USE OF A RELATIONSHIP BETWEEN PRIVATE AND RENTAL BOATS TO ESTIMATE FISHING EFFORT AND HARVEST AT LEESVILLE LAKE

A Thesis

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for the Degree Master of Science

by

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PART I

INTRODUCTION

It is seldom possible to obtain absolute measures of the annual sport-fishing effort and harvest of fish at a large lake. Interviews with all anglers at the completion of fishing are precluded by the magnitude of such a fishery and its complex distribution in area and time. Consequently for research purposes or to determine specific management requirements, estimates of the total catch-effort must be projected from sample statistics.

Review of Literature

The design of sampling methods for large lakes and for streams, which present a similar problem in the form of numerous access points, has received much attention from biologists.

Moyle and Franklin (1955) and Rose (1956) developed modifications of a systematic count-and-interview method used by Tarzwell (1941) on TVA reservoirs. Rose's modification involved total counts of boats on the water and fishermen along shore every two hours throughout one half of a 16-hour fishing day. The schedule alternated between two consecutive first-half days (6 a. m. - 2 p. m.) and two consecutive second-half days (2 p. m. - 10 p. m.), omitting one day a week to allow respite for survey personnel. A subsample of anglers that had completed fishing was contacted to determine average time fished, number and pounds of fish caught per man-hour, and mean number of men per boat. Daily estimates of fishing effort in man-hours were computed as

follows:

$$\text{Total man-hours} = \frac{\Sigma \text{ of hourly boat counts}}{\text{Mean hours fished}} \text{ (2 hours)(Men per boat)}$$

Man-hours multiplied by the catch rate for each species equaled estimated daily catches of fish. Seasonal summations of the half-day effort and catch estimates then were expanded to include the uncensused days and half days of the season. Rose (op. cit.) has adapted his method for data processing by IBM 650 electronic computer, including all mathematical expansions.

Other investigators used parametric statistics as a basis for the design of sampling methods.

Regenthal (1952) used multiple regression on the assumption of a linear model to estimate the seasonal total of automobiles parked by anglers along the Logan River, Utah. Time division included ten 2-week intervals and four 4-hour daily periods, with week days and holidays treated separately to reduce variation. One hundred thirty-five 4-hour car count periods, representing 30 percent of the total periods, were distributed through the season in proportion to fishermen distribution observed in earlier investigations. The mathematical model used by Regenthal equated individual car counts to the mean car count of all periods, week effects and individual period effects. Anglers per car, mean hours fished, and catch rates of fish were obtained in concurrent interviews of a portion of the complete-trip anglers.

Several experimental designs of the analysis of variance were also

used to evaluate effects of time and area factors on mean numbers of anglers or mean catches of fish and to note interactions among the factors. Schmulbach (1958) arranged an angler count schedule in a 7 by 7 latin square with seven weekly intervals, seven days of the week, and seven 2-hour periods in the fishing day. Embody (1954) described the application of randomized complete block design to test for differences in mean catches of fish from an Idaho stream among days of the week, among periods of the season, and between consecutive seasons. Log transformation of the catch data was necessary before testing, and ultimately the mean catches were expanded to an estimate for an entire season. More recently, Bjornn (1960) used a factorial arrangement for analyzing boat counts from two Idaho lakes. He divided the season into twelve 14-day intervals, days of the week into three classes, each day into four 3-hour periods, and each lake into five areas. Fishing boats were counted by circling the lakes in an outboard motor boat during twelve counts each 14-day interval, amounting to 144 or 21 percent of the 3-hour periods in the season. The boat counts approximated a Poisson distribution and were modified by a square root transformation. A majority of the concurrent interviews for catch-rate data was made on the water before anglers had stopped fishing.

In the preceding methods, the angler count data in the form of boat parties, car parties or individual anglers generally were more amenable to statistical analysis than were the interview data. Counts of vehicles can be close to absolute for a given period, whereas the laborious interview procedure may leave considerable latitude for

judgement sampling. DiCostanzo (1955) found no statistically significant difference between catch rates obtained before and after the completion of boat fishing at Clear Lake, Iowa, but concluded that interviews on the water are quicker and less subject to bias than those made after anglers have come ashore. Similar findings were reported by Bjornn (op. cit.) who also found no significant differences in catch rates between fishing trips of short and long duration.

Statement of the Problem

A project to evaluate stocking of the Ohio muskellunge (Esox masquinongy ohioensis) in lakes of the Maskingum Watershed Conservancy District of eastern Ohio was begun in 1960. Fingerling muskellunge had been stocked in Leesville Lake each year of the period 1953-1957 by the Ohio Department of Natural Resources, Division of Wildlife. A total of 3,335 fish was stocked in the lake during the 5-year period. Some indication of returns to anglers was obtained from records kept by boat concessionaires. One concessionaire recorded five muskellunge caught by anglers in 1956 and 16 in 1957; while two concessionaires recorded 48 and 43 muskellunge for 1958 and 1959, in that order. All record keeping by concessionaires was voluntary without control of accuracy or completeness by fishery biologists.

The present study, representing one phase of the evaluation, was conducted to devise a method for estimating annual harvests of muskellunge and indigenous species from systematic catch-effort statistics. Estimates so obtained could be compared with records of the concessionaires to indicate completeness of the voluntary method.

A specific line of investigation was suggested by Conservancy District policy that concessionaires must record fishing boat rentals on printed cards. Booklets of the cards filed with the Conservancy office represented a potential way of obtaining the yearly fishing effort of a sizable segment of the fishermen population. Furthermore it was believed that numbers of private boats or private-boat hours might be estimated from known numbers of rental boats if a numerical relationship could be demonstrated between the two kinds of boats.

The specific objectives of the present study therefore were as follows: 1) to determine the extent of an expected relationship between numbers of private and rental fishing boats and the effects of time of sampling on boat distribution; and 2) to use the expected relationship and time effects for estimating total man-hours of fishing by boat anglers and the numbers of muskellunge and other species caught annually.

PART II

EXPERIMENTAL PROCEDURE

The procedures of this study involved collection and analysis of three kinds of data: counts of private and rental boats observed on the lake, interviews of private- and rental-boat anglers engaged in fishing, and boat-rental records from the Conservancy office.

Boat-count Method

Paired observations of private and rental boats were obtained to measure the degree of relationship between types of boats and the effects of time of sampling on boat numbers. Three time intervals were considered including week, day of the week, and hour of the day.

Time arrangement.--Weeks and hours of the boat-count schedule were systematically arranged as shown in Tables 1 and 2. The first week was picked at random from the month of April and every third week was scheduled thereafter through the week of October 23-29. An earlier start in March when fishing often had commenced in other years was prevented by late ice cover in 1960. Five hourly periods were arbitrarily designated for counting boats within each survey day allowing 2-hour periods between counts for interviewing anglers. Selection of the first count at 8-9 a. m. omitted the early morning for a more practicable work arrangement with part-time survey personnel. Boats were counted on all seven days within each of the ten survey weeks.

Arrangement of the counts every third week was intended to reveal a seasonal trend in boat fishing intensity. The systematic layout,

TABLE 1. Weekly boat-count and interview schedule followed at Leesville Lake in 1960

Month	Survey week[1]	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
April	-	10	11	12	13	14	15	16
"	1	17	18	19	20	21	22	23
"	-	24	25	26	27	28	29	30
May	-	1	2	3	4	5	6	7
"	2	8	9	10	11	12	13	14
"	-	15	16	17	18	19	20	21
"	-	22	23	24	25	26	27	28
May-June	3	29	30	31	1	2	3	4
June	-	5	6	7	8	9	10	11
"	-	12	13	14	15	16	17	18
"	4	19	20	21	22	23	24	25
June-July	-	26	27	28	29	30	1	2
July	-	3	4	5	6	7	8	9
"	5	10	11	12	13	14	15	16
"	-	17	18	19	20	21	22	23
"	-	24	25	26	27	28	29	30
July-August	6	31	1	2	3	4	5	6
August	-	7	8	9	10	11	12	13
"	-	14	15	16	17	18	19	20
"	7	21	22	23	24	25	26	27
August-September	-	28	29	30	31	1	2	3
September	-	4	5	6	7	8	9	10
"	8	11	12	13	14	15	16	17
"	-	18	19	20	21	22	23	24
September-October	-	25	26	27	28	29	30	1
October	9	2	3	4	5	6	7	8
"	-	9	10	11	12	13	14	15
"	-	16	17	18	19	20	21	22
"	10	23	24	25	26	27	28	29
October-November	-	30	31	1	2	3	4	5

[1]These numbers are used to identify the ten survey weeks in the remaining tables and text.

TABLE 2. Daily boat-count and interview schedule followed at Leesville Lake in 1960

Hour	Activity	
8- 9 a. m.	counts	-
9-10 a. m.	-	interviews
10-11 a. m.	-	interviews
11-12 a. m.	counts	-
12- 1 noon	-	interviews
1- 2 p. m.	-	interviews
2- 3 p. m.	counts	-
3- 4 p. m.	-	interviews
4- 5 p. m.	-	interviews
5- 6 p. m.	counts	-
6- 7 p. m.	-	interviews
7- 8 p. m.	-	interviews
8- 9 p. m.	counts	-

however, allowed a measure of variation only among survey weeks. For a complete statistical measure of variation and trend it would have been necessary to randomly distribute hourly counts within all ten of the 3-week intervals shown in Table 1. The latter plan was impracticable with the amount of time and money that could be made available.

Two men were hired on a part-time basis to count boats and interview anglers. On each survey day, one man worked from 8 a. m. until 5 p. m. while the other worked from 5 p. m. until 9 p. m. By alternating between the 9-hour and 4-hour parts of the day, they were able to work 42 hours each during the survey week, exclusive of one hour for lunch between 12 noon and 2 p. m.

Counting procedure.—Fishing boats were counted by traveling the 8-mile length of the lake in a small boat equipped with outboard motor. Pleasure boats were identified by the absence of people with fishing gear and were excluded from the counts. Counting trips lasted between

45 minutes and one hour, corresponding to the hourly count periods designated in the schedule. Rental and private boats observed each day were tallied separately in order of appearance on standard field sheets. Use of binoculars increased accuracy of observation and identification of boat type. To enable measurement of possible areal variation in the proportions of rental and private boats, the lake was divided into zones A, B and C. Care was taken to record observations in the correct zone columns of the field sheet as the observation boat moved down the lake.

Observation from the water was necessary because of the physical nature of the study area. Leesville Lake is a greatly elongated, 1,000-acre impoundment situated in densely wooded hills of Carroll County (Figure 1). Automobile routes between access areas are long and indirect, and only a small sector of lake can be seen from any point on land. It was therefore unfeasible to count boats from vantage points along shore as described by Rose (op. cit.) for Spirit Lake, Iowa.

Boat-contact Method

Boat anglers were interviewed on the water primarily to obtain catch-rate data which were needed to estimate total fish harvest. The interviews also provided data for computing mean hours fished and mean numbers of anglers per boat which were needed to estimate total fishing effort. Essential catch-effort data recorded from each boat party contacted were as follows: 1) time started to fish and time of the contact for obtaining hours fished; 2) numbers of anglers; and 3) numbers and kinds of fish caught.

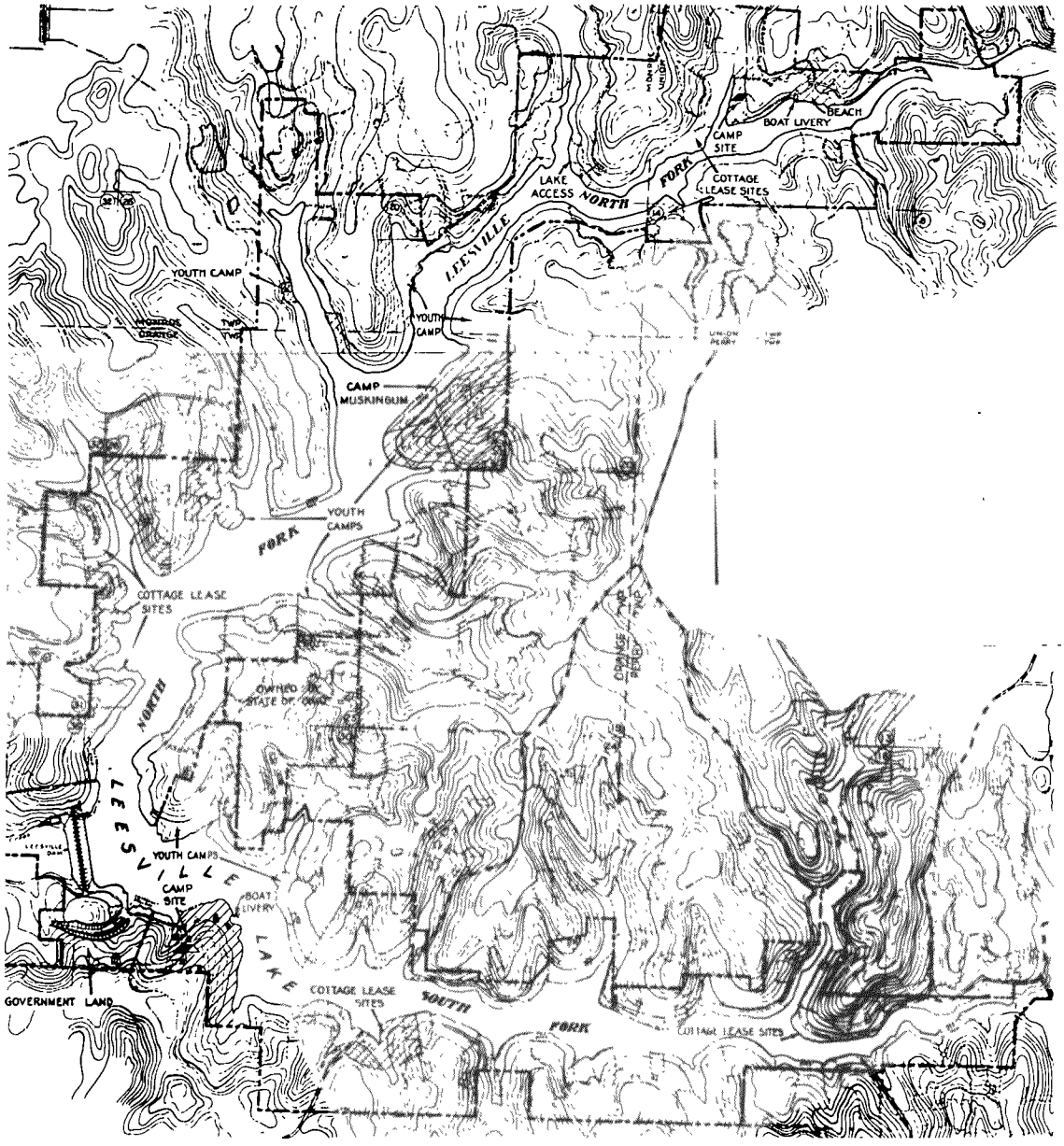


FIGURE 1. Leesville Lake photographed from exhibit No. 6 of the Muskingum Watershed Conservancy District; Zone A included south fork of lake to the boat livery just east of dam; Zone B extended north to Camp Muskingum; and Zone C included extreme north fork.

As many boats as possible were contacted during the four 2-hour periods between the boat counts (Table 2). Individual boat parties were interviewed once in any 2-hour period and again if contacted in later periods. All species of fish in possession were recorded at first contact of a given party, while only muskellunge were recorded for second or third contacts. This procedure was used to increase chances of checking some of the small numbers of muskellunge that were expected to appear in the annual catch. Small cards with the time of contact circled were distributed among boat parties at all first contacts to prevent duplication of hours fished.

Interview data were recorded on the creel census sheet reproduced in Figure 2, where each horizontal line represents one boat party. Interviews were identified by area of the lake and by type of boat to detect possible differences among areas and between rental and private boats. The four types of fishing categories were included for characterizing boat fishing in general and the taking of muskellunge in particular. The time of last contact from the party's time card was entered under the started-to-fish column when a boat party was interviewed twice or more in one day. During tabulation, the total man-hours of all contacts were used to compute muskellunge catch rates; man-hours of first contacts only were used to compute catch rates of other species. This differentiation was made by reference to the column (Figure 2) headed number of previous stops. The question whether fishing was completed was asked so that mean lengths of the private and rental boat trips could be estimated from samples of completed trips. The question whether fishing was only for muskellunge

Lake:_____ Month:_____ Day:_____ Year:_____ Census Taker:_____

Sky: (Check one blank for each time)

10 a.m. clear_____, partly cloudy_____, overcast_____, rain_____.
3 p.m. clear_____, partly cloudy_____, overcast_____, rain_____.
7 p.m. clear_____, partly cloudy_____, overcast_____, rain_____.

Water Surface:

10 a.m. smooth_____, rippled_____, wavelets_____, white caps_____.
3 p.m. smooth_____, rippled_____, wavelets_____, white caps_____.
7 p.m. smooth_____, rippled_____, wavelets_____, white caps_____.

Check One			Check One		Check One Or More				NUMBER OF FISHERMEN	Check One			TIME				Check One		NUMBER OF FISH CAUGHT							Check One		Leave Blank	
AREA OF LAKE			Kind Of Boat		Type of Fishing					Number of Previous Stops			Started to Fish		Of This Contact													
A	B	C	Private	Concession	Still	Drifting	Trolling	Casting		C	1	2	AM	PM	AM	PM	Fishing Completed	Not Completed	MUSKELLUNGE	Crappies	Bluegill & Sunfish	Black Bass	Bullheads & Catfish	Walleye	Others	Yes	No	Boat-hours fished	Man-hours fished
																										Fishing only for muskies			

FIGURE 2. Standard form used to record interview data obtained from boat anglers contacted on the water at Leesville Lake in 1960.

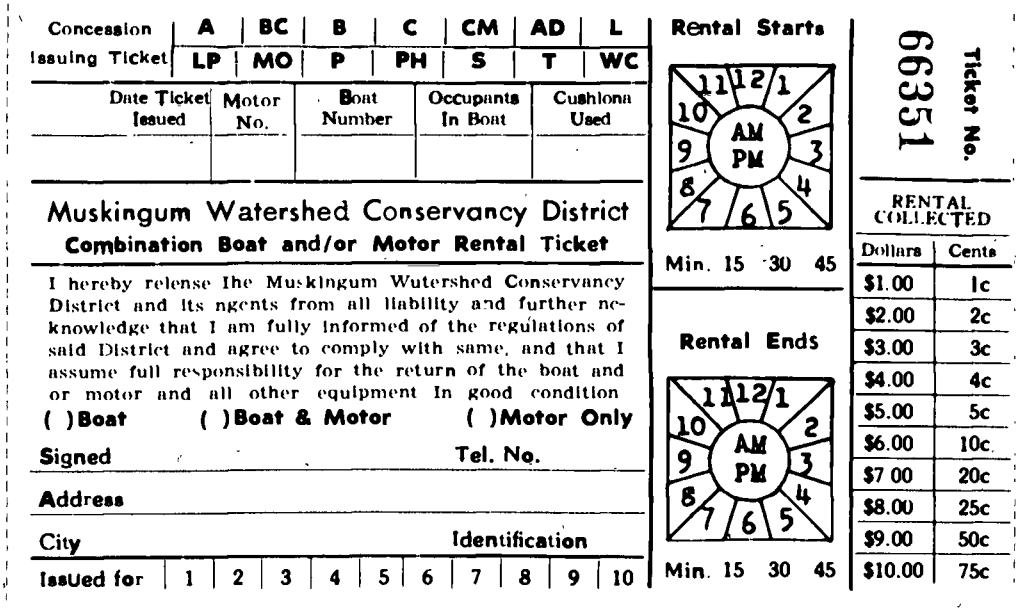
was asked to attempt to segregate muskellunge fishermen. In practice, both of these questions produced inconclusive data since they were answered negatively by almost all parties.

Observations of sky cover and water surface conditions at the top of the creel census sheet in Figure 2 were solely for use while interpreting daily census results. The rather subjective observations were not intended for quantitative analysis of weather effects.

Boat-rental Records

The records of boats rented from licensed concessionaires were borrowed from the Conservancy office at New Philadelphia, to obtain total rental-boat fishing effort and known quantities for estimating private-boat effort. A blank rental card is reproduced in Figure 3 showing the layout and kind of information that was available. Four items were copied from the cards: date, number of anglers, time out and time in. The copying process was tedious because time was read from holes punched in the small clock faces (Figure 3). Standard clock times were converted into service times (0100 through 2400) prior to subtracting for boat-hours rented.

The Conservancy District controls a strip of land around Leesville Lake and licenses two concessions on a share basis. The Petersburg concession located at the northeast end of the lake (Figure 1) had 38 rowboat-type boats available for rental in 1960. The Leesville concession located just south of the dam toward midlake had 53 boats available. No other commercial rental facilities were in operation. Boats were rented with or without motors, which some fishermen supplied



Concession	A	BC	B	C	CM	AD	L
Issuing Ticket	LP	MO	P	PH	S	T	WC

Date Ticket Issued	Motor No.	Boat Number	Occupants In Boat	Cushions Used

Muskingum Watershed Conservancy District

Combination Boat and/or Motor Rental Ticket

I hereby relense Ihe Muskingum Wutershed Conservancy District and its ngents from all liability and further neknowledge that I am fully informed of the regulations of said District and agree to comply with same, and that I assume full responsibility for the return of the boat and or motor and all other equipment In good condition

( )Boat ( )Boat & Motor ( )Motor Only

Signed Tel. No.

Address

City Identification

Issued for	1	2	3	4	5	6	7	8	9	10

Rental Starts

Min. 15 30 45

Rental Ends

Min. 15 30 45

Ticket No. 66351

RENTAL COLLECTED

Dollars	Cents
$1.00	1c
$2.00	2c
$3.00	3c
$4.00	4c
$5.00	5c
$6.00	10c
$7.00	20c
$8.00	25c
$9.00	50c
$10.00	75c

FIGURE 3. Official boat-rental card used by licensed concessionaires at Muskingum Watershed Conservancy District Lakes; issued for 1 and 2 (bottom left) indicate fishing boat without and with motor respectively, while other numbers identify other pleasure uses.

themselves.

Data Processing and Analysis

Machine processing was used extensively for the large quantities of data analyzed in this study. Multiple regression analyses of the boat counts made on the lake were run on an IBM computer under a contract with the Statistics Laboratory of The Ohio State University. The interview and rental-card data were key-punched into Remington-Rand cards and sorted on a mechanical sorter at the Division of Wildlife's Olentangy Experiment Station.

PART III

A BOAT-TYPE RELATIONSHIP AND EFFECTS OF TIME OF SAMPLING

The degree of relationship between numbers of private and rental boats and how boat counts are affected by area and time of sampling were determined using contingency tables and regression analyses. Statistical characteristics of the boat-count variates were examined in respect to applicability of the statistical methods.

Comparison of Boat-count Ratios by Area and by Period

Contingency tables were used to test whether the ratios of private boats to rental boats differed among the three arbitrary zones A, B and C into which the lake had been divided. The ratios were first tested by combining counts from all periods within each area (Table 3). The computed chi-square (1.95) was below the 5 percent level of significance at which the null hypothesis of independence would be rejected. To detect possible variation within a shorter period, the ratios were tested on a daily basis by combining five hourly pairs of boat counts within each zone. Two computed chi-squares from a total of 46 tests exceeded the 5 percent reference value. The null hypothesis consequently was rejected only twice, approximating the accepted probability of committing a type-I error ($P = 0.05$). One of the two chi-squares exceeded the 1 percent reference value. It was concluded from these tests that private and rental boats appeared to be distributed randomly over the lake in respect to each other and that the zonal

TABLE 3. Comparison among zones of ratios of private to rental boats counted at Leesville Lake during ten survey weeks in 1960

Zone	Number of boats counted			Ratio
	Private	Rental	Total	
A	1,069 (1,086)[1]	414 (397)	1,483	2.58
B	1,791 (1,770)	626 (647)	2,417	2.86
C	1,879 (1,883)	692 (688)	2,571	2.72
Total	4,739 -	1,732 -	6,471	2.74

[1]Using expected values in parentheses $\chi^2 = 1.95$; whereas $\chi^2_{0.05\ (2d.f.)} = 5.99$.

counts could be combined for regression analyses.

An indication of the areal distribution of boat fishing was also obtained from the arrangement in Table 3. The null hypothesis that total boats were distributed equally among the zones was rejected ($\chi^2 = 321.4$; 2 d.f.), but no difference was detected between zones B and C ($\chi^2 = 4.76$; 1 d.f.). Despite the lesser density in zone A, boat fishing generally was well distributed over the lake.

The zonal boat counts were next combined into total-lake counts, and contingency tables were used to find whether the ratios of private to rental boats differed among sampling periods.

First the ratios were compared by weeks, combining all hourly and daily counts within each week (Table 4). The computed chi-square (12.66) fell short of the 5 percent reference value when low-ratio weeks 1 and 2 were omitted indicating no significant differences for the ratios among weeks 3 through 10. Unweighted mean weekly ratios for these two groups of weeks were 1.58 : 1 and 3.06 : 1, respectively. Seasonal conditions and the social behavior of fishermen likely

contributed to the low ratios of weeks 1 and 2. Many private boats including those of summer people might not have been ready that early, while a large number of fishermen apparently desired to try spring fishing.

TABLE 4. Comparison among ten survey weeks of ratios of private to rental boats counted at Leesville Lake in 1960

Week	Number of boats counted					Ratio
	Private		Rental		Total	
1	335	-	282	-	617	1.19
2	221	-	112	-	333	1.97
3	730	(732)[1]	236	(234)	966	3.09
4	828	(832)	270	(266)	1,098	3.07
5	783	(747)	203	(239)	986	3.86
6	703	(705)	227	(225)	930	3.10
7	542	(549)	183	(176)	725	2.96
8	238	(240)	79	(77)	317	3.01
9	244	(261)	101	(84)	345	2.42
10	115	(117)	39	(37)	154	2.95
Total	4,739	-	1,732	-	6,471	2.74

[1]Using expected values in parentheses $\chi^2 = 12.66$; whereas $\chi^2_{0.05\ (7d.f.)} = 14.07$.

Secondly the comparisons were made among days of the week, combining the counts from all hours and all weeks into seven totals (Table 5). The computed chi-square (12.86) slightly exceeded the 5 percent reference value, so the hypothesis of no difference was rejected.

Thirdly the comparisons were made among hours of the day, combining the counts of all days and all weeks into five hourly totals (Table 6). Large differences among the resulting ratios were obvious by inspection. The ratio for 8-9 p. m. was more than twice as large as ratios of the first three hours, and remained larger in nine out of ten comparisons made on an individual week basis. The increase was

TABLE 5. Comparison among days of the week of ratios of private to rental boats counted at Leesville Lake during ten survey weeks in 1960

Day	Number of boats counted			Ratio
	Private	Rental	Total	
Sunday	1,157 (1,125)[1]	379 (411)	1,536	3.05
Monday	412 (409)	147 (150)	559	2.80
Tuesday	415 (403)	135 (147)	550	3.07
Wednesday	424 (428)	161 (157)	585	2.63
Thursday	395 (388)	135 (142)	530	2.93
Friday	520 (516)	184 (188)	704	2.83
Saturday	1,416 (1,470)	591 (537)	2,007	2.40
Total	4,739 -	1,732 -	6,471	2.74

[1]Using expected values in parentheses $\chi^2 = 12.86$; whereas $\chi^2_{0.05\ (6d.f.)} = 12.59$.

apparently caused by the necessity for rental-boat anglers to return boats to concessions and by an increase in fishing from nonrestricted private boats in the evening.

TABLE 6. Comparison among hours of the day of ratios of private to rental boats counted at Leesville Lake during ten survey weeks in 1960

Hour	Number of boats counted			Ratio
	Private	Rantal	Total	
8-9 a. m.	721 (760)[1]	317 (278)	1,038	2.27
11-12 a. m.	979 (1,029)	426 (376)	1,405	2.30
2-3 p. m.	784 (858)	387 (313)	1,171	2.03
5-6 p. m.	939 (934)	337 (342)	1,276	2.79
8-9 p. m.	1,316 (1,158)	265 (423)	1,581	4.97
Total	4,739 -	1,732 -	6,471	2.74

[1]Using expected values in parentheses $\chi^2 = 121.0$; whereas $\chi^2_{0.01\ (4d.f.)} = 13.28$.

Because the interaction of hours with boat ratios may have affected the preceding day of the week comparison in the presence of missing hourly counts, boat ratios among days of the week were compared

separately for each of nine weeks. The hypothesis of no differences within weeks was accepted five times and was rejected once at the 5 percent level and thrice at the 1 percent level. Exclusion from three of the latter comparisons of the pair of daily counts that caused the most divergent ratio resulted in chi-squares that were less than the 5 percent reference value. It was concluded therefore that although a small number of aberrant ratios existed, a large percentage of daily ratios did not differ within weeks.

Variances, Means and Frequency Distributions of the Boat Counts

Variances of the hourly counts of private and rental boats are compared in Table 7 by hour of the day, by day of the week, and by week of the season. A sound application of regression analysis is precluded unless variances of the dependent variate, private boats, are homogeneous among all levels of each independent variate. This requirement also should be met for samples whose means are to be compared by analysis of variance.

A two-tailed F test and Bartlett's test were used to find whether certain pairs and groups of variances, respectively, were homogeneous (Steel and Torrie, 1960). Variances of both private and rental boats differed significantly among hours ($\chi^2 = 16.69$ and 24.29 with 4 d.f.). Since variation obviously was greater on weekends than on week days, the variances were compared separately between Sundays and Saturdays and among week days. The week day group comparisons for private boats and for rental boats detected no significant differences ($\chi^2 = 8.11$ and 9.14 with 4 d.f.) nor did the weekend comparison for rental boats ($F = 1.33$ with 44 and 42 d.f.). Variances of private boats differed

TABLE 7. Comparisons of variances and means of boat counts among hours, days and weeks; Leesville Lake, 1960

Period	Number of counts[1]	Private boats		Rental boats	
		Variance	Mean	Variance	Mean
8-9 a. m.	62	178.2	11.5	54.2	5.1
11-12 a. m.	63	216.4	15.2	41.4	6.6
2-3 p. m.	63	136.2	11.8	47.6	5.9
5-6 p. m.	62	176.5	13.4	28.0	5.3
8-9 p. m.	62	354.6	20.4	16.9	4.1
Sunday	43	434.9	24.5	58.6	7.2
Monday	44	85.6	9.4	8.6	3.3
Tuesday	45	76.3	9.2	5.9	3.0
Wednesday	45	65.9	9.3	8.4	3.6
Thursday	45	60.7	8.7	5.4	3.0
Friday	45	128.4	11.3	3.9	3.9
Saturday	45	196.5	31.7	78.0	14.0
Week 1	35	124.1	9.6	118.5	8.1
Week 2	32	68.4	6.9	18.2	3.5
Week 3	35	467.2	20.9	47.8	6.7
Week 4	35	250.6	23.7	39.8	7.7
Week 5	35	199.8	22.4	21.5	5.8
Week 6	35	238.9	20.1	32.0	6.5
Week 7	35	111.0	15.5	12.0	5.2
Week 8	35	69.0	6.8	8.7	2.3
Week 9	35	66.0	7.0	11.3	2.9
Week 10	23	36.7	5.0	6.3	1.7

[1]Counts of week 10 are not included in the hourly and daily comparisons because of numerous missing values.

significantly, however, between Sunday and Saturday ($F = 2.21$ with 42 and 44 d.f.). Inspection was sufficient to indicate that the boat counts were more variable for some weeks than for others.

Means of the hourly counts of private and rental boats are compared in Table 7 and in Figures 4, 5, and 6 by hours, days and weeks, respectively. Private boat mean counts were extremely variable among hours compared to rental boat means. Mean counts of both kinds of boats were relatively uniform among week days but increased greatly on

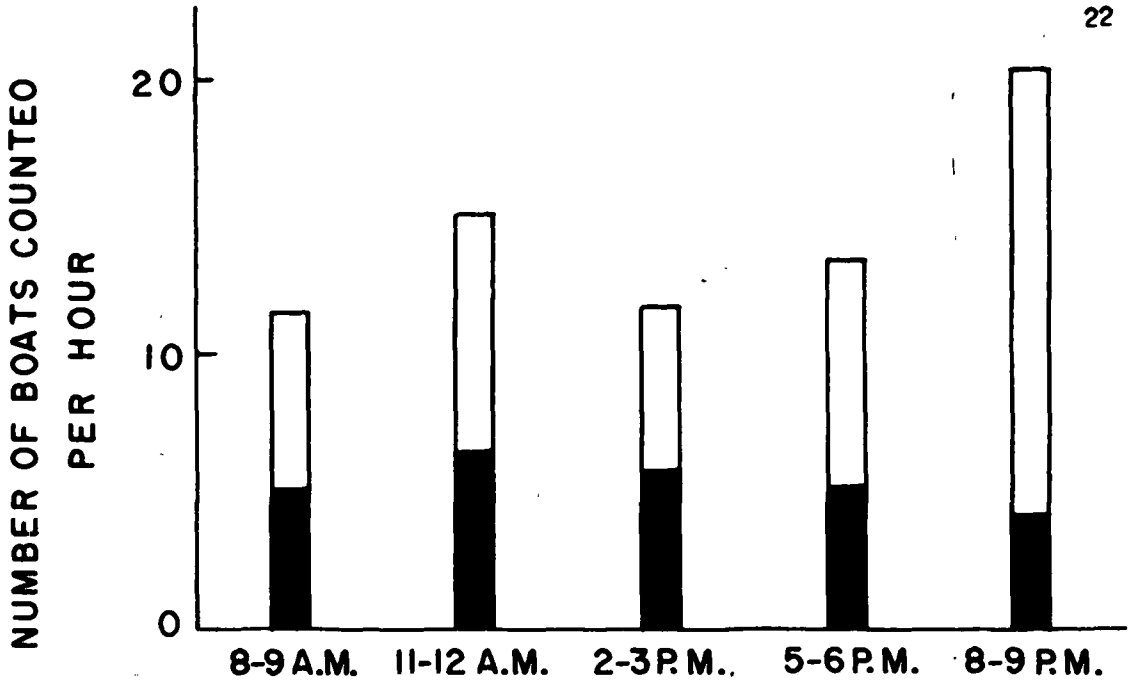


FIGURE 4. Hour-of-the-day distribution of mean boat counts at Leesville Lake in 1960 with rental boats (black) superimposed on private boats (white).

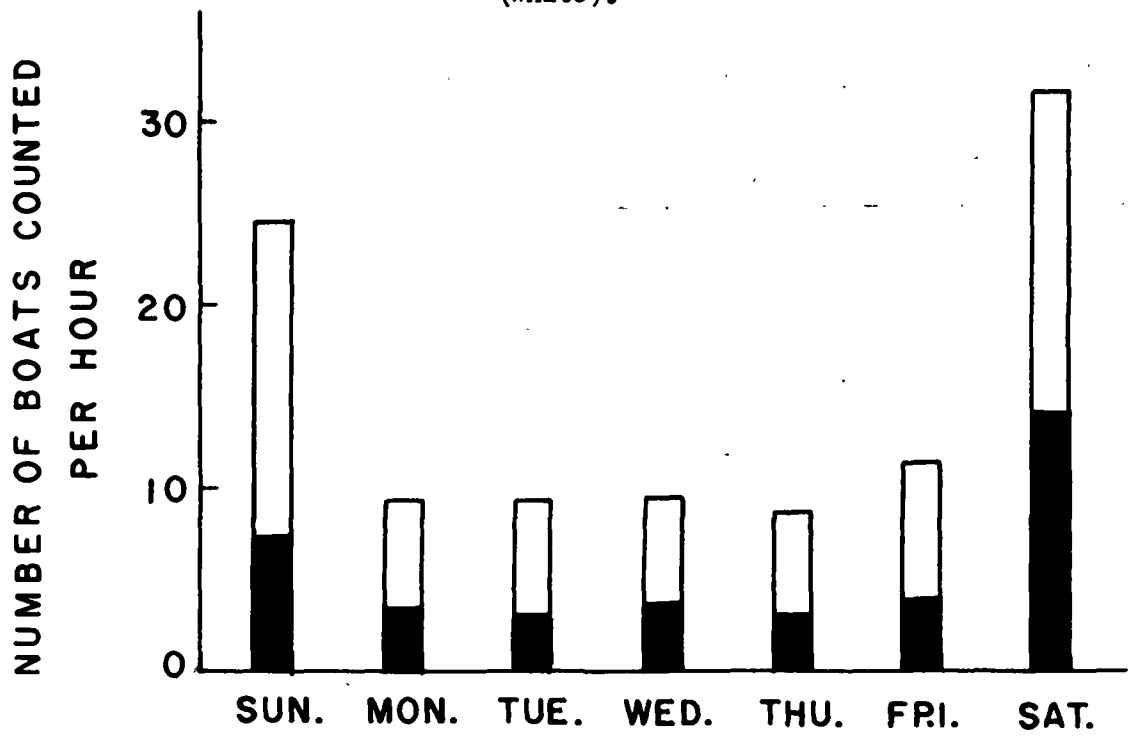


FIGURE 5. Day-of-the-week distribution of mean boat counts at Leesville Lake in 1960 with rental boats (black) superimposed on private boats (white).

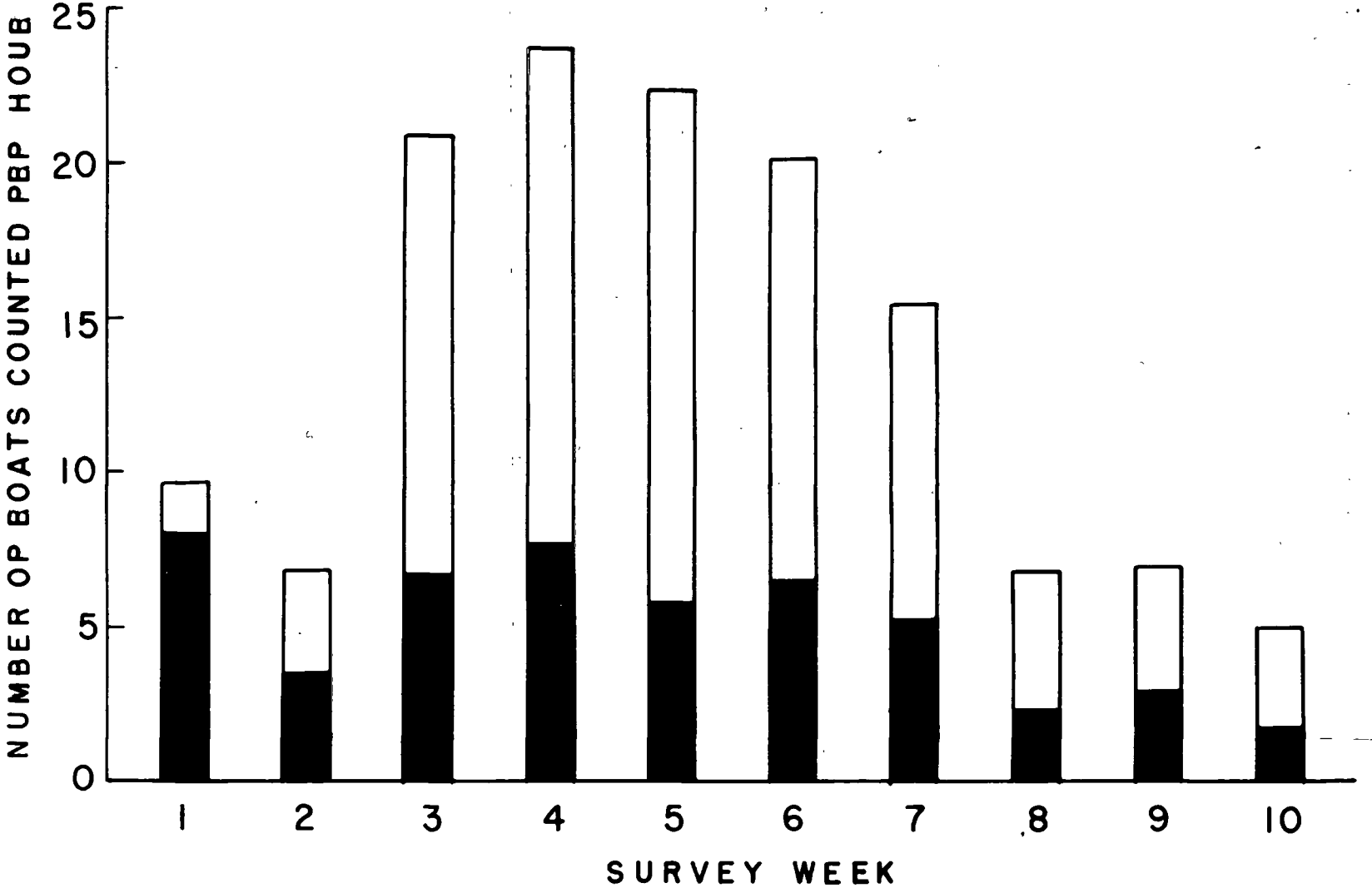


FIGURE 6. Week-of-the-season distribution of mean boat counts at Leesville Lake in 1960 with rental boats (black) superimposed on private boats (white).

on weekends. Hypotheses of no differences for mean counts of each boat type among certain of the preceding periods were tested by analysis of variance. The results are summarized in Table 8 where significant F values indicate rejection of the hypotheses. The private boat means and to a lesser extent the rental boat means followed a roughly parabolic trend by weeks, with irregularities that partly resulted from the influence of weather conditions. Objective measurement data were not obtained on weather which consequently was not treated as a variable in regression. The high mean count of rental boats during week 1 (April 17-23) may have resulted from a combination of good weather and the impatience of anglers to try spring fishing. As mentioned earlier, the lake had contained ice cover until the end of March.

TABLE 8. Results of tests bf the hypothesis that mean boat counts among or between time periods were equal

Comparison	Degrees of freedom	Computed values[1]		Reference values
		F	F'	
Private boats:				
Hours	4; 153	-	3.30	F 0.05 = 2.43
Week days	4; 219	0.521	-	F 0.05 = 3.41
Weekend days	1; 73	-	39.36	F 0.01 = 7.01
Rental boats				
Hours	4; 152	-	2.15	F 0.05 = 2.43
Week days	4; 219	1.09	-	F 0.05 = 3.41
Weekend days	1; 86	14.70	-	F 0.01 = 6.96

[1] F' is a special variance ratio used when variances are heterogeneous (Snedecor, 1956).

An association was apparent between large means and large variances in Table 7. The means were correlated with standard deviations indicating that a log transformation of the counts might equalize variances (Bartlett, 1947). Since regression equations subsequently were computed from raw counts, utility of a transformation should be

considered to satisfy the theoretical requirements of the method.

The preceding tests of hypotheses about means and variances are applicable with normally distributed variates. Figure 7 shows, however, that the boat counts deviated considerably from normal distributions. The large weekend counts and the 8-9 p. m. week day counts of private boats were not included in Figure 7 to decrease heterogeneity. The rental-boat counts of weeks 3 through 7 formed a fairly symmetrical histogram with a mode at four boats; whereas, inclusion of counts from the first two and last three weeks resulted in strong asymmetry. The private-boat counts were more variable as indicated by the compressed horizontal scale and were skewed toward the right. A log transformation would remove the skewness, but would not alter the asymmetry produced by including the counts of weeks 1, 2, 8, 9 and 10. Because of these various departures from normality and the use of unrectified data, the regression analysis described in the following section does not rest on an absolutely sound theoretical base. Additional study of the nature of the distribution is planned as a continuation phase of the muskellunge evaluation project.

Regression Analysis

Several equations were obtained for the multiple regression of numbers of private boats counted on numbers of rental boats and on one or more of the independent variables hours, days and weeks. The partial regression coefficients relating to effects of the independent variates were tested for significance and the equations were compared with reference to multiple regression coefficients R and standard deviations (residual) of the private boat counts about regression.

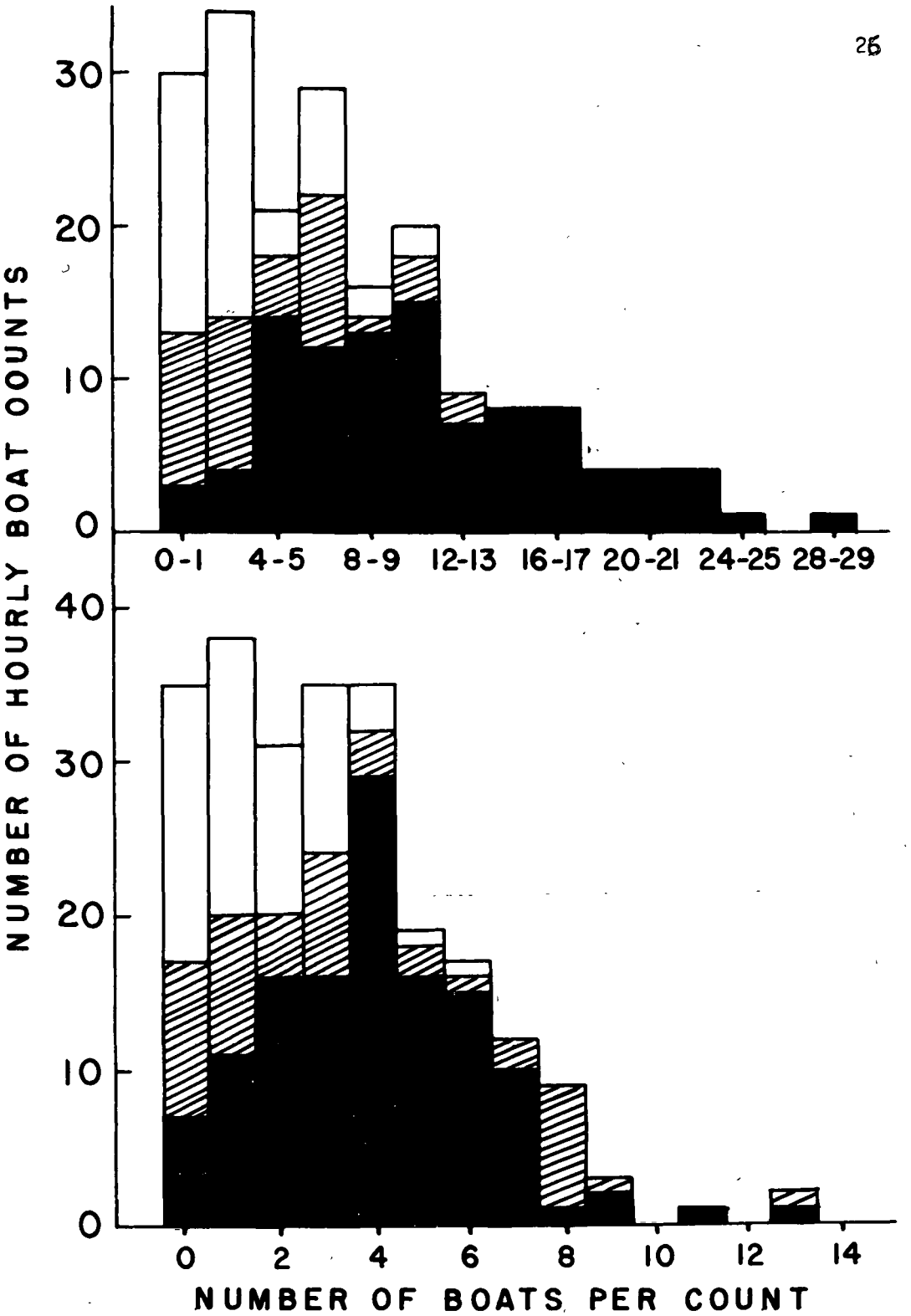


FIGURE 7. Frequency distributions of private (top) and rental (bottom) boat counts for survey weeks Nos. 1 and 2 (crosehatched), 3 through 7 (black), and 8 through 10 (white) at Leesville Lake in 1960, exclusive of weekend counts and private boat counts of 8-9 p.m.

A key step in development of each equation was the use of a third degree polynomial of the general form $y = a + hx + cx^2 + dx3$ to describe (fit) the seasonal distribution of private boat counts: where y equals private boats counted per hour or per day as designated; x equals survey weeks 1, . . ., 10; and a, b, c and d are coefficients to be computed. The polynomial part of one of the equations is graphed in Figure 8 showing goodness of fit.

In developing the first equation, two series of terms for day of the week effects and hour of the day effects and a single term for the effect of numbers of rental boats counted were added to the polynomial. It was assumed that day of the week effect upon numbers of private boats may differ among days but is constant for the same day from week to week. In this sense, the seven day of the week effects were considered as being superimposed upon the effect for each week with the weekly sum of day effects equal to zero. Similarly, it was assumed that hour of the day effect upon numbers of private boats may differ among hours but is constant for the same hour from day to day and from week to week. Finally, it was assumed that the partial regression of private boats on rental boats was rectilinear and constant within all periods. The latter assumption apparently was only partly correct because of the different boat count ratios recorded for the first two survey weeks and for the last survey hour 8-9 p. m. (Tables 4 and 6).

The following notation was used for the first equation:

y_1 : number of private boats counted during a given hour.

x_1 : survey week 0, 1, . . ., 9 where 0 equals week 1, etc.

x_2 : x_1^2

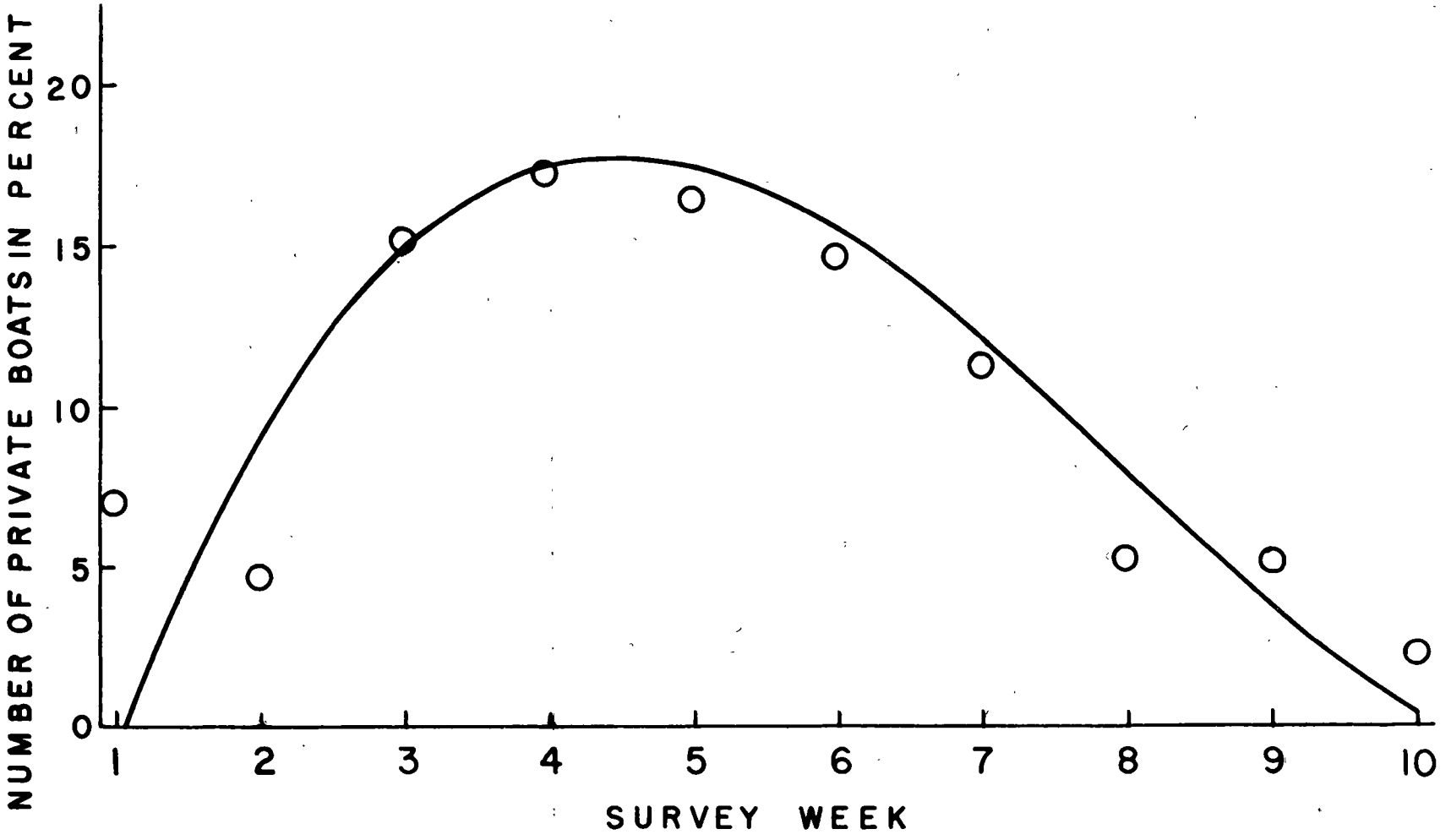


FIGURE 8. Graph of $y_1 = 39.324x_1 - 7.5354x_1^2 + 0.3574x_1^3 - 2.85$ where y_1 equals the daily total of five hourly counts of private boats and x_1 equals a given survey week; weekly totals of hourly counts (circles) indicate goodness of fit.

x_3 : x_1^3

x_4 : Sunday effect, x_4 equals 1, 0 according to whether the corresponding y_1 was observed on Sunday or not.

x_5 : Monday effect, etc.

x_6 : Tuesday effect, etc.

x_7 : Wednesday effect, etc.

x_8 : TThursday effect, etc.

x_9 : Friday effect, etc.

x_{10} : 8-9 a. m. effect, x_{10} equals 1, 0 according to whether the corresponding y_1 was observed during 8-9 a. m. or not.

x_{11} : 11-12 a. m. effect, etc.

x_{12} : 2-3 p. m. effect, etc.

x_{13} : 5-6 p. m. effect, etc.

x_{14} : Number of rental boats counted during a given hour.

Using this notation the several assumptions became:

$$y_1 = b_0 + b_1x_1 + \cdots + b_{14}x_{14}$$

Least squares estimates of the regression coefficients b_i were obtained by solution of a set of 15 normal equations based on a total sample of 332 hourly boat counts. The necessary computations are relatively easy with a small number of independent variates but become increasingly complex as variates are added. Days of work with matrix algebra and a desk calculator were reducted to minutes by programing into the IBM computor system. It can be seen that the notation did not include Saturday and 8-9 p. m. effects. Those effects were hidden in the other b_i by the mathematical procedure for solving sets of dependent equations. Final readjustment of $b_4 \cdots b_9$ and $b_{10} \cdots b_{13}$ revealed the hidden effects. The resulting equation was as follows:

$$y_1 = 10.120x_1 - 2.0218x_1^2 + 0.10372x_1^3 + 1.3275x_{14} - 1.86$$

$$+ \begin{cases} 6.59 \text{ if Sunday} \\ -2.90 \text{ if Monday} \\ -2.34 \text{ if Tuesday} \\ -2.96 \text{ if Wednesday} \\ -2.67 \text{ if Thursday} \\ -1.62 \text{ if Friday} \\ 5.89 \text{ if Saturday} \end{cases} + \begin{cases} -2.95 \text{ if 8-9 a. m.} \\ -1.49 \text{ if 11-12 a. m.} \\ -3.00 \text{ if 2-3 p. m.} \\ 0.00 \text{ if 5-6 p. m.} \\ 7.44 \text{ if 8-9 p. m.} \end{cases}$$

Tests of hypotheses relative to the overall significance of the regression and of the partial regression coefficients are summarized in Table 9. The test statistics exceeded the reference values in all cases. Consequently the hypotheses were rejected meaning that the independent variates had significant effects upon numbers of private boats y_1. The overall regression was highly significant ($F = 57.65$ with 14 and 317 d.f.), implying that the multiple regression coefficient R which equalled 0.847 also was significant. R^2 equals the sum of squares due to regression divided by the total sum of squares of y_1. Therefore R^2100 equaled 72 percent or the variation in counts of private boats that was accounted for by the 14 variates, i. e., hour, day, week and number of rental boats counted (Steel and Torrie, op. cit.).

TABLE 9. Results of tests of hypotheses relative to the significance of regression coefficients of the first equation

Hypothesis tested	Degrees of freedom	Computed values t	Computed values F	Reference values
$b_3 = 0$	317	4.08	-	t 0.01 = 2.58
$b_{14} = 0$	317	13.27	-	t 0.01 = 2.58
$b_4 = \ldots = b_9 = 0$	6; 317	-	10.07	F 0.01 = 2.80
$b_{10} = \ldots = b_{13} = 0$	4; 317	-	19.69	F 0.01 = 3.32
$b_1 = \ldots = b_{14} = 0$	14; 317	-	57.65	F 0.01 = 2.15

Three additional equations were obtained with the experimental data still treated on an hourly count basis. These equations are

compared for relative efficiency in the first section of Table 10. Substitution of $y_1 / 1 + x_{14}$ for y_1 greatly reduced the amount of variation in the dependent variate that was accounted for by regression (use of 1 in the denominator enabled mathematical manipulation when rental boat counts, x_{14}, equaled zero). Omission of the terms for hour of the day reduced the amount of total variation accounted for by regression, $R^2 100$, from 71.8 to 64.8 percent, while omission of both hour of the day and day of the week terms reduced the same quantity to 58.8 percent.

The five pairs of hourly boat counts of each day were combined for final analyses, and two equations were obtained where y_1 became the estimated count of private boats in a 5-hour period of any specified day. All days with one or more missing hourly counts were excluded leaving a sample of 61 counts. Six day of the week terms in the first of the two equations were replaced in the second by a single term representing one weekend variate (week day means did not differ significantly). An additional term representing rental boats squared was used in both equations to test the assumption that the partial regression of private boats on rental boats was rectilinear. These equations accounted for approximately 90 percent of the variation in counts (daily summations) of private boats (Table 10). Variation in y_1 among hours of the day was partly nullified by adding hourly counts within days. The summation process had an averaging or smoothing effect. The second of the two equations was used to estimate private boat fishing effort. It follows with modification of the earlier notation:

TABLE 10. Comparison of the relative efficiencies of six regression equations for estimating numbers of private boats

Equation	R	$R^2 100$	s^1	Mean of y_1	Coefficient of variation in percent
By hourly boat counts					
Regression of y_1 on all variates	0.847	71.8	7.86	14.02	56.1
Hour of the day effects unaccounted	0.805	64.8	8.78	14.02	62.6
Hourly and daily effects unaccounted	0.767	58.8	9.49	14.02	67.7
Regression of $y_1/1 + x_{14}$ on all variates	0.552	30.4	1.80	2.44	73.7
By daily boat counts[2]					
Separate day of the week effects	0.948	89.9	21.56	72.38	29.8
Weekend or week day effects	0.947	89.6	20.86	72.38	28.8

[1]Standard deviation (residual) of y_1 about regression.

[2]Summations of five hourly counts each day.

$$y_1 = 39.324x_1 - 7.5354x_1^2 + 0.35714x_1^3 + 1.8298x_5 + 0.000037x_5^2 - 2.850 + \begin{cases} 17.70 \text{ if Sunday or Saturday} \\ -17.70 \text{ if a week day} \end{cases}$$

where y_1 : Number of private boats counted during five hourly periods.

x_1 : Survey week 0, 1, . . ., 9 as before.

x_2 : x_1^2 as before.

x_3 : x_1^3 as before.

x_4 : Weekend effect, x_4 equals 1, 0 according to whether the corresponding y_1 was observed on Sunday or Saturday or not.

x_5 : Number of rental boats counted during five hourly periods.

x_6 : x_5^2

Tests of hypotheses relative to the preceding equation are summarized in Table 11. Six rejections indicated significant effects on private boats (y_1) by the respective independent variates.

TABLE 11. Results of tests of hypotheses relative to the significance of regression coefficients of the final equation

Hypothesis tested	Degrees of freedom	Computed values t	Computed values F	Reference values
$b_1 = 0$	54	4.83	-	t 0.01 = 2.67
$b_2 = 0$	54	- 3.36	-	t 0.01 = 2.67
$b_3 = 0$	54	2.08	-	t 0.05 = 2.01
$b_4 = 0$	54	4.14	-	t 0.01 = 2.67
$b_5 = 0$	54	3.79	-	t 0.01 = 2.67
$b_6 = 0$	54	0.01	-	t 0.05 = 2.01
$b_1 = \ldots = b_6 = 0$	6; 54	-	77.71	F 0.01 = 3.15

Nonrejection of $b_6 = 0$ implied that the partial regression of private boats on rental boats was rectilinear as assumed. Therefore b_6 (0.000037) was ignored in subsequent computations for estimates of y_1.

PART IV

FISHING EFFORT ESTIMATED AND DESCRIBED

Fishing effort of private boat anglers on a boat-hour basis was estimated for the ten survey weeks by three methods: 1) use of the final regression equation and counts of rental boats made on the water; 2) use of the equation and counts of rental boats estimated from the rental cards; and 3) use of direct proportion involving counts of private and rental boats made on the water, numbers of rental boats from the rental cards, and estimated mean length of the private boat trips. The methods were compared and biases were examined. Effort for the entire season was obtained by combining private boat hours of survey weeks and intervening weeks as estimated by the latter two methods. This procedure represented a direct projection of relationships from observed into nonobserved periods.

Fishing effort of rental boat anglers for the entire season was obtained from the rental cards. Discrepancies between boats rented and boats observed were described and biases related to unaccounted for boats and length of time fished were examined.

Boat-hours ultimately were converted to man-hours preparatory to estimating the harvest of fish.

Estimation of Private-boat Hours for Survey Weeks

Method 1.--In the first estimation method, rental boat counts (x_5) and all coefficients in the regression equation except the coefficient of x_5 were multiplied by the factor 3. This procedure was equivalent

to multiplying y_1 by 3 and projecting estimated counts of private boats from 5 hours to 15 hours or 7 a. m. through 10 p. m.: where total estimated hourly counts equaled total estimated boat-hours fished. Use of the factor 3 was examined with respect to the hourly distribution of fishing boat rentals in Table 12. The distribution was obtained by tabulating rentals out and in for each hour, accumulating previous entries, and subtracting accumulative rentals in from rentals out. Rentals still out for the five survey hours multiplied by 3 equaled 6,900 compared with the actual summation of rentals still out for 15 hours (7 a. m. - 10 p. m.) which equalled 6,840 for a difference of 0.9 percent. Use of the factor 3 excluded the hours before 7 a. m. and after 10 p. m. when 2.7 percent of the rentals were still out. From Table 12 it is apparent that the projection procedure should have produced good results if the hourly distribution of private boat counts on the water were as evenly and smoothly distributed as the hourly rentals still out. The high 8-9 p. m. private counts may have caused considerable error because it is likely that later counts would have decreased.

Method 2.--Coefficients of the equation were also multiplied by 3 in this method, but a different procedure was needed to convert numbers of boats rented from the cards into boats observable on the water during 15 hours. Again reference was made to Table 12. The grand total of boats still out (7,030) divided by the total boats rented (1,266) equaled the mean boat rental interval of 5.553 hours. Multiplication of the number of boats rented during a given period by 5.553 conversely equaled the number of rentals countable for that period if counts were made every hour. But it was apparent from Table 12, that

actual counts of rental boats on the water differed from the mean numbers of rentals out (daily column) during the five survey hours. The mean counts were smaller than the mean rentals still out during the first four hours and larger during the last hour (8 or 8-9 p. m.). The summation of counts represented 78.48 percent of the summation of rentals still out when the five hourly values were combined for each variable. Consequently for substitution in the equation $3x_5$ was estimated as follows: $3x_5$ = (Number of boats rented)(5.553)(0.7848). Use of a fixed adjustment for all periods provided rough approximations, because the proportions of boats counted to boats rented differed appreciably.

TABLE 12. The hourly distribution of fishing boat rentals at Leesville Lake in 1960 from the rental cards of two concessions, with mean counts on the water from the ten survey weeks for comparison

Hour[1]	Boats out		Boats in		Boats still out		Boats counted
	Number	Accumulative	Number	Accumulative	Season	Daily	
5 a. m.	8	8	1	1	7	0.10	-
6	154	162	-	-	162	2.31	-
7	139	301	1	2	299	4.27	-
(8)	110	411	-	-	411	5.87	4.80
9	113	524	2	4	520	7.43	-
10	94	618	36	40	578	8.26	-
(11)	82	700	53	93	607	8.67	6.17
12 noon	83	783	80	173	610	8.71	-
1 p. m.	77	860	97	270	590	8.43	-
(2)	94	954	72	342	612	8.74	5.69
3	87	1,041	112	454	587	8.39	-
4	81	1,122	107	561	561	8.01	-
(5)	57	1,179	99	660	519	7.41	5.11
6	46	1,225	130	790	435	6.21	-
7	29	1,254	158	948	306	4.37	-
(8)	8	1,262	163	1,111	151	2.16	4.02
9	2	1,264	99	1,210	54	0.77	-
10	1	1,265	38	1,248	17	0.24	-
11	1	1,266	16	1,264	2	0.03	-
12 p. m.	-	-	2	1,266	2	0.03	-
Total	1,266	-	1,266	-	7,030	-	-

[1]Hours corresponding to the boat-count periods are in parentheses.

A weekly comparison of the two variates was made in Table 13. Total counts were almost always larger than total rentals because some boats were counted two or more times in the same day. It is believed that part of the deviation of boats counted from expected, including that of week 3, was caused by weather conditions. Variations in the social behavior of fishermen also may have been a factor. The deviations represented a source of error in the use of rental card data, even though time of sampling (week and day effects) also had important bearing upon private boat counts (y_1) in the equation.

TABLE 13. Comparison of the proportions of rental boats counted to total rentals at Leesville Lake in 1960

Survey week	Number of rental boats		Ratio
	Rented	Counted	
1	168	282 (230)[1]	1.68
2	85	112 (116)	1.44*
3	246	236 (336)	0.96
4	214	270 (293)	1.26
5	145	203 (199)	1.40
6	173	227 (237)	1.31
7	112	183 (152)	1.63
8	46	79 (62)	1.72
9	46	101 (62)	2.20
10	31	39 (42)	1.92*
Total	1,266	1,732 -	1.37

[1]Expected counts computed from the rental distribution are in parentheses.

*Adjusted for missing counts of 2nd and 10th weeks.

Method 3.--In the third estimation method, the numbers of boats rented per week were multiplied by the weekly ratios of private boats counted to rental boats counted giving direct proportion estimates of private boats. Estimated numbers of private boats then were multiplied by the mean length of trip (4.022 hours) for conversion to boat

hours.

The figure 4.022 was derived from the following relationship in the absence of data from completed private boat trips:

$$\frac{\bar{h}_p}{\bar{h}_r - 0.5} = \frac{\bar{h}'_p}{\bar{h}'_r}$$

where $\bar{h}_p$: Estimated mean hours fished by private boats.

$\bar{h}_r$: Mean length of boat rentals in hours from rental cards of the entire season.

$\bar{h}'_p$: Mean hours fished by private boats until contacted on the lake.

$\bar{h}'_r$: Mean hours fished by rental boats until contacted on the lake.

0.5 : An arbitrary value used on the assumption that at least one-half hour of each rental period was not used in fishing.

Examination was also made of the frequency distribution of hours rented and of weekly variations among mean hours rented and among mean hours fished until contacted. The rental hours were more variable during the first eight weeks than during the last two weeks as shown in Table 14 and Figure 9. Variances and means of rental hours for the first eight weeks did not differ significantly, however, according to Bartlett's test ($\chi^2 = 8.47$, 7 d.f.) and analysis of variance ($F = 1.70$; 7 and 1,162 d.f.), respectively. Inclusion of weeks 9 and 10 led to rejection of the hypothesis of equal variances. Mean hours fished by rental boats until contacted were much less variable than mean hours fished by private boats (Table 14). A single geographical location (the lake itself) and the restrictions of renting must have contributed

to the smaller variability of hours fished by rental boat anglers.

TABLE 14. Comparison among mean hours rented as computed from rental cards and mean hours fished by rental and private boats at Leesville Lake in 1960

Survey week	Rental hours from cards			Boat-hours fished (interviews)			
				Rental boats		Private boats	
	Number	Mean	Variance	Number	Mean	Number	Mean
1	168	6.02	8.07	96	3.61	117	3.62
2	85	4.76	4.99	63	3.51	83	3.70
3	244	5.70	8.01	113	3.54	346	2.93
4	196	5.66	7.54	124	3.65	399	3.10
5	145	5.59	8.31	106	3.24	397	2.62
6	173	5.66	7.57	105	3.54	354	2.51
7	112	5.89	8.00	106	3.41	300	2.36
8	47	5.88	9.12	47	3.27	146	2.12
9	46	5.37	3.97	60	3.28	129	2.41
10	31	4.88	3.59	31	3.78	78	2.82
Total	1,247	5.64	-	851	3.48	2,349	2.75

To find whether disproportionate sampling of boats on the water (judgement sampling) had affected mean hours fished until contacted, means and numbers of contacts were tabulated separately for each of four 2-hour census periods with data of all weeks combined. The mean hours fished were then weighted according to percentage distribution of boat counts within periods and combined giving adjusted grand means. Rental and private boat means were increased by the adjustments but in proportion so that no appreciable effect was had on the estimation of $\bar{h}_p$ (4.022 hours).

Comparison of methods.--Estimates of private boat-hours made by the three methods are compared in Table 15. Relative accuracy was indicated by deviations from hypothetical boat hours based on the percentage distribution of private boat counts (weekly means) made on the lake (Figure 6). Differences among estimates within weeks were proportionately greater than differences with the ten weeks combined. The

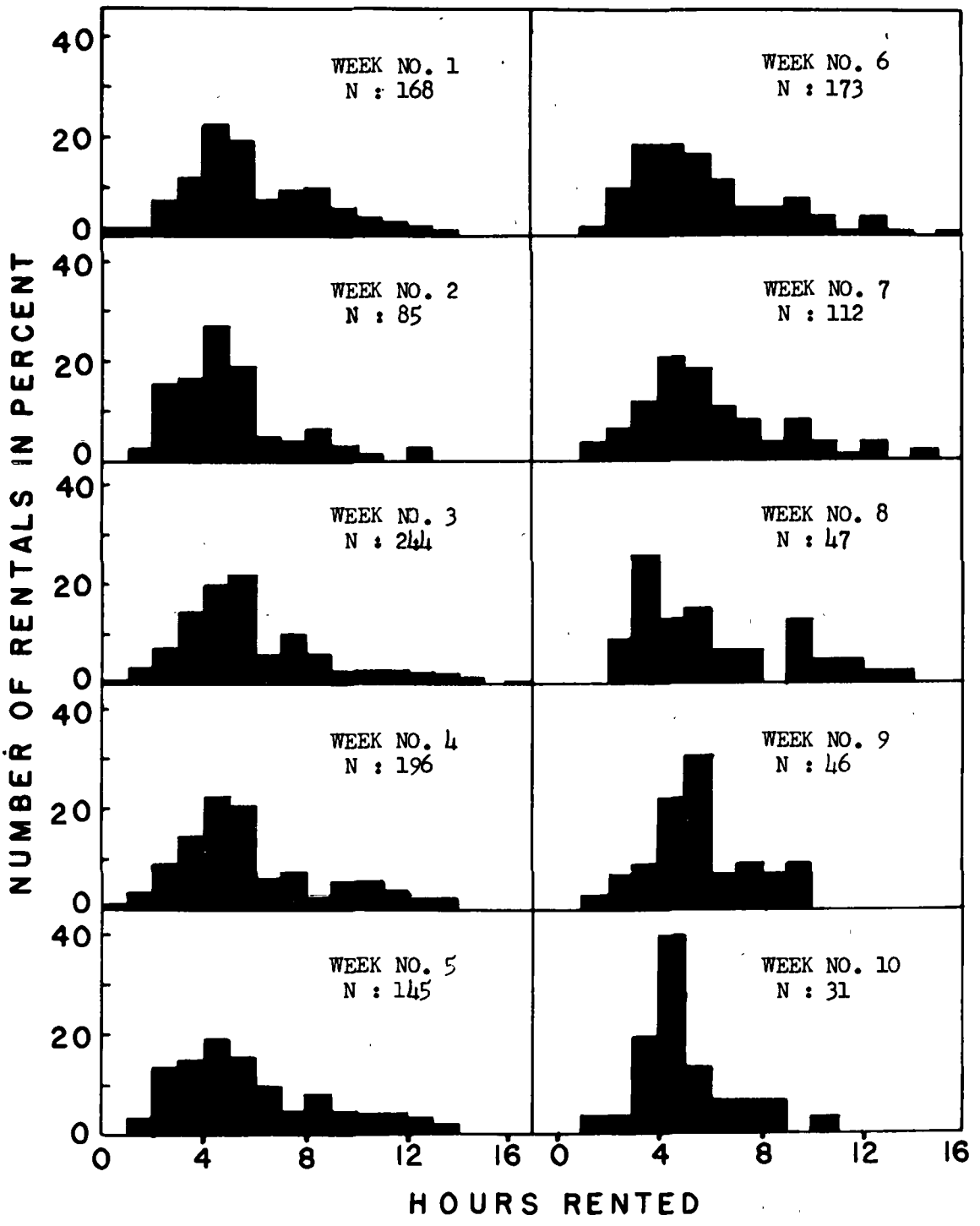


FIGURE 9. Frequency distribution of concession-boat rental periods by survey weeks at Leesville Lake, April 17-23 through October 23-29, 1960.

TABLE 15. Comparison of private boat-hours fished at Leesville Lake in 1960 as estimated by three methods: 1) by the equation and boat counts; 2) by the equation and rental-card data; and 3) by direct proportion using boat counts and rental card data

Survey week	Method 1		Method 2		Method 3	
	Boat hours	% deviation[1]	Boat hours	% deviation	Boat hours	% deviation
1	1,329	31.5	1,108	6.1	803	-18.6
2	1,071	46.3	1,127	49.0	674	-5.6
3	2,155	-2.5	2,803	22.7	3,060	41.9
4	2,519	0.1	2,728	4.8	2,640	7.4
5	2,147	-9.5	2,178	-11.1	2,250	-2.8
6	2,138	0.0	2,258	2.2	2,155	3.3
7	1,665	1.5	1,545	-8.8	1,334	-16.6
8	876	22.1	805	8.6	557	-20.4
9	657	-12.0	466	-39.6	447	-38.7
10	81	-84.6	112	-79.4	368	-28.5
Total	14,639	-	15,130	-	14,288	-

[1]From hypothetical boat-hours computed from the percentage distribution of private boat counts made on the water.

The maximum difference when combined was 5.9 percent with the smallest total (14,288) as 100 percent. Part of the deviation of boat-hours estimated by the first two methods from expected values resulted from the use of a mathematical curve to describe the weekly distribution of private boats (Figure 6). Part of the deviation of boat-hours estimated by the second two methods from expected values was associated with use of the rental card data.

Estimation of Private boat-hours for the Season

The use of methods 2 and 3 to estimate private boat-hours for nonsurvey weeks involved the following projection procedures. Since method 2 required substitution of 0, 1, . . ., 9 representing weeks 1, 2, . . ., 10, respectively, for x_1 in the equation, intermediate values were used for intervening nonsurvey weeks. The two weeks between survey weeks 2 and 3, for example, were assigned the values 1.33

and 1.67. Otherwise the computations were the same as described previously for survey weeks. For method 3, the number of boat rentals of each nonsurvey week was multiplied by the ratio of private boat counts to rental boat counts from the adjacent survey week (see Table 1).

The seasonal estimates of private boat hours fished obtained by summation of all survey and nonsurvey week estimates of the period March 31 through October 30, 1960 were 49,162 by method 2 and 48,907 by method 3.

Estimation of Rental Boat-hours for the Season

The total estimated rental boat-hours fished for the season was obtained by multiplying the number of boat rentals from the rental cards of each week by the corresponding mean hours per rental minus 0.5 hours: where the latter value was the same arbitrary correction factor used in the computations for private boat-hours. The summation of weekly estimates, which were needed in later catch-effort computations, equaled the seasonal estimate of 22,696 rental boat-hours fished. Approximately the same value could have been obtained directly by multiplying the season total of 4,445 rental boats by the season mean of 5.606 hours per rental minus 0.5 hour.

Ih addition to the 4,445 rental boats included in the preceding estimation methods, 311 rental boats were listed in the following categories: 151 night rentals, 81 weekly rentals, and 74 regular daily rentals that were incompletely recorded on the cards by concessionaires. These weekly and daily rentals represented a source of bias since the study was concerned with daytime fishing. If it can be

conjectured that the weekly rentals each represented an average of five fishing trips, then $[(86 \times 5) + 74]$ (5.106) equaled 2,573 unaccounted for boat hours; and (2,573 / 2,573 + 22,696)(100) equaled an underestimate of about ten percent. Part of this bias also was injected into the estimates of private boat-hours by use of the rental card data.

Conversion of Boat-hours to Man-hours

Boat-hours of fishing effort were converted to man-hours before estimating the harvest, because catch rates were in the basic unit of fish caught per man-hour. All weekly estimates of private boat-hours were multiplied by 2.071, the mean number of anglers per private boat as recorded by interviews on the water. Weekly estimates of rental boat-hours were multiplied by the corresponding mean number of anglers per boat computed separately from rental cards of the respective weeks. The mean number of anglers per rental boat for ten survey weeks combined was 2.397 from the rental cards and 2.172 from the interviews on the water. It is uncertain whether the difference actually represented a bias caused by certain members of rental parties not fishing. Using the rental card means should have overestimated man-hours by approximately 11 percent since the bias was in the positive direction, tending to offset the negative bias caused by unaccounted for rentals.

Summation of the weekly man-hour estimates produced season totals of 102,726 man-hours for private boats obtained by method 2, 101,283 man-hours for private boats obtained by method 3, and 54,812 man-hours for rental boats. These figures represented a total annual fishing effort of 156 man-hours per surface acre of water.

Frequency distributions formed by the anglers per boat observations are graphed in Figure 10. The distribution for rental boats contacted on the water differed significantly from the distribution for private boats contacted on the water and rental boats recorded from the rental cards. Computed chi-squares were 26.51 and 52.23 (4 d.f.), respectively, using the latter two distributions to determine expected values. Proportionately more private boats were occupied by single anglers, while the rental records listed a comparatively large number of boats with four anglers, causing an irregular descent by the right hand limb of the distribution curve. Apparently certain members of boat rental parties did not fish and therefore were not recorded by interviewers. The general shapes of these curves apparently were typical since they appear similar to curves recorded from Hoover Reservoir in central Ohio. Regenthal (op. cit.) described anglers per automobile observations in Utah which when modified approximated a Poisson distribution unlike the distributions drawn in Figure 10.

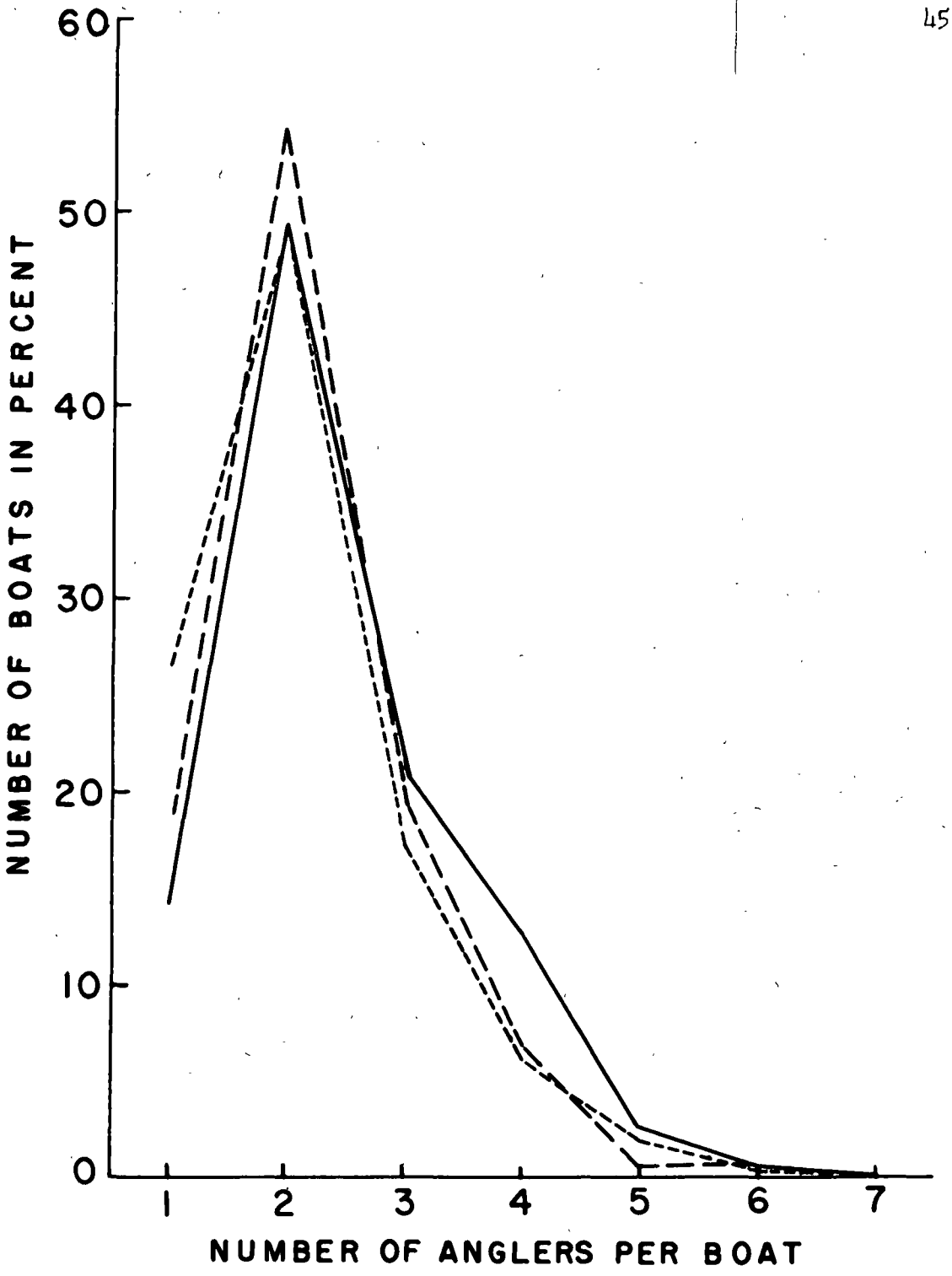


FIGURE 10. Frequency distribution of anglers per boat at Leesville Lake in 1960: rental boats from cards (solid line), rental boats contacted on the water (long dashes) and private boats contacted on the water (short dashes).

PART V

FISH HARVEST ESTIMATED AND DESCRIBED

The total number of fish harvested by boat anglers during each week of the 1960 season was estimated by multiplying man-hours fished by catch rates computed from the interview data. Catch rates from adjacent survey weeks were used in the computations for nonsurvey weeks. Summation of the weekly estimates indicated the size of the harvest for the entire season.

The season harvest totals by species together with catch rates from the interview data are presented in Table 16. Private boat anglers harvested an estimated grand total of more than 45,000 fish based on man-hours of fishing effort obtained by two estimation methods. Rental boat anglers harvested an estimated grand total of 12,878 fish. The smaller of the private boat harvest estimates added to the rental boat estimate equaled 58,256 fish or 58 per surface acre of lake per year. Since the average fish exclusive of muskellunge certainly weighed less than one pound, the harvest in terms of pounds per acre must have been relatively small. Bluegills dominated the harvest numerically, while muskellunge represented a minute fraction. Private boat anglers were twice as successful as rental boat anglers catching fish at the rate of 0.470 per hour compared with 0.231 per hour by the latter group. The catch rate for both types of anglers combined during the ten survey weeks was 0.398 fish per man-hour, meaning that $2\frac{1}{2}$ hours were required to catch one fish.

TABLE 16. Estimated harvests of fish by private and rental boat anglers at Leesville Lake for the period March 31 through October 30, 1960

Speoies	Estimated harvest by private-boat anglers					Estimated harvest by rental-boat anglers		
	Equation method		Proportion method		Catch-rate[1]			
	Number	Percent	Number	Percent		Number	Percent	Catch-rate
Bluegills etc.	36,054	79.5	36,493	80.0	0.381	9,677	75.1	0.176
Orappies	5,488	12.1	5,483	12.0	0.056	1,643	12.8	0.028
Blaok bass	3,014	6.6	2,833	6.2	0.026	1,384	10.7	0.024
Bullheads etc.	510	1.1	498	1.1	0.003	96	0.7	0.002
Others	281	0.6	279	0.6	0.003	78	0.6	0.002
Muskellunge	31	0.1	31	0.1	0.0002	-	-	-
Total	45,378	100.0	45,621	100.0	0.470	12,878	100	0.251

[1]Catch-rates in fish caught per man-hour for both private- and rental-boat anglers are actual rates from interview data of the ten survey weeks.

The Estimated Muskellunge Harvest Compared with Concessionaires' Records

The seasonal summation of 31 muskellunge (Table 16) was close to a total of 22 observed by concessionaires but represented a crude estimate because of its projection from catch-rates involving only three fish.

A more reasonable method with such small numbers might have been to make a single computation by multiplying total man-hours for the season by the catch rate for the ten survey weeks combined. This procedure gave estimates of 24 and 23 muskellunge using private boat man-hours based on the equation and proportion methods, respectively. The proximity of these figures to the total of 22 fish checked in at concessions still did not imply high precision.

The observed catch of 22 fish included 16 fish caught by private boat anglers and 6 fish caught by rental boat anglers, yet no muskellunge were recorded from rental boat anglers in the interviews. If only one muskellunge had been checked among rental boat creels, the estimates of 24 and 23 would have been increased by 13 representing the projected catch estimate for rental boats. Three muskellunge were observed by concessionaires during the survey weeks and by chance, all three were recorded during interviews on the water.

PART VI

CONCLUSIONS

1. A positive relationship existed between numbers of private and rental fishing boats counted at Leesville Lake during eight of ten survey weeks in 1960. The relationship was expressed as a ratio of 3.06 private boats to 1 rental boat. Ratios of private to rental boats from counts of all weeks combined differed significantly among days of the week and among hours of the day, with a large increase during 8-9 p. m. The majority of daily ratios did not differ within individual weeks.

2. Time of sampling had important effects upon numbers of fishing boats counted. Mean counts of both kinds of boats increased greatly on Sundays and Saturdays, and counts of private boats increased during the last hourly period 8-9 p. m. Mean counts did not differ significantly among week days but did differ between weekend days.

3. A correlation between standard deviations and means of boat counts and departures of counts of certain time periods from normality, indicated that additional study should be made of the nature of the boat-count variates and of the utility of rectifying counts by a transformation.

4. Regression of hourly counts of private boats on hourly counts of rental boats and on 13 other independent variates including week, week squared, week cubed, four hourly periods and six days of the week accounted for 72 percent of the variation in the dependent variate.

Regression of daily sums of five hourly counts of private boats on daily sums of five hourly counts of rental boats, the preceding week terms, and one weekend term accounted for 90 percent of the variation in the dependent variate.

5. Statistically it would be desirable to have the boat counts randomly distributed among seasonal intervals including all weeks and among daily intervals including all hours, rather than every third week and every third hour as used in the present study.

6. Feasibility of using the regression equations of this study for estimating private boat fishing effort of other years depends upon the constancy of the boat-type relationship from year to year and similarity of time effects, particularly the seasonal or weekly trend. Ownership of private boats, for example, may still be increasing among Leesville Lake boat anglers.

7. Weather conditions apparently caused variations in boat counts over and above differences accounted for by time effects. Consequently the possibility of including weather factors as independent variates in regression should be considered.

8. The differences among proportions of total boats rented to total boats observed, the unknown amounts of nonfishing time in rental periods (from rental cards), the estimation of mean hours fished by private boat anglers, and the conversion of total daily rentals to boats countable on the water affected the accuracy of the estimation of fishing effort. These factors should be studied in more detail if further perfection of the method is desired.

9. Despite various limitations, use of the rental card data in conjunction with the methods of this study provided means of obtaining reasonable estimates of the total fishing effort and harvest at a large lake.

PART VII

SUMMARY

An introductory literature review indicated a number of methods for estimating fishing effort at large lakes and streams: these included direct expansion of counts of boats or anglers taken over a large proportion of the season; regression of random counts within time strata on independent time variables; and several designs of the analysis of variance. Catch-rates for estimating harvests of fish were obtained by supplementary interviews with anglers.

The present study was described as part of a project to evaluate stocking of the Ohio muskellunge in lakes of the Muskingum Watershed Conservancy District. The general objective was to devise a method for estimating annual harvests of muskellunge and indigenous species at Leesville Lake from catch-effort statistics, taking advantage of fishing boat rentals recorded on cards by licensed boat concessionaires. The specific objectives were to determine the nature of an expected relationship between numbers of private and rental fishing boats and the effects of time of sampling on boat distribution; and to use those factors as a basis for estimating total fishing effort of boat anglers and total harvests of fish.

The experimental procedures involved collection and analysis of counts of private and rental boats on the water, interview data from private- and rental-boat anglers engaged in fishing, and boat rental records from the Conservancy office. Boat counts were scheduled

every third week beginning with the week of April 17-23 and ending with the week of October 23-29, 1960; each day of every scheduled week; and every third hour of the day beginning with 8-9 a. m. and ending with 8-9 p. m. The counts were made by out-board motor boat along the 8-mile length of lake divided into zones A, B and C. Boat anglers were interviewed while fishing during the four intervening 2-hour periods. Each interview was identified by zone, kind of boat and type of fishing. Other essential items included number of anglers, hours fished, and numbers and kinds of fish caught. Rental cards from two concessionaires with a combined capacity of 91 boats were borrowed from the Conservancy office. The date, number of anglers, time out and time in were recorded from all cards that represented fishing boat rentals.

Results of analyses of the boat counts were described in respect to the nature of a boat-type relationship and the effects of area and time on boat-count distribution.

Ratios of private to rental boats counted on the lake were compared by zones, weeks, days of the week, and hours of the day using contingency tables and chi-square as the test statistic. Since the ratios did not differ significantly among zones, zonal counts were combined into total lake counts for other analyses. Total boats were less numerous in zone A than in zones B and C but were generally well distributed over the lake. Weekly boat-count ratios did not differ significantly among eight survey weeks when tested with low ratio weeks 1 and 2 excluded. The unweighted mean weekly ratios were 3.06 : 1 for the group of eight weeks and 1.58 : 1 for weeks 1 and 2 combined. Daily ratios differed significantly among days of the week; and hourly ratios

differed among hours of the day where a large increase was observed for 8-9 p. m. When the day of the week comparisons were made separately for each week, it was concluded that a large percentage of daily ratios of private to rental boats counted did not differ significantly within weeks.

Variances, means and frequency distributions of the boat counts were examined in respect to differences among time periods and to validity of subsequent analyses. After considering whether variances were homogeneous or not, means of each kind of boat count were compared within different time categories: hours, week days and weekend days. The two daily comparisons were used because the mean counts obviously were much greater on weekends. Hypotheses of equal means were accepted for private boat counts among week days and for rental boat counts among hours and among week days. Other comparisons resulted in rejections of the hypotheses. The private boat means and to a lesser extent the rental boat means followed roughly parabolic trends by weeks. Correlation of means and standard deviations indicated that a log transformation of the counts might have equalized variances. Hourly rental boat counts of survey weeks 3 through 7 formed a fairly symmetrical frequency distribution, while the hourly private boat counts were more variable and skewed toward the right. Inclusion of counts from the other five weeks caused strong asymmetry.

Several equations were obtained for the multiple regression of private boat counts on rental boat counts and on one or more of the independent variates hours, days and weeks. Third degree polynomials were used in each equation to describe the seasonal distribution of

private boat counts (weekly effects). In the first equation, two series of terms for day of the week effects and hour of the day effects and a single term for the effect of rental boat counts were added to the polynomial. Summations of individual hourly and daily effects were equated to zero and were considered as being superimposed upon the effect for each week. The assumption that the partial regression of private boat counts on rental boat counts was rectilinear and constant within all periods was only partly correct on the basis of the ratio analyses. The overall regression was highly significant and accounted for 72 percent of the variation in the counts of private boats. The five pairs of hourly counts within each day were combined and used to obtain two equations which accounted for 90 percent of the variation in daily counts of private boats. Separate terms for individual day of the week effects were replaced in the last equation by a single term for weekend effect. The latter equation was used to estimate private boat hours.

Boat-hours of fishing effort expended by private boat anglers were estimated for the ten survey weeks by three methods: 1) use of the final multiple regression equation and counts of rental boats made on the water; 2) use of the equation and counts of rental boats estimated from the rental cards; and 3) use of direct proportion involving counts of private and rental boats made on the water, numbers of rental boats from the rental cards, and estimated mean length of the private boat trips. All terms of the regression equation except x_5 (rental boats) were multiplied by 3 making y_1 (private boats) equal to total estimated private boat-hours within a 15 hour day (7 a. m. - 10 p. m.). Numbers

of daily boat rentals from the cards were converted to boats observable during 15 hours before substitution in the equation. Reference was made to the complete hourly distribution of boat rentals and to differences in the weekly distributions of boats rented and boats counted on the water. A mean private boat fishing trip of 4.022 hours was estimated by direct proportion from means of hours fished until interviewed by private and rental boats and the mean rental period minus an arbitrary factor of 0.5 hour representing nonfishing time. Summations of weekly boat-hour estimates by the three methods differed by a maximum of 5.9 percent of the smallest summation (14,288). Differences among estimates within weeks were much greater. Each series of weekly estimates was compared with its hypothetical distribution based on the percentage distribution of private boat counts made on the lake.

Private boat fishing effort for the season (March 31 - October 30) was obtained by combining estimates of survey weeks and intervening weeks as estimated by the second and third methods listed in the preceding paragraph. The procedure, including the projection of relationships from observed into nonobserved periods, produced totals of 49,162 and 48,907 boat-hours, respectively.

Rental boat fishing effort for the season was obtained by multiplying the number of boat rentals from the cards of each week by the corresponding mean hours per rental minus 0.5 hour nonfishing time. Summation gave 22,696 rental boat hours fished. Incomplete rental data and unaccounted for weekly rentals may have caused as much as a 10 percent underestimate.

Boat-hours were converted to man-hours before computing fish

harvests. Weekly private boat hours were multiplied by 2.071 anglers per boat as computed from interview data, while weekly rental boat hours were multiplied by the corresponding mean numbers of anglers per boat as computed separately from rental cards of each week. Since the mean number of anglers per boat was higher from the rental cards than from interview data, a positive bias of approximately 11 percent may have resulted, tending to offset the negative bias caused by unaccounted rentals. Summation of the weekly figures produced season totals of 102,726 and 101,283 private boat man-hours for the two estimation methods, respectively, and 54,812 rental boat man-hours. Combined, these figures amounted to an annual fishing effort of 156 man-hours per surface acre of water.

The frequency distribution of anglers per rental boat contacted on the water differed significantly from similar distributions of private boats contacted on the water and rental boats recorded from the cards. A larger percentage of private boats was occupied by single anglers, whereas the rental cards listed what appeared to be an excessive number of boats with four anglers. Apparently certain members of boat rental parties did not fish and therefore were not recorded by interviewers.

The total numbers of fish harvested by boat anglers during each week of the 1960 season were estimated by multiplying man-hours fished by catch rates computed from interview data. Catch rates from adjacent survey weeks were used in the computations for nonsurvey weeks (Table 1), and all weekly estimates were then combined. Private boat anglers harvested an estimated grand total of more than 45,000 fish (45,378 and 45,621 by the two methods of computing fishing effort),

while rental boat anglers harvested an estimated grand total of 12,878 fish. Combined these figures amounted to 58 fish per surface acre of water per year. Bluegills dominated the catch comprising 80 and 75 percent of the separate harvests, respectively. Muskellunge comprised only 0.1 percent of the private boat harvest and were not recorded among rental boat interviews.

The estimated muskellunge catch obtained by the alternative method of multiplying total man-hours for the season by the overall catch rate of the ten survey weeks amounted to 24 and 23 fish (according to the two methods of computing fishing effort) compared with 22 fish checked in at the concessions. Despite this proximity of estimated and reported catches, the estimates were crude because of their computation from catch rates that involved only three fish.

In completing the study, the following conclusions were made:

1. A positive relationship between private and rental boats during eight of ten survey weeks was expressed as a ratio of 3.06 to 1. Boat-type ratios for all weeks combined differed significantly, however, among days of the week and among hours of the day.

2. Time of sampling had important effects upon numbers of fishing boats counted.

3. Additional study should be made of the utility of rectifying boat counts by a transformation.

4. A final regression equation accounted for 90 percent of the variation in daily totals of hourly counts of private boats.

5. It would be desirable statistically to have the boat counts randomly distributed among seasonal intervals including all weeks and

all hours.

6. Feasibility of using the regression equation for estimating private boat fishing effort of other years depends upon the constancy of the various factors (effects) that were included.

7. Treatment of weather factors as independent variates should be considered for refinement of the regression method.

8. Various other limiting conditions that affected accuracy should also be studied in more detail.

9. Use of the rental card data in conjunction with the methods of this study provided reasonable estimates of the total fishing effort and catch at a large lake.

PART VIII

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APPENDIX A

SUMMARY OF FISH CAUGHT AND RATES OF CAPTURE BY PRIVATE BOAT ANGLERS INTERVIEWED WHILE FISHING AT LEESVILLE LAKE EVERY THIRD WEEK STARTING WITH THE WEEK OF APRIL 17-23 AND ENDING THE WEEK OF OCTOBER 23-29, 1960

SURVEY WEEK	NUMBER OF ANGLERS	MAN-HOURS FISHED		MUSKELLUNGE		BLUEGILLS ETC.		CRAPPIES		BLACK BASS		BULLHEADS ETC.		OTHERS		TOTAL[3]	
		FIRST CONTACTS	ALL CONTACTS[1]	NUMBER	RATE[2]	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE
1	209	601	736	-	-	17	.0283	30	.0499	47	.0782	8	.0133	-	-	102	.1697
2	142	317	520	1	.0019	1	.0032	2	.0063	17	.0587	-	-	-	-	20	.0631
3	749	1,518	2,108	-	-	480	.8172	194	.1282	17	.0112	1	.0007	2	.0013	694	.4536
4	888	1,739	2,540	-	-	927	.5330	38	.0218	35	.0201	4	.0023	1	.0006	1,005	.5779
5	829	1,548	2,144	1	.0005	575	.3727	64	.0415	44	.0285	8	.0052	3	.0019	694	.4499
6	766	1,491	1,979	-	-	549	.3682	120	.0805	29	.0195	10	.0067	12	.0080	700	.4629
7	688	1,121	1,474	-	-	501	.4467	48	.0428	34	.0303	13	.0116	5	.0045	601	.5359
8	272	482	580	-	-	318	.6541	22	.0452	11	.0226	3	.0062	4	.0082	358	.7363
9	247	473	603	-	-	228	.4820	19	.0402	8	.0169	-	-	-	-	255	.5391
10	154	377	426	1	.0023	89	.2363	-	-	6	.0159	1	.0027	-	-	96	.2548
TOTAL	4,864	9,661	13,109	8	.0002	3,685	.3814	537	.0556	248	.0257	48	.0050	27	.0028	4,545	.4704

[1] INCLUDES TWO OR MORE CONTACTS OF THE SAME PARTIES FOR COMPUTING MUSKELLUNGE CATCH RATES.

[2] NUMBER OF FISH CAUGHT PER MAN-HOUR.

[3] EXCLUSIVE OF MUSKELLUNGE.

APPENDIX B

SUMMARY OF FISH CAUGHT AND RATES OF CAPTURE BY RENTAL BOAT ANGLERS INTERVIEWED WHILE FISHING AT LEESVILLE LAKE EVERY THIRD WEEK STARTING WITH THE WEEK OF APRIL 17-23 AND ENDING THE WEEK OF OCTOBER 23-29, 1960

SURVEY WEEK	NUMBER OF ANGLERS	MAN-HOURS FISHED		MUSKELLUNGE		BLUEGILLS ETC.		CRAPPIES		BLACK BASS		BULLHEADS ETC.		OTHERS		TOTAL	
		FIRST CONTACTS	ALL CONTACTS[1]	NUMBER	RATE[2]	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE	NUMBER	RATE
1	195	576	721	-	-	43	.0747	8	.0139	25	.0434	-	-	-	-	76	.1320
2	112	280	404	-	-	20	.0715	7	.0250	13	.0465	-	-	-	-	40	.1431
3	245	607	863	-	-	290	.4778	14	.0231	7	.0115	-	-	-	-	311	.5124
4	272	527	881	-	-	142	.2693	16	.0303	31	.0588	-	-	-	-	189	.3584
5	242	554	748	-	-	75	.1354	7	.0126	8	.0144	1	.0018	-	-	91	.1643
6	257	544	851	-	-	85	.1563	35	.0644	4	.0074	2	.0037	6	.0110	132	.2428
7	242	511	811	-	-	68	.1332	15	.0294	9	.0176	3	.0059	2	.0039	97	.1900
8	92	194	286	-	-	9	.0464	15	.0774	4	.0206	1	.0052	-	-	29	.1496
9	122	267	385	-	-	22	.0823	2	.0075	1	.0037	-	-	-	-	25	.0936
10	69	229	261	-	-	-	-	-	-	-	-	-	-	1	.0044	1	.0044
TOTAL	1,848	4,288	6,210	-	-	754	.1758	119	.0278	102	.0238	7	.0016	9	.0021	991	.2311

[1] INCLUDES ALL CONTACTS OF INDIVIDUAL PARTIES.

[2] NUMBER OF FISH CAUGHT PER MAN-HOUR.

APPENDIX C

WEEKLY ESTIMATES OF FISHING EFFORT AND CATCH BY PRIVATE BOAT ANGLERS AT LEESVILLE LAKE IN 1960

BASED ON REGRESSION ESTIMATES OF BOAT-HOURS

WEEK	ESTIMATED BOAT-HOURS	ESTIMATED MAN-HOURS[1]	ESTIMATED NUMBER OF FISH CAUGHT					
			MUSKELLUNGE	BLUEGILLS ETC.	CRAPPIES	BLACK BASS	BULLHEADS ETC.	OTHERS
3/31-4/2	195	485	-	11	20	32	5	-
4/3-9	215	446	-	13	22	35	6	-
4/10-16	1,060	2,196	-	62	110	172	29	-
4/17-23 *	1,108	2,294	-	65	114	179	31	-
4/24-30	1,316	2,726	-	77	136	213	36	-
5/1-7	1,665	3,448	7	11	22	185	-	-
5/8-14 *	1,127	2,335	4	7	15	125	-	-
5/15-21	2,468	5,112	10	16	32	275	-	-
5/22-28	1,958	4,056	-	1,287	520	45	3	5
5/29-6/4 *	2,803	5,805	-	1,841	744	65	4	6
6/5-11	2,424	5,020	-	1,592	644	56	4	7
6/12-18	2,062	4,270	-	2,276	93	86	10	3
6/19-25 *	2,728	5,649	-	3,011	123	114	13	3
6/26-7/2	2,702	5,595	-	2,982	122	112	13	3
7/3-9	3,307	6,849	3	2,553	284	195	36	13
7/10-16 *	2,178	4,518	2	1,681	187	129	23	9
7/17-23	2,604	5,393	3	2,010	224	154	28	10
7/24-30	2,517	5,213	-	1,919	420	102	35	42
7/31-8/6 *	2,258	4,677	-	1,722	376	91	31	37
8/7-13	2,184	4,522	-	1,665	364	88	30	36
8/14-20	2,154	4,461	-	1,993	191	135	52	20
8/21-27 *	1,545	3,199	-	1,429	137	97	37	14
8/28-9/3	1,644	3,404	-	1,521	146	103	39	15
9/4-10	1,670	3,458	-	2,262	156	78	21	28
9/11-17 *	805	1,668	-	1,091	75	38	10	14
9/18-24	840	1,739	-	1,137	79	39	11	14
9/25-10/1	629	1,302	-	628	52	22	-	-
10/2-8 *	466	965	-	465	39	16	-	-
10/9-15	496	1,027	-	495	41	17	-	-
10/16-22	283	586	1	138	-	9	2	-
10/23-29 *	112	232	1	55	-	4	1	-
10/30	79	164	-	39	-	3	-	-
TOTAL	49,162	102,726	31	36,054	5,488	3,014	510	281

* SURVEY WEEK.

[1] BOAT-HOURS X 2.071 MEN PER BOAT.

APPENDIX D

WEEKLY ESTIMATES OF FISHING EFFORT AND CATCH BY PRIVATE BOAT ANGLERS AT LEESVILLE LAKE IN 1960

BASED ON DIRECT PROPORTION ESTIMATES OF BOATS

WEEK	NUMBER OF BOATS	BOAT HOURS[1]	MAN HOURS[2]	ESTIMATED NUMBER OF FISH CAUGHT					
				MUSKELLUNGE	BLUEGILLS ETC.	CRAPPIES	BLACK BASS	BULLHEADS ETC.	OTHERS
3/31-4/2	40	162	336	-	10	17	26	4	-
4/3-9	65	263	543	-	15	27	42	7	-
4/10-16	192	774	1,603	-	45	80	125	21	-
4/17-23 *	200	803	1,662	-	47	83	130	22	-
4/24-30	316	1,271	2,632	-	74	131	206	35	-
5/1-7	337	1,357	2,810	5	9	18	151	-	-
5/8-14 *	168	674	1,397	3	4	9	75	-	-
5/15-21	472	1,896	3,927	7	13	25	211	-	-
5/22-28	461	1,854	3,839	-	1,218	492	43	3	5
5/29-6/4*	761	3,060	6,338	-	2,010	813	71	4	8
6/5-11	588	2,364	4,895	-	1,553	628	55	3	6
6/12-18	408	1,641	3,398	-	1,811	74	68	8	2
6/19-25 *	656	2,640	5,467	-	2,914	119	110	13	3
6/26-7/2	641	2,578	5,339	-	2,846	116	107	12	3
7/3-9	1,103	4,436	9,188	5	3,424	381	262	48	17
7/10-16 *	559	2,249	4,659	2	1,736	193	133	24	9
7/17-23	779	3,134	6,489	3	2,418	269	185	34	12
7/24-30	619	2,491	5,159	-	1,900	415	101	35	41
7/31-8/6 *	536	2,155	4,463	-	1,643	359	87	30	36
8/7-13	526	2,118	4,386	-	1,615	353	86	29	35
8/14-20	536	2,156	4,465	-	1,995	191	135	52	20
8/21-27 *	332	1,334	2,763	-	1,234	118	84	32	12
8/28-9/3	394	1,584	3,281	-	1,466	140	99	38	15
9/4-10	464	1,866	3,865	-	2,528	175	87	24	32
5/11-17 *	139	557	1,154	-	755	52	26	7	9
9/18-24	202	812	1,682	-	1,100	76	38	10	14
9/25-10/1	140	563	1,167	-	562	47	20	-	-
10/2-8 *	111	447	925	-	446	37	16	-	-
10/9-15	140	563	1,167	-	562	47	20	-	-
10/16-22	136	546	1,130	3	267	M	18	-	-
10/23-29 *	91	368	761	2	180	-	12	2	-
10/30	47	190	393	1	93	-	6	1	-
TOTAL	12,113	48,907	101,283	31	36,493	5,485	2,835	498	279

*SURVEY WEEK.

[1]NUMBER OF BOATS X 4.022 HOURS.

[2]BOAT-HOURS X 2.071 MEN PER BOAT.

APPENDIX E

WEEKLY ESTIMATES OF FISHING EFFORT AND CATCH BY RENTAL BOAT ANGLERS AT LEESVILLE LAKE IN 1960

BASED ON RENTAL CARD DATA

WEEK	NUMBER OF BOATS RENTED	HOURS PER RENTAL -0.5	BOAT HOURS[1]	MEN PER BOAT	MAN HOURS[2]	ESTIMATED NUMBER OF FISH CAUGHT				
						BLUE-GILLS ETC.	CRAP-PIES	BLACK BASS	BULL-HEADS ETC.	OTHERS
3/31-4/2	34	5.26	179	2.03	3633	27	5	16	-	-
4/3-9	55	4.02	221	2.02	446	33	6	19	-	-
4/10-16	162	4.88	791	1.97	1,562	117	22	68	-	-
4/17-23 *	168	5.52	927	2.11	1,954	146	27	85	-	-
4/24-30	266	5.67	1,508	2.14	3,226	241	45	140	-	-
5/1-7	171	4.73	810	2.08	1,686	121	42	78	-	-
5/8-14 *	85	4.26	362	1.88	681	49	17	32	-	-
5/15-21	239	5.13	1,226	2.23	2,738	196	66	127	-	-
5/22-28	149	5.10	760	2.22	1,687	806	39	19	-	-
5/29-6/4 *	246	5.20	1,279	2.48	3,176	1,517	73	37	-	-
6/5-11	190	5.29	1,005	2.52	2,533	1,210	59	29	-	-
6/12-18	133	4.74	631	2.50	1,574	424	48	93	-	-
6/19-25 *	214	5.16	1,104	2.53	2,796	753	85	164	-	-
6/26-7/2	209	4.99	1,044	2.51	2,622	706	79	154	-	M
7/3-9	286	5.19	1,485	2.66	3,951	535	50	57	7	-
7/10-16 *	145	5.09	737	2.59	1,912	259	24	28	3	-
7/17-23	202	4.98	1,006	2.54	2,550	345	32	37	5	-
7/24-30	200	5.34	1,068	2.70	2,877	450	185	21	11	-
7/31-8/6 *	173	5.16	892	2.65	2,361	369	152	17	9	26
8/7-13	170	4.92	836	2.68	2,236	349	144	17	8	25
8/14-20	181	5.44	984	2.67	2,632	351	77	46	16	10
8/21-27 *	112	5.39	603	2.53	1,524	203	45	27	9	6
8/28-9/3	133	5.19	690	2.58	1,780	237	52	31	10	7
9/4-10	154	4.99	768	2.73	2,100	97	163	43	11	-
9/11-17 *	46	5.39	248	2.11	523	24	40	11	3	-
9/18-24	67	5.21	349	2.31	808	37	63	17	4	-
9/25-10/1	58	4.82	279	2.33	651	54	5	2	-	-
10/2-8 *	46	4.87	224	1.91	429	35	3	2	-	-
10/9-15	58	4.68	271	2.05	557	46	4	2	-	-
10/16-22	46	4.59	211	2.13	450	-	-	-	-	2
10/23-29 *	31	4.38	136	2.10	285	-	-	-	-	1
10/30	16	4.06	65	2.19	142	-	-	-	-	1
TOTAL	4,445	5.61	22,699	2.41	54,812	9,677	1,643	1,384	96	78

*SURVEY WEEK.

[1]NUMBER OF BOATS RENTED X HOURS PER RENTAL -0.5 HOUR.

[2]BOAT HOURS X MEN PER BOAT.