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RIVER ELECTROFISHING AND FISH POPULATION ESTIMATES

RICHARD VINCENT
Fisheries Division, Montana Fish and Game Department
Bozeman, Montana 59715

IN MONTANA, considerable effort is placed on studying fish populations, particularly trout populations, in streams. This paper was prepared to meet the need for a uniform procedure for sampling and estimating standing crop, age structure, mortality, and production. Also, information is given on electrofishing including safety and first-aid considerations.

The techniques described in this paper are not new; they were drawn from several sources. The objective was to assemble them into an easy-to-use procedure. We have used this procedure for 4 years in Montana and feel that it is a practical approach to obtaining population dynamics information needed in fishery management. It is presented here with the hope that it will be useful to fishery workers in other areas.

Types of Electronic Current

1. *Continuous direct current* (*d.c.*).—This type has a continuous flow of unidirectional current between permanent positive and negative electrodes (fig. 1). This is the best type for electrofishing in rivers which have good brushy bank cover or where the turbidity is high (but not so high as to comprise excessive electrolyte) because: (1) the fish show strong galvanotaxis (a tendency to swim toward the positive electrode) and little galvanonarcosis (used here to mean inability of fish to swim due to narcosis or to contraction of muscles) when near the positive electrode; thus fish can be brought to the surface for easy capture; (2) it is the least dangerous to the shocking crew, especially if the amperage is not high (not in excess of five); and (3) it causes the least tissue damage to the fish.

2. *Full-pulsed direct current* (*half-wave rectified alternating current*)—This type has an interrupted flow of unidirectional current between permanent positive and negative electrodes (fig. 2). This is the best type of current for electrofishing in large open rivers which have little bank cover and little turbidity because the area of galvanotaxis is larger than with continuous d.c., but galvanonarcosis is common, making capture more difficult unless the water is open and clear. Also, this current may be effective in waters with too much electrolyte for continuous d.c. It is more dangerous to the shocking crew than continuous d.c., so lower amperages (two to three) should be used; and it causes more tissue damage in fish than continuous d.c.

3. *Half-pulsed direct current* (*half-wave rectified alternating current*).—This type has an interrupted flow of unidirectional current which fluctuates between full and half voltage (fig. 3). This is an intermediate current between continuous and full-pulsed d.c. Fish exhibit a greater degree of galvanotaxis than with full-pulsed d.c., but less than continuous d.c. They exhibit less galvanonarcosis than with full-pulsed d.c., but more than with continuous d.c.

4. *Alternating current* (*a.c.*).—This type of current has a continuous regular reversal of positive and negative poles (fig. 4). This is the poorest type of current for electrofishing because: (1) there is no galvanotaxis, so capturing fish is difficult; (2) it is the most dangerous to the shocking crew; and (3) tissue damage to fish is common.

NOTE.—This work was performed as part of Dingell-Johnson Projects F-9-R-15-17, Montana, Job VIII, Evaluation of River Fish Populations.

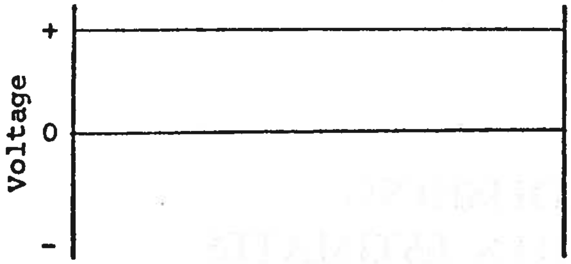

Figure 1.—Continuous direct current.

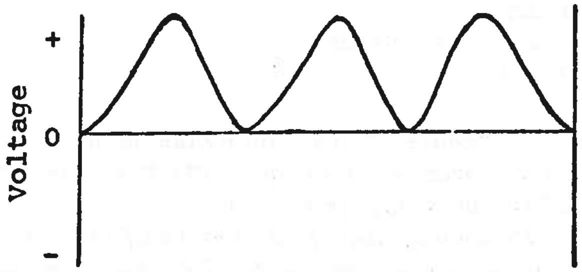

Figure 2.—Full-pulsed direct current.

Electrode Arrangement

1. The use of a single positive electrode is preferred, as multiple positives tend to create weak electrical fields around each positive electrode rather than a strong field around one.

2. The negative electrode may be either single or multiple, but the surface area should be approximately 30 times the surface area of the positive electrode.

3. The negative electrode should be within 10 to 15 feet of the positive electrode and can be placed on a boom near the bow of the boat or on the bottom of the boat.

Water Conditions Influencing Electrofishing

1. *Temperature.*—Most salmonids are more easily captured by electrofishing when the water temperatures are low (32° to 50° F.); thus shocking is more effective early in the day or during the seasons when water temperatures are the lowest.

2. *Conductivity.*—Generally fish are easier to shock in the more conductive waters, but on occasion a water may be so conductive that continuous direct current is ineffective. Pulsating or alternating current may be more effective in this situation.

Population Estimation

1. Mark-and-recapture formulas:

a. Basic Petersen:

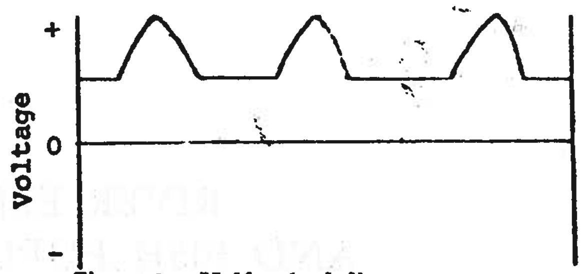

Figure 3.—Half-pulsed direct current.

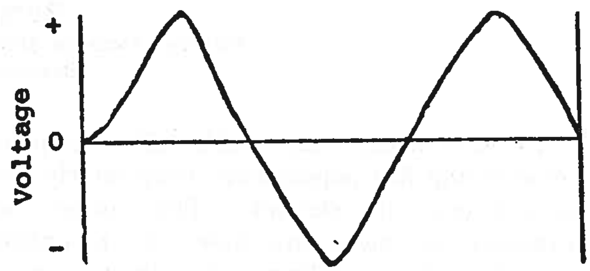

Figure 4.—Alternating current.

$$N=\frac{MC}{R} \text{ where}$$

N = Population estimate.
M = Number of fish marked.
C = Number of fish in recapture sample.
R = Number of marked fish in recapture sample (C).

b. Chapman's modification of the Petersen formula (Ricker, 1958):

$$N=\frac{(M+1)\quad(C+1)}{R+1}$$

c. Conditions for using the two mark-and-recapture formulas:

(1) According to Bailey (1951) and Chapman (1951), the basic Petersen formula tends to overestimate the population when the population is small and/or the number of marked recaptures (R) is low. Chapman's modification was derived to eliminate this tendency to overestimate. In using Chapman's modification, one or both of the following conditions must be met to insure an unbiased estimate: (1) $M+C \geq N$, or (2) $MC>4N$ (Robson and Regier, 1964). Chapman's modification should be used on all popu-

lation estimates, as long as the above conditions are met, and if these conditions are not met, then no reliable estimate can be made.

2. Procedure in setting up shocking sections on rivers:

   a. The length of a shocking section is determined by sample size, a rough estimate of population size and habitat type. These can be determined by survey shocking. Access points should also be considered in setting up sections.

      (1) As a general rule, a section should be long enough to insure a sample size of at least 150, but 250 to 300 is preferred.

      (2) The length of a section should not be less than 1,000 feet.

      (3) The following steps should be followed to set up a new shocking section for the purpose of population estimates: (1) determine the sample size you can obtain on one shocking run; (2) make a rough population estimate allowing a 2 to 3 day interval between mark and recapture trips to let the fish redistribute; (3) choose a level of accuracy necessary for the final population estimate; and (4) use Robson and Regier's charts (see appendix) to determine the desired number of fish to mark (M) and the number necessary in the recapture sample (C) to give the predetermined level of accuracy. More than one marking and/or recapture trip may be necessary to obtain the level of precision previously set.

   b. *Example*: A section of river was shocked and a sample of 250 fish were marked. Two to four days later, the recapture trip was made and a new sample (C) of 250 fish was taken, of which 31 were previously marked. This gives a rough population estimate of 2,000. The level of accuracy chosen was 25 percent (which means the population estimate confidence interval would be 1,500 to 2,500). Using this rough population estimate, Robson and Regier's figure 5 indicates that 400 fish should be marked and the recapture sample should be about 250 to achieve the 25 percent level of precision in the estimate. Although Robson and Regier state that an equal division of resources between the number marked and the number examined in the recapture sample is optimal, in this case it would take two marking trips and one recapture trip to achieve 25 percent precision, whereas with equal division it would take two marking and two recapture trips.

3. Other information from population data:

   a. *Age structure.*—The age structure of a population is the number of fish in the population which are in each age-group. Using scales taken during the shocking period (20 per inch-group), various size-groups can be set up according to age. The number of fish per age-group can be estimated by the following method: (1) set up two types of size-groups, those which contain just one age-group and those which include areas of age-group overlap; (2) then estimate the number in each size-group by the mark-and-recapture method; and (3) using the scale data, determine the percent age composition for each overlap group and then proportion the estimate between the appropriate age-groups. The total population is then determined by adding the number of fish estimated for each size-group.
   Example: (See top of next page.)

   b. *Estimation of standing crop (biomass)*.—Total pounds of fish for a given section of river can be estimated by the following method: (1) determine the average weight of the fish in each size-group; (2) multiply each average weight by the corresponding population estimate; and (3) add the

Size-Group Estimation

Size-group	M	C	R	Population estimate	Percent age composition		
4.0- 6.9	80	70	20	273		100%	I
7.0- 8.5	20	23	7	62	43/	70%	I
					/19	30%	II
8.6-10.8	40	37	12	119		100%	II
					31/	60%	II
10.9-12.1	15	22	6	52	/21	40%	III
12.2-14.0	40	45	18	98		100%	III and older

Age Structures

I	316
II	169
III and older	119
Total	604

computed weights for each size-group to give total weight. Using the scale data, the pounds of fish per age-group can be determined by proportioning the estimated weights for each size-group among the proper age-groups.

c. *Confidence interval.*—At the 95 percent level, confidence interval for the total population estimate is determined by formula 3.8 in Ricker (1958, p. 84) and the following procedure: (1) determine the variance for each size-group; (2) add these variances; and (3) take the square root of the sum of the variances. The confidence interval is the population estimate $\pm 2\sqrt{\text{variance}}$. The formula for the variance when using Chapman's formula is as follows:

$$\text{Variance} = \frac{(\text{Pop. Est.})^2\ (C-R)}{(C+1)\ (R+2)}$$

d. *Mortality rates.*—The mortality rate is the percent of a given unit of the population, which die during a given period of time. Mortality rates can be computed for each age-group or the total population. The formula for mortality rates in percent is as follows:

$$\text{Mortality rate} = \frac{N_1 - N_2}{N_1} \times 100$$

where

N_1 = Population estimate at the start of the period.

N_2 = Population estimate at the end of the period.

e. *Production rates.*—Production is the biomass produced by all fish in a population over a given period of time including that produced by fish which die during the time period. The formula for computing production is as follows:

$$P = k\ P_0 \left(\frac{e^{k-i} - 1}{k-i}\right)$$

where

k = Instantaneous growth rate

P_0 = Initial weight of population unit.

i = Instantaneous survival rate.

To compute the instantaneous growth rate (k), use the following procedure:

compute

$$e^k = \frac{\text{average weight of individual in the population unit at the end of time period}}{\text{average weight of individual in the population unit at the start of time period}}$$

obtain the value of k for e^k in a table of exponential functions. To compute the instantaneous survival rate (i), use the following procedure:

compute

$$e^{-i} = \frac{\text{number of fish in the population unit at the end of the time period}}{\text{number of fish in the population unit at the start of the time period}}$$

obtain the value of i for e^{-i} in a table of exponential functions.

Example: Using one age-group of a brown trout population, the production of trout in pounds will be computed. The initial population figures on a group of 2 year olds show: (1) a population estimate of 800, (2) the average weight of an individual trout (0.50 pound), and (3) the total weight of this group (400 pounds). After a 6-month period, the population figures on these 2 year olds show: (1) a population estimate of 500, (2) the average weight of an individual trout (0.90 pound), and (3) the total weight of this group (450 pounds).

First, k is computed as:

$$e^{k}=\frac{0.90\ \text{lb.}}{0.50\ \text{lb.}}=1.80 \qquad k=0.59$$

Second, i is computed as:

$$e^{-i}=\frac{500}{800}=0.63 \qquad i=0.46$$

Then, production for the 6-month period is computed as follows:

$$P=\frac{(0.59)\ (400\ \text{lbs})\ (e^{0.13}-1)}{0.13}$$

$$=\frac{(0.59)\ (400\ \text{lbs})\ (1.14-1)}{0.13}$$

$$=\frac{33.0}{0.13}=253.8\ \text{lbs}$$

Safety Precautions

1. Safety switches should be installed on the boat and on the electrofisher, which breaks the circuit to the electrodes.

2. The person operating the boat should be in charge of the electrofisher controls.

3. No one should ever touch the positive or negative electrodes in or out of the water when in operation.

4. The positive electrode should never touch the negative electrode or the boat (if the boat is metal).

5. No exposed electrode wire should be exposed to the shocking crew at any time.

6. Rubber boots or waders and electricians gloves should be worn by *all* members of the shocking crew.

7. For the crew's safety, amperage being put into the water should not exceed five at any time.

First Aid Treatment for an Electric Shock

The following first aid procedures are recommended in case of an electric shock which appears to have stopped the heart:

1. Place the patient on his back.
2. Get down on your knees beside his chest.
3. Find the lower end of his breast bone.
4. Put the heel of your hand 1 inch above its end.
5. Place your other hand on top of the first hand.
6. Press down firmly with about 60 pounds of weight.
7. Repeat every second until heart starts.
8. If necessary, apply mouth-to-mouth respiration for 5 seconds every 30 seconds.

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APPENDIX

Charts for determining size of samples when making population estimates. (These charts are from Robson and Regier (1964) and are reproduced by the courtesy of the authors and the American Fisheries Society.)

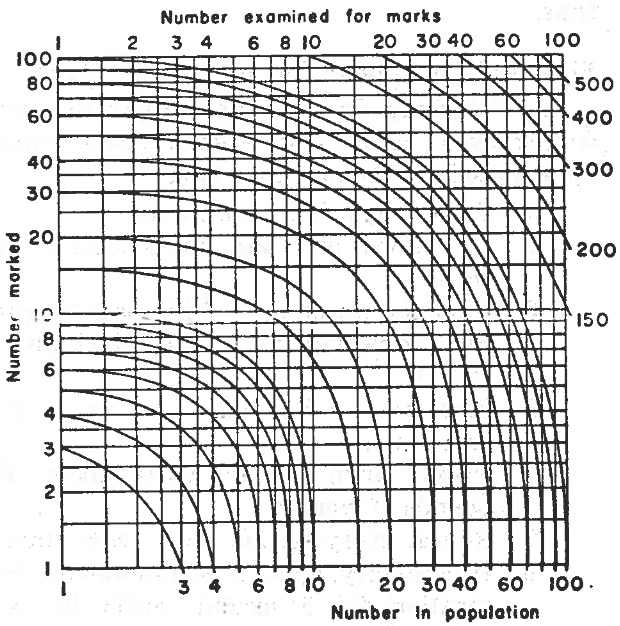

Chart 1.—Sample size when $1\text{-}\alpha=0.95$ and $p=0.50$; recommended for preliminary studies or management surveys. Data $N \leqq 100$ based on tables of hypergeometric distribution.

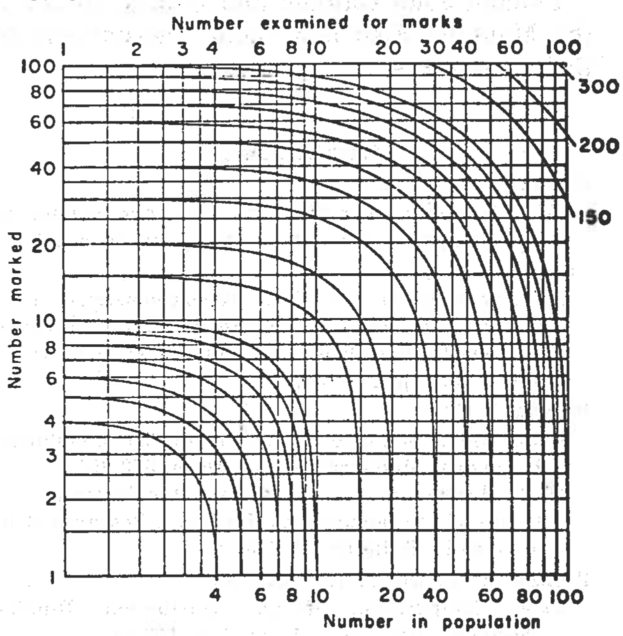

Chart 2.—Sample size when $1\text{-}\alpha=0.95$ and $p=0.25$; recommended for management studies. Data for $N \leqq 100$ based on tables of hypergeometric distribution.

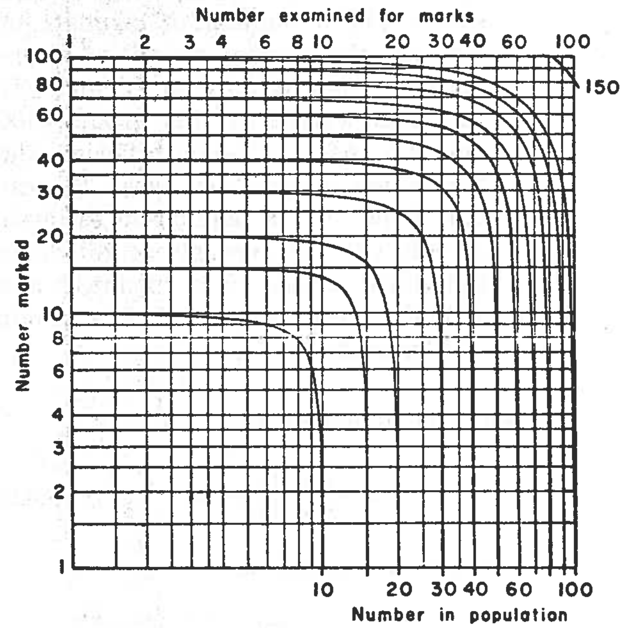

Chart 3.—Sample size when $1\text{-}\alpha=0.95$ and $p=0.10$; recommended for research. Data for $N \leqq 100$ based on tables of hypergeometric distribution.

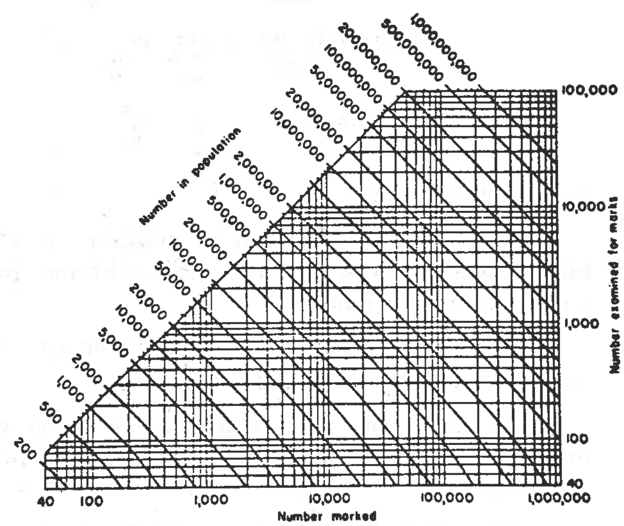

Chart 4.—Sample size when $1\text{-}\alpha=0.95$ and $p=0.50$; recommended for preliminary studies and management surveys. Data based on normal approximation to the hypergeometric distribution.

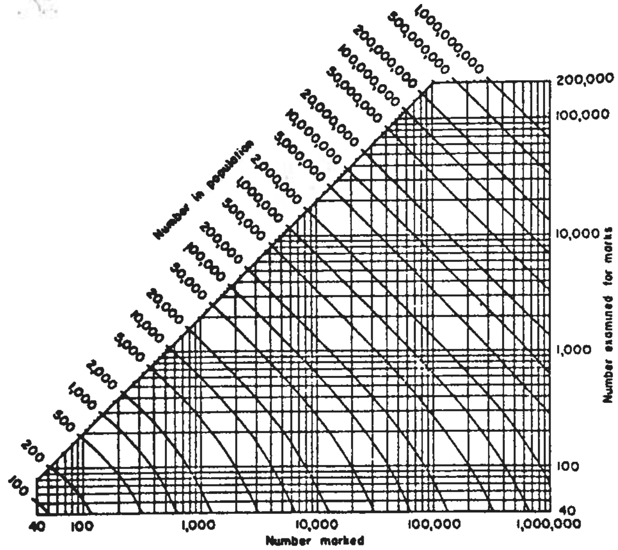

Chart 5.—Sample size when $1-\alpha=0.95$ and $p=0.25$; recommended for management studies. Data based on normal approximation to the hypergeometric distribution.

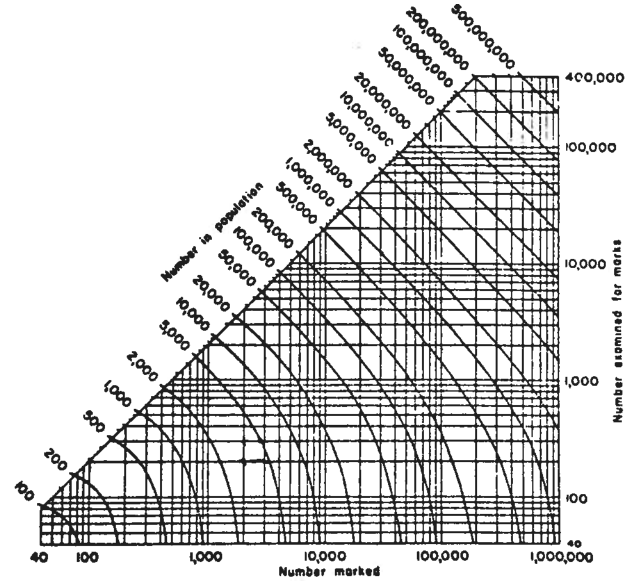

Chart 6.—Sample size when $1-\alpha=0.05$ and $p=0.10$; recommended for research. Data based on normal approximation to the hypergeometric distribution.