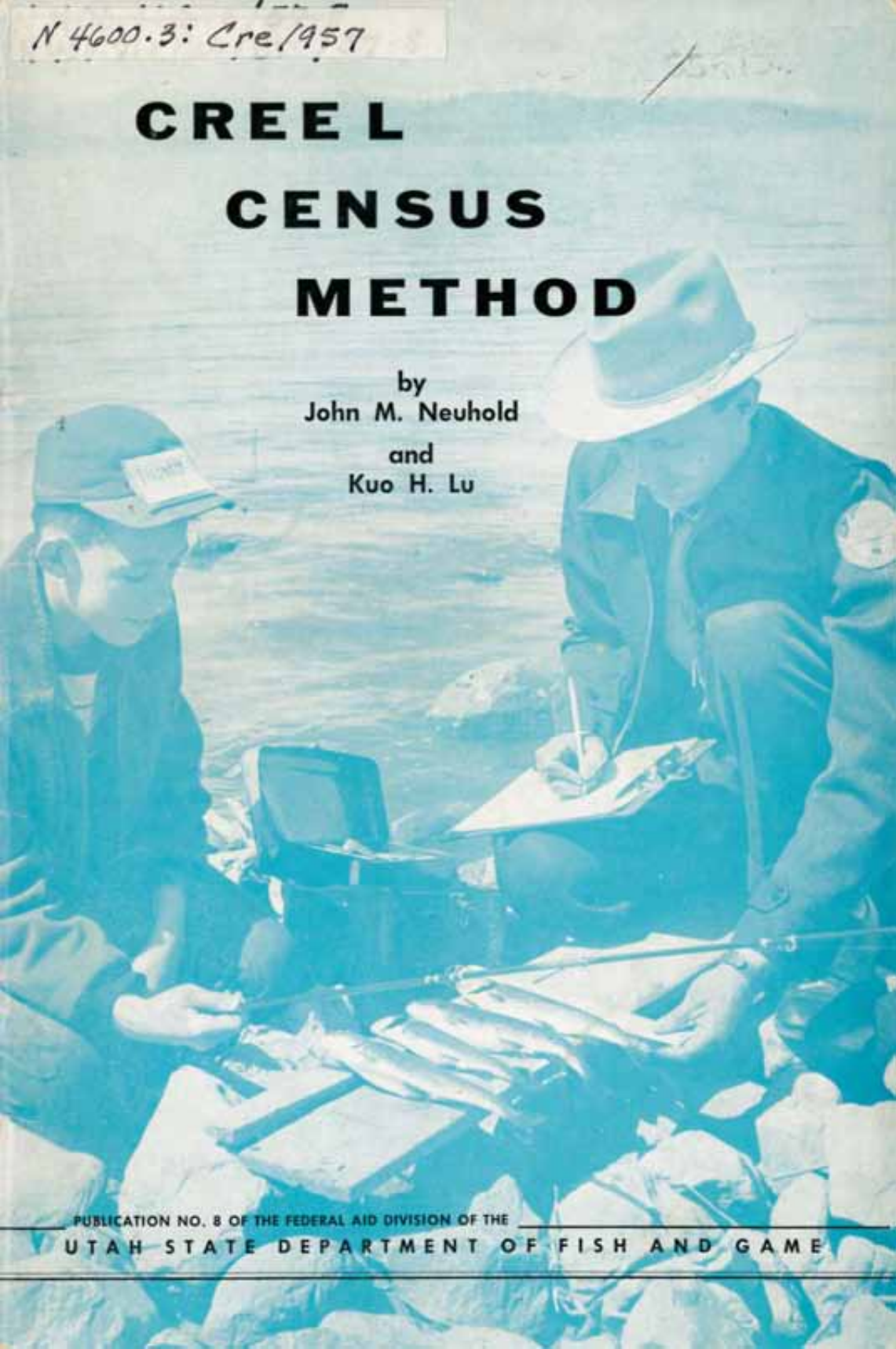


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# **CREE L CENSUS METHOD**

by  
John M. Neuhold  
and  
Kuo H. Lu



PUBLICATION NO. 8 OF THE FEDERAL AID DIVISION OF THE  
UTAH STATE DEPARTMENT OF FISH AND GAME

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### ERRATA

Figure 2, page 12.

The solid lines represent the pressure and the dotted lines the rate of success. (Omitted from the discussion)

Page 28, line 3 should read:

"... and  $S_r^2$  equals the root mean square errors of the mean number of boat fisherman hours and the mean rate of fishermen per boat ..."

Page 29, line 26 should read:

"... = 286,870  $\pm$  82,732 fishermen hours."

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## INTRODUCTION

Creel census in a cold water trout fishery is, perhaps, one of the most useful tools available in the management of that fishery. This statement is particularly true in situations where the fishery is being maintained, of necessity, by artificial means, and true to a lesser extent when the fishery is maintained through natural processes.

Such basic information concerning the mortality from fishing in the fish population as a total fishing pressure, rate of fishing success, and total harvest can be obtained by the application of creel census. From this information the investigator can derive an assortment of data concerning the fish population, e.g., (1) the extent of harvest of fish, (2) the size of the fish population, (3) the effect of a given fishing pressure on a fish population, and (4) the numbers of fish required to replace a mortality caused by fishing.

Creel censuses can be accomplished by two methods: (1) observing the total pressure and harvest for an entire season, or (2) estimating the pressure and harvest by sampling of the total population. Observing the total pressure and harvest is costly as well as time and effort consuming except in some isolated instances. One need not argue, however, as to the validity of the values obtained by this method. Estimates, on the other hand, are done with considerable saving in time, money, and effort but with the subsequent sacrifice of certainty that the total observation offers.

Estimates number many in methods and analysis. They range from a voluntary fisherman-questionnaire return to counting and interviewing fishermen, all with varying degrees of success and reliability. Since an estimate is obtained from sampling a portion of the whole population, great variance in the accuracy and precision can be encountered depending upon the thoroughness of the design and the simplicity of the analysis.

Accuracy can only be attained through careful design of the creel census and precision through sound application of statistical principles.

The primary objective of a creel census in management is the determination of the harvest or fishing mortality during a specified period. Secondly, the objectives include such varied information as the economics of the fishery (a function of the fishing pressure) and further estimates of the fish population (related, in some extent, to the fishing mortality).

As stated previously, two methods exist whereby values concerning the fishing pressure and harvest can be obtained: (1) observation of all



fishermen and their catches during a specified period of time, and (2) observation of a portion of the fishing pressure and harvest during a specified period with a final expansion to an estimate of the whole.

Observation of the whole provides the most desirable kind of data since no variance in the totals is encountered. Data of this nature represent the true values of the population being enumerated. This type of a creel census, however, is usually impractical in terms of time, money, and effort necessary for accomplishment.

Observation of a portion of the whole (the sample) and a final expansion to the estimate of the whole can be made only with palpable reservations. Since the sample is based on only a part of the total situation, allowances must be made for that portion of the universe not sampled. Thus the error that may or may not be encountered by expanding the sample to the whole is taken into consideration and qualifies the final statement about the universe. The estimate, if used properly, can give good and even excellent approximations of the actual population values with an expenditure of money, time, and effort somewhat less than what would be necessary were the universe obtained.

The goal of most fishery managers is to conduct as many creel censuses as limited funds will permit; consequently, the estimate becomes, to them, even more important. However, estimates that require excessive expenditures gain little over obtaining the actual population values. The necessity arises, then, to provide an estimate that will afford a critically accurate value at the least possible cost.

The object of this paper is to present a method that can be used under a variety of conditions with reasonably accurate results.

## CREEL CENSUS DESIGN

Creel census methods have been designed under a number of techniques. Designs range from those that provide substantially accurate estimates of the mean values to those that are palpably inaccurate. The primary basis for providing accuracy to the estimates of the mean values is the consideration of all variables, some of which are cryptically subtle; e.g., the estimate of the average number of fishermen per day for an entire season must consider the length of the possible fishing day (where daylight hours are used as the criterion for the length of the fishing day) progressively and not as an entity. This becomes obvious when the peak of the fishing pressure occurs in June, that time of the year with the longest possible day, and the trough of the fishing pressure occurs in December, that time of the year with the shortest possible fishing day. If an average value for the length of the day for the season were used, the low pressure would receive weight equal to the high pressure with a resulting under-estimate of the total pressure.

Precision of the estimate in most creel censuses is not even considered, and yet, without precision the values derived from an estimate are but guesses. Fishery biologists commonly tend to temper what they call the precision of their estimate with assumptions, many of which are unqualified; e.g., in a fisherman count along a 20-mile stretch of stream where an attempt is made to count and contact all the fishermen for the sample day, the assumption is made that all fishermen are counted and contacted during the sample day or that the number of fishermen missed is probably insignificant. In most situations the number of fishermen missed is probably insignificant and probably has little bearing on the accuracy of the estimate of the mean number of fishermen per day. However, if fishermen are missed, they are probably missed in proportion to the intensity of the fishing pressure and, consequently, would have a variance similar to the variance of the fishermen count. The precision of the mean number of fishermen per day, then, could be and probably is adversely affected.

Fishermen numbers, as many other biological populations not under laboratory control, are influenced by a number of non-predictable phenomena as well as some that are predictable. Factors such as weather and rate of fishing success definitely have an effect on numbers of fishermen fishing a given body of water during a season; yet, weather and fishing success are not predictable.

Data collected from Scofield Reservoir and Fish Lake during 1956 show a significant difference in mean numbers of fishermen between counts made during the inclement weather and counts made during non-inclement weather (Table 1). The counts were made on the basis of water condition (calm, choppy or white caps) and on the weather index (clear, less than 50% overcast, greater than 50% overcast, and raining or snowing). Andriano found that weather categories, similar to those mentioned, produced one of the greatest differences in numbers of fishermen on Henry's Lake in Idaho of all the variables examined.<sup>1</sup>

TABLE 1. Differences in the mean pressures of shore fishermen on Scofield Reservoir and boat fishermen on Fish Lake during June and July, 1956, between inclement and non-inclement weather categories.

Place	Mean Pressure		Computed t-value <sup>3</sup>	t-value at 95% Confidence Level
	Inclement Weather	Non-inclement Weather		
Fish Lake .....	31.45 <sup>2</sup>	51.14 <sup>1</sup>	2.09	2.04
Scofield Reservoir .....	16.40 <sup>2</sup>	22.64 <sup>2</sup>	3.45	2.04

<sup>1</sup> Both values represent mean number of boats per count.

<sup>2</sup> Both values represent mean number of fishermen per count.

<sup>3</sup> Hypothesis tested is one of equal means (after Dixon and Massey, 1951, pp. 102 and 103). Both instances show a t-value greater than would be expected at the 95% confidence level, and the hypothesis of equal means is rejected.

Not only does the nature of the weather at the particular body of water under surveillance have a direct effect on the numbers of fishermen, but the weather at nearby centers of population shows indications of affecting fishermen numbers. Data from Bear Lake, Utah-Idaho, imply that weather in the cities of Logan and Ogden might have some influence on numbers of fishermen even though the weather at the lake was opposite the weather at the municipalities.

Additional data from the 1955 Deer Creek Reservoir Creel Census indicate a significant difference in mean numbers of fishermen between days following periods of good success and days following periods of poor success (Fig. 1). The effect appears to be somewhat delayed in that the rate of success appears to influence fishermen numbers after occurrence rather than during occurrence.

Similarly, the time of day seems to have delayed effect on the daily fishing pressure. The fishermen numbers, except for the opening hours of the day, appear to be influenced by the rate of success in the period preceding, as on Deer Creek Reservoir during the 1955 season (Fig. 2).

<sup>1</sup> Personal correspondence with Don Andriano of the Idaho Department of Fish and Game dated August 22, 1956.

Since fishermen fish to catch fish this quasi-correlation probably has validity.

Differences in mean pressures between week days and week-end days and holidays also appear to be significant from creel censuses conducted in Utah (Table 2). Best and Boles (1956) implied as much when they sampled all week-end days and holidays of the 1953 Rush Creek and Castle Lake data.

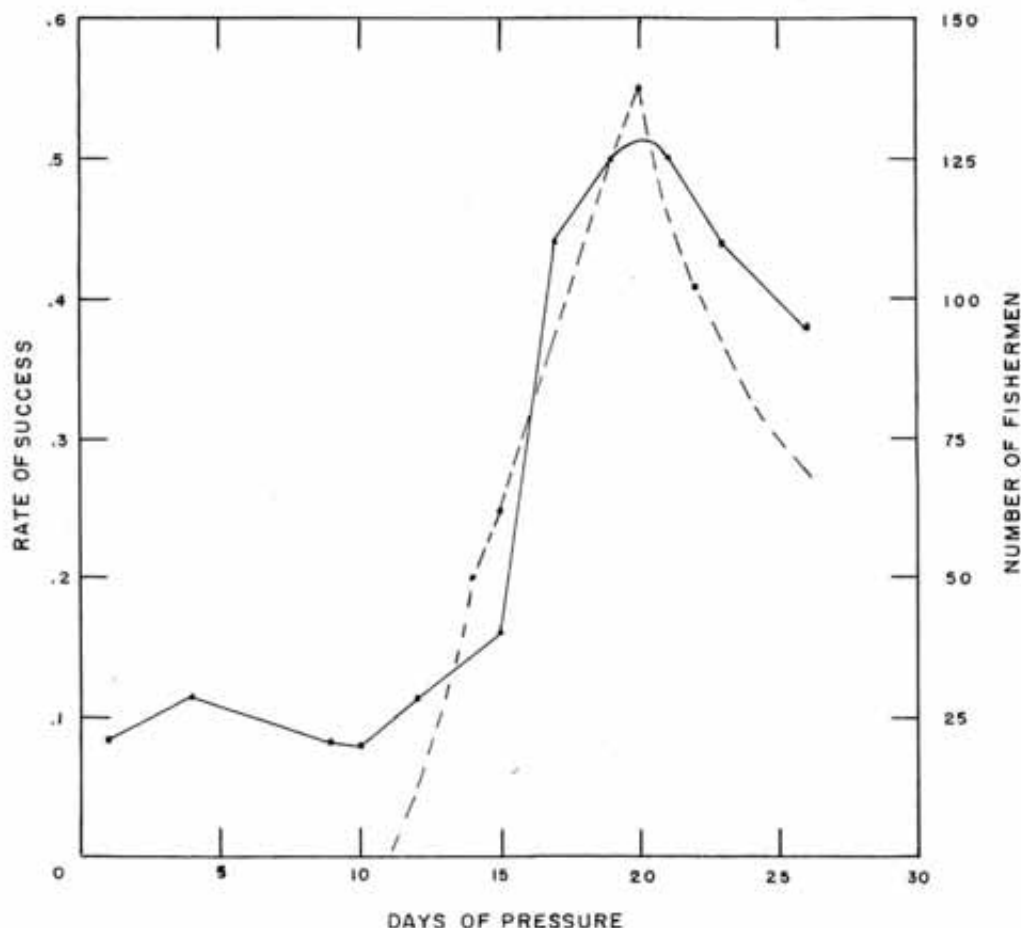


Figure 1. Fishing pressure and rate of success on Deer Creek Reservoir during August, 1955. The solid line represents the fishing pressure and the dotted line the rate of success in fish per hour. Note that the fishing pressure tends to lag after the rate of success. The peak in the rate of success occurred after an application of copper sulfate for plankton control.

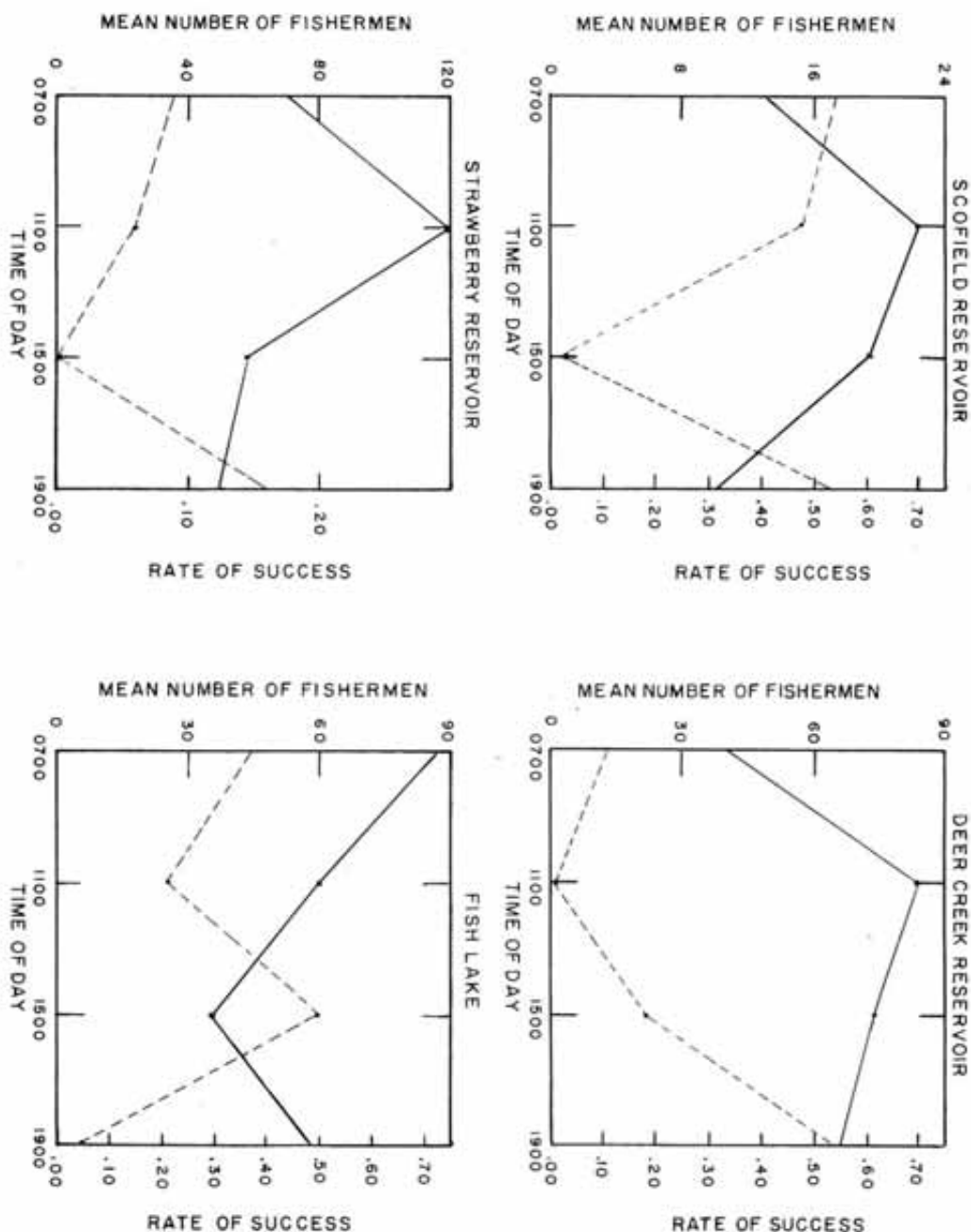


Figure 2. Mean daily rate of success and pressure on four 1955 creel census waters. Note that the rate of success in fish per hour appears to produce a latent effect on the pressure. A possibility also exists that the rate of success is affected by increasing numbers of in-experienced fishermen which tends to reduce the rate of success in the period following.

TABLE 2. Differences in mean pressures on Scofield, Deer Creek, Strawberry Reservoirs and Fish Lake during 1955 between weekdays and week-end days and holidays.

Place	Mean Pressure <sup>1</sup>		Computed t-value <sup>2</sup>	t-value at 95% Confidence Level
	Weekdays	Week-end Days and Holidays		
Scofield Reservoir .....	12.89	54.88	8.33	1.97
Deer Creek Reservoir ..	14.35	79.42	4.88	1.97
Strawberry Reservoir ....	38.64	114.80	9.95	1.97
Fish Lake .....	36.72	108.00	6.25	1.97

<sup>1</sup> Mean pressure is in terms of boats per count.

<sup>2</sup> Hypothesis tested is: two populations have the same mean when the population variance is unknown (after Dixon Massey, 1951, pp. 102 and 103). Note that the computed t-values in each situation are significantly larger than the t-value at the 95% confidence level, requiring the rejection of the hypothesis of equal means.

Air temperature was also found to be quite closely correlated with fishermen numbers. Numbers of fishermen appear to increase as the temperature rises but center primarily in the 60-80 degree Fahrenheit range (Fig 3). The correlation coefficient was .456 indicating a significant dependence of fishermen numbers on temperature at the 95% confidence level.

The time of season also appears to have an effect on fishermen numbers. Numbers of fishermen, in Utah, during the general, 135-day trout season decrease as the season progresses. Fishermen per count on Fish Lake during the 1955 creel census averaged 150 during the first 20 days of the season and declined to 45 during the last 20 days of the season (Fig.4).

This decrease in fishermen numbers is attributed, in a large extent, to the caprice of the fisherman. Data from the 1952 creel census on Panguitch Lake indicate that fishermen who took fewer trips during the season made those trips during the fore part of the season or on holidays. Of the fishermen questioned on Panguitch Lake; 65% made fewer than 10 trips during the season, 24% made between 10 and 20 trips, and the remaining 34% made between 20 and 110 trips during the season.

A close correlation was also found between the number of trips a man made during the season and his rate of success. The more trips fishermen made the better was their rate of success (Fig. 5), i.e. the more experienced fishermen catch more fish and tend to influence the seasonal rate of success upward toward the end of the season.



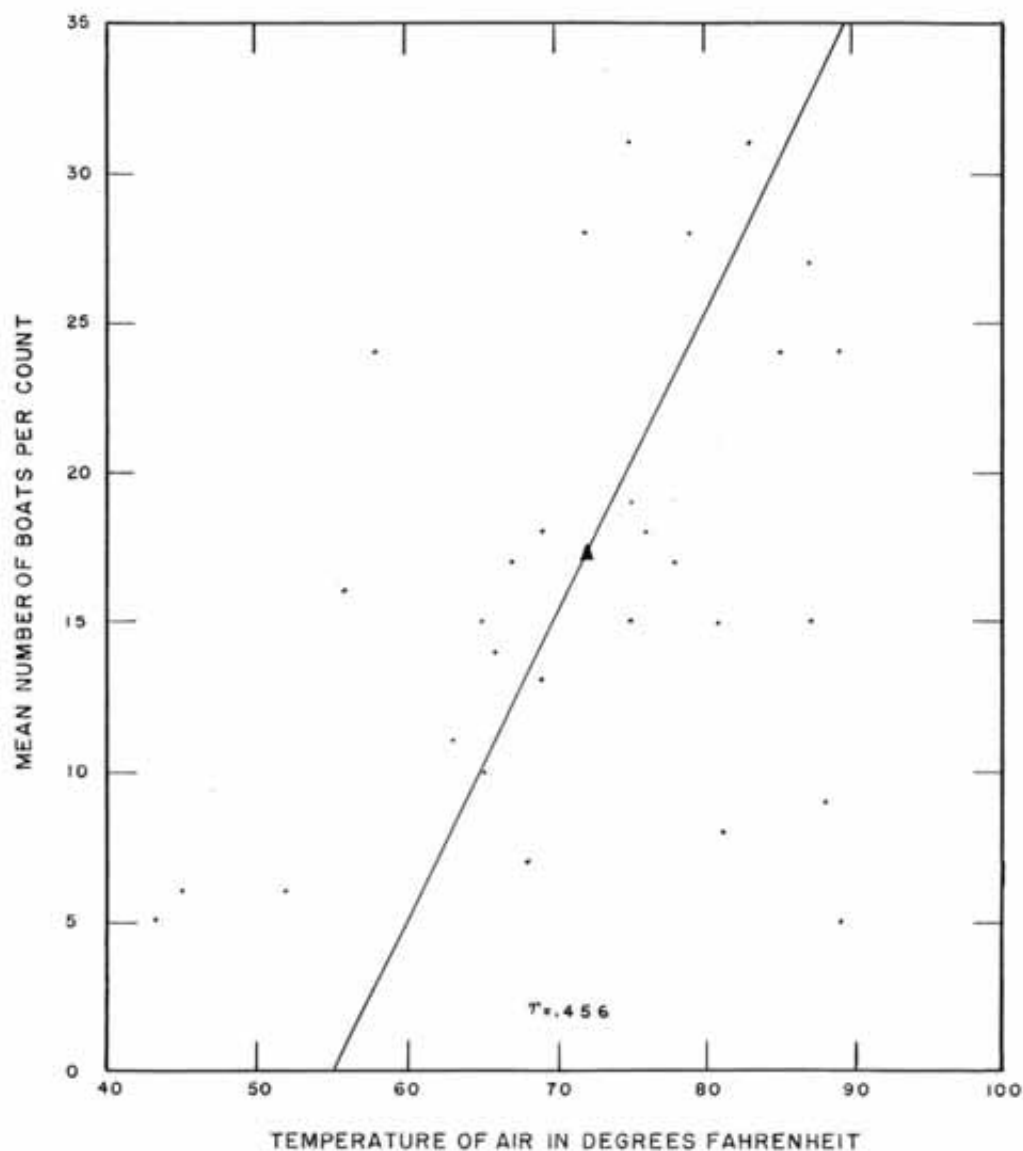


Figure 3. A correlation between air temperature and fishing pressure. The correlation coefficient was calculated at 0.456 during June and July of 1956 on Deer Creek Reservoir.



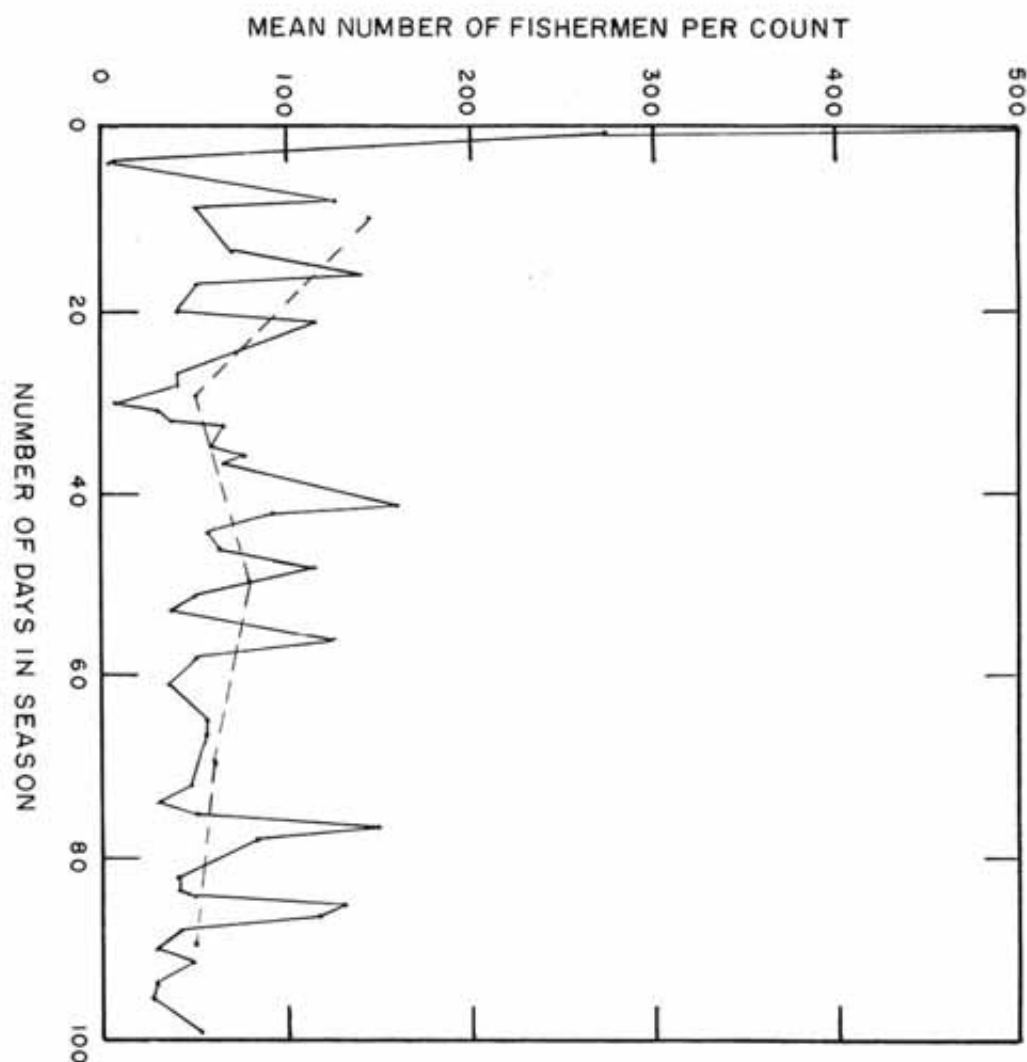


Figure 4. Seasonal fishing pressure curve on Fish Lake during the 1955 season (solid line). The dotted line represents the means in pressure for 20-day periods. Note that the pressure tends to decrease slightly as the season progresses.

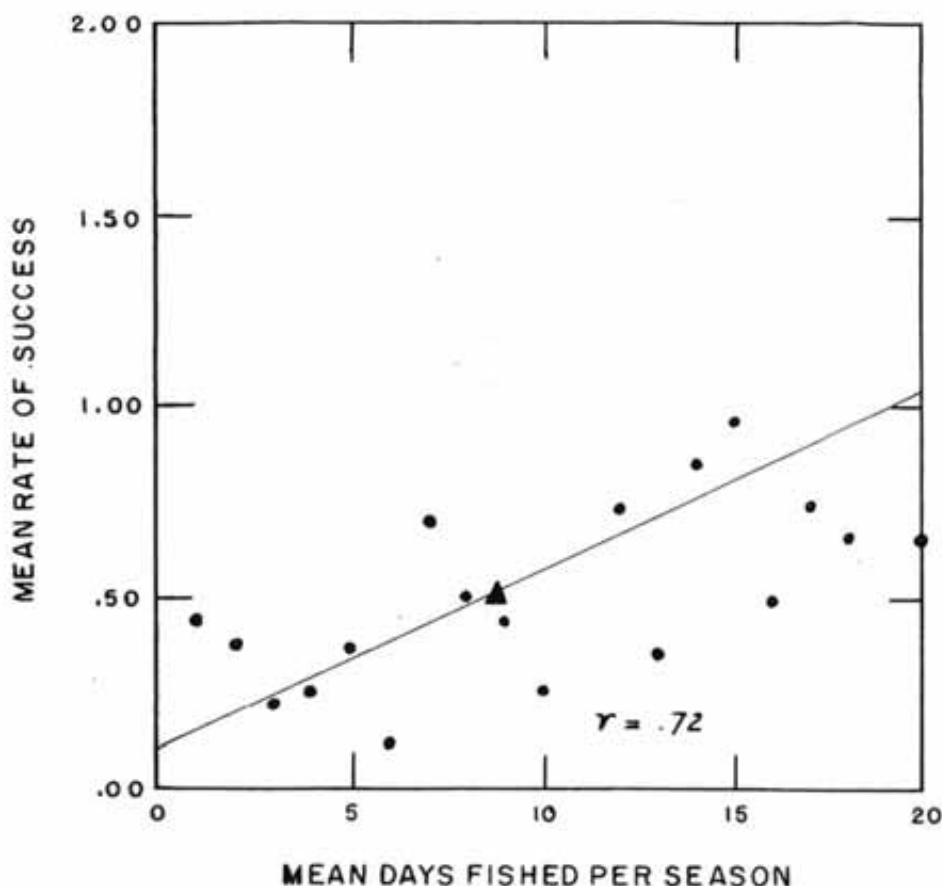


Figure 5. Correlation between mean days fished per season and rate of success. The correlation coefficient was calculated at 0.72. Note that the more successful fishermen fished oftener during the season. (From 1952 Panguitch Lake and a Navajo Lake creel censuses).

The variables just mentioned all tend to influence fishermen numbers. If accuracy of the estimates of the mean is to be attained such variables and their interactions must be carefully scrutinized for significant effects. If significant effects occur, the effect produced must be taken into the consideration of both the design and the analysis of the creel census.

## FISHERMAN COUNTS

Fishermen fish either from boats or from the shore (wading, docks and piers to be construed as from the shore) in all inland water situations. This quality in fishermen situations makes the fisherman or his boat amenable to counting. Since the fisherman or his boat can be counted, the census taker can conceivably obtain indices to fishermen numbers either in total or in terms of average number of fishermen or boats per count per average fishing day.

A number of types of counts are possible but all fall into two major groups: (1) the instantaneous count in which all the fishermen fishing a body of water can be counted at once; and (2) the progressive count in which the census taker moves along the bank of a stream or the shore of a lake and counts the fishermen as he comes to them.

The instantaneous count simply involves counting the fishermen from a vantage point, surveying the entire body of water, and is most easily accomplished on relatively small lakes in mountainous country or from an airplane. A fisherman situation employing an instantaneous count is illustrated graphically in Figure 6.

The progressive count involves moving along the bank of a stream or along the shore of a lake at a constant rate of speed, either on foot or by vehicle, and recording the numbers of fishermen as they come within a line of sight. Progressive counts can also be accomplished by airplane or boat on long stretches of stream or on large bodies of water.

The progressive count is also graphically illustrated in Figure 7 as an oblique line in relation to the axis of the graph. This count line can never have a slope or tangent greater than 1 or less than -1. If the slope of this line exceeded these limits, it becomes obvious that the entire body of water would not be covered by that particular count.

Unlike the instantaneous count, the progressive count is a moving one and must take direction of movement and starting point as well as time of initiation of count into consideration. If the direction of the counter and the starting point are not considered, an inadequate sample will result. This is not too important if the situation has a completely random distribution of fishermen with respect to time and place on the lake fished. However, the starting place and direction of the count, when not considered, do have a pronounced effect on the accuracy of the count when randomness of fishermen does not occur. In other words, if more fishermen fished a given area of a lake during a given period than in other areas at other times, the progressive count could very likely give a biased

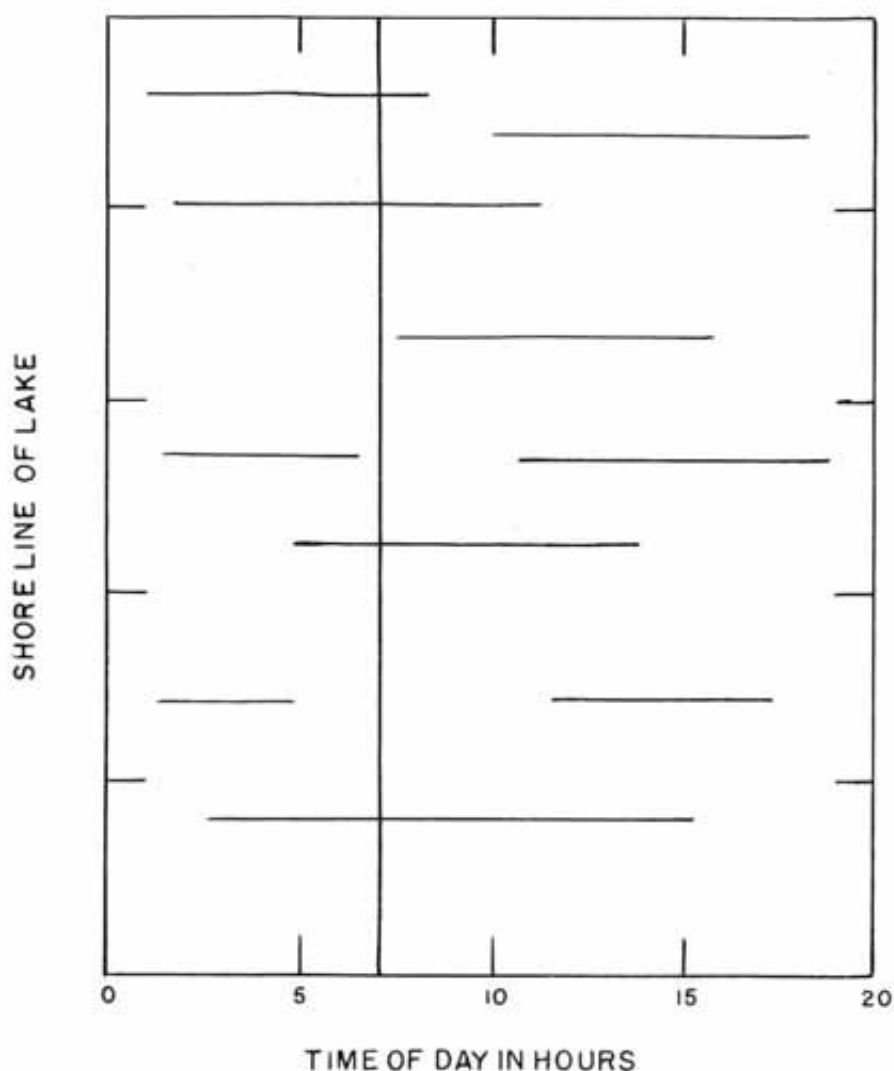


Figure 6. A shore fisherman situation on which an instantaneous count is made. The vertical axis of the graph represents the shoreline of a lake in linear concept. The short horizontal lines represent the fishermen at their locations along the shoreline and the time they spent fishing. The vertical line at the 7th hour represents the count. The number of intersections of the count line and the fishermen lines represents the value obtained from the count.

estimate of the number of fishermen per count. Figure 8 illustrates just such a situation where two areas of the lake during a period of time are never sampled.

This situation is rectified rather simply by dividing the time of the count into the length of the total possible fishing day to establish the number of equidistant starting points necessary to adequately sample all the area during all the time. Let us assume that the count takes two hours to complete and the length of the possible fishing day is 20 hours, then, the number of starting points is 10. The order in which the starting

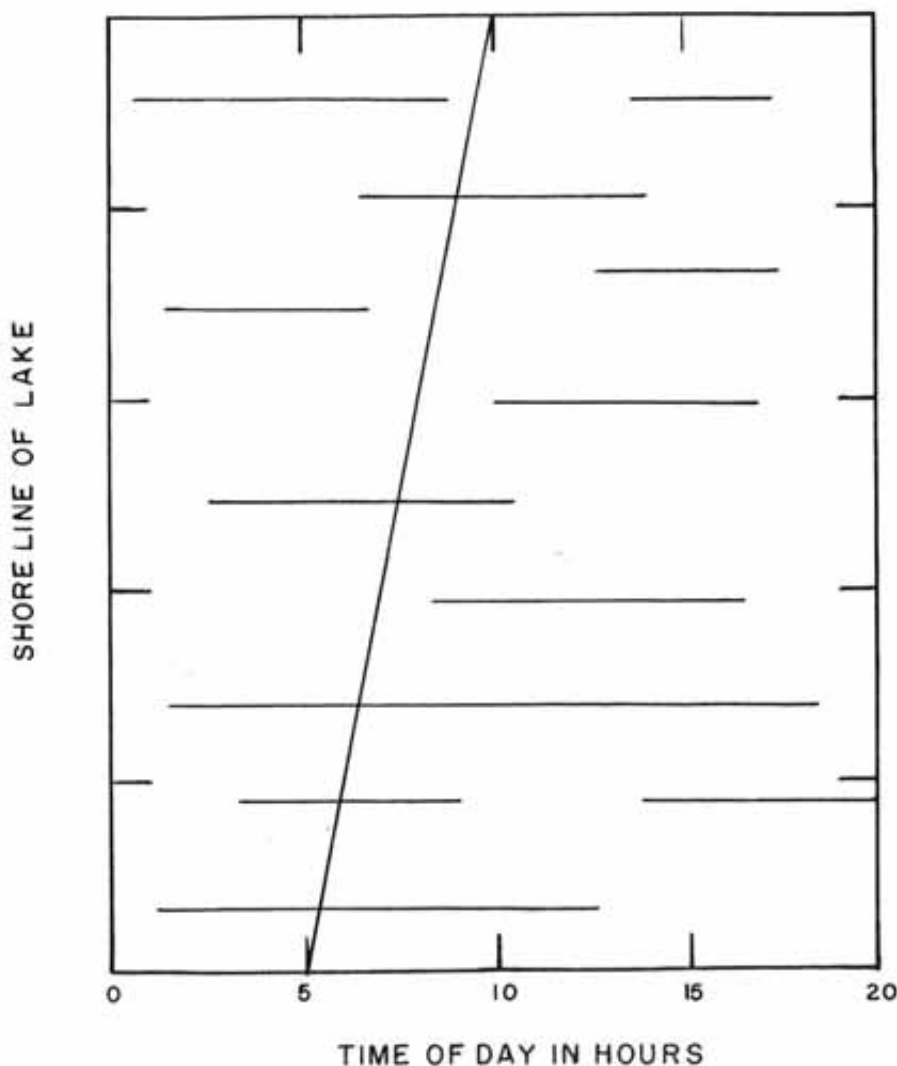


Figure 7. A shore fisherman situation representing a progressive count. The count, as represented, takes 5 hours to complete.

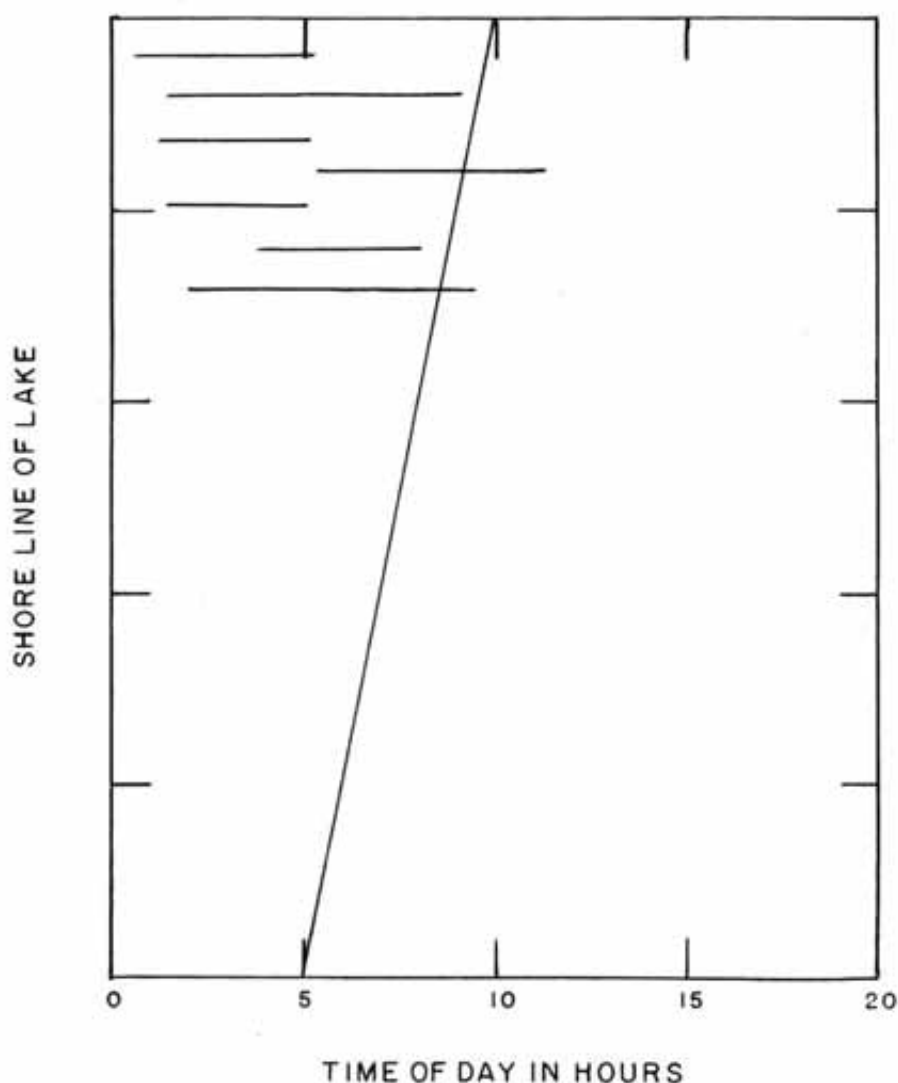


Figure 8. A biased progressive count situation. Note that as long as starting point and direction of the count are the same the mean number of fishermen per count would be inaccurate.

points are to be used is determined randomly either for the season or in random order for stratified periods. Direction of the count is simply alternated for successive counts.

This procedure has proved to be unnecessary on creel censuses in Utah where the time required for the count was less than an hour. Evidence collected on these creel censuses has shown no differences in the

mean number of fishermen per count between instantaneous counts and progressive counts requiring less than an hour.

Let us assume a hypothetical shore fisherman situation in which the fishing season is ten days long and the total pressure is 944 fisherman hours. The fishermen, as they are distributed around the shore of the lake or along the bank of the stream, are indicated opposite the vertical axis and the hours spent fishing from that location are indicated as horizontal lines (Figure 9).

Since we wish to sample the total, the simplest way, also least time consuming, is to sample-count sufficient intervals of the average fishing day to give an adequate estimate of the average number of fishermen per interval per average day. This is in turn expanded by the total possible fishing hours per season to give an estimate of the mean-total fishing pressure in terms of fisherman hours for the season.

Since the season in our example is short, and since the number of possible intervals in the average fishing day is very high, accuracy of the mean value of the estimate will depend largely on the number and randomness of the counts, while precision of the estimate will reflect an increase with the number of counts made each day.

To further simplify this situation, let us assume that the counts were made instantaneously, i.e., the counts were made from a vantage point from which all the fishermen were seen at once. Such a count is represented as a vertical line on the graph of Figure 6. The intersections of the vertical count lines with the horizontal lines representing the fishermen indicate the values obtained from each count.

By randomly selecting days and times for the counts in progressively larger samples, we can establish that accuracy of the estimate of the mean increases with the number of counts made. Similarly, the precision of the estimate of the mean increases with the number of counts made (Table 3). Best and Boles (1956) also illustrate the increase in accuracy of the estimate of the mean with an increase in the size of the sample.

The situation presented here is purely a hypothetical one and greatly simplified over any situation encountered under real conditions. However, the basic premises are identical to those found in an authentic fishermen situation, and the method presented here remains quite applicable.

An actual creel census would certainly cover more than ten days and would be affected by all the conditions of variability mentioned previously. Since these factors of variability affect fishermen numbers, an increase is reflected in the variance of the mean number of fishermen per count over one under essentially homogeneous conditions as that of our example.



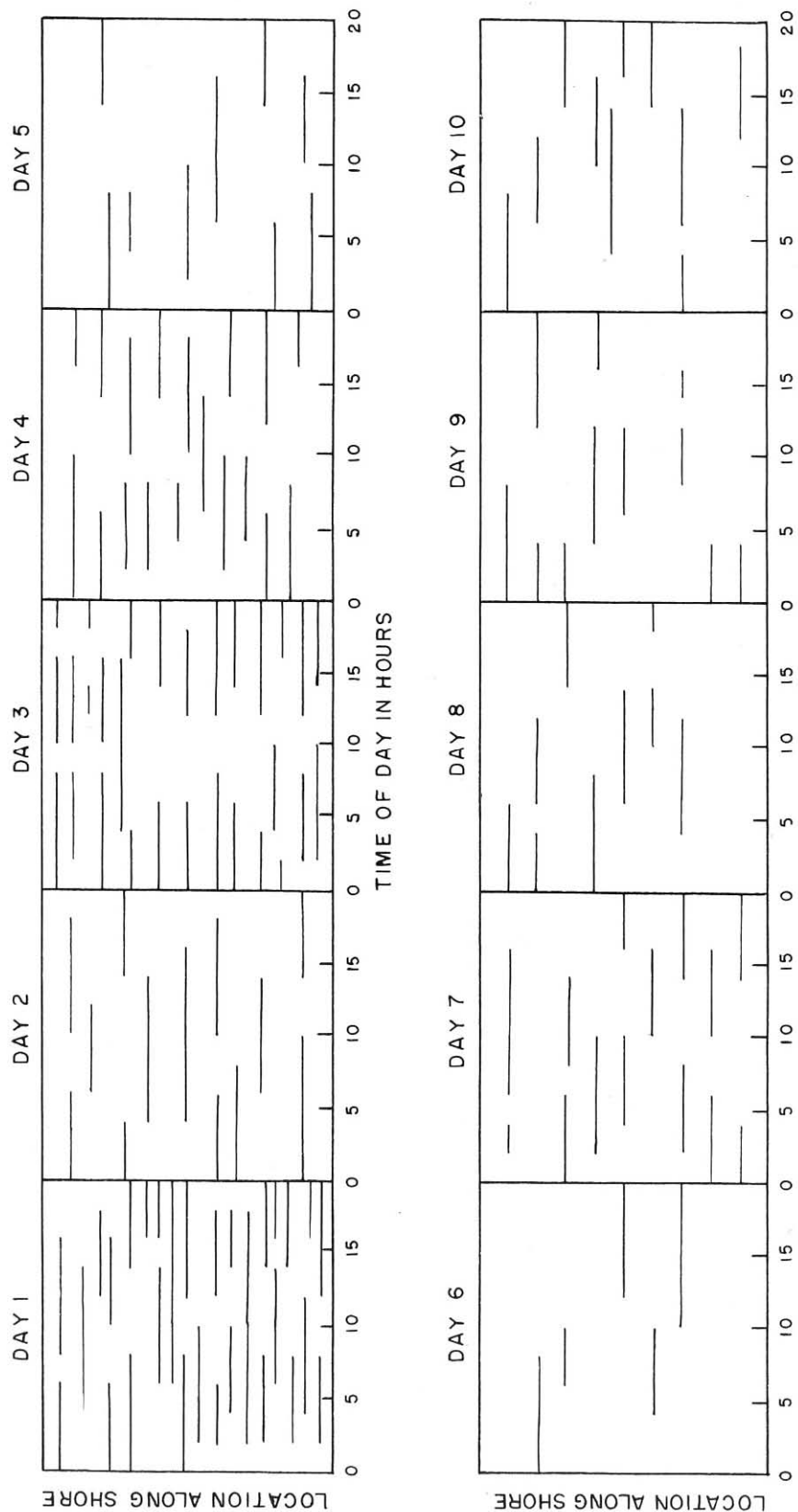


Figure 9. A hypothetical 10-day fishing season. Each day is represented by 20 hours. Each horizontal line represents a fisherman, his location and the time he fished. Counts can be made by placing a straight edge vertically at any time during the day across each graph. The count is then represented by the total number of fishermen lines that intersect the straight edge.

TABLE 3. Relation of number of counts of fishermen to accuracy and precision of the estimate in which the total number of fishermen hours per season is 944.

Number of Days Sampled	Number of Counts Per Day	Total Number of Counts	Degrees of Freedom	Mean Number of Fishermen Per Count	Variance	t-value at the 95% Level	Standard Error of the Mean	Mean-total Fisherman Hours	Limits to the Sample Mean
5	1	5	4	7.2	760.25	2.78	12.30	1440	$\pm 6838$
5	2	10	9	4.8	5.11	2.26	.71	960*	$\pm 320$
5	5	25	24	5.8	9.50	2.06	.61	1160	$\pm 252$
5	10	50	49	4.7	8.47	2.01	.41	940	$\pm 164$
10	1	10	9	4.6	15.11	2.26	1.22	920	$\pm 552$
10	2	20	19	4.2	6.10	2.09	.55	840*	$\pm 230$
10	5	50	49	4.7	8.63	2.01	.41	940	$\pm 164$
10	10	100	99	4.7	9.85	1.99	.31	940	$\pm 124$

\*Examples of chance occurrence. The order of distribution of sample means for a given sample size is random, consequently, an accurate estimate of the mean is always possible though becoming more improbable as the size of the sample decreases.

Since each day or, in a broader sense, a group of consecutive days is, in effect, a separate fisherman population, use can be made of the concept of stratification. Stratification of the sample in a fishermen count simply insures adequate distribution of the counts throughout the season which, in turn, results in a more accurate estimate of both the mean and the variance. Table 4 illustrates the differences obtained by a completely random sample of 20 counts out of 100 possible counts in the hypothetical situation of Figure 9 and a sample of 20 counts stratified on the basis of days. Two counts were selected in random order without repetition for each day of the 10-day season in the stratified sample.

TABLE 4. The effect of stratifying a sample on the basis of days in the 10-day hypothetical situation of Figure 9.

	Sample Size	Population Mean	Sample Mean	Population Variance	Sample Variance
Completely Random Sample .....	20	944	1040	2791.04	5284
Sample Stratified on basis of each day .....	20	944	980	2791.04	3640

Stratification of this nature was employed in the selection of count days in the example that follows.

The fishing season during 1955 on Scofield Reservoir extended from May 28 to October 9, a period of 135 days. The season was stratified into two-week periods starting with May 28 and ending with September 30. The last 9 days were included as a period in proportion. Fifty percent of all the week days in each two-week period were selected in random order without repetition. The first weekend day was selected by chance and all following weekend days were in alternate order. The count days during the 9-day period at the end of the season were selected on the same basis as the count days of the two-week stratified periods.

Since the legal fishing day in Utah is from 05:00 A.M. to 09:00 P.M., each count day was stratified into four 4-hour periods to facilitate the selection of the count time. Two counts each count day were considered adequate for the precision required and were again selected in random order without repetition for each count day. The initial hour for the count in each period was selected by chance and all subsequent hours within each period were taken in consecutive order.

In each two-week period, then, each day of the week was represented by a count day, and, in the season, each hour was represented by a count at least eight times.

## CALCULATION OF THE PRESSURE

In the calculation of pressure and also in the calculation of the harvest, importance of the application of the "Normal Theory" must be stressed. Use is made exclusively of the means in all the following calculations. The variance itself is used simply as a step in determining the standard error of the mean, and the fiducial statement is made with the mean as its basis.

Though the distribution of the individuals, in some of the estimates, follows a pattern other than normal, e.g. the distribution for the rates of success approaches a Poisson curve, the distribution of the means for that estimate is normal or approaches normal to a point where normal theory can safely be applied. Snedecor (1946, page 59) makes a similar statement concerning the distribution of means. Dixon and Massey (1951, page 94) confirm this.

The count obtained on Scofield Reservoir was of the instantaneous type in that it took approximately 30 minutes to accomplish. In addition, the count included two fishermen populations: the shore fishermen and the boat fishermen. Each populations had to be treated separately.

Shore fishermen could be discerned as individual fishermen with the aid of field glasses, but boat fishermen were not quite so readily counted, and, often, they could not be distinguished from the boat. Consequently, only boats were counted which necessitated the adjustment of the data by a "number of fishermen per boat" factor.

The time expansion factor during the 1955 season for Scofield Reservoir was 2160 hours, i.e., one fisherman could conceivably fish for 2160 hours during the 1955 season, or the season contained a total of 16 hours each day for 135 days.

The mean number of fishermen per boat for the season was 2.52 with a variance of 0.974 from a sample of 494 boats.

You will note from Table 5 that the mean number of shore fishermen per count for the entire season is 60.18. In other words, 60.18 shore fishermen can be counted at any time during the average fishing day for the season.

The mean-total shore fishing pressure for the entire season is computed simply by expanding the mean number of fishermen per count by expanding the mean number of fishermen per count by the total possible fishing hours in the season:

Table 5. Fishermen counts from Scofield Reservoir during the 1955 Season.

	Boat	Shore		Boat	Shore		Boat	Shore
May	337	1028		14	21		34	39
	204	785		15	23		48	52
	221	630		51	58		14	16
	121	509		47	104		17	14
	99	349		81	176		16	17
	76	165		5	17		13	14
	61	235		13	14		13	11
	21	152		4	6		17	9
	8	124		15	47		23	40
June	0	19		7	3		27	43
	0	5		46	95		13	11
	2	21		34	55		17	9
	10	19		47	70	Sept.	14	12
	2	11		11	8		16	20
	3	11		21	59		9	11
	23	151		12	10		4	12
	15	138		27	18		42	36
	29	90		56	44		47	53
	10	44		11	0		36	41
	20	25		27	31		30	47
	22	24		48	99		18	12
	19	33		28	13		11	16
	35	55		30	17		11	8
	77	130		10	10		7	14
	5	9		31	27		11	14
	15	12		78	96		23	34
	61	53		77	76		6	4
	68	73	Aug.	18	13		3	10
	11	9		16	20		3	4
	13	17		19	17		2	3
	7	3		22	20		11	14
	27	19		38	27		9	18
	17	13		88	79		4	6
	53	42		15	11		10	9
	9	30		14	25		3	6
	10	24		15	15		6	8
	4	24		14	22		6	10
	14	47		8	10		5	10
	9	23		15	19		11	14
	18	35		52	75		9	17
July	27	31		57	78	Oct.	2	5
	34	134		32	27		4	7
	29	90		36	41		10	24
	25	87		18	8		9	31
	9	22		15	11			
<b>Boats</b>				<b>Shore</b>				
$\Sigma X = 3862$		$(\Sigma X)^2 = 14,915,044$		$\Sigma X = 8064$		$(\Sigma X)^2 = 65,028,096$		
$n = 134$		$\Sigma X^2 = 341,890$		$n = 134$		$\Sigma X^2 = 2,664,106$		
$\bar{X} = 28.82$		$s^2 = 1734$		$\bar{X} = 60.18$		$s^2 = 16,382$		

$$P = (F) (H), \quad (1)$$

where  $F$  = mean number of shore fishermen per count and  $H$  = total possible fishing hours and  $P$  = mean total shore fishing pressure in fisherman hours, or

$$\begin{aligned} P &= (60.18) (2,160), \\ &= 129,989 \text{ fisherman hours.} \end{aligned}$$

The precision of the estimate is determined by following the expedient of deriving the standard error of the mean from the variance of the mean number of shore fishermen per count:

$$s_f = \sqrt{\frac{s^2}{N}}, \quad (2)$$

where  $s_f$  = the standard error of the mean,  $s^2$  = the variance of the mean shore fishermen per count and  $N$  = the number of counts for the period covered, then,

$$\begin{aligned} s_f &= \sqrt{\frac{16.382}{134}}, \\ &= \sqrt{122.2537}, \\ &= 11.05. \end{aligned}$$

Since the standard error of the mean follows a t-distribution with 133 degrees of freedom, the confidence limits to the mean are

$$\begin{aligned} \text{C.L.}_{.95} &= F \pm (t_{.95}) (s_f), \\ \text{C.L.}_{.95} &= 6.18 \pm (1.96) (11.05), \\ &= 6.18 \pm 21.66 \text{ fishermen per count} \end{aligned} \quad (3)$$

and is expanded to

$$\begin{aligned} \text{C.L.}_{.95} &= (60.18) (2160) \pm (21.66) (2160), \\ &= 129,989 \pm 46,786 \text{ fisherman hours.} \end{aligned}$$

The boat fishing pressure is obtained similarly with one exception. Two estimates are involved in the achievement of the pressure: (1) the boats per count and (2) the fishermen per boat. The combination of the two estimates into one estimate involves a propagation of error technique similar to that presented by Deming (1943) and by Snedecor (1946). If the means of two or more variables are multiplied to obtain a combined mean as

$$F = (K) (B) (R), \quad (4)$$

where  $F$  = mean boat fishermen per count,  $K$  = a constant,  $B$  = mean boats per count and  $R$  = mean rate of fishermen per boat, then the root mean square errors are related by the equation



$$s_f^2 = (KF)^2 \left[ \frac{s_b^2}{B^2} + \frac{s_r^2}{R^2} + 2 \frac{(s_b)(s_r)(\tau_{br})}{BR} \right] \quad (5)$$

where  $s_f^2$  = the root mean square error of the combined means and  $s_b^2$  and  $s_r^2$  equal the root mean square errors of the mean number of boat respectively, while  $\tau_{br}$  equals the coefficient of variation between numbers of boats and numbers of fishermen per boat. The root mean square errors are obtained simply by dividing the variance by N.

In the example of Table 5, the combined mean is

$$F = (2,160) (28.82) (2.52) = 156,881 \text{ boat fisherman hours,}$$

and the root mean square error is

$$\begin{aligned} s_f^2 &= (156,881)^2 \left( \frac{12.94029}{830.59} + \frac{.100197}{6.35} \pm \frac{2(3.597)(.316)(0)}{(28.82)(2.52)} \right), \\ &= (24,611,648,161)(.0158898), \\ &= 391,074,164, \end{aligned}$$

and the standard error of the mean is

$$\begin{aligned} s_f &= \sqrt{391,074,164}, \\ &= 19,776 \text{ fisherman hours.} \end{aligned}$$

The value of the  $\tau_{br}$  was insignificant at the 95% level and no correlation was considered to exist.

In samples of the size involved in arriving at the above estimates, the t-table can be entered safely using the degrees of freedom of the smallest sample, in this situation 133. For smaller samples it is perhaps safer to calculate the degrees of freedom for the combined standard error where

$$\begin{aligned} \text{d. f.} &= \frac{(s_b^2 + s_r^2)^2}{\frac{(s_b^2)^2}{N_b + 1} + \frac{(s_r^2)^2}{N_r + 1}} - 2 \quad (6) \\ &\quad \text{(Dixon \& Massey, 1951).} \end{aligned}$$

Here  $N_b$  = the sample size of the mean number of boat fishermen per count and  $N_r$  = the sample size of the mean number of fishermen per boat.

In the example, then, the degrees of freedom are calculated as

$$\text{d. f.} = \frac{(12.94029 + .100197)^2}{\frac{(12.94029)^2}{135} + \frac{(.100197)^2}{495}} - 2,$$



$$\begin{aligned}
&= \frac{167.50}{1.24 + .00} - 2 \\
&= 133.
\end{aligned}$$

The combined standard error follows a t-distribution with 133 degrees of freedom, and the confidence limits are

$$\begin{aligned}
C.L._{.95} &= 156,881 \pm (1.96) (19,776), \\
&= 156,881 \pm 38,761 \text{ boat fisherman hours.}
\end{aligned}$$

In some situations, it may be desirable to present an estimate of the total fishing pressure or the sum of the boat fishing pressure and the shore fishing pressure. To accomplish this, the mean total fishing pressures are simply added,

$$\begin{aligned}
T.P. &= 156,881 + 129,989 \\
&= 286,870 \text{ fisherman hours.}
\end{aligned}$$

The mean root square errors of the estimates are also additive,

$$s_{T.P.}^2 = s_{F_1}^2 + s_{F_2}^2 + 2(s_{F_1})(s_{F_2})(r_{F_{12}}) \quad (7)$$

where  $s_{F_1}^2$  = the mean root square error of the shore fishermen and  $s_{F_2}^2$  = the mean root square error of the boat fishermen. Substituting the values of the example into the formula, we obtain,

$$\begin{aligned}
s_{T.P.}^2 &= 569,681,424 + 391,074,164 + 2(23,868) (19,775) (0.87), \\
&= 1,782,017,666,
\end{aligned}$$

and the standard error is,

$$\begin{aligned}
s_{T.P.} &= \sqrt{1,782,017,666}, \\
&= 42,213 \text{ fisherman hours.}
\end{aligned}$$

The standard error follows a t-distribution with 133 degrees of freedom as before, and the

$$\begin{aligned}
C.L._{.95} &= 286,870 \pm (1.96) (42,213), \\
&= 286,870 \pm 82,732 \text{ fisherman hours.}
\end{aligned}$$

The fiducial statement for these estimates indicates that the population mean (the universe mean) is encompassed by the expressed limits at the 95 percent confidence level.

## THE INTERVIEW

Interviewing the fishermen is as important as counting the fishermen and must be performed with extreme care to avoid biasing the estimates. The interview is conducted primarily to determine the rate of success of the fishermen. Secondary information such as species composition of the creel, economics of the fishery, fisherman residence, etc., can also be obtained.

In the interests of accuracy, the data obtained from fishermen should be observed. This, of course, is not possible for all categories. However, numbers of fish and species composition can be observed correctly by competent interviewers with no loss in the quality of the data. Fishermen, though sincere, often times misrepresent data, particularly where differentiation between species is desired.

Information must be asked concerning the time fished to catch the observed creel. To ask the time started fishing is probably more desirable than to ask the number of hours required to catch the creel fish. Since the interviewer knows the time of the interview, the time spent fishing is a simple computation. Once the interviewer has the observed number of fish and the hours spent fishing, the rate of success can easily be determined.

Important too, is the necessity of interviewing all segments of the fisherman population equitably. An attempt should be made to interview the fishermen in proportion to the pressure. One can easily see that if more interviews are taken on days of light pressure with good rates of success than on days of heavy pressure with poor rates of success, the mean rate of success would be biased upward and accuracy would be decreased. Similarly, if more interviews were taken from areas on the body of water with good rates of success than from areas on the same body of water with poor rates of success, not considering the distribution of the pressure, the mean rate of success would be biased.

An interview program cannot be outlined in detail since such a program must mold itself to the endemic qualities of the fishery on a given body of water. However, an attempt should be made to interview in proportion to the fishing pressure on the day of the interview as well as in proportion to the pressure distribution on the lake (if the latter is possible).

In the interests of thoroughness, it is perhaps desirable to oversample the interviews since they are quite easily taken and can readily be subsampled for an exact percentage of the total pressure from the tabulated pressure data.

Again, as in the estimation of the pressure, precision of the rate of success as derived from these interviews is dependent upon the size of the sample and is increased as the size of the sample increases.

In the type creel census being presented here, the need to obtain information concerning numbers of fishermen per boat when only the boats can be counted also arises. The application of this estimate was presented under "Calculation of Pressure."

#### CALCULATION OF THE RATE OF SUCCESS

Rate of success is determined from the interviews by totaling the numbers of fish caught and dividing by the total hours required to catch these fish from all the interviews for the entire season. In other words, the mean number of fish per fisherman is divided by the mean number of hours fished per fisherman with the resulting quotient being the mean rate of success:

$$R = \frac{F}{H} \quad (8)$$

where  $R$  = the mean rate of success;  $F$  = the mean number of fish per fisherman; and  $H$  = the mean number of hours per fisherman.

Table 6 presents the rate of success data from the 1955 Scofield Reservoir creel census and is substituted into the above formula for the rate of success of all species as follows:

$$R_s = \frac{4.57}{6.81},$$

$$= 0.67 \text{ fish per hour,}$$

where  $R_s$  = the rate of success of all species from boats.

The mean root square errors for both estimates are additive and will result in the mean root square error of the combined estimate when the values are applied to the propagation of error formula (5) of the boat pressure calculations:

$$s_s^2 = (.67)^2 \left( \frac{.0340}{(4.57)^2} + \frac{.0204}{(6.81)^2} + \frac{2(0.18)(0.14)(0.50)}{(4.57)(6.81)} \right)$$

$$= (.4489)(.003413),$$

$$= .001532.$$

The correlation of 0.50 between hours and fish was determined significant at the 95% level.

The standard error of the mean, then is

$$s_s = \sqrt{.001532},$$

$$= 0.39 \text{ fish per hour, and the confidence limits at the 95\% level are:}$$

$$C.L._{.95} = 0.67 \pm (1.96)(.039),$$

$$= 0.67 \pm .07 \text{ fish per hour.}$$

The fiducial statement again states that the universe mean rate of success stands but 1 chance in 20 of not being encompassed by the expressed limits.

Rates of success for individual species in a trout fishery are somewhat difficult to determine precisely. Most fishermen fish for trout without the intention of catching a specific type. Those that fish for a given species can and do catch trout of another species if several species are present. The mackinaw trout is a possible exception, though, even when fishermen fish exclusively for mackinaw trout, their creels frequently include rainbow trout as on Fish Lake.

The rates of success for species, as determined from the method presented here, are calculated on the basis of all the fishermen interviewed. In other words, the mean rates of success for each species will total to the mean rate of success for all species.

We must remember, then, that the mean rates of success for species, as calculated by this method, are an incidental step to the calculation of the harvests. The mean rates of success for given species are not necessarily the true rates of success for these species when intent of fishing is taken into consideration, but these rates of success will give accurate and precise estimates of the harvest.

The mean rates of success and limits for rainbow trout, brown trout and cutthroat trout caught during the 1955 season on Scofield Reservoir are presented in Table 7. These values are obtained by precisely the same method as for the mean rate of success for all species presented earlier.

TABLE 7. Summary of mean rate of success estimates for species by boat and shore fishermen on Scofield Reservoir during 1955 creel census.

Type of Fishing	Species	Combined Mean Root Square Error	Standard Error	t at the 95% Level of Confidence	Combined Mean	Limits at the 95% Level of Confidence
Boat	Rainbow	.001305	.036	1.96	.58	±.07
Shore	Rainbow	.000075	.009	1.96	.24	±.02
Boat	Cutthroat	.000089	.009	1.96	.088	±.018
Shore	Cutthroat	.00000024	.0005	1.96	.027	±.001
Boat	Brown	.00000211	.0014	1.96	.0029	±.003
Shore	Brown	.0000000001	.00001	1.96	.00069	±.00002
Boat	All Species	.001168	.034	1.96	.67	±.07
Shore	All Species	.000091	.009	1.96	.27	±.02

TABLE 6. Scofield Reservoir 1955 creel census rate of success.

Type of Fishing	Species	Size of Sample	Mean No. Fish Per Fisherman	Variance of Mean No. Fish Per Fisherman	Mean No. Hours Per Fisherman	Variance of Mean No. Hours Per Fisherman	Mean Root Square Error of Fish	Mean Root Square Error of Hours
Boat	Rainbow	494	3.95	26.55	6.81	10.06	.0537	.0204
Shore	Rainbow	2178	1.05	2.49	4.35	12.58	.0011	.0058
Boat	Cutthroat	494	0.60	1.98	6.81	10.06	.0040	.0204
Shore	Cutthroat	2178	0.12	0.19	4.35	12.58	.0001	.0058
Boat	Brown	494	0.02	0.05	6.81	10.06	.0001	.0204
Shore	Brown	2178	0.003	0.003	4.35	12.58	.000001	.0058
Boat	All Species	494	4.57	26.70	6.81	10.06	.0540	.0204
Shore	All Species	2178	1.173	2.72	4.35	12.58	.0013	.0058

## CALCULATION OF THE HARVEST

An estimation of the harvest is, of course, the primary objective of this creel census, and is calculated by multiplying the mean-total fishing pressure in fisherman hours by the mean rate of success:

$$H = (P) (R), \quad (9)$$

where  $H$  = the harvest of fish;  $P$  = the mean-total fishing pressure in fisherman hours; and  $R$  = the mean rate of success in fish per hour.

By substituting the value obtained for the mean pressure by boats and for the mean rate of success from boats for all species, the mean-total harvest for all species can be obtained:

$$\begin{aligned} H &= (156,881) (0.67), \\ &= 105,110 \text{ mean total of all species harvested.} \end{aligned}$$

The precision is calculated in the same manner as for the propagation of error formula, (5):

$$\begin{aligned} s_p^2 &= (105,110)^2 \left( \frac{391,074,164}{(156,881)^2} + \frac{.001168}{(.67)^2} \right), \\ &= (11,048,112,100) (.01849), \\ &= 204,279,590, \end{aligned}$$

and the standard of error is calculated as:

$$\begin{aligned} s_p &= \sqrt{204,279,590}, \\ &= 14,293 \text{ fish of all species from boats.} \end{aligned}$$

The confidence limits, then, are

$$\begin{aligned} \text{C.L.}_{.95} &= 105,110 \pm (1.96) (14,293), \\ &= 105,110 \pm 28,014 \text{ fish of all species from boats.} \end{aligned}$$

The correlation between pressure and rate of success was insignificant.

The fiducial statement remains the same as before: that the actual number of fish caught will be encompassed by the expressed limits at the 95% confidence level.

The total harvest by species for both the boat and the shore pressure is obtained in this same manner and is summarized in Table 8.



TABLE 8. Summary of harvest from Scofield Reservoir during the 1955 season.

Type of Fishing	Species	Combined Mean Root Square Error	Standard Error	t at the 95% Level of Confidence	Combined Mean	Limits at the 95% Level of Confidence
Boat	Rainbow	163,666,428	12,793	1.96	90,991	±25,074
Shore	Rainbow	4,565,529	2,138	1.96	31,197	± 4,190
Total	Rainbow	168,231,957	12,971	1.96	122,188	±25,423
Boat	Cutthroat	5,218,407	2,284	1.96	13,805	± 4,477
Shore	Cutthroat	45,806	214	1.96	3,510	± 419
Total	Cutthroat	5,264,213	2,294	1.96	17,315	± 4,496
Boat	Brown	55,218	235	1.96	455	± 461
Shore	Brown	27	5	1.96	90	± 10
Total	Brown	55,245	235	1.96	545	± 461
Boat	All Species	204,279,590	14,293	1.96	105,110	±28,014
Shore	All Species	5,711,854	2,591	1.96	35,097	± 5,078
Total	All Species	209,991,444	14,491	1.96	140,207	±28,402

## EVALUATION OF THE METHOD

As with any creel census method yet devised, this one, too, has its shortcomings. The limits presented by the examples of this method are somewhat wide, but sufficiently precise to apply to most management problems requiring information on pressure and harvest.

The sampling of the examples in this paper was done on the basis of 50 percent of the days with two counts per sample day. Precision can be increased if either more days are selected as count days or if more counts are made for each existing count day. Since the estimation of the pressure produces the greatest variance, the number of counts can easily be increased with a smaller variance as the result.

Pooling units of homogeneous variances can also reduce the variance. Such units as weather categories or weekdays and weekend days can, occasionally, be used in this manner with a somewhat better final estimate of the variance.

Scrutiny of the method under which data on fisherman numbers are taken reveals the possibility of the variance being influenced by the length of time each fisherman fishes in relation to the time he is counted. Analysis of the empirical distribution of the time a fisherman starts and ends fishing with respect to time of day is at present being undertaken on data collected over a number of years from various reservoirs in Utah and will be published at a later date.

With only means being represented in the statistical treatment of the data, application of the Normal Theory is considered safe and yields advantages to the treatment not otherwise available.

Design of the creel census is also an important part of the method. Care must be exercised to avoid bias in all instances. A great deal of atten-



tion must also be given to the elimination of assumptions if precision is desired.

The method presented here has its shortcomings, but the premises upon which it is based have definite value to many phases of management in which knowledge of pressure and harvest are necessary.

## LITERATURE CITED

- Best, E. A. and H. D. Boles  
1956. An evaluation of creel census methods. California Fish and Game. Vol. 42, No. 2, pp. 109-143.
- Deming, W. Edwards  
1943. Statistical adjustment of data. New York. John Wiley and Sons. 261 pp.
- Dixon, Wilfred J. and Frank J. Massey, Jr.  
1951. Introduction to statistical analysis. New York, McGraw-Hill. 370 pp.
- Snedecor, George W.  
1946. Statistical methods. Ames, Iowa. The Iowa State College Press. 485 pp.