EFFECTS OF A HIGH RAINFALL YEAR ON TROUT HABITAT IN BULL SHOALS RESERVIOR

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Abstract: Main channel measurements of temperature and dissolved oxygen concentration are used to describe trout habitat in Bull Shoals Reservoir during August, September and October for 1963-1965 and 1969-1973. These months were chosen to show selected events preceding the October minimum of potential trout habitat. Watershed inflow to the reservoir, generation releases, and inflow from upstream Table Rock Dam were analyzed to determine correlations among these factors and minimum volume of potential trout habitat remaining in Bull Shoals Reservoir each year prior to recirculation. Rainfall is the governing influence over watershed inflow, Table Rock Dam inflow, and release from Bull shoals Dam. During 1973, 161.3 cm of rain fell on the watershed compared to an average of 106.7 cm; trout habitat in the hypolimnion of the reservoir was completely lost by mid-October.

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Introductions of nonnative fish into reservoirs, particularly piscivorous species, have provided new sport fishing opportunities through utilization of nonexploited forage populations. Reservoir fishing for rainbow trout (*Salmo gairdneri*) has increased in popularity in certain areas of Arkansas. The fisheries are associated with a few deep impoundments and their tail-waters which provide suitable trout habitat throughout the year. In these impoundments, variations in rainfall influence the volume and quality of hypolimnetic trout habitat by differing levels of biochemical oxygen demand. The direct elimination of the oxygenated hypolimnion through hydroelectric generation can reduce available trout habitat in any case.

In 1961, fishery biologists Baker and Mathis (1967) investigated the possibiliy of establishing a trout fishery in Bull Shoals Reservoir similar to that described for Lake Hamilton by Stevenson and Hulsey (1961). They theorized that the cold oxygenated generation water from upstream Table Rock Dam would course through Lake Taneycomo, pick up additional oxygen, and proceed under Bull Shoals Reservoir as a subsurface current (Baker and Mathis 1967). Their work concluded that conditions for a trout fishery did exist but was created by a large volume of winter stored water instead of a density underflow. However, the dissolved oxygen and temperature patterns of the present study documents the presence of the subsurface current originating from Table Rock Dam, entering Buss Shoals Reservoir as a density underflow changing with increasing reservoir depth to a density interflow.

In 1961, the impoundment received its initial stocking of rainbow trout. Trout habitat in Bull Shoals Reservoir has 4.0 mg/l dissolved oxygen at temperatures between 15≤C and 21≤C and 3.0 mg/l minimum dissolved oxygen below 15≤C.

RESERVOIR DESCRIPTION

Bull Shoals Reservoir is an 18,400 ha mainstream storage impoundment with an average depth of 20.4 m and maximum depth of 61.3 m. It is the lowermost of 4 hydroelectric and flood control reservoirs constructed on the upper White River in Arkansas and Missouri. Beaver Reservoir, the upstream reservoir on the White River system, covers about 11,400 ha. The tailwater of Table Rock Dam in turn becomes the headwater of Lake Taneycomo, a narrow, run-of-the river lake, 37.5 km in length with a surface area of about 1,000 ha. Impounded in 1952, Bull Shoals Reservoir extends 118 km along the White River, inundating dolomites and limestones which contribute calcium and magnesium carbonates to the water (Mullan et al, 1970).

Water temperatures in the shallower upstream areas increase more rapidly in the spring than deeper downstream areas and decrease more quickly in the fall. Stratification begins in May and maximum temperatures are reached in early August. Water temperatures below the thermocline show little increase above the winter minimum prior to the summer maximum and so remain sufficiently cool to allow trout to inhabit that region of the reservoir all year long. Dissolved oxygen concentration limits available trout habitat within and below the thermocline.

Cooling begins in mid to late August but no significant mixing occurs until October when surface waters cool sufficiently to begin sifting down and "eroding" the thermocline. Thermal stratification persists into December and chemical stratification may not disappear entirely until early January (Mullan et al, 1970).

After turnover is completed, Bull Shoals Reservoir is a cold, oxygenated, homogenous mass of water. As seasonal warming takes place, density stratification results in inhibition of vertical mixing while horizontal water movements become more pronounced. With a thermocline established, movement of water through the reservoir is accomplished primarily by exchanges below the thermocline. At this time the volume of trout habitat starts to shrink with the initial loss in the shallower upper end of the reservoir proceeding in the direction of the dam. Dissolved oxygen reductions in the hypolimnion continue until fall turnover.

METHODS

Three hydrological factors were investigated to determine their relationship and degree of influence on quantity variations of trout habitat in the reservoir. These factors were 1) release (Fig. 11), 2) inflow from Table Rock Dam (Fig. 12) and, 3) inflow from the local watershed (Fig. 13). All 3 are directly related to rainfall (Fig. 14) but express the effect on trout habitat from 3 different angles.

Dissolved oxygen and temperature collections were obtained by personnel from the U.S. Fish and Wildlife Service, South Central Reservoir Investigations, Fayetteville, Arkansas with a Yellow Springs Instrument Company Model 54R oxygen meter. Stations for the collections were at Corps of Engineer point markers 35, 33, 26, 24, 21, 18, 9 and 1 (Fig. 1). Rainfall, inflow from Table Rock Dam and release data were obtained from the U.S. Army Corps of Engineers. Inflow from the watershed was calculated as the difference between total inflow and release corrected for leakage and evaporation.

Release Data

Following thermal stratification, hydroelectric generation releases from Bull Shoals Dam begin to preferentially remove the oxygenated winter stored water of the hypolimnion. For this reason, release data were summed May through October of each year to express quantitative removal of trout habitat during the period of definite chemophysical reservoir stratification (Fig. 11).

Table Rock Inflow Data

Referring to Figs. 2 through 10, inflows from Table Rock Dam form an oxygenated density current in the upstream main channel of Bull Shoals Reservoir, entering the hypolimnetic zone above station 35 as a density interflow. From August through October, dissolved oxygen concentrations in the mid reservoir region of the hypolimnion are generally low. The density interflow gradually loses velocity and the original density and dissolved oxygen concentration are modified by dilution. During summer months physical aeration of Table Rock discharges passing through Lake Taneycomo is retarded by increased biochemical oxygen demand. Table Rock Dam inflow data were compiled January through December each year, since after Table Rock Reservoir has recirculated, suspended nutrient materials from these inflows are added to the upstream end of Bull

Shoals. The exchange of hypolimnetic water through Bull shoals Reservoir is closely tied to inflow from Table Rock Dam; on an annual basis the 2 values are approximately equal. Inflows from Table Rock Dam account for between 75% and 80% of the total inflow into Bull Shoals Reservoir.

Watershed Inflow Data

Bull shoals watershed inflow data were summed January through October each year to account for enrichment of the reservoir by persistent influx of organic materials from the watershed below Table Rock Dam (Fig. 13). The influence here is complex because some consideration should be given intensity of precipitation periods and duration of preceeding dry periods.

RESULTS AND DISCUSSION

The critical period for trout survival in the reservoir each year is late October when maximum time has been given factors reducing the volume of trout habitat before the epilimnion cools and begins to mix into the hypolimnion, carrying dissolved oxygen and eroding the thermocline. Figs. 2 through 10 show that a similar pattern developed each year. The shrinking mass of potential trout habitat tends to be congregated 30 m deep (which is approximate penstock intake depth) in the downstream area of the reservoir. The minimum thickness of October trout habitat ranged from 3 to 30 m at station 1 during the study period.

Fig. 3 shows that thermal stratification was broken and trout habitat extended to the surface by October 1964. By mid October in the years 1965, 1970, and 1971 the entire surface had cooled below 21≤C and had mixed to various depths (Figs. 4, 7 and 8). In October 1973 surface temperatures in the lower half of the impoundment had dropped below this reading.

Large water masses are seen in the shallower upper end of the reservoir which meet requirements for trout habitat (Figs. 2-10). This area lying between stations 24 and 35 represents oxygenated generation flows from Table Rock Dam which pass through Lake Taneycomo and enter Bull Shoals as an underflow changing to interflow between stations 26 and 33, beyond which the interflow looses its identity.

The October mean vertical depth of potential trout habitat in the hypolimnion at station 1 was 1/m. Extremes were 0 m in 1973 and 30 m in 1965. The October trout habitat extended past station 7 in years 1965, 1969 and 1970; the lines of all other years (excluding 1973) do not reach station 7 but readings indicate that adequate dissolved oxygen levels faded out not far below there.

The receding pattern for 1972 (Fig. 9) was slightly atypical. Trout habitat at the 30 m depth had been lost by October, however an area near station 1 3 m thick was isolated at 12 to 15 m depth. In 1971 and 1972 rainfall (Fig. 14) was well below average allowing increased accumulation of organic materials in the watershed. Concievably, the influx of these materials in 1972 attributed to increased biological oxygen demand and consequent degradation of the winter stored trout habitat that year and again in 1973.

By mid August 1973 Bull Shoals still contained a large volume of trout habitat about 30 m thick near the dam that extended uplake to station 35. One month later this was reduced to a band averaging 5 m thick and extending uplake to station 21 with dissolved oxygen concentrations just adequate to support trout. By the time of the next sample in mid October the hypolimnion contained little dissolved oxygen with a majority of readings below 2.0 mg/ l. Although the surface temperature upstream from the dam to station 21 had cooled to 21C from the surface to 15 m deep, the trout were isolated from this zone by about 15 m of water very low in dissolved oxygen. The low dissolved oxygen concentration in the upstream area of the reservoir indicated that by August Table Rock Dam releases also contained low levels of dissolved oxygen concentrations.

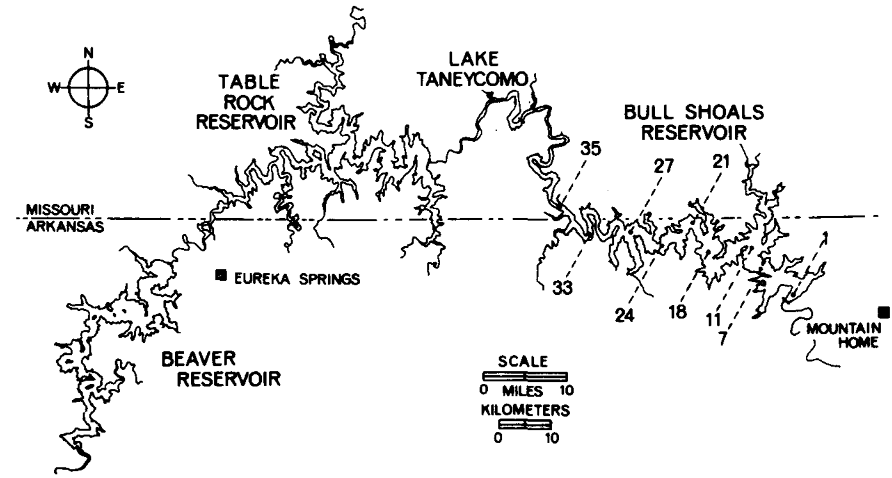

Fig. 1. Bulls Shoals Reservoir dissolved oxygen-temperature profile sampling stations..

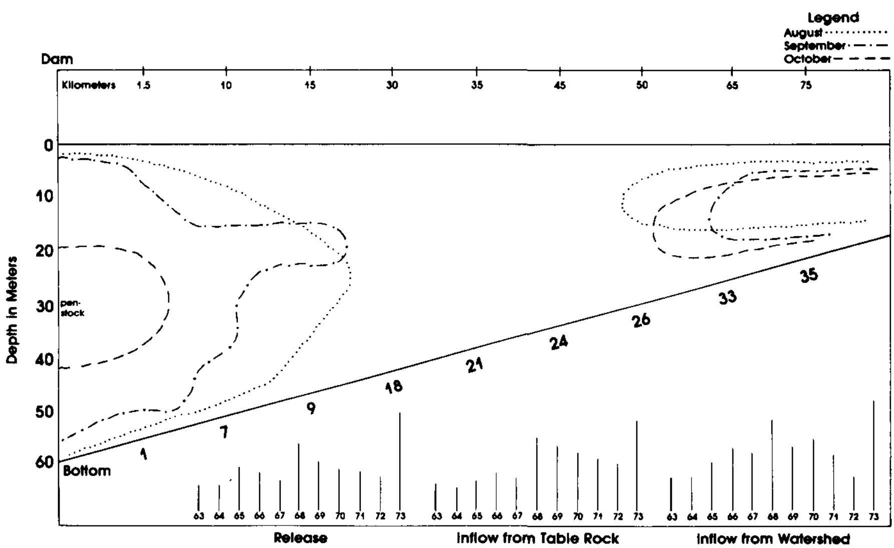

Fig. 2. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1963.

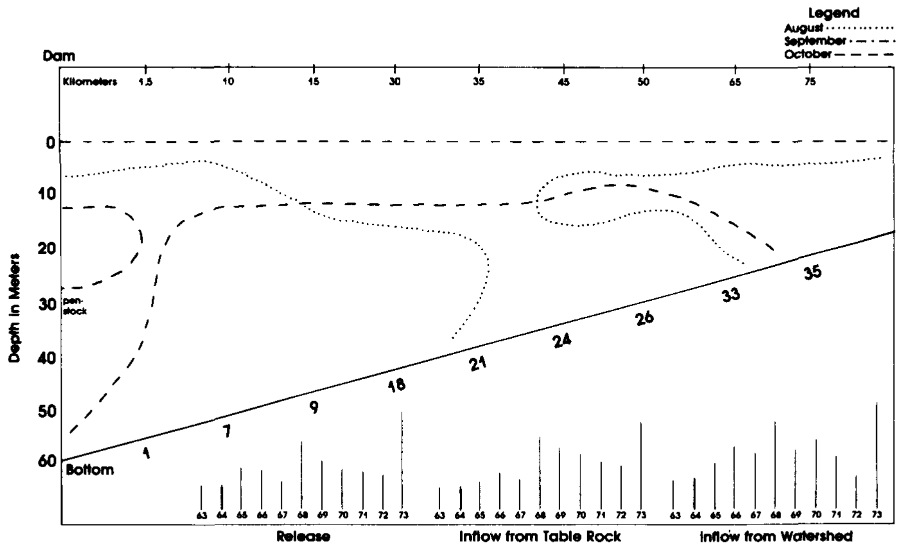

Fig. 3. Potential Trout Habitat, Bull Shoals Reservoir, August, October 1964 (Sept. data not available).

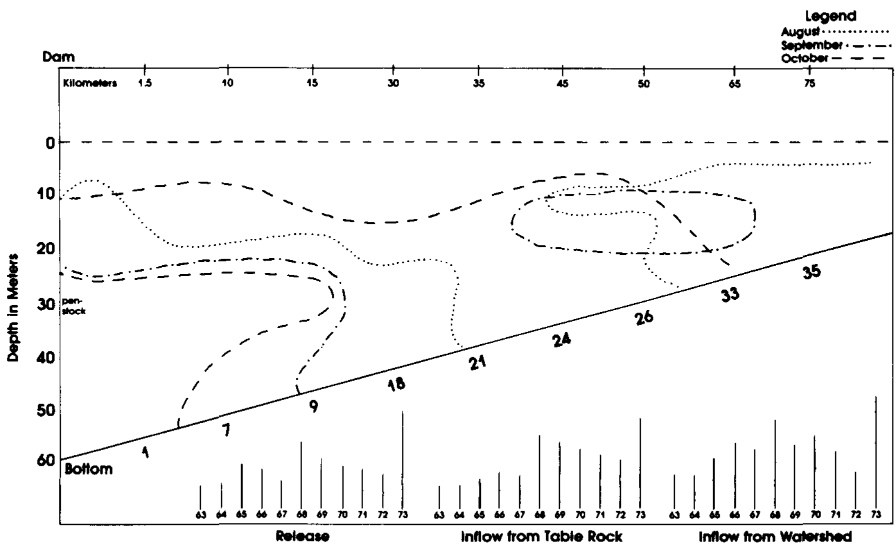

Fig. 4. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1965.

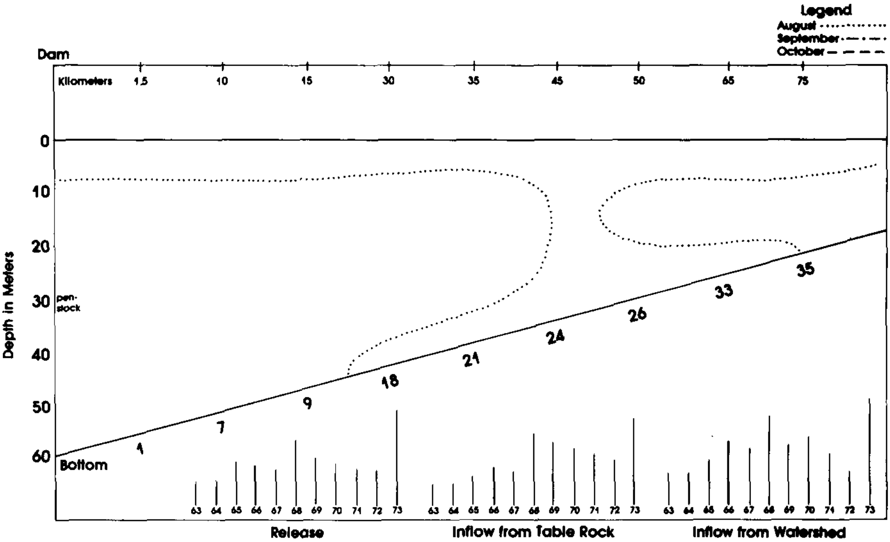

Fig. 5. Potential Trout Habitat, Bull Shoals Reservoir, August 1966 (Sept. and Oct. data not available).

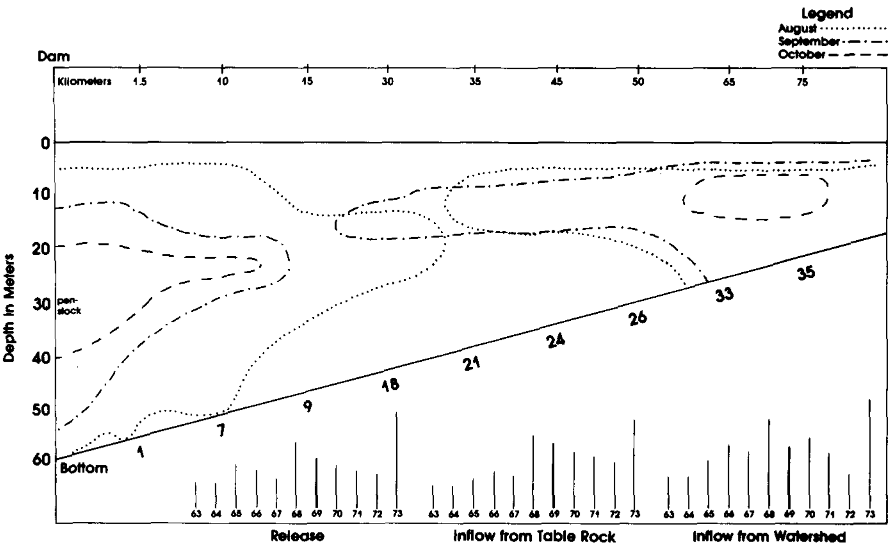

Fig. 6. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1969.

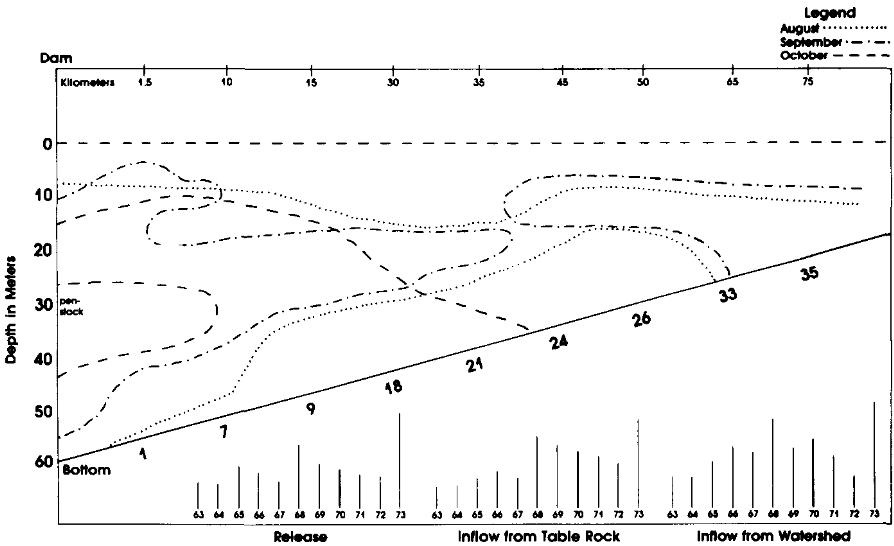

Fig. 7. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1970.

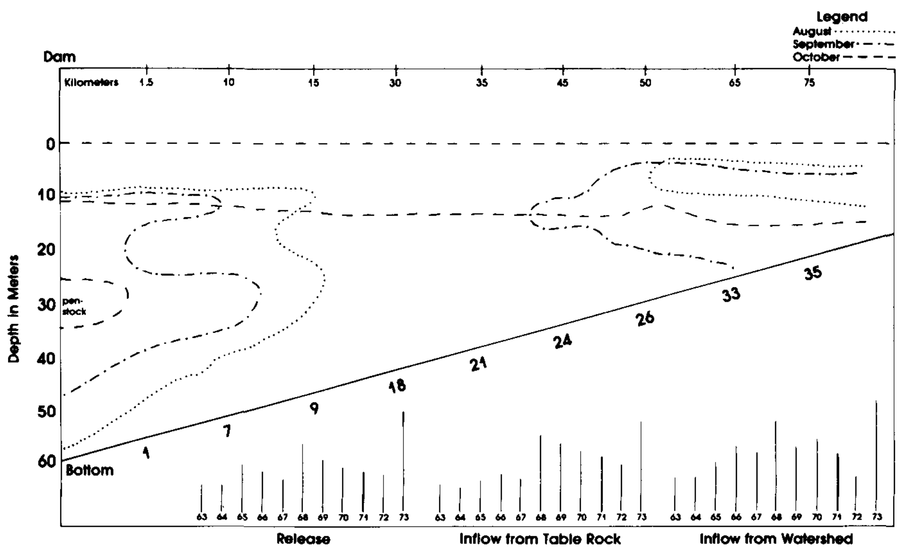

Fig. 8. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1971.

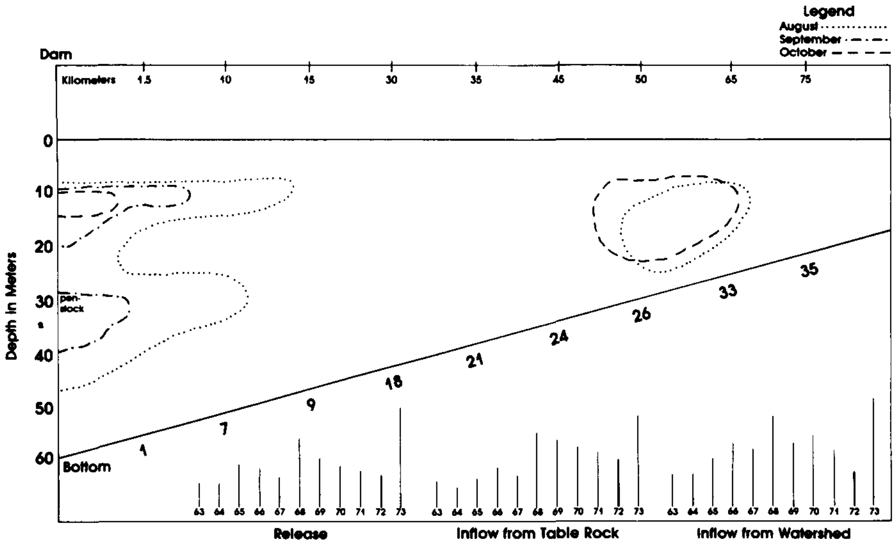

Fig. 9. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1972.

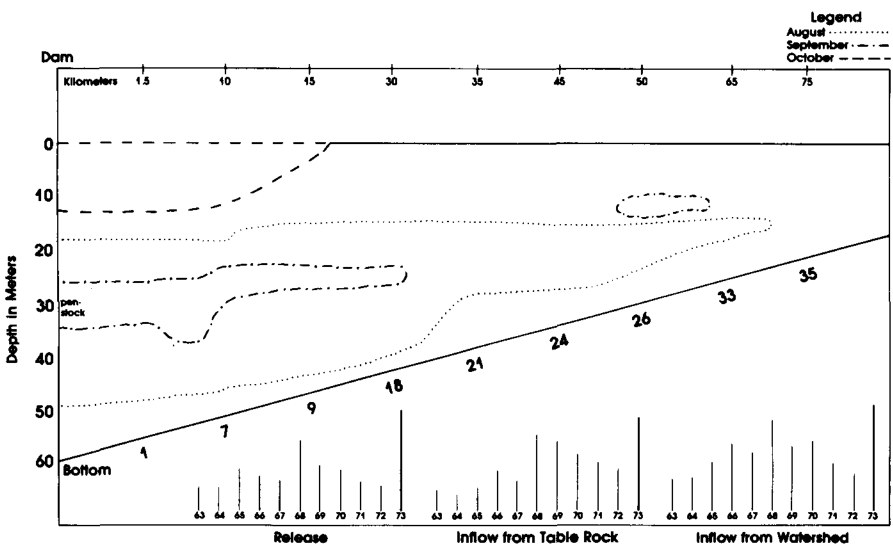

Fig. 10. Potential Trout Habitat, Bull Shoals Reservoir, August, September, October 1973.

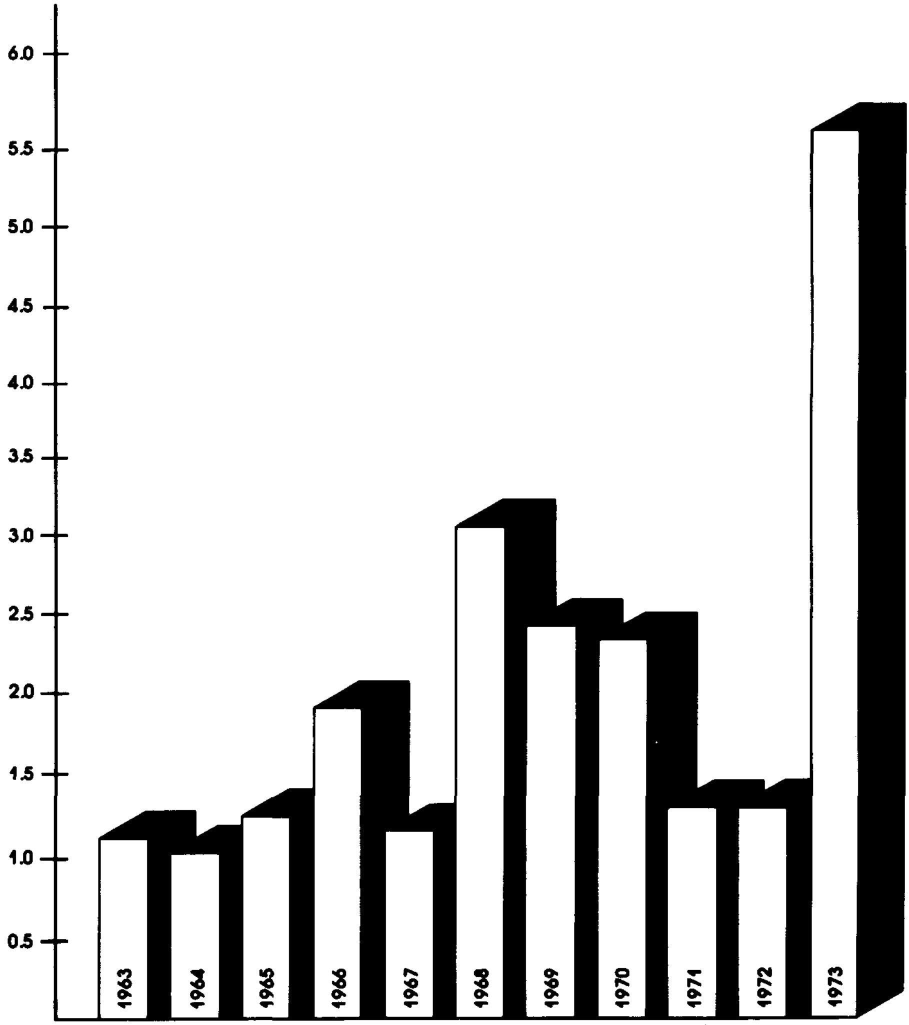

Fig. 11. Release May-October x10^9 cubic meters.

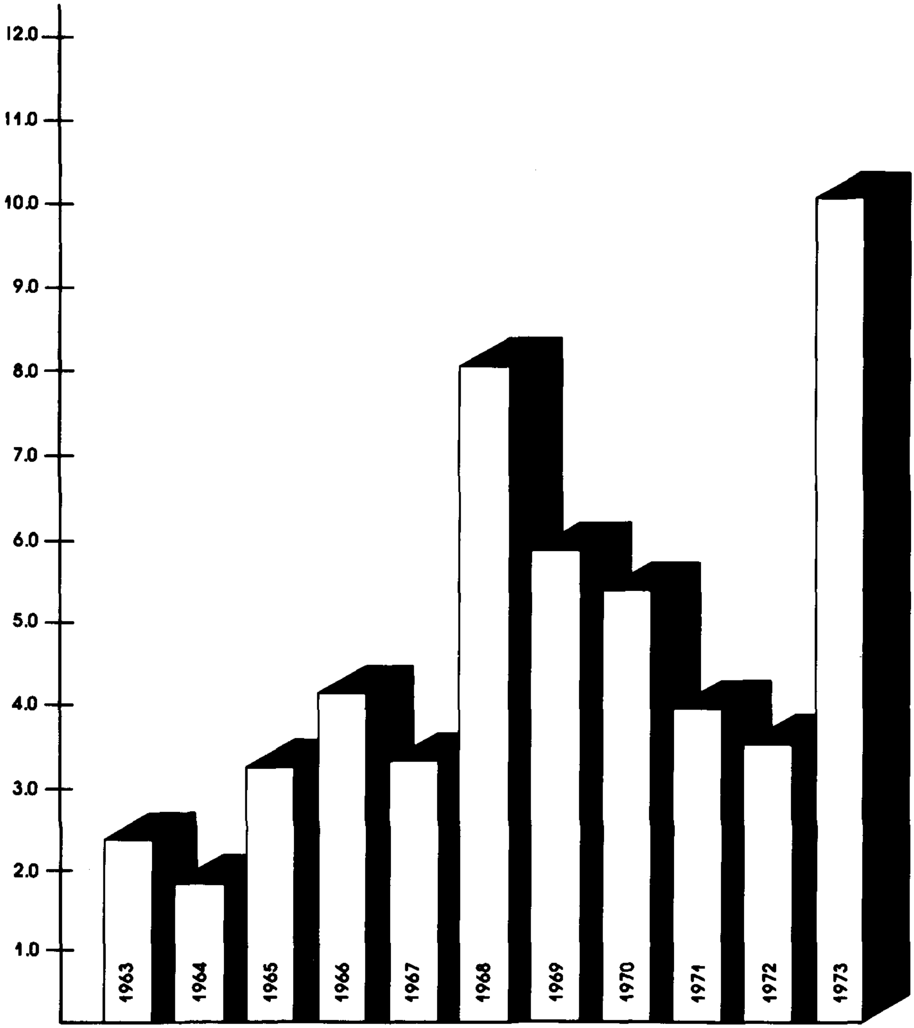

Fig. 12. Inflow from Table Rock Dam January-December x 10^9 cubic meters.

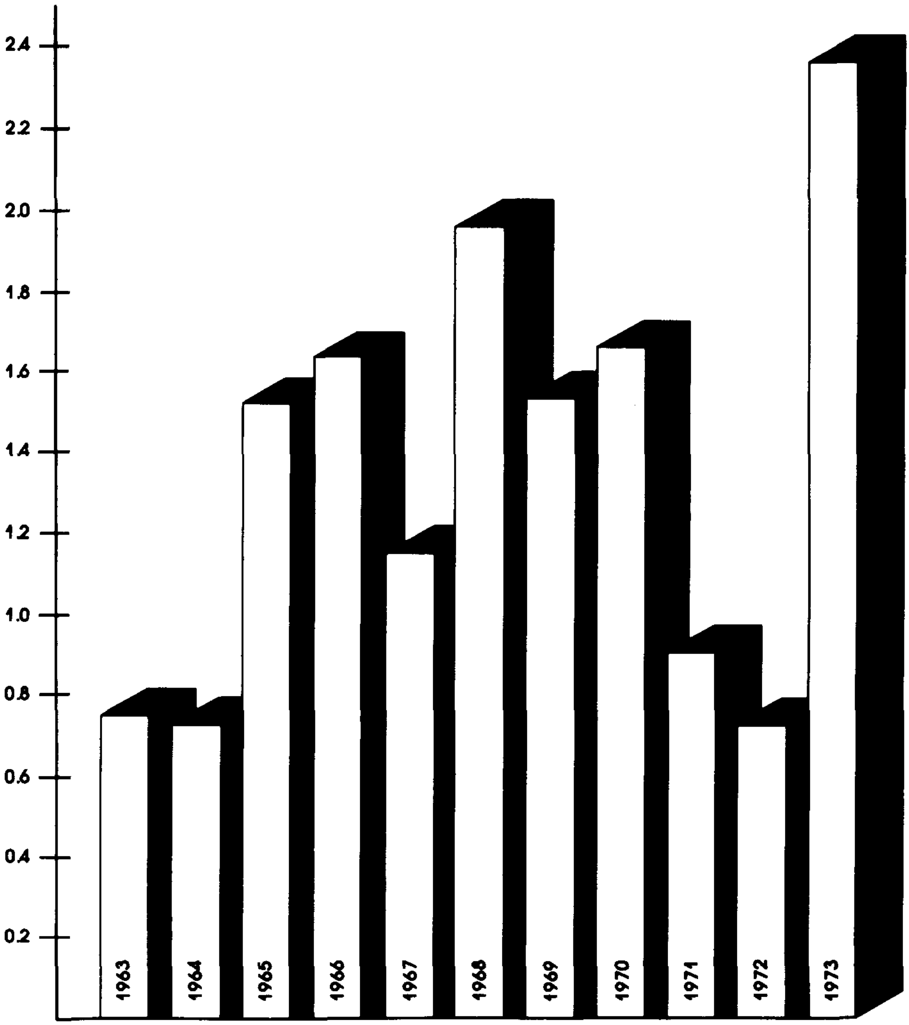

Fig. 13. Inflow from Watershed January-October x 10^9 cubic meters.

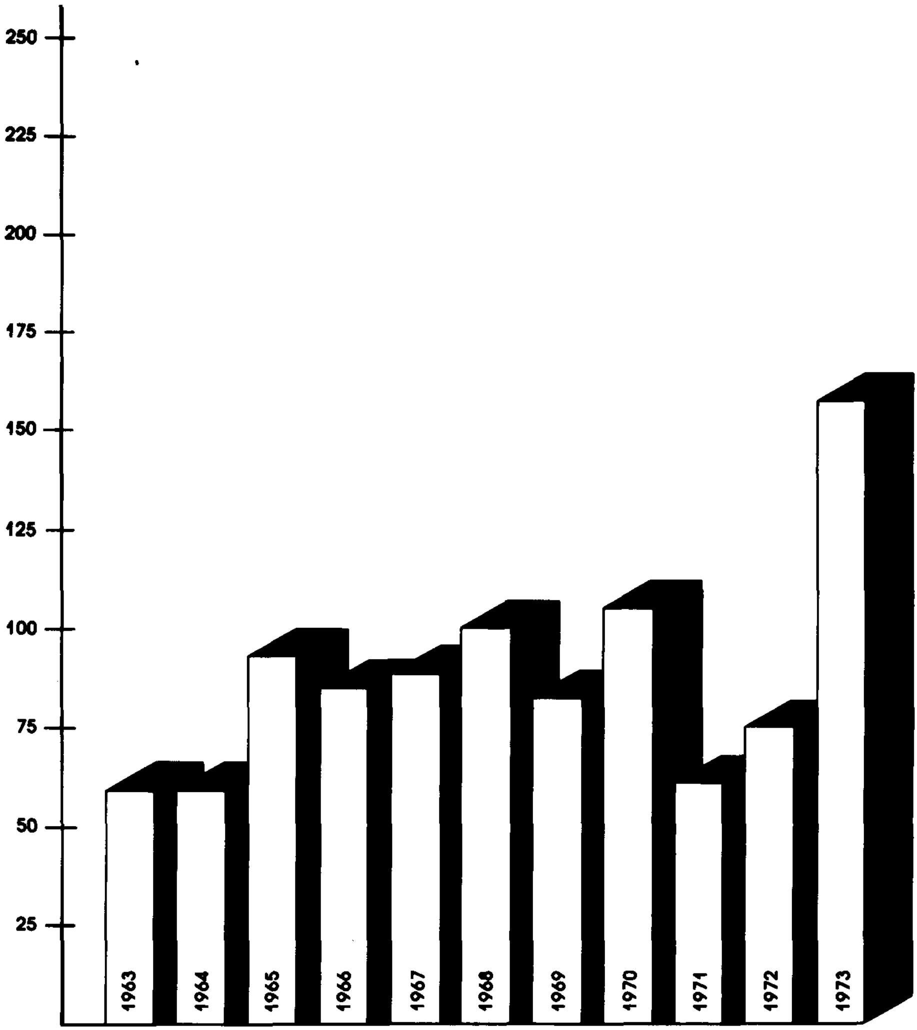

Fig. 14. Rainfall January-October in centimeters.

Releases from Bull Shoals Dam for the period May through October 1973 (Table 1, Fig. 10) were high and contributed to loss of trout habitat by discharge of the hypolimnion. Along with increased biological oxygen demand and inflow of anoxic water a critical situation was created; the loss of trout habitat was perhaps 6 weeks ahead of average for the study period. For the first time since rainbow trout were introduced, Bull Shoals Reservoir was briefly without trout habitat and dead or moribund trout were observed floating on the surface in the lower area of the reservoir (personal observation).

TABLE 1. Bull Shoals Reservoir Flow Data, 1963-1973.

Year	Rainfall centimeters	Release $x10^9$cubic meters	Inflow from Table Rock $x10^9$cubic meters	Inflow from Watershed $x10^9$cubic meters
1963	61.0	1.17	2.28	0.75
1964	61.0	1.05	1.79	0.74
1965	95.3	1.30	3.21	1.54
1966	86.4	2.04	4.19	0.43
1967	91.4	1.11	3.21	1.17
1968	101.6	3.80	8.26	1.99
1969	83.8	2.47	5.92	1.55
1970	106.7	2.34	5.43	0.44
1971	62.2	1.37	4.07	0.93
1972	77.5	1.37	3.45	0.74
1973	161.3	5.61	10.36	2.41

LITERATURE CITED

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