THE FISHERY OF A MISSOURI RESERVOIR RECEIVING THERMAL EFFLUENT

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ABSTRACT

Thomas Hill Reservoir, built by the Associated Electric Cooperative, is located in north central Missouri in a soft coal strip-mine area. Its waters provide cooling for a steam-powered electric generating plant. Fishing pressure averaged 18.2 hours per acre per year during the study. There was a yearly average of 4.9 fishing trips per acre. Anglers averaged 3.9 fish per trip. The average yearly harvest was 21.7 fish, or 13.5 pounds per acre. About 37 percent of all fish caught were taken in the warm-water discharge area mostly during winter. The relationships between angler use, angler success, and fishing pressure and the annual average Secchi disk reading were an important finding of this study. Linear correlations calculated for these paramenters were significant to the five percent level (95 percent confidence). Another important finding of this study was that white crappies were stockpiled during 1969 and 1970, the years of very turbid water conditons, which greatly increased the catch in 1971 and 1972 when the water cleared. The winter catches of fishes in the warm-water arm of the lake were exceptionally good. In 1971, the catch from this 117 acre arm was 689.7 fish per acre. Wind, shallow water, and turbidity characterized Thomas Hill Reservoir. Wave action kept clay particles in suspension and greatly influenced shoreline development. Thomas Hill is the only large Missouri Reservoir that remains frozen through the cold season and should typify other north Missouri reservoirs scheduled for construction.

INTRODUCTION

The objectives of this study were to determine the fishing pressure, rate of fishing success, and the hook-and-line yield in Thomas Hill Reservoir, north central Missouri. Return to the creel of stocked northern pike was also measured. Since this lake was the first, large northern Missouri reservoir built in a prairie setting, it afforded a unique opportunity to study a large reservoir fishery under these ecological conditions.

MATERIALS AND METHODS

Thomas Hill Reservoir was built by the Associated Electric Cooperative in a coal strip-mine area on the Middle Fork of the Chariton River (Figure 1). The lake is situated in Macon and Randolph counties in the North Missouri glacial and loessial physiographic region draining soils of the Putnam Silt Loam, Shelby Loam, and Waverly fine Sandy Loam types (Miller and Krusekopf, 1929). Land uses include row crop farming, grazing, and soft coal strip-mining. Extensive areas are currently in soil bank type programs. The general topography is mostly gently rolling hills of low relief with timbered draws and streams. The average annual rainfall is 35 to 40 inches and the average temperature is 53° to 54°.

The reservoir was completed in 1965 and began holding water in 1966. A lakeside coal burning, power producing facility first produced electricity in December, 1966. The plant discharges heated water into a cove that was

designated for this study as the warm-water arm or Census Area 5 (Figure 1).

The main axis of the reservoir is in a north-south orientation. Therefore, the prevailing southwesterly or northwesterly winds frequently cause intensive wave action resulting in reduced water clarity. The shallow average depth of the reservoir also contributes to the turbidity caused by wind action. Soil types consist largely of very fine particles which are slow to settle out from inflowing runoff water or when stirred up along the shoreline by the waves. This gives a generally murky character to the waters of this reservoir.

The maximum depth in the old river channel is 35 feet, and the mean depth of the reservoir at 710 feet m.s.l., is 13.8 feet. At 710 feet m.s.l. the reservoir covers approximately 4,406 acres.

Thomas Hill Reservoir was divided into five areas to facilitate "instantaneous" fisherman counts for the Conservation Department's creel census study. The census areas (Figure 1) were Area 1 (1,056 acres); Area 2 (1,681 acres); Area 3 (553 acres); Area 4 (760 acres); and Area 5 (117 acres). Thus, creel census data were taken so that sections of the reservoir could be examined as they contributed to the total fishery, or information from all of the areas could be combined to represent the total harvest for the year.

The creel census began in March, 1968, and ran on a March 1 to February 28 yearly basis and was terminated in June, 1972. The year was divided into quarters: Spring, March-May; Summer, June-August; Fall, September-November; and Winter, December-February. A trained clerk censused on a one-half time basis. That is, he worked about 11 days out of 22 to 23 working days per month. The census was stratified so that one-half the weekend days, in which most fishing took place, were sampled. Holidays were treated as weekend days.

Creel census methods used were originally described by Kathrein (1953) and modified more recently by stratified sampling techniques and other updating. Field data from this study were key-punched and computer processed.

Estimated total fishing hours were calculated as the product of the average daily count times the average length of the census day times the number of days in the period. The counting period was short enough so that an instantaneous count was assumed. All five areas were counted in sequence beginning at each end of the lake alternately.

fished times the rate of catch. Empirical data were used to compute the catch rate. Only the length of completed trips was used to arrive at a figure for estimated total trips. The clerk used the time before, between and after counts to interview fishermen and inspect catches. Data from weekdays and weekend days were treated separately and then combined, for total figures. Measurements of total length of some fishes were made so that average lengths of each species were available for calculating yield by weight to the fishery for each species of fish.

RESULTS

Fishing pressure

An estimated total of 384,553 hours was fished during the census period, March 1968 through June of 1972 (Table 1). This amounted to a yearly average of 18.2 hours per acre and reflects the modest amount of fishing pressure exerted upon Thomas Hill Reservoir during this study. Average number of hours fished per acre per year ranged from a low of 7.0 in 1970 to a high of 28.4 in 1971.

Areas 3 and 4 received the lightest fishing pressure while the smallest area, Area 5 received by far the greatest. This dramatically demonstrated the influence of the warm-water discharge upon the fishery that occurred in Area 5. In this area, most of the pressure was exerted in the colder months while the other four areas were fished mostly during the warmer months. About 36.7 percent of all

fish caught during this study were taken in the warm-water area mostly during the winter.

The estimated total fishing trips during the study were 100,596 which amounted to an average of approximately 4.9 trips per acre per year from March 1968 through February 1972.

The greatest number of trips per acre was recorded from Area 5, the warm-water arm. However, the greatest number of total trips was on Area 2, which was also the largest in surface area. The total number of trips on an annual basis was much lower in 1970, a year of turbid water conditions.

The relationship between angler use and fishing success and water clarity was an important finding of this study (Figures 2 and 3). There was an apparent direct relationship between turbidity and angler trips. The lower the Secchi disk readings, the fewer the fisherman trips, and the clearer the water, the greater the angler attendance. The same pattern was evident in all five of the creel census areas with minor variations. Linear correlations between Secchi disk readings and trips per acre for Areas 1-4 were significant to the five percent level.

In comparing Secchi disk readings with average annual number of hours of fishing effort, the same relationship was apparent (Figure 3). Linear correlations between Secchi disk readings and hours fished per acre for Areas 1-4 also were significant to the five percent level.

Catch of fish

The estimated total catch of fish for the study period was 392,503 (Table 2). This averaged out to about 3.9 fish for each fishing trip during the study. The catch for 1970, the year of greatest turbidity, was noticeable, ower than for other years. The catch for 1969, another year of relatively high turbidity, would have been much lower except for bullheads and carp, both species that bite well in turbid water. These two species were exceptionally abundant in the early years of impoundment, and a portion of these year classes was still present in 1969 thus influencing the creel. By contrast the catch of channel catfish increased noticeably in 1971 and 1972. The Department of Conservation had stocked 52,000 fingerlings averaging four inches in length in December of 1969. the increased catch of channel catfish undoubtedly resulted form this stocking or recruitment from natural reproduction during the two relatively turbid water years (1969 and 1970).

Had the census continued throughout the 1972 season, March 1, 1972, through February 28, 1973, the total catch would probably have been greater than for all the other years censused combined. Angling during four months, March through June, 1972 yeilded the largest catch recorded during this study. An obvious question was what caused such a large increase in the catch, mainly of crappie. Crappies averaged nearly nine inches in length in the 1971 creel and must have been on hand in 1969 and 1970 although the crappie catch was low during those years (Table 2).

An analysis of fall netting information revealed that these crappies were, indeed, on hand in 1969 and 1970, but were growing slowly, probably due to the very turbid water conditions (8 to 12-inch Secchi disk readings). Then, in 1971 and 1972 when water transparency improved (18 to 25-inch Secchi disk readings) the crappies were able to forage better and strike the angler's lures and baits more readily. The 1969 and 1970 growth increments for these crappies were quite small, but were greatly improved in 1971 according to scale samples processed by Mr. Fred Vasey of the Department of Conservation (Table 3).

Therefore, another significant concept suggested by this study was that white crappies either recruited or already on hand during years of high turbidity may survive and can in effect become "stockpiled" to await better water, foraging, and angling conditions. This is apparently what happened at Thomas Hill

Table 1. The estimated total number of hours fished and yearly average number of hours fished per acre on the entire reservoir and on five creel census areas on Thomas Hill Reservoir, 1968 - 1972 (1972 data not included in averages).

	Area 1	Area 2	Area 3	Area 4	Area 5	Totals	Ave./Acre/Year
1968	12,946	35,222	11,900	8,700	20,076	88.844	21.3
1969	3,884	39,749	3,382	3,621	16,627	67,263	16.1
1970	1,865	9,712	1,337	2,615	13,717	29,246	7.0
1971	28,243	34,381	3,717	8,409	43,743	118,493	28.4
1972*	18,816	26,604	6,860	9,219	19,208	80,707	19.4
Totals	65,754	145,668	27,196	32,564	113,371	384,553	
Ave./Acre/Year	11.1	17.7	9.2	7.7	201.2		18.2

*1972 March through June only.

Reservoir during the course of this study.

The catch rates of fishes were considered good for Thomas Hill Reservoir during the entire period of census (Table 4). Usually, catch rates over 0.5 fish per hour are considered adequate.

Catch rates for 1970 were low and probably were a reflection of the adverse affect that turbid water had upon angling. Again, a positive correlation existed between water clarity and fishing success. Linear correlations between Secchi disk readings and catch rates were not significant to the five percent level, but they were very close.

Thomas Hill is the only large Missouri reservoir to freeze over and remain so for all of the winter census period. As a result, the clerk did not encounter a single angler during any of the years on areas 1-4. Area 5, the warm-water arm, did not freeze over and was usually 50° or warmer.

The yield in fish per acre for the five census areas and the lake-wide annual average catch per acre also revealed the effects of turbid water upon angling. The yield was exceptionally low in 1970 (Table 5). In 1972, the lake-wide yield in fish per acre during the months of March through June exceeded that of any previous year for the entire study. Obviously, clearer water conditions and an abundance of catchable size fish made this possible. White crappie, the major species in the 1972 catch, averaged nearly nine inches in length and most likely were from the 1970 year-class. This lends further support to the thesis that these fish were, in effect, stockpiled from that year and perhaps earlier.

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Warm-water fishery

One-third of the total catch of fish for the study period were taken from the smallest areas, Area 5, the warm-water arm. The majority of the fishes caught in this area were taken during the coldest months, usually December through mid-March, which illustrates the influence of heated water discharge upon the fishery of Thomas Hill Reservoir. Most of the largemouth bass taken from this area were caught during the colder months. Also, most of the recorded catch of stocked northern pike occurred during the winter in Area 5.

The apparent influx of fishes into Area 5 during winter may have been due partly because of increased plankton production. This was not measured in Area 5, but Smith (1971) found that heated effluent during winter months caused a significant increase in plankton volume in the immediate area of the discharge canal on Wilkes Reservoir in eastern Texas. Random plankton tows from the main part of Thomas Hill Reservoir during the summer of 1969 and 1970 revealed a very heavy production of plankton, particulary zooplankton, indicating the productive capability of the water.

Fish population samples obtained in Area 5 during winter revealed high numbers of small gizzard shad, apparently attracted by the heated water and,

Table 2. The estimated total numbers of each species of fish caught by anglers each year from Thomas Hill Reservoir, 1968 - 1972.

Species	Estimated Total Catch					
	1968	1969	1970	1971	1972*	Totals
White crappie	14,079	6,524	1,420	77,907	112,329	212,259
Largemough bass	32,808	7,810	3,515	17,192	8,744	70,069
Bullhead sp.	17,438	12,267	1,950	2,387	4,876	38,918
Carp	32,911	9,208	3,969	4,903	4,454	55,445
Bluegill	3,523	1,258	85	501		5,367
Green sunfish	3,433	288				3,671
Freshwater drum	123					123
Channel catfish	74	197	360	2,945	2,448	6,024
Northern pike		173	136	198	67	574
Buffalo sp.		53				53
Totals	104,389	37,728	11,435	106,033	132,918	392,503

*1972 March through June only.

Table 3. Annual average growth increments in millimeters for white crappie captured in Thomas Hill Reservoir in the fall, 1971.

Age Group	I	II	III	IV	V	VI	VII
Year Class							
1971	97						
1970	77	87					
1969	74	28	80				
1968	67	38	11	53			
1967	60	36	16	11	46		
1966	51	33	18	13	12	35	
1965	62	29	19	18	16	13	10

Table 4. The annual average catch rates (fish per hour) of fish taken by anglers on five creel census areas on Thomas Hill Reservoir, 1968 - 1972.

Year	Area 1	Area 2	Area 3	Area 4	Area 5
1968	1.47	1.06	1.37	1.02	1.13
1969	0.77	0.46	0.84	0.44	0.73
1970	0.27	0.55	0.42	0.17	0.33
1971	0.32	0.39	0.28	0.24	1.84
1972*	2.31	1.70	2.03	0.77	1.21

*1972 March through June only.

Table 5. The estimated annual catch of fish per acre from five creel census areas and the lake-wide annual catch of fish per acre on Thomas Hill Reservoir, 1968-1972. Surface acreage of each area in parentheses.

	Area 1 (1,056)	Area 2 (1,681)	Area 3 (553)	Area 4 (760)	Area 5 (115)	Lake-wide (4,167)
1968	18.0	22.3	29.5	11.6	194.7	25.1
1969	2.8	10.8	5.1	2.1	104.2	9.1
1970	0.5	3.2	1.0	0.6	39.3	2.7
1971	8.5	7.9	1.9	2.7	689.7	25.4
1972*	27.2	17.2	25.0	8.4	180.7	31.9

*1972 March through June only.

perhaps, plankton. One angler described the display on his electronic fish locator as "almost solid fish". Barkley and Perrin (1971) in studying the effects of heated effluent in Lake Catherine, Arkansas found that there was a very marked seasonal migration of several species of fish into the warm-water area in winter and a much lesser concentration in summer. Dryer and Benson (1956) found tremendous numbers of threadfin shad in the Johnsonville Steam Plant harbor near Waverly, Tennessee during winter and the abundance of the sauger and skipjack were related directly to the presence and abundance of these shad. Stomach samples of these two predators were 100 percent shad. Frey (1970) found that thermal pollution resulted in a good winter fishery for bass, crappies, and white bass in the discharge area in Lake Sinclair, Georgia. However, in June, July, and August it became apparent that fish moved out of the winter concentration areas when water temperatures rose above 90°

Not only did the warm-water discharge at Thomas Hill Reservoir serve to concentrate an abundance of fishes in a small area, about three percent of the total acreage, during the winter when normally the fishery would be at a minimum, but it kept the water from freezing thus enabling fishermen to take advantage of a unique angling situation. Concentrated fish and concentrated anglers resulted in a harvest of Area 5, in 1971 of 689.7 fish per acre.

The situation became reversed in summer when surface temperatures in this area reached 90° or greater while the rest of the lake remained near 80°. As a result, summer catches in Area 5 were quite low. Water temperatures apparently influenced fish location and abundance which, in turn, influenced angling patterns and fishermen locations and abundance. Without the warm-water discharge, the angler use patterns and total harvest in Thomas Hill would have been quite different.

Northern pike stocking

Thomas Hill Reservoir offered an opportunity to experiment with northern pike in a reservoir other than those in the southern Missouri Ozarks. Thus, it was decided to stock them as a bonus fish or trophy fish in waters close to the southern most part of their natural range. All of these fish were received from federal hatcheries as fry and reared to stocking sizes in Missouri hatcheries with the exception of the 1967 fry releases. It became apparent that fry stocking resulted in little or no survival so larger fingerling pike were released.

During the course of this study, only 574 pike were estimated to have been caught (Table 2). Most of these were caught in the warm-water area during the winter. At first, a 24 inch length limit was established, but the pike grew so

Table 6. The estimated total pounds caught in five creel census areas on Thomas Hill Reservoir, 1968 - 1972 (1972 data not included in averages).

	Area 1	Area 2	Area 3	Area 4	Area 5	Totals	Pounds/Acre
1968	13,205	29,915	12,080	7,208	18,099	80,507	19.3
1969	1,855	11,412	1,342	1,219	7,357	23,185	5.6
1970	386	5,709	416	694	5,523	12,728	3.1
1971	11,534	16,360	1,617	2,787	36,778	69,076	16.6
1972*	13,590	21,382	5,503	5,358	12,733	58,566	14.1
Totals	40,570	84,778	20,958	17,266	80,490	244,062	
Ave./Acre/Year	6.4	9.4	7.0	4.0	144.8	11.1	

*1972 March through June only.

rapidly that they reached this length before they had a chance to spawn at least once. Thus, a state-wide length limit on all pike was set at 30 inches total length in 1971. Several large pike were found dead along the shoreline during the study. Some of these showed evidence of having been hit by outboard motors. Reasons for the relatively poor return of northern pike to anglers remain unknown.

Limnological conditions

Wind, shallow water, and turbidity characterized Thomas Hill Reservoir. Wave action, although it was not measured quantitatively did, during the period of this study, noticeably change the slope and character of the affected shoreline. Banks eroded away building shallower areas as the soil was deposited off-shore. In many places it became increasingly difficult to approach the shore by boat without grounding the outboard motor in the soft bottom muds. Also, winds and wave action have precluded the establishment of shoreline aquatic vegetation. Cattails once became established only to be washed out by heavy wave action. Wave action also caused haevy damage to the road-fill crossing on Highway T (Figure 1).

The low profile of surrounding hills provided little protection from the wind which blew above 20 miles per hour (as measured by a hand-held wind meter) much of the time. The creel census clerk measured strong winds (20 m.p.h. or greater) 21 days and moderate winds (12 to 18 m.p.h.) 44 days in 101 working days from March 1, 1970 through November 30, 1970. During the same period, rain was recorded on 20 of those working days.

In 1971, a year of much clearer water, the clerk measured 16 days of strong winds and 41 days of moderate winds out of 96 that he worked from March 1, 1971 through November 30, 1971. He recorded rain on only 11 of these working days. Apparently, strong winds and rainfall were large factors in water turbidity in this reservoir when comparing these two years.

Strong winds and resulting high turbidities may adversely affect the well being and recruitment of some fishes. For example, Kramer and Smith (1962) found that the wind was the most important single factor of year-class formation of largemouth bass in Lake George, Minnesota. Wind-swept, silty waters were detrimental to successful largemouth bass nesting. They measured winds from 17.2 to 18.6 miles per hour average velocity during three, 2-day periods when bass nests were lost. Lowest egg survival in their studies occurred on sandy bottom while highest survival occurred on bottoms where needlerush, an aquatic plant, was present. Thomas Hill bottom types were hard clay, sand, and silt depending upon location. As previously stated, little emergent aquatic vegetation occurred in Thomas Hill Reservoir. Although bass nesting success was not measured during this study, it would seem that the conditions described in Lake George also exist in Thomas Hill, and in years of high winds during spawning season, these conditions might also be detrimental to largemough bass nesting success in Thomas Hill.

DISCUSSION

Turbidity in Thomas Hill Reservoir had a marked influence upon the fishery. The physical characteristics of the reservoir basin, its orientation with prevailing winds, watershed soil types, and runoff from cultivated lands were factors which caused this lake to be turbid much of the time. During periods of lesser winds, the water would clear some. However, the potential for turbid conditons was ever present and turbidity increased with strong winds. The result was decreased fishing success and angler attendance. Consequently the harvest was less. There seemed to be a certain intangible effect of turbid waters, aesthetically speaking,

upon angler attendance. Their trips were fewer and definitely of shorter duration during years of greater turbidity.

The total catch of fish from Thomas Hill Reservoir would have been much less had the warm-water discharge not been present. It served to concentrate fish and fishermen in winter when there normally would have been little, if any, angling. A large portion of the annual catch was made in this part of the lake. This warm-water fishery was probably north Missouri's number one winter fishery much of the time.

Thomas Hill Reservoir may typify other north Missouri reservoirs scheduled to be built by the U.S. Army Corps of Engineers. Each will, of course, have individual characteristics, but they will all be on prairie streams that tend to become muddy at the slightest rise and they will drain watersheds that contain considerable areas of row crop cultivation. Winds will probably cause decreased water clarity in these reservoirs. Some will be better protected by higher surrounding relief features than Thomas Hill Reservoir, and some will be oriented differently to prevailing winds. Some will have a greater average depth (13.8 feet for Thomas Hill) and steeper sides which should inhibit the wind from stirring up shallow bottom sediments. Therefore, the information acquired in this study should serve only as a base from which to anticipate the limnological conditions and fisheries of other north Missouri reservoirs built on prairie streams.

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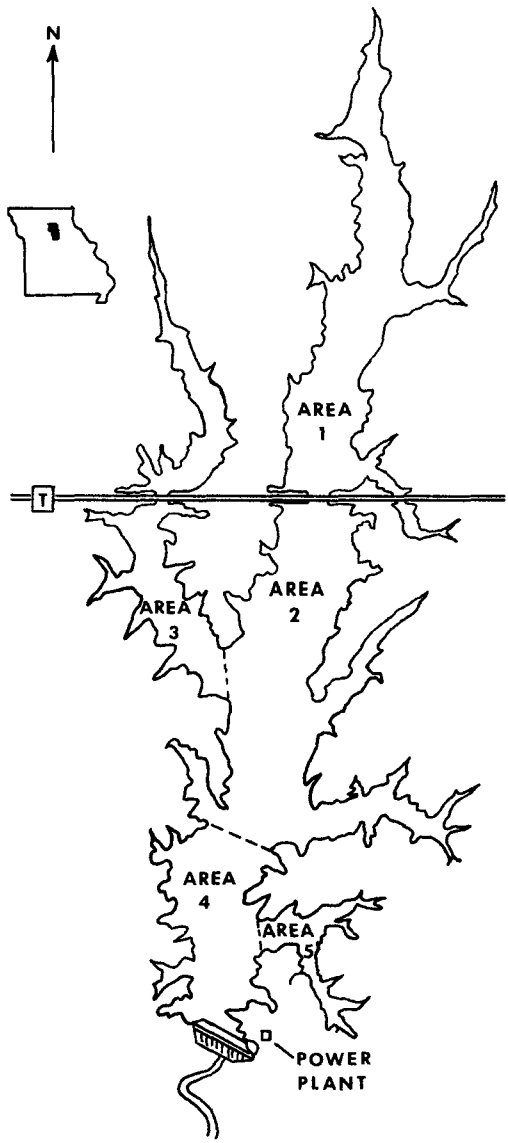

Figure 1. Creel census areas on Thomas Hill Reservoir.

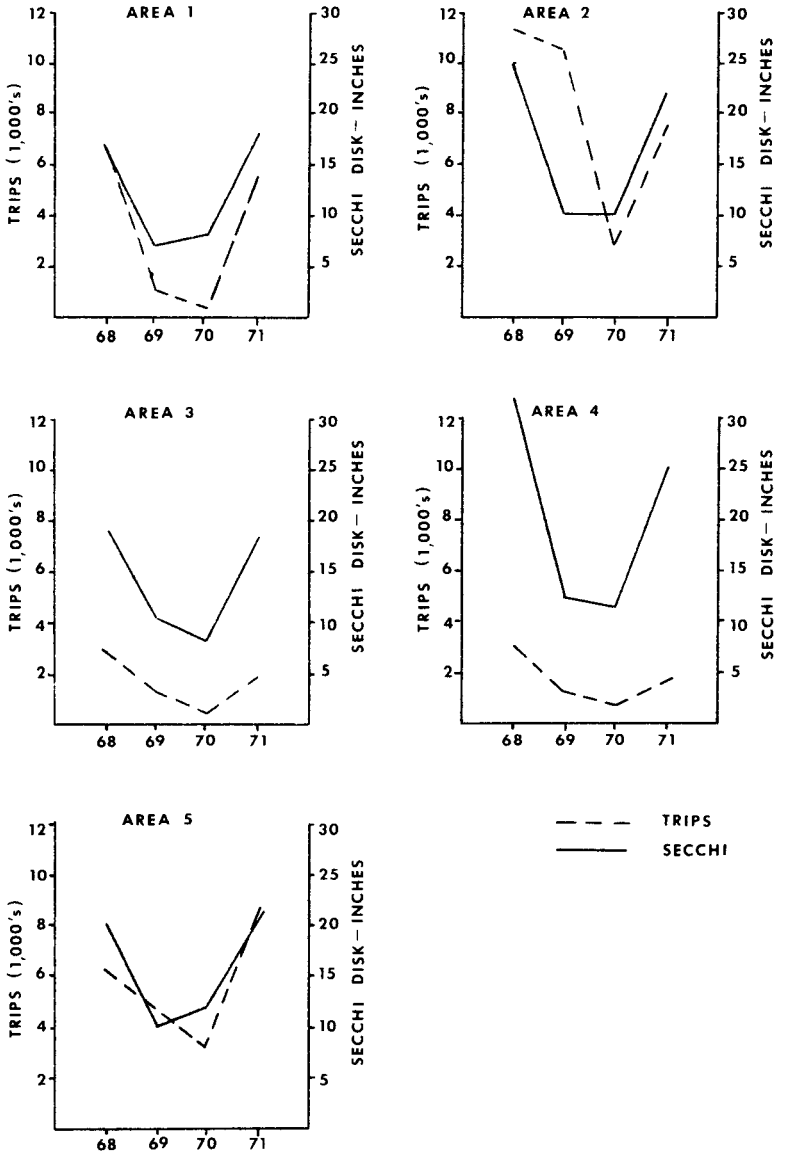

Figure 2. The annual average Secchi disk readings as compared with the annual number of estimated fisherman trips and five creel census areas on Thomas Hill Reservoir, 1968 - 1971.

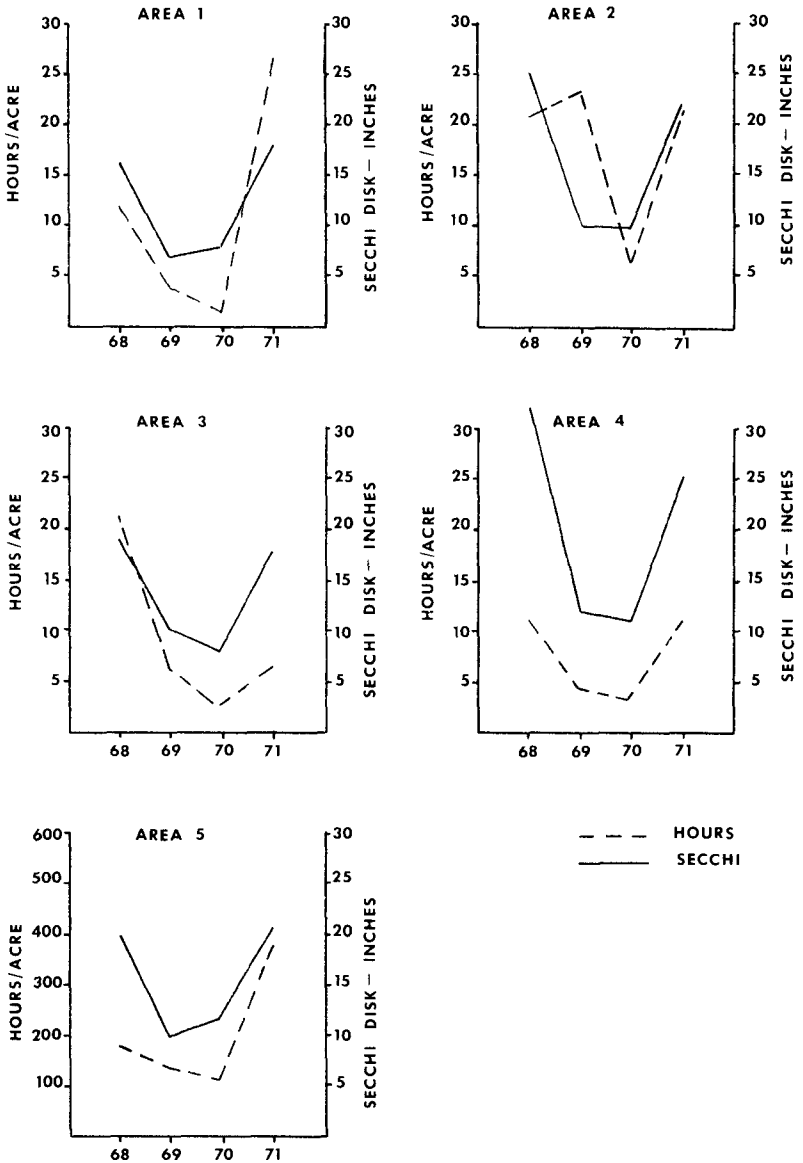

Figure 3. The annual average Secchi disk readings as compared with the annual number of hours of fishing effort on five creel census areas on Thomas Hill Reservoir, 1968 - 1971.