VERTICAL DISTRIBUTION OF FISHES

IN THE CENTRAL POOL OF

EUFAULA RESERVOIR, OKLAHOMA

By

RONALD JIMMIE HOVER

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Thesis Approved:

Robert C. Summerfelt
Thesis Advisor

Troy Dorris

D. D. Durham
Dean of the Graduate College

PREFACE

The objectives of the present study were: (1) to determine the vertical distribution of fishes in the central pool of Eufaula Reservoir during periods of pre-stratified, stratified, and post-stratified thermal conditions, (2) to evaluate the use of artificial destratification as a method to increase the area of habitat used by fishes.

The study was supported by Federal Aid to Fish Restoration (Dingell-Johnson Act, 1950) as Oklahoma Project F-24-R from the Oklahoma Department of Wildlife Conservation. Other equipment used during the study was provided by the Oklahoma Cooperative Fishery Unit (OCFU). Cooperators are the Fish and Wildlife Service of the U.S. Department of the Interior, the Oklahoma Department of Wildlife Conservation, and the Research Foundation of the Oklahoma State University. The Army Corps of Engineers is also acknowledged for its cooperation during the project.

Sincere thanks age given to Dr. Troy C. Dorris for serving on my advisory committee and for providing financial support through a Federal Water Pollution Control Administration (FWPCA) Traineeship (Grant No. 5T1-WP-185) which was administered through the Reservoir Research Center and the Research Foundation of the Oklahoma State University.

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I would also like to acknowledge Mr. Lowell Leach of the Robert S. Kerr Water Research Center (South Central Region, Water Quality Office, EPA) for providing temperature and dissolved oxygen data and maps from which figures 1 and 2 of this study were made. Mr. Jack Ball of the U.S. Corps of Engineers Tulsa District Office is also acknowledged for his cooperation and assistance in providing area-capacity information pertaining to Eufaula Reservoir.

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CHAPTER I

INTRODUCTION

Summer stratification of lakes and reservoirs has often been of concern to limnologists and fisheries investigators (Toetz et al. 1972). Thermal stratification is important in determining both fish distribution and production. Dendy (1945) related changes in depth distribution of fishes to changes in temperature and dissolved oxygen (DO) concentration as a density current passed through a thermally stratified reservoir. Using gill nets set at various depths he found most species of fish showed a tendency to remain in the affected strata until DO concentration of 1.5 mg/l or less forced them to ascend to warmer, but more oxygenated strata. Sprugel (1951) reported that as thermal stratification of a 2.8 ha lake developed and deeper waters became oxygen deficient the fish population was "squeezed" into the upper more oxygenated strata. He suggested that such confinement during the summer when fish production should be maximal, might reduce production by limiting the availability of prey. Although this "habitat squeeze" caused by stratification is normally a relatively limited temporal phenomenon, Ziebell (1969) reported that hypolimnetic oxygen depletion in Pena Blanca Lake lasted 7 months and eliminated a maximum of 46% of the volume and 60% of the benthic area available for habitation by fishes.

It was reported by Johnson (1966) that in Erdman Lake, Washington, only the strata between 2.1 m and 3.4 m (e.g. 15% of the total volume) of the 8.2 ha lake were sufficiently cool and oxygenated (less than 25 C and more than 5 mg/l DO) to be habitable to juvenile or smolt coho salmon. After artificial destratification by forced aeration during the summers of 1961-1963 there was a five-fold increase in minimum habitable volume, and a greater than three-fold increase in annual smolt survival and production (Johnson 1966). In addition to the increases in fish survival and production he also noted that carbon fixation in the artificially destratified surface waters indicated primary production had increased by a factor of 2.3. Standing crop of phytoplankton increased by a factor of 8 to 10 when artificial circulation was induced by pumping hypolimnetic water to the surface of a 1.5 ha thermally stratified Michigan lake (Hooper et al. 1953). Fast (1971) reported that in El Capitan Reservoir zooplankton distribution had been limited by hypolimnetic stagnation and thermal stratification (85% of total found below 10 m after destratification as compared to 99% occurring above 10 m prior to artificial destratification). Fast and Monat (1973) found that depth distribution of crayfish (*Orconectes virilis*) in thermally stratified 1.2 ha Section Four Lake, was limited to shallow strata having temperatures above 10 C. After using forced aeration to completely destratify the lake, crayfish distribution was expanded to all depths.

All of the destratification studies cited were done in relatively small bodies of water, but a 1967 artificial destratification study conducted by Leach et al. (1968) was in the central pool of Eufaula Reservoir. Twenty-five days of forced aeration affected an area of approximately 1,200 ha and a volume in excess of 8×10^7 m^3 (Leach et al.

1968). During that project SCUBA divers observed fish at greater depths in the area of the diffuser apparatus when aeration was underway than prior to initiation of aeration. Assuming that water with less than 2.0 mg/l DO limits fish distribution (Carter 1967) an estimated area of 6,300 ha and volume of 3×10^8 m^3 of Eufaula Reservoir was unavailable to fishes during the summer of 1967.

The present study was conducted in 1968 concurrent to a second effort by Leach et al. (1970) to destratify the central pool of Eufaula Reservoir. Objectives of the study were to characterize the vertical distribution of fishes in the study area prior to and during forced-air destratification, and to evaluate the potential of the technique to increase the lake volume habitable to fish.

CHAPTER II

DESCRIPTION OF STUDY AREA

Eufaula Reservoir is a large mainstream impoundment located in eastern Oklahoma (Figure 1). It occupies much of the lower Canadian River system and has a large central pool and four main arms arising from its major tributaries (e.g. North Canadian River, South Canadian River, Deep Fork River, and Gaines Creek). The dam site is 43.5 km upstream from the confluence of the Canadian River with the Arkansas River. The reservoir as a whole is located principally in McIntosh, Haskell and Pittsburg counties, with the central pool being shared primarily by the two former counties (Figure 2).

At maximum power pool elevation of 178 m, the reservoir has a surface area of 253,086 ha, and a storage capacity of 3.45×10^9 m^3. At the same elevation, the central pool has an area of 4,371 ha and a storage capacity of 7.04×10^8 m^3 (Leach et al. 1968). These data deviate somewhat from the tabulated values computed from an Army Corps of Engineers area-capacity curve (Table 1).

This netting study was limited to the central pool region of the reservoir. Five of the 17 bouy-marked sampling stations set up by personnel of the Robert S. Kerr Water Research Center, Federal Water Pollution Control Administration (FWPCA) were selected as netting stations (Figure 2). In an effort to maintain comparable depths and to avoid submerged trees, stations over or near the inundated river channel

Figure 1. Eufaula Reservoir map with reference to central pool (outlined with dotted lines) area where 1967-68 (FWPCA) destratification efforts were undertaken.

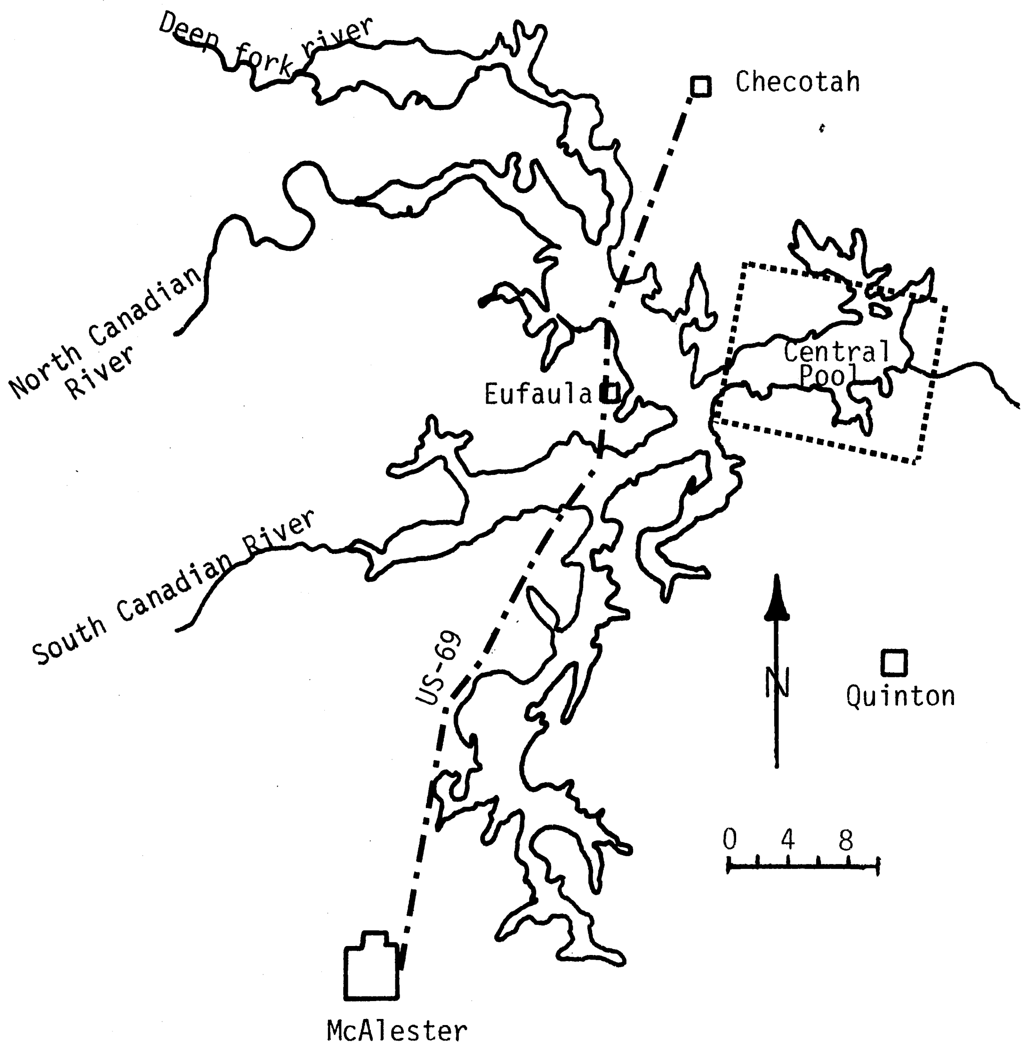
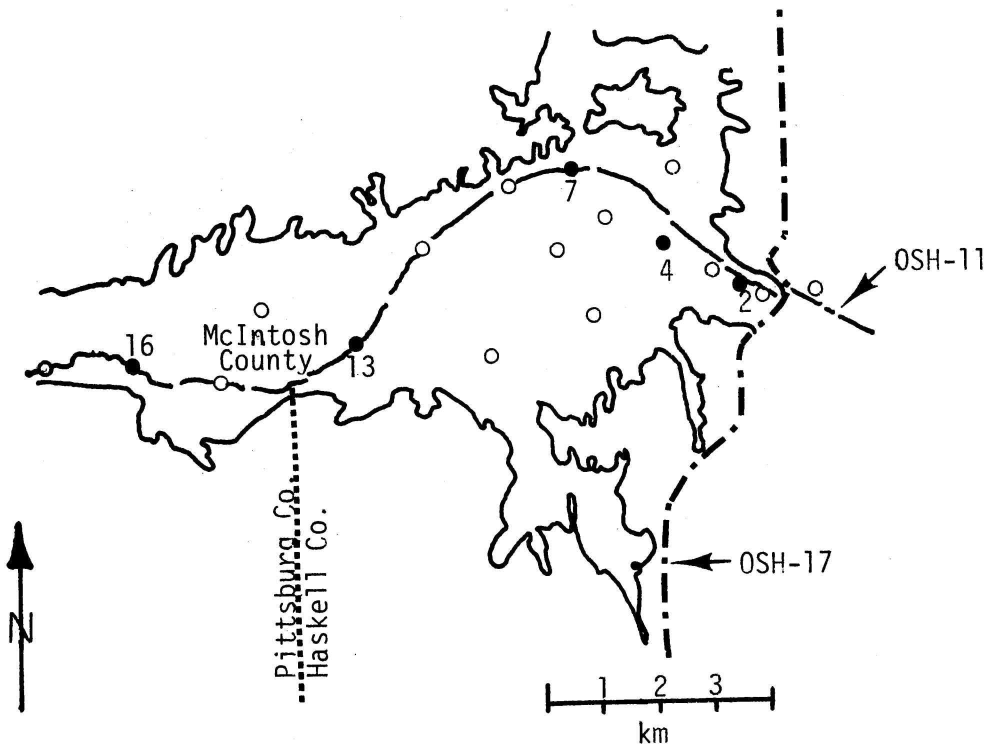

Deep fork river
Checotah
North Canadian River
Central Pool
Eufaula
South Canadian River
US-69
N
Quinton
0 4 8
McAlester

Figure 2. Central pool area of Eufaula Reservoir showing FWPCA water quality sampling sites (circles) and netting sites (darkened circles) used in present study.



OSH-11
7
4
2
16
McIntosh
County
13
OSH-17
Pittsburg Co.
Haskell Co.
N
1
2
3
km

Table 1. Area capacities of Eufaula Reservoir (adapted from U.S. Army Corp of Engineers area-capacity data).

Elevation[1] (m M.S.L.)	Area (ha)	Capacity (m^3)	Elevation (m M.S.L.)	Area (ha)	Capacity (m^3)
150.67	0	0	168.97	10,886.4	6.2×10^8
151.28	4.0	1.2×10^4	169.58	11,817.2	6.9×10^8
151.89	12.1	6.2×10^4	170.19	12,990.9	7.6×10^8
152.50	24.3	1.7×10^5	170.80	14,528.7	8.5×10^8
153.11	40.5	3.7×10^5	171.41	16,349.9	9.4×10^8
153.72	80.9	7.4×10^5	172.02	18,373.4	1.0×10^9
154.33	121.4	1.4×10^6	172.63	20,477.8	1.2×10^9
154.94	242.8	2.5×10^6	173.24	22,541.8	1.3×10^9
155.55	485.6	4.7×10^6	173.85	24,727.2	1.4×10^9
156.16	809.4	8.6×10^6	174.46	26,710.2	1.6×10^9
156.77	1,092.7	1.4×10^7	175.07	28,693.2	1.8×10^9
157.38	1,456.9	2.2×10^7	175.68	30,757.2	2.0×10^9
157.99	1,740.2	3.2×10^7	176.29	32,902.1	2.1×10^9
158.60	2,064.0	4.4×10^7	176.90	35,208.9	2.4×10^9
159.21	2,387.7	5.7×10^7	177.51	37,596.6	2.6×10^9
159.82	2,671.0	7.3×10^7	178.12	40,105.8	2.8×10^9
160.43	2,954.3	9.0×10^7	178.73	42,655.4	3.1×10^9
161.04	3,318.5	1.1×10^8	179.34	45,245.5	3.3×10^9
161.65	3,642.3	1.3×10^8	179.95	48,037.9	3.6×10^9
162.26	4,047.0	1.5×10^8	180.56	50,789.9	3.9×10^9
162.87	4,370.8	1.8×10^8	181.17	53,703.7	4.2×10^9
163.48	4,775.5	2.1×10^8	181.78	56,698.5	4.6×10^9
164.09	5,180.2	2.4×10^8	182.39	59,693.3	4.9×10^9
164.70	5,665.8	2.7×10^8	183.00	62,769.0	5.3×10^9
165.31	6,272.9	3.1×10^8	183.61	65,763.8	5.7×10^9
165.92	6,920.4	3.5×10^8	184.22	69,001.4	6.1×10^9
166.53	7,729.8	3.9×10^8	184.83	72,117.5	6.5×10^9
167.14	8,498.7	4.4×10^8	185.44	75,476.6	7.0×10^9
167.75	9,308.1	5.0×10^8	186.05	78,916.5	7.5×10^9
168.36	10,117.5	5.6×10^8			

[1]Maximum elevation (186.05 m) is the top of dam; 182.09 is top of flood gates; during the 1968 study surface elevation approximated maximum power pool elevation (178.43 m) with a maximum of 180.11 m recorded.

were selected. Sites selected were at water quality monitoring stations numbers 2, 4, 7, 13 and 16, which ranged from 0.5 to 10.6 km upstream from the dam. Depths at the netting sites ranged from 21 to 25 m, with an overall mean depth of 23 m.

CHAPTER III

METHODS AND MATERIALS

A considerable diversity of sampling gear has been employed to determine depth distributions of fishes in freshwater lakes. Cady (1945) used conventional gill nets set horizontally at measured depths to determine depth distributions of fishes in Norris Reservoir, Tennessee. Tibbles (1956), selected sonar as a primary sampling gear in Lake Mendota, but had to rely on other types of gear to verify and identify echo-located targets. He concluded that vertical gill nets overcame many of the disadvantages associated with the use of conventional gill nets and that vertical nets were useful in depth distribution studies involving pelagic species.

Other investigations have employed tiers of horizontally set conventional gill nets in vertical suspension systems to determine the vertical distribution of fishes (Smith et al. 1968 and McConnell et al. 1957). Suspension systems of horizontal gill nets tend to require more or less permanently installed supportive equipment, are cumbersome to operate, and do not contiguously sample the entire water column. These inefficiencies are probably most responsible for the use of columnar vertical gill nets by numerous recent investigators (Fast 1971, Wiltzius 1970, Finnell and Reed 1969, Heimer 1968, Lackey 1968, Eley et al. 1967, Miller and Perrin 1967, Grinstead 1965, Horak and Tanner 1964, von Geldern 1964, Hartman 1962).

In a comparison of selectivity between five types of intensively fished sampling gear, gill nets produced relatively low catches per unit effort, but gave a good indication of species composition (Bennett and Brown 1970). Bonn (1969) compared species composition of catches produced by trawling, seining, and gill net sampling methods and found gill nets to sample some portions of the population not sampled by the other methods. Bonn found that the nets were selective for larger fish but gill nets captured four species not collected with other gear. Grinstead (1965) attributed differences in size of white crappie (Pomoxis annularis) caught in horizontal latin-square gill nets and vertical latin square gill nets to depth-related behavior rather than net sampling bias since mesh sizes and area of netting fished at given strata were similar in both net designs. Carter (1967) found catch rates of vertical latin-square and columnar vertical gill nets to be statistically similar. Findings of other investigators indicated that vertical column gill nets would be an effective technique for study of vertical distribution of fishes.

Net Specifications

The vertical column gill nets measured 4.87 m wide by 30.48 m deep. Each of the nets contained four 1.22 m by 30.48 m columns of 2.54 cm, 3.81 cm, 5.08 cm, and 6.35 cm square mesh webbing. The vertical margins (side-lines) were of number 72 braided nylon rope and were marked at one meter intervals with numbered brass clinch-on brads. Both ends of the net were bounded by lead-cored, number 5½ braided nylon. Side and end lines were extended beyond net margins to aid in attachment to net-rollers and spreader-weight assemblies at net corners. Nets were further secured at intervals to the rollers and weights with plastic electrical tape.

Roller-Float Assemblies

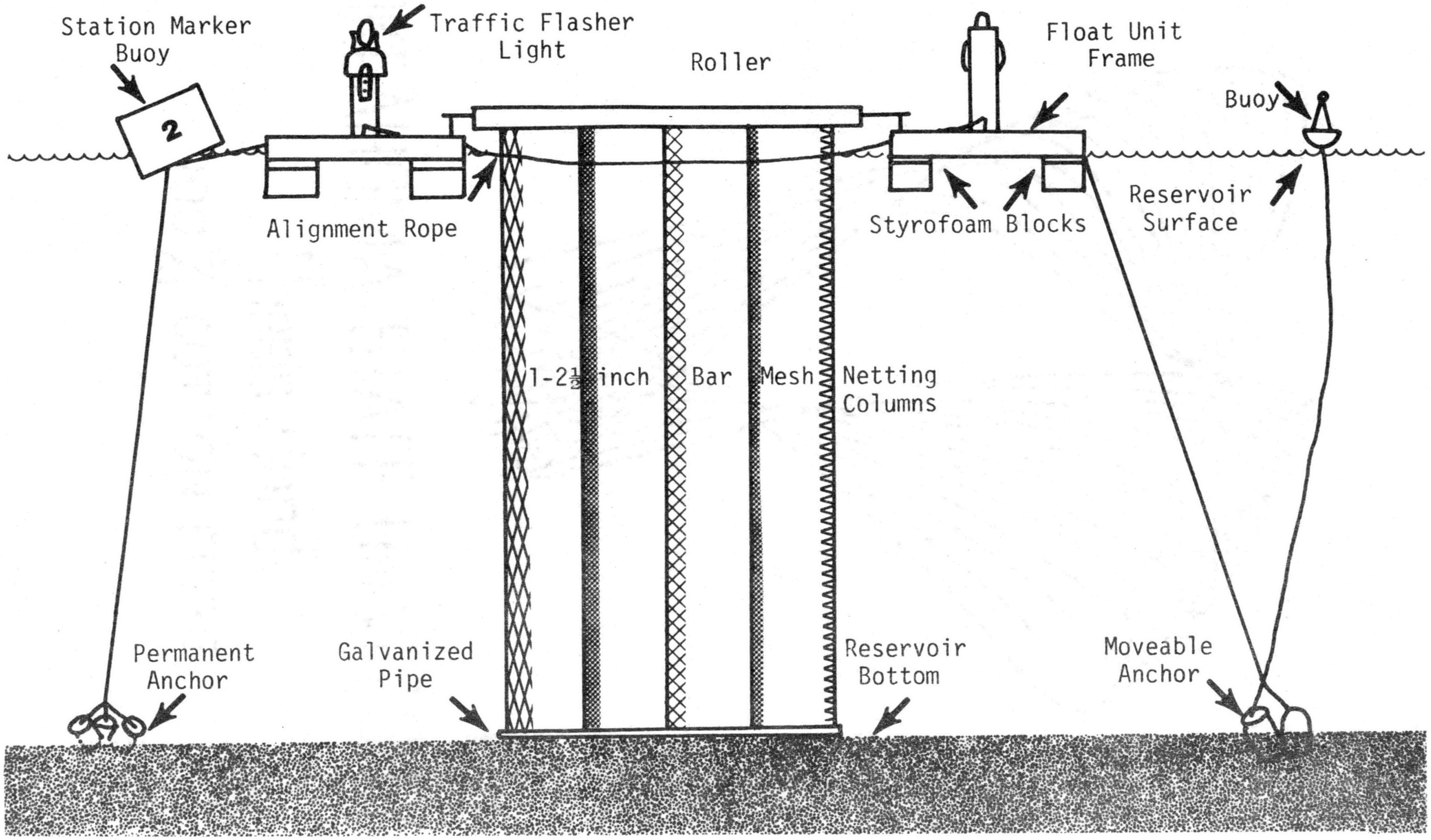
The roller-float assemblies (Figure 3) used to suspend the vertical gill nets were similar to that described by Carter (1968). Net rollers were constructed of 6.1 m sections of 10.6 cm plastic well casing. Ends of the rollers were closed with cemented plastic couplings and bushings with a threaded galvanized central bushing being brazed to a 1.91 cm diameter steel shaft. Holes drilled through the steel shafts near the ends permitted pinning the rollers to the float units and to an automobile steering wheel used to facilitate net tending operations. The spreader-weight was attached to the net bottom and consisted of a 4.87 m length of 1.27 cm galvanized pipe.

Float unit frames for the assemblies were constructed of redwood 4 x 4 and 1 x 12 lumber with styrofoam floatation blocks bolted to each corner. To reduce the hazard to navigation, these units were painted bright orange and had an amber flashing light elevated on the upright of each unit. The upright also functioned to support the net roller during tending operations.

Netting Schedule

In order to maintain a comparable degree of uniformity in data collection, net sets were conducted on a netting-week basis. A netting week approximated a calendar week, and usually included three 2-day net sets at each of the five netting stations. Inclement weather, equipment failure, or other logistic problems, caused some net sets to

Figure 3. Roller-float unit design with vertical column net in the set position.


Station Marker Buoy
2
Traffic Flasher Light
Roller
Float Unit Frame
Buoy
Alignment Rope
Styrofoam Blocks
Reservoir Surface
1-2½ inch Bar Mesh Netting Columns
Permanent Anchor
Galvanized Pipe
Reservoir Bottom
Moveable Anchor

be extended or omitted. A net set consisted of lowering the net in a predetermined direction (90^{o} or 188^{o} from direction of prior set and depending on wind direction and velocity) from the station marker bouy, then raising it two days later, and recording catch data for all fish collected. Rotations of 90^{o} were preferred both to reduce bias due to net orientation such as that reported by Coke 1968, and the possibility of local exploitation (i.e., with 90^{o} rotations it would be a minimum of 6 days before the net was again fished in the same position. All simultaneous sets were uniform in orientation to marker-bouys.

Data Collection and Transformation

Data recorded from each net lift included species identification, mesh size in which the fish was captured and distance above the bottom (nearest 0.5 m), dates and times of lowering and lifting the nets, directional orientation of net set, and water depth at the beginning and end of the set. Depth of capture was observed from numbered metal brads attached to the net margin. The depth of capture for each fish collected was subsequently converted to depth relative to the surface. This conversion facilitated comparisons of fish distribution with temperature and DO data which had been collected relative to the lake surface. In order to make comparisons of frequencies of occurrence between months, catch rates per 24-hour netting interval were calculated for each species collected.

Temperature was recorded at the surface and depths of 5, 10, 15, and each meter from 15 meters to the bottom at lowering and lifting of each net set. Secchi transparency was determined and recorded at both the beginning and end of each net set. Dissolved oxygen was measured bi-weekly preceeding and twice weekly during aeration at 1.5 m intervals at all water quality monitoring stations by FWPCA personnel. These observations and measurements of DO made intermittantly during the netting operations were used to estimate average DO concentrations for each netting week.

During June, vertical gill nets were fished only at stations 2, 4, and 13; net sets at stations 7 and 16 began the first and third weeks of July, respectively. Fish catch was not obtained at any station during the second week of September because the float roller assembly at station 7 was struck by a boat during that week; the net was inoperable until the second week of October.

CHAPTER IV

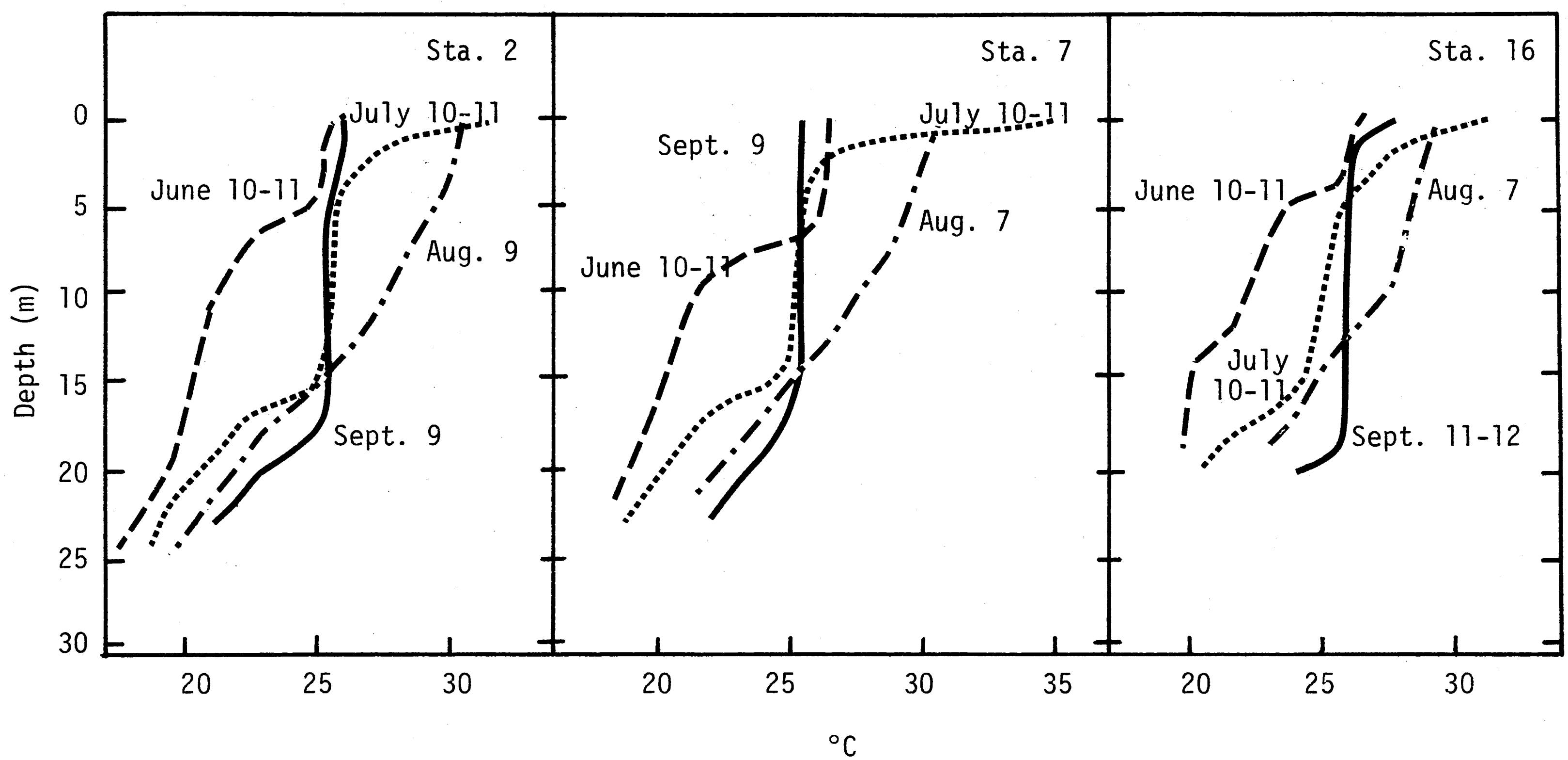
RESULTS

The 1967 pilot study on the central pool of Eufaula Reservoir indicated that the reservoir would be intensely stratified by early June (Leach et al. 1968). In 1968, because of a prolonged cool spring and unusually high runoff thermal stratification did not develop until mid-July, and aeration was initiated on 2 August. Temperature profiles obtained at netting stations 2, 7, and 16 indicate antecedent, summer-stratified, and post-stratified conditions (Figure 4). An identifiable thermocline was evident on 10-11 July at about the 15 m depth. Leach et al. (1970) reported the thermocline depth to be identifiable at approximately the 9-12 m depth at the time aeration was initiated on 2 August. They reported DO above the depth of 9 m, varying from 7.3 to 8.3 mg/1, while the DO concentration below 9 m decreased rapidly to zero at depths of 18-21 m.

Maximum Effects of Aeration

Maximum effect of aeration was achieved on 27 August, following 26 days of aeration. At this time aeration was detectable upstream between stations 4 and 5 (approximately 3,350 m) and was affecting a volume of approximately 36,309,000 m^3, but less than half the volume reported affected during the 1967 pilot study (Leach et al. 1970). The DO of approximately 1,289,000 m^3, or about 3.6% of the total volume affected

Figure 4. Temperature profiles 9 June through 12 October 1968 of stations 2, 7 and 16, Eufaula Reservoir.


Sta. 2
Sta. 7
Sta. 16
June 10-11
July 10-11
Aug. 9
Sept. 9
Sept. 9
July 10-11
June 10-11
Aug. 7
June 10-11
Aug. 7
July 10-11
Sept. 11-12
Depth (m)
0
5
10
15
20
25
30
20
25
30
20
25
30
35
20
25
30
°C

was increased to the 2 mg/1 level, the concentration considered as limiting ("critical") for fish distribution. Netting station 2 was the only sampling site included in this affected area, and for this reason catch data from this station has been considered separately for comparisons with pooled "control" data from stations 4, 7, 13 and 16.

Netting Efforts and Catch Composition

Vertical gill netting was initiated the first week of June and continued through the second week of October 1968. During this 19-week interval 9,928.8 hours of netting were completed. A total catch of 941 fish representing 15 species was obtained in 168 net lifts. The calculated combined average catch rate was 2.16 fish per 24 hour set. Of the 15 species of fish collected, carp (Cyprinus carpio) was the most abundant comprising 29.1% of the total catch (Table 2). White crappie (Pomoxis annularis) and channel catfish (Ictalurus punctatus) represented an additional 24.3 and 13.5%, respectively. An additional 30.1% to the total catch was of five species, in decending order of abundance, freshwater drum (Aplodinotus grunniens), white bass (Morone chrysops), gizzard shad (Dorosoma cepedianum), goldeye (Hiodon alosoides), and shortnose gar (Lepisosteus platostomus).

The eight species listed above constituted 97% of the total catch and were the only species having sufficient frequencies of occurrence to warrant consideration in subsequent comparisons of mean depth of capture to observed temperature and DO conditions. The remaining 3% of the total catch was made up of seven species: longnose gar (Lepisosteus osseus), bluegill (Lepomis macrochirus), river carpsucker (Carpiodes carpio), black bullhead (Ictalurus melas), blue catfish (Ictalurus

Table 2. Species composition of fish collected in vertical gill nets in the central pool of Eufaula Reservoir, June-October 1968.

	June		July		August		September		October		Total	
SPECIES	% Monthly Catch	No. per 24 hr.	% Monthly Catch	No. per 24 hr.	% Monthly Catch	No. per 24 hr.	% Monthly Catch	No. per 24 hr.	% Monthly Catch	No. per 24 hr.	No.	% Total Catch
Carp	20.33	.5184	32.77	.7392	34.44	1.0536	24.24	.4320	6.06	.0432	274	29.12
White crappie	20.33	.5184	25.68	.5784	23.26	.7128	21.21	.3768	51.52	.3600	228	24.23
Channel catfish	21.43	.5472	10.14	.2280	12.69	.3888	13.13	.2328	9.09	.0648	127	13.50
Freshwater drum	8.79	.2232	9.80	.2280	6.95	.2136	24.24	.4320	6.06	.0432	94	9.99
White bass	4.95	.1272	5.41	.1224	8.46	.2592	5.05	.0888	6.06	.0432	60	6.38
Gizzard shad	8.79	.2232	1.35	.0312	7.85	.2400	3.03	.0528	----	----	49	5.21
Goldeye	7.14	.1824	3.72	.0840	3.63	.1104	4.04	.0720	3.03	.0216	41	4.36
Shortnose gar	3.85	.0984	9.46	.2136	1.21	.0360	----	----	3.03	.0216	40	4.25
Longnose gar	1.65	.0432	1.01	.0240	----	----	----	----	6.06	.0432	8	0.85
Bluegill	----	----	----	----	0.19	.0288	2.02	.0360	6.06	.0432	7	0.74
River carpsucker	1.65	.0432	0.34	.0072	----	----	1.01	.0168	3.03	.0216	6	0.64
Black bullhead	1.10	.0288	0.34	.0072	----	----	----	----	----	----	3	0.32
Blue catfish	----	----	----	----	----	----	2.02	.0360	----	----	2	0.21
Bigmouth buffallo	----	----	----	----	0.30	.0096	----	----	----	----	1	0.11
Flathead catfish	----	----	----	----	0.30	.0096	----	----	----	----	1	0.11
Total number	182		296		331		99		33		941	
Total weight (kg)	59.21		93.04		96.93		25.85		12.14		287.17	
No. net days	71.3		131.4		108.1		55.7		47.2		413.7	

furcatus), bigmouth buffalo (Ictiobus cyprinellus), and flathead catfish (Pylodictus olivaris).

Catch Composition and Vertical Distribution Relative to Summer-Stratification

Vertical gill net sets during the month of June produced catch rates in excess of 0.5 fish/24 hr lift for channel catfish, carp, and white crappie. In June these three species accounted for 62% of the total catch; freshwater drum, white bass, gizzard shad, goldeye, and shortnose gar (ranging about 4-9%) making up all but 4.5% of the balance.

Vertical distribution of fish collected during June was primarily in the upper 10 m where temperatures above 24 C and DO concentrations of greater than 6 mg/l predominated. Goldeye and shortnose gar occupied the near-surface waters and were subtended slightly by white crappie, white bass, freshwater drum, and channel catfish. Carp and gizzard shad were most consistently collected from strata below 10 m where temperatures were less than 22 C and DO concentrations as low as 4 mg/l or less.

Net catches during July and August, during development of summer-stratification, produced some changes in catch composition, rate of capture, and vertical distribution of fishes. The percent of total catch for the eight major species increased to 98-99% during July and August. Percentage composition of carp, white crappie, and white bass increased slightly, and catch rates for these species and for channel catfish, gizzard shad and shortnose gar reached their observed maxima. Vertical distribution during summer-stratification was similar to that observed during June prior to the onset of stratification. The majority of fishes were caught in the upper 10 m and the order of vertical succession by species was nearly the same. The most notable exception being the occurrence of gizzard shad at much shallower mean depths (4-5 m) than during the June netting period (18.5 m). Fishes occupying the upper 10 m of the water column were subjected to temperatures of 26 C or greater but DO concentrations were not less than 4 mg/l. In contrast to shad, mean depth of capture of carp increased as summer-stratification progressed (16-17 m in July and August as opposed to 13 m during June). During August, temperatures at the mean depths of capture of carp were about 24 C and DO concentrations were 2 mg/l or less.

Post-stratification fish collections during September and early October were less intensive than during preceeding months, and produced smaller catches composed of fewer species. During this period, catch rates for most species declined by a considerable margin and two of the eight primary species were absent from netting samples of at least one month. Freshwater drum, during September, and white crappie, during October, made up a substantial part of the total catch; contribution to total catch by other major species was particularly reduced during October. Vertical distribution and species successions were similar to pre-stratified patterns; most species occupied depths of about 10 m or less but channel catfish, carp, and gizzard shad again were found in deeper water than other fish. Water temperature during this period was decreasing, but all fishes caught were taken from water of 22 C or more and with DO concentrations in excess of 4 mg/l.

Interspecies Variation in Vertical Distribution

Statistical comparisons between weekly mean depths of capture for each of eight species at one "treated" and four pooled "control" stations were made (Tables 3-10). Only during three weeks were the mean depths of capture for a species at the "treated" site (station 2) significantly different (.05 level) from the untreated "control" (stations 4, 7, 13 and 16 pooled). In addition to the statistical comparisons the tabulated weekly mean depth has been plotted with relative temperature and DO data (Figures 5-12) to facilitate graphic correlation of observed vertical distribution of environmental parameters.

Carp

Weekly mean depth of capture of carp at station 2 was not found to differ significantly from the pooled mean depth for the other four stations in any week during the study (Table 3). Carp were fairly well represented at all stations during most of the period of aeration. Carp apparently did not avoid the stratified anoxic hypolimnion in late July and during August, mean depths of capture of carp sometimes occurred in water with less than 2 mg/l DO (Figure 5).

White Crappie

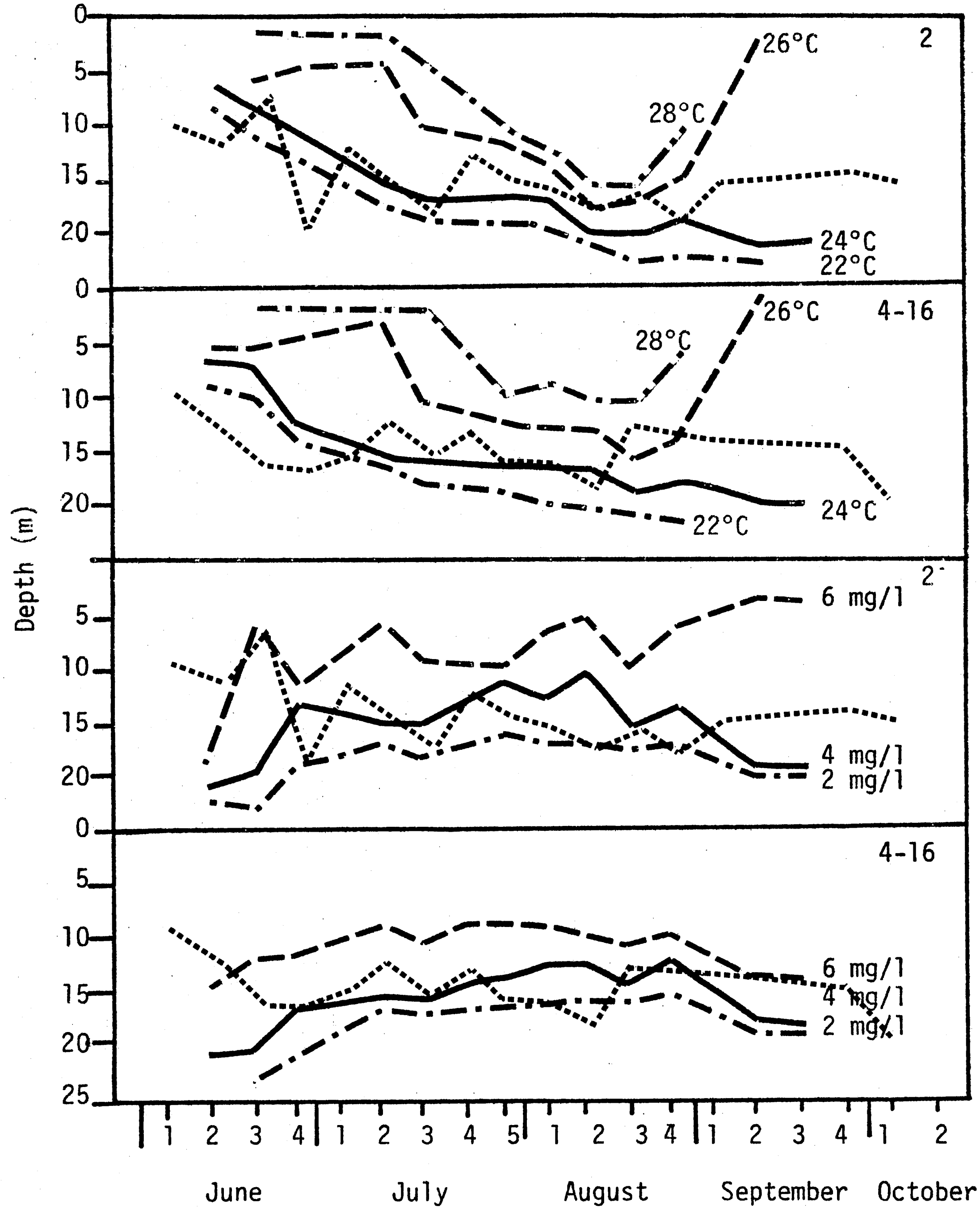
White crappie were well represented in the monthly catch in all months (Table 4). The high percentage of white crappie caught during October reflects a reduction in catch of other species rather than an increase in catch of crappie.

Table 3. Average depth (m) of capture of carp in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																		
		June				July					August				September				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
2	N	5	7	1	4	2	2	1	8	10	3	7	2	4	1			1	1	
	$\bar{X}$	9.8	11.2	7.5	19.3	12.0	15.0	18.5	12.1	14.9	15.7	17.6	16.0	19.0	15.5			14.5	15.5	
	S_D	7.9	9.2		4.9	3.5	7.8		4.6	3.2	4.9	2.0	8.5	6.3						
4	N		7		6	5	6	5	2		6	6	6	4	1			1		
	$\bar{X}$		12.8		17.5	13.6	11.3	14.6	14.0		18.0	14.5	14.0	13.4	15.5			15.5		
	S_D		2.5		2.3	0.9	2.0	1.1	5.0		2.0	2.4	2.1	1.8						
7	N					8	6	5	3	4	8	19		11	4					
	$\bar{X}$					17.8	15.0	19.7	16.8	15.8	17.8	19.9		17.1	17.5					
	S_D					1.5	1.8	1.2	0.5	1.4	1.6	1.0		2.10	1.8					
13	N	2	2	3		2	1	1	1	2	4	6	5	6	9				1	
	$\bar{X}$	9.5	13.8	17.2		13.5	13.5	21.5	8.5	13.5	14.3	16.2	14.5	16.2	15.3				20.5	
	S_D	4.0	3.3	2.8		4.0				4.0	0.8	1.4	1.4	1.1	1.2					
16	N							3	5	5	1	1	2	13	9					
	$\bar{X}$							8.2	12.9	16.3	13.5	10.5	10.5	13.6	13.6					
	S_D							4.2	2.7	0.9			9.0	1.3	1.8					
4-16	N	2	9	3	6	15	13	14	11	21	19	32	13	34	22			1	1	
	$\bar{X}$	9.5	13.0	17.2	17.5	15.8	13.2	15.6	13.8	15.7	16.3	18.0	13.6	14.8	15.0			15.5	20.5	
	S_D	5.6	5.9	4.9	5.6	4.3	4.6	5.9	5.0	4.7	4.2	5.1	5.4	4.9	4.4					
2 vs. 4-16	t	0.05	-0.47		-0.51	1.19	0.48		0.72	-0.51	-0.26	-0.16	-0.54	1.59						

[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 5. Mean depth of capture (----) of carp in relation to isotherms (— °C) and dissolved oxygen isopleths (— mg/1) at station 2 and stations 4-16 combined.



0
5
10
15
20
26°C
2
28°C
24°C
22°C
26°C
4-16
28°C
24°C
22°C
Depth (m)
2
6 mg/l
4 mg/l
2 mg/l
4-16
6 mg/l
4 mg/l
2 mg/l
25
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

Table 4. Average depth (m) of capture of white crappie in Eufaula Reservoir, 5 June through 12 October 1968.

Station No.	Stat.	June 1	June 2	June 3	June 4	July 1	July 2	July 3	July 4	July 5	August 1	August 2	August 3	August 4	September 1	September 2	September 3	September 4	October 1	October 2
		Months and Netting Weeks[1]																		
2	N	1	3	3	2	1	3	1	2	3	5	4	1	1	1			1	1	
	$\bar{X}$	5.5	3.5	3.3	3.8	14.0	3.8	8.5	6.3	4.8	6.6	7.9	1.0	1.0	10.5			2.5	14.5	
	S_D		5.2	0.8	3.9		0.8		3.2	6.6	2.7	1.3								
4	N	3	4	5	4	1	2	2	1		4	9	4	3	5				4	2
	$\bar{X}$	1.5	3.3	4.9	3.5	2.5	4.5	8.0	3.5		4.8	7.5	5.0	4.5	8.9				1.8	3.0
	S_D	0.5	0.5	0.7	1.2		0.9	5.0			1.0	0.3	1.3	2.1	1.1				1.1	2.5
7	N					12	1	4	1	3	4	7		9	3					
	$\bar{X}$					5.3	8.5	6.8	8.5	2.8	9.8	6.1		3.8	2.5					
	S_D					0.8		2.6		1.9	1.9	0.4		1.0	1.2					
13	N	3	3	6		3	1	3	5	1		2		2	3			7	3	2
	$\bar{X}$	1.8	5.0	3.2		2.8	3.5	3.5	4.0	3.5		6.5		6.0	8.2			5.5	2.5	2.8
	S_D	0.3	1.8	0.7		1.8		2.8	0.7			1.0		0.5	2.7			2.4	2.0	2.3
16	N							2	18	6	6	7	2	7	1				5	
	$\bar{X}$							1.8	4.9	3.5	6.3	5.6	3.0	4.9	3.5				4.0	
	S_D							1.8	0.7	0.9	1.5	0.7	1.5	0.7					0.7	
4-16	N	6	7.0	11	4	16	4	11	25	10	14	26	6	21	12			7	12	4
	$\bar{X}$	1.7	4.0	4.0	3.5	4.7	5.2	5.7	4.8	3.3	6.8	6.6	4.3	4.5	6.7			5.5	2.9	2.9
	S_D	0.7	2.1	1.8	2.4	3.0	2.8	4.6	2.8	2.2	3.7	1.4	2.4	2.5	4.0			1.8	2.4	2.8
2 vs. 4-16	t		-0.22	0.56	0.10		0.84		0.69	0.67	0.12	1.75								

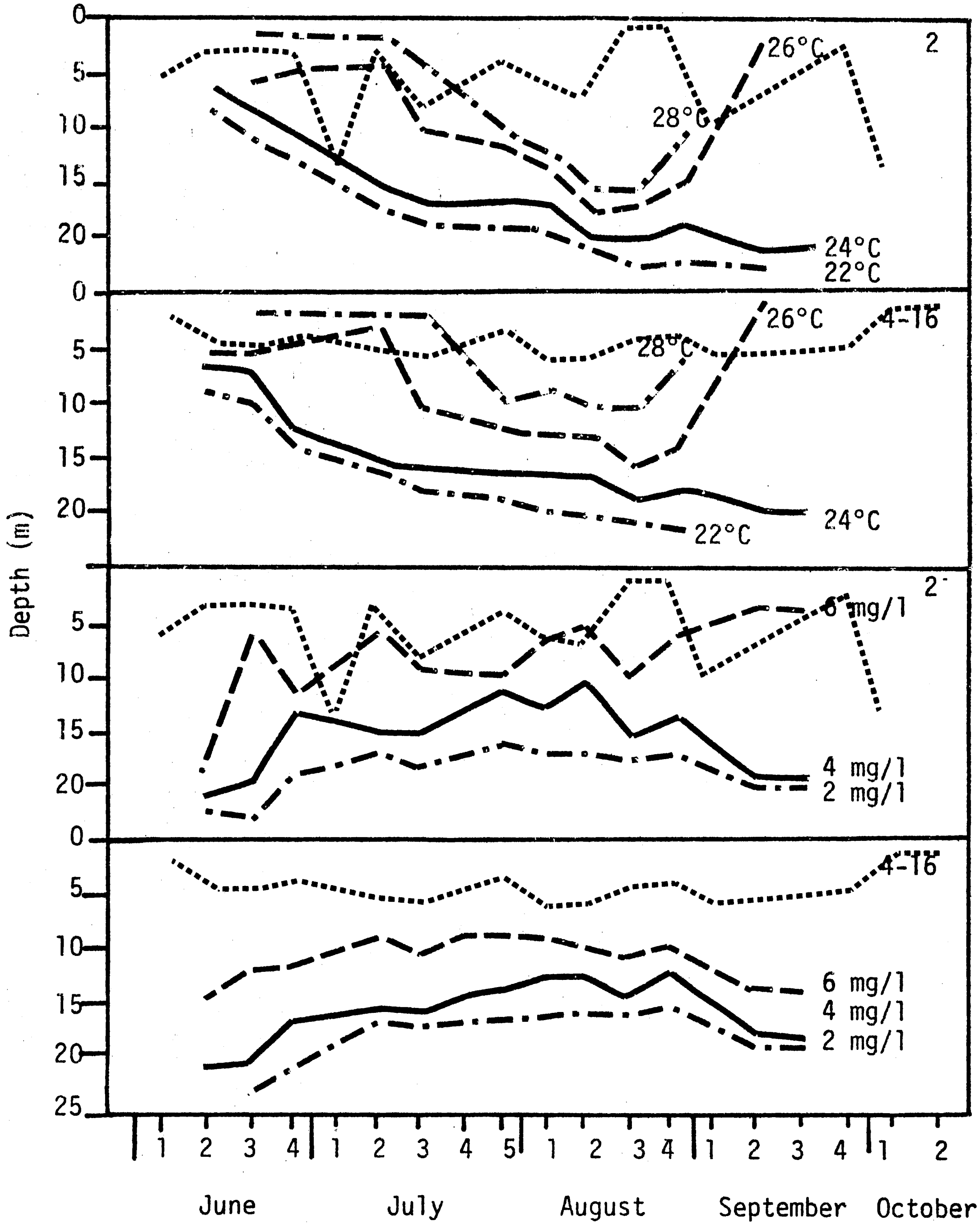
[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Mean depths of capture for crappie were generally less than 6 m in June; they tended to be deeper (up to 14.0 m) in July through the first week of September, followed by a return to less than 6 m during late September and October (Table 4). Carter (1967) reported that white crappie were caught at depths of 9 m or less. Grinstead (1965) recorded an average depth of capture for white crappie of 7 m during the summer and he indicated that these fish were surface oriented. During the present study white crappie were surface oriented and occupied strata having temperatures of 26 C or greater and DO greater than 6 mg/1 (Figure 6).

Channel Catfish

Channel catfish were more variable in average depths of capture (Table 5) than either carp or white crappie (Tables 3 and 4). Although channel catfish were fairly well represented numerically during this study, their variable vertical distribution would tend to preclude their use as an indicator organism in habitat enhancement studies. Carter (1967) reported that distribution of this species was quite variable between stations. It is probably this variable nature of channel catfish rather than a temperature or oxygen difference which accounts for the one significant difference in weekly mean depth between station 2 and stations 4, 7, 13 and 16 pooled for the first week of September. Channel catfish were generally caught in strata having temperatures greater than 24 C and DO concentrations of 4 mg/1 or greater (Figure 7).

Figure 7. Mean depth of capture (----) of channel catfish in relation to isotherms (— °C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.



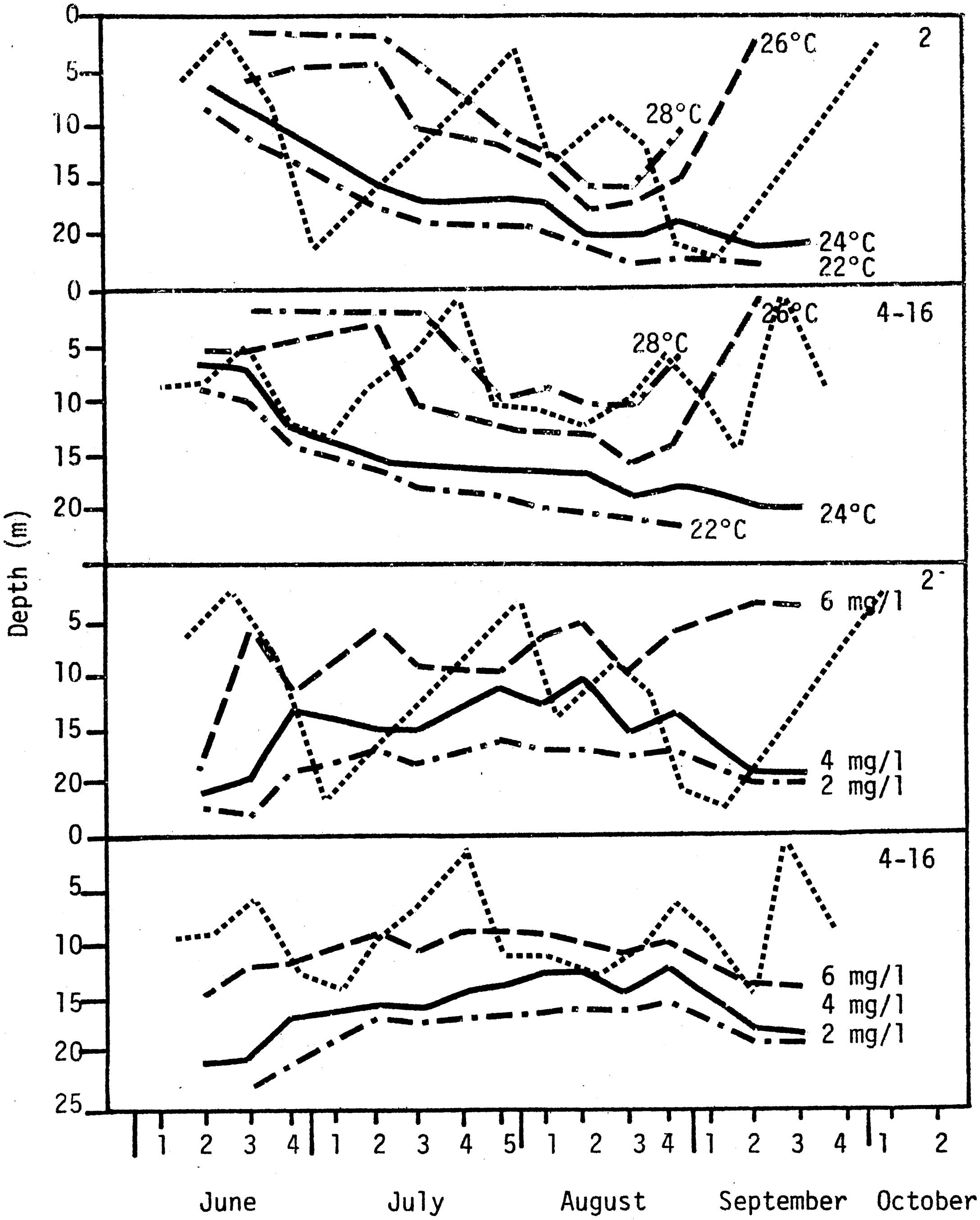
Depth (m)
0
5
10
15
20
2
26°C
28°C
24°C
22°C
0
5
10
15
20
26°C
4-16
28°C
24°C
22°C
5
10
15
20
2
6 mg/l
4 mg/l
2 mg/l
0
5
10
15
20
25
4-16
6 mg/l
4 mg/l
2 mg/l
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

Table 5. Average depth (m) of capture of channel catfish in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																		
		June				July					August				September				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
	N	5	3	4	1					2	5	2	1	1	2				1	
2	$\bar{X}$	5.4	1.5	8.4	21.5					2.2	13.2	9.8	12.0	21.0	22.8				1.5	
	S_D	6.8	1.7	6.4						2.5	4.4	2.5			2.5					
	N	3	6	3	3						3		1	3	1			1		
4	$\bar{X}$	16.2	11.3	4.2	12.7						12.5		10.5	5.0	13.5			14.5		
	S_D	0.7	3.1	0.7	2.8						3.5			1.8						
	N					9	5			3	4	3		2	2					
7	$\bar{X}$					14.3	10.0			8.8	9.8	15.7		9.5	9.5					
	S_D					2.2	3.6			0.3	2.3	3.0		1.0	7.0					
	N	3	3	5		1	3	1		2	1	1		5	5				1	1
13	$\bar{X}$	3.5	5.5	5.8		20.5	9.5	6.5		12.5	17.5	17.5		8.5	11.5				0.5	9.0
	S_D	1.2	2.0	2.1			3.5			7.0				2.4	3.1					
	N								1	3	4	3		2	1			1		
16	$\bar{X}$								1.5	12.8	11.0	8.5		0.5	0.5			17.5		
	S_D									3.76	2.7	5.0		0						
	N	6	9	8	3	10	8	1	1	8	12	7	1	13	9			2	1	1
4-16	$\bar{X}$	9.8	9.4	5.2	12.7	14.0	9.8	6.5	1.5	11.2	11.5	12.8	10.5	6.0	10.0			16.5	0.5	9.0
	S_D	7.1	7.0	3.7	4.8	5.7	6.8			5.5	5.0	7.2		4.9	7.1			1.4		
2 vs. 4-16	t	1.05	-1.88	-1.12						-2.18	-0.65	-0.78			-2.41					

[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 6. Mean depth of capture (----) of white crappie in relation to isotherms (— ^{o}C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.



26°C
2
28°C
24°C
22°C
26°C
4-16
28°C
24°C
22°C
2
6 mg/l
4 mg/l
2 mg/l
4-16
6 mg/l
4 mg/l
2 mg/l
Depth (m)
0
5
10
15
20
25
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

Freshwater Drum

Except for September when freshwater drum accounted for over 24% of the total catch, this species averaged about 8% of the monthly total catches (Table 2). Their abundance in September was probably due to recruitment of young-of-the-year (YOY) fish rather than an environmentally triggered migratory behavior.

Overall weekly mean depths of capture was about 10 m (Table 6). Their mean depths of capture was about 7 m in middle and latter July, then about 10 m again in early August. Freshwater drum were most abundant between 5 and 10 m where the maximum temperature was about 28 C and DO concentration approximately 6 mg/l (Figure 8). Carter (1967) found freshwater drum to be concentrated at depths of 3-6 m during the summer and in water ranging up to 27 C. High concentrations of freshwater drum were caught at a depth of about 6 m in Wheeler Reservoir during August and September (Bryan and Howell 1946). Cady (1945) netted highest concentrations of freshwater drum in 6-12 m depths of Norris Reservoir during June, July and August.

White Bass

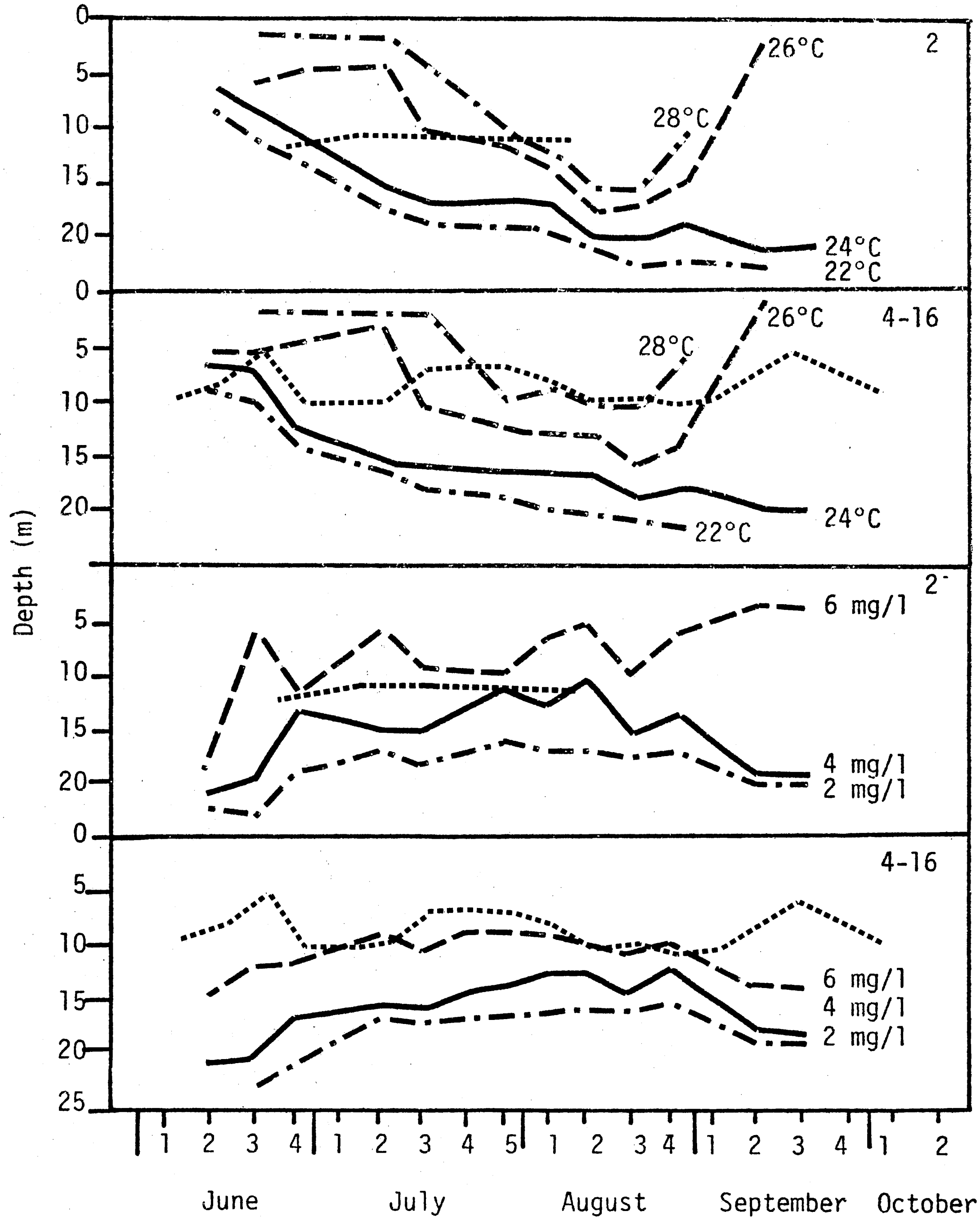
White bass usually represented 5-6% of the total monthly catch, with a maximum contribution of 8.46% recorded for the month of August (Table 2). Weekly mean depth of white bass at station 2 was found to differ significantly from the mean depth for stations 4, 7, 13 and 16 combined. This difference, however, is due to a change in mean depth at station 7 rather than a change at station 2, hence, it cannot be considered to be a result of the artificial destratification effort

Table 6. Average depth (m) of capture of freshwater drum in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																		
		June				July					August				Septeber				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
	N			1		2					1									
2	$\bar{X}$			12.0		10.5					11.0									
	S_D					0														
	N		1	1	1	1			1				2	1	1					
4	$\bar{X}$		13.5	6.5	10.5	12.5			6.5				10.5	11.0	13.5					
	S_D												0							
	N					2	2	2	1	4	1	6		1	1					
7	$\bar{X}$					8.5	12.5	8.3	8.5	8.8	10.5	11.2		8.5	7.5					
	S_D					2.0	1.5	0.3		1.4		0.6								
	N	4	2	6		5	1	1		2	3		1	1	8				1	
13	$\bar{X}$	9.6	6.5	5.8		11.9	5.5	7.5		6.5	7.8		7.5	14.5	12.3				10.5	
	S_D	2.6	1.0	1.3		2.0				0	0.3				0.7					
	N							1	2	2	1	1	2	2	12		2		1	
16	$\bar{X}$							6.5	7.0	7.0	10.5	9.5	11.5	10.5	9.6		4.5		9.5	
	S_D								0	0.5			0	3.0	0.9		2.0			
	N	4	3	7	1	8	3	4	4	8	5	7	5	5	22		2		2	
4-16	$\bar{X}$	9.6	8.8	5.9	10.5	11.1	10.2	7.6	7.2	7.8	8.9	10.9	10.3	11.0	10.7		4.5		10.0	
	S_D	5.1	4.2	2.9		3.9	4.3	0.9	0.9	2.2	1.5	1.5	1.6	3.0	2.9		2.8		0.7	
2 vs. 4-16	t					0.22														

[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 8. Mean depth of capture (----) of freshwater drum in relation to isotherms (— ^{o}C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.



0
5
10
15
20
26°C
2
28°C
24°C
22°C
0
5
10
15
20
26°C
4-16
28°C
24°C
22°C
Depth (m)
2-
6 mg/l
5
10
15
20
4 mg/l
2 mg/l
0
4-16
5
10
15
20
25
6 mg/l
4 mg/l
2 mg/l
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

(Table 7). White bass were concentrated primarily in strata where temperatures were greater than 28 C and DO concentrations in excess of 6 mg/l (Figure 9). Average depths of capture of white bass in June, July, August and September did not exceed 5 m in Keystone Reservoir (Carter 1967).

Gizzard Shad

The percent of montly catch contributed by gizzard shad ranged from 0 to 8.79 during the present study (Table 2). During the first week of August there was a significant difference in weekly mean depth of capture between station 2 and stations 4 and 7 pooled (Table 8). Both mean depths were less than 10 m, and while the aeration apparatus started operating at this time, it is not likely this significant difference resulted from that process.

There was both a reduction in gizzard shad collected and in their mean depth of capture during late June, most of July and August (Table 8). During stratified conditions at station 2 gizzard shad occurred at depths where temperature was greater than 22 C and DO concentration greater than 2 mg/l, while at stations 4, 7, 13 and 16 combined, gizzard shad occupied waters having temperatures of 28 C or more and DO concentration in excess of 6 mg/l (Figure 10).

Goldeye

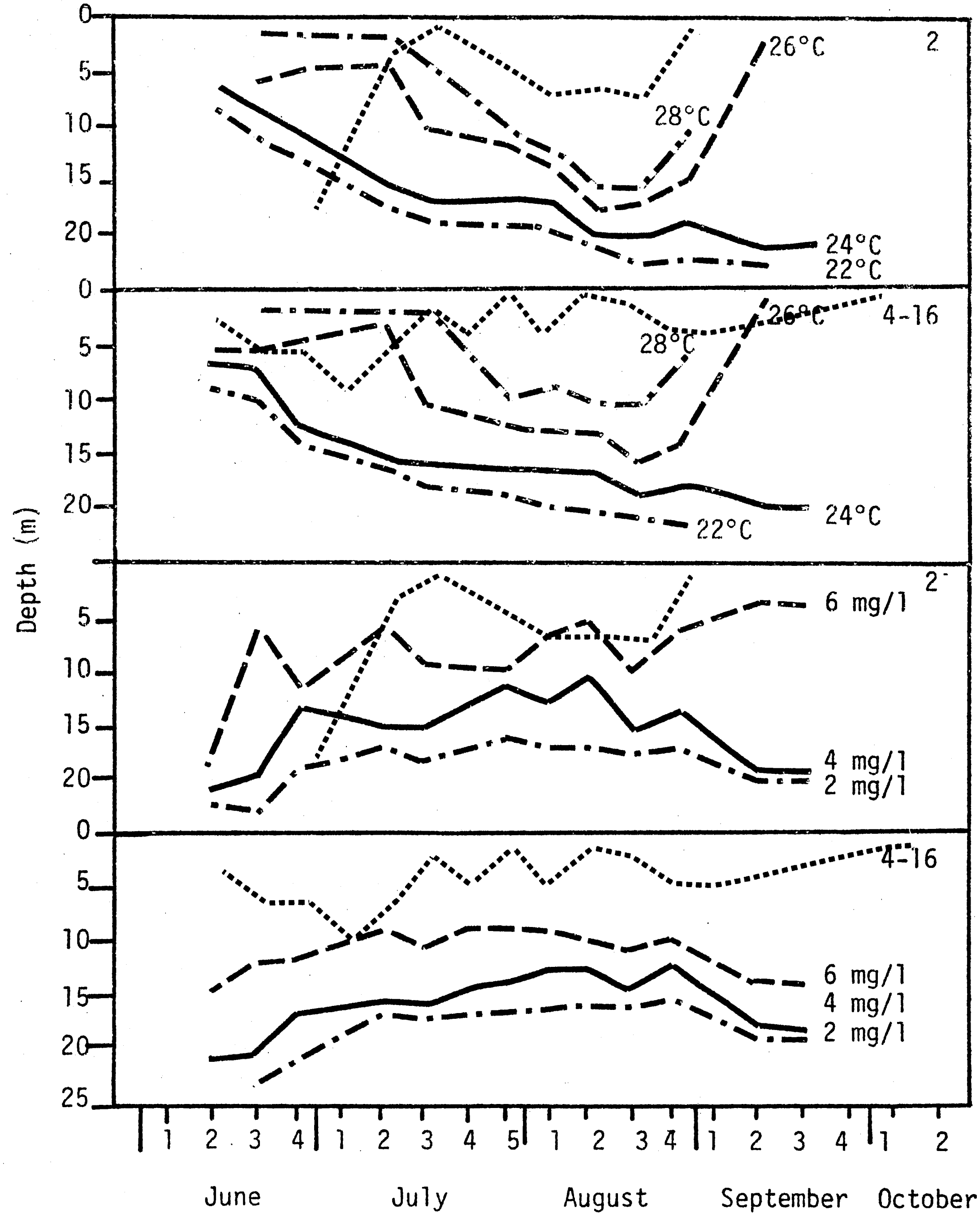
Percents of monthly catch for goldeye normally ranged from 3-4% with a maximum of 7.14% occurring in June (Table 2). Maximum average depth of capture of goldeye was 6 m recorded in early July; the majority of mean depths were at levels of less than 3 m (Table 9). Due

Table 7. Average depth (m) of capture of white bass in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																
		June				July					August				September				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
	N				1		2	1			4	2	1	2						
2	$\bar{X}$				17.5		3.0	0.5			6.9	6.8	7.0	1.5						
	S_D						0.7				4.2	1.1		0.7						
	N		2	1	2	1		1	2		3		1		1				2	
4	$\bar{X}$		7.8	3.5	6.0	4.5		1.5	5.0		4.2		2.5		10.5				0.8	
	S_D		2.3		2.5				1.5		1.8								0.3	
	N					1	2	1	1	1	2	2		7	1					
7	$\bar{X}$					4.5	6.8	2.5	4.5	0.5	4.0	1.5		3.5	2.5					
	S_D						1.3				0.5			1.0						
	N			3		1									1					
13	$\bar{X}$			7.2		19.5									6.5					
	S_D			3.2																
	N								2					4	2					
16	$\bar{X}$								3.0					4.5	0.5					
	S_D								1.1					1.2	0					
	N		2	4	2	3	2	1	5	1	5	2	1	11	5				2	
4-16	$\bar{X}$		3.9	6.2	6.0	9.5	6.8	2.0	4.1	0.5	4.1	1.5	2.5	3.8	4.1				0.8	
	S_D		4.8	4.9	3.5	8.7	1.8	0.7	1.8		2.2	0.0		2.4	4.3				0.4	
2 vs. 4-16	t						-2.78				-1.28	7.00		1.27						

[1] Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 9. Mean depth of capture (----) of white bass in relation to isotherms (— °C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.



Depth (m)
0
5
10
15
20
26°C
28°C
24°C
22°C
2
4-16
6 mg/l
4 mg/l
2 mg/l
25
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

Table 8. Average depth (m) of capture of gizzard shad in Eufaula Reservoir, 5 June through 12 October 1968.

Station No.	Stat.	June 1	June 2	June 3	June 4	July 1	July 2	July 3	July 4	July 5	August 1	August 2	August 3	August 4	September 1	September 2	September 3	September 4	October 1	October 2
		Months and Netting Weeks[1]																		
	N	2	1	2		1					6				3					
2	$\bar{X}$	21.5	10.0	17.5		15.5					9.6				21.3					
	S_D	4.2		0							0.9				2.8					
	N	1	2	2							2		2	1						
4	$\bar{X}$	22.5	18.5	19.0							2.0		1.5	2.0						
	S_D		2.8	4.5							0.5		0							
	N					1	1				2			7						
7	$\bar{X}$					6.0	0.5				5.0			0.8						
	S_D										1.5			0.6						
	N			6								1		1						
13	$\bar{X}$			16.8								7.5		10.5						
	S_D			2.2																
	N							1				2		2						
16	$\bar{X}$							20.5				5.5		4.5						
	S_D											0		2.0						
	N	1	2	8		1	1	1			4	3	2	10						
4-16	$\bar{X}$	22.5	18.2	17.3		6.0	0.5	20.5			3.5	6.2	1.5	3.0						
	S_D		3.9	5.3							2.2	1.2	0	3.7						
2 vs. 4-16	t			-0.05							6.25									

[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 10. Mean depth of capture (----) of gizzard shad in relation to isotherms (— ^{o}C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.

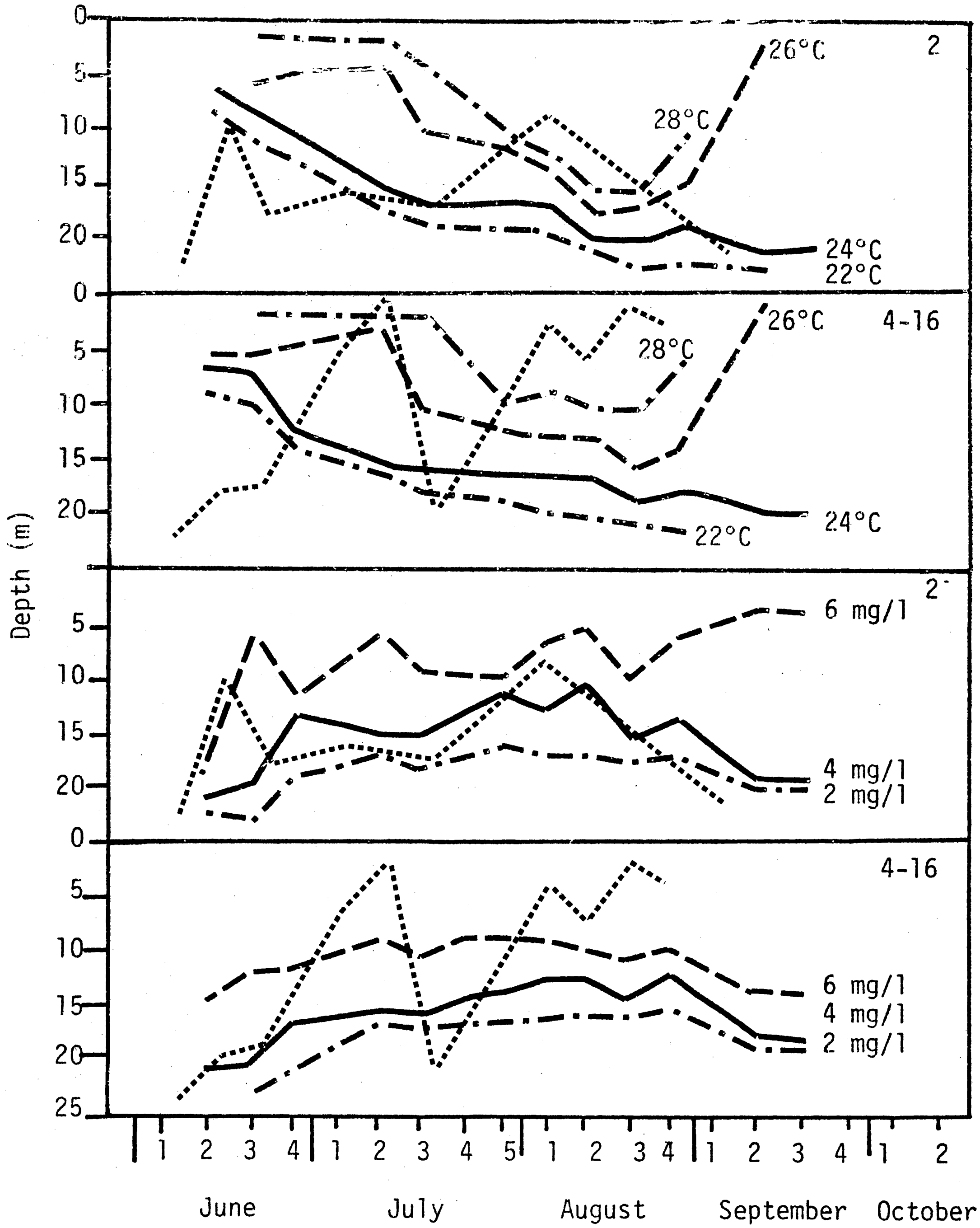

26°C
2
28°C
24°C
22°C
26°C
4-16
28°C
24°C
22°C
2
6 mg/l
4 mg/l
2 mg/l
4-16
6 mg/l
4 mg/l
2 mg/l
Depth (m)
June
July
August
September
October

Table 9. Average depth (m) of capture of goldeye in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																		
		June				July					August				September				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
	N		2	1					1	1			1	3	2			1	1	
2	$\bar{X}$		0.5	2.5					2.5	0.5			1.0	2.7	0.5			0.5	5.5	
	S_D		0											0.6	0					
	N	2	2	2			2					2		1						
4	$\bar{X}$	1.3	1.5	4.5			6.0					2.0		0.5						
	S_D	0.8	1.0	1.0			0.5					0.5								
	N					4								2						
7	$\bar{X}$					5.0								0.5						
	S_D					3.1								0						
	N		1	3		1				1	1			2			1			
13	$\bar{X}$		0.5	2.5		1.5				3.5	3.5			4.0			0.5			
	S_D			0.6										0.5						
	N									1										
16	$\bar{X}$									3.5										
	S_D																			
	N	2	3	5		5	2			2	1	2		5			1			
4-16	$\bar{X}$	1.2	1.2	3.3		4.3	6.0			3.5	3.5	2.0		1.9			0.5			
	S_D	1.1	1.2	1.5		5.5	0.7			0.0		0.7		1.9						
2 vs. 4-16	t													0.33						

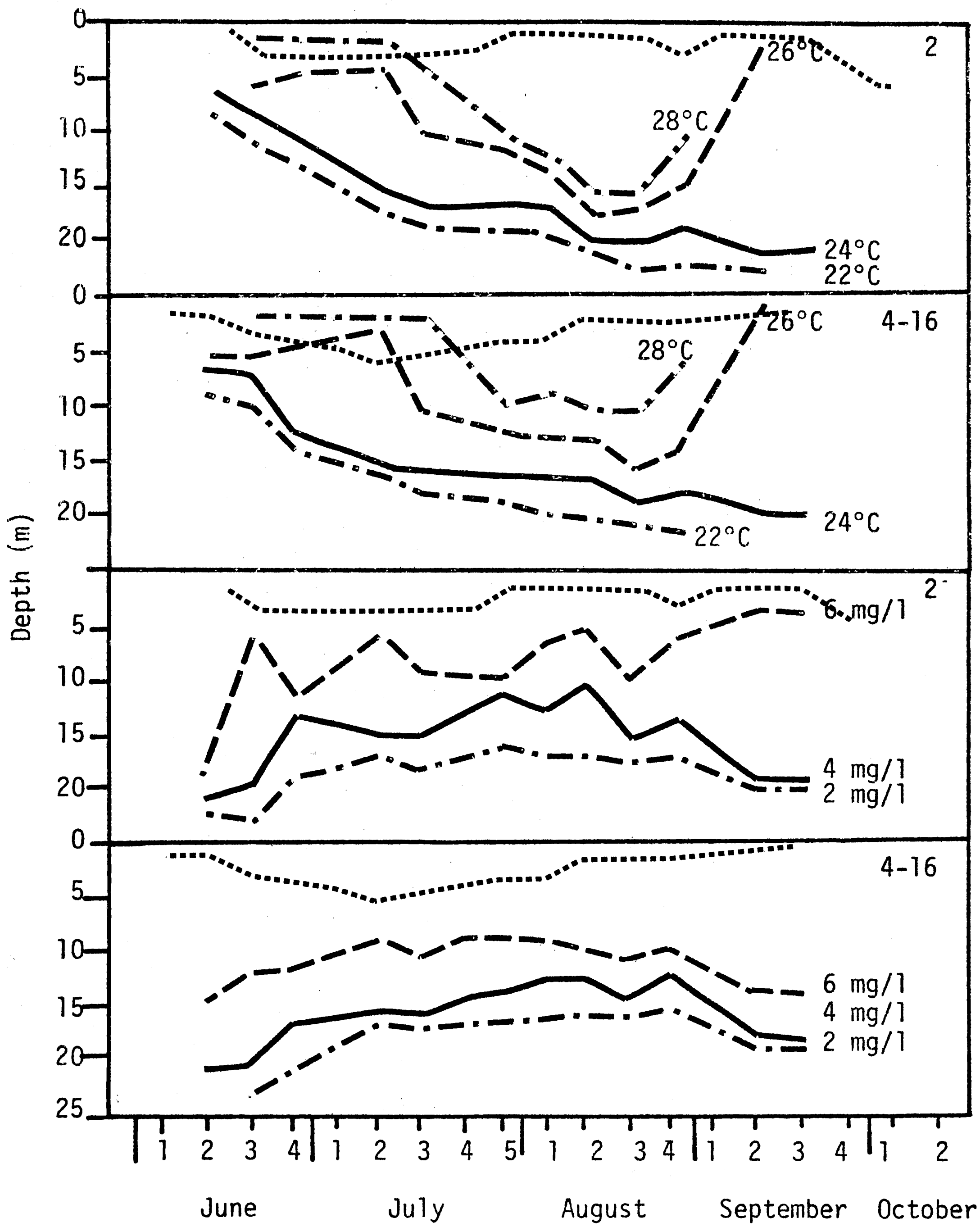
[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

to the surface oriented distribution of goldeye they were always located in strata having maximum or near maximum temperatures and DO concentrations (Figure 11). Carter (1967) noted that goldeye were caught near the surface during all seasons.

Shortnose Gar

Percents of monthly catch of shortnose gar varied from 0 in September to 9.46 in July (Table 2). With regard to shortnose gar distribution: (1) mean depth of capture was always within 7.5 m of the surface, (2) shortnose gar may have been migrating up the reservoir during this netting study (Table 10). Shortnose gar were distributed so they were associated with water temperatures around 26-28 C and DO concentration in excess of 6 mg/l (Figure 12).

Figure 11. Mean depth of capture (----) of goldeye in relation to isotherms (— ^{o}C) and dissolved oxygen isopleths (— mg/1) at station 2 and stations 4-16 combined.



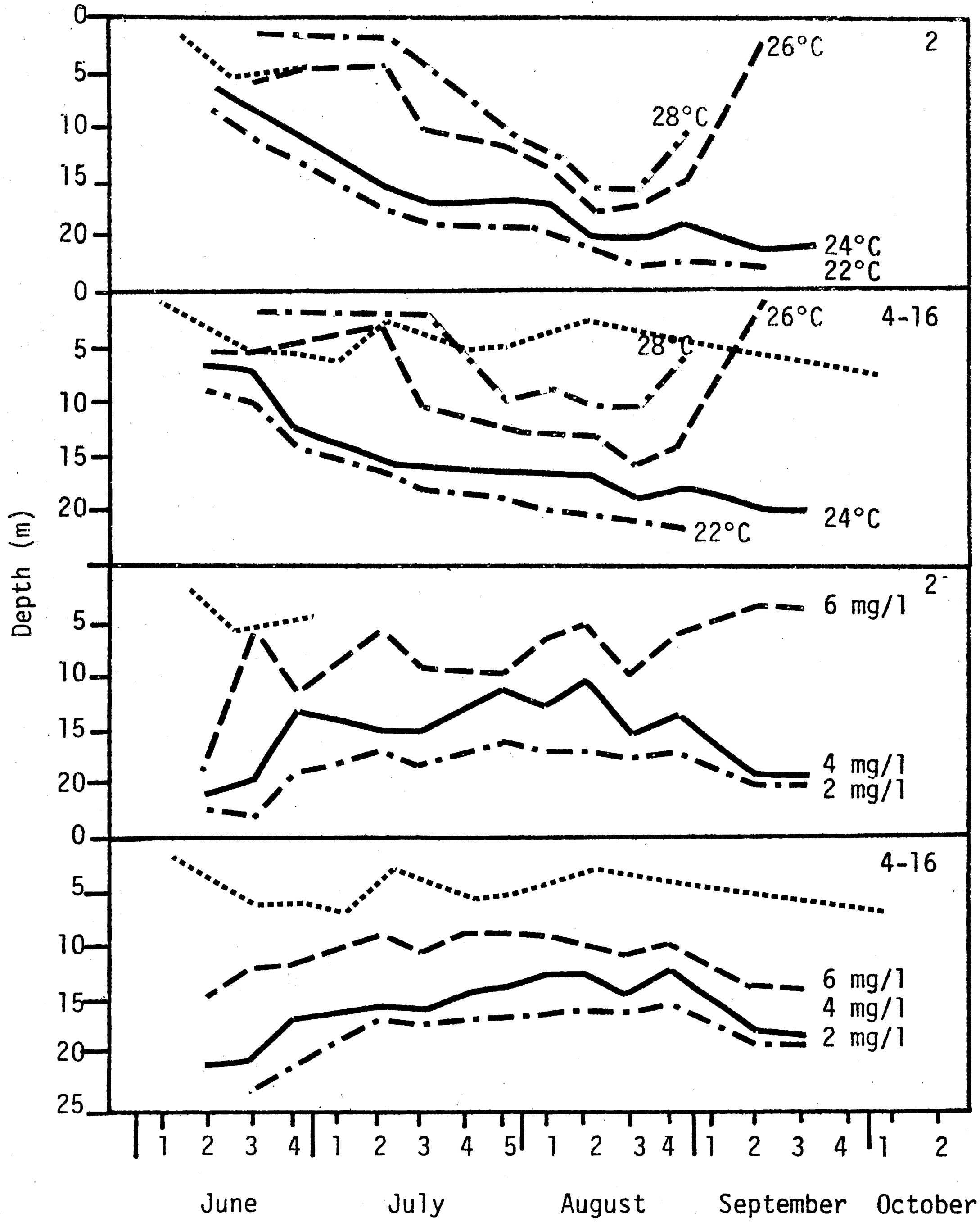
Depth (m)
0
5
10
15
20
2
26°C
28°C
24°C
22°C
0
5
10
15
20
4-16
26°C
28°C
24°C
22°C
2
5
10
15
20
6 mg/l
4 mg/l
2 mg/l
0
5
10
15
20
25
4-16
6 mg/l
4 mg/l
2 mg/l
1 2 3 4 1 2 3 4 5 1 2 3 4 1 2 3 4 1 2
June
July
August
September
October

Table 10. Average depth (m) of capture of shortnose gar in Eufaula Reservoir, 5 June through 12 October 1968.

		Months and Netting Weeks[1]																		
		June				July					August				September				October	
Station No.	Stat.	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2
	N	1	1		1															
2	$\bar{X}$	1.0	4.5		5.0															
	S_D																			
	N				1				1											
4	$\bar{X}$				5.5				7.5											
	S_D																			
	N					2	1			1										
7	$\bar{X}$					3.8	3.0			5.5										
	S_D					0.8														
	N	2		1		3	2												1	
13	$\bar{X}$	1.3		5.5		7.8	2.8												7.5	
	S_D	0.3				2.0	0.3													
	N								12			1		3						
16	$\bar{X}$								5.3			3.5		6.8						
	S_D								0.4					1.2						
	N	2		1	1	5	3		13	7		1							1	
4-16	$\bar{X}$	1.2		5.5	5.5	6.2	2.8		5.5	5.2		3.5							7.5	
	S_D	0.4				3.4	0.3		1.6	2.1										

[1]Netting weeks generally approximate calendar weeks and usually include 3 net sets.

Figure 12. Mean depth of capture (----) of shortnose gar in relation to isotherms (- ^{o}C) and dissolved oxygen isopleths (— mg/l) at station 2 and stations 4-16 combined.



Depth (m)
2
26°C
28°C
24°C
22°C
4-16
26°C
28°C
24°C
22°C
2
6 mg/l
4 mg/l
2 mg/l
4-16
6 mg/l
4 mg/l
2 mg/l
June
July
August
September
October

CHAPTER V

DISCUSSION

Effects of Aeration on Stratification

It had been anticipated that stratification of Eufaula Reservoir would begin during mid-May becoming fully established by early June and last for a period of several months. It was also assumed that by increasing the capacity of aeration equipment (from 140 cfm at 65 psi to 1200 cfm at 125 psi), a volume greater than the 8×10^7 m^3 of central pool affected during the 1967 pilot study could be artificially destratified (unpublished research proposal, FWPCA 1968). During the 1968 research effort however, exceptionally high runoff and unseasonably cool weather both delayed the establishment and limited the extent and duration of summer stratification. The increased capacity of the aeration equipment was offset by a combination of unusually high power discharge releases due to excessive runoff and the proximity of the diffuser apparatus to the power penstocks. An estimated 69% of the oxygen pumped into the reservoir by the aeration apparatus was lost through the penstocks to power releases (Leach et al. 1970). Due to the high discharge rate the volume of aerated hypolimnetic water in the central pool did not accumulate, and less than one-half (3.6×10^7 m^3) the 8×10^7 m^3 volume affected during the 1967 pilot study was affected. As a result, the hypothesis of expanding available fish habitat through artificial destratification could not be adequately tested.

Despite the reduction in total reservoir volume affected by the aeration apparatus in 1968 relative to the 1967 effort, the percent reduction in volume considered limiting to fish distribution (DO concentration of 2 mg/l or less) was greater (32.7% of the 1.1×10^8 m^3 volume in 1968 compared to 26.7% of the 3.0×10^8 m^3 volume estimated during 1967). The 1.1×10^8 m^3 of lake volume with less than 2 mg/l DO was 1.2% of the estimated volume of the reservoir. Station 2 was the only sample site where effects of aeration could be detected, therefore fish collections at station 2 were considered separately from the other collection sites to detect the effect of aeration on the vertical distribution of fishes.

Vertical Distribution of Fishes

While the gill net has been demonstrated to give a relatively accurate indication of the species present in a piscean community, it is a passive gear type and is subject to a variety of activity-related sampling biases. It is quite probable that changes in activity patterns were more responsible for some observed changes in abundance and monthly percent of catch, than were actual changes in community composition. Two notably suspect changes are the increases in number as well as depth of capture of carp during July and August when stratified reservoir conditions were prevalent, and the increased relative abundance (from about 20-25% to 51.5% of monthly catch) of white crappie during October when water temperature was declining. The increased catch frequency (from .52 to .74-1.05/24 hr lift) and mean depth (from 13.2 m to 15.4 m) at which carp were taken during stratification was probably the result of short periods of hyper-activity following excursions into the anoxic strata to forage at the benthic interface. Bryan and Howell (1946) determined from gill net catches in both Wheeler and Norris Reservoirs that carp had an affinity for the bottom. This affinity presumably results from carp feeding on benthic materials (Summerfelt et al. 1970). Haslbaur (1945) noted that even though data suggested carp were primarily a benthic species, they were frequently seen "jumping" over deep water far from shore. This phenomenon was observed on several occasions during the Eufaula study when the hypolimnion was known to be anoxic. I hypothesize that "jumping" in carp is an over-extension of a dyspnoea triggered rapid swimming response to avoid suffocation while foraging in anoxic hypolimnetic strata. It is further suggested that this rapid swimming behavior is responsible for the observed increases in catch frequency and depth of carp.

Gizzard shad were the only other species to demonstrate an affinity for benthic strata (June mean depth greater than 18 m) for an extended period during the study. Carter (1967) collected gizzard shad at benthic depths (15-20 m) during the winter and spring, but not during summer-stratified or fall sampling of Keystone Reservoir. Gizzard shad numbered 1780 of the 3282 fish collected during the year-long Keystone Reservoir study, but only 49 of the 941 fish collected in the present study. The inclusion of a smaller mesh (1.9 cm) in the vertical nets used in the Keystone study probably accounts for this difference. The same eight species constituted 90% or more of the total catch in both studies.

Species specific mean depths of capture indicated three patterns of vertical distribution were prevalent during the present study. The first of these distribution patterns is that of the strongly bottom oriented species (e.g., carp throughout the study and gizzard shad during the month of June). The second pattern is that of surface oriented species such as goldeye, shortnose gar, white crappie, white bass and freshwater drum, all of which were usually caught at 10 m or less. The third distribution pattern was that of fish which were randomly distributed in the water column. The primary species in this group was the channel catfish. All of these distribution patterns are probably related to the feeding habits of the fishes. All the surface oriented species are considered carnivorous sight-feeders, while the omnivorous opportunistic channel catfish and the benthic feeding carp account for the other two patterns of distribution.

Catch rates of carp increased during stratification when they would be expected to decrease due to higher exploitation resulting from increased netting effort. The increase in carp catch during stratification probably results from higher succeptability to netting resulting from dyspnoea caused hyper-activity. This increased catch rate and increased mean depth of capture of carp during stratification indicates that carp were not completely displaced from the deeper DO depleted benthic strata, thus they could not be considered as "indicator species" to test the use of aeration to expand fish habitat. The gizzard shad was the only other species having a sufficiently deep antecedent distribution to be affected by aeration produced destratification. There were, however, too few shad collected over too wide a range of stations and depths during the period of stratification and aeration to justify their use as "indicator species" for testing the habitat expansion hypothesis. The change in vertical distribution pattern of gizzard shad from benthic in June to variable (0.5-20.5 m) in July and August was similar to the pattern observed during stratification of Keystone Reservoir (Carter 1967) and may represent the normal avoidance of stagnant hypolimnetic waters. The significant difference (t .05 = 6.25 with 8 d.f.) in mean depth of capture of shad between station 2 and stations 4-16 combined during the first week of August probably was not a result of the aeration which was initiated that week. Channel catfish and white bass had single occurrences of significantly different weekly mean depths of capture between station 2 and stations 4-16 combined. Both of these occasions were the result of only two fish and were such that neither could be attributed to the affect of aeration.

As a result of the delayed stratification, exceptionally high runoff, and voluminous power discharge releases, the actual destratification test period and area affected were quite limited, but netting data indicated that habitat limitations due to stratification were confined to a few benthic oriented and variably distributed species (carp, channel catfish, gizzard shad and perhaps freshwater drum).

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VITA

Ronald Jimmie Hover

Candidate for the Degree of

Master of Science

Thesis: VERTICAL DISTRIBUTION OF FISHES IN THE CENTRAL POOL OF EUFAULA RESERVOIR, OKLAHOMA

Major Field: Zoology

Biographical:

Personal Data: Born in Oakland, California, March 6, 1943, the son of William Arthur and Mae Reno Hover; married Kay Louise Adair on August 19, 1967.

Education: Graduated from John Marshall High School, Oklahoma City, Oklahoma in May, 1961; received Bachelor of Science degree from Oklahoma State University, Stillwater, Oklahoma, in 1967; completed requirements for Master of Science degree in May, 1976, at Oklahoma State University, Stillwater, Oklahoma.

Professional Experience: Undergraduate Research Assistant, Oklahoma Cooperative Fishery Unit, Stillwater, Oklahoma, 1967-1968; Graduate Research Trainee (FWPCA), Stillwater, Oklahoma, 1968-1970; Research Technician, Dow Chemical, Freeport, Texas, 1970 to present.

Member: American Fisheries Society; World Mariculture Society.