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Depth Distribution of Goldeye, Hiodon Alosoides (Rafinesque), in Moccasin Bay of the Little Missouri Arm of Garrison Reservoir, North Dakota

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DEPTH DISTRIBUTION OF GOLDEYE, HIODON ALOSOIDES (RAFINESQUE), IN MOCCASIN BAY ON THE LITTLE MISSOURI ARM OF GARRISON RESERVOIR, NORTH DAKOTA

by

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This thesis submitted by Spencer A. Peterson in partial fulfillment of the requirements for the Degree of Master of Science in the University of North Dakota is hereby approved by the Committee under whom the work has been done.

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ABSTRACT

The depth distribution of goldeye, Hiodon alosoides, and yellow perch, Perca flavescens, was studied in Moccasin Bay on the Little Missouri Arm of Garrison Reservoir, North Dakota, using a specially constructed vertical gill net (June through August, 1966). Ten other species were captured in relatively small numbers. Throughout the summer nearly all goldeye were caught at night in the upper ten feet of water. Indications were that goldeye depth distribution was affected more by light and feeding habits than by the limnological factors measured. Small numbers of yellow perch caught in June indicated no distinct depth preference; however, all yellow perch caught during July and August were captured between 25 feet and the bottom at 50 feet. It was thought that higher temperatures prevailing in the upper waters during July and August might account for yellow perch being caught in deeper water during those months. Even though the Little Missouri River is heavily silt-laden, investigation of the river-reservoir confluence failed to reveal a density current. Extremely high turbidity levels in the upper end of the Little Missouri Arm of the reservoir may affect fish distribution.

INTRODUCTION

Large populations of potentially valuable commercial fish are found in Garrison Reservoir, N. Dak. At present, carp, Cyprinus carpio Linneaus, black bullhead, Ictalurus melas (Rafinesque), channel catfish, Ictalurus punctatus (Rafinesque), largemouth buffalofish, Ictiobus cyprinellus (Valenciennes), and smallmouth buffalofish, Ictiobus bubalus (Rafinesque) are fished commercially in the impoundment. Records of test netting by the North Dakota Game and Fish Department indicate that goldeye, Hiodon alosoides (Rafinesque) and yellow perch, Perca flavescens (Mitchill) are the most abundant species in the reservoir.

The purpose of this study was to investigate the depth distribution of fishes and identify the principal environmental factors affecting their distribution. Particular emphasis was given to goldeye because, as an unexploited species in North Dakota, it has the greatest commercial potential. Goldeye have an excellent market in Canada and are fished commercially in certain limited areas of Minnesota and Montana.

A knowledge of fish depth distribution and an understanding of influencing factors might help commercial fishermen to increase their catches. Previous studies in other reservoirs indicated that water temperature and density currents may have a controlling effect on the vertical distribution of fishes. Since the Little Missouri River is very turbid, it was suspected that its inflow would create density currents in this arm of the reservoir. Density currents, if present, might have an effect upon the depth distribution of fishes for some distance downstream from the headwater of the reservoir.

DESCRIPTION OF THE AREA

Garrison Reservoir is a large, multi-purpose reservoir located in northwestern North Dakota on the main stem of the Missouri River (Fig. 1). It was created by closing Garrison Dam at Riverdale in April 1953. The dam was constructed by the U.S. Army Corps of Engineers for flood control, irrigation, navigation, and hydro-electric power. This impoundment, the largest in the chain of main stem Missouri reservoirs, encompasses an area of 326,000 acres and contains 24,500,000 acre-feet of water when full (Neel, 1963). This 200 mile long reservoir has an average width of three miles, a maximum depth of 180 feet, and approximately 1,600 miles of shore-line (Duerre, 1965).

Topography ranges from fairly smooth, rolling plains to rough local badlands. Vegetation consisting of trees, brush, and grasslands was present in bottom lands prior to flooding. Soils north of the reservoir are glacial while those to the south and west are mostly residual (Duerre, 1965). The latter is composed of soft clays, shales, and sandstones which date back to the Cretaceous Period and are eroded easily (U.S. Dep. Interior, 1951). The bentonitic clays are especially susceptible to erosion and have a tendency to "flow" when wet (Laird, 1956).

The climate of the area is semiarid or subhumid with an average rainfall of approximately 16 inches. Seventy-five percent of the precipation occurs between April and October. The average date of the first killing frost of autumn is September 20 (U.S. Dep. Interior, 1951). Average annual snowfall is approximately 30 inches.

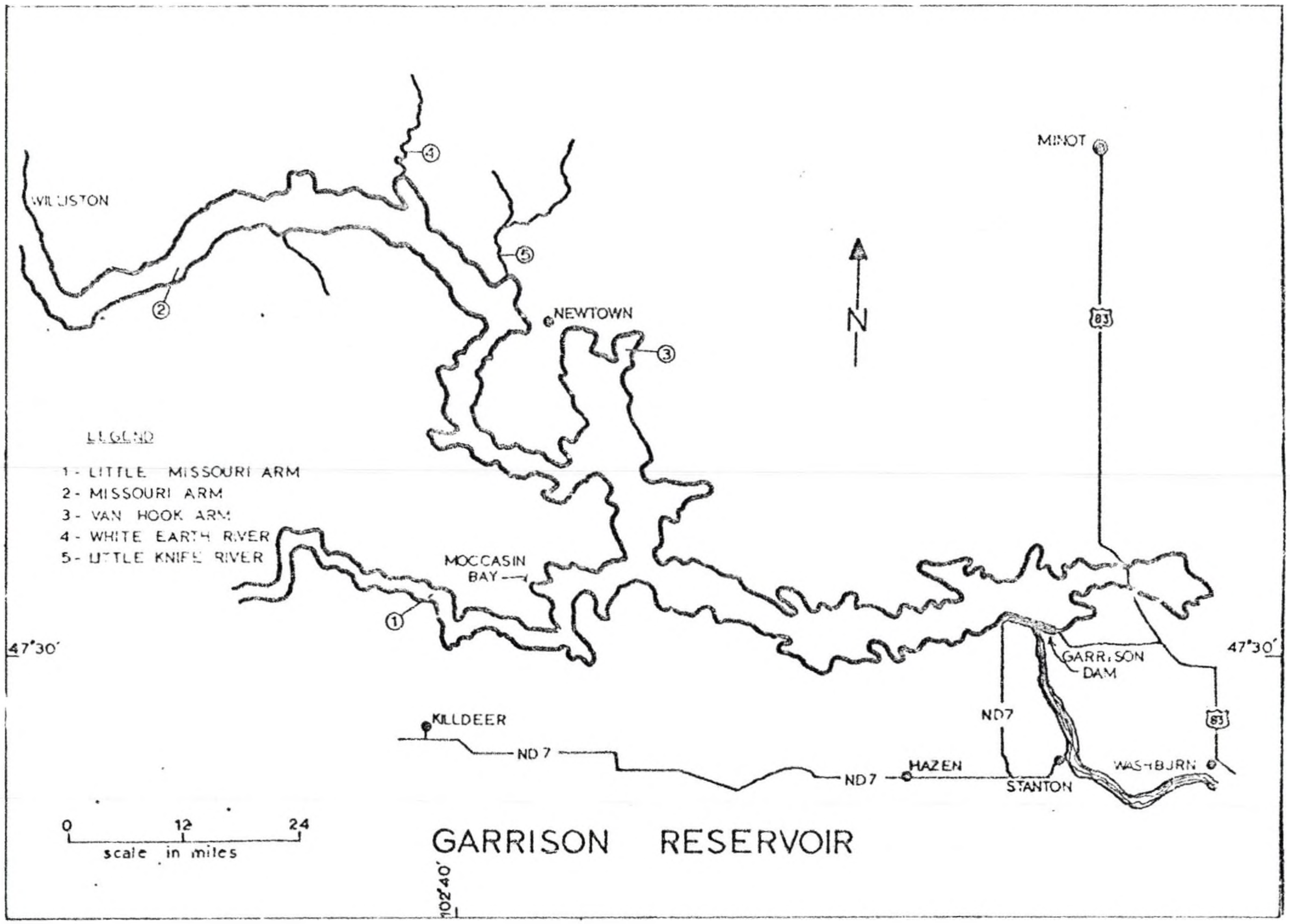

FIG. 1. Garrison Reservoir, North Dakota.

Weather records from Williston, N. Dak., are typical for the Garrison Reservoir area. The maximum recorded summer temperature at Williston is 110 F; minimum winter temperatures range from -20 to -60 F (Neel, Nicholson, and Hirsch, 1963). The average July temperature is 69.4 F; the average January temperature is 7.9 F.

The Little Missouri River is the largest tributary entering Garrison Reservoir from the southwest. The reservoir inundates the lower 57 miles of the river when it is at operating level, 1,850 feet mean sea level (U.S. Dep. Interior, 1952). The Little Missouri River drains a 9,500 square mile area meandering over a 560 mile course with a gradient averaging about 4.6 feet per mile. The average silt load of the river from September 1929 to July 1931 was 7,630 ppm; however, hydrologists of the Geological Survey have measured a maximum silt concentration of 20,100 ppm (Love, 1957). The Corps of Engineers have estimated the silt concentration in the river to be more than twice that in the Missouri River at Kansas City (U.S. Dep. Interior, 1951). Silt deposits up to 14 feet deep have been measured where the Little Missouri River enters Garrison Reservoir (Duerre, 1965). River discharge ranges from spring highs of 10,000 cubic feet per second to winter lows of less than ten cubic feet per second (Public Health Service, 1952). Because of the latter and high turbidity levels, only fish having low oxygen demands can survive the winter in these waters (U.S. Dep. Interior, 1951).

The shore-line in the southwestern part of the reservoir is quite irregular due to the undulating terrain which blends into badlands in the valley of the Little Missouri River. Many small bays are formed from impounded water inundating these irregularities. Among them is Moccasin Bay (Fig. 1), the location chosen as a representative area for sampling depth distribution of fish in the Little Missouri Arm of the reservoir. The bay, which is about three miles long and half a mile wide, is surrounded by high bluffs which partially shelter it from the prevailing westerly winds and, therefore reduce wave action. The bay, approximately 65 feet deep, is quite shallow compared to the average depth of the reservoir. Aquatic vegetation in the littoral zone is practically nonexistent due to fluctuating water levels.

LITERATURE REVIEW

It is well established that large, deep lakes in temperate regions have a tendency to stratify thermally during the summer months (Ruttner, 1963; Hutchinson, 1957; and Welch, 1952). Summer thermal stratification is most readily explained by first considering the spring warm-up period. In an ice covered lake, the coldest, about 0 C, and less dense water is found just below the ice while the warmest, about 4 C, and densest water is at the bottom. Rising spring air temperatures gradually melt the ice and warm the surface water to about 4 C causing it to become denser and sink below the colder underlying water which, in turn, rises. This process continues, with the help of spring winds, until the whole lake becomes homothermous and therefore of the same density. Continued wind action mixes the entire body of water from surface to bottom constituting the phenomenon known as spring overturn. A water mass oriented longitudinally in the direction of the prevailing winds is less likely to stratify thermally, because of extensive mixing, than is one oriented otherwise.

The spring overturn ends when heat accumulates in the surface water faster than wind action can dissipate it. The result is a temperature gradient within which thermal resistance between surface water and subsurface water reduces, and eventually stops mixing the body of water as a whole. Circulation confined to the upper water stratum causes it to become much warmer than the underlying water and thermal stratification is established. Summer stratification is broken up in the fall due to cooling of the surface water with consequent mixing of the entire water mass. The fall overturn period is typically followed by a quiescent period of winter stratification under the ice. Thermal stratification is most easily recognized by examination of the variations in temperature from surface to bottom in the water mass. The most obvious feature of stratification is the thermocline which is marked by a fall in temperature of at least 1 C per meter with increasing depth (Welch, 1952).

Large, deep reservoirs tend to be affected by thermal stratification in the same manner as lakes. However, the expected annual thermal stratification cycle may be modified by special features and conditions peculiar to reservoirs such as location of the outlet, variations in the drawdown, and currents from inflowing streams.

The bottom of a reservoir usually includes an impounded stream, and gradually slopes toward the dam. The basin shape is such that the deepest water is normally found just behind the dam. In contrast, the basin of a glaciated lake is often dish-shaped (Fig. 2) and the deepest water may occur near the center or any other place in the basin.

Reservoirs may have outlets at any level (Fig. 2). The level and quality of impounded water varies, depending upon the outlet in use. According to Ruttner (1963), a surface outlet tends to remove considerable heat from a reservoir and generally reduce the overall temperature. An outlet near the bottom of a dam releases cold hypolimnetic water and may result in particularly high surface temperatures in the reservoir. Bell (1942) pointed out the advantage of locating reservoir outlets at various depths, indicating that silting can be controlled to some extent by the systematic withdrawals of water at the level of the silt-carrying currents.

The presence of density currents is probably one of the most important physical factors affecting large reservoirs (Neel, 1963). These currents are produced by the inflow of water from rivers. During the summer,

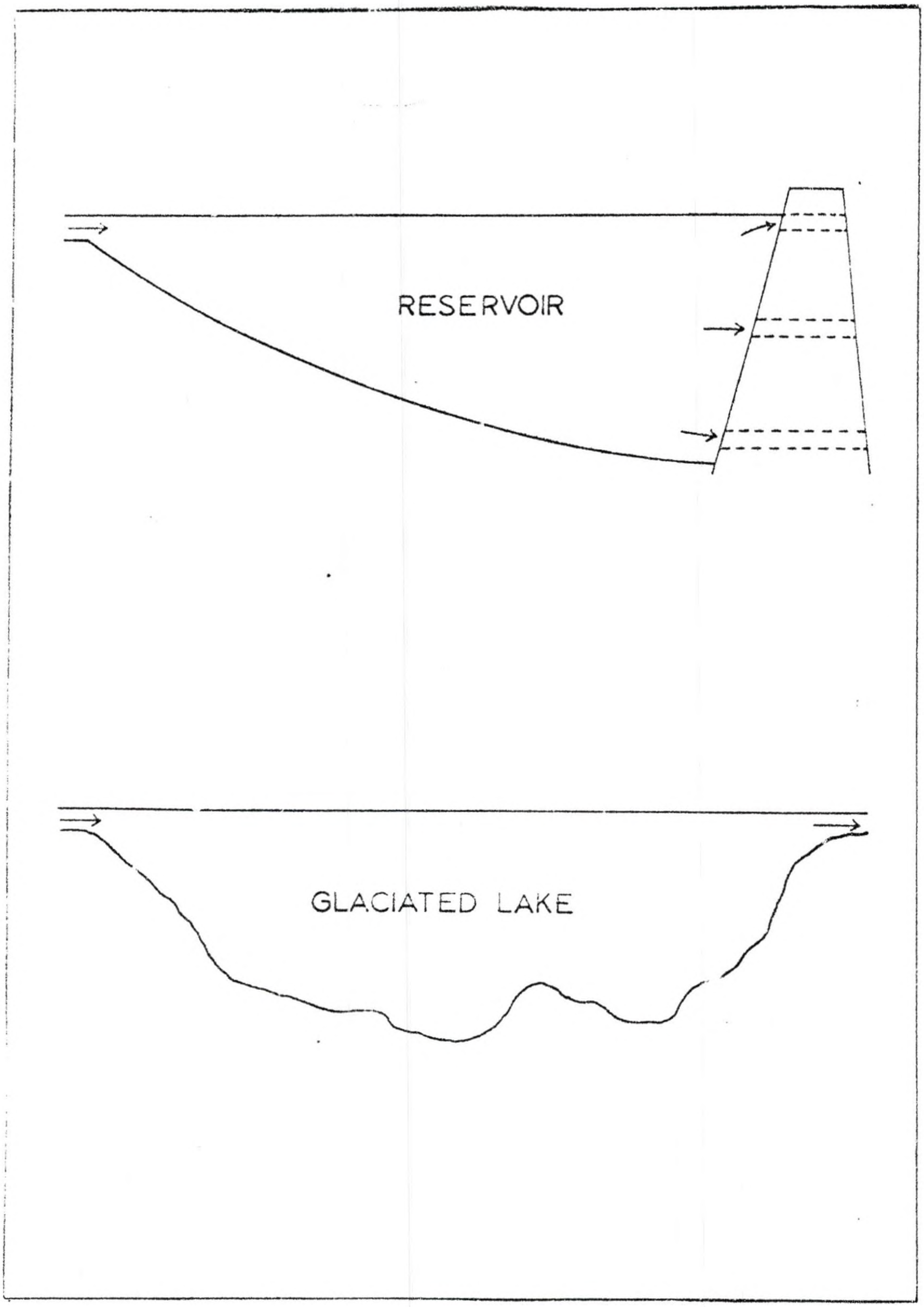

FIG. 2. Outlets of typical reservoirs and glaciated lakes.

their inflow is usually colder, and thus heavier than the surface water of a reservoir. Therefore, they sink until they reach a water stratum of equal or greater density and their downward flow is checked (Ruttner, 1963). Density currents then spread horizontally as distict, sharply defined layers (Neel, 1963). When these currents sink to the bottom of the reservoir, as occurs in some situations, they are known as an underflow. On the other hand, inflowing water may be less dense than reservoir water; it then remains on the surface and forms an overflow (Bell, 1942).

River water usually contains silt and other dissolved and suspended materials which make it heavier than pure water alone. These factors favor the establishment of a density current in situations where river and reservoir intermix. According to Welch (1952), density currents caused by turbidity-producing substances, especially erosion silts, have a pronounced effect upon the distribution of certain organisms.

Perhaps, the first intensive studies of density currents and their effects on the immediate environment were those of Auerbach (1926) in Ruttner (1963), who investigated these currents in the confluence of the Rhine River and Lake Constance. Studies concerning density currents and other phenomena occurring in reservoirs began in earnest in this country when the Tennessee Valley Authority impoundments came into existence during the 1930's.

While making routine limnological observations on Norris Reservoir, Norris, Tenn., Wiebe (1939) discovered the existence of a nearly constant density current at four sampling stations ranging from one-quarter to 50 miles above the dam site. In the interval from the surface to a depth of 30 feet, dissolved oxygen and methyl orange alkalinity were: 6 to 8 ppm and 85 to 90 ppm respectively. At 40 feet the dissolved oxygen level dropped to nearly zero and the alkalinity decreased to 40 ppm. Below 40 feet there was an increase in the dissolved oxygen level to 3.5 to 4.5 ppm at a depth of 80 feet, with a gradual decrease to the bottom. Alkalinity followed about the same pattern except that it continued to increase from a depth of 40 feet to the bottom.

Conversely, turbidity patterns were almost opposite those of dissolved oxygen and alkalinity. Turbidity did not exceed 50 ppm from the surface to a depth of 25 feet; at 30 feet it increased about six fold to approximately 300 ppm, gradually decreased with depth and increased slightly in the bottom five feet of the reservoir. Wiebe (1939) attributed this increased turbulence at the bottom to the sampling technique.

Although Wiebe did not measure actual currents, he recorded chemical and physical factors which would indicate their existence. Subsequently, these indicators have been used by several investigators to locate density currents. Evans (1939) found such currents present in several ponds and lakes in the United States. Further work by Wiebe (1940) provided more evidence for the existence of density currents in Norris Reservoir. To substantiate Wiebe's suggestions concerning the formation and operation of density currents in large reservoirs, Bell (1942) created similar density currents experimentally in a reservoir model in the laboratory.

Wiebe (1941) suggested that density currents in a reservoir probably influenced the distribution of fish. Depth distribution of fish in Norris Reservoir, Tenn., varied widely over an eight month netting period from March through October, 1943 (Cady, 1945). During this same peiod the greater concentrations (middle 50%) of most species of fish correlated closely with water temperatures (Dendy, 1945a). Most species moved to deeper water as the summer progressed and surface water temperatures increased.

As density currents flow in a reservoir, they tend to deplete the oxygen supply in the strata below them. This is due to the dissolved oxygen demand of the settling silt (Reid, 1961). Thus, fish normally indigenous to deep water remain in the aerated layer beneath the density current until forced to move by depleted oxygen levels (Fig. 3). Moore (1942) indicated that most species succumb at a minimum of 3.5 ppm or less dissolved oxygen for a 24 hour period. Because fish apparently selected deeper, colder water until driven out by low oxygen levels, Dendy (1945a) concluded temperature was more significant than dissolved oxygen, alkalinity, food, pressure, light, spawning, drawdown, and cover.

Subsequent study of Norris Reservoir confirmed previous findings. According to Dendy (1946), there was a definite correlation between temperature and fish distribution in reservoirs which permitted accurate predictions of depth distribution from a vertical temperature series. Predictions of fish distribution based on Dendy's work appeared to increase the catch of many fishermen (Dendy, 1945b).

According to Eschmeyer and Tarzwell (1941), storage and main stem reservoirs differ greatly in their habitat types. Drawdown of storage reservoirs is usually by hypolimnetic opening. This draws the surface waters into a narrower channel, thus increasing the thickness of epilimnion and metalimnion layers. Main stem reservoir levels usually have less fluctuation. Water is released through penstocks and flood control tunnels just above the dead storage area (Neel, 1963), and thermal stratification is seldom observed (Bryan and Howell, 1946). Thus, the environments of the two reservoir types and depth distribution of fish would differ.

One of the first investigations of a main stem reservoir in the TVA system was carried out on Lower Wheeler Reservoir, Ala., (Bryan and Howell, 1946). They found the depth distribution of fish in this reservoir much

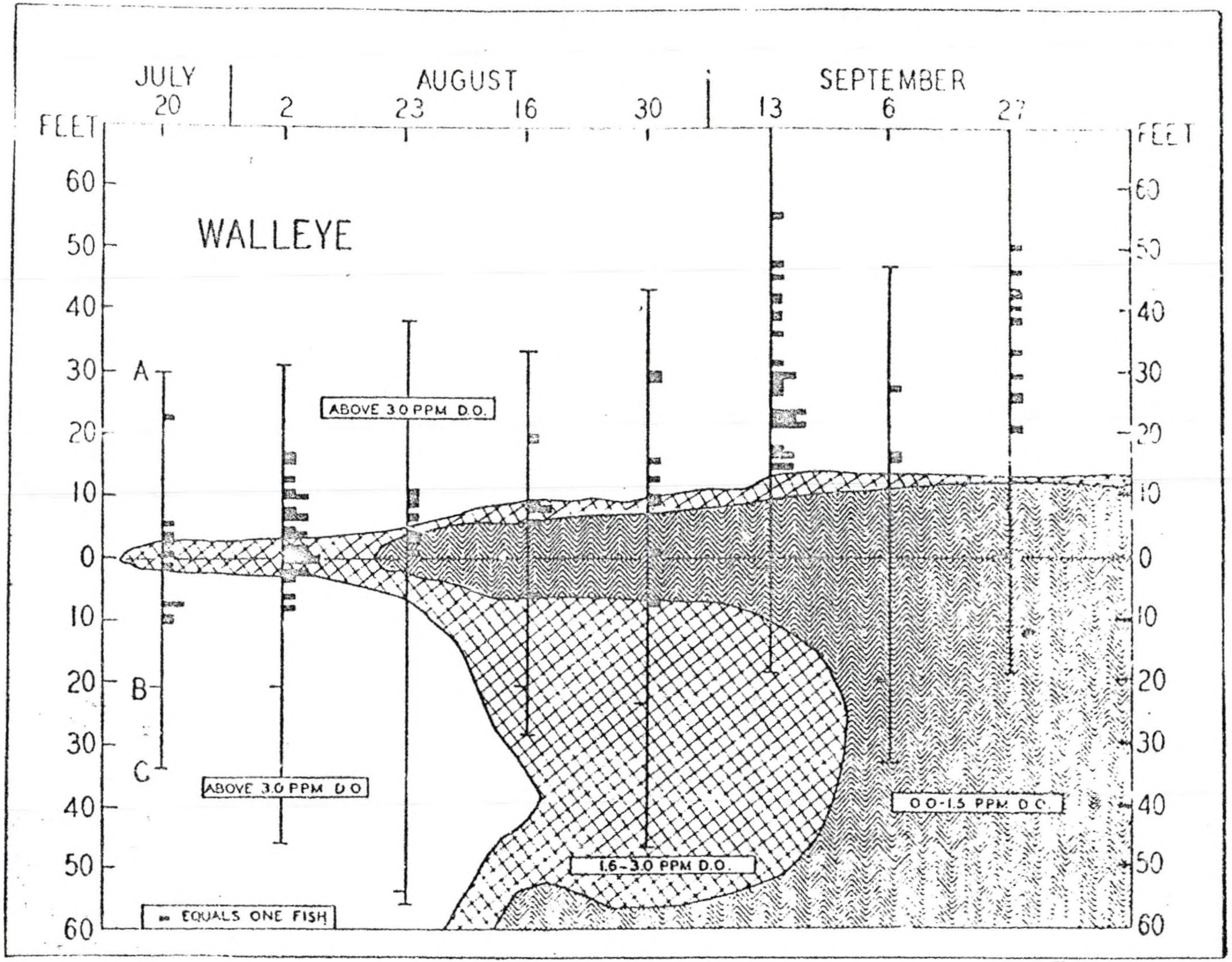

FIG. 3. Distribution of walleye in relation to oxygen depletion resulting from density currents (After Dendy, 1945a).

different from that of Norris Reservoir. The upper third of their nets caught three times as many fish and the middle third caught almost twice as many fish as did the lower third. This was almost a complete reversal of the distribution reported by Haslbauer (1945) in Norris Reservoir (Table 1).

TABLE 1

A comparison, by species, for those forms reasonably well represented in both Norris Reservoir, Tenn., and Wheeler Reservoir, Ala. Figures represent percentage of the total for the entire nets (After Bryan and Howell, 1946).

SPECIES	NORRIS			WHEELER		
	TOP	MIDDLE	BOTTOM	TOP	MIDDLE	BOTTOM
Shad.	24	40	36	61	24	15
Carp.	15	18	67	32	28	40
Channel catfish . .	33	37	30	54	26	20
Drum.	11	19	70	50	26	24
Total	83	114	203	197	104	99
Simple average. . .	21	28	51	49	26	25

This confirmed the work of Hile and Juday (1941) who found that the response of various species of fish to differences in the temperature and dissolved oxygen may vary in different bodies of water. They found that data collected from one body of water did not necessarily apply to another even though they were in close proximity and chemically and physically similar. This implied that any accurate prediction of depth distribution for any body of water must be preceded by limnological and netting observations.

More recently, Borges (1950) discovered that fish distribution in the Niangua Arm of the Lake of the Ozarks, Mo., was greatly influenced by a cold, highly oxygenated spring-water density current. He concluded that oxygen depletion outweighed the effect of temperature as an influencing factor on fish distribution. The latter was in opposition to the observations of Dendy (1945a) on Norris Reservoir, probably because the two reservoirs were of different types.

Depth distribution in the Lake of the Ozarks resembled that of Wheeler Reservoir. In both cases the largest percentage of fish were caught in the upper third of the gill nets. In the depth distribution study by Borges (1950), 45% of the goldeye were caught in the upper third of the gill nets, 44% in the middle third, and only 10% in the lower; fishing depth did not exceed 50 feet.

Horak and Tanner (1964) used a unique type of vertical gill net, similar to the one used in this study, to sample the depth distribution of fish in Horsetooth Reservoir, Colo. A "net set" consisted of nine to eleven individual nets, five to seven feet wide and of mesh sizes varying from 3/4 to 2¼ inches. Each net was wound around a cylindrical float which operated like a window shade roller to raise and lower the net; spreader bars at 30 foot intervals kept the net from sagging (Fig. 4).

The investigation of Dendy (1945a) and Borges (1950) tend to support the relationship between depth distribution and water temperature. Their study was similar to those of the Lake of the Ozarks, Norris, and Wheeler Reservoirs in that they were concerned with game fish distribution. Rough and commercial species were given brief attention.

Goldeye, the species of primary concern in the present study ranges from Saskatchewan and the Hudson Bay drainage south to Ohio and Tennessee (Eddy, 1957), and is not found in Norris, Wheeler, and Horsetooth Reservoirs. Borges (1950) reported that goldeye are not important to the sport fishery in the Lake of the Ozarks even though it often strikes artificial lures; other values for this species were not indicated.

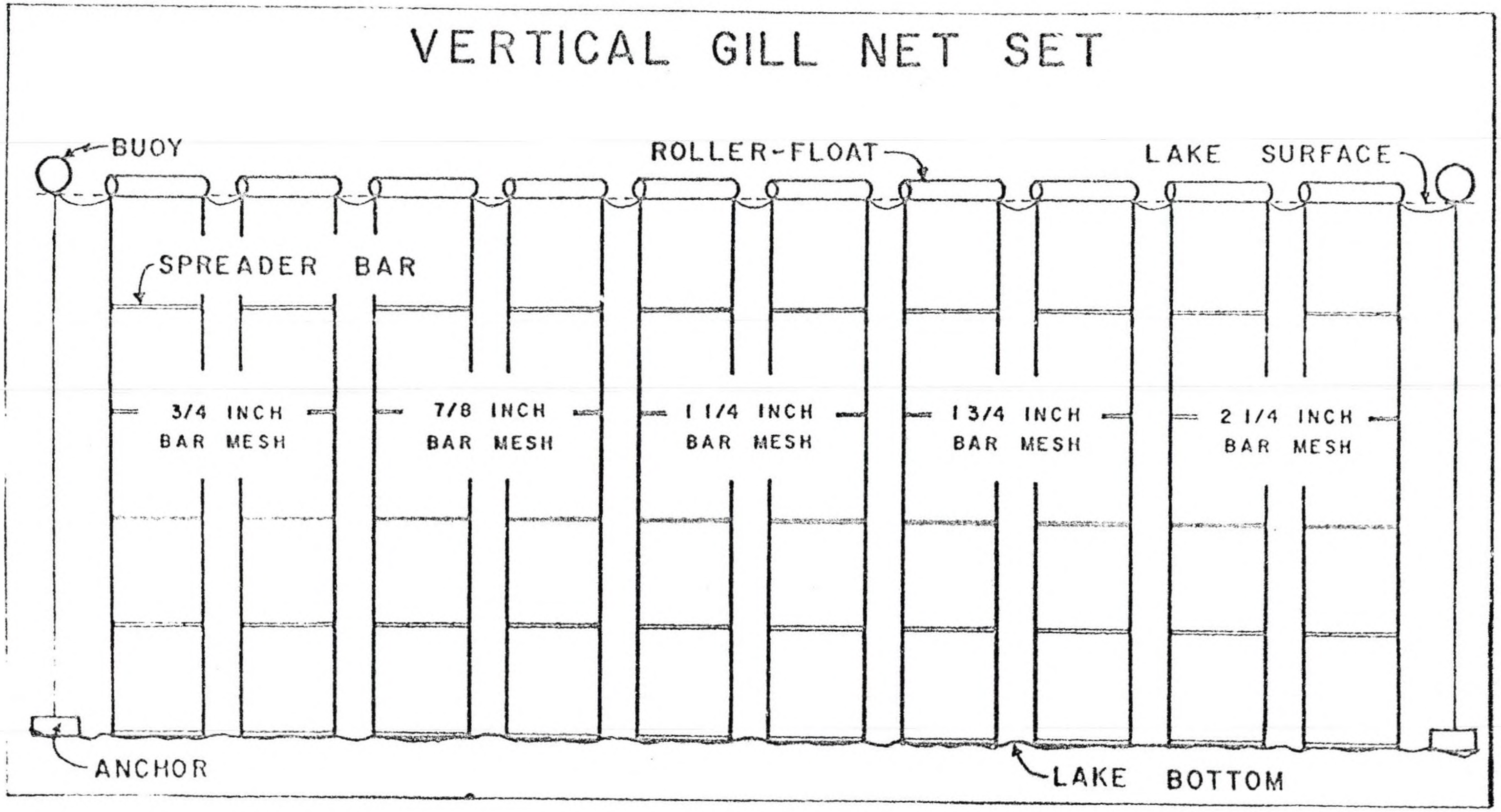

FIG. 4. Diagram of vertical net set with ten vertical gill nets set between buoys (After Horak and Tanner, 1964).

Grosslein and Smith (1959) investigated the Red Lakes, Minn., fishery because of reduction in the goldeye population and scarcity of published material concerning this species. They indicated that increased fishery effort was definitely associated with this decline. Until 1924, goldeye had been considered an undesirable fish with practically no commercial value. At that time smoked goldeye was introduced in Canada and a substantial market developed for it.

Ultimately, goldeye became of considerable economic importance in the Province of Manitoba, where annual catches averaged about one million pounds (Bajkov, 1930). Fifteen years later the annual commercial catch had dwindled to 300,000 pounds (Hinks, 1943). Sprules (1947) also indicated that commercial fishing of Canadian waters had substantially reduced the goldeye populations. Smith and Krefting (1953) reported a decline in the goldeye catch in Red Lakes, Minn., during the same period. They attributed this decline to a substantial increase in the level of fishing; however, believed fishing was not the sole cause of reduced catches.

Missouri River reservoir impoundments, within the distributional pattern of goldeye, are potential new sources for this species. Goldeye has been taken in Fort Peck Reservoir, Mont., more frequently than any other species except yellow perch. It has been predicted (U.S. Dep. Interior, 1953) that similar abundances of goldeye might be expected to develop in other main stem Missouri River reservoirs. Test netting by the North Dakota Game and Fish Department over the past few years has confirmed this prediction for Garrison Reservoir.

METHODS AND MATERIALS

A special experimental gill net, 36 feet wide and 50 feet deep, was constructed for use in this investigation. For ease in handling, the net was divided into two sections, each 18 feet wide by 50 feet deep. One section contained three 6 by 50 foot panels of 3/4, 1, and $1\frac{1}{4}$ inch machine stitched nylon mesh; the other three similar panels of $1\frac{1}{2}$, 2, and $2\frac{1}{2}$ inch mesh (Fig. 5). Use of six mesh sizes favored catching fish of all sizes. Each panel was hand sewn to a one-quarter inch polyethylene line, thus separating it from the adjacent ones. This eliminated the difficulty of sewing different sized mesh together, clearly marked vertically the different mesh sizes, and greatly facilitated net repair. Horizontal lines were painted at five foot intervals to aid in determining depth distribution of gilled fish. Twelve cylindrical styrofoam floats, 4 inch diameter by 12 inch length, were attached to the top of the net to serve as a float line and assure maximum buoyancy.

A netting area with a water depth of 50 feet and a smooth unobstructed level bottom about 40 feet in length was selected using as electronic echo sounder (Sportsman 80, Ross Laboratories). At this site, the net was set perpendicular to the shore-line approximately in the center of the bay (Fig. 6). It was fished vertically as a unit from the surface to the bottom. To simplify setting and lifting the net, pulleys were fastened to anchors which were permanently placed at the center and ends of the net. A continuous vertical line was looped through each pulley making an easily accessible device for pulling the lead line of the net

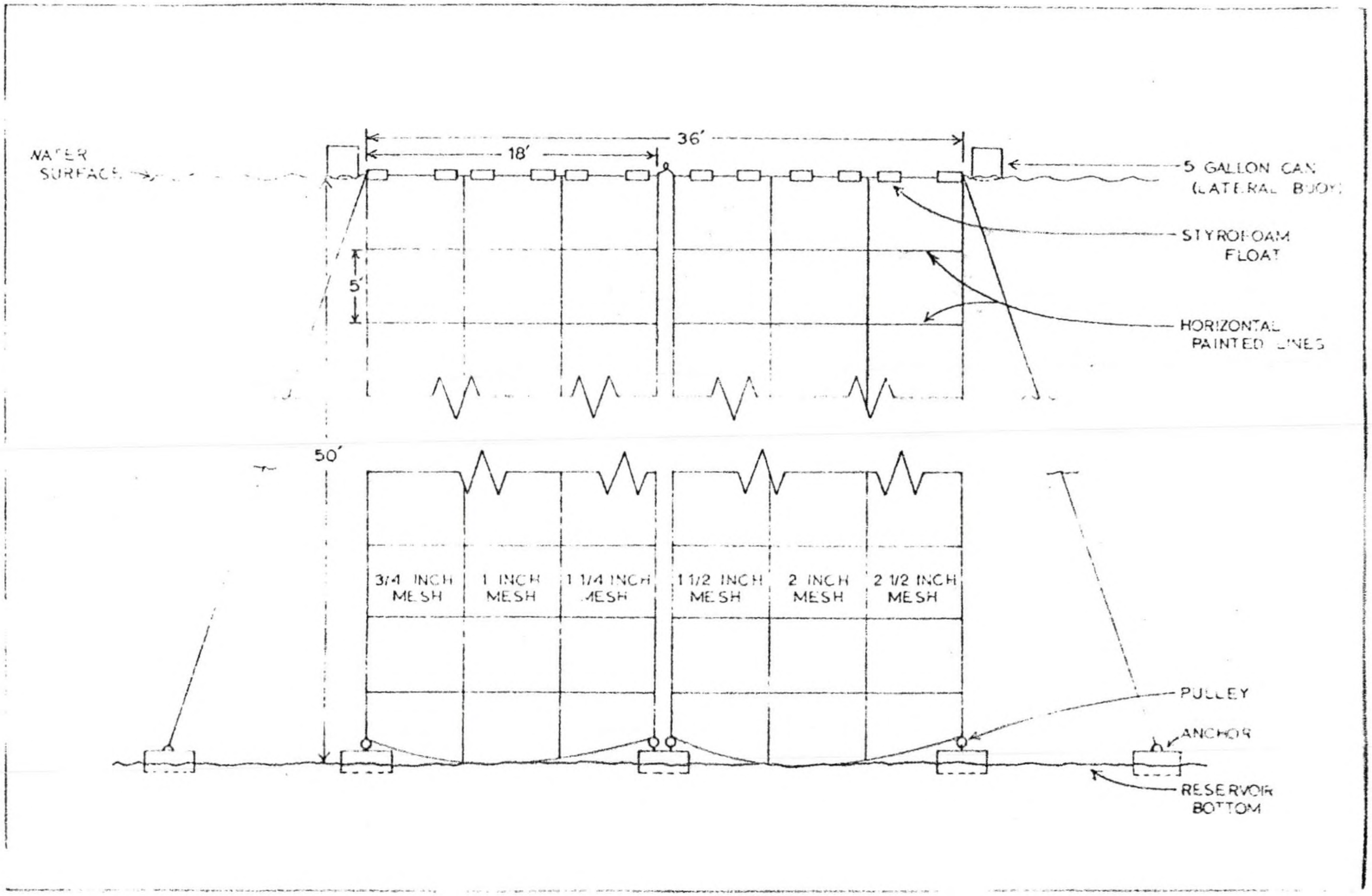

FIG. 5. Diagram of vertical net in place.

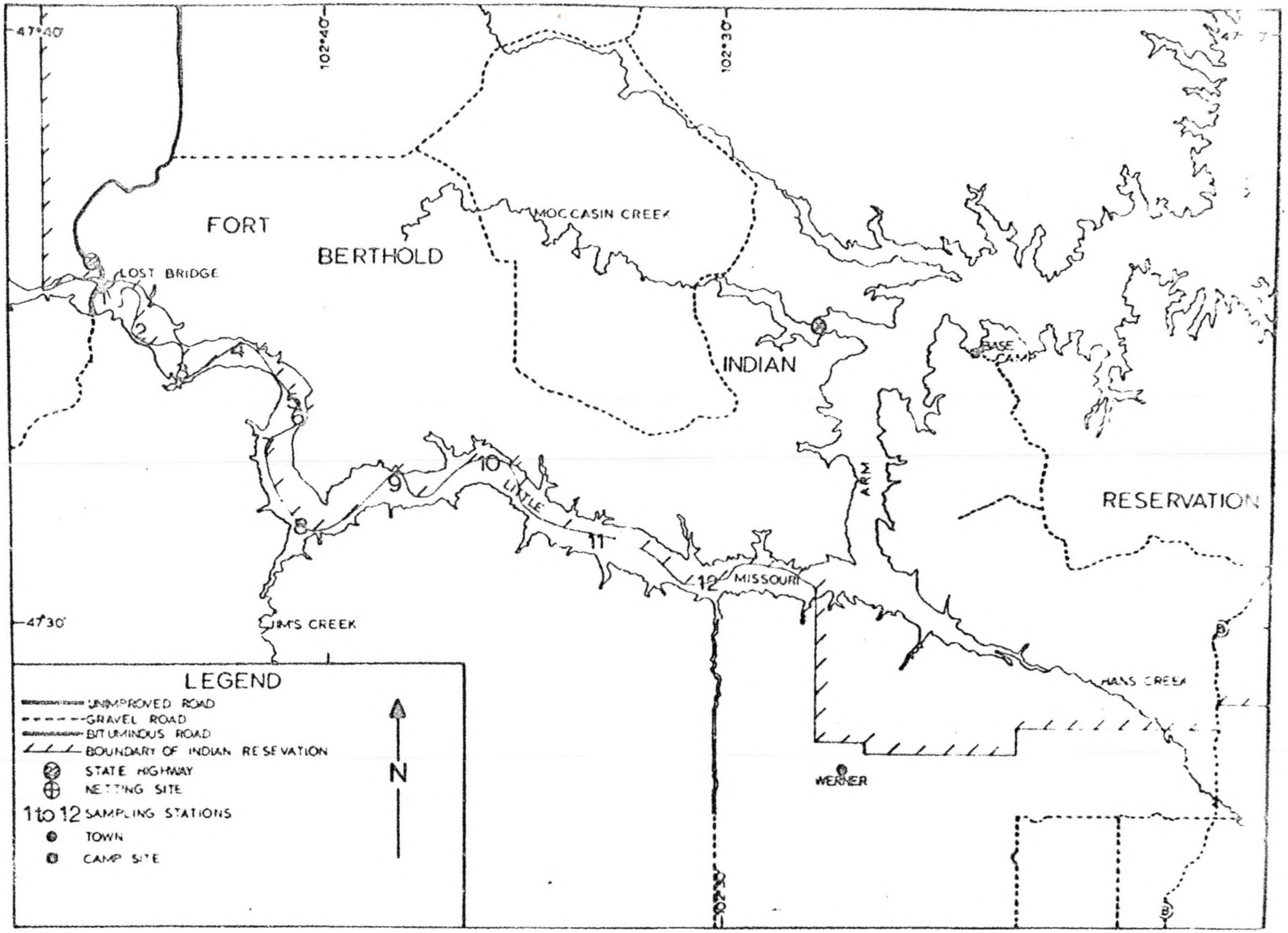

FIG. 6. Detail of the Little Missouri Arm, Garrison Reservoir, North Dakota.

to the bottom. Metal rings were attached to net margins and taut vertical anchor lines keeping the net expanded when set (Fig. 7).

A five-gallon can at each corner of the net and the styrofoam float line held the net in a vertical position when lateral anchor lines were cinched tight. These cans were painted luminous orange (Sher-will-glo comet orange, Sherwin-Williams Paints) and served a secondary purpose of marking the net.

To determine the depth distribution of different species of fish, the net was set as often as repairs and the weather permitted. Netting began June 1, 1966, and continued throughout the summer for 24, 12, and 6-hour periods. The 24-hour sets were made in the morning and pulled the following morning while the 12-hour were made in the evening and pulled the following morning. Six-hour periods divided the day into quarters: 2400 - 0600, 0600 - 1200, 1200 - 1800, 1800 - 2400 (twenty-four-hour Military Time) and were used to determine which period goldeye were most active.

In order to remove fish from the net, it was pulled in sections, draped in tubs, and taken ashore. The net was spread on a large tarpolin which kept it from becoming entangled in grass and therefore, simplified the removal of fish. These were removed from one mesh at a time, starting at the bottom and working to the top in five foot intervals.

The catch was weighed, measured, and scale samples were collected. Weights taken on a spring balance, were recorded to the nearest gram. Fish were measured to the nearest tenth of an inch. Scale samples were taken only from goldeye and were collected above the lateral line just below the dorsal fin, according to the method described by Rounsefell and Everhart (1953).

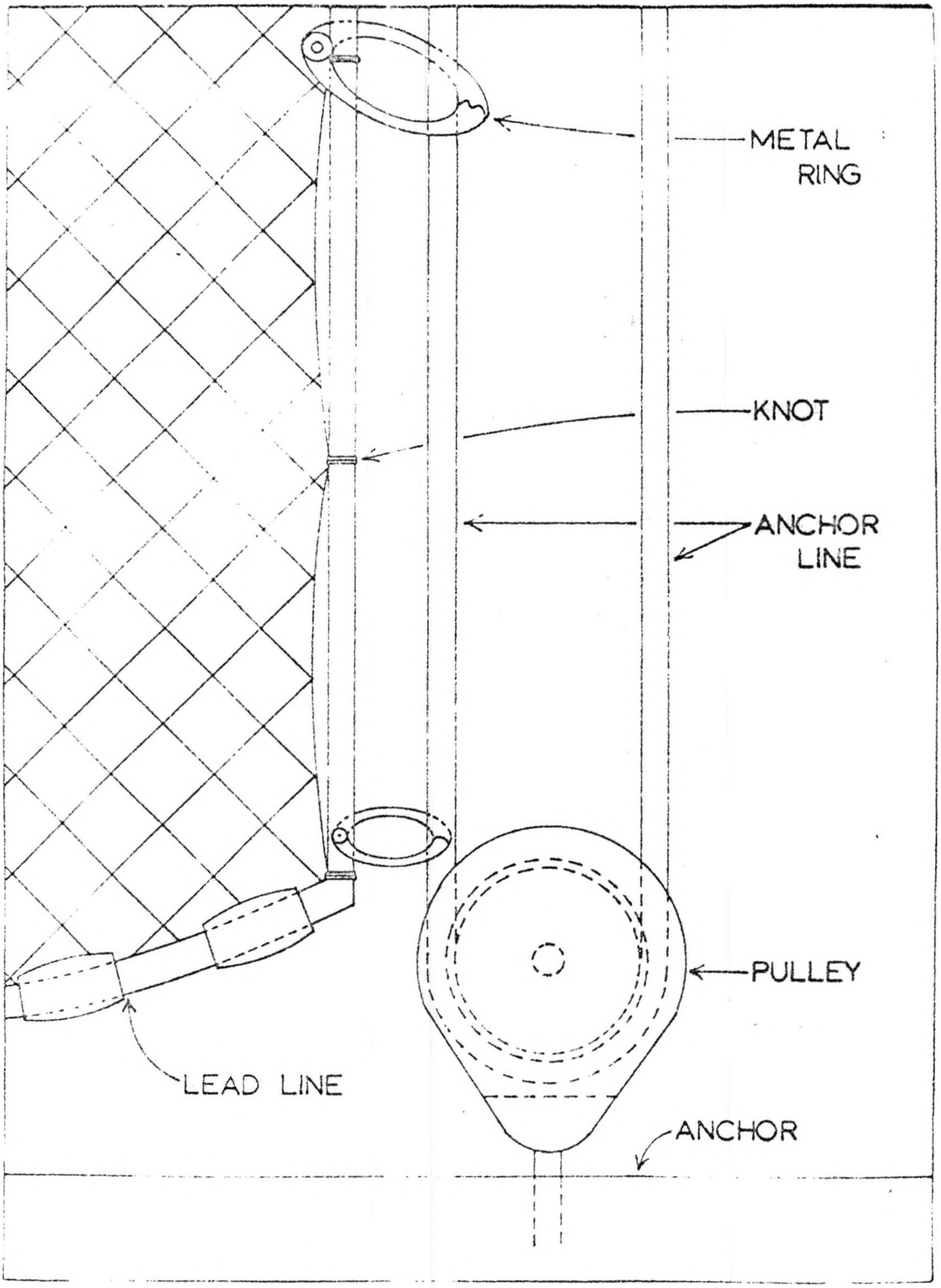

FIG. 7. Method of attaching net to the anchor line.

A weekly descending vertical temperature series was made in the immediate area of the net using a thermister thermometer model 43T (Yellow Springs Instrument Company). Temperatures were recorded at five foot intervals beginning 2½ feet below the surface so that they corresponded approximately with the center of the intervals marked on the suspended net. Water samples were collected using a one-liter Kemmerer water bottle in like manner.

Dissolved oxygen and turbidity of the water at the net site were determined with a Hach Kit model DR 2834B according to the methods decribed in the fourth edition of the Hach Chemical Manual (Hach Chemical Company). Dissolved oxygen was recorded in parts per million and turbidity in Jackson turbidity units. In addition, 12 sampling stations were established along a 15 mile segment in the headwater of the Little Missouri Arm of the reservoir (Fig. 6). Depth soundings and Secchi disc readings were taken at these sites. The latter was determined according to the method described by Welch (1948).

RESULTS

A total of 1,661 fish representing 12 different species were captured in Moccasin Bay during June, July, and August. These species were: goldeye, *Hiodon alosoides* (Rafinesque); yellow perch, *Perca flavescens* (Mitchill); channel catfish, *Ictalurus punctatus* (Rafinesque); black bullhead, *Ictalurus melas* (Rafinesque); white crappie, *Pomoxis annularis* Rafinesque; walleye, *Stizostedion vitreum* (Mitchill); sauger, *Stizostedion canadense* (Smith); European carp, *Cyprinus carpio* Linnaeus; northern pike, *Esox lucius* Linnaeus; smallmouth buffalofish, *Ictiobus buballus* (Rafinesque); carpsucker, *Carpiodes carpio* (Rafinesque); and freshwater drum, *Aplodinotus grunniens* Rafinesque. Over one-half of the fish caught were goldeye and one-third were yellow perch (Table 2).

Weekly depth distribution patterns of goldeye and yellow perch with limnological conditions were compiled from representative 12-hour netting periods (Fig. 8 - 15). Depth distribution for 24, 12, and 6-hour sets were basically the same. Goldeye were usually most abundant at or near the water surface. A minimum of 31% and a maximum of 74.99% of all goldeye during a 12-hour sampling period were taken in the upper ten feet of water (Fig. 8 - 15). The average percentage of goldeye at this same interval was 49.74%. Most of the goldeye were caught during overnight sets while only 10 of 579 of them were caught during daylight hours. Day sets from 0800 - 2000 represented 17.64% of the total fishing time; but yielded only 1.73% of the total catch.

An unusually large daytime catch of goldeye occurred on August 24

TABLE 2

Catch per sampling period in Moccasin Bay;
June, July, and August, 1966

Date	Time Interval	Goldeye	Yellow Perch	Channel Catfish	Black Bullhead	White Crappie	Walleye	Sauger	European Carp	Northern Pike	Smallmouth Buffalofish	Carp-sucker	Freshwater Drum
6-08-66	0800-0700	41	3			3	2	1					
6-10-66	2100-1000	74		7		1	2			2			
6-14-66	2100-1000	53	3	1	1	3		1					
6-16-66	0800-2000	1	4										
6-22-66	2100-1000	25	6	5	1		1			1			
6-24-66	0800-2000	22	36	2		4	2		1				
6-28-66	2000-0900	20	6	1	1	2	1	1					
6-29-66	2000-0900	30	11	2									
6-30-66	0830-2000	3	24			1							
7-06-66	2100-0900	29	53	2		1	1		1				
7-07-66	0800-2000	5	47						1				
7-16-66	2130-0930	32	43	1	2	3	2	2					
7-18-66	0500-0900	4	8										
7-18-66	0900-1300		42					1					
7-19-66	0600-1200	4	64			2							
7-27-66	2100-0900	58	13	3	6		1	2					
7-28-66	2100-0930	37	15	2	1	1	2	1			1		
7-29-66	2100-0900	23	4	3	2	1	2		1			2	
8-02-66	0000-0600	23	4	1	3			1					
8-02-66	1200-1800	3	22	1									1
8-03-66	0600-1200	1	16			2							
8-03-66	1800-0000	13	1		6				1				
8-05-66	1200-1200	34	20	5	6			1	3				
8-09-66	2000-0800	42	2	3	3	2		1	1			1	
8-10-66	2000-0900	32	7	3	4	3			1				
8-18-66	1000-1000	64	31	9	6	5						1	
8-19-66	2000-1000	90	6		6		1	1					
8-23-66	1800-0000	23	1										
8-23-66	1200-1800	10	13	2									
8-24-66	0600-1200	17	22	1									1
8-25-66	0000-0600	25	3	2	2				1				
8-26-66	0830-0830	23	27	3	2	1	2					1	
8-31-66	2000-0930	24	12	3		1				2			
Total		885	569	62	52	37	19	13	11	5	1	5	2
Percentage		53.28	34.25	3.73	3.13	2.22	1.14	.78	.66	.30	.06	.30	.12

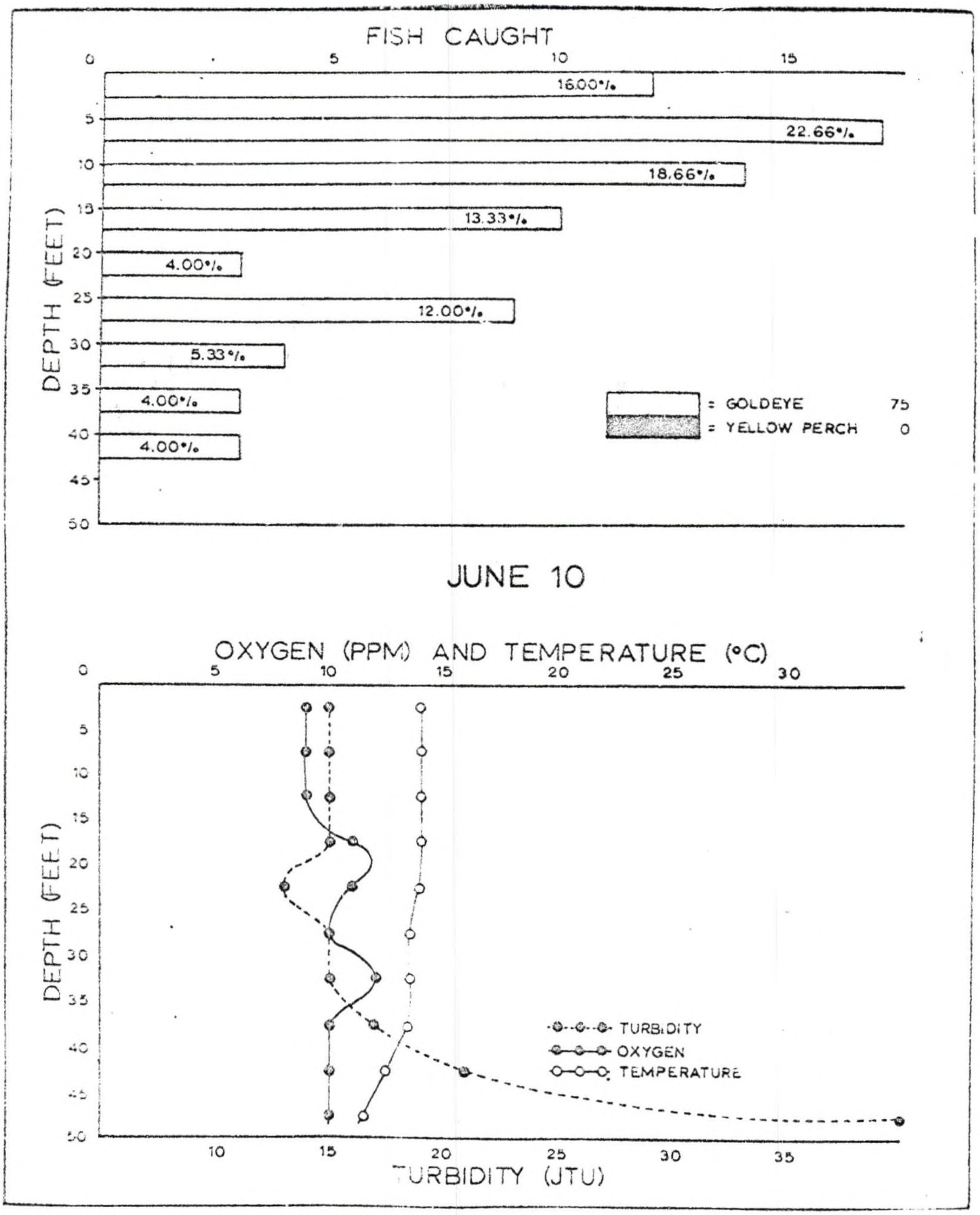

FIG. 8. Depth distribution of goldeye and yellow perch with limnological conditions, June 10, 1966.

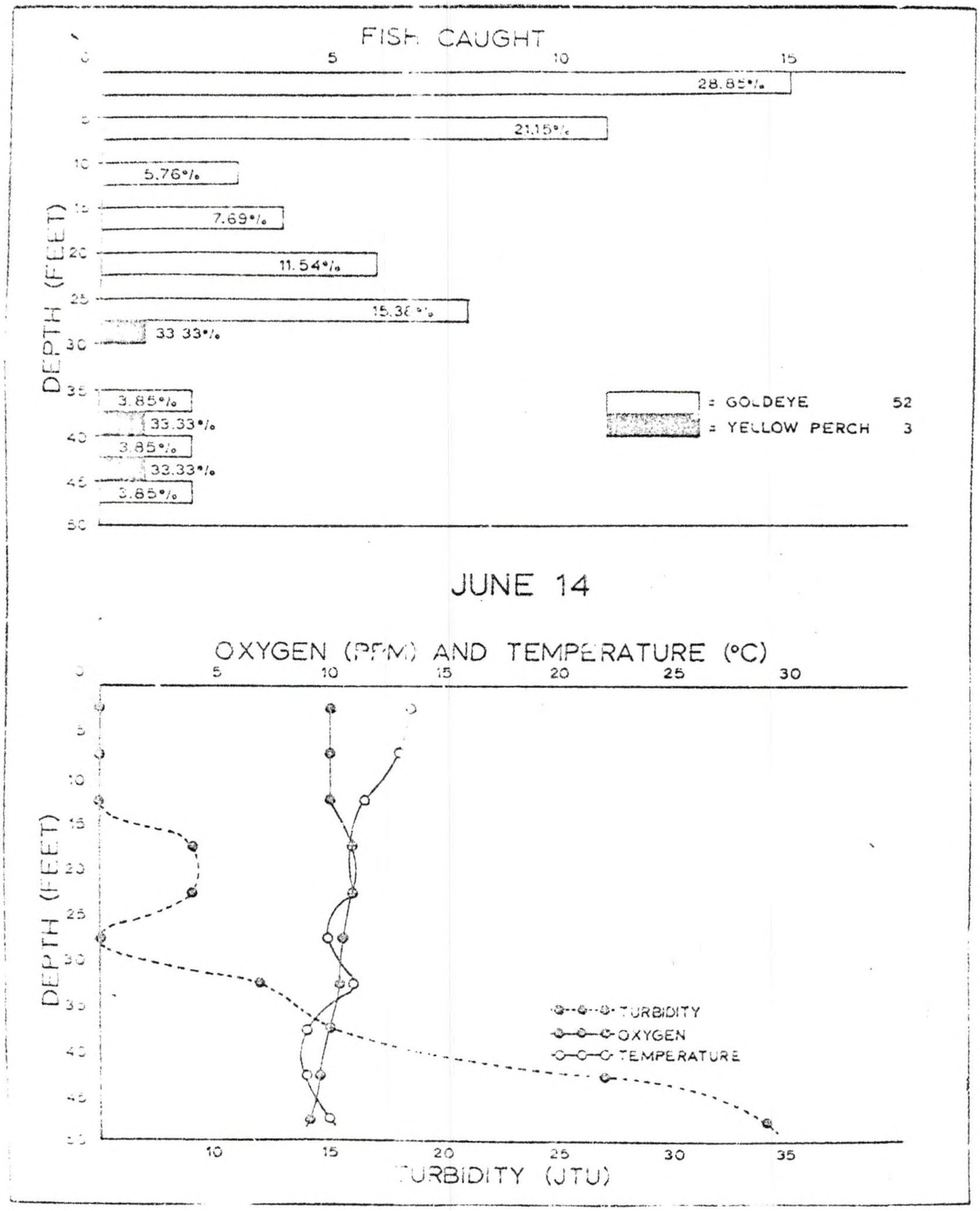

FIG. 9. Depth distribution of goldeye and yellow perch with limnological conditions, June 14, 1966.

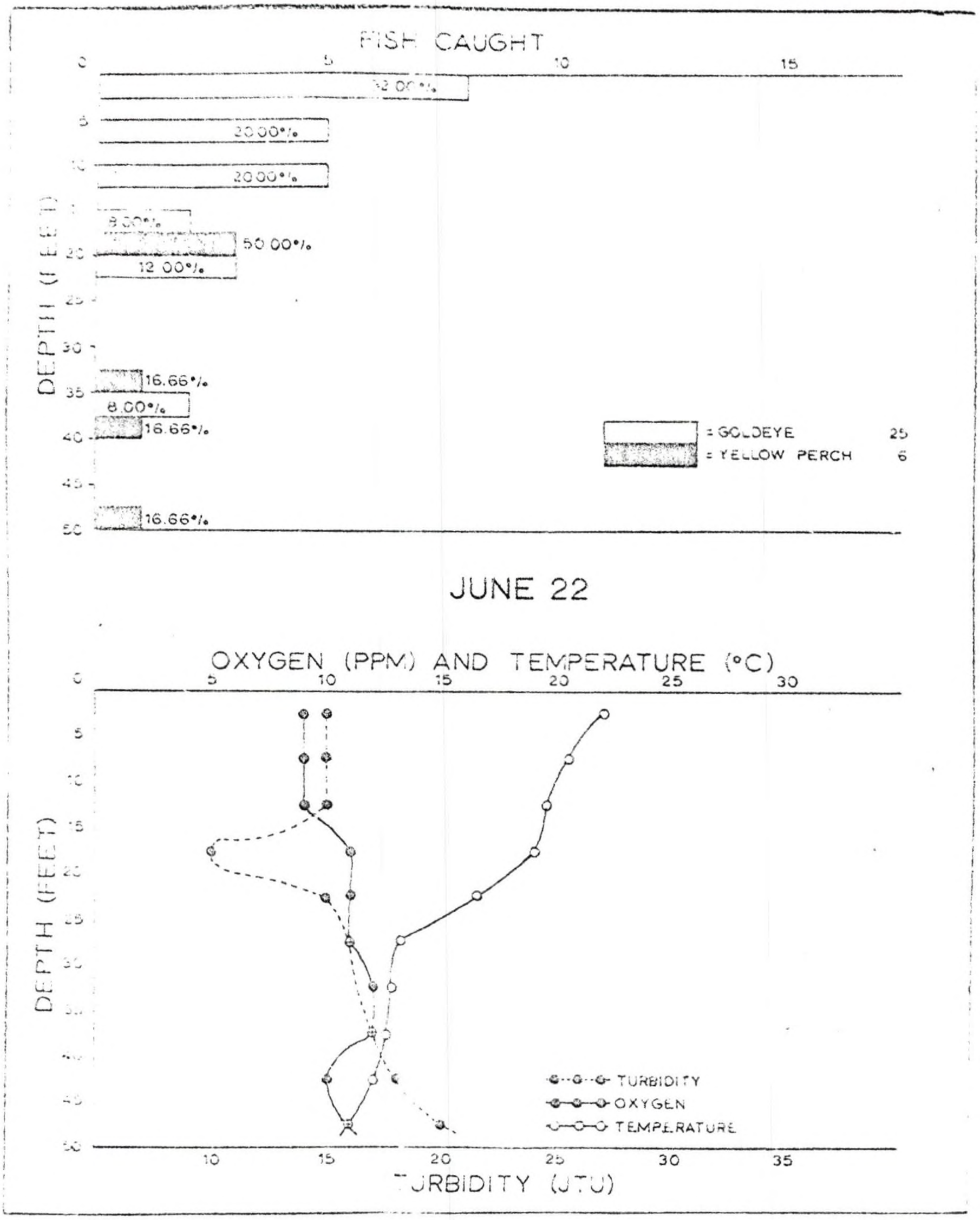

FIG. 10. Depth distribution of goldeye and yellow perch with limnological conditions, June 22, 1966.

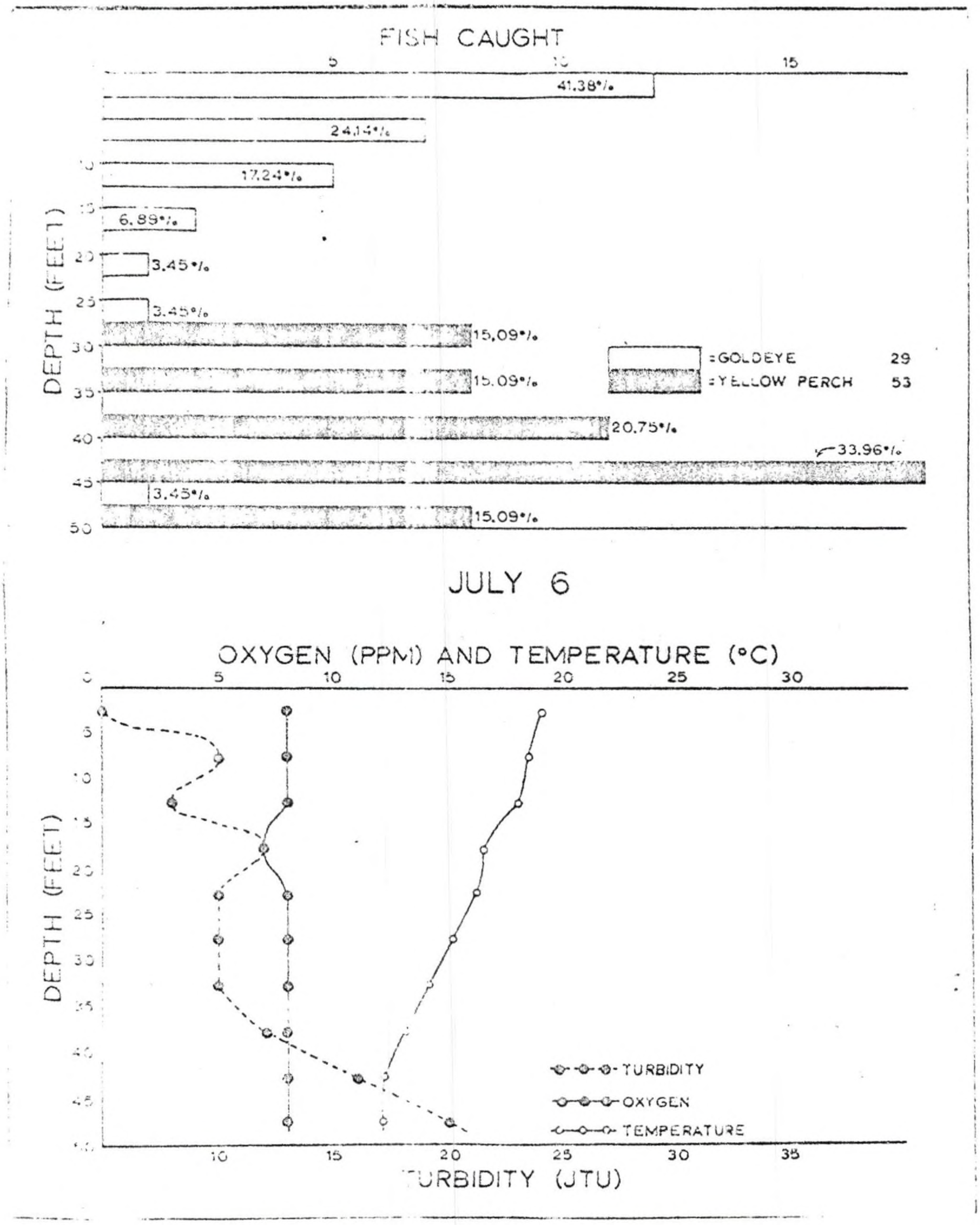

FIG. 11. Depth distribution of goldeye and yellow perch with limnological conditions, July 6, 1966.

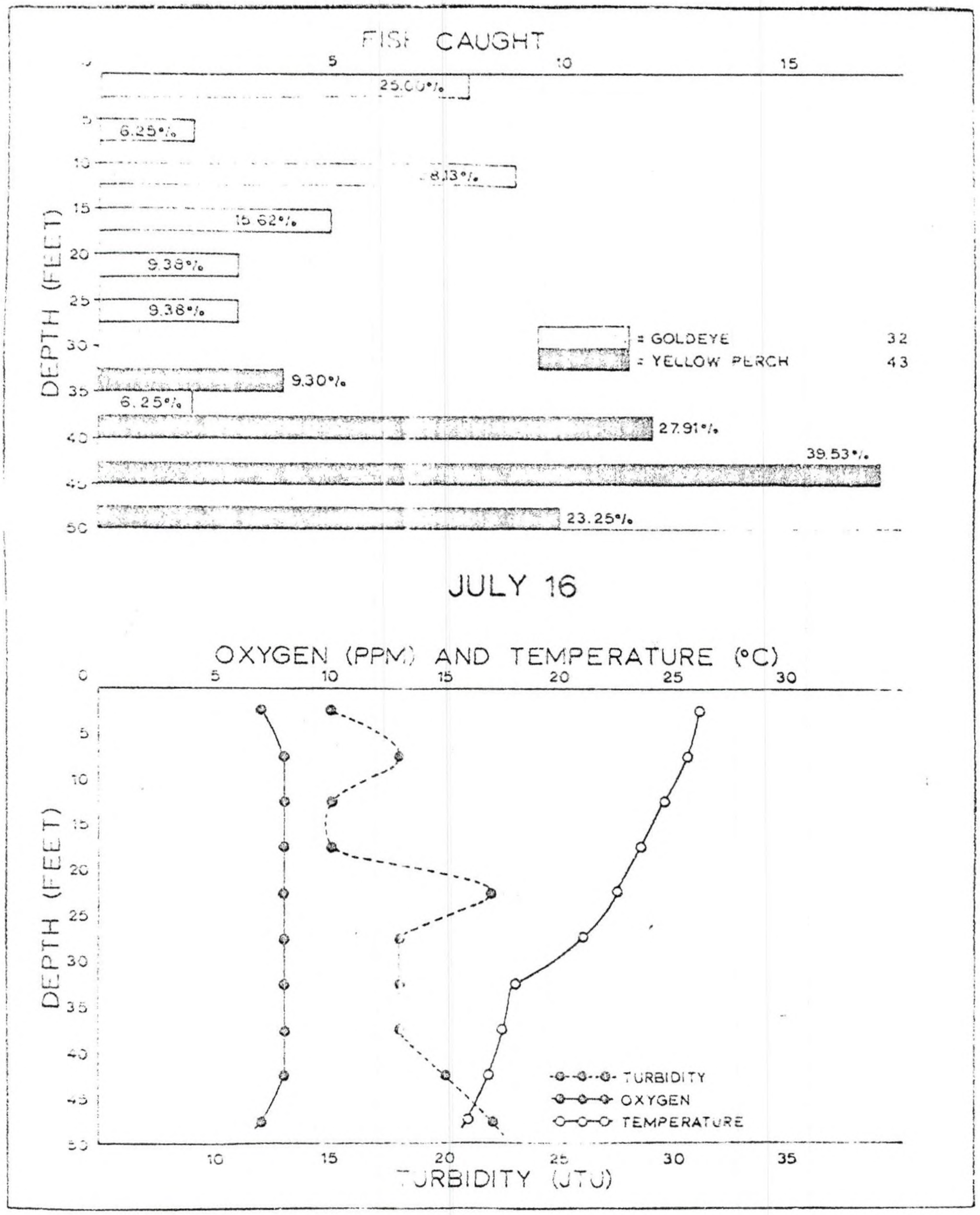

FIG. 12. Depth distribution of goldeye and yellow perch with limnological conditions, July 16, 1966.

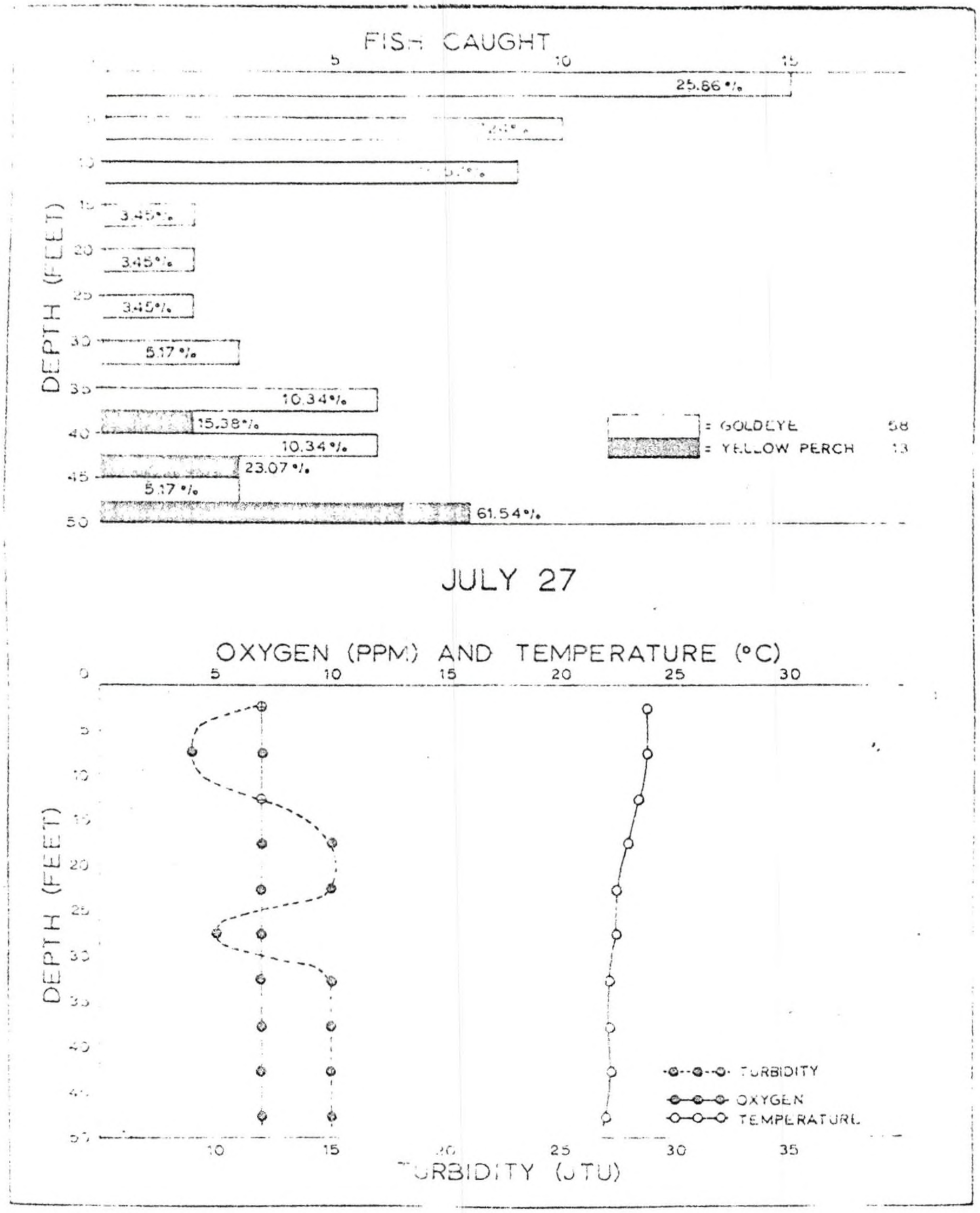

FIG. 13. Depth distribution of goldeye and yellow perch with limnological conditions, July 27, 1966.

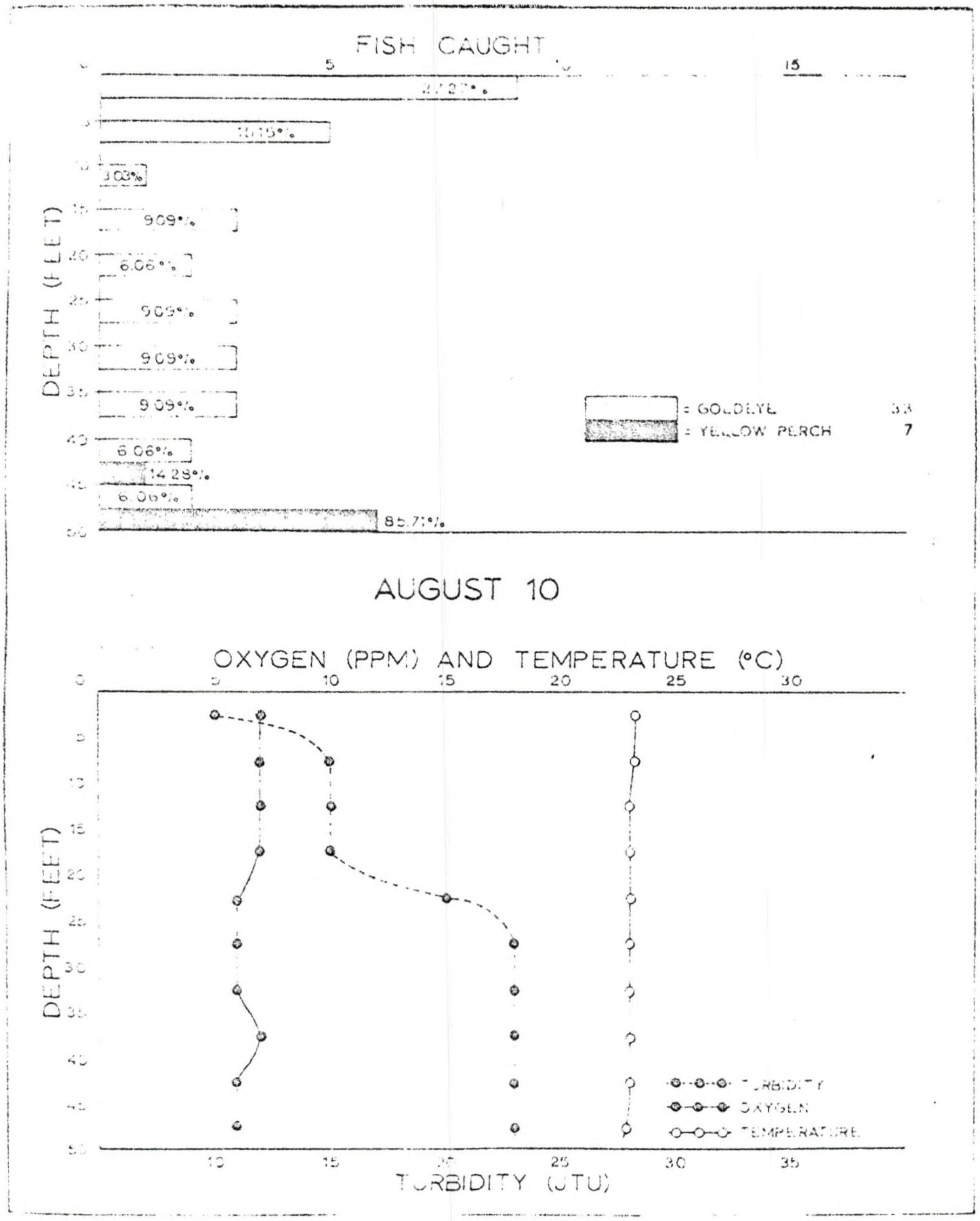

FIG. 14. Depth distribution of goldeye and yellow perch with limnological conditions, August 10, 1966.

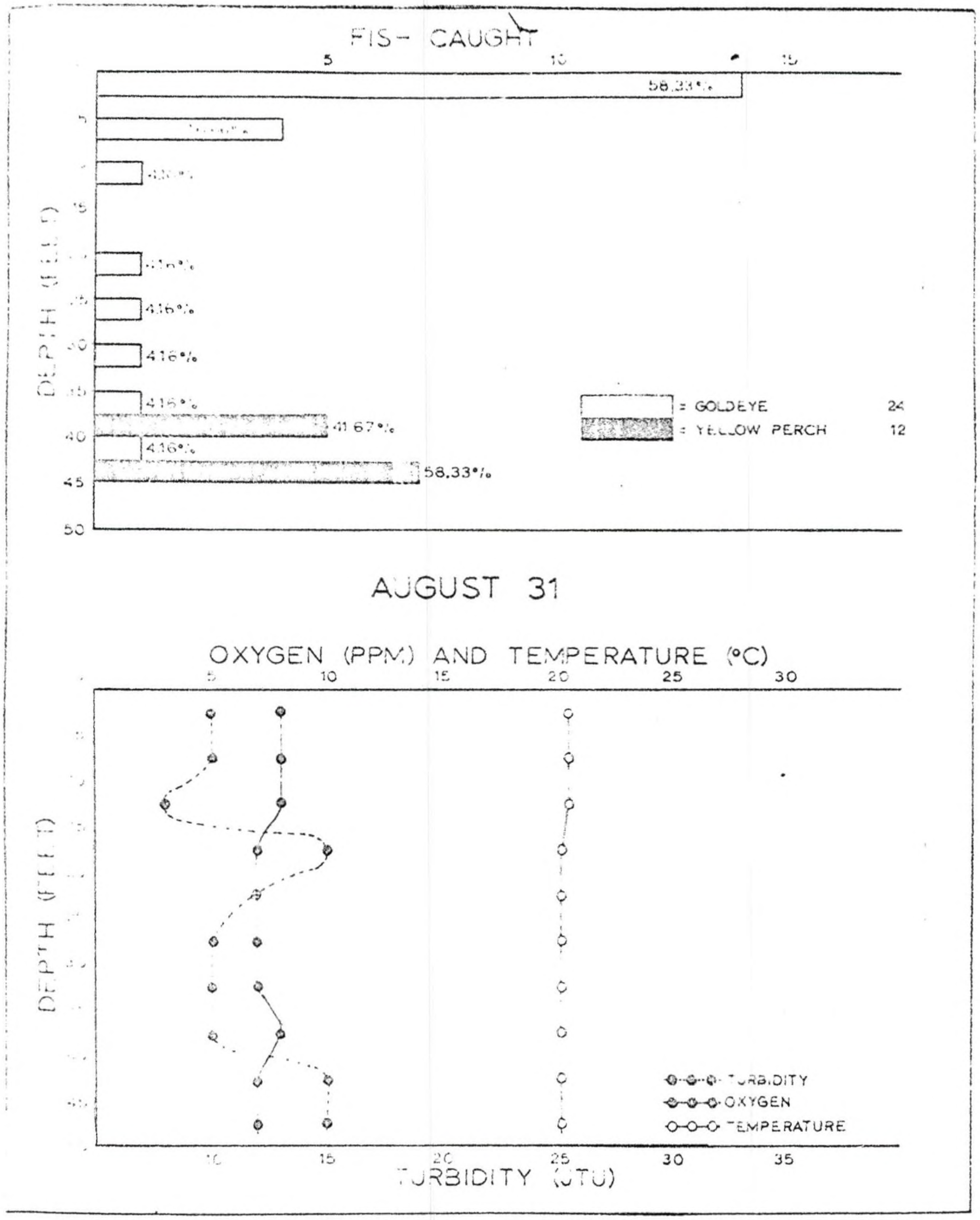

FIG. 15. Depth distribution of goldeye and yellow perch with limnological conditions, August 31, 1966.

between 0600 - 1200. Almost twice as many goldeye were caught during this six-hour period as were recorded ordinarily during three 12-hour day sets, 0800 - 2000. This catch had a unique depth distribution since all goldeye were captured below 30 feet, with 58.82% of them between 45 and 50 feet (Fig. 17). A large number of winged male ants, identified as members of the genera Tapinoma, Lasius, and Acanthomyops (Wheeler, personal communication), were observed on the water surface during this time. Goldeye caught the following two days were extremely distended and their stomachs were found to be full of these ants.

The six-hour netting periods which yielded the most goldeye were: 2400 - 0600 and 1800 - 2400 (Fig. 16 - 17). Comparison of the catches for each of the sequential six-hour sets indicated that few fish were caught between 0600 - 1200 and 1200 - 1800 (Fig. 16). The total goldeye captured during four sequential six-hour sets was approximately equal to the number caught during a continuous 24-hour netting period.

Eight hundred and eighty-five goldeye ranging from 4.5 to 18 inches total length were captured during this study. Three hundred and eighty-nine, or almost 44%, were between ten and twelve inches long (Fig. 18). The mean length of the catch for each depth and mesh size from 12-hour sets was examined for gross indications of mesh or depth selectivity by size (Table 3). No trends for depth selectivity by size were recognized; however, Table 3 suggests possible mesh selectivity for fish size as the mesh size increases from 3/4 to 1½ inch.

While goldeye were found near the surface during July and August, all yellow perch were found below 25 feet with the largest percentage of them captured within five to ten feet from the bottom (Fig. 11 - 15). Five hundred and sixty-nine yellow perch ranging from 5.3 to 7.3 inches total length were captured during this study. Approximately 95% of the

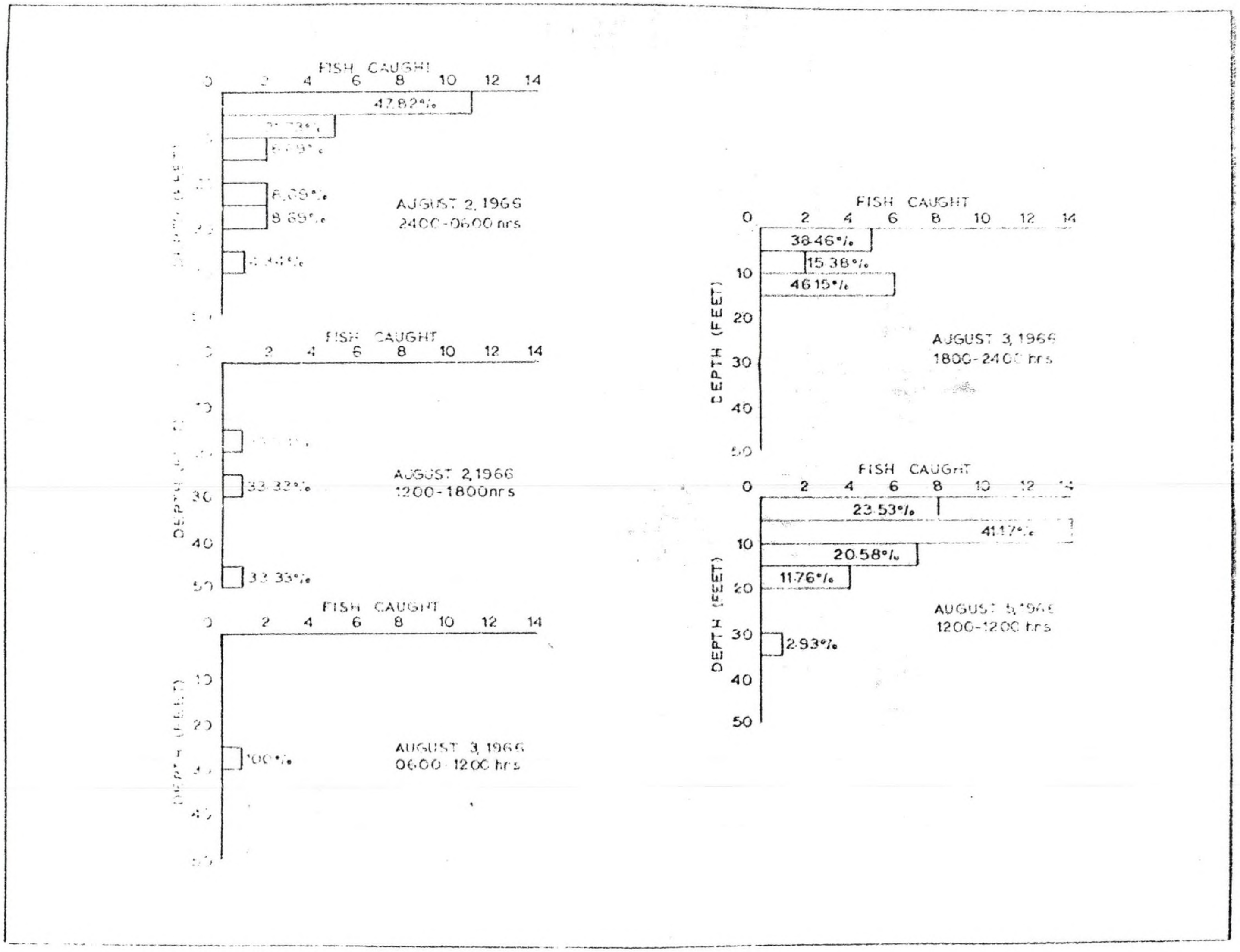

FIG. 16. Depth distribution of goldeye captured during six-hour netting periods in Moccasin Bay; August 2 to August 5, 1966.

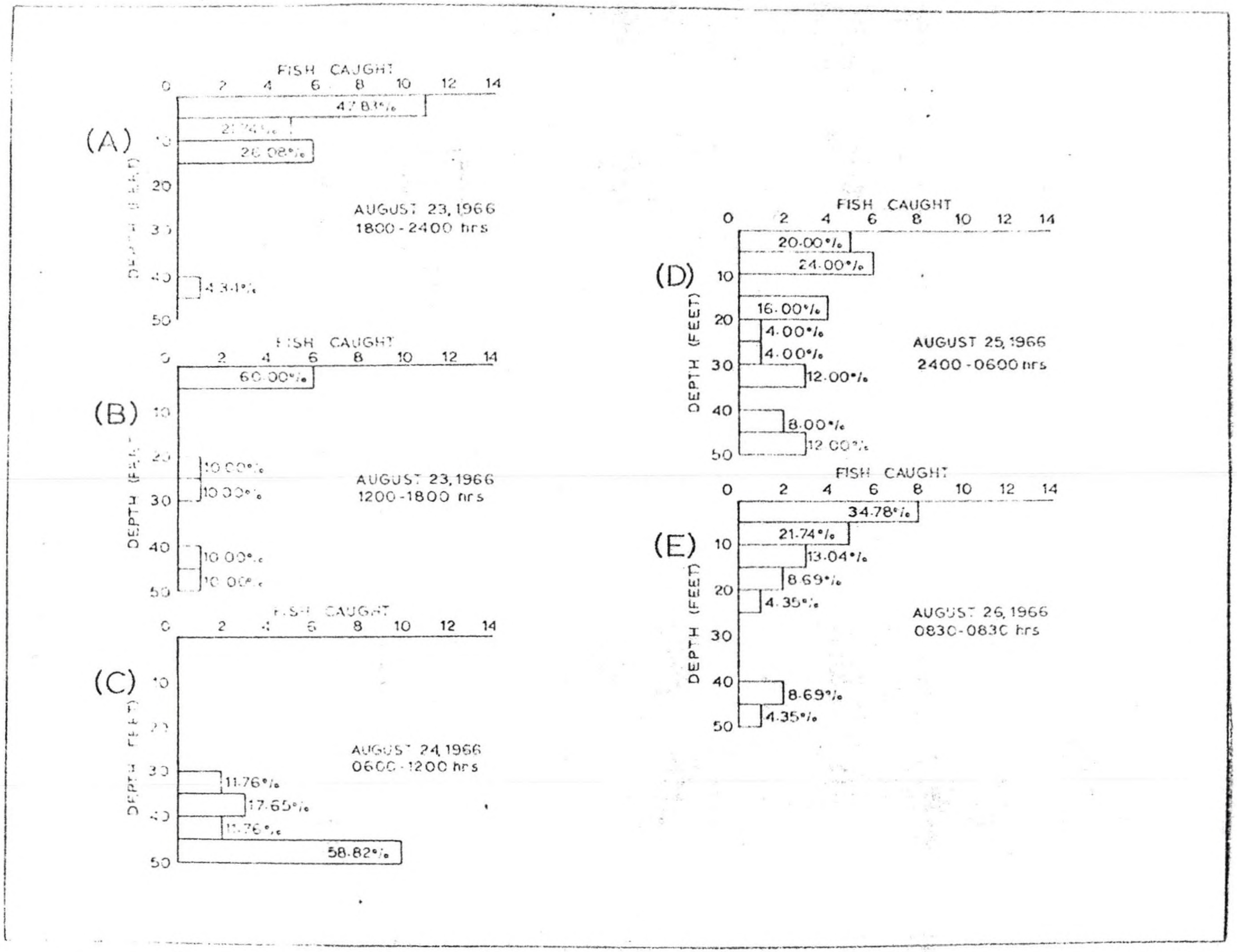

FIG. 17. Depth distribution of goldeye captured during six-hour netting periods in Moccasin Bay; August 23 to August 26, 1966.

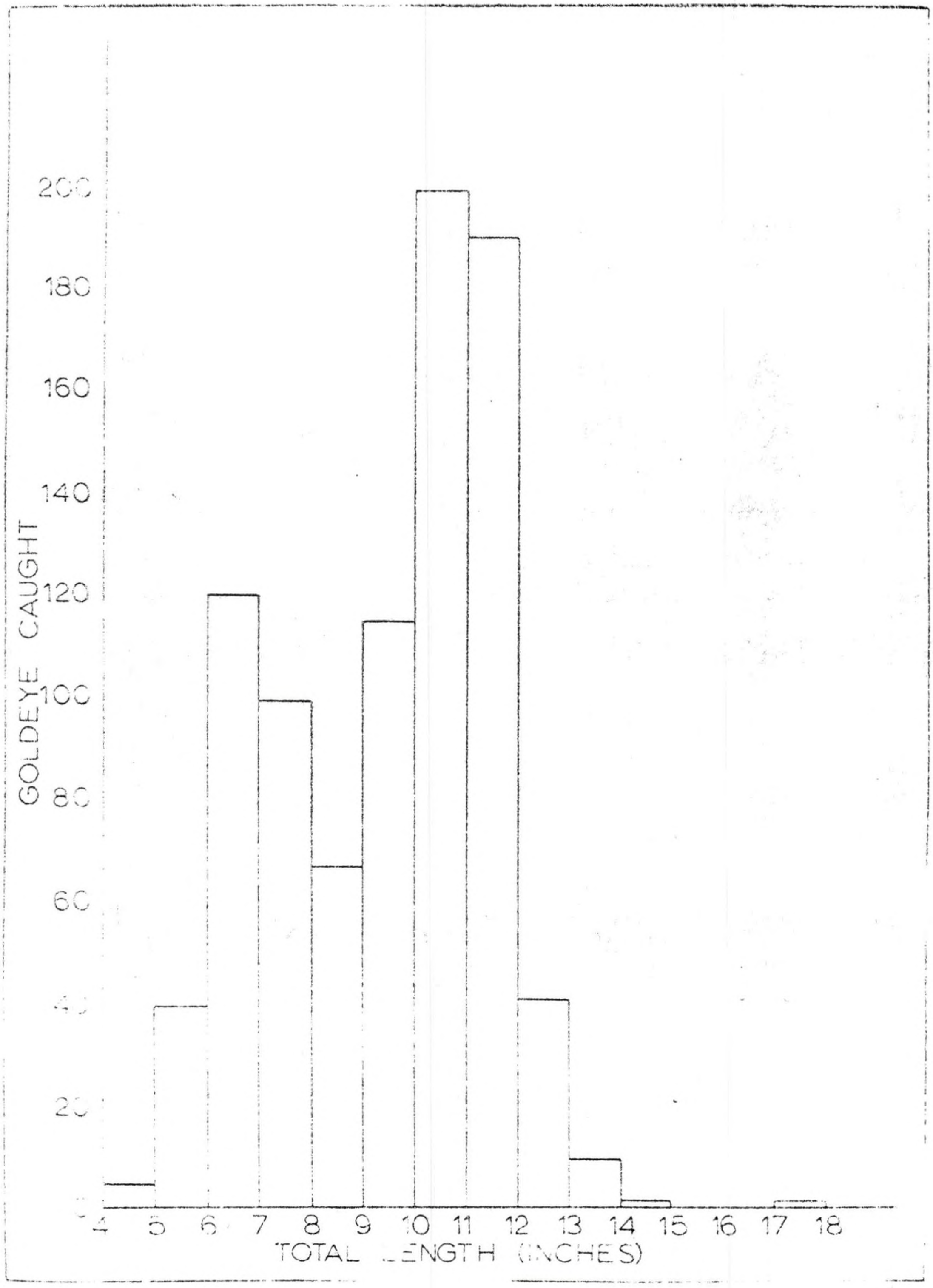

FIG. 16. Length frequency of goldeye caught in Moccasin Bay, 1966.

TABLE 3

Mean length (inches) of goldeye captured during
12-hour sets in Moccasin Bay, 1966

Depth	3/4" mesh		1" mesh		1¼" mesh		1½" mesh		2" mesh		2½" mesh	
	Number of fish	Mean total length	Number of fish	Mean total length	Number of fish	Mean total length	Number of fish	Mean total length	Number of fish	Mean total length	Number of fish	Mean total length
0-05	46	8.539	59	9.927	45	10.844	23	11.117	9	10.578	--	--
05-10	30	8.240	29	9.607	18	10.678	11	11.473	1	12.300	--	--
10-15	29	8.769	17	8.747	16	10.719	8	11.750	1	11.800	--	--
15-20	27	7.607	10	8.710	7	10.843	3	12.367	2	10.000	--	--
20-25	16	7.231	12	8.850	6	10.583	4	11.500	-	--	--	--
25-30	24	7.187	12	10.108	7	10.043	4	9.950	-	--	--	--
30-35	18	6.961	6	10.067	3	10.633	2	11.400	-	--	--	--
35-40	12	6.858	9	8.656	10	10.420	2	11.450	-	--	--	--
40-45	9	7.378	5	8.720	4	9.875	3	10.433	-	--	--	--
45-50	3	8.967	8	8.987	5	10.980	3	11.500	-	--	--	--
Total	214		167		121		63		13		--	
Mean total length		7.892		9.517		10.677		11.275		10.715		--

perch were from six to seven inches in total length.

Ordinarily, the vertical temperature profile in Moccasin Bay from June through August was almost a straight line and varied only four or five degrees from surface to bottom. Thermoclines were noted on two occasions, June 22 and July 16, when water temperatures at a depth of 20 to 30 feet decreased rapidly. These thermoclines were apparently temporary and the only indication of thermal stratification during the summer.

The dissolved oxygen content of the water was between 9 and 12 ppm in early June. Dissolved oxygen had decreased by the middle of July but was never below 5 ppm at any depth tested during the summer.

Turbidity levels ranged from 0 to 15 Jackson turbidity units in the upper 20 feet of water in the netting area. Little variation in turbidity levels occurred between 20 and 35 feet; however, occasionally an increase was noticed below 35 feet (Fig. 8 - 15).

Secchi disc readings in the netting area ranged from 139 to 150 inches and indicates relatively high water transparency in Moccasin Bay. In contrast, Secchi disc readings in the headwater of the Little Missouri Arm of the reservoir between stations one and four (Fig. 19) were between zero and two inches. Secchi disc readings generally increased down river along the length of the Little Missouri Arm of the reservoir; however, a distinct convergence line was noted between stations five and six on August 25. This line was so distinct that Secchi disc readings increased from 0.25 inches to 8 inches within a distance of approximately five feet. The same type of increase was observed at this point on September 1; however, the increase was not as abrupt. Water color between sampling points one and five was slate grey; the color abruptly changed to rust red at station six through twelve and allowed increased light penetration as shown by Secchi disc readings (Fig. 19).

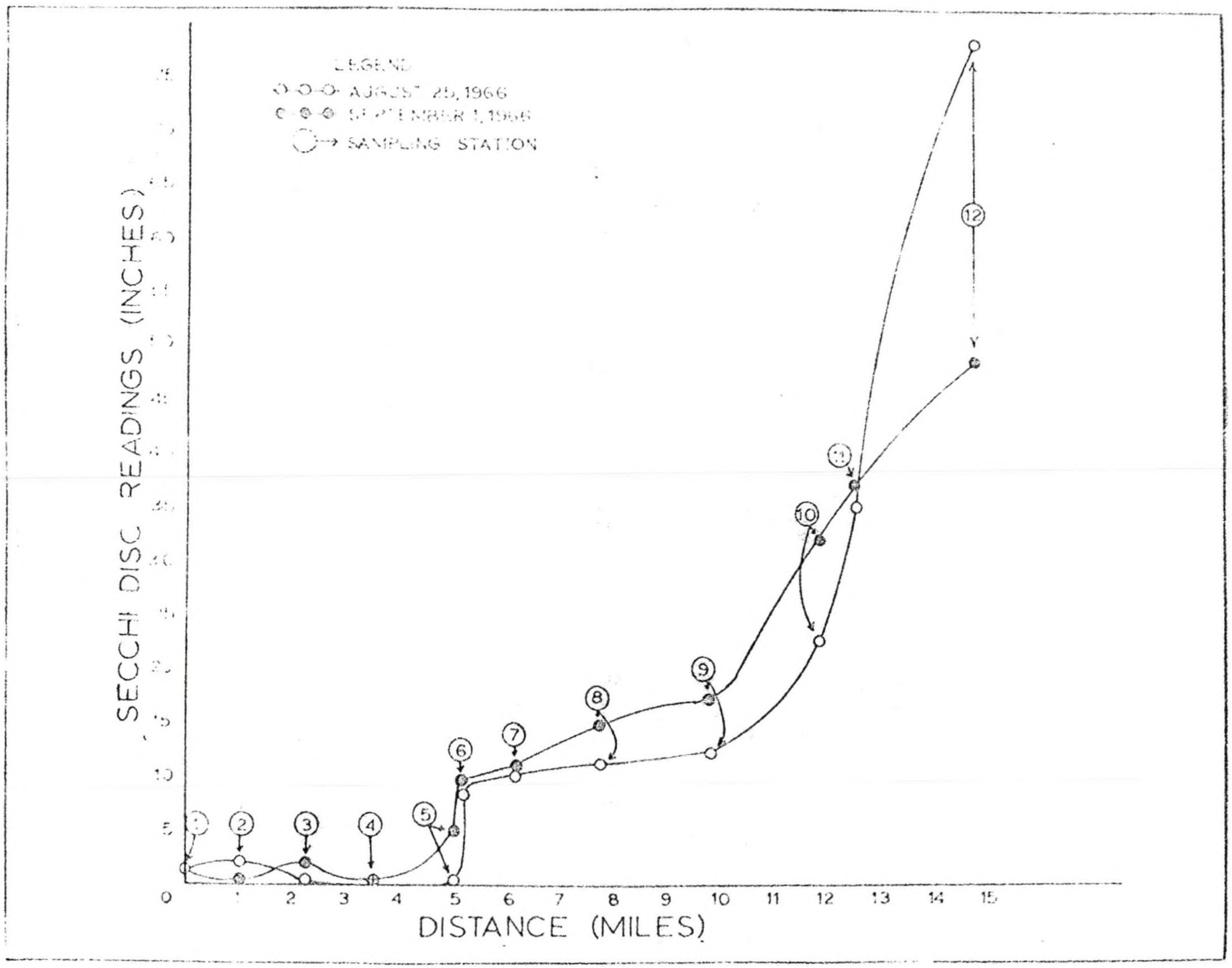

FIG. 19. Secchi disc readings in the Little Missouri Arm of Garrison Reservoir downstream from Lost Bridge.

Water temperatures and water samples were not taken in the reservoir headwater because the water was so silt-laden that the thermometer probe and the one-liter Kemmerer bottle would not sink in it more than two feet. At this depth, the Kemmerer laid on its side and the messenger would not strike it with sufficient force to close it. Maximum depths were 4, 1, 1, 0, 2, 4, 8, 11, 16, 20, 23, and 30 feet at sampling stations 1 through 12 respectively according to electronic soundings.

DISCUSSION AND CONCLUSIONS

Garrison Reservoir is located almost in the center of goldeye distribution in North America as described by Eddy (1957). A prediction of future goldeye populations in Garrison Reservoir by the U.S. Fish and Wildlife Service about 14 years ago stated, "Fishes such as carp, suckers, and goldeye are expected to become numerous and furnish the stock for future commercial fishing ventures" (U.S. Dep. Interior, 1952). Test netting of Garrison Reservoir in 1964 by the North Dakota Game and Fish Department revealed many goldeye to be present. Their gill nets set at 17 different locations in the reservoir, during July and August, caught 1,115 goldeye which represented 26.38% of the total catch.

In the present study, gill net sets in Moccasin Bay caught 885 goldeye from June through August. This represented 53.28% of the catch composition. Although these figures may not indicate a true proportion of the goldeye population in Moccasin Bay, they do suggest that relatively large numbers of goldeye are present in this area.

Depth distribution of goldeye as depicted in Figures 8 - 15 did not vary greatly during June, July, and August in the bay. Results of goldeye depth distribution in the current study paralleled those of Borges (1950) for July and August. He reported taking goldeye at all depths during June; however, Moccasin Bay goldeye generally demonstrated a preference for upper water strata during that month also.

Limnological conditions in this area of the reservoir seem to have little influence on the depth distribution of goldeye. The absence of thermal stratification causes little variation of water temperatures from surface to bottom. Therefore, fish had little opportunity to demonstrate preferences over a wide range of temperatures such as those found in Norris Reservoir, Tenn., (Dendy, 1945b), Horsetooth Reservoir, Colo., (Horak and Tanner, 1964), and the Lake of the Ozarks, Mo., (Borges, 1950).

Ellis (1937) stated that, in general, 3 ppm at a temperature of 77 F (25 C) is the upper limit in water at which asphyxia from low oxygen will occur for most fishes. Since dissolved oxygen content of the water in Moccasin Bay did not drop below 5 ppm throughout the summer and temperatures did not exceed 26 C, oxygen was probably not a limiting factor for fish distribution.

Dendy (1945a) indicated that turbidity associated with an interflow type density current in Norris Reservoir, Tenn., affected fish distribution. As noted before, Norris Reservoir was highly turbid, 300 ppm, at times (Wiebe, 1939). Wallen (1951) reported that 16 different species of fish did not demonstrate observable behavioral reactions to the effects of montmorillonite clay turbidity until concentrations neared 20,000 ppm. Considering the low turbidity levels encountered in Moccasin Bay (Fig. 8 - 15), it seems unlikely that turbidity had much effect on the depth distribution of fish in the bay.

If temperature, dissolved oxygen, and turbidity had only a negligible effect on goldeye depth distribution in Moccasin Bay, then obviously, there was some other factor responsible for the distribution of almost 50% of them in the upper ten feet of water. Bryan and Howell (1946) stated that main stem reservoirs seldom stratify thermally. They suggested, that where relatively uniform temperature conditions exist in a reservoir, light might be expected to influence fish distribution. There were strong indications that few goldeye were caught in Moccasin Bay during daylight hours and that they were most active in the hours of darkness. Only 10 of 579 were caught during 12-hour daylight sets. The fact that 24-hour sets did not catch significantly more goldeye than 12-hour night sets indicated that nearly all the goldeye caught during the 24-hour sets were, in fact, entangled in the gill net during the hours of darkness. This provided additional evidence indicating that light might affect fish activities in an unstratified segment of a reservoir.

Six-hour netting periods revealed another factor that might have greater influence on the depth distribution of goldeye than light. While setting the net at 1800 on the evening of August 22, it was noted that many dead insects littered the water surface and that goldeye were leaping above the surface of the water. The following day, when the net was lifted, the catch indicated the expected distribution with many goldeye caught near the surface (Fig. 17A). The next sampling period indicated that goldeye were caught at the usual depths but more of them were caught than normal for this time of day (Fig. 17B). During the following six-hour period, 0600 - 1200, August 24, a relatively large number of goldeye were caught and their distribution was confined to the bottom 20 feet of water (Fig. 17C). Catches during this period suggest that goldeye feeding activities might influence their depth distribution and consequently the number of them caught near the surface in gill nets. An examination of goldeye stomachs during these two days revealed that the fish had been feeding on insects, later identified as three genera of ants.

It is well established that goldeye are generally surface feeders (Grosslein and Smith, 1959; Sprules, 1947; and Hinks, 1943). The common occurrence of noctuid moths and fireflies in goldeye stomachs from the Red Lakes, Minn., indicates that goldeye are also nocturnal feeders (Grosslein and Smith, 1959). Bajkov (1930) says, "The fact that in the stomachs of goldeye caught during the night period near the surface above the depth of several fathoms, often are found great amounts of deep water organisms such as Daphnia longispina, which come to the surface at night, shows that the goldeye is mostly a night feeder." These citations, especially the latter two, strongly suggest that the feeding habits are probably more important than any other factor in establishing the depth distribution of goldeye. This factor should have high priority in a non-stratifying area such as Moccasin Bay where other factors do not seem to be limiting. Future study of maximum periods of activity for goldeye may profit from the use of shorter netting periods, two to four hours, correlated with light intensity.

Depth distribution of yellow perch during this study indicated that they were not affected by the various physical and chemical factors present in the same manner as the goldeye. The perch were distributed in a pattern essentially opposite that of goldeye. Ferguson (1958) indicated that perch under laboratory conditions selected water which was about 24 C while those in Lake Nipissing, Ont., followed the 20 C isotherm as it increased in depth throughout the summer. Hasler and Villemonte (1953), using echo-sounder traces and direct observations by divers, ascribed the evening shoreward movements of yellow perch in Lake Mendota to their general nocturnal habits. Either or both of these factors may have affected the perch distribution in Moccasin Bay. Indications are that temperature, in this case, was the more important of the two factors since yellow perch were usually caught at the same depth during the day and night netting periods.

Prior to beginning the present study, it was thought that silt-carrying density currents formed from the Little Missouri River inflow would be conspicuous for some distance down the Little Missouri Arm of the reservoir. Gould (1954) in Neel (1963) indicated that density currents have apparently laid down all silt that occurs below the river deltas in Lake Mead. Since bottom silt deposits are found over the entire length of this lake, about 115 miles long, this implies that density currents, in some cases, may transport silt a great distance. However, low turbidity readings encountered in Moccasin Bay, about 15 miles downstream from the confluence of the Little Missouri River and the reservoir, indicated density currents were not markedly affecting Moccasin Bay. This prompted an investigation of the upper reaches of the Little Missouri Arm of Garrison Reservoir in an attempt to determine the fate of the inflowing silt turbidity, previously determined to be very high in the Little Missouri River (Love, 1957).

Silt was found to be so thick between stations one and four (Fig. 6) that echo soundings at these points were probably inaccurate since echoes were returned from silt deposits and not the actual reservoir basin. Where soundings indicated a depth of zero to four feet a pike pole would stand upright in the silt without sinking and the reservoir bottom could not be sounded by probing. The "water" in this area was so thick on August 25 that the boat wake made through it could still be seen, and photographed, 45 minutes later.

According to Neel (1963), a convergence line, such as the one noted on August 25 during the present study, may indicate the presence of a turbid underflow or interflow. However, a vertical series of temperatures in the vicinity of the convergence line and at stations seven and eight downstream (Fig. 6) failed to provide evidence of a density current. Benson (unpublished material) states that density currents have not been recorded in Garrison Reservoir except temporary ones in the extreme upper ends. If a density current existed on August 25, it was not readily recognizable and must have deminished over a short distance.

Wallen (1951) found that fishes under laboratory conditions began showing adverse behavioral reactions to turbidity when subjected to concentrations approaching 20,000 ppm. He also found evidence that turbidity concentrations of 20,000 ppm and greater apparently interfered with respiration. Turbidity readings in excess of 20,000 ppm have been made in the Little Missouri River by the U.S. Geological Survey (Love, 1957) and; therefore, turbidity may affect the distribution and activity of fishes in this area of the reservoir.

The amount to which fish distribution in the Little Missouri Arm of the reservoir is affected by turbidity has yet to be determined. Since this area was about 25 miles from the base camp and inaccessible except by boat, it was investigated only briefly. However, future studies of the Little Missouri Arm might profit from use of gill nets similar to the one used in the present study and set at various points down the length of this arm of the reservoir at depths of 15 to 30 feet. Netting information together with adequate limnological data should prove useful in determining the river's effect on fish distribution of the area. However, special limnological equipment such as heavily weighted thermometer probes and water sampling bottles would have to be employed.

SUMMARY

The present study of vertical distribution of fishes in Moccasin Bay on the Little Missouri Arm of Garrison Reservoir was based on the catch records from specially constructed gill nets and concomitant limnological observations made during the period from June 1 through August 31, 1966. One-thousand, six hundred and sixty-one fish of twelve different species were caught.

The water of Moccasin Bay was not stratified thermally for any length of time during this investigation. Therefore, temperature, dissolved oxygen, and turbidity showed no marked variation from surface to bottom throughout the summer and were probably not limiting factors in depth distribution of fish.

Goldeye, the species of primary concern in this study, showed a rather consistent depth distribution from June through August. Most of the goldeye were caught at night in the upper ten feet of water with only 10 of 579 being caught during daylight hours. Stomach examination of goldeye caught during the night from August 23 through August 25 revealed the presence of many terrestrial insects which had died and littered the water surface. These factors suggest that depth distribution of goldeye is affected by photoperiod and the innate feeding habits of the species.

Yellow perch demonstrated a distribution in contrast to that of goldeye. Perch were caught equally well during night and day netting periods and were invariably located in deep water. This distribution may have been a result of temperature preference or, as prior investigations indi-

cate, merely in accord with their nocturnal behavior.

Lack of significant turbidity in the netting area led to a brief inspection of limnological conditions in the upper reaches of the Little Missouri Arm of the reservoir. At some points the reservoir was so silt-laden that thermometer probes and Kemmerer bottles would not sink, thus preventing limnological determinations. Secchi disc readings in the extreme upper reaches of the reservoir were zero but gradually increased over a 15 mile distance down reservoir. Density currents in the upper arm of the reservoir were not recognized even though a distinct convergence line was observed at times.

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