A Sampling Design and Estimation Formula for a
Creel Census of Stream Fishermen: A Preliminary Report

BU-275-M D. S. Robson March, 1970

ABSTRACT

A creel census of stream fishermen conducted by two teams of interviewers, one team interviewing fishermen on the stream and the other interviewing departing fishermen, provide a data base for estimating the day's total catch of the fishery. The first team obtains data for estimating the average "catch in hand" for the day,

$$\bar{C} = \frac{1}{T}\int_0^T C(t)dt$$

where C(t) is the combined number of fish which all fishermen on the stream at time t are carrying on their person at that time, and T is the legal length of the fishing day. The second team of interviewers obtains an estimate of the average length of time a fish is kept in hand,

$$\frac{1}{M}\left[\int_0^T N(t)dt - \int_0^T R(t)dt\right] = \bar{t}_r - \bar{t}_c$$

where N(t) is the combined catch prior to t, R(t) is the number of these which have been removed from the stream (i.e., deposited in the fishermen's cars) prior to t, $\bar{t}_c$ is the average time of capture and $\bar{t}_r$ the average time of removal. The total day's catch M of the entire fishery is related to the above parameters by

$$M = \frac{T\bar{C}}{\bar{t}_r - \bar{t}_c} .$$

A Sampling Design and Estimation Formula for a Creel Census of Stream Fishermen: A Preliminary Report

BU-275-M

D. S. Robson

March, 1970

A variety of sampling designs have been employed for interviewing fishermen on a stream in order to estimate the day's total catch from a specified, fishable section of the stream. A common technique involves interviewing anglers at their cars as they prepare to leave, thus obtaining "completed trip" information on angler catch; another technique involves roving interviewers who contact anglers on the stream and obtain "incomplete trip" information on catch at the time of interview. A sampling plan is proposed here which utilizes both types of interviews to obtain data for the estimation equation:

$$\left\{\begin{matrix}\text{average catch in hand}\\ \text{during the day}\end{matrix}\right\} = \left\{\begin{matrix}\text{total catch per hour}\\ \text{for the day}\end{matrix}\right\} \times \left\{\begin{matrix}\text{average length of time a fish}\\ \text{is kept in hand}\end{matrix}\right\} .$$

The "catch in hand" at any given time of the day is the total number of fish that anglers on the stream at that time are carrying on their person excluding, for example, fish which anglers had caught earlier and deposited in their car before returning to the stream to continue fishing. An individual fisherman's "catch in hand" at any given time is precisely the catch observable by the stream interviewer should he contact the fisherman at that time. Summing over all fishermen on the stream at time t gives the total catch $C(t)$ in hand at time t, and averaging $C(t)$ over time gives the "average catch in hand during the day".

"Total catch per hour for the day" is the catch rate of the entire fishery, obtained by dividing the combined day's catch of all fishermen by the length (in hours) of the fishing day. This catch rate or its numerator, total catch, is the unknown quantity which the creel census is designed to estimate.

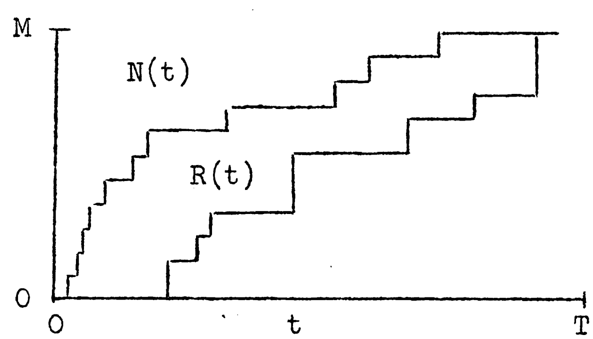
The length of time a fish is kept in hand is the time between capture and removal to the fisherman's car; this is also the length of time during which that fish would be observable by the stream interviewer as part of the fisherman's catch in hand. The average time in hand for all fish is the difference between the average time of capture and average time of removal.

Derivation of the estimation equation

If $N(t)$ denotes the total number of fish caught prior to time t and $C(t)$ is the number in hand at time t then the difference

$$R(t) = N(t) - C(t)$$

is the number that have been caught and removed prior to t. Graphically, the functions $N(t)$ and $R(t)$ will have the form:



where T is the length (in hours) of the legal fishing day and M is the total catch for the day. At the end of the day the relation

$$N(T) = R(T) = M$$

must obtain, and during the day the catch in hand $C(t)$ at any time t is the difference between N(t) and R(t),

$$C(t) = N(t) - R(t) \; . \qquad (1)$$

The average value of C(t) during the day is defined by

$$\bar{C} = \frac{1}{T}\int_0^T C(t)dt$$

or, from (1),

$$\bar{C} = \frac{1}{T}\int_0^T N(t)dt - \frac{1}{T}\int_0^T R(t)dt \; . \qquad (2)$$

The function R(t) is a step function, a step upward occuring whenever a fisherman carries fish to his car, the height of the step being equal to the number of fish carried. If the i^{th} step occurs at time t_i and consists of r_i fish then for the $M = \Sigma r_i$ fish ultimately removed the average time of removal, $\bar{t}_r$, may be expressed by the formula

$$\bar{t}_r = \frac{1}{M}[t_1r_1 + t_2r_2 + t_3r_3 + t_4r_4 + \cdots]$$

$$= \frac{1}{M}[t_1(r_1+r_2+r_3+r_4+\cdots$$

$$+ (t_2-t_1)(r_2+r_3+r_4+\cdots$$

$$+ (t_3-t_2)(r_3+r_4+\cdots$$

$$+ \cdots]$$

$$= \frac{1}{M}[t_1(M) + (t_2-t_1)(M-r_1) + (t_3-t_2)(M-r_1-r_2) + \cdots]$$

$$= \frac{1}{M}[t_1M + (t_2-t_1)\{M-R(t_1)\} + (t_3-t_2)\{M-R(t_2)\} + \cdots$$

$$= \frac{1}{M}[MT - \int_0^T R(t)dt] \quad .$$

Thus, the integral of $R(t)$ may be expressed as

$$\int_0^T R(t)dt = M(T-\bar{t}_r)$$

and an exactly analagous argument gives

$$\int_0^T N(t)dt = M(T-\bar{t}_c)$$

where $\bar{t}_c$ is the average time of capture for the M fish. Substitution of these results into equation (2) then gives the estimation equation

$$\bar{C} = \frac{M}{T}(\bar{t}_r-\bar{t}_c)$$

or

$$M = \frac{\int_0^T C(t)dt}{\bar{t}_r-\bar{t}_c} \quad .$$

Sampling design

The total length of the stream will be divided into k sections of known length and designed to contain equal amounts of fishing pressure; in the absence of prior information the sections will be equal in length. Each roving interviewer will be assigned a random sequence of sections to patrol, with the constraint that no two interviewers patrol the same section at the same time. The interviewer will record the time he enters and leaves a section and determine the catch in hand of each fisherman encountered, including any who might be just passing through the section seeking a new fishing site or moving with some other purpose. For each creeled fish seen the interviewer will record the time of capture as accurately as can be determined, and attach an unobtrusive tag to the fish bearing the time of capture or, preferably, a code number which can be matched with the recorded time of capture. If a fisherman's creel contains fish already marked with a code number from a previous interview, these code numbers rather than the times of capture will be recorded by the interviewer, and such fish will be included as part of the catch in hand at the time of each interview.

If it were possible to continuously and simultaneously monitor the catch in hand of all fishermen present in the j^{th} stream section during the time period T_{i-1} to T_i then the total catch in hand $C_j(t)$ for that section would be known for all $T_{i-1} < t < T_i$ and the integral

$$\int_{T_{i-1}}^{T_i} C_j(t)dt$$

could be calculated directly. The interviewer's data does provide an approximation to this integral in the form

$$\int_{T_{i-1}}^{T_i} C_j(t) \approx (T_i - T_{i-1}) \times \begin{pmatrix}\text{combined catch in hand of all fishermen} \\ \text{interviewed in section j}\end{pmatrix}$$

where T_{i-1} and T_i are the interviewer's time of entering and leaving the section, respectively. This estimate when multiplied by k (the number of sections in the stream) provides an estimate of the integral

$$\int_{T_{i-1}}^{T_i} C(t)dt$$

over the time period T_{i-1} to T_i for the entire stream fishery.

If an interviewer could be transported instantaneously to another sample section so that he would be patrolling continuously throughout the day then each interviewer's records would provide an independent estimate of

$$\int_0^T C(t)dt = \int_0^{T_1} C(t)dt + \int_{T_1}^{T_2} C(t)dt + \cdots + \int_{T_{m-1}}^{T} C(t)dt \quad .$$

Allowing for travel time between sample sections, however, results in data gaps which must be filled in by a smoothing operation. This operation can be greatly facilitated by marking off each section into subsections and requiring the interviewer to record the time that he passes each subsection mark.

In order to estimate the average length of time a fish is kept in hand, $\bar{t}_r-\bar{t}_c$, another crew of interviewers will be patrolling the access roads and interviewing fishermen when they return to their cars or otherwise leave the stream to deposit their catch. The time the fisherman returned to his car is t_r, and for each fish the interviewer will determine as accurately as possible the time of capture, t_c. Only fishermen with fish provide the data on t_r and t_c. The code numbers of any fish marked by a roving stream interviewer will be recorded and all fish will be generically marked to indicate that they have been recorded as fish removed from the stream and thus no longer countable as fish in hand should that fisherman return to the stream to continue his fishing. Records of such generic marks encountered by the roving stream interviewer should be kept but not included in $C(t)$.