VERTICAL DISTRIBUTION PATTERNS OF GOLDEYE, *HIODON ALOSOIDES*, IN FORT PECK RESERVOIR, MONTANA

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ABSTRACT

In November 1967 and continuing into December 1969, the goldeye, *Hiodon alosoides* (Rafinesque), in Fort Peck Reservoir, Mont., exhibited seasonal vertical distribution patterns, which seemed to be related to the surface-water temperature. When surface-water temperatures were above 8.9°C (summer and early fall), the goldeye congregated near the surface. During the late fall, ice-covered period, and spring when surface temperatures varied between 8.9° and 1.1°C, the goldeye usually congregated between the 8- and 32-ft level. However, it is the opinion of the author that the goldeye were following the food source and were not responding to temperature per se.

The goldeye, *Hiodon alosoides* (Rafinesque), is one of two shadlike freshwater fishes belonging to the Family Hiodontidae. Distribution of goldeye is limited in the United States and Canada (found mostly in the prairie States and Provinces). The goldeye is generally described as being found in shallow, turbid lakes and large river systems (Battle and Sprules, 1960; Kennedy and Sprules, 1967) and in the shallow waters of large lakes (Kennedy and Sprules, 1967). However, Bajkov (1930) observed that goldeye were found on the surface over deep water in Lake Winnipeg, Manitoba, and Borges (1950) netted goldeye in the deep water of the Lake of the Ozarks, Mo., in September.

Fort Peck Reservoir is basically a deep, clear body of water in contrast to the lakes generally described as being inhabited by goldeye. However, goldeye were netted during 1966 in quantity on the surface in clear water. Good numbers of goldeye continued to be netted in clear water during 1967-70 (unpublished data available in annual report form of Montana Fish and Game Department).

Mature goldeye often exceed 15 inches in total length in nutrient-rich bodies of water; the Montana record is 18.7 inches total length (Brown, 1971) and was taken from Nelson Reservoir, a fertile lake about 70 miles from Fort Peck Reservoir. In Fort Peck Reservoir, the goldeye rarely exceeded 15 inches in total length and most were less than 14 inches total length; they seldom lived longer than 8 years; most spawned in June; and they withstood water temperatures as low as 1.1°C (unpublished data).

The coho salmon, *Oncorhynchus kisutch*, which was first introduced in 1969, was the only species to compete with goldeye for food in pelagic areas of the reservoir. In shallow-water areas, the goldeye contributed to the diets of sauger, *Stizostedium canadense*; walleye, *S. vitreum vitreum*; and northern pike, *Esox lucius* (personal observations).

The goldeye is one of the most important commercial fish taken from the reservoir. The goldeye are trucked to Winnipeg, Manitoba, which has the only substantial commercial market (up to 1 million lb of drawn fish are utilized annually). However, it has only been since 1967 that the market for goldeye from Fort Peck Reservoir has been significant. Declining populations of goldeye in Canadian waters, probably due to overharvesting by commercial fishermen, were responsible for the interest in Fort Peck Reservoir's goldeye (goldeye harvest from Fort Peck Reservoir varied from 53,318 to 199,279 lb round weight during 1967-71). See Battle and Sprules (1960), Grosslein and Smith (1959), and Kennedy and Sprules

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(1967) for a past history of the commercial fishery in Canada and the United States.

To better understand the problems associated with harvesting goldeye from the clear waters of Fort Peck Reservoir, the availability of goldeye to gill net fishermen at different times of the day and year was investigated. Emphasis was placed on selective fishing; i.e., floating gill nets, 8 ft deep, were set in open-water areas away from shallow bays and shorelines to avoid game fish. The results of selective netting revealed that goldeye were present in commercial quantity away from shallow, turbid areas and that the catch consisted of almost 100% goldeye (unpublished data).

However, during the winter, spring, and late fall, the goldeye were not gilled in the floating gill nets. Preliminary netting with 8-ft-deep, sinking gill nets (nets were set obliquely and horizontally at different depths) indicated that the goldeye were present during the fall and spring periods, but usually at the 20- to 30-ft level. To better determine some of the parameters associated with the vertical distribution of goldeye, the following study was begun in November 1967.

DESCRIPTION OF FORT PECK RESERVOIR AREA AND SAMPLING SITE

Fort Peck Reservoir is located in sparsely populated northeastern Montana. At maximum pool the reservoir has a surface area of 245,000 acres, a maximum depth of 225 ft near the dam, and an irregular shoreline over 1,500 miles long. Only the Missouri River and Musselshell River continuously flow into the reservoir. There are detailed descriptions of the area (U.S. Fish and Wildlife Service, 1952).

The water of the reservoir is clear except for the shallow ends of large bays and upper ends of the two main arms (Missouri Arm formed by the Missouri River and the Big Dry Arm formed by the intermittent Big Dry Creek). Surface-water temperatures varied from freezing in winter (the Reservoir is completely ice-covered for almost 4 mo) to the low 20°C in summer.

There was little indication of thermal stratification. During the ice-cover period, the water temperature in the sampling area was 1.1°C from the surface to at least a depth of 50 ft. Also, water tapped from approximately 140 to 160 ft below the surface for the turbines at the dam was 1.1°C during most of the above period (records kept by U.S. Corps of Engineers at Fort Peck). The continued withdrawal of water for power production (10,000 cfs) probably discouraged formation of a winter inverse stratification. The almost ever present prairie winds and withdrawal of water for power production probably discouraged the formation of a true summer thermocline. During the warm months of July and August, the temperature from the surface to depth of 50 ft varied only a few degrees Celsius in the sampling area. Phenicie (1950) found little evidence of a thermocline, and he recorded a high temperature of 8.3°C at a depth of 180 ft. Temperature data kept by the U.S. Army Corps of Engineers during July and August were usually in the 9°-13°C range for water taken from the 140- to 160-ft level.

The area sampled was open water located from ½ to 1 mile off a point of land near the west end of Fort Peck Dam. The water was clear, and depths ranged from 50 ft to over 100 ft. Netting efforts in other parts of the lower reservoir area by the Montana State Fish and Game Department and commercial fishermen indicated that the sampling site was representative of open, clear-water areas of the lower reservoir.

MATERIALS AND METHOD

To determine the vertical distribution of the goldeye, a floating nylon gill net was used. The net measured 100 ft long and 40 ft deep. The webbing, of No. 139 nylon twine, was 1½-inch mesh, square measure. The net was divided into five horizontal sections, each 8 ft deep. The depth of 40 ft was chosen since numerous (approximate number not known) test-netting efforts during spring, summer, and fall of 1966-69 gilled few goldeye below the 40-ft depth (oblique, horizontal, and bottom sets were utilized). Most of the Montana State Fish and Game Department and commercial

fishery goldeye nets have No. 139 nylon twine. This 1½-inch mesh was selected because it gilled more goldeye than 1-inch, 1¼-inch, 1¾-inch, or 2-inch mesh (unpublished data). Eight-foot sections represented the width of gill nets used for goldeye on the Reservoir.

Usually the net was set for overnight and then lifted. It was observed that daylight sets rarely caught many goldeye in clear water. The exact time of setting and lifting the net usually had little influence on the catch as long as the net was set well before dusk and lifted after sunrise. Because so few goldeye were caught in overnight sets during the ice-cover period in 1968, the net was set for several days before lifting during the 1969 ice-cover period.

RESULTS

The vertical distribution pattern can be followed in Table 1.

During the summer and early fall, the goldeye exhibited maximum stratification within 8 ft of the surface, and they were easily captured by floating gill nets. The summer and early fall pattern began in 1968 and 1969 once the surface temperature reached 7.2°C and remained above 13.3°C.

The late fall pattern in 1967, 1968, and 1969 eventually exhibited the reverse of the summer pattern; i.e., the greatest concentration in the top 40 ft was between the 32- and 40-ft level. However, the goldeye did not move quickly from the surface to deeper depths. There was a transitional period during which the goldeye were scattered throughout all depths sampled (0-40 ft). The late fall pattern began as the surface temperature approached 6.1°C in 1967 and 8.9°C in 1968 and 1969.

During the ice-cover period, the goldeye appeared to concentrate between the 8- and 32-ft level; however, few goldeye were taken per night set. In 1968, the catch per night set was 22 goldeye; in 1969, the equivalent catch per night set was 3.5 goldeye. In contrast, the ice-free period usually had catches of 60 or more goldeye per night set. The water temperature was 1.1°C both winters.

The goldeye vertical distribution pattern in the spring was not as predictable as in other periods. The goldeye were caught at all depths, near the surface, or near the 40-ft depth. No clear relationship between the distribution pattern and temperature was evident. Apparently quick shifts in wind direction affected surface temperatures more in spring than in summer and fall. Since the warm surface-water column in summer and fall penetrated to deeper levels than the spring warm surface column, maybe upward convection currents more easily displaced surface water in the spring.

DISCUSSION

The following discussion concerns mostly the open-water area; i.e., little reference is made to the goldeye that may habitually seek shallow, turbid conditions such as would be found in small bays and near river mouths.

It is evident that the goldeye in the sampling area do exhibit consistent seasonal vertical distribution patterns and that the patterns can usually be predicted from the surface-water temperature. The cause of the patterns is not clear, but it is suspected that the goldeye is following the food source, which in Fort Peck Reservoir consists of zooplankton, terrestrial insects, aquatic insects, and small fishes. It is believed from observations (regurgitation of stomach contents when goldeye were forced through the mesh), daytime versus night-time sets, and cursory stomach examinations that the goldeye do most of their feeding at night during the summer and early fall when zooplankton and terrestrial and emergent aquatic insects are available on or near the surface. Work by Bajkov (1930) and Grosslein and Smith (1959) support the above contention as does work by Sprules (1947).

It is not known whether the goldeye move to deeper water during the day. Surface sets over clear, deep water during the day have caught few goldeye although sets in turbid, shallow areas often produce substantial catches. Possibly the fish gilled in the shallow, turbid water could not see the net.

Obviously, terrestrial insects do not contribute significantly to the diet during the

TABLE 1.—Vertical distribution pattern of goldeye in an open-water area of Fort Peck Reservoir, from November 1967 into December 1969.

[Number of goldeye per night per 8-ft deep section of 100-ft net.]

Pattern	Date	Temperature (°C)[1]	Depth (ft) 0-8	8-16	16-24	24-32	32-40
1967							
Summer-early fall	20 Nov.	8.9	48	28	7	1	0
	24 Nov.	7.8	66	56	22	4	2
Late fall	5 Dec.	6.1	18	46	51	40	52
	16 Dec.	4.4	1	6	26	25	44
1968							
Winter ice-cover	17 Jan.	1.1	0	9	14	6	3
	9 Feb.	1.1	4	14	8	2	0
	15 Feb.	1.1	2	0	1	0	0
	16 Feb.	1.1	2	3	0	1	0
	23 Feb.	1.1	0	13	1	0	0
	1 Mar.	1.1	0	4	7	0	0
Spring	11 Apr.	2.8	1	7	9	6	2
	19 Apr.	3.2	14	31	47	41	25
	23 Apr.	3.2	2	6	5	4	0
	24 Apr.	7.2	6	17	16	11	7
	25 Apr.	3.9	20	11	3	1	3
	1 May	5.0	86	82	86	57	40
	12 May	6.1	11	10	15	6	15
Summer-early fall	20 May	7.2	21	14	13	10	16
	24 May	8.3	12	4	2	5	3
	6 June	12.2	41	39	38	20	20
	13 June	13.3	41	8	5	6	6
	26 June	15.6	75	35	18	18	18
	17 July	19.4	37	8	11	3	3
	25 July	18.7	38	7	5	2	2
	6 Aug.	20.0	51	18	3	5	5
	27 Aug.	17.8	61	19	15	13	22
	4 Sept.	17.2	26	10	17	14	6
	10 Oct.	14.4	34	26	16	7	10
	23 Oct.	12.8	86	79	19	10	10
	12 Nov.	10.6	37	35	9	13	6
Late fall	22 Nov.	8.9	15	21	26	11	9
	3 Dec.	7.2	5	20	20	29	8
	10 Dec.	6.1	0	12	18	14	18
	18 Dec.	5.0	0	9	21	50	57
1969							
Winter ice-cover	15 Jan.	1.1	0	6	15	20	9
	6 Feb.	1.1	0	0	1	0	0
	6-10 Mar.	1.1	0	1	2	0	0
	10-13 Mar.	1.1	1	5	1	2	0
	13-18 Mar.	1.1	2	2	7	1	0
	18-25 Mar.	1.1	1	2	6	2	0
	25 Mar.-3 Apr.	1.1	1	9	1	3	0
	3-7 Apr.	1.1	2	5	4	5	0
Spring	22-24 Apr.	2.8	12	14	28	17	19
	1 May	3.3	0	1	3	4	3
	8 May	3.9	24	9	6	14	15
	14 May	8.3	63	9	8	6	8
	21 May	7.2	3	8	5	5	11
	29 May	6.7	18	26	22	8	8
	6 June	14.4	77	11	7	10	9
	13 June	7.8	19	26	6	5	3

TABLE 1.—Vertical distribution pattern of goldeye in an open-water area of Fort Peck Reservoir, from November 1967 into December 1969.—Continued.

[Number of goldeye per night per 8-ft deep section of 100-ft net.]

Pattern	Date	Temperature (°C)[1]	Depth (ft) 0-8	8-16	16-24	24-32	32-40
1969 — Continued							
Summer-early fall	20 June	13.3	52	24	26	12	5
	11 July	16.7	110	77	39	21	21
	16 July	[2]	27	6	8	10	5
	23 July	17.2	46	14	5	2	1
	27 Aug.	21.1	46	21	25	6	4
	18 Sept.	[2]	60	45	40	16	12
	9 Oct.	15.0	55	35	19	1	4
	22 Oct.	[2]	25	23	17	9	7
	30 Oct.	10.6	21	11	5	1	2
	5 Nov.	11.1	19	15	3	8	5
	15 Nov.	9.4	23	11	4	2	2
Late fall	19 Nov.	8.9	10	20	11	8	6
	21 Nov.	8.3	6	21	20	9	1
	26 Nov.	7.8	8	9	3	2	7
	9 Dec.	5.6	0	1	16	21	35

[1] Taken at surface.
[2] Temperature not known.

late fall, winter, and early spring. Cursory examination of stomachs and observation of regurgitated materials during the above periods showed that goldeye preyed almost exclusively on cladocerans.

To better understand if goldeye in fact follow the food source during the late fall, winter, and early spring, the seasonal vertical distribution patterns of cladocerans would have to be known. Although no studies have been conducted to establish distribution patterns of Fort Peck Reservoir zooplankton, work by other investigators indicated that many zooplankters exhibit seasonal vertical migratory patterns. Accordingly, the season migrations are not necessarily hydrographic (McLaren, 1963), but it has been suggested by some authors that winter hibernation of zooplankton may just be an interruption of diurnal rhythm; i.e., once the body of water cools to a given temperature, diurnal movement is no longer advantageous and ceases. Possibly, the goldeye is browsing on zooplankton which have ceased to exhibit diurnal movement patterns similar to their summer pattern, thus accounting for the late fall, winter, and spring distribution patterns exhibited by the goldeye.

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