Three reservoirs proposed for the first study are Beaver, Bull Shoals, and Norfork. A contract is being negotiated with the University of Arkansas for certain pre-impoundment studies on Beaver Reservoir. Headquarters of the project are expected to be at Fayetteville because of the obvious advantages of the University library facilities and faculty consultation. A mobile laboratory will serve as field work headquarters.

The second program on fish control problems may be headquartered at the Warm Springs, Georgia, National Fish Hatchery. Studies will be coordinated with similar work already beginning on cold and cool water springs at the LaCrosse, Wisconsin, fish control laboratory. Both centers will work on the possibilities of employing electricity, chemicals, sound, and mechanical methods to control unwanted fish species.

DETERMINATION OF FISHING PRESSURE FROM FISHERMEN OR PARTY COUNTS WITH A DISCUSSION OF SAMPLING PROBLEMS

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INTRODUCTION

One of the basic and often most difficult aspects of creel surveys on large reservoirs and other large bodies of water is the problem of determining fishing pressure. Often the only feasible method of determining fishing pressure is by making counts of fishermen or fishing parties while the fishermen are in the process of fishing. The purpose of this report is to review this method of determining fishing pressure and to discuss the sampling problems involved.

Many workers have used variations of this method of determining fishing pressure. I am not aware who was the first to use the method. Among the earliest to use it were Eschmeyer (1942) and Tarzwell and Miller (1943) in their work on TVA lakes. Other example of the use of the method are Tait (1953), Kathrein (1953), DiCostanzo (1956a and 1956b), Moyle and Franklin (1957), Neuhold and Lu (1957), and Freeman and Huish (undated). Also the method is discussed in the papers of Carlander, DiCostanzo and Jessen (1958), Carlander (1956), Jessen (1956) and Robson (1960 and undated). Some of the terminology in the papers cited above is different than presented here, as well as their method of analyses and/or how the data should be interpreted, nevertheless basically the method is the same as presented here.

As part of an assignment from the 1960 Reservoir Committee, Southern Division of the American Fisheries Society, I have attempted to review creel survey methods being used in the southeast and in other sections of the country which would have general applications on large reservoirs. Because of the importance of the problem of determining fishing pressure from fishermen or party counts, I have attempted to review the method in detail, resulting in this report. I am indebted to the following members (and their associates) of the 1960 Reservoir Committee for their assistance, suggestions, criticisms and for providing material: C. E. Ruhr, chairman; Gordon Hall, Charles J. Chance, Barry O. Freeman, Clarence White, Bernard Carter, Samuel Jackson, Marion Toole, Albert Sanderson, Raymond Martin, Robert Martin, Buford Tatum, Robert Stevens, Leon Kirkland, Edward Heinen, Don Pfitzer and the late Nat Bowman. I am also indebted to Dr. Vincent Schultz, Atomic Energy Commission, Washington, D .C., and C. E. Lane, U. S. Fish and Wild Life Service, Atlanta, Georgia, for their criticisms and suggestions on an earlier draft of the manuscript. All of the above mentioned persons have contributed much to this paper; however, inasmuch as I have not always chosen to take their sound advice, the responsibility for any errors rests solely with me. Some of the literature, research and collection of data for this report was undertaken while I was working on Louisiana Federal Aid in Fish Restoration, Project F-1-R. I would like to acknowledge the contribution of data, time, etc., made

by Louisiana Federal Aid in Fish Restoration, Project F-1-R, which made this report possible.

DETERMINING FISHING PRESSURE

There are several ways fishing pressure can be determined by this method. Moyle and Franklin (1957) used the following method in their work on Minnesota lakes:

$$y = \sum x_i \left(\frac{\Delta A}{b} \right) \qquad (1)$$

where y=estimated number of boats using the body of water

x_i=number of boats counted during the ith count (instantaneous count)

ΔA=interval between counts

b=mean length of trip

In order to convert this to man-hours of fishing, the mean length of the trip and the mean number of fishermen per boat must be known. If we let x_i be the number of fishermen during the ith count instead of the number of boats then y would be an estimate of the number of fishermen. Thus it would only be necessary to know the mean length of the trip in order to estimate the man-hours of fishing. Usually it will be more efficient to estimate the man-hours of fishing directly from the data rather than by formula (1), since there will be present experimental error in only one variable rather than two if we let x_i be the number of fishermen or three if we let x_i be the number of boats counted.

The man-hours of fishing can be estimated as follows:

$$f = C\bar{x} \qquad (2)$$

where f=number of time units of fishing

$\bar{x}$=mean number of fishermen observed per count

C=number of time units in the population

The use of formula (2) can be illustrated by the following example. In the hypothetical population shown in Figure 1, there are five fishermen who fished 2 hours each or a total of 10 man-hours of fishing. Five counts were made on the body of water and during each count one fisherman was checked. Therefore $x=5/5=1$ and since there are 10 hours of possible fishing time on the body of water $C=10$. Substituting into formula (2);

$$f = 10\frac{5}{5} = 10 \text{ man-hours of fishing}$$

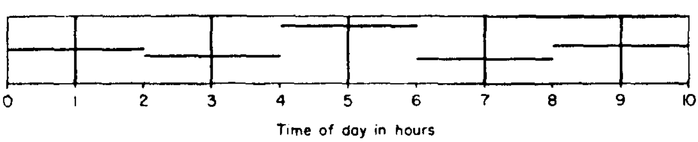

Figure 1. Illustration of method of estimating fishing pressure on a body of water for more than a one-day period. The horizontal lines trip while the vertical lines represent fishermen counts made on a body of water.

It is curious that by measuring the mean number of fishermen which can be observed on a body of water and multiplying this by the possible number of hours during the day when fishing could occur, an estimate of the man-hours of fishing can be arrived at. However, it should be realized that $\bar{x}$ is an estimate of the mean number of fishermen that can be observed at any time on the body of water during the day. Therefore during any hour of the day one would expect to count $\bar{x}$ number of fishermen and therefore $\bar{x}$ times the number of hours gives an estimate of

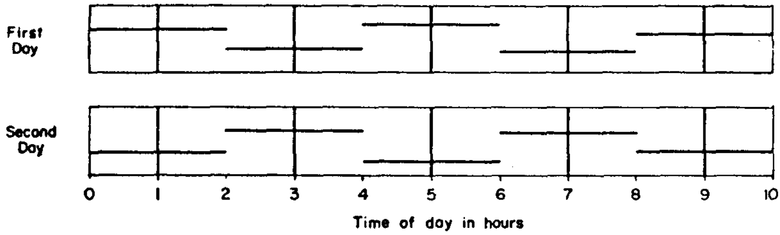

Figure 2. Illustration of method of estimating fishing pressure on a body of water for more than a one day period. The horizontal lines represent the length of the fishing trip while the vertical lines represent fishermen counts made on a body of water.

the number of man-hours of fishing . The use of C (*i.e.*, if C is expressed in hours) converts the estimate into man-hours. Also, C could be any time unit we would want to use. For example, C could equal the number of ½ hours in the fishing day. Therefore there would be twenty ½ hours in the fishing day shown in Figure 1. Substituting into formula (2):

$$f = 20 \frac{5}{5} = 20 \text{ ½-hours of fishing}$$

$$= 10 \text{ man-hours of fishing}$$

This method also can be used to make estimates for more than one day of fishing. For example in Figure 2 there are two days of fishing. Substituting into formula (2):

$$f = 20 \frac{10}{10} = 20 \text{ man-hours of fishing}$$

In some cases it is not possible to make observations on the whole body of water at one time and thus the body of water has to be divided into areas for purposes of observing the number of fishermen. Figure 3 is an example of this. Substituting into formula (2):

$$f = 20 \frac{20}{20} = 20 \text{ man-hours of fishing}$$

This could be expanded for as many days and areas on the body of water as necessary.

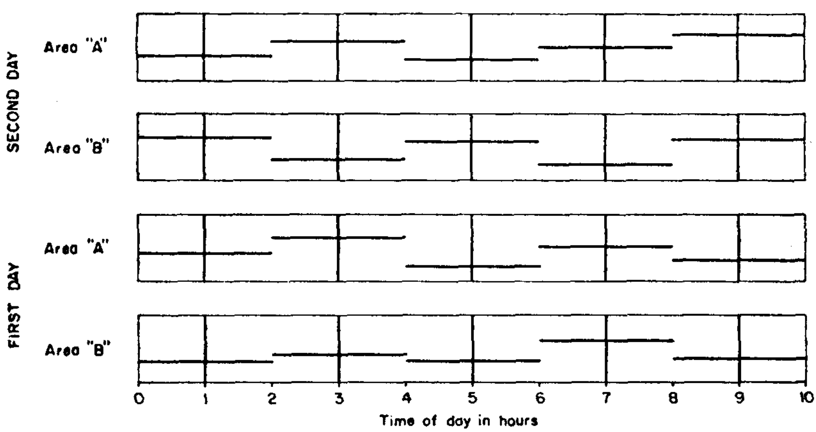

Figure 3. Illustration of method of estimating fishing pressure on a body of water sub divided into areas. The horizontal lines represent the length of the fishing trip while the vertical lines represent fishermen counts made on a body of water.

In all the previous examples, fishermen counts were instantaneous counts, *i.e.*, all fishermen were counted at once. In some cases it is not possible to make instantaneous counts. The creel checker moves at a fixed rate over or on the body of water (by boat, plane, etc.) or along the shore (by car, foot, etc.) and counts the fishermen as he comes to them. This I shall call a progressive count.

In actuality, the progressive count is the same as an instantaneous count in making an estimate of the fishing pressure. Consider the example in Figure 4 to illustrate this. One progressive count was made (the sloping line)—it could have been more than one count. Therefore $\bar{x}=10/1$ or 10 and C=10. Substituting into formula (2):

$$f=10\frac{10}{1}=100 \text{ man-hours o fishing}$$

which is an exact estimate of the total man-hours of fishing in the hypothetical population shown in Figure 4. The instantaneous counts would give the same estimate. Thus:

$$f=10\frac{50}{5}=100 \text{ man-hours of fishing}$$

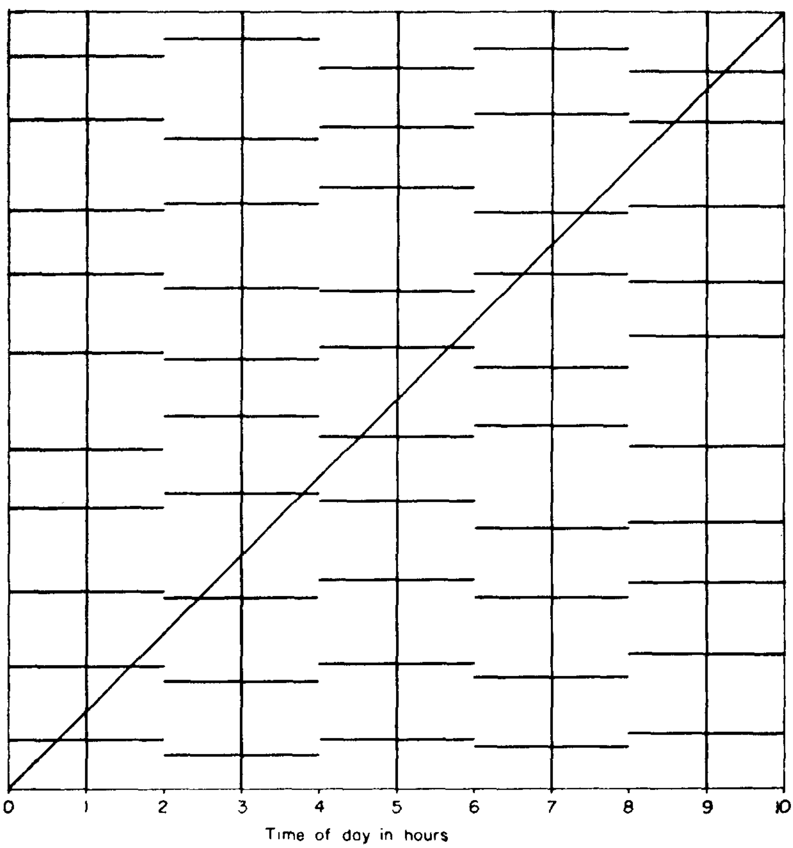

Figure 4. Illustration of method of estimating fishing pressure on a body of water by making progressive counts. The horizontal lines represent the length of the fishing trip while the sloping line represents progressive fishermen counts and the vertical lines represent instantaneous fishermen counts made on a body of water.

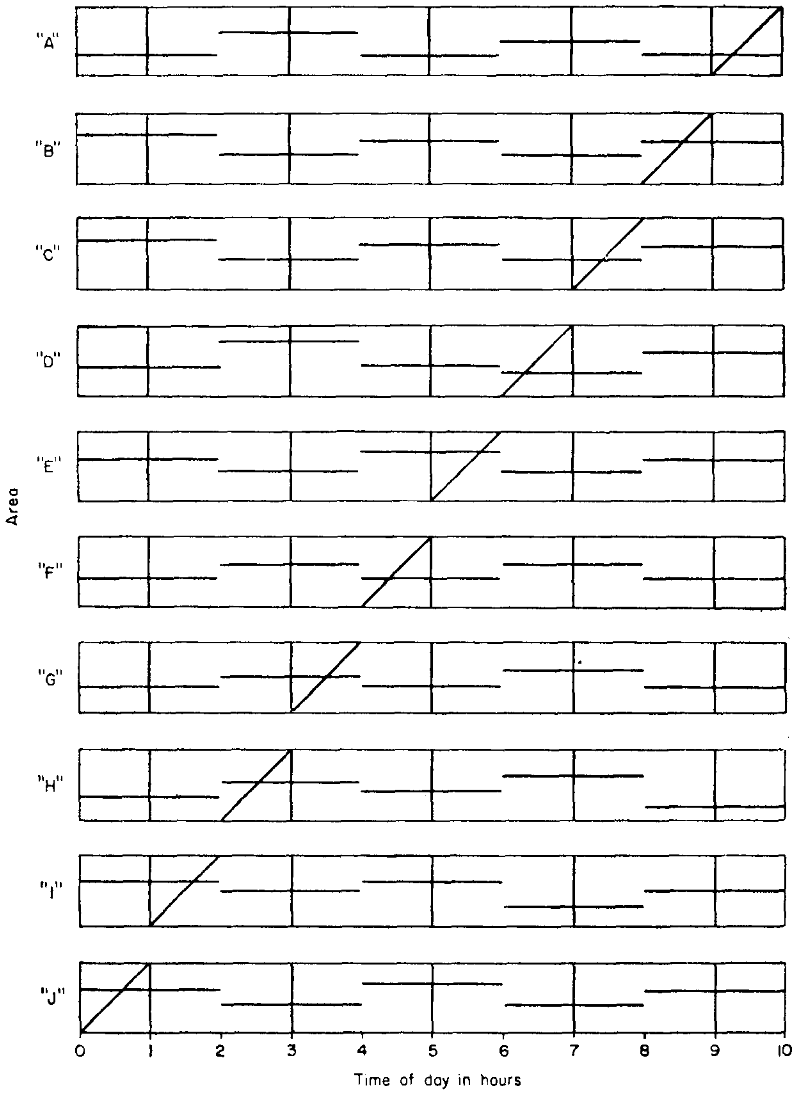

Figure 5. Illustration of method of estimating fishing pressure on a body of water by making progressive counts when the body of water is sub divided into areas. The horizontal lines represent th elength of the fishing trip while the sloping line represents progressive fishermen counts and the vertical lines represent instantaneous fishermen counts made on a body of water.

As in the instantaneous counts it might not be possible or practical to cover the whole body of water in one count and thus the body of water could be subdivided into areas. In Figure 5 the body of water is sub divided into ten areas. Thus we have ten separate progressive counts and substituting into formula (2):

$$f = 100 \frac{10}{10} = 100 \text{ man-hours of fishing}$$

Also the estimate based on the instantaneous counts would equal:

$$f = 100\frac{50}{50} = 100 \text{ man-hours of fishing}$$

which is exactly the same as the estimate based on the progressive counts.

USE OF PARTY COUNTS INSTEAD OF FISHERMEN COUNTS

In formula (2), $\bar{x}$ is the mean number of fishermen per observation. However, in some instances it is not possible to count individual fishermen but fishing parties can be counted. For example, boat counts or car counts might be taken where each boat or car would be considered as one fishing party. Therefore, if we let $\bar{x}$ be the mean number of *parties observed per observation, f will be an estimate of the party-hours* of fishing. If the mean number of fishermen per party is known from a separate estimate, this time f will be an estimate of the man-hours of fishing. However, the use of fishermen counts is preferred where possible instead of party counts because there will be present experimental error in only one variable rather than two, *i.e.*, experimental error will be present in only the fishermen counts rather than in the party counts and in the number of fishermen per party.

SAMPLING PROBLEMS

In all examples so far, the hypothetical population of fishermen was distributed homogenously in time and area for simplicity's sake. However, we know that in actuality fishermen are not distributed homogenously in time or area and therefore there are sampling problems in estimating $\bar{x}$. In formula (2), C is known without error and therefore in determining the confidence of the estimate f it is necessary only to determine the variance of $\bar{x}$. This can be determined in the standard manner.

A biased estimator is one that will not, on repeated sampling from the same population, have a sampling distribution whose mean is the true value being estimated. If $\bar{x}$ is not to be biased it is important that each fisherman will have equal chance of being counted. In the case of instantaneous counts where the body of water is not divided into areas, this will not occur unless the time the counts are started are chosen by some unbiased sampling scheme, *e.g.*, random sampling. In the case of progressive counts where the body of water is not divided into areas, this will not occur unless the time the counts are started are chosen by some unbiased sampling scheme. In the case of instantaneous counts where the body of water is divided into areas and progressive counts it will be necessary also to choose the starting points on the body of water by some unbiased sampling scheme.

To illustrate this, consider the population of fishermen in Figure 6. These fishermen are not distributed homogeneously in either time or area. By repeatedly starting the progressive counts from the same area without randomization most of the fishermen would be missed and our estimate would be biased. Also by repeatedly taking the instantaneous counts at the same time most of the fishermen would be missed and our estimate would be biased. If, during the sampling period, the fishermen were distributed randomly in time, counts could be made repeatedly at the same time of the day and the estimates would not be biased. However, any one familiar with sport fisheries knows that fishermen are not distributed randomly in time. There are more fishermen out during certain times of the day and during certain days of the week, etc. The same would apply to their distribution as to area of the body of water. Therefore, some unbiased sampling scheme must be used to select the areas and/or time to start the counts.

In the case of the instantaneous counts where the body of water is not divided into areas, there is almost an infinite number of times to start the counts, depending upon how small units of time the fishing day is divided into. All that is necessary is to pick at random the times to start the counts. In some cases this has been done through the use of a systematic scheme such as used by Moyle and Franklin (1957) where counts were made at 2-hour intervals on the hour. Moyle and Franklin stated that for such counts to be valid it is necessary for the length of the fishing trip to be longer than the interval between the counts. However, Jessen (1956) pointed out that if instantaneous counts are made at a random instance within each 2-hour period, the 2-hour requirement for the length of the trip is unnecessary. Also it is not necessary if the starting and stopping points of the fishing trips are randomly distributed within the 2-hour period or started differently if there is no correlation of the starting and stopping of fishing with the time the instantaneous counts are made. In the case of the instantaneous counts where the body of water is divided into areas, it also is necessary to choose the areas to be checked in such a manner that there is equal chance of each area being checked.

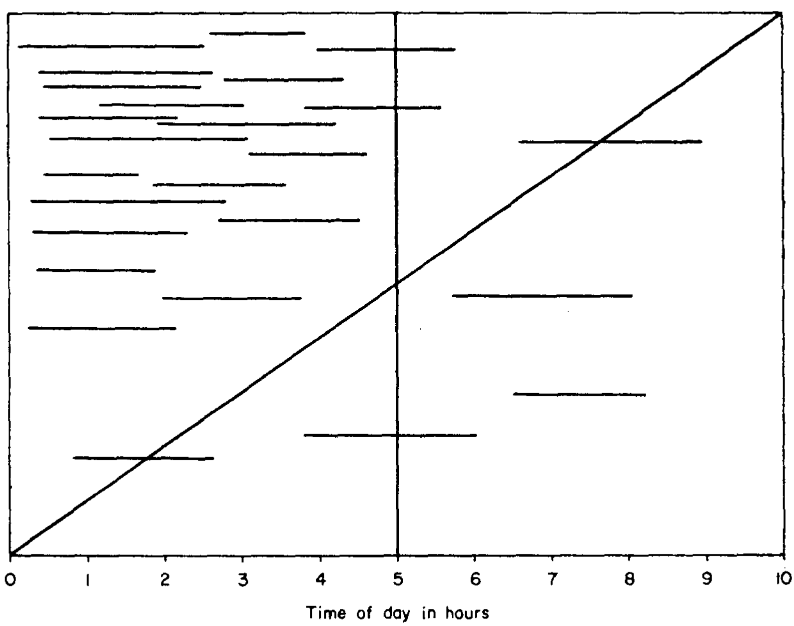

Figure 6. Illustration of effects of a non-homogeneous distribution of fishermen on the estimation of fishing pressure. The horizontal lines represent the length of the fishing trip while the sloping line represents a progressive fisherman count and the vertical line represents an instantaneous fishermen count made on a body of water.

In the progressive counts the same is true. The starting time and starting location must be chosen in such a manner that there is equal chance of each fisherman being checked. In some cases the body of water is divided into areas and separate progressive counts are made in each area. The area to be checked should also be picked by some unbiased sampling scheme. It is probable that if the area is small enough that progressive counts can be made in a relatively short period of time it will be possible to use the same starting point each time a check is made in each area. For this to be valid there must be assumed a random distribution of starting and stopping of fishing trips for the period of time it takes to make the count in the area. The shorter the period of time required to make the count the greater the likelihood of nearly meeting this requirement. Neuhold and Lu (1957) stated that they found it unnecessary to randomize the starting points for progressive counts when the time required to make the count was less than one hour since the creel census data collected on Utah reservoirs showed no differences in the mean number of fishermen counts between instantaneous and progressive counts requiring less than one hour. However, if the progressive counts are randomized by starting point, area and time, it will not matter how long it takes to make the count.

In some instances, where the same starting and ending points are used, a procedure of alternating the direction of the counts is followed, *i.e.*, the starting point for one count becomes the ending point for the next count and so on. Even though such a procedure has much to recommend it, it should be noted that it does not guarantee that there will be equal chance that each fisherman will be checked and estimates based on such counts could be biased. The remarks contained in the previous paragraph relative to using the same starting point where the direction of the counts is not alternated would also apply to the procedure where they are alternated.

When the starting points or progressive counts on a body of water or within an area on a body of water are randomized, it will be desirable whenever possible to arrange the route followed by the creel checker in a manner where he can make a complete circuit of the area and thus the randomly chosen point will be both the starting and ending point for the count. Such a procedure will be convenient and make it possible for the creel checker to cover a given area with a minimum amount of effort and in a minimum amount of time. When this is done, it is important that the creel checker does not count the number of fishermen at a given point twice.

It is not necessary that the above procedure be followed. For example, if the area, or body of water is approximately trapezoidal in shape, a random start could be made anywhere in the area and the creel checker could travel at a fixed speed longitudinally through the area counting fishermen until he reached one end of the area and then move at an increased speed to the other end and resume his counting speed and count fishermen until he arrived at his starting point.

Even though it is not necessary, there appear to be certain gains in efficiency possible by keeping the progressive counts as short as possible. This could also apply to keeping the area covered by progressive counts as small as possible.

As stated before, fishermen are not usually distributed randomly in time and area. Undoubtedly fishermen will in many, if not most cases be distributed according to some type of contagious distribution, *i.e.*, they will be distributed more patchily than would be expected in a random distribution. With the negative binomial distribution and some other types of contagious distribution, the variance is related to the mean in the following form: $V=a\bar{x}+b\bar{x}^2$. Under these conditions decreasing the size of the observed mean will decrease the variance and smaller sampling units will be more efficient in estimating the population. Therefore if contagion is present in the fishermen counts, it is possible that it will be more efficient to use the smallest sampling unit possible, *i.e.*, if the sampling fraction remains the same. Also in some instances, assuming that we take the same number of samples, increasing the size of the sampling unit might not necessarily increase the precision of the estimate enough to be of much practical value. For a more detailed discussion of the problem of what size sampling unit will be the most efficient when sampling from contagious distributions see Taylor (1953), Taft (1960) and Lambou (MS).

Also with smaller sampling units it will be possible to use more efficient sampling schemes such as two-way stratification or optimum allocation of sample size. With smaller units it will be such easier to sample all major components of variance (day of week, time of day, month, etc.) more efficiently.

One problem, which could be considered a sampling problem, is whether or not to count fishermen who are moving about on the lake, *i.e.*, unless they are fishing while moving. I would recommend that fishermen's time in motion not be considered as fishing and that fishermen in motion not be counted. Then our estimate will be the actual amount of time units of fishing, excluding traveling time. It is important that when combining estimates of fishing pressure with other data, *e.g.*, number of fish caught per man-hour of effort determined by interviewing fishermen, that the same definition of fishing be used.

ESTIMATING FISHING PRESSURE AS AREA UNDER THE CURVE

Some workers have estimated fishing pressure as the area under the fishing curve, either by calculating the area or by graphic means (Figure 7). An interesting variation of this was presented by Parker (1956) at the symposium on creel censuses at the Iowa Cooperative Fisheries Research Unit. He discovered from analyzing the fishing curve that there was a relatively fixed relationship between the number of anglers out at noon and the number out the rest of the day. Hence, the number counted at noon multiplied by an appropriate factor gave an estimate of total fishing effort.

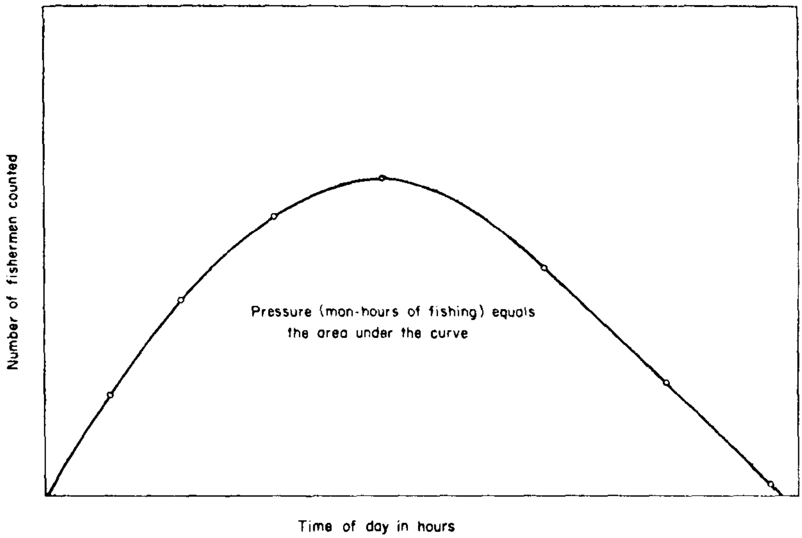

Figure 7. Illustration of method of estimating fishing pressure as area under the fishing curve.

Scott Overton of the Cooperative Statistical Project, North Carolina State College, in his design for sampling the 20-mile canal sport fishery along the Tamiami Trail in Florida has recommended that the area under the fishing curve be calculated following Simpson's Rule (Herke, 1960).

According to Simpson's rule:

$$f=\frac{\Delta A}{3}\left[x_0 + 4\,(x_1 + x_3 + x_5 + \ldots + x_{n-1}) + 2(x_2 + x_4 + x_6 + \ldots + x_{n-2}) + x_n\right] \qquad (3)$$

where f=number of time units of fishing

ΔA=interval between counts

x=number of fishermen or fishing parties counted during the 1st, 2nd, . . ., nth count

In applying Simpson's Rule it is necessary that the number of intervals ΔA between counts be even which means that an odd number of counts must be made. Also it is necessary that the spacing between counts be exact, *i.e.*, all ΔA must be of the same size. Also a count must be made at the beginning and the end of the day (or period being evaluated) unless we assume that these values are zero and record them as such without actually making the counts. Simpson's Rule will give the exact area under the curve for only relatively sample curves—cubic or less.

In using Simpson's Rule to determine fishing pressure, we have a very rigid design, from which we can't deviate at all. If a count is missed, Simpson's Rule can't be used, *i.e.*, unless we estimate the numerical value of the missing count. Therefore, it is possible that the area under the fishing curve calculated using the Trapezoidal Rule will have considerable utility in some situations, however, I know of no instance where it has been used so far. In using the Trapezoidal rule, we are not limited by any fixed type of interval. We can have an odd or even number of intervals and the intervals do not have to all be of the same size. The fact that the intervals don't have to be of the same size might have some advantages. If for some reason, a count was missed, a valid estimate of fishing pressure could still be made. Also more counts could be made at the time of day when there was more variation in the number of fishermen and fewer counts when there was little variation in the number of fishermen. This would result in a form of stratification, which has often been shown to be more efficient in many different types of sampling designs.

According to the Trapezoidal Rule; if the intervals between counts are all of the same size:

$$f=\frac{\Delta A}{2}(x_0 + 2x_1 + 2x_2 + \ldots + 2x_{n-1} + x_n) \qquad (4)$$

or alternately:

$$f=\Delta A\ (\tfrac{1}{2}x_0 + x_1 + x_2 + \ldots + x_{n-1} + \tfrac{1}{2}x_n) \qquad (5)$$

where f = number of time units of fishing
ΔA = interval between counts
x = number of fishermen or fishing parties counted during the 1st, 2nd, . . ., nth count

and if the intervals between the counts are not all of the same size:

$$f=\tfrac{1}{2}(x_0 + x_1)\,\Delta A_1 + \tfrac{1}{2}(x_1 + x_2)\,\Delta A_2 + \ldots + \tfrac{1}{2}(x_{n-1} + x_n)\,\Delta A_n \qquad (6)$$

where f = number of time units of fishing
x = number of fishermen or fishing parties counted during the 1st, 2nd, . . ., nth count
ΔA = length of the interval between counts during the 1st, 2nd, . . ., nth interval

In using both Simpson's and the Trapezoidal Rule, if the counts are made on fishermen, f will be an estimate of the number of man-hours of fishing; however, if fishing parties are counted f will be an estimate of party-hours of fishing. If the mean number of fishermen per party is known, then party-hours can be converted into man-hours of fishing.

The use of Simpson's and the Trapezoidal Rules have the disadvantage that it is doubtful that the variance of the estimate can be determined. Also, because of the manner in which the spacing between the counts is determined, a systematic sample usually will be taken. Under some conditions, especially if there is periodicity present in the data, such a systematic sample can be biased. Further explanation relative to the advantages and disadvantages of the various types of estimators and a comparison of formula (2); Simpson's Rule and the Trapezoidal Rule will be taken up in a later section.

SYSTEMATIC SAMPLING

Some of the sampling schemes of taking creel surveys described in the literature, even though the investigator has stated that the sampling design was random, cannot in the accepted meaning of the word be termed random. Most of these are systematic sampling designs. A systematic sample would, *e.g.*, be where fishermen are checked on the body of water every 2nd day, every 2nd hour, or every other week. The examples shown in most of the figures would be systematic samples. The samples were made systematically in the figures in order to simplify the interpretations of the graphs. In actual practice random samples could easily be drawn.

Under some conditions there are certain potential advantages in systematic sampling; however, there are some potential serious dangers in such sampling. Under some conditions systematic sampling can be badly biased, *i.e.*, if the start of the systematic sample was not taken at random. However, if the start is chosen at random the mean of such a sample will be unbiased, and in some instances be very precise. However, in some cases they may give poor precision, especially if coincidental periodicity is present. Any estimate is subject to experimental error and it is important to make some statement about the probable size of such error. Therefore, a sampling design should provide a valid estimate of the experimental error as well as a good estimate of fishing. Standard formulas for determining variance and confidence limits of estimates are for random samples and not systematic samples. Also, no trustworthy method of estimating the variance of an estimate from the sampling data is known, *i.e.*, from a strictly systematic sample with one or no random starts (Cochran, 1953, pp. 185). Many approximate methods have been proposed for computing variance; however, the validity of such methods depends on the satisfaction of the assumptions needed and the type of population, which cannot be predicted from the sample itself.

Because of the nature of the fishing process and creel surveys, it is possible that a sampling design which includes systematic samples with multiple random starts will have utility in creel surveys. It is possible to make exact estimates of the variance of the estimate from the sampling data with such design. For a good discussion of systematic sampling with multiple random starts see Shiue (1960).

It is not the purpose of this report to discuss in detail systematic versus random sampling other than to point out that some of the so-called random creel survey designs in actuality do not take random samples but systematic samples of the populations. For a discussion of systematic versus random sampling the reader is referred to Cochran (1953, pp. 160-188; 1956, p. 504) and Shiue (1960).

EFFECT OF DEPARTURES FROM NORMALITY

As stated previously, fishermen are not distributed randomly in time or area on a body of water. There are more fishermen fishing during certain days of the week, months of the year and time of the day. Also, some areas are more productive than other areas on a lake, and some areas are more accessible to fishermen. Because of this, the distribution of the fishermen will not be random.

Counts of fishermen are discontinuous variables and if fishermen are distributed randomly on a body of water, *i.e.*, if they are distributed in a manner in which each individual fisherman has an equal chance of being found at every position on a body of water, their distribution will be Poissonian and the counts will follow the Poisson distribution. However, in most cases, the counts do not and contagion is present. Also, the distributions are not normal. Therefore if the sample size is small, the data should be transformed in order to normalize the data before applying statistical tests based on the "Norman Theory." However, fortunately the sampling distribution of means approach normality with increasing sample size. Therefore, if the sample size is sufficiently large, the distribution of the mean number of fishermen should approach normality so that the "Normal Theory" can safely be applied. For a discussion of this see Cochran (1953, pp. 22-30).

In some of the published papers on creel surveys, a square root transformation of fishermen counts has been used. The square root transformation is appropriate for variables distributed Poissonianly and therefore when used we are assuming that the fishermen are distributed randomly and that we are sampling from the Poisson probability distribution. This may be a reasonable assumption for some sport fisheries; however, for the sport fisheries I am familiar with, and I would speculate that for most of them, this is an unreasonable assumption. It is possible, when the sample size is small, that even enough the population does not follow the Poisson distribution, we may not be able to demonstrate statistically from the sampling data that the distribution differs from the Poisson.

VARIANCE OF A PRODUCT

In many instances, the estimates of man-hours of fishing will be multiplied by another estimate in order to obtain an estimate of a third value. For example the man-hours of fishing times the number of fish caught per hour of effort will give an estimate of the total number of fish harvested from a body of water. The experimental error in both estimates will contribute to the experimental error of the product—the estimate of the total harvest. Inasmuch as most standard statistical texts used by fishery biologists don't give formulas for determining the variance of a product, the formula as given by Schumacker and Chapman (1954) will be presented here. It should be noted that Schumacker and Chapman's formula is a large sample approximation and is valid only for large samples. If M and N are independently subject to sampling error, *i.e.*, there is no correlation between M and N, then the variance of the product, MN is as follows;

$$V(MN) = M^2 \left[V(N)\right] + N^2 \left[V(M)\right] \qquad (7)$$

where $V(MN)$ = variance of the product
$V(M)$ = variance of M
$V(N)$ = variance of N

The standard error would then equal $\sqrt{V(MN)}$. In sampling, we substitute the variance of the estimate (standard error squared) estimated from the sample into formula (7) and thus we can arrive at an estimate of the variance of the product.

FURTHER EXPLANATION AND COMPARISON OF THE USE OF FORMULA (2), SIMPSON'S RULE AND THE TRAPEZOIDAL RULE

The number of man-hours of fishing, F, can be expressed as the integral of a counting function $x(t)$ over the entire fishing day, where $x(t)$ is the number of fishermen (or fishing parties) present at time t (Robson, 1960). As can be seen in Figure 8, $x(t)$ is a step function with discontinuities at the points in time when fishermen enter or depart from the body of water during the fishing day. Time during the day can be measured from an origin defined by the start of the fishing day. If we divide the fishing day into H segments in which it is possible to make counts of the fishermen, the length of the segments depending on how long it takes to make a count, say β hours, then the length of the fishing day can be assumed to be an integer (=H) multiple of β hours. If the length of the fishing day is $H\beta$, then it is possible to make H counts of fishermen during the day, and during D days, DH counts. If the body of water is divided into S areas then it is possible to make SDH counts or N counts. Thus during D days, SD/β equals the number of counts which can be made and during any day there will be H time segments. If β is not very small, we are making progressive counts. However, if β is made very small (*i.e.*, if $B \longrightarrow 0$), then $SD/\beta \longrightarrow \infty$, and $H \longrightarrow \infty$. Thus it is possible to make an almost infinite number of counts and we are making instantaneous counts.

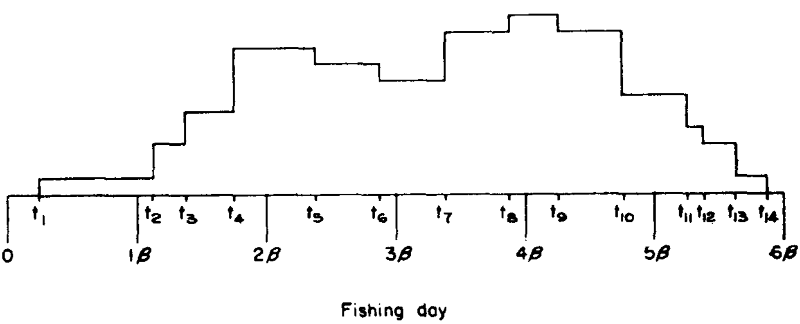

Figure 8. Illustration of a hypothetical graph of the counting function $x(t)$.

Since F is the area under the graph of $x(t)$:

$$F = \int_0^{H\beta} x(t)\,dt$$

If $t_1, \ldots, t$ are the points in time when fishermen enter or leave the body of water:

$$F = \sum_{\lambda=0}^{K} (t_{\lambda-1} - t_\lambda)\, x(t_\lambda)$$

where $t_0=0$, $t_{k+1}=H\beta$, and where $x(t_\lambda)$ is the number of fishermen present during the interval from t_λ to $t_{\lambda+1}$.

An instantaneous count is made in the zth area during the pth day selected at random and without replacement from all possible S areas and D days. There will be s areas and d days selected from all possible S areas and D days. The eth time unit in which this count is made is selected at random from all possible H time units in a fixed z and p (Figure 9). There will be h time units selected from all possible H time units. However, as would be the usual case, only one count is made in the zth area during the pth day, *i.e.*, $h=1$. Thus it is assured that each fishermen in the zth area during the pth day will have equal chance of being counted. (It should be noted that the fishing day could be defined as any time period that is convenient, *e.g.*, a ½ day, ¼ day, ⅛ day, 24-hour period, dawn to dusk, etc.) The count $x_{ezp}(t)$ during this interval is a chance variable having the expected value of

$$E\left[x_{ezp}(t)\right] = \frac{1}{H\beta} \lim_{\substack{H \to \infty \\ \Delta t_e \to 0}} \sum_{e=1}^{H} x_{pze}(t_e)\, \Delta t_e$$

$$= \frac{1}{H\beta} \int_0^{HB} x_{zp}(t)\,dt$$

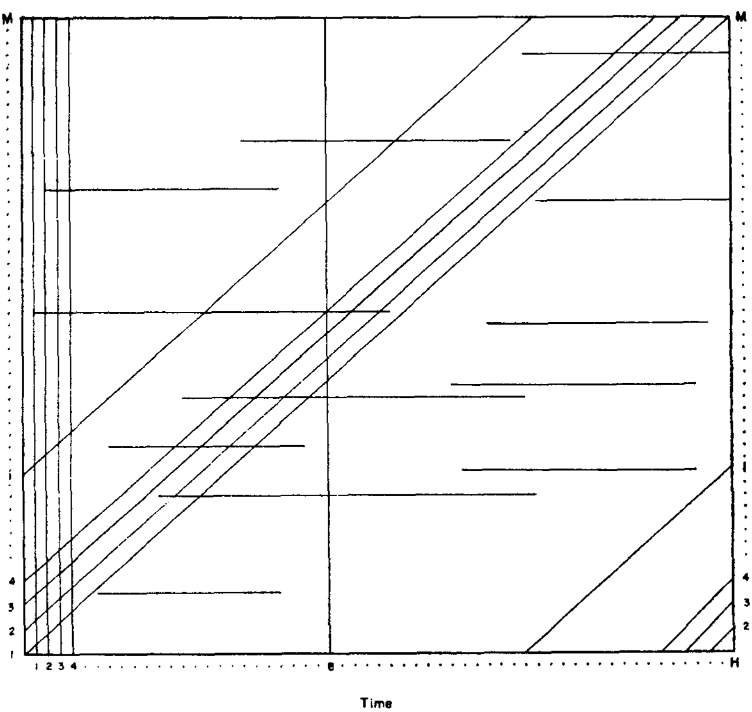

Figure 9. Illustration of instantaneous count made in the eth time unit in the zth area during the pth day and progressive count made

from the ith starting point in the eth time unit in the zth area during the pth day. Note that in the case of the instantaneous count there are H time units in which it is possible to make a count in the zth area during the interval 0 to HB. In the case of the instantaneous count there are M starting points in the interval (e-1) B *to* eB in the zth area during the pth day. The horizontal lines represent the length of the fishing trip while the sloping lines represent progressive counts and the vertical lines represent instantaneous counts.

This function, except for the factor 1/HB is the area under the graph of x_{zp} (t) during the pth fishing day in the zth area, hence HB x_{ezp} is an estimate of the total man-hours of fishing F_{zp} during the pth fishing day in the zth area. The s areas and d days are also chosen at random, therefore the expected value of the estimate f_{zp} over all possible areas and days is

$$E(f_{zp}) = \frac{1}{SD} \sum_{Z=1}^{S} \sum_{p=1}^{D} F_{zp} = F/SD$$

Therefore, an unbiased estimate of F which is the man-hours of. fishing and the area under the graph of x(t) is

$$f = \frac{NB}{n} \sum_{e=1}^{h} \sum_{z=1}^{s} \sum_{p=1}^{d} x_{ezp}$$

where N=SDH
n =shd

If a progressive count is made, there will be more than one starting point from which to make the count. A progressive count is made during the eth time unit in the zth area during the pth day selected at random and without replacement from all possible H time units, S areas and D days. There will be h time units, s areas and d days selected from all possible H time units, S areas and D days. The ith starting point for this count in a fixed e, z and p is selected at random from all possible M starting points (Figure 9). However, as would be the usual case, only one count is made in a fixed e, z and p, *i.e.*, m=1. This assures that each fisherman in the fixed e, z and p will have equal chance of being counted in the interval (e-1)B to eB. The count $x_{iezp}(t)$ during this interval is a chance variable having the expected value of

$$E\left[x_{iezp}(t)\right] = \frac{1}{M} \sum_{i=1}^{M} x_{iezp}(t)$$

and $$\frac{1}{M} \sum_{i=1}^{M} x_{iezp}(t) = \frac{1}{B} \int_{(e-1)B}^{eB} x_{zp}(t)\,dt$$

This function, except for the factor 1/B, is the area under the graph of $x_{zp}(t)$ between (e-1)B and eB, hence B $x_{iezp}(t)$ is an estimate of the total man-hours of fishing, Fzp, during the interval (e-1)B to eB in the zth area on the pth day. If shd, or n, intervals are chosen at random from all possible SHD, or N, intervals, then the expected value of the estimate over all possible N intervals will be

$$E(f_{ezp}) = \frac{1}{N} \sum_{e=1}^{H} \sum_{z=1}^{S} \sum_{p=1}^{D} F_{ezp} = F/N$$

Therefore, an unbiased estimate of F, which is the man-hours of fishing and the area of the graph of x(t), is

$$f = \frac{N\beta}{n} \sum_{i=1}^{m} \sum_{e=1}^{h} \sum_{z=1}^{s} \sum_{p=1}^{d} x_{iezp} \qquad (9)$$

which is the same as formula (8) considering that for the instantaneous count there is one possible starting point i Δ*i.e.*, since $\Delta t_e \longrightarrow o$, all fishermen are counted almost at once and every possible starting point is covered almost at the same instance; therefore the count would be the same no matter where the count was started) for a fixed e, z and p, *i.e.*, m=M=1.

These formulas, (8) and (9), are the same as formula (2) inasmuch as $N\beta$ would be equal to C, the number of time units in the population and

$$\frac{1}{n} \sum_{i=1}^{m} \sum_{e=1}^{h} \sum_{z=1}^{s} \sum_{p=1}^{d} x_{iezp} = \bar{x}$$

If the count is instantaneous and assuming simple random sampling over all possible N intervals, the sample estimate of the variance of the estimate $\bar{x}$ is

$$v(\bar{x}) = \frac{(N-n)}{Nn(n-1)} \cdot \left[\sum_{e=1}^{h} \sum_{z=1}^{s} \sum_{p=1}^{d} (x_{ezp} - \bar{x})^2 \right] \qquad (10)$$

where the factor (N-n)/N is the finite population correction factor. Theoretically, we could consider the population infinite, inasmuch as with the instantaneous counts, there is almost an infinite number of time units to select from, however, in practice this is not quite true. For example, we could select five or ten-minute intervals from the fishing day and have the clerk count the mean number of fishermen present during the interval, or make one observation and assume the number of fishermen entering or leaving during the interval is negligible. Therefore, we could consider our sampling as being from a finite population; however, it is probable that in many creel surveys, the finite population correction factor will be negligible and can be ignored.

The purpose of estimating the variance by formula (10) will be to provide a measure of the precision of the estimate of x and consequently our estimate of F. If our sample size is large enough so that large sample theory will apply and assuming that x is approximately normally distributed, then the confidence interval of our estimate at the .05 probability level is

$$\bar{x} \pm 2 \sqrt{v(\bar{x})} \qquad (11)$$

and the estimate of the variance of f will be

$$v(f) = C^2 \, v(\bar{x}) \qquad (12)$$

and the confidence interval is

$$f \pm 2 \sqrt{v(f)} \qquad (13)$$

It should be noted that if we use stratified random sampling, *i.e.*, some form of stratification of days, areas, and time periods; or subsampling, formula (10) will have to be modified accordingly. Formulas for the estimation of the variance of estimates based on stratified random sampling and where sampling is carried out in two or more stages are given by Cochran (1953). Also subsampling will be discussed in conjunction with the estimate of the variance for progressive counts. It should be noted that in most cases the sd's will be selected at random and the h's selected at random from the sd's. Thus sampling will be carried out in two or more stages and we will be subsampling.

If progressive counts are made, formula (10) for the estimation of the variance of x will not be appropriate under all conditions. If one count is made with a random starting point in each fixed e, z and p, we have a form of stratification with one sampling unit per stratum. The exact estimation of the variance of an estimate from the sample requires that there be two or more randomly selected units in the sample from each stratum.

Approximate methods of determining the variance of an estimate based on stratification with one unit per stratum are covered by Cochran (1953, pp 105-106). These include grouping the strata into pairs. Such grouping could cause problems and if possible it might be wise to try to avoid it. One method would be to modify our sampling design presented previously and to select two random starting points for a fixed e, z and p and thus make two counts per stratum. Thus standard formulas for determining the variance of estimates based on stratified random sampling could be used and our estimate of the variance would be on firmer footing. However, this would have the disadvantage that it would require at least two creel checkers for each stratum being sampled and thus our manpower requirements would be more formidable.

If we select intervals at random (assuming simple random sampling) and without replacement from all possible HDS or N intervals and then make one count in each of the selected intervals we have a form of subsampling with one subunit per primary unit. Then each fixed e, z and p in which a count is made is a primary sampling unit and n of these are drawn at random from all possible N units. Then the count x_{iezp} is our subunit chosen at random from the primary unit. There will be m of these subunits drawn from all possible M subunits in each primary unit. If the sampling fraction n/N is small so that the fpc can be ignored, which probably would be true in many creel surveys, then the variance of the mean count can be estimated as follows:

$$v(\bar{x}) = \frac{\sum_{i=1}^{n} (\bar{x}_i - \bar{x})^2}{n(n-1)} \qquad (14)$$

where $\bar{x}$ = over-all sample mean per subunit
$\bar{x}_i$ = sample mean per subunit in the ith primary unit

For the above formula to be valid it is required only that n/N be negligible, say less than 0.05 (Cochran, 1953). However, formula (14) does not allow us to estimate the variance within primary units between submit which would be necessary for the estimation of the $V(\bar{x})$ if n/N is not negligible. For the estimation of variance within primary units, it is required that there be two or more randomly selected units in the sample from each primary unit.

In the usual case only one count is made in each primary unit (*i.e.*, m=1). If this is true, formula (14) would be the same as formula (10) where the factor (N-n)/N is ignored. In this case the count x_{iezp} would equal $\bar{x}_i$ and the variance formula could be stated as

$$v(\bar{x}) = \frac{\sum_{i=1}^{m=1} \sum_{e=1}^{h} \sum_{z=1}^{s} \sum_{p=1}^{d} (x_{iezp} - \bar{x})^2}{n(n-1)} \qquad (15)$$

However, if the unusual case occurs where m > 1 then formula (15) would not be appropriate. It should be noted that if m > 1 and the subsampling is systematic with one or more random starts in the ith primary unit, formula (14) is still valid unless n/N is substantial. However, if the primary units are chosen systematically, formula (14) is not valid.

If n/N is substantial the variance formula is

$$v(\bar{x}) = \left[\frac{1}{mn} \quad \frac{(N\text{-}n)}{N} s_b^2 + \frac{(M\text{-}m)}{M} \quad \frac{n}{N} \quad s_w^2 \right] \qquad (16)$$

where sb^2=mean sq. between units

$$= \frac{m \sum_{i=1}^{n} (\bar{x}_i - \bar{x})^2}{n - 1}$$

sw^2=mean sq. within units between subunits

$$\frac{\sum_{i=1}^{n} \left[\sum_{j=1}^{m} (x_{ij} - \bar{x}_i)^2 \right]}{n(m\text{-}1)}$$

xij=observation in the jth subunit in the ith unit

As with formula (14), the subsampling could be done systematically and formula (16) would still be valid if two or more random starts are utilized so that s_w^2 could be estimated. If this is done we should substitute m′ and x'_{ij} for m and x_{ij} where m′ equals the number of random starts made and x'_{ij} equals the mean of the counts for the jth random start in the ith unit.

Subsampling may be combined with stratification and other types of sampling schemes. Also, it is possible to sample the subunits or even to carry the sampling to further stages. So far, I have been assuming that the sampling units are of equal size, however, subsampling can be used with units of unequal size. For a further discussion of such sampling schemes and formulas for the estimation of the variance of the estimate, the reader is referred to Cochran (1953) and other standard statistical texts on sampling techniques.

Formulas for the estimation of variance of the estimate which have been given previously have been based on relatively simple sampling schemes. It is possible that in many creel surveys, such simple schemes will not be practical. However, the formulas presented should serve as a starting point. Formulas for more complicated sampling schemes can be found in Cochran (1953) and Hansen, Hurwitz and Madow (1953).

With the progressive counts, as with the instantaneous counts, we could consider M as being infinite since we could have an almost infinite number of starting points. However, in practice this would not be true and with a similar line of reasoning as was used with the instantaneous counts we could consider M as being finite. If so considered, it is possible that in many cases the finite population correction factor (M-m)/M will be negligible and can be ignored.

If the area is small enough so that the same starting point is used each time, we would consider each progressive count in the same light as the instantaneous counts and use formula (10) or, if n/N is negligible, formula (15) as an approximation to the estimate of the variance. The shorter the period of time required to make the count, the more likely this is to be true. Thus we would be considering that the difference between the number of fishermen counted in the ith count and the true mean for all possible H counts in the interval would be negligible, and that the contribution of the variance within units between subunits to the $\overline{v(x)}$ is negligible. It would be wise in most instances to test such an assumption before accepting it. In some publications on creel surveys this contribution of the variance within units between subunits to the $\overline{V(x)}$ has been ignored, where it would appear that it would not be negligible.

Even though formula (2), Simpson's Rule, and the Trapezoidal Rule all give estimates of the area under x(t), which in this case is equal to the man-hours of fishing, it probably will be worthwhile to briefly compare the use of the three types of estimates.

The use of Simpson's Rule will give an approximation of the area under the graph of x(t) as if it were the area under a curve rather than that of a step function with discontinuities where fishermen enter or depart from the area being checked. However, in most cases it is expected that the approximation will surely be accurate enough for most practical purposes, especially considering the experimental error contained in most estimates of man-hours of fishing based on relatively small samples. Also, in many instances, especially when the counts of fishermen are rather large, it is expected that the graph of x(t) will approximate a smooth curve fairly closely.

The Trapezoidal Rule will make a linear interpolution of the area between the points counted on the graph of x(t). Probably in most cases, this approximation of the area between the points counted on the graph of x(t) will be accurate enough for most practical purposes.

One could also use the mean of the counts with fixed intervals all of the same size between the counts as used with Simpson's and Trapezoidal Rules and make an estimate by formula (2). I shall call this a mean of the counts estimate in order to distinguish it from estimates based on Simpson's and Trapezoidal Rules. This would be a systematic sample with no random starts. Actually this would give the same estimate as the Trapezoidal Rule if we weight the first and last counts by a factor of ½ and use the weighted mean. This weighting is necessary because using the beginning and end of the intervals to make counts gives too much weight to the first and last count. If we divide the fishing day up into equal size intervals and take a count at the midpoint of each interval, this weighting procedure is unnecessary. The use of the midpoints of each interval is, I believe, the way most fishery workers have done it, *i.e.*, those not using a random sample. Of course as the number of intervals increase, the less effect the first and last count will have on the mean and if there is a relatively large number, there will be little difference between the weighted and unweighted mean. If we use a mean of the count estimate with a systematic sampling design with one or more random starts, it would be possible to use end corrections to weight the first and last counts for each random start such as described by Cochran (1953, pp. 172).

I thought it might be interesting to compare estimates made by the different methods on some actual creel survey data. Therefore, without prior knowledge of the shape of the graph of x(t), I used the creel survey data for April 4, 1958, on Clear Lake, Richland Parish, Louisiana, for which we had a complete census of the fishing on the lake that day. Inasmuch as we recorded the time of day the fishing party was checked and the length of the trip, it was possible to construct a graph of x(t) for that day (Figure 10). There were 102.25 man-hours of fishing for that day and 35 fishermen, constituting 18 fishing parties, were checked. I am defining the fishing day as being 15 hours long. Let's divide this day into 6 intervals ($\Delta A = 2.5$) and make 7 instantaneous counts. From the graph of x(t) it is possible to determine the number of fishermen which would have been counted for each count. Then the estimate of fishing for the various types of estimates would be as follows:

(1) Simpson's Rule:

$$f = 2.5/3 \left[0+4(13)+2(16)+4(1)+2(6)+4(4)+0\right] = 96.6667 \text{ man-hours}$$

(2) Trapezoidal Rule:

$$f = 2.5/2 \left[0+2(13+2(16)+2(1)+2(6)+2(4)+0\right] = 100.00 \text{man-hours}$$

(3) Mean of the Counts:

$$f = 15 \left[(0+13+16+1+4+0)/7\right] = 85.7 \text{ man-hours}$$

However, if we divide the fishing day into 7 intervals and make a count at the midpoint of each interval, the mean of the counts estimate is 111.429 man-hours. In the above, the Trapezoidal Rule gives the best estimate (2.25 or 2.2 percent off). Simpson's Rule is 5.58 or 5.5 percent off and the mean of the counts using 7 intervals is 9.18 or 9.0 percent off. The above is some indication that, at least, for some creel surveys there is no clear-cut superiority in any of the three methods where fixed intervals between the counts are used. Probably if we had chosen another day the Trapezoidal Rule would not have given the best estimate. One thing the above example shows, is that if a mean of the counts type of estimate is used, we should use the midpoints of the intervals Δ A and not the beginning and end of the intervals, *i.e.*, unless we use a weighted mean. If we weight the first and last count, as previously mentioned, the mean of the count estimate utilizing 7 counts and 6 intervals is equal to 100.00 man-hours which is exactly the same estimate as given by the Trapezoidal Rule.

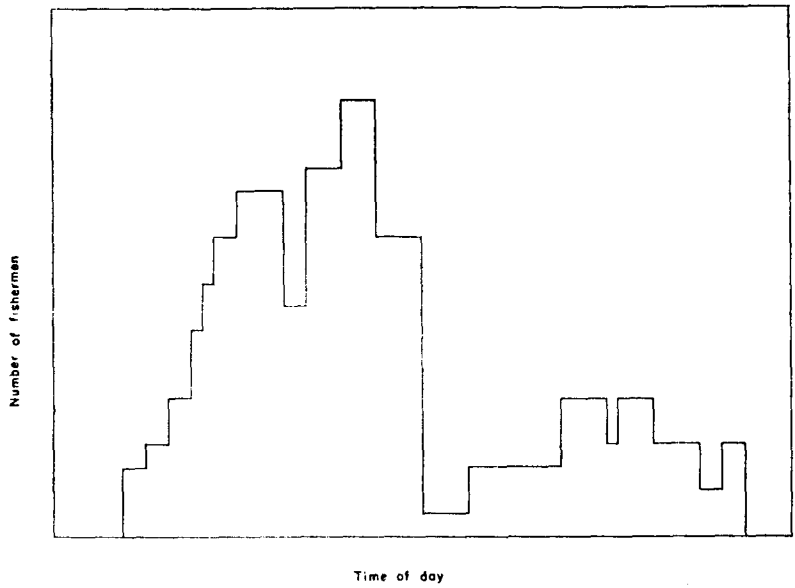

Figure 10. Graph of the counting function x(t) for April 4, 1958, on Clear Lake, Richland Parish, Louisiana.

Generally when the curve is relatively simple and the number of counts are the same, Simpson's Rule will give a better estimate of area than either the Trapezoidal Rule or the Mean of the Counts estimates. This is because Simpson's Rule evaluates or interpolates the area between the points counted as a curve and does not use a linear interpolation as would the Trapezoidal Rule and the Mean of the Counts. Simpson's Rule will give the exact area for curves cubic or less. However, as the curve becomes increasingly complex the superiority of Simpson's Rule disappears. Some of the graphs of x(t) are rather complex—the one in Figure 10 is.

If there is any reason for large numbers of fishermen to either leave or enter a body of water at approximately the same time during the fishing day, the graph of x(t) might not approximate a smooth curve. Therefore the determination of the area under x(t), as if it was a smooth curve, could introduce error into the estimate of man-hours of fishing. Many variables which could cause large numbers of fishermen to either leave or enter on a body of water at the same time would be expected to occur over a period of time in essentially a random pattern, *e.g.*, sudden changes in weather. Even though such a random variable might cause the graph of x(t) for any single fishing day to depart markedly from a smooth curve, when many fishing days are pooled it is expected such departures will tend to average themselves out and the graph of x(t) will tend toward a smooth curve.

However there is another type of variable which could cause large numbers of fishermen to leave or enter on a body of water at approximately the same time during the fishing day. This would be a cause which occurred in a non-random or fixed pattern. On many or possibly most sport fisheries such a cause does exist, however, there are some sport fisheries in which I feel certain it occurs. For example, a large number of shift workers at a plant close by a body of water might enter a body of water at approximately the same time of day each working day after work. This would not average out over a period of time and might introduce a bias into the estimate of man-hours of fishing where fixed intervals between the counts are used.

Any estimate is subject to experimental error and it is important to make some statement about the probable size of such error. Therefore, a sampling design should provide a valid estimate of the experimental error as well as a good estimate of fishing. With the Trapezoidal Rule, Simpson's Rule and the Mean of the Count estimates where the counts of fishermen are taken with fixed intervals between them, I know of no valid way of estimating the experimental error. Standard formulas for estimating the variance of estimates are based on the assumption that our sampling is random. If a valid estimate of the variance of estimates based on sampling designs where a fixed interval between counts is used could be developed, the value of such sampling schemes would be greatly enhanced. One advantage of the use of the Mean of the Count type of estimate is that it can be used with random sampling designs or with systematic designs with two or more random starts, from which a valid estimate of the variance of the estimate can be made from the sampling data. However, because of the nature of the fishing process, I believe that in most instances some form of stratified random sampling or systematic sampling with one or more random starts will be more efficient and practical than simple random sampling. Also, I believe systematic sampling where one or more random starts is used in conjunction with subsampling should have a lot of utility in creel surveys.

SUMMARY

One of the basic and often most difficult aspects of creel surveys on large reservoirs and other large bodies of water is the problem of determining fishing pressure. Often the only feasible method of determining fishing pressure is by making counts of fishermen or fishing parties while the fishermen are in the process of fishing. This report reviews this method of determining fishing pressure and discusses the sampling problems involved.

There are several ways fishing pressure can be determined by this method. One of the more efficient ways is to estimate fishing pressure by the formula $f = C\bar{x}$, where f equals the number of time units of fishing, $\bar{x}$ equals mean number of fishermen observed per count and C equals number of time units in the population. This formula can be used where the body of water is divided into areas and also where fishermen counts are made instantaneously (*i.e.*, where all fishermen are counted at once), and where fishermen counts are made progressively (*i.e.*, where fishermen are counted as the creel checker moves at a fixed rate over or on the body of water and counts fishermen as he comes to them). In some instances it is not possible to count individual fishermen but fishing parties can be counted. Therefore, if we let $\bar{x}$ be the mean number of parties observed per observation, f will be an estimate of the party-hours of fishing. If the mean number of fishermen per party is known, this time f will be an estimate of man-hours of fishing.

Fishermen are not distributed homogeneously in time or area and there will be sampling problems in estimating $\bar{x}$. In the formula $f = C\bar{x}$, C is known without error and therefore in determining the confidence of the estimate f, it is necessary only to determine the variance of $\bar{x}$. If $\bar{x}$ is not to be biased it is important that each fishermna will have equal chance of being counted. This will not occur unless the time, area and day, and in the case of progressive counts, the starting point for the counts are chosen by some unbiased sampling scheme, *e.g.*, random sampling.

Some workers have estimated fishing pressure as the area under the fishing curve, either by calculating the area or by graphic means. Estimates of area under the fishing curve can be estimated by Simpson's Rule

or the Trapezoidal Rule. The use of Simpson's and the Trapezoidal Rules has the disadvantage that it is doubtful that the variance of the estimate can be determined.

Some of the sampling schemes of taking creel surveys described in the literature, even though the investigator has stated that the sampling design was random, cannot in the accepted meaning of the word be termed random. Most of these are systematic sampling designs. Under some conditions there are certain potential advantages in systematic sampling; however, there are some potential serious dangers in such sampling. No trustworthy method of estimating the variance of an estimate from systematic sampling data is known, *i.e.*, from a strictly systematic sample with one or no random starts.

The effects of departures for normality of $\bar{x}$ on statistical tests are discussed. In many instances, the estimate of man-hours of fishing will be multiplied by another estimate in order to obtain an estimate of a third value. A formula for determining the variance of a product is presented.

The number of man-hours of fishing, F, can be expressed as the integral of a counting function x(t) over the entire fishing day, where x(t) is the number of fishermen (or fishing parties) present at time t. Fishing during the day is the area under the graph of x(t). The use of Simpson's Rule, the Trapezoidal Rule and the formula, $f = C\bar{x}$, will all give estimates of the area under x(t) which is equal to the man-hours of fishing. Formulas for determining the variance of $\bar{x}$ for simple random sampling and subsampling are given and discussed. The use of the formula $f = C\bar{x}$, Simpson's Rule and the Trapezoidal Rule are compared and discussed.

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INFORMATION AND EDUCATION SESSION

SOUTHEASTERN STATE WATER LEGISLATION IN RELATION TO FISH AND WILDLIFE*

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I. INTRODUCTION

In the last decade, efforts have been made in each southeastern state to modernize laws relating to use of water. Prompted by increasing population, the movement of northern industry into the Southeast, and by accelerated state, federal, and private water developments for flood control, power, and recreation, every southeastern state legislature has been asked to revamp its state's basic water-governing legislation.

During the drought years of 1953-1956, water scarcities for municipalities, irrigators, and industry prompted citizen formation of water-use study committees, which later led to legislation creating water study commissions as official state agencies. Both lay and official study commissions usually investigated problems of water scarcity, abundance, use, and quality, examined the legal framework, and attempted an inventory of water resources. Pressures of the drought years resulted in ill-conceived, rather hasty attempts at revision of legislation, most of which failed to become law. Coincident with the drought, immediate efforts were made to secure adoption of the western system of prior appropriation, often with little modification, in some thirty-three eastern states. During the last decade, these states have been faced with pressure to modify the riparian system or to accept with modification, the prior appropriation doctrine *primarily* to insure protection of a user's water rights. This has been the overriding question in some thirty-three eastern states.

Since the drought, the pace of the water law revision movement has ebbed, leading to more orderly progress, coupled with better understanding of some of the complex problems involved. This report attempts to

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