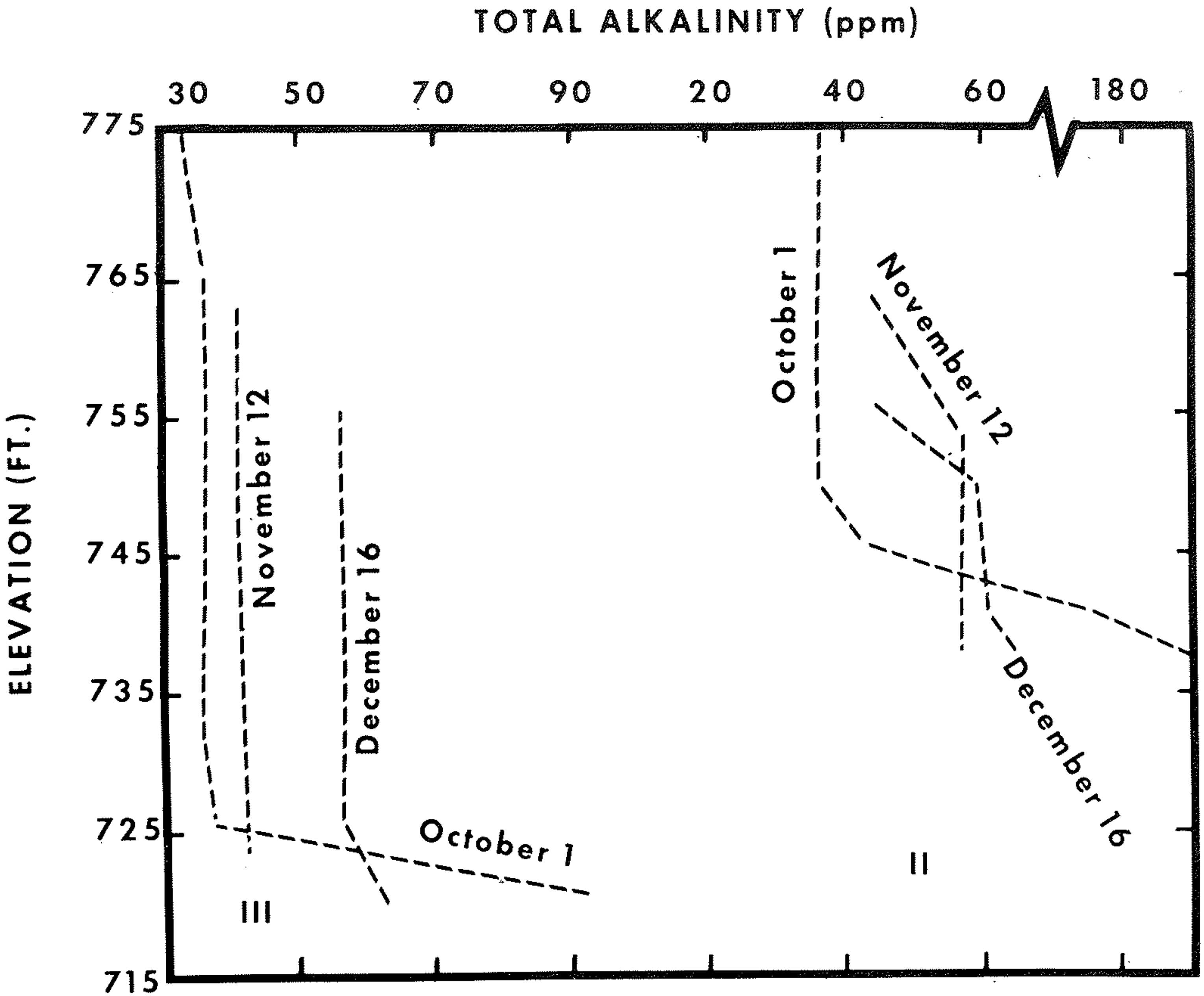
throughout the water column, as indicated by the mean values in Fig. 9. The accrual of bicarbonates at greater depths was attributed to the settlement of particulate matter in suspension while down-lake decreases coincided with current abatement. In addition to the accumulation of bicarbonates at greater depths, profound increases paralleled anoxic conditions in the lower strata during September and October. Alkalinity values during those months ranged from 60 to 92 ppm at Area III, and attained 189 ppm at Area II on October 1, corresponding to the only time stagnant conditions were noted at mid-lake (Fig. 10).

By November 12 autumnal circulation dispersed the high concentrations in the profundal zone, and there was a general increase in alkalinity values throughout the reservoir. Alkalinity concentrations were essentially uniform from surface to bottom at Area III, and in Area II, where the gradation was much greater from surface to bottom, the differential was reduced to 13 ppm.

During December, concentrations increased further at both areas; however, a decrease occurred beneath the ice cover at Area II and was probably caused by dilution from melt-water (Fig. 5). The increase in bicarbonates at the bottom during the period of ice cover is ascribable to diffusion of solutes at the mud-water interface. During the three ensuing months bicarbonates were nearly homogeneous from surface to bottom.

Based on classifications designated by Moyle (1946) for Minnesota lakes, Buckhorn Reservoir is essentially a soft-water lake, ranging from very soft during the winter (January - March) to medium hard in December. Throughout most of the spring, summer, and fall, the surface waters ranged within the soft category, 21 - 40 ppm.

Figure 10. Vertical alkalinity profiles in Buckhorn Reservoir, October - December 1963.



Carbon Dioxide and Hydrogen-Ion Concentration - The waters of Buckhorn Reservoir were circumneutral, and annual extremes of surface pH ranged from 7.0 to 7.4 at Area III, from 6.4 to 7.6 at Area II, and from 6.4 to 7.8 at Area I. Bottom waters generally were more acidic and ranged from 6.3 to 7.3 at Area III, from 6.5 to 7.5 at Area II, and from 6.2 to 7.2 at Area I. The greatest extremes occurred during the warmer months, while recordings were more uniform during the winter and during the circulation periods.

During the summer, free CO_2 at the surface usually varied from 1.1 to 5.8 ppm. A high reading of 19.3 ppm was obtained at the surface in Area II on June 10, after a rainfall, coinciding with the lowest pH recording from that area, 6.4. Free CO_2 at the bottom reached its maximal values when anaerobic conditions prevailed; at Area III, 36.8 and 46.7 ppm occurred in July and September, respectively, and at Area II, 51.0 ppm in September.

Free CO_2 was more uniformly distributed in November, and extreme concentrations ranged from 2.1 ppm at the surface to 5.5 ppm at the bottom. In January, February, and March, when oxygenation was greatest and bicarbonate concentrations were lowest, free CO_2 content was minimal. During this period, values at Area III varied from 1.3 ppm at the surface to 2.3 ppm at the bottom, while at Area II, the range was 0.2 to 0.9 ppm from surface to bottom. In April and May, the free CO_2 content increased throughout the reservoir.

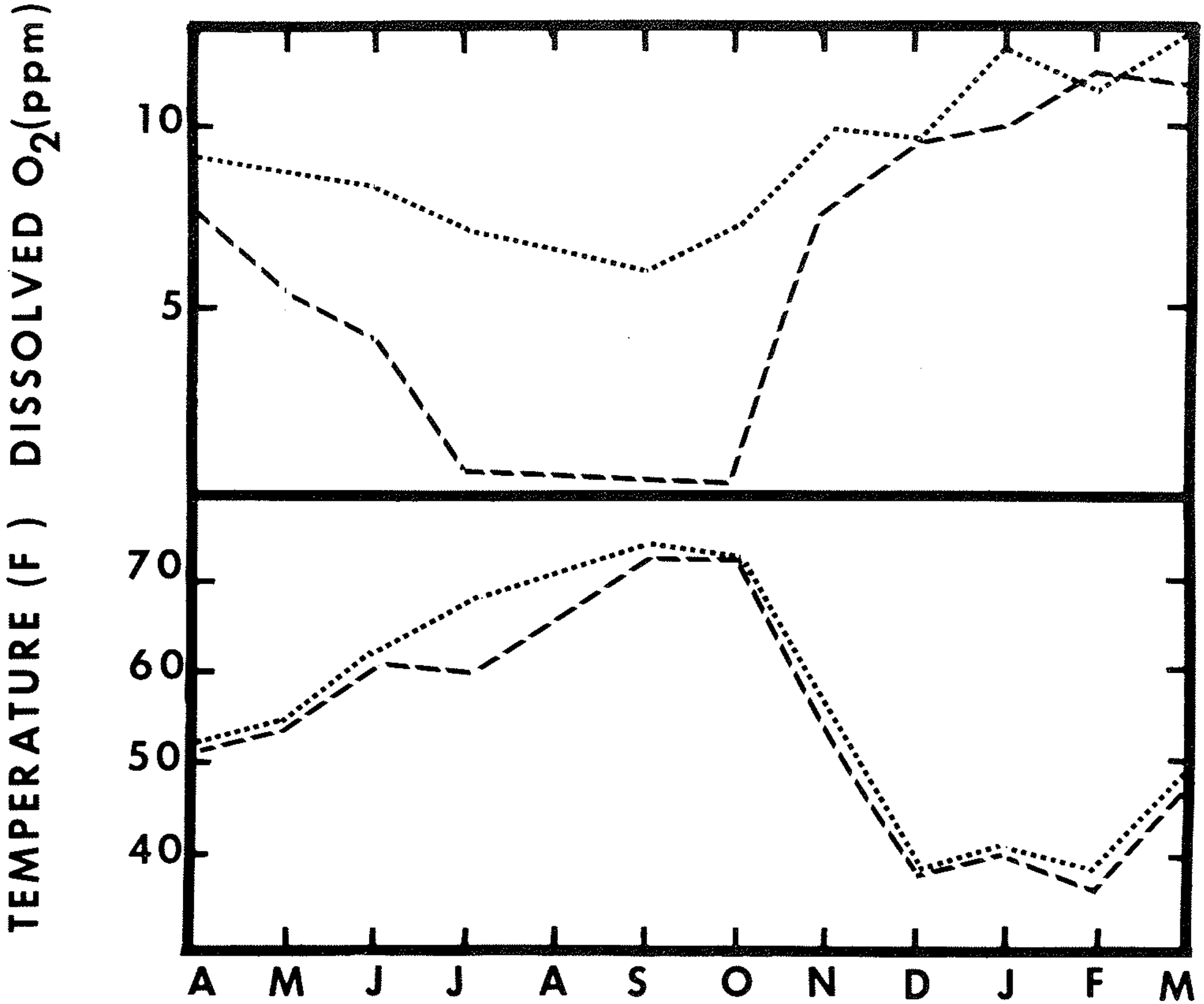
Water Quality of the Tailwater

Dissolved oxygen concentrations were measured and temperatures were recorded from the surface waters in the tailwater, 1,000 feet downstream from the dam, to evaluate the effects of the low-level discharge on stream conditions and to explore the potentialities of a trout fishery in that area. Generally, water temperatures and dissolved oxygen concentrations in the tailwater paralleled respective values in the bottom waters of the reservoir (Fig. 11). Temperatures in the tailwater were approximately the same as those from the discharge level (April - August) and from the bottom of the reservoir (September - November).

Stagnant waters were aerated considerably as they passed through conduits in the dam and over the adjoining shoal area. During the critical period of July - October when anoxic conditions occurred in the lower levels of the reservoir, the dissolved oxygen content in the tailwater ranged from a minimum of 6.2 ppm to a maximum of 7.2 ppm. In general, dissolved oxygen concentrations in the tailwater were consistently greater than those at the intake level in the reservoir. The reason for this is that air is deliberately introduced into the outflowing water by the Corps of Engineers. A breather tube or "venturi" which is connected to the main conduit introduces air into the discharge water to prevent cavitation within the conduit. The only exceptions occurred on December 16 when equal values of 9.6 ppm were noted at both areas, and on February 27 when the dissolved oxygen concentration at the bottom of the reservoir, 11.4 ppm, exceeded that in the tailwater by 0.2 ppm.

Temperature and dissolved oxygen characteristics were conducive to a trout fishery in the tailwater; water temperatures ranged from 39° in February to 74° in September, while dissolved oxygen concentrations ranged from 6.2 ppm in September to 12.2 ppm in January and March.

Figure 11. Monthly variations in temperature and dissolved oxygen in the tailrace and at the discharge level in Buckhorn Reservoir. Broken lines denote values from the discharge level in the reservoir. Solid lines connect values from the tailrace.



Summary of Water Quality

In September 1960, a 21.2-mile section of the Middle Fork of the Kentucky River was transformed into a 1,230-acre eutrophic reservoir. Buckhorn Reservoir is an open system subject to drastic fluctuations in water level for the purpose of flood control. From April 1963 to March 1964 physico-chemical water quality studies disclosed that inflow and currents frequently disrupted thermal patterns. Typical thermal stratification was most nearly approached in June, whereas during most of the summer a thermocline occurred in the deeper waters and extended to the bottom of the reservoir, while a secondary thermocline persisted near the surface.

During the 1963-1964 study year, Buckhorn Reservoir had two circulation periods interrupted by an ice cover in December. Because of the marginal climatic region, however, the reservoir is probably monomictic during years with mild winters (Krumholz and Cole, 1959). Inverse stratification occurred during December but was not paralleled by winter stagnation; 10.5 ppm dissolved oxygen were measured beneath the ice.

Vertical oxygen distribution characterized the eutrophic nature of the reservoir. A clinograde distribution pattern occurred during the warmer months, distinguished by an upper trophogenic layer and a well-defined tropholytic zone where oxygen was thoroughly depleted.

Free CO_2 and bicarbonates increased in an inverse relationship to dissolved oxygen. As waters at greater depths became more acidified during summer, maximal oxidation occurred and the cumulative increases of free CO_2 mounted to 46.7 ppm at Area III and 51.0 ppm at Area II. Bicarbonates decreased down-lake and increased with depth within the water column. The vertical accumulations and down-lake decreases of bicarbonates were attributed to the diffusion of solutes from particulate matter in suspension - the rate of settling paralleling current abatement. The derivation of bicarbonates from particulate matter and its independence of anaerobiosis was indicated by the consistently greater accumulations of bicarbonates at mid-lake depths than at Area III. Cushing (1964) postulated that the accumulation or dissipation of dissolved nutrients in an open lake-stream system was dependent upon the degree of autotrophic enrichment of the system - downstream decreases being related to increased plankton production. In Buckhorn Reservoir, however, total alkalinity was minimal during the winter, corresponding to the period when photosynthetic organisms are usually greatly reduced.

Surface values for total alkalinity ranged from 11 to 47 ppm but were usually less than 40 ppm. Middle Fork drains a predominantly sandstone region, and the soft waters of the lake characteristically reflect those of the watershed.

Despite a low-level discharge, physico-chemical conditions in the tailwater were adequate for the sustenance of a trout fishery throughout the year. Even during the critical summer period, when anoxic conditions prevailed at greater depths in the reservoir, waters were sufficiently aerated as they passed through conduits in the dam and over the adjoining shoal area. The minimum annual dissolved oxygen concentration recorded was 6.2 ppm in September. Correspondingly, the highest annual water temperature, 79°, was noted in September.

FISHES OF THE MIDDLE FORK DRAINAGE

Collections were made in the Middle Fork drainage to determine the kinds of fishes present, their distributional patterns, relative abundance, biomass, and population structure before and after impoundment. Before impoundment, fishes were collected from the three stream sections previously described (Fig. 1): Section I - Greasy Creek, from the mouth of Upper Bad Creek upstream to the junction of Laurel Fork; Section II - the segment of Middle Fork delineated by the seasonal pool of the incipient reservoir; and Section III - roughly the segment of Middle Fork extending from the dam site to 5 miles downstream.

After impoundment, Section I was retained to measure changes that occurred in the headwaters. Section II, which encompassed the entire reservoir at seasonal-pool stage, was sampled at three different areas (Fig. 4): Area I, Spring Branch, near the head of the reservoir; Area II, Eversole Branch, approximately 5 miles up-lake from Buckhorn Dam; and Area III, Meetinghouse Branch, approximately 3 miles up-lake from the dam. No sampling sites were available between Eversole Branch and Spring Branch. Stream Section III, the tailwater, was not sampled after impoundment.

Sampling Methods

In order to fulfill the objectives outlined, it was necessary to procure quantitative as well as qualitative fish population estimates. Since these studies represented the pioneer pre- and post-impoundment survey work in Kentucky, stream sampling techniques were varied during the initial phase of the project.

An electric shocker was the first tool employed for sampling the fish population of Middle Fork. The limitations of this device for collecting fishes in a stream of this size are multiple, and some of the most salient factors have been discussed by various workers (Kirkwood, 1957; Turner, 1959; Larimore, 1961; and others). The principal limiting factors are depth and transparancy of the water, selectivity for larger fishes, proficiency of the crew recovering fishes, and operational hazards. After two years of unsatisfactory trials, many of these limitations were circumvented by using rotenone-containing preparations. Although many species differ in tolerance to rotenone (Krumholz, 1948; Clemens and Martin, 1953; and Hester, 1959), it is the least selective method for sampling fish populations of large streams and lakes on a quantitative basis. Sanderson (1960) evaluated several different methods of sampling the fish population of a small lake (electrical, chemical, and mechanical), and concluded that results obtained by rotenone studies most nearly approached the values disclosed by subsequent reclamation. In the present studies, fish population samples obtained by rotenone exclusively were used in the final treatment of data.

Quantitative samples were obtained with rotenone by using nets to confine fishes to selected areas of the stream. A riffle was always designated as the downstream limits of a sample area, and was effectively blocked with a small-mesh net. The next riffle upstream was frequently utilized as a block for the upper end of the area, but if this was inappropriate, the fishes were confined by setting another net at a strategic point across the pool.

The surface area encompassed by the nets was calculated by measuring the length of the study area and multiplying by the average width. Average width was determined by stretching a calibrated line across the stream at five approximately equidistant intervals. Soundings were made along these same transects, and the average depth was computed by summing the readings and dividing by one more than the total number of recordings to allow for zero depth at the banks (Lagler, 1956). Sample area size ranged from 0.57 to 2.01 surface acres.

The volume of water within the study area was treated with 1.0 ppm emulsifiable preparation containing 5 percent rotenone (0.05 ppm rotenone). The product was diluted with water and dispersed by means of a venturi-type boat bailer in the wake of an outboard motor. As the rotenone flowed over the downstream riffle, it was oxidized with a finely granular form of potassium permanganate. Potassium permanganate was applied at the rate of 2.0 ppm as recommended by Lawrence (1955). The detoxifying agent was apportioned to several burlap sacks and these were secured in the riffle below the downstream block net. This method was not always successful in Middle Fork, and after several extensive downstream fish kills, the following modification was employed. In addition to the potassium permanganate dispersed in the riffle, an equivalent amount was put in a burlap sack and, upon termination of the study, was towed throughout the sample area. This augmented the detoxification of restive rotenone in eddies and slack waters which, presumably, later escaped and caused downstream fish kills. No downstream kills occurred when this modification was used.

After treatment of the waters with rotenone, all fishes that could be captured were recovered in dip nets. When fishes ceased to appear on the surface, the recovery crew picked the stream bottom clean in shallow areas. All stream studies were based on a one-day recovery.

All fishes recovered were sorted to species, measured to the nearest inch group, and weighed to the nearest 0.01 pound. Most cyprinids, darters, and young of various other groups were preserved in 10 percent formalin and identified, measured and weighed in the laboratory. Choice specimens were cataloged and housed in fish museums at the University of Louisville and Kentucky Division of Fisheries. The chief taxonomic references used were keys by Eddy (1957), Moore (1957), and Trautman (1957), supplemented by miscellaneous publications treating particular groups or species.

In Buckhorn Reservoir, fish population estimates were obtained from cove samples exclusively. Fishes in coves were isolated from the remainder of the reservoir by a 300' x 20' x 5/8" block net. The coves were mapped to determine the surface area, and the average depth and volume were computed in the same manner as for stream studies. Extremes of surface areas ranged from 0.51 acre at Spring Branch to 2.00 acres at Eversole Branch during the three years.

The waters were treated with a 5 percent emulsifiable rotenone product, at a concentration of 1.0 ppm, applied with a venturi-type boat bailer. Application was always started and intensified adjacent to the block net to discourage small fishes from entering or leaving the study area. All cove studies were begun between 7 and 9 a.m. and were conducted from June, after the waters had warmed to 70° F., through the summer.

Recovery operations commenced as soon as distressed fishes appeared at the surface and were concluded after 3 days. Weights of fishes recovered on the second and third days were adjusted to weights of fresh fishes of the same size group. Fresh fishes recovered during the second and third days were excluded from the study. Fishes were processed in the same manner as during stream studies.

The values of cove population studies have been criticized controversially in recent years. Buck and Cross (1952) reported that poisoning operations on small bays in Canton Reservoir, Oklahoma, were unsatisfactory and concluded that the samples could not be presumed representative of the actual proportions of fishes occupying those bays. Carter (1957) advocated that cove samples were invaluable for obtaining information on success and survival of reproduction, species abundance, and relative standing crop approximations.

Although cove samples impose many limitations upon the analyses of data from a particular body of water, valid comparisons are possible among and between cove fish populations, *per se*, in lakes. Because of the disparity of habitat preferences, the frequency of many species may be disproportionate in cove samples; however, if techniques are adequate and sufficiently standardized, trends in relative abundance, biomass, and population structure are obtained from those areas and are subject to valid regional and annual comparisons.

Annotated List of Species

The list of fishes collected from the Middle Fork drainage, before and after impoundment, included 67 different species representing 13 families. Six of these were introduced into Buckhorn Reservoir or its tributaries, while the remaining 61 were native components of the Middle Fork fish fauna.

In the accompanying tables, the distribution and relative abundance of each species is summarized. The linear distribution and relative abundance of species are indicated for each stream section sampled prior to impoundment, Table 4. Data including all 4 years were combined within each stream section to obtain maximum sample size, and estimates of relative abundance were based on the number of each species collected per unit of area - equated to one surface acre. The abundance of each species throughout the drainage area was designated cumulatively by the weighted mean of the combined samples, M_c. Arbitrary terms, such as rare, scarce, frequent, and common, indicated abundance in collections equivalent to < 0.5; 0.5 - 0.9; 1.0 - 10.0; and > 10.0 per acre, respectively. After impoundment, the relative abundance of fishes collected in the reservoir was designated annually; while in Section I - Greasy Creek, data representing 2 years of collections, 1961 and 1962, were combined, Table 5.

Table 4. *Relative abundance and distribution of fishes collected from Middle Fork of the Kentucky River prior to impoundment, 1957 - 1960.*

	Number of fish per acre			Weighted mean of combined samples (Mc)
Stream section	I	II	III	
Total surface area sampled - acres	5.83	6.15	0.57	
Ichthyomyzon greeleyi		0.2		0.1
Lampetra lamottei	0.2			0.1
Lepisosteus osseus	1.9	2.0		1.8
Dorosoma cepedianum			12.3	0.6
Carpiodes cyprinus	0.3	2.0		1.0
Carpiodes velifer	1.0	1.5	1.8	1.3
Hypentelium nigricans	10.1	3.1		6.2
Moxostoma anisurum		0.2	1.8	0.2
Moxostoma breviceps	0.7	3.0		1.8
Moxostoma carinatum	0.7		3.5	0.5
Moxostoma duquesnei	51.8	60.4		54.8
Moxostoma erythrurum	43.7	3.8	26.3	23.3
Campostoma anomalum	31.9	2.8		16.2
Ericymba buccata	2.6			1.2
Hybopsis amblops	19.0	17.0		17.1
Hybopsis dissimilis	0.3	8.0	10.5	4.5
Hybopsis micropogon	8.7	2.6	1.8	5.4
Notropis ariommus	6.5	2.5	1.8	4.3
Notropis atherinoides	0.5	1.8	1.8	1.2
Notropis chrysocephalus	11.8	4.0		7.4
Notropis photogenis	18.7	5.6	10.5	11.9
Notropis rubellus	18.0	12.3	1.8	14.4
Notropis spilopterus	24.7	4.8	5.3	14.0
Notropis stramineus	7.5	4.3		5.6
Notropis volucellus	13.4	4.1		8.2
Notropis whipplei	13.7	11.0	22.8	12.7
Phenacobius mirabilis		0.7		0.3
Pimephales notatus	19.2	9.3	1.8	13.5
Pimephales vigilax		0.2	1.8	0.2
Semotilus atromaculatus	0.7	0.2		0.4
Ictalurus natalis		0.2		0.1
Ictalurus punctatus	4.3	13.1	31.6	9.8
Noturus eleutherus		1.3	5.3	0.9
Noturus miurus			1.8	0.1
Noturus nocturnus		0.3	1.8	0.2
Pilodictis olivaris	2.7	7.4		4.9
Labidesthes sicculus	1.7	0.5		1.0
Ambloplites rupestris	9.4	1.8		5.3
Lepomis cyanellus		1.8		0.9
Lepomis machrochirus	3.3		3.5	1.7
Lepomis megalotis	12.9	11.0	26.3	12.5
Micropterus dolomieui	14.8	5.6	1.8	9.6
Micropterus punctulatus	2.9	1.8	1.8	2.3
Pomoxis annularis		0.2		0.1
Ammocrypta pellucida	0.5	0.8		0.6
Etheostoma blennioides	9.6	3.8	3.5	6.5
Etheostoma caeruleum	10.8		5.3	5.3
Etheostoma flabellare	0.7	2.0	1.8	1.4
Etheostoma maculatum	0.7	0.2		0.4

(Table 4 - concluded)

Stream section	Number of fish per acre I	II	III	Weighted mean of combined samples (Mc)
Total surface area sampled - acres	5.83	6.15	0.57	
Etheostoma nigrum		0.8	1.8	0.5
Etheostoma sp. *(Ulocentra)*	0.9			0.4
Etheostoma variatum	2.1		1.8	1.0
Etheostoma zonale	2.6	4.4	7.0	3.7
Percina caprodes	3.8	3.4	1.8	3.5
Percina copelandi	0.2		5.3	0.4
Percina evides			1.8	0.1
Percina maculata	10.5	7.5	12.3	9.1
Percina phoxocephala	0.7	1.1	7.0	1.2
Percina sciera		1.5	3.5	0.9
Aplodinotus grunniens		1.8	8.8	1.3
Average number of fish per acre	402.7	239.7	241.2	315.9
Total number of species collected	45	49	36	60

Petromyzontidae

Ichthyomyzon greeleyi Hubbs and Trautman: Allegheny brook lamprey. *Ichthyomyzon greeleyi*, a degenerate derivative of *I. bdellium* (Jordan), was described from the upper tributaries of the Ohio River system in Pennsylvania and Ohio by Hubbs and Trautman (1937). In 1952, four specimens were collected from the Green River drainage of the lower Ohio River system in Kentucky, extending the known range approximately 400 miles and partially bridging the gap between this species and three other allopatric, non-parasitic species of *Ichthyomyzon* (Clay and Lachner, 1955). The collections from the upper Kentucky River are the first records of this species from that drainage and add to the continuity of the previously extended range.

One specimen of *I. greeleyi* was taken before impoundment from Section II about two miles upstream from the dam site. This specimen was an ammocoete and identification was not verified until the collection of several adults after impoundment. Five specimens were taken from Buckhorn Reservoir in 1961 and 1962 and five from Greasy Creek (Section I) during those same years.

Table 5. *Relative abundance of fishes collected from the Middle Fork Drainage subsequent to impoundment.*

	Number of fish per acre			
Section number	I - Greasy Creek	II - Buckhorn Reservoir		
Sample year	1961 - 1962	1961	1962	1963
Total surface area sampled - acres	1.85	3.00	4.50	4.52
Ichthyomyzon greeleyi	2.7	0.3	0.9	
Lampetra lamottei			0.7	
Lepisosteus osseus	1.6	2.0	0.9	0.7
Dorosoma petenense			254.4	
Carpiodes cyprinus	1.6			
Hypentelium nigricans	11.9	0.3	4.4	0.9
Moxostoma breviceps		2.0		
Moxostoma carinatum	5.4		2.0	0.9
Moxostoma duquesnei	29.7		13.3	0.7
Moxostoma erythrurum	40.5	18.7	8.4	37.2
Campostoma anomalum	57.3	22.3		
Hybopsis amblops	22.7			
Hybopsis micropogon	27.0			
Notropis ariommus	27.0			
Notropis atherinoides				0.2
Notropis chrysocephalus	35.1	9.0	0.2	
Notropis photogenis	70.3	21.7	0.2	
Notropis rubellus	57.3	1.3		
Notropis spilopterus	67.6	5.3	0.2	0.2
Notropis volucellus	70.8			
Notropis whipplei	50.3	1.7		0.7
Pimephales notatus	70.3	87.7	24.2	4.0
Pimephales vigilax		0.7		
Ictalurus natalis		22.0	34.2	23.5
Ictalurus punctatus	12.4	4.0	6.0	2.4
Pilodictis olivaris	4.3	2.3	2.0	0.9
Labidesthes sicculus	1.1	10.0	20.4	53.8
Roccus chrysops	4.3		0.9	2.2
Ambloplites rupestris	26.5	46.7	21.8	5.1
Lepomis cyanellus				0.4
Lepomis macrochirus	2.7	173.7	2705.6	846.5
Lepomis megalotis	43.8	332.3	412.9	189.4
Micropterus dolomieui	14.6	1.3	1.3	
Micropterus punctulatus	8.1	718.0	164.0	25.4
Micropterus salmoides	0.5	347.7	98.4	89.8
Pomoxis annularis	2.2	75.0	69.8	181.4
Ammocrypta pellucida	2.2			
Etheostoma blennioides	10.8	0.3	0.2	
Etheostoma caeruleum	7.6			
Etheostoma flabellare	2.7		0.2	
Etheostoma maculatum	2.7			
Etheostoma nigrum	1.6		0.4	
Etheostoma sp. *(Ulocentra)*	4.9			
Etheostoma variatum	17.3	1.7		
Etheostoma zonale	16.2			
Percina caprodes	27.6	32.3	28.2	11.3
Percina maculata	19.5	16.0	3.6	0.4
Percina phoxocephala			0.2	
Aplodinotus grunniens		0.3	2.4	21.2
Average number of fish per acre	882	1957	3882	1499
Total number of species collected	40	29	31	24
		---- 39 ----		

Lampetra lamottei (LeSueur): American brook lamprey. One specimen of the brook lamprey was taken from Section I prior to impoundment, and three specimens were collected from the reservoir in 1962.

Both species of lampreys were sparsely represented in the pre-impoundment collections and attained their greatest numbers in Buckhorn Reservoir in 1962. Neither species, however, was recorded from the reservoir in 1963.

Lepisosteidae

Lepisosteus osseus (Linnaeus): longnose gar. Approximately two longnose gar per acre were taken from the Middle Fork drainage before impoundment, and the relative abundance of this species changed little after impoundment. Several additional longnose gar were taken in block nets during reservoir studies as they attempted to enter the area to capture distressed fishes. Fishes taken in this manner were not included in population estimates.

Clupeidae

Dorosoma cepedianum (LeSueur): gizzard shad. In 1960, seven gizzard shad were collected from Section III, about 0.2 mile downstream from the dam site. The gizzard shad was not taken upstream from this point either before or after impoundment. It is unique that a species of such high vagility was precluded from Buckhorn Reservoir.

The gizzard shad has a tendency to ascend streams during spawning migrations (Miller, 1960), usually during the late spring or early summer in Kentucky. During the fall and early winter, gizzard shad vacate streams of steeper gradient and migrate to regions approximating base level conditions. Construction on Buckhorn Dam began in September 1956, coinciding with the period of gizzard shad emigration. By spring of 1957, the stream channel at the dam site may have been altered to such a degree as to prevent gizzard shad ascention above this point. Although it is not tenable, fish population samples indicate this because the gizzard shad was not collected from the region of the incipient reservoir from 1957 through 1960, but they were taken a short distance downstream from the dam site.

An alternative is that this species attained maximum penetration in Middle Fork below the dam site. However, gradient, *per se*, was not considered an effective barrier to gizzard shad dispersal, as the declivity in the area where the shad were collected differed only slightly from that extending several miles upstream. Unfortunately, the fish population of Middle Fork was not sampled prior to 1957.

D. petenense (Gunther): threadfin shad. This clupeid was not indigenous to the Middle Fork drainage but was introduced into Buckhorn Reservoir to supplement the diminishing native forage species. Three hundred and five adult threadfin shad, obtained from the head of Watts Bar Reservoir, Tennessee, were stocked in Buckhorn Reservoir on June 5, 1962. These threadfin shad reproduced in the reservoir that summer and 254.4 per acre, age group 0 fish, were recovered in population samples. Success was ephemeral, however, as a record cold winter during 1962-1963 totally eliminated this species from the reservoir. Another introduction was made in the spring of 1964 using a stock of fish from Lake Cumberland, Kentucky, in hopes that it would prove a hardier strain.

The widely distributed and extremely prolific gizzard shad usually supplies the forage demand in Kentucky reservoirs, but in many impoundments, growth rate is so rapid that it does not provide forage for sustained periods (Lagler and Applegate, 1942; Lagler and Van Meter, 1951; Turner, 1953; and others). The gizzard shad has also been reported to suppress desirable game fish populations by virtue of its density(Swingle, 1953; Jenkins, 1957; and Whitney, 1962). In reservoirs where gizzard shad occur, the smaller threadfin shad is now stocked to supplement available forage and to suppress gizzard shad through direct competition (Carter, pers. comm.).

Salmonidae

Salmo gairdneri Richardson: rainbow trout. An estimated 2,000 rainbow trout, 7 to 10 inches long, were stocked in the Middle Fork drainage on July 17, 1962; 1,000 were released in the tailrace of Buckhorn Reservoir, and 1,000 were distributed along an 8-mile section if Greasy Creek. For the first time since the studies began, drought conditions prevailed in Greasy Creek, and trout mortality was very high. A fish population study conducted one month later at one of the release points failed to disclose any trout. Many of the trout released in the tailwaters survived, and local conservation officers attested that a considerable number were harvested by fishermen.

In 1963, 4,113 rainbow trout (10 to 12 inches long) were stocked in the tailrace of Buckhorn Reservoir. Reportedly, this trial was also successful, and additional introductions in 1964 and 1965 were evaluated by an intensive creel survey.

Esocidae

Esox masquinongy ohioensis Kirtland: Ohio muskellunge. This elusive game fish is indigenous to the Middle Fork drainage, but its presence was not authenticated by population studies and creel surveys. The occurrence of the muskellunge was formally documented in 1962 when the local conservation officer found a 45-inch, 25-pound dead specimen afloat in Middle Fork about two miles downstream from the mouth of Greasy Creek.

Catostomidae

Carpiodes cyprinus hinei Trautman: central quillback. Although none were collected in the small sample from Section III, the quillback tended to increase as gradient decreased. After impoundment, however, this species increased in Greasy Creek but was not collected from the reservoir.

C. velifer (Rafinesque): highfin carpsucker. The highfin carpsucker also increased in abundance downstream but was not recorded after impoundment. Both species of *Carpiodes* showed a preference for low gradient, but seemingly did not adapt to the lacustrine habitat; however, cove sampling techniques may not be conducive to collecting carpsuckers.

Hypentelium nigricans (LeSueur): hogsucker. The hogsucker was common in Section I (Greasy Creek) and frequent in the total drainage area sampled, 6.2 fish per acre. After impoundment, there was a slight increase (10.1 to 11.9 per acre) in the number of hogsuckers in Section I, and a moderate population was sustained in the reservoir.

Moxostoma anisurum (Rafinesque): silver redhorse. The silver redhorse was the rarest of five species of moxostomine fishes collected from the Middle Fork drainage. One specimen each was collected from Sections II and III, but none was taken after impoundment.

M. breviceps (Cope): shorthead redhorse. This species was frequent in Middle Fork before impoundment, especially in Section II. Two per acre were taken in cove samples during the first summer of impoundment, but it was not recorded from either the reservoir or the headwaters afterwards.

M. carinatum (Cope): river redhorse. Although frequent in Section III, the river redhorse was scarce throughout the total drainage area sampled. This species was definitely more abundant after impoundment, and in Section

I, increased from 0.7 to 5.4 per acre. The river redhorse was not collected from the reservoir during the first summer of impoundment, but 2.0 and 0.9 per acre were taken during the second and third years, respectively.

M. duquesnei (LeSueur): black redhorse. The black redhorse was the predominant species in the Middle Fork drainage before impoundment and was represented in the total collections by 688 individuals - 54.8 per acre. This species declined appreciably after impoundment, and in Section I the decrease amounted to 22.1 fish per acre, while in Section II, where it formerly occurred in greatest numbers (60.4 per acre), the reduction was even more drastic.

M. erythrurum (Rafinesque): golden redhorse. This was the second most abundant species that occurred in the Middle Fork drainage, and 23.3 per acre were taken in the combined collections. The golden redhorse readily adapted to the lentic environment and was the dominant catostomid in the reservoir. By 1963, the population in the reservoir amounted to 37.2 per acre. Concurrently, the golden redhorse maintained a substantial population in the headwaters, 40.5 per acre, so this species must be considered as one of the most facultative components of the native fish fauna.

Cyprinidae

Campostoma a. anomalum (Rafinesque): stoneroller. The stoneroller was the second most abundant cyprinid in the Middle Fork drainage and was exceeded in numbers per unit area only by the bigeye chub, *Hybopsis a. amblops* (Rafinesque). This species was primarily a riffle inhabitant and decreased downstream as the habitat diminished. Habitat destruction induced many stonerollers to migrate upstream after impoundment, as evinced by the increase in Greasy Creek and the absence of this species in reservoir collections after the first year of impoundment.

Ericymba buccata Cope: silverjaw minnow. This cyprinid rated as frequent in the drainage but occurred only locally in Greasy Creek where 2.6 per acre were collected. The silverjaw minnow was not recorded in post-impoundment collections, including those from Greasy Creek.

Hybopsis a. amblops (Rafinesque): bigeye chub. This was the most abundant cyprinid in the Middle Fork collections. This species prefers sandy bottomed areas in medium-sized streams of moderate gradient (Trautman, 1957). Its aversion of low-gradient areas was substantiated by the disappearance of this species from the inundated section of the river, while the bigeye chub population in Greasy Creek increased from 19.0 to 22.7 per acre after impoundment.

H. d. dissimilis (Kirtland): streamline chub. The streamline chub was scarce in Greasy Creek and increased downstream. It was common in Section III. This species was not recorded from either the resérvoir or its headwaters after impoundment.

H. micropogon (Cope): river chub. Chubs of the subgenus *Nocomis* from the Middle Fork drainage were intermediate in character between *H. micropogon* and *H. biguttata* (Kirtland). They were tentatively classified as *micropogon* on the basis of pharyngeal dentition; however, coloration patterns apply generally to the hornyhead chub. The subgenus *Nocomis* is currently being revised by E. A. Lachner and R. E. Jenkins (pers. comm.), and the Kentucky River form will probably be treated as a distinct species.

This species was frequent throughout the Middle Fork drainage but decreased downstream. This chub apparently migrated from the inundated section as it was not recorded from the reservoir after impoundment and increased from 8.7 to 27.0 per acre in Greasy Creek.

Notropis a. ariommus (Cope): northern popeye shiner. This species was frequent in the drainage and had a pre- and post-impoundment distributional pattern nearly identical to that of the preceding species.

N. a. atherinoides Rafinesque: emerald shiner. The emerald shiner was scarce in Greasy Creek and frequent in Middle Fork. This is the most abundant fish in the Ohio River (Krumholz, Charles, and Minckley, 1962), and although this species is usually associated with large rivers and impoundments (Clay, 1962), the emerald shiner did not prosper in Buckhorn Reservoir. The emerald shiner was not recorded after impoundment until 1963, when one specimen was taken in the reservoir. Generally, none of the cyprinids favorably adapted to the lacustrine habitat, and their decline was attributed to the increase of piscivorous fishes and lack of suitable spawning areas. Many cyprinids migrated from the reservoir into the headwater tributaries, but these swifter streams presented a barrier to the dispersal of species preferring lower gradient, such as the emerald shiner.

N. c. chrysocephalus (Rafinesque): northern striped shiner. This species was common in Greasy Creek and frequent in Middle Fork, and was represented by 7.4 per acre for the entire drainage. Subsequent to impoundment, the striped shiner increased from 11.8 to 35.1 per acre in Greasy Creek. Nine per acre occurred in the reservoir samples during 1961, but by 1962, it decreased to 0.2 per acre. The striped shiner was not recorded from the reservoir in 1963. The nomenclature of this species complies with that proposed by Gilbert (1964).

N. photogenis (Cope): silver shiner. *Notropis photogenis* was common in the Middle Fork drainage, especially in Section I. After impoundment, the abundance of this species irrupted to 70.3 per acre in Greasy Creek. During the first year of impoundment, 21.7 per acre were recovered from the reservoir samples, but by 1962, the population dwindled to 0.2 per acre. It was not recorded from the reservoir in 1963.

N. rubellus (Agassiz): rosyface shiner. *Notropis rubellus* was the most abundant shiner in the combined samples from the drainage. It was most common in Section I and decreased downstream. The rosyface shiner was not recorded in the reservoir after 1961 when only 1.3 per acre were taken in the cove samples. More than a threefold increase occurred in Greasy Creek after impoundment.

N. s. spilopterus (Cope): spotfin shiner. This was the second most abundant shiner in the Middle Fork drainage and was the most numerous in Greasy Creek, 24.7 per acre. Subsequent to impoundment, 67.6 per acre were recorded from Section I. In 1961, 5.3 per acre were taken in the cove samples, but it was represented by only one specimen during the next two successive years.

N. s. stramineus (Cope): sand shiner. Conditions in the Middle Fork drainage were favorable for the sand shiner. It was frequent in Greasy Creek and diminished downstream, exemplifying its habitat preferences. According to Trautman (1957), the sand shiner prefers streams of moderate to steep gradient with sandy bottoms and considerable current in the pools. This species was not recorded from the drainage after impoundment.

N. v. volucellus (Cope): mimic shiner. The mimic shiner was common in Greasy Creek and was classified as frequent for the entire drainage. It was not recorded from Buckhorn Reservoir but its relative increase in the headwaters was greater than that of any other species.

N. whipplei (Girard): steelcolor shiner. *Notropis whipplei* was common throughout the drainage area sampled, but was most numerous in Section III.

Like most of the other cyprinids, the steelcolor shiner drastically diminished in the reservoir and increased in the headwaters after impoundment.

Phenacobius mirabilis (Girard): suckermouth minnow. The suckermouth minnow was rare in the Middle Fork drainage and was represented by only four specimens, all from Section II. This species was not recorded after impoundment.

Pimephales notatus (Rafinesque): bluntnose minnow. This is one of the most ubiquitous species that occurs in Kentucky and is found in practically every stream in the state. It was abundant in the Middle Fork drainage, especially in Greasy Creek. Despite its plasticity, the bluntnose minnow progressively decreased in Buckhorn Reservoir, probably because of increased predation. During the first year of impoundment, 87.7 per acre were taken in the cove samples; in 1962, 24.2 per acre were collected; and in 1963, 4.0 per acre. The bluntnose minnow followed the same trend in Clearwater Lake, Missouri, after the impoundment of Black River (Martin and Campbell, 1953). The frequency of the bluntnose minnow increased from 19.2 to 70.3 per acre in Greasy Creek after impoundment.

P. vigilax perspicuus (Girard): northern bullhead minnow. The bullhead minnow was rare in Middle Fork and was collected from Sections II and III. This species was recorded from Buckhorn Reservoir during the first year of impoundment but was not taken afterwards.

Semotilus a. atromaculatus (Mitchill): northern creek chub. The creek chub was rare in the combined samples from the drainage but, nevertheless, tended to increase upstream. In a tributary to the North Fork of the Kentucky River, Kuehne (1962) noted that the creek chub increased in abundance as stream order decreased, corresponding to an increase in gradient. He found that the creek chub was most abundant in streams of the first, second, and third orders, and rare in streams of the fourth order and higher. Based on this same system of dichotomous classification, the Greasy Creek and Middle Fork study sections were of the fourth and fifth orders, respectively. Therefore, the paucity of this species in the drainage was a direct reflection of the gradient in the stream sections sampled. *Semotilus* was not recorded from the reservoir or from Greasy Creek after impoundment.

Ictaluridae

Ictalurus natalis (LeSuer): yellow bullhead. *Ictalurus natalis*, the only bullhead collected from the drainage, was rare in Middle Fork and was represented by one specimen taken in Section II. The yellow bullhead increased after impoundment and rapidly became established among the dominant species in the reservoir. The yellow bullhead population has remained essentially constant since 1961.

I. punctatus (Rafinesque): channel catfish. The channel catfish was frequent in the drainage and was the most abundant member of the family. This species showed a propensity to increase as gradient decreased; after impoundment, however, the distributional pattern reversed and more channel catfish were collected from the headwaters than from the reservoir. Despite its decline after impoundment, the channel catfish was an important component of the fishery in both the reservoir and its headwaters.

Noturus eleutherus Jordan: mountain madtom. The mountain madtom was represented in the combined pre-impoundment collections by 0.9 fish per acre, but was recorded only from Section II and III. This species inhabited the swifter waters of medium to large-sized streams in Indiana and was found in association with *N. miurus* (Gerking, 1945). Although Middle Fork was seemingly an ideal environment for this species, the mountain madtom was not collected after impoundment and probably perished because of habitat destruction and predation.

N. miurus Jordan: brindled madtom. *Noturus miurus* was represented in the pre-impoundment collections by only one specimen from Section III. The brindled madtom was not collected after impoundment. According to Woolman (1892), this species was formerly one of the most abundant fishes in the Middle Fork drainage.

N. nocturnus Jordan and Gilbert: freckled madtom. The freckled madtom was rare in the drainage and was represented in the combined collections by three specimens, two from Section II and one from Section III. This species was not recorded after impoundment.

Pilodictis olivaris (Rafinesque): flathead catfish. The flathead catfish was represented in pre-impoundment collections by 61 specimens and was approximately one-half as abundant as the channel catfish. After impoundment, this species increased in Section I. The flathead diminished in the reservoir each successive year, and in 1963, only 0.9 per acre were taken in the cove samples.

Atherinidae

Labidesthes sicculus (Cope): brook silversides. This fish was collected from the drainage at the rate of 1.0 per acre. Following impoundment this species increased significantly each successive year and by 1963 ranked among the predominant fishes in the reservoir, 53.8 per acre. Conversely, Martin and Campbell (1953) found that the brook silversides decreased annually after the impoundment of Black River, Missouri.

In view of the relative success of this fish in Buckhorn Reservoir, its importance as a forage species is unequivocal. Observations during field operations showed that piscivorous species readily preyed upon brook silversides incapacitated by rotenone when other fishes were equally vulnerable. These observations were corroborated by field examination of game fish stomachs. Because of its body structure, brook silversides are easily devoured by predatory fishes, and consequently, are preferred to deep bodied or spiny rayed species. Buck and Cross (1952) noted that the brook silversides was an excellent forage fish in Canton Reservoir, Oklahoma, where it ranged into open waters and was readily available to capture, and that its size and body conformation rendered it utilizable by carnivorous species.

Serranidae

Roccus chrysops (Rafinesque): white bass. The white bass was not indigenous to the upper Middle Fork drainage, but was introduced in Buckhorn Reservoir during the first year of impoundment to furnish an additional sport fish. In April 1961, 171 adult white bass in spawning condition were netted in South Fork of the Cumberland River and stocked in Buckhorn Reservoir. The introduction was successful and in 1962 and 1963, 0.9 and 2.2 white bass per acre, respectively, were taken during the cove population studies. These estimates probably provide a disproportionate index to the abundance of the white bass, since it is a pelagic species and usually does not frequent coves. Young-of-the-year white bass were first taken in the samples in 1963.

When the white bass migrated upstream to spawn, apparently a portion of the population remained in the headwaters pools. An average of 4.3 per acre was collected from Greasy Creek during the summer population estimates.

Centrarchidae

Ambloplites r. rupestris (Rafinesque): rock bass. The rock bass was the second most numerous panfish in the drainage and was exceeded only by the longear sunfish. It was most abundant in Greasy Creek, 9.4 per acre, and decreased downstream. The estimated abundance for the total drainage was 5.3 per acre. After impoundment, the rock bass increased to 26.5 per acre in Greasy Creek. In 1961, the rock bass population in the reservoir was 46.7 per acre but decreased each year thereafter. By 1963, it no longer ranked among the dominant forms in the reservoir.

Lepomis cyanellus Rafinesque: green sunfish. *Lepomis cyanellus* was scarce in the drainage and was represented in the collections by 11 specimens from Section II. The green sunfish was not taken in post-impoundment collections until 1963 when two specimens were recovered at Eversole Branch.

L. m. macrochirus Rafinesque: bluegill. The bluegill was frequent in the drainage (1.7 per acre), and although it was not recorded from Section II, a rather uniform distributional pattern was indicated by its frequency at Section I (3.3 per acre) and Section III (3.5 per acre). There was an upsurge in the bluegill population immediately after impoundment, and by the summer of 1962, it was the dominant species in the reservoir. This dominance was maintained during the following year. In the headwaters, 2.7 bluegill per acre were taken after impoundment.

L. m. megalotis (Rafinesque): longear sunfish. The longear sunfish was perhaps the most facultative species in Middle Fork and was common in collections from all stream sections. After impoundment, the longear sunfish increased markedly in both the reservoir and its headwaters. By the second summer of impoundment, it was the second most abundant species in the reservoir. In Greasy Creek, 43.8 per acre were collected during 1961 and 1962.

L. microlophus (Gunther): redear sunfish. One thousand redear sunfish, 2 - 3 inches in length, were introduced in Buckhorn Reservoir during April 1962. This species was excluded from the tabulated list as it was not recorded in any collections after stocking.

Micropterus d. dolomieui Lacepede: smallmouth bass. The smallmouth bass was frequent (9.6 per acre) in Middle Fork, and was the predominant game fish in the drainage. It was most abundant in Greasy Creek (14.8 per acre) and decreased successively downstream. After impoundment, the smallmouth bass population remained essentially stable in Section I (14.6 per acre), but decreased drastically in the reservoir. During the first and second summers of impoundment, only 1.3 per acre were recovered, and none were taken in 1963.

M. p. punctulatus (Rafinesque): spotted bass. The spotted bass was considerably less numerous than the smallmouth bass but was distributed more uniformly throughout the drainage. The impounding of Middle Fork, however, was beneficial to the spotted bass population. During the summer of 1961, the spotted bass was the most abundant fish in Buckhorn Reservoir, 718.0 per acre. By the end of the third summer, the population had diminished severely, but this species still ranked seventh among the dominant fishes in the reservoir. In Greasy Creek, the spotted bass increased from 2.9 to 8.1 per acre after impoundment.

M. s. salmoides (Lacepede): largemouth bass. The largemouth bass was not a component of the native fish fauna but was introduced in Buckhorn Reservoir soon after impoundment. Approximately 16,000 sub-adults, 6 - 9 inches in length, were stocked in the spring of 1961. A substantial number of these fish spawned during the first summer as 347.7 per acre, chiefly young-of-the-year, were recovered from cove samples in 1961. However, this year class strength was not duplicated afterwards, and like the other black basses, the population has since diminished. The largemouth bass invaded the headwaters to the extent of 0.5 per acre.

Generally, all three species of black basses were abundant during the initial year of impoundment and diminished subsequently. This same trend was noted by Bennett (1954) in Ridge Lake, Illinois, where relatively sparse numbers of largemouth bass produced the greatest number of fry when the lake was new and afterwards decreased to a very low level.

Pomoxis annularis Rafinesque: white crappie. This species was rare in the drainage and was represented in the combined collections by only one specimen from Section II. The white crappie population irrupted to 75.0 per acre during the first summer of impoundment and increased substantially thereafter. It was the only centrarchid that increased during the third year of impoundment. The white crappie was collected from Greasy Creek at the rate of 2.2 per acre after impoundment.

Percidae

Ammocrypta pellucida (Baird): eastern sand darter. This species frequented the extensive sand bars in Sections I and II and was obviously more abundant than indicated by population estimates. Because of its slender form, the sand darter frequently escaped through the mesh in the nets. After impoundment, the sand darter was not taken from the reservoir, but 2.2 per acre were collected from Greasy Creek.

Etheostoma blennioides Rafinesque: greenside darter. *E. blennioides* was the most numerous of the etheostomine fishes in Middle Fork and 6.5 per acre were recovered in the combined samples. The greenside darter was most frequent in Section I and decreased in numbers downstream. This species remained nearly constant in Greasy Creek after impoundment but was not recorded from the reservoir after 1962.

E. caeruleum Storer: rainbow darter. The rainbow darter was frequent in the drainage and was the most common darter in Greasy Creek. It was not recorded from Buckhorn Reservoir and decreased slightly in Section I after impoundment.

E. f. flabellare Rafinesque: fantail darter. The fantail darter was frequent in the Middle Fork drainage and was more numerous in the main stream than in Greasy Creek. This species increased in Section I after impoundment, but only one specimen was collected from the reservoir.

E. maculatum Kirtland: spotted darter. This species was rare in the drainage and the greatest numbers were collected in Greasy Creek, where it occurred in the chutes of deeper riffles. The spotted darter increased in the headwaters after impoundment, but was not recorded from the reservoir.

Raney and Lachner (1939) noted that *E. nigrum, E. variatum, E. zonale, E. caeruleum, E. flabellare,* and *E. blennioides* frequently occurred in the same habitat, and that *Hybopsis micropogon, Notropis rubellus, Campostoma anomalum,* and *Hypentelium nigricans* were common summer associates. Findings during the present studies were in agreement.

E. n. nigrum Rafinesque: central johnny darter. The johnny darter was scarce in the Middle Fork drainage and only two specimens were collected from Buckhorn Reservoir. This species was not recorded from Section I prior to impoundment, but 1.6 per acre were taken afterwards.

Etheostoma sp. *(Ulocentra)*: emerald darter. Darters of the subgenus *Ulocentra*, including this species, are currently being revised by Reeve M. Bailey (pers. comm.). This species was scarce in the drainage, and its distribution was confined to the study section of steepest gradient, Greasy

Creek. After impoundment, it was frequent (4.9 per acre) in Section I but was not recorded from Buckhorn Reservoir. The emerald darter was probably transferred from the Cumberland River system through stream capture (Kuehne and Bailey, 1961).

E. variatum Kirtland: variegated darter. *E. variatum* was frequent in the Middle Fork drainage. Subsequent to impoundment, the variegated darter increased profusely (2.1 to 17.3 per acre) in Greasy Creek. This species was collected from the reservoir in 1961 but was not recorded afterwards.

E. z. zonale (Cope): banded darter. The banded darter was the third most numerous representative of the Etheostominae in the drainage, 3.7 per acre. Although this species increased as stream gradient decreased, it did not adapt to the lacustrine habitat. The increased abundance in Greasy Creek, 2.6 to 16.2 per acre, indicated that the banded darter emigrated from the inundated region, at least during the summer.

Percina c. caprodes (Rafinesque): logperch. The logperch was collected from all sections of the drainage at an average of 3.5 per acre but was most numerous in Greasy Creek and decreased uniformly downstream. After impoundment, this species increased from 3.8 to 27.6 per acre in Section I. The logperch was the most adaptive of the percid fishes and rated among the ten predominant species in the reservoir during the first three years of impoundment. Other than the brook silversides, the logperch was the only forage species that prospered in Buckhorn Reservoir.

P. copelandi (Jordan): channel darter. The channel darter was rare in the Middle Fork drainage and upstream from the dam site was represented in the combined collections by one specimen from Greasy Creek. It was frequent (5.3 per acre) in the collection from Section III. The channel darter was not recorded after impoundment.

P. evides (Jordan and Copeland): gilt darter. The gilt darter was rare in the total collections and was represented by one specimen from Section III. It was not recorded after impoundment.

P. maculata (Girard): blackside darter. The blackside darter was the most abundant of the percid fishes in the Middle Fork drainage. This species was numerous in the reservoir during the first year of impoundment but declined appreciably afterwards. The blackside darter increased from 10.5 to 19.5 per acre in Greasy Creek after impoundment.

P. phoxocephala (Nelson): slenderhead darter. This species was frequent in the Middle Fork drainage and increased inversely with gradient. Only one specimen was collected after impoundment and was taken from the reservoir in 1962.

P. s. sciera (Swain): dusky darter. The dusky darter was scarce in the combined samples from the drainage. This species was absent from the Greasy Creek collections but frequent in the parent stream, especially in Section III. The dusky darter was not recorded after impoundment.

Stizostedion v. vitreum (Mitchill): yellow walleye. The walleye was not indigenous to the Middle Fork drainage, but approximately 6,000 fry were stocked in Buckhorn Reservoir in April 1961. Although this species was not collected during ensuing population studies, it was recorded in creel surveys.

Sciaenidae

Aplodinotus grunniens Rafinesque: freshwater drum. This species was frequent in the main stream (Sections II and III) before impoundment. Subsequent to impoundment, this species increased each successive year in the reservoir but did not invade the headwaters. By 1963, 21.2 drum per acre were taken in population studies, and this fish was established among the dominant species in the reservoir.

Discussion of Fish Distribution and Abundance

Changes before impoundment -- Comparisons with early collections by Woolman (1892), which represented the most thorough studies of the Middle Fork fishes prior to the present survey, indicated pronounced changes in the ichthyofauna of the drainage during the past 70 years. Woolman recorded 18 species from Bull Creek (see Fig. 1), 29 from Middle Fork near Asher Branch, and 20 from Cutshin Creek at a piont approximately three miles upstream from the mouth.

Most notable among the Woolman collections was the "abundance" of *Cliola (=Pimephales) vigilax* and *Semotilus atromaculatus* recorded from the mouth of Bull Creek. In the present studies, these species were rare in Section II. *Catostomus teres (=commersoni)* was also recorded and undoubtedly would have been taken in the present studies had smaller headwater streams been sampled. The redfin shiner, *Notropis umbratilis cyanocephalus*, was also listed in the Woolman collections from Bull Creek but was not recorded during the present studies. This species was often confounded with *N. rubellus* by early workers.

In the main stem of Middle Fork, Woolman noted *Noturus miurus* and *Etheostoma zonale* were very abundant, "several hundred taken in a few hauls of the seine". The banded darter was numerous in recent collections from this section, but the brindled madtom was rare in Middle Fork. Also listed as common in the Woolman collections were *Micropterus dolomieui*, *M. salmoides* (=*punctulatus*, an undescribed species at that time), *Notropis whipplei*, *N. arge* (=*photogenis*), *Etheostoma aspro* (=*Percina maculata*), *E. variatum*, *E. spilotum*, and *E.* (=*Ammocrypta*) *pellucidum*. Of these species, only *E. spilotum*, recently relegated to a subspecies of *E. s. sagitta* by Kuehne and Bailey (1961), was not recorded in the present studies. This species was described from the

South Fork drainage (Sturgeon Creek) and was collected in abundance from the North Fork drainage (Kuehne and Bailey, *loc. cit.*), but to my knowledge has not been recorded from the Middle Fork drainage since the Woolman survey in 1890. Although differences in collecting methods made comparisons difficult, it was obvious that a few species formerly abundant, such as *Noturus miurus*, *Pimephales vigilax* and *Etheostoma zonale*, have declined considerably; while two others, *Notropis umbratilis* and *Etheostoma sagitta spilotum*, may no longer occur in this section of the Middle Fork drainage.

The present studies disclosed 61 different species of fishes, including the Ohio muskellunge, from the Middle Fork drainage. According to the arbitrary categories employed, 10 species were classified as common, 29 as frequent, 7 as scarce and 15 as rare. The black redhorse was the predominant species in the combined samples from the drainage and was followed in order of decreasing abundance by golden redhorse, bigeye chub, stoneroller, rosyface shiner, spotfin shiner, bluntnose minnow, steelcolor shiner, longear sunfish, and silver shiner.

The distributional patterns of many species were related to stream gradient. Most notable among those species showing a preference for steeper gradients were the hogsucker, stoneroller, silverjaw minnow, striped shiner, sand shiner, creek chub, rock bass, smallmouth bass, spotted darter, and emerald darter. Among the species showing an affinity for moderate gradient were gizzard shad, silver redhorse, river redhorse, streamline chub, channel catfish, madtoms, slenderhead darter, and freshwater drum.

Kuehne (1962) demonstrated that the total number of different species increased as stream order increased in Buckhorn Creek, a tributary to North Fork of the Kentucky River. Larimore and Smith (1963) showed that the number of species per collection increased as stream size increased in selected

Illinois streams. Excluding the disproportionately small sample from Section III, the number of species in the Middle Fork drainage likewise increased as gradient decreased, or as stream order and stream size increased. Forty-five different species were collected from Greasy Creek (an Order 4 stream) in Section I where the average gradient was 17.4 feet per mile; while 49 species were taken from Middle Fork (Order 5) in Section II where the average gradient was 3.3 feet per mile.

Although the frequency occurrence of many species varied appreciably with gradient, only three had distributional patterns limited to Section I. These were the American brook lamprey, silverjaw minnow and emerald darter. Five species were recorded from Section II that did not overlap the extreme sections; Allegheny brook lamprey, suckermouth minnow, yellow bullhead, green sunfish and white crappie. The distribution of three species, gizzard shad, brindled madtom and gilt darter, was confined to Section III. Most of these species were rare or scarce in collections from the upper Middle Fork drainage (the gizzard shad and silverjaw minnow were abundant locally), and their disjunct distributional patterns may be a reflection of their paucity.

An average of 316 fish per acre were collected from the combined samples throughout the drainage, and the number of fish per unit area decreased downstream. Approximately 403 fish per acre were collected from Section I, 240 per acre from Section II, and 241 per acre from the small sample at Section III. This same trend was indicated in Illinois streams by Larimore and Smith (*loc. cit.*).

Changes after impoundment -- Transition from the lotic to the lentic environment was accompanied by trenchant changes in the distribution and relative abundance of most species. Fourteen species that were native to the drainage were not recorded after impoundment, and this was ascribable to a combination of initial scarcity, deficient upstream penetration, and increased competition. These species were gizzard shad, highfin carpsucker, silver redhorse, silverjaw minnow, streamline chub, sand shiner, suckermouth minnow, creek chub, madtoms (3 species), channel darter, gilt darter, and dusky darter. Some species were relatively numerous in the reservoir the first year, but declined in abundance thereafter. Most notable among these were the stoneroller, striped shiner, silver shiner, rock bass, and blackside darter. Other species emigrated from the reservoir into the headwaters, as indicated by their increased abundance in Section I.

The influx of fishes from the impounded segment caused profound changes among the dominant forms in the headwaters. The previously dominant catostomids, *Moxostoma duquesnei* and *M. erythrurum*, were displaced by the cyprinids, *Notropis volucellus* and *N. photogenis*. Although the actual abundance of some species remained nearly constant, such as *M. erythrurum* and *Micropterus dolomieui*, their relative abundance was altered by the profusion of immigrants, chiefly cyprinids, from the reservoir. The smallmouth bass, which ranked ninth numerically (14.8 per acre), declined considerably in relative abundance after impoundment, but the actual number per unit area remained essentially unchanged, 14.6 per acre.

A complete revolution occurred among the predominant forms in the inundated segment in relation to the pre-impoundment fish fauna of the drainage, and changes transpired throughout the first three years of impoundment. Considering the 10 most abundant species, the fish population of Middle Fork was dominated numberically by redhorses, cyprinids, and the longear sunfish. During the first year of impoundment, the fish population in the reservoir was dominated by centrarchids, chiefly black basses and lepomids. No catostomids and only two cyprinids, bluntnose minnow and stoneroller, remained among the 10 most abundant species. By 1962, bluegill and longear sunfish, surpassed the black basses numerically, and the following year, lepomid supremacy was supplemented by the white crappie. By 1963, the fish population of Buckhorn Reservoir approached a typical lacustrine species complex. In conjunction with the five centrarchids, brook silversides, golden redhorse, yellow bullhead, freshwater drum, and logperch were well established. Both the brook silverside and freshwater drum increased annually after impoundment, and in view of the dimunition of cyprinids, the former species became the most important forage fish in the reservoir. Young lepomids undoubtedly are important as forage by virtue of their numbers. Small bluegill and longear sunfish probably contributed substantially to the diets of many piscivorous fishes in Buckhorn Reservoir, but because of their spiny fin rays and body conformation, were not preferred forage species.

Generally, the number of species in Middle Fork upstream from Buckhorn Dam decreased each successive year after impoundment, while the number of fish per unit of area increased. Thirty-nine different species of fishes were collected from Buckhorn Reservoir, whereas, 49 were recorded from the inundated section prior to impoundment. During the third year of impoundment, the number of species recorded from the reservoir was reduced to 24. In Greasy Creek, 45 species were collected before impoundment and 40 afterwards. Excluding species introduced after impoundment, these reductions are even greater. The number of fish per unit area more than doubled in Greasy Creek after impoundment - 403 to 883 per acre. In Section II, 240 fish per acre were collected before impoundment, while the weighted mean of the reservoir samples for all three years combined was 2,506 fish per acre.

Fish Biomass and Population Structure

Fish production in Middle Fork reflected the low fertility of the surrounding terrain, and the average biomass upstream from the dam site was estimated as 30.7 pounds per acre. Estimates of productivity were nearly equal in both stream sections intensively surveyed (Sections I and II), and there was a high degree of similarity in the biomass of representative families, Table 6. The biomass of catostomids and ictalurids, the two dominant groups, was nearly identical and amounted to more than 75 percent of the total sample weight in each section. Centrarchids ranked next in both sections, and their biomass was greater in Greasy Creek than in the parent stream. Cyprinids ranked next in Section I, but in Section II, the biomass of freshwater drum was slightly greater than that of cyprinids. The freshwater drum did not contribute to the productivity of Greasy Creek. Longnose gar, percids, brook silverside, and lampreys, in that order, made up the remaining biomass in both sections. Although the biomass in Section III was not comparable because of the limited sample size, the preponderance of gizzard shad in that section was noteworthy.

Table 6. *Biomass of fishes, arranged by families, collected from Middle Fork drainage prior to impoundment (1957 - 1960). Total weight (pounds) is followed by percent of total weight in parentheses.*

Stream section	I		II		III	
Total area sampled - acres	5.83		6.15		0.57	
Petromyzontidae	0.01	(0.01)	0.04	(0.02)		
Lepisosteidae	5.20	(2.81)	3.33	(1.83)		
Clupeidae					4.38	(38.25)
Catostomidae	102.40	(55.34)	102.76	(56.38)	3.31	(29.91)
Cyprinidae	13.41	(7.24)	7.52	(4.13)	0.30	(2.62)
Ictaluridae	38.48	(20.76)	39.08	(21.44)	0.41	(3.58)
Atherinidae	0.16	(0.09)	0.03	(0.02)		
Centrarchidae	24.32	(13.12)	16.14	(8.86)	0.36	(3.14)
Percidae	1.36	(0.73)	2.43	(1.33)	0.24	(2.10)
Sciaenidae			10.92	(5.99)	2.45	(21.40)
Total weight collected	185.34		182.25		11.45	
Avg. weight per acre (M_c)	31.79		29.63		20.09	

After the impoundment of Middle Fork, the fish biomass of Greasy Creek (Section I) increased from 31.8 to 55.6 pounds per acre, Table 7; however, the percentage of the biomass of principal groups remained nearly the same. The white bass, an adventitious species which invaded Greasy Creek, constituted 5.3 percent of the sample weight.

The biomass in Section II (Buckhorn Reservoir) increased from 29.6 pounds of fish per acre before impoundment to 75.6 pounds per acre in the first year of impoundment, 1961. The following year, the biomass rose to 89.1 pounds per acre, and in 1963 was estimated as 89.0 pounds per acre. Centrarchids became established as the dominant fishes immediately after impoundment, and their biomass decreased only slightly the two following years. Three species of black bass and the white crappie constituted 20.4 percent of the total sample weight in 1961, 19.3 percent in 1962, and 21.0 percent in 1963. The white bass contributed less than one percent to the total biomass in 1962 and 1963.

Although the percent of the total weight composed of centrarchids was very stable during the first three years of impoundment, pronounced structural changes occurred within the family. Young-of-the-year fishes, less than four inches total length, dominated the population during the first summer of impoundment. Spotted bass spawned prodigiously the first year of impoundment, but this initial abundance was not duplicated in subsequent year classes. The white crappie, a rare fish in the upper Middle Fork drainage before impoundment, spawned successfully in 1961, dominated the intermediate-sized fishes in 1962, and attained harvestable size by 1963. Substantial recruitment, by both reproduction and growth, was maintained in 1962 and 1963 indicating a high degree of adaptability to the lentic environment. The remaining centrarchids, classified as lepomids (genus *Lepomis*), were the most successful competitors

Table 7. *Biomass of fishes, arranged by families, collected from Greasy Creek (Section I) and Middle Fork (Section II - Buckhorn Reservoir) after impoundment. Total weight (pounds) is followed by percent of total weight in parentheses.*

Section Number	I		II - Buckhorn Reservoir					
Sample year	1961 - 1962		1961		1962		1963	
Total area sampled - acres	1.85		3.00		4.50		4.52	
Petromyzontidae	0.03	(0.03)	0.02	(0.01)	0.07	(0.02)		
Lepisosteidae	1.22	(1.19)	2.99	(1.32)	1.65	(0.41)	0.16	(0.04)
Clupeidae					13.38	(3.34)		
Catostomidae	54.41	(52.88)	29.35	(12.94)	79.62	(19.85)	111.52	(27.73)
Cyprinidae	5.62	(5.46)	2.37	(1.05)	0.31	(0.08)	0.15	(0.04)
Ictaluridae	23.79	(23.12)	34.25	(15.10)	30.21	(7.53)	19.56	(4.86)
Atherinidae	0.02	(0.02)	0.05	(0.02)	0.19	(0.05)	1.80	(0.45)
Serranidae	5.40	(5.25)			1.66	(0.41)	2.82	(0.70)
Centrarchidae	11.21	(10.89)	154.23	(68.01)	269.38	(67.16)	241.43	(60.04)
Percidae	1.19	(1.16)	0.66	(0.29)	2.10	(0.52)	0.85	(0.21)
Sciaenidae			2.84	(1.26)	2.52	(0.63)	23.85	(5.93)
Total weight collected	102.89		226.76		401.09		402.14	
Avg. weight per acre (M_c)	55.62		75.59		89.13		88.97	

in the new reservoir. Lepomid success was attributed almost entirely to the high sustained recruitment of two species, bluegill and longear sunfish.

The biomass of most other families was less stable than the Centrarchidae. Ictalurid biomass was second to that of centrarchids during the first year of impoundment but diminished each successive year. The biomass of channel catfish was slightly greater than that of flathead catfish all three years. Conversely, catostomid biomass ranked third in 1961 and increased annually. In 1963, this family comprised 27.7 percent of the total weight and was second only to the Centrarchidae. Biomass of the brook silverside, white bass, and freshwater drum also increased each year after impoundment, while that of lampreys, longnose gar and cyprinids decreased.

Fish production in cove areas of the reservoir varied annually; however, the biomass of each cove maintained the same respective status every year, Table 8. Area I (Spring Branch) was consistently the most productive, while Area II (Eversole Branch) was the least productive. Higher production in Spring Branch was attributed to the expanse of littoral area and to enrichment by the greater amount of dissolved nutrients at the head of the reservoir. Northcote and Larkin (1956) considered the quantity and quality of dissolved nutrients, as determined by edapic characteristics, to be a primary factor in determining levels of fish production in British Columbia lakes. Although Area III (Meetinghouse Branch) was located farthest down-lake, and dissolved nutrients were lowest in that region, it was consistently more productive than Area II. Flooded timber at the head of Meetinghouse Branch probably attracted fish to that cove.

The percent of the total weight composed of harvestable-sized fishes (A_t value) fluctuated annually within each component area and for all areas in aggregate, Table 8. The A_t values in this report correspond to the A_t^H of

Swingle (1950) modified to satisfy the length requirements of harvestable-sized fish designated by Surber (1959). A further modification, the A_{tr}, was necessitated by a state regulation which established a minimum size limit of 12 inches on black basses. A_{tr} is the percent of the total weight made up of harvestable-sized fish conforming to legal regulations. The decreased percentage of harvestable-sized fish during the second year of impoundment was caused by the abundance of young-of-the-year as many species became established in the reservoir and spawned prodigiously. Despite low values in 1962, A_{tr} values in 1963 exceeded any since impoundment, indicating increased recruitment into the harvestable-sized category. Most of the 1963 increase was ascribable to redhorses, freshwater drum, and white crappie.

Table 8. *Fish population dynamics and productivity of Buckhorn Reservoir during the first three years of impoundment.*

		Fish biomass			
Year	Area	pounds per acre	number per acre	A_t	A_{tr}
1961	I	-	-	-	-
	II	64.3	1,258	23.2	23.2
	III	81.2	2,275	50.3	48.7
	M_c	75.6	1,957	42.6	40.8
1962	I	111.9	3,556	39.1	33.5
	II	81.7	5,949	30.3	29.3
	III	88.9	1,906	35.1	31.5
	M_c	89.1	3,882	34.5	31.8
1963	I	172.3	1,652	46.5	42.0
	II	74.5	1,340	50.9	48.4
	III	82.1	1,587	42.6	41.5
	M_c	89.0	1,499	46.1	43.8

Discussion of Biomass and Population Structure

Prior to impoundment, the average fish biomass of Middle Fork was estimated as 30.7 pounds per acre. After impoundment, fish production in Greasy

Creek, 20 miles upstream from the head of the reservoir, increased to 55.6 pounds per acre, and the cove areas in the reservoir were substantially more productive. Fish biomass in Buckhorn Reservoir during the first summer of impoundment was 75.6 pounds per acre, and increased to 89.1 pounds per acre during the second summer. The average biomass was estimated as 89.0 pounds per acre during the third summer, suggesting that the fish population in Buckhorn Reservoir reached carrying capacity in the second year of impoundment. Threadfin shad, an adventitious species introduced in 1962, contributed 3.3 pounds per acre to the biomass that year. The threadfin shad was extirpated the following severe winter and did not contribute to the 1963 biomass. Ignoring the contribution of threadfin shad, the fish biomass increased each successive year after impoundment but definitely approached stability in 1962.

In general, the low fish production in Middle Fork and Buckhorn Reservoir alluded to the infertility of the drainage basin. Fish production in Middle Fork was slightly lower than that in other Kentucky streams of the Eastern Coalfield physiographic region, and compared favorably with Southeastern streams draining infertile areas. Estimates of fish biomass in Laurel River (Cumberland River drainage) averaged 43.0 pounds per acre; Russell Fork (Big Sandy River drainage), 53.7 pounds per acre; and Little Sandy River (Ohio River drainage), 49.4 pounds per acre (Turner, unpublished data). Rotenone studies in Alabama indicated that the Tallapoosa River supported 45.7 pounds of fish per acre, and the biomass of Lake Martin, a downstream impoundment, was estimated at 26.7 to 31.4 pounds per acre in cove areas (Swingle, 1954). Ponds in the same area of low fertility supported an average of 40.0 pounds of fish per acre. It is noteworthy that in the absence of gizzard shad, the game fish population of Lake Martin made up 24.6

to 27.9 percent of the fish weight. In Buckhorn Reservoir, game fishes constituted 19.3 to 21.0 percent of the total sample weight. In Kentucky reservoirs containing gizzard shad, the percent of the fish weight made up of game fishes (species upon which creel limits are imposed) is less than in those that do not; however, the total game-fish weight per unit area is usually greater in reservoirs with shad.

UTILIZATION OF THE MIDDLE FORK FISHERIES

The Kentucky Department of Fish and Wildlife Resources conducted creel surveys on the Middle Fork for two years before impoundment, 1959 and 1960, and on Buckhorn Reservoir during the first three years after impoundment, 1961-1963. This study represented the first pre- and post-impoundment creel survey on a Kentucky stream. It was designed to evaluate changes in the sport fishery (pole and line fishing) caused by the transition from stream to reservoir, and to provide information on the quality of fishing in the new reservoir. Such annual inventories are invaluable to the application of proper management of impounded waters. Furthermore, these pre- and post-impoundment observations may provide some insight into what may be expected when similar streams in the Eastern Coalfields region are impounded.

Impounded in September 1960, Buckhorn Reservoir was not opened to fishing until July 1, 1961, to allow both the native and introduced fishes to spawn before being fished. The policy of the Kentucky Division of Fisheries has been to provide "quality" fishing rather than "quantity" fishing, and a 12-inch minimum size limit for black basses was established on opening day and then retained throughout the study period. There was no size restriction on bass before impoundment.

Survey Methods

Creel surveys were conducted by local conservation officers who counted and interviewed fishermen according to a prearranged sampling schedule. The sampling scheme was designed to yield estimates of fishing effort, fishing success, total harvest, and catch composition for each day of the week throughout each survey year. On Middle Fork, the survey year began on or about April 1 and ended October 31 to coincide with the periods of spring filling and winter drawdown in the new reservoir. With the exception of the opening year, the survey period was the same on Buckhorn Reservoir. The 12-hour survey day, 7 AM to 7 PM, was divided into three periods of 4 hours each: 7 AM - 11 AM, 11 AM - 3 PM, and 3 PM - 7 PM. Only one time period was sampled on any given day. Samples were obtained from 63 different days during the survey year, and were rotated throughout the same weekday in successive weeks. Schedules were arranged so that equal numbers of each time period and each week day were included in the survey year. The survey year was ultimately represented by 21 complete days (3 Sundays, 3 Mondays, etc.).

The pre-impoundment survey covered 32 stream miles in 1959 and included a 7-mile stretch of river downstream from the dam site. In 1960, the survey area was reduced to 19 stream miles, and was made up of a series of discontinuous stretches of river extending from the dam site upstream. After impoundment, the survey was confined to a 19-mile section of Buckhorn Reservoir, extending up-lake from the dam; the uppermost 2 miles of the reservoir were inaccessible and were excluded from the survey. Because of the disparity in mileage, the 1959 pre-impoundment data were adjusted to the other years for comparison.

Sampling techniques differed before and after impoundment, because of changes in physical conditions. Prior to impoundment, a road paralleled Middle Fork and anglers were counted and interviewed at each access point.

This method provided a fisherman count extending over a 4-hour period and did not take into account some exchange of anglers in the stream as each day's survey progressed. The pre-impoundment estimates assume that the fishermen tended to aggregate at the access points.

On Buckhorn Reservoir, fishermen were counted by covering the 19-mile section as quickly as possible in a 14-foot boat powered by an 18 hp outboard motor. This method permitted a more rapid count and all of the interviews either preceded or followed the enumeration of fishermen. Fishermen counts were thereby obtained during one of 6 different hourly periods during a survey day - 7-8 AM, 10-11 AM, 11-12 AM, 2-3 PM, 3-4 PM, 6-7 PM.

Fishing effort was estimated using the mean-count method outlined by Lambou (1961), namely, $\hat{F} = C\bar{x}$

where $\hat{F}$ = the estimated number of time units of fishing (man-hours), C = the total number of hours in the survey year, and $\bar{x}$ = the mean number of fishermen observed per count. Both bank and boat fishermen were included in the counts, but occupants of moving boats were not counted unless they were fishing. On both Middle Fork and Buckhorn Reservoir, starting and ending points for the counts were systematically alternated throughout the survey.

Angler interviews provided information on the amount of time fished and the number, kind, and length of fish caught. Weights of fishes in the creel were estimated from the average weights of those taken from the same waters during the fish population studies. This information was used to determine rate of harvest and species composition in the creel. Total harvest for the survey period was estimated by multiplying the rate of harvest by the total fishing effort.

Fishing Effort and Intensity

After impoundment, fishing effort in the survey area of Middle Fork increased more than sixfold (Table 9). The average estimated fishing effort on Middle Fork was 54 man-hours per day for 419 days in the 2 years preceding impoundment. During the first 2 complete years of fishing on Buckhorn Reservoir (1962 and 1963), fishing effort increased to 347 man-hours per day for 428 days. Fishing intensity increased from a mean of 49 man-hours per acre before impoundment to 62 man-hours per acre during the first two complete fishing seasons on the reservoir. The relatively low amount of effort and intensity during the first year of impoundment (1961) can be chiefly attributed to the prohibition of fishing during 2 peak months, May and June. Because of this, the 1961 estimates of fishing effort and intensity were not included in the comparisons.

Table 9. *Estimated fishing effort, fishing intensity, and fishing success on Middle Fork before and after impoundment.*

	Middle Fork		Buckhorn Reservoir		
	1959	1960	1961	1962	1963
Survey period (days)	215	204	123	214	214
Survey Area (surface acres)	230	230	1,200	1,200	1,200
Fishing effort:					
Total man-hours	11,996	10,647	32,724	75,963	72,738
Man-hours per day	55.8	52.2	266.0	355.0	339.9
Fishing intensity:					
Man-hours per acre	52.1	46.2	27.3	63.3	60.6
Fishing success:					
No. of fish per man-hour	1.16	0.76	1.28	1.27	1.55
Weight per man-hour (lb.)	0.69	0.38	0.37	0.28	0.38

Most fishermen who utilized Middle Fork were resident license holders. During the first 3 years of impoundment, residents made up from 97 to 99 percent of the total number of fishermen. Utilization of the reservoir by nonresidents should increase with the development of Buckhorn State Park.

Fishing Success

Fishing success, measured as fish per man-hour, increased from a mean of 0.97 before impoundment to 1.38 after impoundment; however, the average weight per man-hour was greater before impoundment. The average weights of fish from Middle Fork were 0.59 pound in 1959 and 0.50 pound in 1960, and from Buckhorn Reservoir were 0.29 pound in 1961, 0.22 pound in 1962, and 0.25 pound in 1963. This reduction in average weight was due chiefly to a greater number of lepomids and white crappie in the reservoir catch.

By the third year of impoundment, most species had attained a greater average weight than that prior to impoundment, Table 10. Although the average weight of lepomids decreased after the first year of impoundment, those harvested from the reservoir were considerably heavier than those harvested from the river. The greater average weight of black basses after impoundment is partially ascribable to the 12-inch minimum-size regulation.

Table 10. *Average weight (pounds) of fishes harvested from Middle Fork before and after impoundment.*

Species	Middle Fork		Buckhorn Reservoir		
	1959	1960	1961	1962	1963
Black basses	0.89	0.63	1.09	1.22	1.40
White bass	0.24		0.30	0.68	0.61
White crappie	1.26		0.13	0.26	0.25
Walleye					2.09
Catfishes	1.63	3.55	1.10	1.29	1.75
Rock bass	0.15	0.15	0.19	0.17	0.25
Lepomids	0.04	0.05	0.12	0.09	0.09
Suckers	0.68	0.51		0.77	
Freshwater drum	1.26	2.28	3.17	0.22	2.88

Estimated Harvest and Creel Composition

After impoundment the total sport-fish harvest was greater than before impoundment, and increased each successive year. The catch from Middle Fork was estimated at 13,915 fish (8,277 pounds(in 1959, and 8,092 fish (4,046 pounds) in 1960. The catch from Buckhorn Reservoir was estimated at 41,887 fish, or 12,108 pounds in 1961; 96,473 fish, or 21,270 pounds in 1962; and 112,744 fish, or 27,640 pounds in 1963. The average number of fish harvested per unit surface area increased from 50 per acre before impoundment to 87 per acre during the first 2 complete years of fishing on the reservoir, but the average weight harvested decreased by 6.4 pounds per acre (from 26.8 to 20.4). The total estimated yield is summarized in Tables 11 and 12.

Black basses - The black bass harvest from Middle Fork was made up entirely of smallmouth bass and spotted bass, whereas largemouth bass, an introduced species, was the principal component of this group in the Buckhorn creel. For the combined catches in the two years before impoundment black basses dominated the creel in number and weight (Table 13). Their contribution to the total catch in number averaged 34 per cent before impoundment, then dropped to 6 per cent for the first 3 years afterwards. Despite this decline in the percentage contribution, a greater average number were harvested during the first 3 years of impoundment than the average number taken during the 2 years immediately preceding impoundment.

Black basses were especially vulnerable during the opening months of fishing on Buckhorn Reservoir. The number harvested during the 4-month survey in 1961 approximated the number harvested during the 7-month surveys in 1962 and 1963. The susceptibility of the largemouth bass to fishing in a new lake has been alluded to by Byrd (1959) and by Thompson and Hutson (1951).

Table 11. *Estimated number of fish harvested from Middle Fork before and after impoundment. Number per acre is shown in parentheses.*

Species	Middle Fork		Buckhorn Reservoir		
	1959	1960	1961	1962	1963
Black basses	5,010 (21.8)	2,549 (11.1)	4,901 (4.1)	5,017 (4.2)	4,623 (3.9)
White bass	139 (0.6)		9,383 (7.8)	2,991 (2.5)	2,142 (1.8)
White crappie	125 (0.5)		377 (0.3)	10,033 (8.4)	37,882 (31.6)
Walleye					225 (0.2)
Catfishes	1,002 (4.4)	429 (1.9)	419 (0.3)	2,219 (1.8)	1,691 (1.4)
Rock bass	3,966 (17.2)	2,678 (11.6)	2,639 (2.2)	2,315 (1.9)	113 (0.1)
Lepomids	2,115 (9.2)	1,813 (7.9)	24,126 (20.1)	73,416 (61.2)	65,617 (54.7)
Suckers	1,099 (4.8)	566 (2.5)		386 (0.3)	
Freshwater drum	459 (2.0)	57 (0.2)	42 (0.1+)	96 (0.1)	451 (0.4)
Total	13,915 (60.5)	8,092 (35.2)	41,887 (34.9)	96,473 (80.4)	112,744 (94.0)

White bass - The occurrence of the white bass has been reported throughout the main stem of the Kentucky River as far upstream as navigation lock 14 at Heidelberg, 53 miles below the dam site (Carter, 1954). This species was observed in Middle Fork during creel surveys in the area immediately downstream from the dam site in 1959. It was not seen, however, during fish population studies or creel surveys conducted upstream from the dam site prior to impoundment.

The white bass was introduced into the reservoir in April 1961, and 9,393 were harvested during the 4-month survey that year. Although the number of white bass in the creel decreased each year after 1961, this species supported an additional fishery in the headwaters during its spawning migration each spring.

Table 12. *Estimated weight (pounds) of fish harvested from Middle Fork before and after impoundment. Weight per acre is shown in parentheses.*

Species	Middle Fork		Buckhorn Reservoir		
	1959	1960	1961	1962	1963
Black basses	4,445 (19.3)	1,610 (7.0)	5,364 (4.5)	6,126 (5.1)	6,468 (5.4)
White bass	33 (0.1)		2,797 (2.3)	2,042 (1.7)	1,299 (1.1)
White crappie	157 (0.7)		48 (< 0.1)	2,595 (2.1)	9,315 (7.7)
Walleye					470 (0.4)
Catfishes	1,631 (7.1)	1,525 (6.6)	461 (0.4)	2,871 (2.4)	2,957 (2.5)
Rock bass	596 (2.6)	397 (1.7)	496 (0.4)	404 (0.3)	28 (< 0.1)
Lepomids	91 (0.4)	93 (0.4)	2,809 (2.3)	6,913 (5.8)	5,804 (4.8)
Suckers	745 (3.2)	291 (1.3)		298 (0.3)	
Freshwater drum	579 (2.5)	130 (0.6)	133 (0.1)	21 (< 0.1)	1,299 (1.1)
Total	8,277 (36.0)	4,046 (17.6)	12,108 (10.1)	21,270 (17.7)	27,640 (23.0)

White crappie - The white crappie was rare in the upper Middle Fork drainage; the entire estimated catch in the 2 years before impoundment was only 125 fish. After impoundment, the white crappie yield increased steadily each year, and in 1963 the catch surged to 37,882 individuals. The estimated total weight of crappie harvested from the reservoir (9,315 pounds) in 1963 was greater than that of any other species.

Walleye - Stocked as fry in April 1961, the walleye was first recorded in the creel in 1963. An estimated 225 walleye weighing 470 pounds were harvested that year.

Catfishes - Two species, the channel catfish and flathead catfish, supported the entire catfish fishery in the Middle Fork, while a third species, the yellow bullhead, was so scarce

Table 13. *Pre- and post-impoundment creel composition of Middle Fork. Percent of total number is subtended by percent of total weight in parentheses.*

Year	Black basses	White bass	White crappie	Walleye	Catfishes	Rock bass	Lepo-mids	Suckers	Drum
				MIDDLE FORK					
1959	36.0 (53.7)	1.0 (0.4)	0.9 (1.9)		7.2 (19.7)	28.5 (7.2)	15.2 (1.1)	7.9 (9.0)	3.3 (7.0)
1960	31.5 (39.8)				5.3 (37.7)	33.1 (9.8)	22.4 (2.3)	7.0 (7.2)	0.7 (3.2)
				BUCKHORN RESERVOIR					
1961	11.7 (44.3)	22.4 (23.1)	0.9 (0.4)		1.0 (3.8)	6.3 (4.1)	57.6 (23.2)		0.1 (1.1)
1962	5.2 (28.8)	3.1 (9.6)	10.4 (12.2)		2.3 (13.5)	2.4 (1.9)	76.1 (32.5)	0.4 (1.4)	0.1 (0.1)
1963	4.1 (23.4)	1.9 (4.7)	33.6 (33.7)	0.2 (1.7)	1.5 (10.7)	0.1 (0.1)	58.2 (21.0)		0.4 (4.7)

it was unimportant. The yellow bullhead increased rapidly in Buckhorn Reservoir and contributed substantially to the catch. Of the three, the channel catfish was the most important to the sport fishery, both before and after impoundment.

Although catfishes harvested from Middle Fork were larger than those from the reservoir, a greater number were harvested after impoundment. The average weight per fish increased each year in the new reservoir, and by 1963 the total catfish yield was 2,957 pounds, nearly twice that in either of the 2 survey years before impoundment.

Rock bass - The catch of rock bass in Middle Fork was surpassed only by the aggregate of black basses. The rock bass diminished in the creel each successive year after impoundment, and by 1963 only 113 were caught from the reservoir. Primarily a stream fish, the reduction of this species in the catch is attributed to elimination of habitat.

Lepomids - Although three species were native to the upper Middle Fork, the longear sunfish practically supported the entire lepomid fishery before impoundment, and was the dominant fish in the creel during the first year of impoundment. By the second year of impoundment, however, the bluegill was the most numerous fish in the creel from the reservoir and this species maintained supremacy throughout the duration of the survey. The green sunfish was rare in the drainage and contributed little to the catch. Numerically, lepomids dominated the catch from Buckhorn Reservoir throughout the first 3 years, and in 1962 constituted a greater percentage of the total weight than any other group harvested.

Suckers - Six species of suckers were present in the reservoir and could have contributed to the sport fishery in Middle Fork but they were not differentiated during creel surveys. In view of their abundance in population studies, however, the black redhorse and the golden redhorse, probably dominated the catch. Of moderate importance in the Middle Fork creel, suckers diminished in the sport-fish catch after impoundment and were observed in the catch from the reservoir in 1962 only.

Freshwater Drum - The freshwater drum supported a minor fishery in Middle Fork and in Buckhorn Reservoir during the first 2 years of impoundment. This species increased in the catch from the reservoir each year, and by 1963 contributed 1,299 pounds to the sport-fish harvest.

Discussion of Creel Surveys

The Kentucky Division of Fisheries conducted creel surveys on the Middle Fork of the Kentucky River for two years (1959-1960) before impoundment, and three years (1961-1963) after impoundment. Fishing effort, angling success, creel composition, and total harvest in a 19-mile segment of the stream were estimated prior to impoundment, and again in the corresponding section of Buckhorn Reservoir after impoundment.

Fishing effort increased approximately sixfold after impoundment, from a mean of 54 man-hours per day for 419 days of fishing to a mean of 347 man-hours per day for 428 days of fishing. The effort per surface acre of water did not increase in this mannitude; 52.1 hours per acre in 1959 as compared to 60.6 hours per acre in 1963. The number of fish harvested per man-hour was greater after impoundment and varied from 1.27 to 1.55; however, the weight harvested per man-hour was lower because of the preponderance of lepomids in the catch from the reservoir.

Black basses dominated the sport-fish catch before impoundment, making up 34 percent of the total number and 49 percent of the total weight harvested. The percentage of black basses decreased each successive year after impoundment; nevertheless this group contributed more than other species to the aggregate weight harvested during the first 3 years of impoundment. Numerically, lepomids (chiefly bluegill) predominated in the creel after impoundment, constituting 65 percent of the harvest from the reservoir for the first 3 years.

The total sport-fish harvest from the Middle Fork was estimated at 13,915 fish (8,277 pounds) in 1959, and 8,092 fish (4,046 pounds) in 1960. After impoundment, the estimated catch was 41,887 fish (12,108 pounds), in 1961, 96,473 fish (21,270 pounds) in 1962, and 112,744 fish (27,640 pounds) in 1963.

The impounding of Middle Fork was obviously beneficial to some species of sport fishes and detrimental to others. Native fishes that flourished in the reservoir were white crappie, yellow bullhead, and bluegill. Most notable among the native species adversely affected by impoundment were smallmouth bass, rock bass and longear sunfish. Fish population studies showed that some of the species that diminished in the reservoir increased in its tributaries, having moved upstream to a more suitable habitat.

The effect of desirable species emigrating from the reservoir was tempered considerably by stocking sport fishes adaptable to the lentic environment, such as largemouth bass, white bass and walleye. In addition to bolstering the sport fishery in the reservoir two of these species, the white bass and the walleye, also made substantial contributions to sport fishing in headwaters during their spring migrations.

Prior to impoundment, the sport fishery in Middle Fork was supported principally by smallmouth bass, spotted bass and rock bass. After impoundment, the rock bass and smallmouth bass populations dwindled rapidly because of habitat alteration, whereas the black bass fishery improved because of the introduction of largemouth bass. Although more black basses were harvested after impoundment than before, their supremacy was supplanted by burgeoning populations of lepomids and white crappie which, after the third year of impoundment, completely dominated the catch from Buckhorn Reservoir.

The percentage of the total biomass harvested from Buckhorn Reservoir increased each year, Table 14. Although the fish biomass in the reservoir apparently reached carrying capacity in 1962, the weight harvested continued to increase. An estimated 26 percent of the total fish crop was harvested in 1963.

Table 14. *Utilization of the fishery resources in Buckhorn Reservoir during the first three years of impoundment.*

Year	1961	1962	1963
Estimated biomass (pounds per acre)	75.6	89.1	89.0
Weight harvested per acre (pounds)	10.1	17.7	23.0
Percent total weight harvested	13.3	19.9	25.9

A more refined survey would disclose the percentage of the total available crop (A_t) harvested, thereby making the creel findings more amenable to population study data. Arbitrary size limits presently used to derive A_t values, such as 6 inches for lepomids, etc. could be precisely determined from creel data for each particular body of water. The average size of lepomids harvested from Buckhorn Reservoir was considerably less than 6 inches, as attested by the average weights of fishes in the creel, and re-evaluation of these data in view of this, would certainly increase A_t values. Further refinement could be obtained by eliminating general groupings, such as black basses, catfishes, suckers, etc., and estimating the harvest by species.

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