TAILWATER FISHERIES OF LAKE OF THE OZARKS AND POMME DE TERRE LAKE, MISSOURI

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Abstract: The tailwater fisheries of Lake of the Ozarks and Pomme de Terre Lake were measured by a part-time roving creel survey from 1965 through 1974. Catch rates of fishes were compared with temperature, conductivity and dissolved oxygen, but no significant correlations were found. However, high positive correlations existed at Lake of the Ozarks tailwater between annual average catch rates and the annual average discharge of water, and also between preceding mean monthly discharges and following monthly catch rates. There was also a high positive correlation between estimated number of fishes caught in this tailwater and the number of days per year that the flood gates were open. At Pomme de Terre tailwater, there was a high positive correlation between discharge and catch rate for monthly, seasonal, and annual periods. Anglers at the Lake of the Ozarks tailwater had short periods of outstanding angling, longer periods of good fishing and intermittent periods of poor fishing, while anglers at Pomme de Terre tailwater had shorter periods of good success and much longer periods of poor fishing. Manipulation of discharges might prolong and enhance fishing success below dams. Structures that cause deepening of tailwater pools and induce water current eddies would also benefit angler success.

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Tailwaters, the portion of a stream directly affected by the water discharge through or over a dam, often support very important fisheries. At times, the quality and quantity of angling in them exceeds that for the reservoir (Fogle and Shields 1961, Miller and Chance 1954). Factors affecting tailwater fisheries have not been well documented so this study was initiated to determine the relationships between the quality of tailwater fisheries and water depth, temperature of the discharge, and the water discharge regime.

G. D. Green and B. P. Summers collected the data at the Lake of the Ozarks tailwater and R. G. Fishback, R. D. McCoy, H. G. Banks, and M. McCoy collected data at the Pomme de Terre tailwater. Financial aid was provided through the Dingell-Johnson Program (Project F-1-R, Missouri).

MATERIALS AND METHODS

This study was conducted on the Lake of the Ozarks tailwater, below a mainstem reservoir, and Pomme de Terre tailwater, below a tributary stream reservoir (Fig. 1). The downstream boundary of the tailwater areas was established by delineation of fishing activity.

Lake of the Ozarks Tailwater

This tailwater was designated as the 25 ha area between the 68 m safety zone immediately below the dam to about 1.2 km downstream. The water discharged from Lake of the Ozarks, a 24,282 ha power production reservoir owned and operated by Union Electric Company, is released from slightly below the typical mid-summer thermocline depth and is cool (usually less than 18 C). At normal pool, (201) m msl), water discharge can vary from 12.7 m^3/s to 5,176 m^3/s (if all 12 flood gates are open and all 8 turbines are operating).

Pomme de Terre Tailwater

The size of this tailwater study area was increased from 2.2 to 4.9 ha in 1969 after the Corps of Engineers extended their access road downstream. Therefore, the area included the stilling basin below the dam downstream to the end of an access road. Water was originally released from Pomme de Terre Lake, a 3,165 ha flood control reservoir built and maintained by the Kansas City District of the Corps of Engineers, through a tunnel gate located at the bottom of the reservoir. However, in 1971, the Corps of Engineers modified the discharge tower so that water was released from about the depth of a typical mid-summer thermocline. Discharges can vary from 1.4 to 170 m^3/s and are largely dependent upon flood control considerations (e.g. downstream water levels and flood control pool).

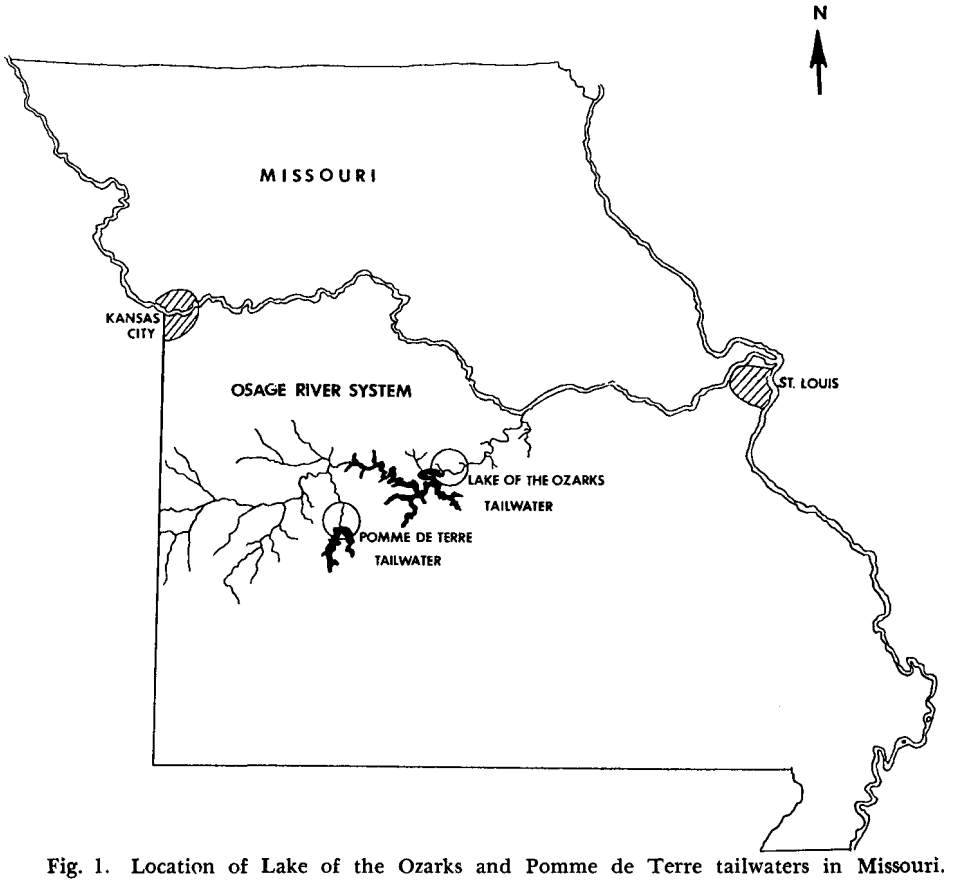

Fig. 1. Location of Lake of the Ozarks and Pomme de Terre tailwaters in Missouri.

Procedures

Pole-and-line fish harvest in the tailwater areas was estimated each year, 1965 through 1974, from 1 March to 30 November. A creel clerk made fisherman counts and interviewed anglers on randomly scheduled days. The clerks worked approximately 7 days/mo, except in 1974, when the schedule was extended to about 11 days/mo. Since most fishing occurred on weekends, the work schedule was stratified so that half of the weekend days were sampled. Holidays were considered as weekend days. The creel survey methods used were developed and described by Kathrein (1953) and later modified by Fry (1962).

The clerk counted all fishermen in the tailwater area each morning and afternoon, then spent the remaining time (8 hrs total) interviewing anglers to ascertain species and sizes caught, time fished, residence, and other pertinent information. The counts were considered to be an instantaneous measure of fishing activity and were randomly scheduled so that all possible daylight hours were sampled. Night fishing activity was not sampled nor estimated.

Hours fished were estimated by multiplying the average daily angler count by the average length of the day surveyed and the number of days in the survey period (spring, summer and fall). The number of fish caught was estimated by multiplying the hours (fished from above) times the catch rate (from empirical interview data). The number of fishing trips was estimated using only information from those fishermen who had completed their fishing trip. Data from week and weekend days were analyzed separately and then combined to obtain estimates of the total. Weight of fish harvested was estimated from length-weight graphs. Only length was measured in the field.

Reservoir water temperature, dissolved oxygen, and conductivity profiles were determined monthly from April through November 1970-1974. Measurements were usually made near mid-month but some were omitted because of inclement weather. Dissolved oxygen was measured in the tailwaters each work day with a Hach Model OX-1 kit which was accurate to the nearest 1.0 ppm. Periodic comparisons were made using the Winkler Method to check accuracy. Water discharge rates from Lake of the Ozarks were obtained from the Union Electric Company.

RESULTS

Lake of the Ozarks Tailwater

There were an estimated 302,400 fishing trips or 934,100 hrs fished in this 25 ha tailwater from 1965 through 1974. Fishing intensity ranged from 2,065 to 6,037 hr/ha/yr (Table 1), and the average number of trips/ha/yr was 1,209. Average trip length was 3.1 hrs.

Fish harvest

I estimate that fishermen harvested 1,121,300 fish in this tailwater during the study. The anglers catch included 27 species. The average catch rate was 1.2 fish/hr and was above 1.0 fish/hr in 7 of the 10 years studied (Table 1). About 48 percent of the anglers caught fish and the average annual harvest was 1,609 kg/ha/yr.

Table 1. The estimated number of fishing trips, hours fished, number of fish caught, kilograms per hectare harvested, rate of catch, and percent of successful anglers at Lake of the Ozarks tailwater, 1965-1974; averages in parentheses.

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Fishing trips	30,154	21,457 (30,236)	25,706	27,813	31,004	39,303	20,013	20,011	36,302	50,595
Hours fished	87,446	51,620 (93,412)	81,572	85,886	107,912	150,921	56,218	55,935	117,744	138,866
Hours fished per hectare	3,498	2,065 (3,737)	3,263	3,435	4,316	6,037	2,249	2,237	4,710	5,555
Number caught	66,223	27,564 (112,130)	118,372	90,751	152,324	151,131	40,594	61,591	198,800	213,961
Kilograms per hectare	646	414 (1,609)	823	1,894	2,045	3,110	346	758	3,400	2,656
Fish caught per hour	0.7	0.5 (1.2)	1.5	1.1	1.4	1.0	0.7	1.1	1.7	1.5
Percent successful	54	40 (48)	61	47	47	36	40	51	51	49

White crappies (*Pomoxis annularis*) were most frequently caught, accounting for 57 percent of the harvest. Channel catfish (*Ictalurus punctatus*), white bass (*Morone chrysops*), and carp (*Cyprinus carpio*) made up 86 percent of the catch by numbers. By weight, paddlefish (*Polyodon spathula*) accounted for 31 percent of the catch. Carp, white crappies, and channel catfish constituted an additional 46 percent.

Water regime and fish harvest

Comparisons were made between discharge values and daily, monthly, seasonal, and annual average catch rates of fishes in the tailwater. In general, there were fairly weak positive correlations between daily mean outflow and daily mean fish-catch rate. Correlations for daily values were significant to the 10 percent level or better in only 3 of 7 years (Table 2). However, when annual average discharge values were combined for all creel survey years and compared to annual average rate, there was a significant positive correlation (Table 3).

Seasonal and monthly water discharges and seasonal and monthly fish catch rates were not correlated. I tested both periods, March to November and April to October, since the latter excluded the 2 coldest months when fishing success is routinely low. Seasonal or monthly water discharge were not significantly correlated with rate for either period.

Correlations between preceding monthly mean water discharges and following monthly mean fish catch rates were significant ($P < 0.01$). There was also a positive correlation between estimated number of fishes caught and the number of days per year that the flood gates were open (Fig. 2).

Table 2. Correlation coefficients of the daily mean flow from Lake of the Ozarks and catch rate of fishes in the tailwater, 1968-1974 (April-November).

Year	*Correlation coefficient*	*Confidence level (%)*	*Degrees of freedom*
1968	0.261	10	52
1969	−0.055	Not significant	54
1970	−0.127	Not significant	45
1971	0.188	Not significant	47
1972	0.313	5[a]	53
1973	0.391	1	50
1974	0.088	Not significant	47

[a]2% level = 0.322 @ 50 degrees freedom.

Table 3. Correlation coefficients of various combinations of water discharge from Lake of the Ozarks and catch rate of fishes from the tailwater, 1968-1974.

Comparison	*Correlation coefficient*	*Confidence level (%)*	*Degrees of freedom*	*Time period*
Total annual outflow/ Annual ave. catch rate	0.730	2	8	Mar-Nov
Seasonal mean outflow/ Seasonal ave. catch rate	0.296	Not significant	28	Mar-Nov
Monthly total outflow/ Monthly ave. catch rate	0.032	Not significant	61	Mar-Nov
Monthly mean outflow/ Monthly ave. catch rate	0.031	Not significant	61	Mar-Nov
Monthly total outflow/ Monthly ave. catch rate	0.130	Not significant	55	Apr-Oct
Monthly mean outflow/ Monthly ave. catch rate	0.120	Not significant	55	Apr-Oct
Preceding monthly mean outflow/ Following monthly ave. catch rate	0.400	1	54	Mar-Nov

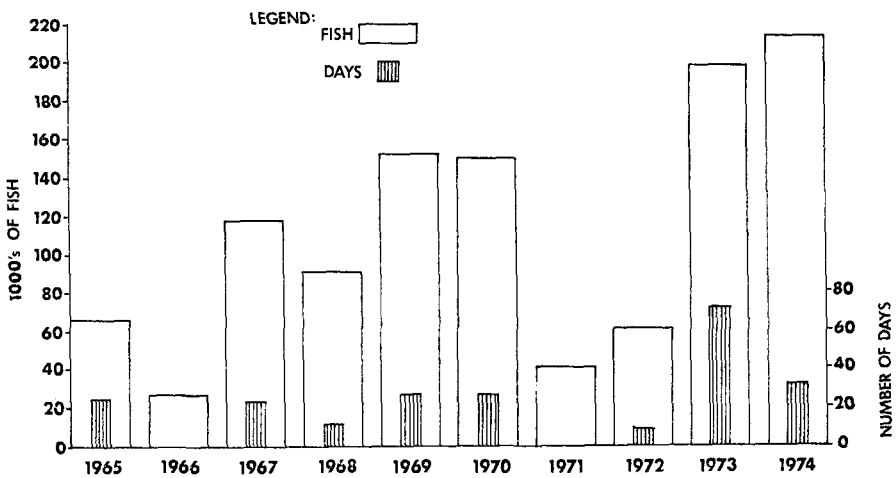

Fig. 2. The estimated number of fishes caught and the number of days per year that the flood gates were open at Lake of the Ozarks, 1965-1974.

All fishes harvested were combined in the above tests. Since paddlefish made up 31 percent of the catch by weight, I calculated the correlation coefficient between the numbers of paddlefish caught and the number of days the flood gates were open from 1965-1974. There was a positive correlation approaching the 10 percent level suggesting that paddlefish move into the tailwaters during high flows.

Chemical and physical characteristics

Monthly water temperatures in Lake of the Ozarks varied considerably between years. During May, for example, surface temperatures varied from 18 to 22 C. Typically the lake stratified thermally by July, but as early as mid-May in some years. Thermal stratification was usually most stable during July, August, and September. By mid-October the reservoir was homothermous.

Dissolved oxygen levels in the tailwater were indicative of the conditions in Lake of the Ozarks. The lowest and highest measurements made in the tailwater were 2 and 11 ppm (Fig. 3). There was a definite seasonal pattern for dissolved oxygen. During July,

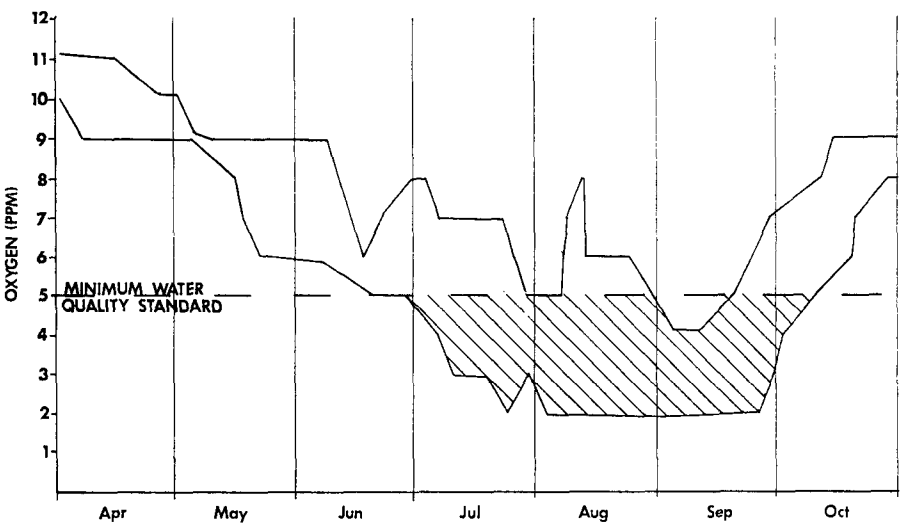

Fig. 3. Levels of dissolved oxygen (ppm) in Lake of the Ozarks tailwater, 1965-1974. Dashed line is the state of Missouri minimum water quality standard.

August, and September readings were frequently below 5 ppm, the minimum acceptable level for warm-water streams (Missouri Clean Water Commission 1973). Generally, by early October, dissolved oxygen levels in the reservoir and the tailwater were mostly above 5 ppm.

Specific conductance values in Lake of the Ozarks were relatively stable but generally increased with water depth. Surface readings ranged from about 250 to 300 micromhos and bottom values ranged from about 250 to 350 micromhos.

Fish catch rates in this tailwater were tested statistically with the water quality parameters measured, but no correlations existed.

POMME DE TERRE TAILWATER

Angling use

Anglers fished an estimated 159,000 hrs during this study. Fishing intensity ranged from 1,951 to 10,144 hr/ha/yr (Table 4). There appeared to be more hours fished per hectare per year from 1965 through 1968 than during the remaining 6 years, but I believe that the number of anglers remained relatively stable because the size of the survey area

Table 4. Estimated number of fishing trips and hours fished, number of fish caught, kilograms per hectare harvested, rate of catch, and percent of successful anglers at Pomme de Terre Reservoir tailwater, 1965-1974; averages in parentheses.

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Fishing trips	9,299 (9,326)	10,620	11,020	7,207	4,793	8,616	4,916	9,475	15,448	11,870
Total hours	22,317 (15,898)	14,868	15,905	16,495	8,346	18,291	9,558	12,923	24,045	16,231
hours per hectare	10,144 (3,224)	6,758	7,230	7,498	1,703	5,733	1,951	2,637	4,907	3,312
Number caught	8,381 (9,269)	6,929	8,090	11,537	2,624	10,558	2,515	3,698	19,824	18,533
Kg/ha	1,031 (752)	829	472	823	139	705	173	275	1,754	1,380
Fish caught per hour	0.4 (0.6)	0.5	0.5	0.7	0.3	0.6	0.3	0.3	0.8	1.1
Percent successful	42 (28)	28	28	33	16	32	15	17	32	33

increased after the U.S. Army Corps of Engineers extended the access road During the study there were an estimated 93,000 fishing trips, or a yearly average of 3,244 hrs and 1,909 trips/ha. Average trip lngth was 1.7 hrs.

Fish harvest

An estimated 92,700 fish comprising 24 species were caught in this tailwater. The average annual catch rate was 0.6 fish/h and ranged from 0.3 to 1.1 fish/h (Table 4). Angler success averaged 28 percent (range 15 to 42%) and they harvested an average of 752 kg/ha/yr.

Five species of fish accounted for about 75 percent of the number harvested; white crappies made up 35 percent, bullheads (*Ictalurus sp.*) 12 percent, freshwater drum (*Aplodinotus grunniens*) 10 percent, bluegill (*Lepomis macrochirus*) 8 percent, and white bass 8 percent. The respective percentage of catch by weight was carp 20 percent, white crappies 15 percent, flathead catfish (*Pylodictus olivaris*) 14 percent, and freshwater drum 12 percent. Several muskellunge (*Esox masquinongy*) were caught. They undoubtedly came through the discharge tunnel since they were stocked only in the reservoir.

Water regime and fish harvest

Fluctuations in fishing success in the Pomme de Terre tailwater were compared with monthly summaries of water discharge to determine whether any relationships existed. A positive relationship between the daily mean discharge and daily average catch rate of all species existed in 4 of 7 yrs (Table 5). Generally the responses of fishing success to

Table 5. Correlation coefficients of the mean daily outflow from Pomme de Terre Reservoir and the catch rate of fishes from the tailwater, 1968-1974.

Year	*Correlation coefficient*	*Confidence level (%)*	*Degrees of freedom*	*Time period*
1968	0.139	—	49	Apr-Nov
1969	0.257	10	56	Apr-Nov
1970	0.611	1	38	Jun-Nov
1971	−0.116	—	55	Apr-Nov
1972	0.376	1	50	Apr-Nov
1973	0.481	1	57	Apr-Nov
1974	0.021	—	72	Apr-Nov

changes in daily discharges were more immediate in this tailwater than at Lake of the Ozarks tailwater.

When catch rates were compared to water discharge over a longer period of time (month, season, and year) significant positive correlations were found consistently (Table 6), indicating that catch rates in this tailwater were directly influenced by increased

Table 6. Correlation coefficients of various combinations of water discharge from Pomme de Terre and the catch rate of fishes from the tailwater, 1968-1974.

Comparisons	*Correlation coefficient*	*Confidence level (%)*	*Degrees of freedom*	*Time period*
Total annual outflow/ Annual ave. catch rate	0.786	1	8	Mar-Nov
Seasonal mean outflow/ Season ave. catch rate	0.442	5	28	Mar-Nov
Monthly total outflow/ Monthly ave. catch rate	0.251	10	57	Mar-Nov
Monthly mean outflow/ Monthly ave. catch rate	0.255	10	57	Mar-Nov
Monthly total outflow/ Monthly ave. catch rate	0.433	1	45	Apr-Oct
Monthly mean outflow/ Monthly ave. catch rate	0.437	1	45	Apr-Oct
Preceding monthly mean outflow/ Following monthly ave. catch rate	0.264	10	51	Mar-Nov

discharge. Correlations were higher during April through October (1% level) than during March through November (10% level), which included 2 colder months.

Chemical and physical characteristics

The Pomme de Terre tailwater was cold throughout the summer prior to 1971 because water was discharged from near the bottom of the reservoir. In early 1971, the Corps of Engineers altered the discharge tower so that water was released from just above the average mid-summer depth of the thermocline. This change was made in an effort to improve the tailwater fishery for warm-water fishes. There was no measured or observed favorable influence, probably because by the time of year when a difference in catch could be noticed, the fishery had already been heavily exploited in this small tailwater.

Temperature profiles in Pomme de Terre Lake did not vary as much annually as did those in Lake of the Ozarks. There was a wide difference between surface temperatures and those near the bottom in Pomme de Terre, espcially in mid-summer. Surface temperatures ranged from 18 C in May up to 29 C in July, and bottom temperatures ranged from 9 C in May up to 15 C in September and October.

Oxygen profiles from Pomme de Terre Lake showed strong thermocline formation and associated chemical stratification in mid-summer. However, dissolved oxygen remained at or near saturation in the Pomme de Terre tailwater due to the plunge in the discharge tower and accompanying entrainment of air and flow through the tunnel. Dissolved oxygen values ranged from 7 to 13 ppm and never declined below the State Water Quality standard of 5 ppm for warm-water streams. There was little year-to-year variations in oxygen profiles.

Specific conductance profiles were made from May to October from 1971-1974. Values ranged from about 200 to 300 micromhos and increased with water depth.

Fish catch rates in the Pomme de Terre tailwater were tested statistically with the water quality values that were measured, but no correlations existed.

DISCUSSION

The quantity of water discharged into the tailwaters markedly affected the catch of fish. Fishing was generally good following periods of substantial discharge, but success was observed to gradually decline if there were extended periods between releases. This suggests that these tailwater fisheries were supported by emigrants from the reservoir and/or immigrants from downstream. Moser and Hicks (1970) concluded that the former were more important. Highly significant positive correlations between total annual discharges and the annual average catch rates and the preceding monthly discharge and the following monthly catch rates support this belief. Also, the catch rate was high during years of high discharge.

There was no significant relationship between temperature, oxygen, or conductivity and catch or catch rate in the Lake of the Ozarks or Pomme de Terre tailwaters. The modification of the discharge tower at Pomme de Terre in 1971 changed the tailwater from a cold-water to warm-water habitat, but that and the following year had quite low catch rates. By contrast, the best harvest occurred in 1973 and 1974 which were years of heaviest discharges.

Catch rates were more closely correlated to discharge rates at Pomme de Terre tailwater than at Lake of the Ozarks tailwater. All comparisons of water discharge and catch rate in the Pomme de Terre tailwater fishery were significant ($P < 0.1$) whereas for Lake of the Ozarks the relationship was not as pronounced. The Lake of the Ozarks tailwater also received daily power discharges that were observed to stimulate fishing whereas the smaller Pomme de Terre tailwater received heavy angling pressure only when flood pool water was periodically released and while fishing remained good. Exploitation in the Pomme de Terre tailwater was heavy when fishing was good and was soon followed by an observed decline in angling success and angler attendance.

Fogle and Shields (1961) found in a nationwide survey of 52 tailwaters, that major water level fluctuations adversely affected fishing success, but moderate fluctuations enhanced angling, especially when flow was increasing. My results were similar to those of Fogle and Shields except that in the Pomme de Terre tailwater, fishing was often best when discharge was highest. The reason for this was that water overflowed into shallow, quiet backwater areas. Fish concentrated in these areas and fishing was good. At the Lake of the Ozarks tailwater, the river banks were high and there were no quiet water areas which made angling both hazardous and relatively unproductive during periods of high floodgate discharge.

Bagnell Dam, which impounds Lake of the Ozarks, is a power producing structure and discharges varied, sometimes hourly, depending upon power demands. Because of the variable discharges, fishing success varied markedly and I believe the large daily fluctuations in discharge greatly affected the catch rate. This could not be measured because hourly discharge rates were not available and and the creel survey was not designed to estimate catch rate each hour. Nevertheless, personal observations and observations by the creel clerk revealed that anglers that regularly fished in the Lake of the Ozarks tailwater fished only when conditions looked "right" to them. However, at the Pomme de Terre tailwater, the relationship between local angler attendance and annual catch rate was significant ($P < 0.01$). This indicates that at the Pomme de Terre tailwater most of the fish were caught by local fishermen who fished only when conditions were optimum.

Miller and Chance (1954) found that tailwaters of reservoirs on tributary streams in the T.V.A. system provided only a limited number of fishing trips compared to tailwaters of mainstream reservoirs. Pomme de Terre is a tributary stream reservoir and Lake of the Ozarks is a mainstem reservoir. Pomme de Terre, because of its small size, produced fewer total hours and trips, but pressure was higher than at Lake of the Ozarks tailwater on a per ha basis. However, the catch rate and kg of fish harvested per ha at Lake of the Ozarks tailwater was double that at Pomme de Terre tailwater. The Pomme de Terre tailwater was a boom-bust fishery with short periods of good success and longer periods of very poor fishing. By contrast, the Lake of the Ozarks tailwater produced some short periods of outstanding fishing, longer periods of good fishing, and intermittent periods of poor fishing.

Good tailwater fisheries can be established and maintained for a longer period of time if flood pool waters in reservoirs could be retained and discharged at greater than minimum flows but at less than flood discharge rates. The placing of structures in tailwater areas should be considered to assist discharge waters in forming pools and eddies thus providing increased habitat diversity. These deeper areas would remain after flood discharges abated and provide additional habitat capable of holding more fish for longer periods.

Manipulation of reservoir discharge to manage tailwater fisheries below reservoirs designed for power production would be difficult unless present practices are modified. The flood storage capacity of these reservoirs, as in Lake of the Ozarks, is frequently small in relation to total reservoir size and discharge rates are varied depending upon power demands. However, if spring releases could be delayed until later when the water has warmed to the point where fish were active, more fish would probably concentrate in the tailwater and the fishery would be enhanced. Clark (1942) found that 12-21 cm of water over the spillway stimulated fish to leave the reservoir. Therefore, prolonged discharges at lesser rates might provide longer periods of good tailwater fishing.

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