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The Use of Vertical Gill Nets in Studying Fish Depth Distribution, Horsetooth Reservoir, Colorado

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ABSTRACT

The depth distribution of four fishes was studied using specially constructed vertical gill nets on Horsetooth Reservoir, Colorado (1960-61). Of several environmental factors measured, water temperature was the one factor that exerted a measurable effect. Depth of capture increased for the rainbow trout, kokanee salmon, and white sucker as each summer progressed and in general followed the isotherms. The distribution of yellow perch was unaffected by temperature changes. Kokanee salmon were most abundant in waters of 51-55° F. while the rainbow trout and white suckers were most numerous in 66-70° F. waters.

INTRODUCTION

An accurate knowledge of fish depth distribution and an understanding of influencing factors is essential to the prediction of the fish-producing capacity of lakes and reservoirs. The present study was undertaken to determine depth-distribution patterns of selected fish species in Horsetooth Reservoir, Colorado. Seasonal and weekly depth-distribution patterns were determined for rainbow trout (*Salmo gairdneri*), kokanee salmon (*Oncorhynchus nerka*), white sucker (*Catostomus commersoni*), and yellow perch (*Perca flavescens*). Longnose sucker (*Catostomus catostomus*) and brown trout (*Salmo trutta*) were also captured but in too few numbers to assign depth-distribution patterns.

Horsetooth Reservoir is primarily a water-storage reservoir located in the Eastern Slope foothills of Colorado near Fort Collins. When full, the reservoir has an area of 1,890 acres and contains 151,750 acre feet of water. It is approximately 6½ miles long, ½ mile wide, and the maximum depth is 166 feet.

METHODS AND EQUIPMENT

Three stations were selected for study. Station 1 was located in a shallow bay protected from the southerly diurnal winds which prevail. As the water level receded, this station was kept approximately 100 feet from shore at a depth of from 40 to 18 feet.

Station 2 was located in the moderate depths of the main body of the reservoir and was exposed to wind and wave action. This station was also adjusted periodically to approximately 100 feet from the shore. Here the water depth varied from 80 to 34 feet in 1960 and from 85 to 68 feet in 1961.

Station 3, the deep-water station, was permanently positioned near the middle of the reservoir. The water depth varied from 160 to 104 feet in 1960 and from 165 to 148 in 1961. The fluctuation of 56 feet in 1960 and 17 feet in 1961 represents the vertical drawdown of the reservoir during the two summers of study.

Depth distribution was determined by suspending modified gill nets from the water surface to the reservoir bottom. Similar nets have been described by Wisby (1955),[2] who used gill nets suspended vertically in Lake Mendota, Wisconsin. Leik (1960)[3] described the use of such nets to study the vertical, diurnal, and seasonal depth distribution of trout in Parvin Lake, Colorado. Vertical nets were used by Hartman (1962), who studied the vertical migration of peamouth chub and kokanee salmon.

The vertical gill net may be likened to a

[1] Data collected under the direction of the second author, then Leader of the Colorado Cooperative Fisheries Research Unit, and presented as a M.S. thesis at Colorado State University, Fort Collins, Colorado in November, 1961.

[2] Wisby, Warren J. (1955). Study of the movements and concentrations of fishes. Wisconsin Cons. Dept. D-J Completion Report, Project No. F-9-R-1. 9 pp.

[3] Leik, Thomas H. (1960). Immature splake trout in a lentic environment. M.S. thesis Colorado State Univ., Fort Collins. 98 pp.

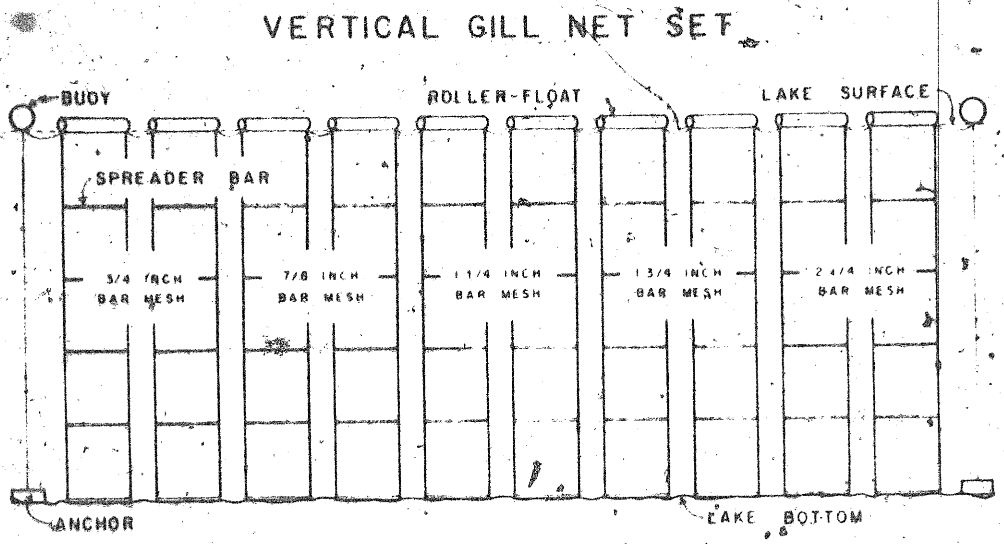

FIGURE 1.—Diagram of gill net set with 10 vertical gill nets set between buoys.

window shade. Each net was wound around a sealed section of four-inch aluminum irrigation pipe. From this floating tube which functioned as a roller-float, the net was unwound and lowered until the lower end reached the reservoir bottom. The net remained in this position, suspended by the float at the surface, and anchored by attachment to stationary lateral buoys forming a gill net screen from the reservoir surface to the bottom (Figure 1).

The procedure for employing the nets was as follows: The net, together with the float around which it was tightly wrapped, was placed in outrigger supports mounted on the boat. Aluminum axles welded on each end of the roller-float suspended it in this "outrigger-cradle" and also served as attachments for the rollers to other nets. A spreader bar of ½-inch thin-walled aluminum conduit with a snap at each end was fastened to the bottom of the net. This conduit served both as a spreader bar and as a weight. The net was then unrolled; the weight of the conduit pulled the net towards the reservoir bottom. Additional spreader bars were snapped into the net at 30-foot intervals. If netting remained on the float when the net had been unrolled sufficiently to reach the reservoir bottom, the net was fastened with a snap to prevent further unrolling. The roller-float was fastened by snaps and ropes to a stationary lateral buoy and later to the rollers of the other nets in the series. Fish caught in these nets were held at the depth of capture. The net was lifted by rolling it back onto the roller-float with the gilled fish removed during rewinding. The nets were color coded on the margins to identify the depth of capture.

A "net set" consisted of from 9 to 11 nets each set in the manner described above. Since each mesh size is somewhat specific to certain fish sizes (Andreev, 1955; Peterson, 1954), five different mesh sizes were set. The mesh sizes employed were: ¾-, ⅞-, 1¼-, 1¾-, and 2¼-inch bar mesh. Usually two nets of each mesh size were incorporated in each net set.

Each net was 150 feet long and made of nylon gill netting dyed a forest-green color. The top and bottom lines of the nets were ⅜-inch manilla rope. Netting material was tied to the top lines using the ½ basis as described in the Commercial Fishermen's Guide[4] which made the nets 5 to 7 feet wide. Side lines were number 21 nylon cord. At 30-foot intervals, a 1¼-inch-diameter metal ring was tied onto each side line to facilitate the attachment and removal of the spreader bars.

The lateral buoys were made from 5-gallon

[4] Commercial Fishermen's Guide. St. Louis, Mo., Adams Net and Twine Co. 48 pp.

cans with welded lids. A 3-pound weight was fastened inside the can on the bottom so that the buoy would float upright. Rings were welded to the bottom, side, and top of the can for attachment of the anchor rope, net roller-float, and the night light, respectively. Red lights powered with single flashlight batteries were used for identification of the nets at night.

Net sets were made weekly at each of the three stations when weather permitted. After each net set was lifted, a profile of water temperatures was made. Water samples were taken weekly at depths of 5 feet, 15 feet, and at every 15-foot interval thereafter. All water samples were collected by employing two water bottles mounted side by side to function simultaneously. Plankton was sampled quantitatively by draining one of the water bottles through a Wisconsin plankton net bucket fitted with No. 20 silk mesh. The second bottle was used for dissolved oxygen, free carbon dioxide, pH, and alkalinity determinations. A workbench-shelf was built into the boat to house equipment and to facilitate chemical analyses in the field. Standard chemical equipment was used with the exception that pipettes were replaced with 30-cc glass hypodermic syringes equipped with 6-inch needles.

Fish food habits were determined by volumetric measurements of the stomach contents of the gill-netted fish.

CHEMICAL CHARACTERISTICS

Of the 277 dissolved oxygen samples taken, only three samples below 4 p.p.m. were recorded. Generally, the lowest values were observed near the reservoir bottom. However, a reverse (minima) heterograde oxygen curve was apparent at Stations 2 and 3. This curve, discussed by Ruttner (1953), was recognized by a decrease followed by an increase of dissolved oxygen in the thermocline as water depth increased.

Ellis (1937) stated that in general, 3 p.p.m. at 77° F. is the upper limit in water at which asphyxia from low oxygen will occur for most fishes. Insofar as can be determined, oxygen was not a limiting factor for fish distribution. However, avoidance of areas with reduced oxygen content may have occurred but was not observed.

Concentrations of free carbon dioxide were never higher than 2 p.p.m. These values are far below 20 p.p.m. which is generally regarded as harmful to fishes (Lagler, 1956), and it was concluded that carbon dioxide concentrations did not measurably affect the distribution of fishes.

The pH varied from 7.0–9.0 and averaged 7.2–8.0 at all stations. Generally, the highest pH values were observed at the surface, decreasing rapidly with increasing depth to 30 feet. The pH changed very little in waters below this depth. Since these values were generally within the common expectations (6.5–8.5) and since fishes tolerate quite rapid changes in pH (Lagler, 1956), fish distribution was likely not affected by pH values.

Bicarbonate alkalinity ranged from 29 to 48 p.p.m. No direct effect upon fishes could be determined as values varied only slightly at different water depths.

WATER TEMPERATURES

Surface-water temperatures varied from 59–76° F. and averaged 69–70° F. at all stations. The temperatures of the bottom waters varied from 43–72° F. In 1960, water temperature averaged 61, 53, and 45° F. at Stations 1, 2, and 3, respectively and in 1961, bottom temperatures averaged 54, 46, and 44° F. at these respective stations. Since data are lacking during the last four weeks in 1961, temperature averages were computed eliminating the last four weeks in 1960 so that these average values between years might be comparable. Temperatures of the bottom waters during the first 12 weeks in 1960 averaged 59, 49, and 45° F. for Stations 1, 2, and 3, respectively. These cooler temperatures in 1961 probably were the result of deeper stations in 1961 from less water drawdown.

The 70-degree isotherm, when present, remained within 26 feet of the water surface of all stations during both summers. The isotherms of 65, 60, 50, and 45° F. sank to positions of significantly greater depth as the summers progressed ($r = 0.78$, $p = 0.14$ with 167 *d.f.*). These isotherms were usually at a greater depth in 1960 than in 1961 (Figure 2). The 45-degree isotherms at Station 3 fluctuated widely because small differences of temperatures occurred at these depths. Since

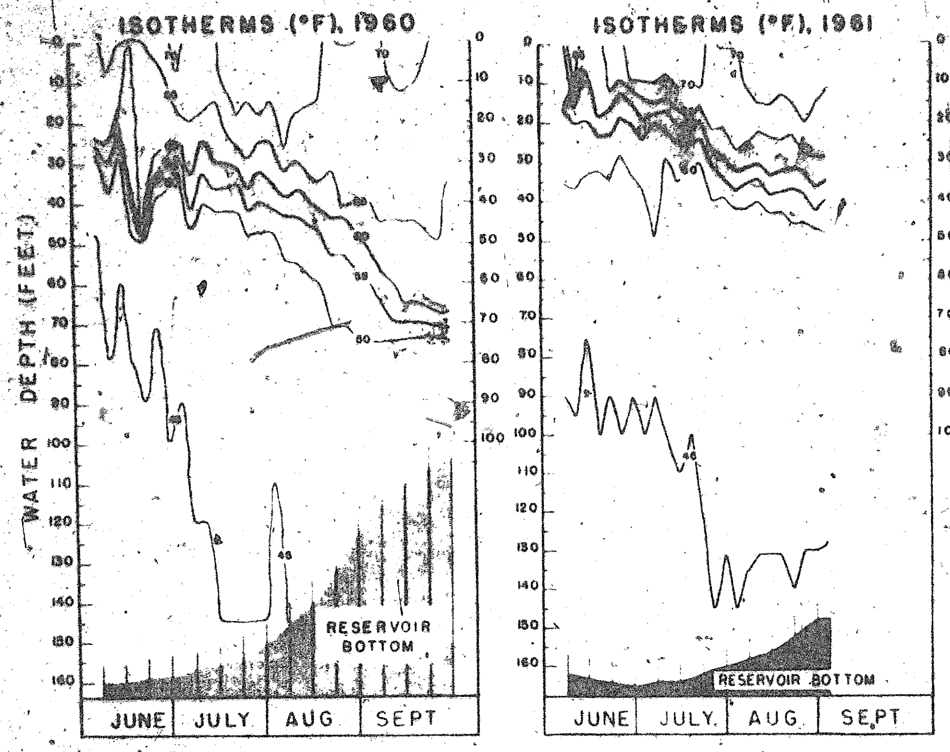

FIGURE 2.—Temperature isotherms at Station 3 on Horsetooth Reservoir, 1960 and 1961. The thermocline is shaded.

isotherms sank to greater depths as both summers progressed, fish which occupy waters of a limited temperature range would also have to move deeper later in the summer.

ZOOPLANKTON ANALYSIS

Plankton was measured volumetrically to determine the standing crop, fluctuations in the standing crop, and the depth distribution patterns. Since cladocerans were the most frequent food item appearing in the diet of the study fish, samples were also analyzed for Cladocera and Copepoda numbers in order that fish distribution patterns might better be related with food-habit studies.

Copepods composed 54.5 percent and cladocerans 45.5 percent by number of 277 plankton samples counted. However, it was apparent from food-habit studies, that cladocerans were consumed as food while copepods were not. Possible explanations are that (1) cladocerans were actively selected as food by the fish while copepods were rejected, or (2) copepods were too small to be filtered from the water by the fish, or (3) copepods were strong enough swimmers to escape being eaten.

The depth-distribution patterns of cladocerans were considered of major importance because of their abundance in the diets of the rainbow trout, kokanee salmon, and yellow perch. The largest numbers of cladocerans were found above the 30-foot level (Figure 3). Numbers of Cladocera decreased as the water depth increased to a depth of 130 feet and then again increased. This increase at depths greater than 130 feet was first hypothesized to consist of dead plankters that had accumulated in these depths. However, examination of fresh samples from 140 to 155 feet revealed that these cladocerans were alive. No explanation for this concentration of zooplankton is apparent.

DEPTH DISTRIBUTION OF FISH

Insufficient dissolved oxygen was rejected as a factor which would limit fish distribution.

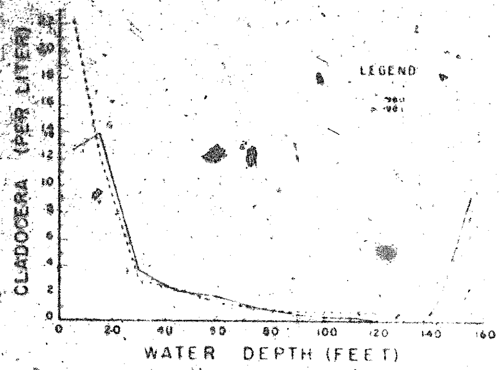

FIGURE 3.—Depth distribution of cladocerans at Stations 2 and 3 on Horsetooth Reservoir, 1960 and 1961.

Concentrations of carbon dioxide were always low, and both alkalinity and pH values were well within the range of values usually encountered. In addition, there were no pronounced changes in these values at different depths nor did there exist important differences as both summers progressed. During both summers, no change in depth distribution of cladocerans was observed. If the explanation for the fish depth-distribution patterns lies within the group of environmental factors measured, water temperature was the one which exerted the greatest influence. Dendy (1948) and Borges (1950) correlated fish distribution with water temperatures and thermal stratification in the presence of an adequate supply of dissolved oxygen.

As the summers of 1960 and 1961 progressed, isotherms significantly increased in depth. If fish attempted to remain within a particular temperature range, they could do so at Stations 2 and 3 by moving to a greater depth. This was not possible at the shallower Station 1. Therefore, correlation coefficients for time of season versus depth of fish capture were computed only with the data from Stations 2 and 3. In these tests, significance was interpreted as demonstrating a positive correlation between time and average fish depth, i.e., as the summer progressed, the average fish depth increased.

Rainbow trout

Five hundred sixty-nine rainbow trout ranging from 6.3 to 25.0 inches total length

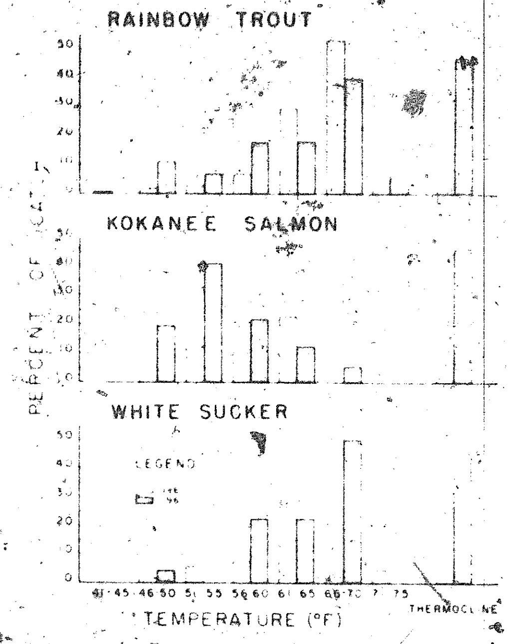

FIGURE 4.—The percent of rainbow trout, kokanee salmon, and white suckers captured in various water temperatures and in the thermocline at Stations 2 and 3 on Horsetooth Reservoir, 1960 and 1961.

were captured during the study period. All correlation coefficients for time of season versus depth of capture were significant at the 95-percent level as was the pooled coefficient ($r = 0.31$, $p = 0.00$ with 503 *d.f.*). As each summer progressed, the mean depth of the rainbow trout increased as did the isotherms. Rainbow trout were captured in waters that ranged in temperature from 41–75° F. However, this species was most commonly captured in waters of from 61–70° F. Eighty-two percent of the rainbow trout captured in 1960 and 59 percent in 1961 were taken in this temperature range. The mode of the rainbow trout was captured in water temperatures of from 66–70° F. (Figure 4). Most captures of this species were also in the 66–70° F. temperature range at the shallower Station 1.

At the deep Station 3, rainbow trout were commonly caught at depths down to 70 feet, with the deepest capture occurring at 130 feet (Figure 5). The depth of capture at Station 2 was slightly shallower. Apparently rainbow trout will occasionally occupy deep water. The average depth of capture for all

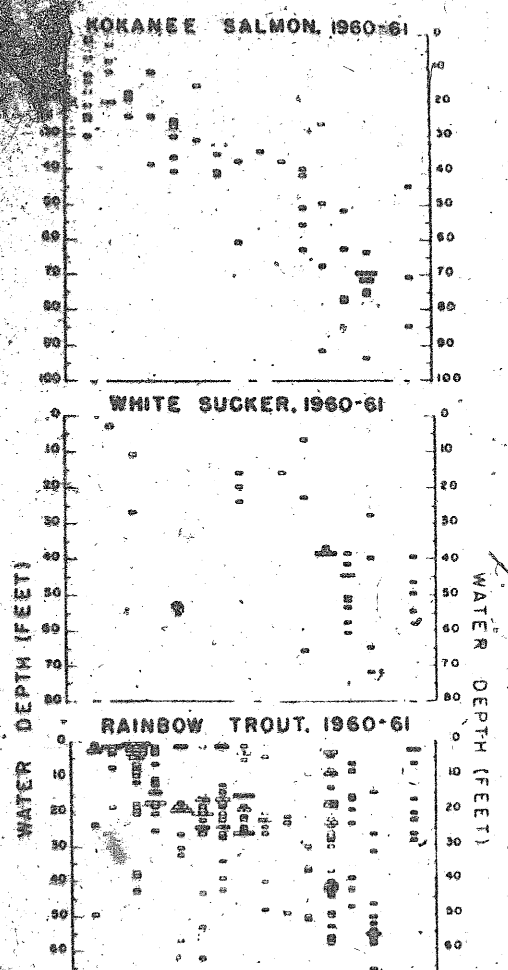

FIGURE 5.—Depth distribution of rainbow trout, kokanee salmon, and white suckers at Station 3 on Horsetooth Reservoir, 1960 and 1961.

TABLE 1. *The average depth of capture in feet for fish species at each station on Horsetooth Reservoir, 1960 and 1961*

Fish species	Station 2		Station 3		Total catch
	1960¹	1961	1960¹	1961	
Rainbow trout	25.4	22.4	26.8	20.4	23.1
Kokanee salmon	36.0	33.7	40.6	34.3	38.3
White sucker	29.3	15.6²	32.3	12.5²	30.1
Yellow perch	27.8	17.4	26.2	18.6	25.5

¹ Averages for 1960 are computed, eliminating the last four sampling weeks in September since comparable weeks were not sampled in 1961.

² Few white suckers were captured in 1961.

rainbow trout taken at Stations 2 and 3 was 23.1 feet (Table 1). The average depth of capture was 3.0 feet and 6.1 feet deeper at Stations 2 and 3 respectively in 1960 than in 1961. Isotherms were also at a greater depth in 1960 than in 1961.

In examining the data of depth distribution of the rainbow trout in relation to the depth of capture and temperature, the data from Station 1 have been considered the least important because of the shallow depth at this station. Rainbow trout at this station were generally taken in shallower depths than those taken at the deeper stations.

The average depths of capture for the rainbow trout were generally in the area of maximum plankton production, above 30 feet. This corresponds with the high utilization of cladocerans and terrestrial insects by the rainbow trout.

Of all the rainbow trout captured, 40.5 percent were taken within and 52.8 percent were taken above the thermocline.

Kokanee salmon

One hundred nineteen kokanee salmon ranging from 6.7 to 15.8 inches total length were captured during the study period. Only five were captured at the shallow Station 1. Evidently the kokanee salmon in Horsetooth Reservoir were seldom in the shallow bay area. All correlation coefficients for time of season versus depth of capture were significant at the 95 percent level as was the pooled coefficient ($r = 0.73$, $p = 0.18$ with 113 *d.f.*). The kokanee salmon also occupied deeper areas of the reservoir as each summer progressed. The kokanee salmon were captured in water temperatures varying from 46–70° F., but only three fish were captured in waters warmer than 66° F. Fifty-four and 63 percent of the kokanee salmon captured in 1960 and 1961 respectively were taken in waters of from 51–60° F. However, high percentages were captured in water temperatures as much as five degrees colder and five degrees warmer than this range (Figure 1). Apparently this species usually occupied waters with a broad temperature range of from 46–65° F. with a mode being captured in the 51–55° F. temperatures.

The majority of the kokanee salmon was captured above 52 feet at Station 2 and above 85 feet at Station 3. The deepest captures were made at 55 feet and 94 feet, respectively (Figure 5). This species, as was true with the rainbow trout, was captured at greater depths at the deep Station 3. The average depth of capture for all kokanee salmon taken at Stations 2 and 3 was 38.3 feet (Table 1). The average depth of capture was 2.3 feet and 6.3 feet deeper at Stations 2 and 3 respectively in 1960 than in 1961. Isotherms were also at a greater depth in 1960 than in 1961.

The kokanee salmon were generally captured below the area of maximum plankton production (30 feet) even though food-habit studies indicated almost exclusive utilization of cladocerans. Apparently the kokanee salmon either fed in the colder, deeper areas even if the cladoceran population was comparatively sparse, or they came into the upper waters to feed where greater concentrations of cladocerans were present. Examination of Figure 5 strongly suggests that the higher temperatures effectively restricted the kokanee salmon to the deeper, less-productive waters.

Of all the kokanee salmon captured, 45.6 percent were within, 36.6 percent were above, and 17.8 percent were taken below the thermocline.

White sucker

Two hundred fifty white suckers ranging from 9.8–13.8 inches total length were captured during the study period. Even though there was less netting at Station 1, 159 of the total were captured at this station; 59 were taken at Station 2; and only 32 were taken at Station 3. These data suggest that the species is more common in shallow water areas than in the deeper water. All correlation coefficients for time of season versus depth of capture were significant at the 95 percent level as was the pooled coefficient ($r = 0.49$, $p = 0.21$ with 90 *d.f.*). It may be concluded that this species also occupied water of greater depth as each summer progressed as did the isotherms. White suckers were captured in water temperatures varying from 46–75° F. However, this species was most commonly captured in waters of from 61–70° F. Eighty-one percent of the white suckers captured in 1960 and 73 percent in 1961 were taken in this range. The mode of the suckers was captured in the five-degree temperature range of 66–70° F. (Figure 1). At Station 1, over 68 percent of the white suckers were taken in water that ranged from 61–70° F.

White suckers were not uncommon at depths down to 44 and 65 feet at Stations 2 and 3. The deepest captures occurred at 52 and 72 feet, respectively (Figure 5). The average depth of capture for all the white suckers except those at Station 1 was 30.1 feet. At Station 3, the average depth of capture was nearly 14 feet deeper than at Station 2. Apparently this species occasionally will occupy deep water.

The average depths of capture at Station 1 are not included in the above discussion because, as previously mentioned, this station was the shallowest of the three. Here 93 percent of the white suckers were caught below 12.3 feet (one-half the average station depth) in 1960. In 1961, 80 percent were caught below 15.3 feet (one-half the average station depth). Sixty-eight percent of the suckers captured were within 5 feet of the reservoir bottom and 85 percent were within 10 feet.

Of all the white suckers captured, 61.8 percent were within and 37.6 percent were above the thermocline.

Yellow perch

A total of 21,729 yellow perch ranging from 3.2–8.9 inches total length were captured during the study period. None of the correlation coefficients computed for time of season versus depth of capture were significant at the 95 percent level including the pooled coefficient ($r = 0.05$ with 15,807 *d.f.*). Since the average depth of capture for this species did

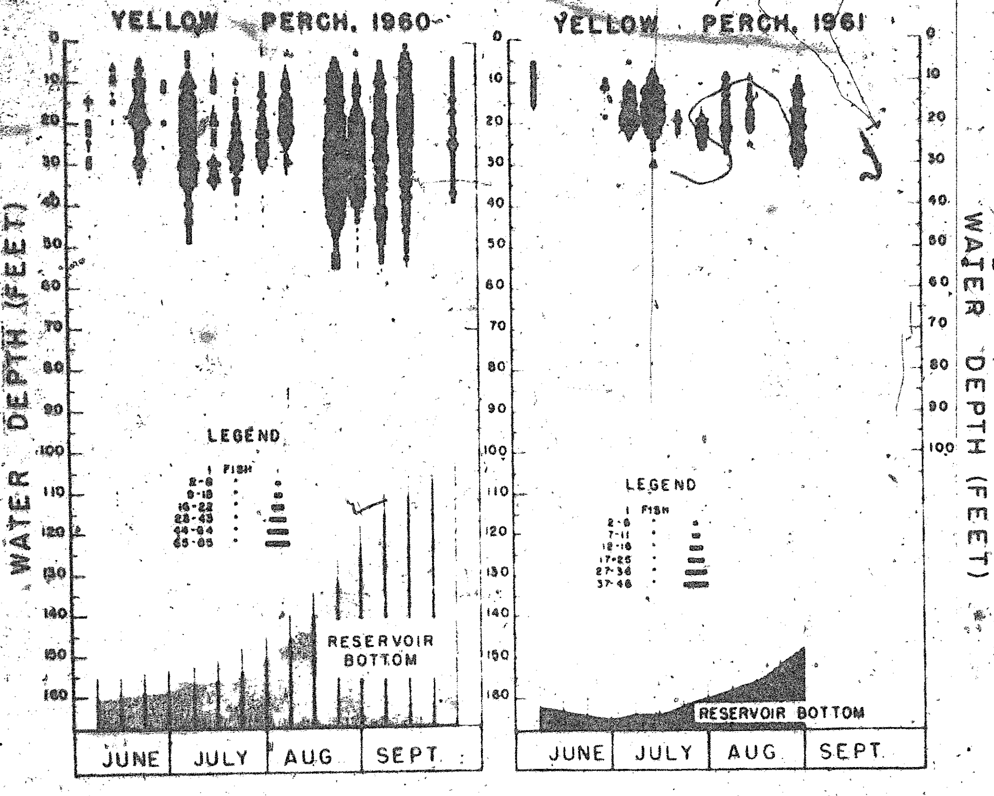

FIGURE 6.—Depth distribution of yellow perch at Station 3 on Horsetooth Reservoir, 1960 and 1961.

not increase as each summer progressed, yellow perch distribution seemed unrelated to the changes in water temperatures that occurred. In Lake Mendota, perch remained in the deepest water (up to 55 feet) with sufficient oxygen to maintain life. However, large numbers of perch were captured in waters with only 0–2 p.p.m. dissolved oxygen and some in waters with no detectable dissolved oxygen (Wisby, 1955).[5] During the current study on Horsetooth Reservoir, the average depth of capture for yellow perch ranged from 17.3 to 27.8 feet for all stations during the two summers (Table 1). At Stations 2 and 3, yellow perch were usually caught above 55 feet in 1960 and above 31 feet in 1961 with the deepest point of capture at 72 and 113 feet, respectively (Figure 6). Wisby (1955) also captured large numbers of perch in Lake Mendota between 15 feet and the maximum depth of his nets, 55 feet. However, in Horsetooth Reservoir it is suspected that some of the yellow perch captured deeper than 15 feet in 1960 may actually have been occupying shallower depths than recorded. Misconception may have occurred because the yellow perch catch was very high in 1960. Considerable time was required to raise the nets since all fish were removed as each net segment cleared the water, and more yellow perch could have been captured while the net was partially raised. This possible error may have contributed, somewhat, to the much deeper maximum and average depths of capture recorded in 1960 as compared to 1961.

The average depths of capture at Station 1 are presented separately because of its shallow depth. In 1960, nearly 90 percent of the yellow perch captured at Station 1 were taken

[5]See previous footnote.

below 12.3 feet, one-half the average depth of the station for the summer. In 1961, the average depth of Station 1 was 30.6 feet, and 74 percent of the yellow perch were taken below 15.3 feet. The large percentages in deeper-than-average water may possibly be the result of the yellow perch moving into the bay area to rest upon the reservoir bottom during the night hours as observed in Lake Mendota by Wisby (1955).[6]

All of the average depths of capture for the yellow perch were in the area of maximum plankton production, above 30 feet. This distribution and the absence of other foods coincide with the high utilization of cladocerans.

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[6] See previous footnote.

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